Institut de Mécanique Céleste et de Calcul des Éphémérides,
Observatoire de Paris, Paris Sciences et Lettres

Habilitation à Diriger les Recherches

Dynamique et observation des météoroïdes

Jérémie Vaubaillon

Defended the 17th November 2020, in front of the jury composed of :

- Dominique Bockélé-Morvan, Directrice de Recherches, LESIA, Observatoire de Paris-Meudon, PSL, (President)
- Cécile Engrand, Directrice de Recherches, CSNSM (referee)
- Patrick Michel, Directeur de Recherches, OCA (referee)
- Bruno Sicardi, Professeur des Universités, LESIA, Observatoire de Paris, PSL (referee)
- Alessandro Morbidelli, Directeur de Recherches, OCA (invited)
- Jean-Marc Petit, Directeur de Recherches, Observatoire de Besançon (invited)

JEREMIE VAUBAILLON

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EDUCATION

IMCCE, PARIS OBSERVATORY, CNES (French Space Agency, France)
PhD. Astronomy, (*with high honors)* Sept. 2000-Oct.2003
Thesis: "Dynamic of meteoroids in the solar system; application to the prediction of the Leonid meteor storms"
Advisor: W. Thuillot, F. Colas (IMCCE)

PARIS OBSERVATORY (FRANCE)
DEA. Astronomy (Graduate degree), Celestial mechanics and geodesy (with honors) 2000

UNIVERSITY OF PARIS 7 (France)
DESS. Optics and material (graduate engineer degree) 1999
Interaction between light and matter (with honors)

AWARDS

2013 CNRS BRONZE MEDAL (FRENCH NATIONAL RESEARCH COUNCIL), rewarding a young researcher for becoming an internationally recognized expert in his domain.

Asteroid 82896 (2001 QV87) is named Vaubaillon

SUMMARY OF TECHNICAL SKILLS & PROFICIENCIES

•*Scientific Instruments*: Subaru (8m), Spitzer Space telescope (IR), Palomar (200in), OHP (1.2m), video wide FOV camera (meteors) on ground or in airplane, Paris observatory 38-cm refractor (built in 1856)
•*Languages*: English (fluent), French (native)
•*Specific knowledge*: frequent usage of parallel supercomputers (CINES - France, SDSC – USA)
•*Program languages*: F90, PYTHON, Perl, Shell
•*Database*: MySql, XML
•*Software*: IDL, DS9, Aladin
•*Operating System*: Linux, MacIntosh, Windows
•Frequent interactions with space agencies (NASA, ESA, CNES) regarding the protection of artificial satellites

RESEARCH & PROFESSIONAL EXPERIENCE

INSTITUT DE MÉCANIQUE CÉLESTE ET DE CALCUL DES ÉPHÉMÉRIDES (FRANCE)
Astronomer (staff) Jan 2009 – Present
Project: Meteor Automated Light Balloon Experimental Camera (MALBEC) 2017 – Present
• *Purpose*: Observe meteors from stratospheric altitude to guarantee the cloud do not prevent the observation
• *Role*: PI of the project ; project management, scientific specification and data exploitation.
• *Impact*: Guarantee success of any meteor observation campaign whatever the time of day and weather.
• *Results*: Nacelle is developed by KYU-ACE Cie ; several flight campaigns for tests purpose ; more to come in the future

Project: Fireball Recovery and InterPlanetary Observation Network (FRIPON) 2013 – Present
• *Purpose*: Observe meteorite fall over the entire French territory and recover the fallen meteorite (**INSU SO6**)
• *Role*: co-I of the project ; Involved in the core team management.
• *Impact*: Find the origin of meteorites as compared to the NEO population ; public outreach.
• *Results*: First version of the pipeline working ; First meteorite fall observation and recovery in January 2020.
• see also: www.fripon.org (ANR 2014-2017)

Project: 2011 Draconids international airborne observation campaign 2010 – 2013

- *Purpose*: observe the Oct 8th 2011 Draconids exceptional meteor shower from 2 scientific aircrafts (CNRS and DLR) with many cameras (visible/IR, images/spectra, video/photo, B&W/color) **(INSU SO6)**
- *Role*: PI of the whole project (2 airplanes, 6 scientists, 20 cameras) ; PI of the French aircraft campaign (SAFIRE/CNRS - Falcon 20) ; onboard observation ; funds raised: 48k€ (consolidated cost: 84k€ ; CSAA) + 10k€ (PNP)
- *Impact*: Get scientific record of a unique event from 2 different aircrafts.
- *Results*: Successful prediction and observation of the outburst ; first double aircraft measurement of meteoroid orbit ; 2 workshops (2012,2013) ; 2 special session at international conferences (IMC2012 and EPSC2012) ; Dedicated volume in EM&P ; 2 documentaries performed for public outreach purposes, by CNRS (J. Mouette) and NHK (Japanese TV).

Project: CAmera for BEtter Resolution NETwork (CABERNET): the French meteor observation network. 2010-present

- *Purpose*: measure most accurate meteoroid orbit to reconcile theory and observations **(INSU SO6)**
- *Role*: PI of the whole project (project, people and money management) ; 3 to 7 people at a time involved in the project (300k€ for 3 years + 100k€ dedicated to hire postdocs only ; main sponsor: "Ville de Paris" - "Emergence" program - and Paris Observatory).
- *Impact*: Demonstrate the flaw in published meteoroid orbits ; propose a new way to do it.
- *Results*: Developed the first high resolution meteor dedicated camera based on 4kx2.7k CCD with an electronic shutter allowing to measure the most accurate orbits ; network continuously operating since 2012.

Project: PODET-MET: the first official meteoroid streams and meteor showers ephemeris server in the world.

- *Purpose*: provide the international community with an expertise of meteoroid streams in the whole Solar system, the associated meteor shower on every planet and provide the ephemeris of all meteor showers **(INSU SO1)**
- *Role*: PI of the project (1 to 3 people)
- *Impact*: coordinate ground based and airborne based observation of meteor showers on Earth and on other planets, protect the artificial satellites
- *Results*: Forecasting of more than 50 meteor showers on all the planets of the Solar System ; public access to the data.

CALIFORNIA INSTITUTE OF TECHNOLOGY (USA)

Postdoctoral Scholar (invited) May 2006 – Dec 2008

Project: Study of cometary trails as observed by the Spitzer Space Telescope, in collaboration with B. Reach

•*Purpose*: To develop a model of meteoroid stream at their very sources (the comets), and to understand the structure of cometary nuclei and their relation with other objects of the Solar System

•*Impact*: Constraining the population of large (mm-size) cometary particles undetectable by all other observations; showed that it may reflect the efficiency of planetesimal growth process

•Results: Unveil the dust and fragments from broken comet 73P and modeling the dust IR emission ; Responsible for the creation of artificial images reproducing the observations; Managed the dynamical study of the fragments and determination of their origin

CALIFORNIA INSTITUTE OF TECHNOLOGY (USA) - SETI INSTITUTE (USA)

Embarked wide field imaging specialist 2004 - 2009

Project: Observation from a NASA airplane (DC8 or Gulfstream) of the Genesis (NASA) and ATV (ESA) spacecraft reentry, and of the Aurigids and Quandrantids meteor showers

- *Purpose*: Get wide field images of the spacecraft atmospheric reentry or of the meteor shower (predicted by mysef)
- *Impact*: successfully predicted the meteor shower events; observed the events; get the 1st published images of the ATV (ESA) also used to derive the temperature of the debris; obtained the activity curve of the activity of the meteor shower; several Astronomy Picture of the Day for NASA

•*Responsible for:* the forecasting of the 2007 Aurigids and 2008 Quadrantids events from which these 2 missions depended on; observation acquisition of the showers and spacecrafts reentry.

THE UNIVERSITY OF WESTERN ONTARIO, London (ON, Canada)

Postdoctoral Scholar (invited) Jan.-Dec. 2005

Project: The meteor showers at Earth and Mars, in collaboration with P. Brown and P. Wiegert

•*Purpose*: Determine the origin of several meteor showers, comets and asteroids; Protect the Deep Impact spacecraft; Plan the first dedicated meteor observations from another planet

•*Impact*: Explained the 2005 Draconids event; Showed that Phaethon can be of cometary origin; Determine the meteoritic environment of comet 9P/Tempel 1 and the consequences for the Deep Impact spacecraft
•Prediction of a meteor shower at Mars caused by comet P/2001R1 and coordination of meteor observations by the Martian rover "Spirit"

SETI Institute, Mountain View, (CA, USA)
Researcher (invited) Aug.-Dec. 2004
Project: The meteor showers at Earth for the coming 50 years, in collaboration with P. Jenniskens
•*Purpose*: To have the most complete view of the coming meteor showers in order to plan in advance future observation missions and alert all space agencies
•*Impact*: Active contribution to the book: "Meteor showers and their parent bodies": providing the forecasting for the coming 50 years
•Participation to the Genesis reentry observation campaign

CNES (French Space Agency), IMCCE-PARIS OBSERVATORY (France)
Researcher - PhD student 2000-Apr. 2004
Project: Forecasting the strong meteor showers (Leonids) in order to protect the artificial satellites
Advisor: W. Thuillot, F. Colas (IMCCE), Jacques Foliard (CNES)
•*Purpose*: Modeling the evolution of natural cometary dust in the Earth environment in prevision of the strong Leonid meteor showers (1998-2002) in order to protect the artificial satellites
•*Impact*: Forecasted the 2002 Leonid, with an accuracy of less than 1 min. for the time of max. and 20% for the level of the shower (best forecasting worldwide)
•Assisted the space agencies (CNES, ESA) with decision making: to protect (cost ~1.3 M€) or not to protect the satellites (high risk)

LEADERSHIP EXPERIENCE

•PI of the "MALBEC" project since 2017
•Co-director of "DU-ECU" astronomy teaching program since 2015
•"PEGASE" science manager (IMCCE local researcher team) since 2017
•co-I of the FRIPON project since 2013
•**PI** of the 2011 Draconids international multiple airborne observation campaign (2 aircrafts, 6 scientists, 14 people on board, 17 flight hours in CNRS/SAFIRE aircraft) 2010-2013
•**PI** of the French meteor network (CABERNET); Managing up to 7 persons since 2009
•Science manager of the PoDET-MET (Pole on the Dynamics of the Earth Environment) since 2009
•Organization of the International Meteor Conference, Giron, France (120 persons) 2014
•Organization of the International Meteor Conference, Barege, France (100 persons) 2007

CONSULTING EXPERIENCE

•**Invited** Editor for "Earth, Moon & Planets", for the 2011 Draconids campaign 2013
•Member of the management team of the International Astronomical Union, Commission 22 since 2009
•Member of the International Meteor Conference scientific committee since 2018
•Consulting about the risk for spacecrafts (Shuttle, space probes & artificial satellites) from meteoroid stream for NASA (MSFC), ESA and CNES since 2002
•Consulting for the advent of any meteor shower on Earth and other planets since 2002
•**Referee** of several books, data and papers in the following international journals: Planetary Data System Galileo and Ulysses dust detector, MNRAS (x8), The Astronomical Journal, Icarus (x5), The Astrophysical Journal (x3), Astronomy & Astrophysics (x6), Meteoritics & Planetary Science (5), Celestial Mechanics (1), Journal of Geophysical Research Earth (1), Moon and Planets (x9), Planetary and Space Science (x5), Advances in Space Research (x3), Geoscientific Instrumentation, Methods and Data Systems, New Astronomy, Czech Science Foundation (GACR) (x5), Proceedings of the AOGS conference (Singapore, July 2006), Proceedings of the COSPAR conference (Paris, July 2004 and Beijing 2006) (x3), "Meteor showers and their parent bodies" (600 pages) P. Jenniskens (SETI Institute/NASA-AMES, San Francisco, USA), Space Science Reviews (1), Cambridge University Press, 2006, "Meteors and Meteor Showers", (238 pages) P. Bias (Florida Southern College, USA), Miracle, 2006, FRS-FNRS, Belgium, 2017

JURY PARTICIPATION

•Member of Dr G. Fedorets PhD thesis jury committee (invited by the University of Helsinki, Finland) fall 2019
•Member of Dr A. Sekhar PhD thesis jury committee (invited by Armagh Observatory, N.Ireland, UK) 2014
•Member of U. of Franche Compté (France) recruiting scientific council (invited) 2013
•Member of Dr L. Ferrier PhD thesis jury committee (invited by ONERA - the French aerospace agency) 2012

ADMINISTRATION DUTIES

•Member of the University Degree (DU) "Explorer et Comprendre l'Univers" organizing committee since 2015
•Editor for "Earth, Moon & Planets" since 2015
•Member of "DIM-ACAV/DIM-ACAV+" grant attribution jury since 2012
•Elected Member of IMCCE "Scientific Council" 2015-2018
•Elected Member of IMCCE "Institute Council" 2012-2015
•IMCCE PhD students career development counsellor 2012-2015
•Responsible for the National French ephemeris of the meteor showers since 2009

PRESENTATIONS & TEACHING EXPERIENCE

Presentations:
•Many talks given during international conferences and seminars
•Chairman & convenor duties ; organization of international conference (IMC2014, Giron, France ; IMC 2007, Barege, France, 2006), workshop (2012 and 2013) and special meteor sessions during international conferences (EPSC, IMC)

Teaching:
• Supervisor of postdoc fellows (x3), PhD (x4), undergraduate (x19) and engineer (x10) students (internship) since 2002
• University Degree (DU) "Explorer et Comprendre l'Univers" (9h per year) since 2012
• **OBSERVATOIRE DE HAUTE PROVENCE** (France), teaching of observation with a 1.20 m telescope since 2011
• **OBSERVATOIRE DE PARIS** (FRANCE), conference for the public, TV and radio interviews, Guide for the public, observations for the public at the 33cm telescope (build in 1856) since 2000
• **California Institute of Technology** (USA), organized 2 star parties in the desert, TV interview, participation to science articles for the public, conference in high school 2006-2008
•**ARMAGH OBSERVATORY** (N. Ireland), Guide for the public 2006
•**CRONYN OBSERVATORY** (UWO, London, Canada), Guide for the public 2005
•**University of Paris 13** (Saint-Denis, France) : teaching of computer science (undergraduate level), 120hrs 2001-2002
•**PUBLIC OUTREACH:** Participation to many activities of **popularization of science** (articles in public papers, radio and TV interviews, conferences for the public and high schools students, organization of a star parties, guide of Paris Observatory, invited researcher at "café des sciences" etc.), 2 documentaries on the 2011 Draconids event (CNRS and NHK TV) since 2000

PROFESSIONAL AFFILIATIONS

SPIE astronomical Telescopes and instrumentation since 2012
IMCCE, Assistant-Astronomer since 2009
American Astronomical Association, Division of Planetary Science since 2006
International Astronomical Union, commission 22, division III, member of the organizing committee since 2005
International Meteor Organization since 2001
SF2A (French Astronomical Society) since 2000

List of publication of Dr Jeremie Vaubaillon

February 24, 2020

1 Refereed Publications with PhD candidates

1. Ott, Theresa ; Drolshagen, Esther ; Koschny, Detlef ; Mialle, Pierrick ; Pilger, Christoph ; Vaubaillon, Jeremie ; Drolshagen, Gerhard ; Poppe, Bjrn, Combination of infrasound signals and complementary data for the analysis of bright fireballs, Planetary and Space Science, 179, 104715, 2019
2. Guennoun, M.; Vaubaillon, J.; Benkhaldoun, Z.; Daassou, A.; Baratoux, D.; Rudawska, R.; Leroy, A., Meteor Detection from the Fireball Moroccan Network: First Orbital Results and Links to Parent Bodies, Astronomy Reports, Volume 63, Issue 8, pp.619-632, 2019
3. Guennoun, M.; Vaubaillon, J.; Capek, D.; Koten, P.; Benkhaldoun, Z., A robust method to identify meteor showers new parent bodies from the SonotaCo and EDMOND meteoroid orbit databases, Astronomy & Astrophysics, Volume 622, id.A84, 9 pp., 2019
4. Egal, A.; Gural, P. S.; Vaubaillon, J.; Colas, F.; Thuillot, W., The challenge associated with the robust computation of meteor velocities from video and photographic records, Icarus, Volume 294, p. 43-57, 2017
5. Egal, A.; Veljkovic, K.; Vaubaillon, J.; Kwon, M. -K.; Perlerin, V.; Hankey, M.; Colas, F.; Thuillot, W., Time perception of a meteorite fall, WGN, Journal of the International Meteor Organization, vol. 46, no. 1, p. 7-23, 2018

2 Refereed Publications with PostDocs

1. Vaubaillon, Jeremie; Koten, Pavel; Margonis, Anastasios; Toth, Juraj; Rudawska, Regina; Gritsevich, Maria; Zender, Joe; McAuliffe, Jonathan; Pautet, Pierre-Dominique; Jenniskens, Peter; Koschny, Detlef; Colas, Francois; Bouley, Sylvain; Maquet, Lucie; Leroy, Arnaud; Lecacheux, Jean; Borovicka, Jiri; Watanabe, Junichi; Oberst, Jürgen, The 2011 Draconids: The First European Airborne Meteor Observation Campaign, Earth, Moon, and Planets, Volume 114, Issue 3-4, pp. 137-157, 2015
2. Rudawska, Regina; Zender, Joe; Jenniskens, Peter; Vaubaillon, Jeremie; Koten, Pavel; Margonis, Anastasios; Tóth, Juraj; McAuliffe, Jonathan; Koschny, Detlef, Spectroscopic Observations of the 2011 Draconids Meteor Shower, Earth, Moon, and Planets, Volume 112, Issue 1-4, pp. 45-57, 2014
3. Rudawska, Regina; Daassou, Ahmed; Moulay Larbi, Mamoun Ait; Benkhaldoun, Zouhair; Vaubaillon, Jeremie; Colas, Francois; Baratoux, David; Bouley, Sylvain, Birth of meteor network in Morocco - Analysis for the 2012 Geminids, WGN, Journal of the International Meteor Organization, vol. 41, no. 4, p. 121-128, 2013
4. Atreya, Vaubaillon, Bouley, Colas, Gaillard B., CCD Modification to obtain High Precision Orbits of Meteoroids, MNRAS, 423, Issue 3, pp. 2840-2844, 2012
5. Rudawska, R.; Vaubaillon, J.; Atreya, P., Association of individual meteors with their parent bodies, Astronomy & Astrophysics, Volume 541, id.A2, 2012
6. Bouley, S.; Baratoux, D.; Vaubaillon, J.; Mocquet, A.; Le Feuvre, M.; Colas, F.; Benkhaldoun, Z.; Daassou, A.; Sabil, M.; Lognonne, P., Power and duration of impact flashes on the Moon: Implication for the cause of radiation, Icarus, Volume 218, Issue 1, p. 115-124, 2012

3 Other Refereed Publications

1. Vaubaillon, Jérémie; Neslusan, Lubos; Sekhar, Aswin; Rudawska, Regina; Ryabova, Galina O., From Parent Body to Meteor Shower: The Dynamics of Meteoroid Streams, Meteoroids: Sources of Meteors on Earth and Beyond, Ryabova G. O., Asher D. J., and Campbell-Brown M. D. (eds.), Cambridge, UK: Cambridge University Press, 336 pp., ISBN 9781108426718, 2019, p. 161-186

2. Christou, Apostolos; Vaubaillon, Jérémie; Withers, Paul; Hueso, Ricardo; Killen, Rosemary, Extra-Terrestrial Meteors, Meteoroids: Sources of Meteors on Earth and Beyond, Ryabova G. O., Asher D. J., and Campbell-Brown M. D. (eds.), Cambridge, UK: Cambridge University Press, 336 pp., ISBN 9781108426718, 2019, p. 119-135, 2019

3. Soja, R. H.; Grn, E.; Strub, P.; Sommer, M.; Millinger, M.; Vaubaillon, J.; Alius, W.; Camodeca, G.; Hein, F.; Laskar, J.; Gastineau, M.; Fienga, A.; Schwarzkopf, G. J.; Herzog, J.; Gutsche, K.; Skuppin, N.; Srama, R., IMEM2: a meteoroid environment model for the inner solar system, Astronomy & Astrophysics, Volume 628, id.A109, 13 pp., 2019

4. Jeanne, S.; Colas, F.; Zanda, B.; Birlan, M.; Vaubaillon, J.; Bouley, S.; Vernazza, P.; Jorda, L.; Gattacceca, J.; Rault, J. L.; Carbognani, A.; Gardiol, D.; Lamy, H.; Baratoux, D.; Blanpain, C.; Malgoyre, A.; Lecubin, J.; Marmo, C.; Hewins, P., Calibration of fish-eye lens and error estimation on fireball trajectories: application to the FRIPON network, Astronomy & Astrophysics, Volume 627, id.A78, 11 pp., 2019

5. Avdellidou, C.; Vaubaillon, J., Temperatures of lunar impact flashes: mass and size distribution of small impactors hitting the Moon, Monthly Notices of the Royal Astronomical Society, Volume 484, Issue 4, p.5212-5222, 2019

6. Daubar, Ingrid; Lognonne, Philippe; Teanby, Nicholas A.; Miljkovic, Katarina; Stevanovic, Jennifer; Vaubaillon, Jeremie; Kenda, Balthasar; Kawamura, Taichi; Clinton, John; Lucas, Antoine; Drilleau, Melanie; Yana, Charles; Collins, Gareth S.; Banfield, Don; Golombek, Matthew; Kedar, Sharon; Schmerr, Nicholas; Garcia, Raphael; Rodriguez, Sebastien; Gudkova, Tamara et al., Impact-Seismic Investigations of the InSight Mission , Space Science Reviews, Volume 214, Issue 8, article id. 132, 68 pp., 2018

7. A. Drouard, P. Vernazza, S. Loehle, J. Gattacceca , J. Vaubaillon , B. Zanda, M. Birlan , S. Bouley , F. Colas, M. Eberhart , T. Hermann , L. Jorda , C. Marmo, A. Meindl, R. Oefele, F. Zamkotsian and F. Zander, Probing the use of spectroscopy to determine the meteoritic analogues of meteors, Astronomy & Astrophysics, Volume 613, id.A54, 16 pp, 2018

8. Andre, N.; Grande, M.; Achilleos, N.; Barthélémy, M.; Bouchemit, M.; Benson, K.; Blelly, P.-L.; Budnik, E.; Caussarieu, S.; Cecconi, B.; and 18 coauthors, Virtual Planetary Space Weather Services offered by the Europlanet H2020 Research Infrastructure, Planetary and Space Science, Volume 150, p. 50-59. 2018

9. Stevanovic, J.; Teanby, N. A.; Wookey, J.; Selby, N.; Daubar, I. J.; Vaubaillon, J.; Garcia, R, Bolide Airbursts as a Seismic Source for the 2018 Mars InSight Mission, Space Science Reviews, Volume 211, Issue 1-4, pp. 525-545, 2017

10. Vaubaillon, A confidence index for the forecasting of meteor showers, Planetary and Space Science, Planetary and Space Science, Volume 143, p. 78-82. 2017

11. Stefan Loehle, Fabian Zander, Tobias Hermann, Martin Eberhart, Arne Meindl, and Rainer Oefele, Jeremie Vaubaillon, Francois Colas, Pierre Vernazza, Alexis Drouard, Jerome Gattacceca, Experimental simulation of meteorite ablation during Earth entry using a plasma wind tunnel, The Astrophysical Journal, Volume 837, Issue 2, article id. 112, 10 pp. (2017).

12. Stevanovic, J.; Teanby, N. A.; Wookey, J.; Selby, N.; Daubar, I. J.; Vaubaillon, J.; Garcia, R., Bolide Airbursts as a Seismic Source for the 2018 Mars InSight Mission, Space Science Reviews, Online First (2017)

13. Segon, Damir; Vaubaillon, Jeremie; Gural, Peter S.; Vida, Denis; Andreic, Zeljko; Korlevic, Korado; Skokic, Ivica, Dynamical modeling validation of parent bodies associated with newly discovered CMN meteor showers, Astronomy & Astrophysics, Volume 598, id.A15, 13 pp. (2017)

14. Ishiguro, Masateru; Kuroda, Daisuke; Hanayama, Hidekazu; Kwon, Yuna Grace; Kim, Yoonyoung; Lee, Myung Gyoon; Watanabe, Makoto; Akitaya, Hiroshi; Kawabata, Koji; Itoh, Ryosuke; Nakaoka, Tatsuya; Yoshida, Michitoshi; Imai, Masataka; Sarugaku, Yuki; Yanagisawa, Kenshi; Ohta, Kouji; Kawai, Nobuyuki; Miyaji, Takeshi; Fukushima, Hideo; Honda, Satoshi; Takahashi, Jun; Sato, Mikiya; Vaubaillon, Jeremie J.; Watanabe, Jun-ichi, 2014-2015 Multiple Outbursts of 15P/Finlay, The Astronomical Journal, Volume 152, Issue 6, article id. 169, 14 pp. (2016)

15. Sekhar, A.; Asher, D. J.; Vaubaillon, J., Three-body resonance in meteoroid streams, Monthly Notices of the Royal Astronomical Society, Volume 460, Issue 2, p.1417-1427 (2016)

16. Neslusan, L.; Vaubaillon, J.; Hajdukova, M., A study to improve the past orbit of comet C/1917 F1 (Mellish) on the basis of its observed meteor showers, Astronomy & Astrophysics, Volume 589, id.A100, 10 pp, (2016)

17. Kwon, Yuna Grace; Ishiguro, Masateru; Hanayama, Hidekazu; Kuroda, Daisuke; Honda, Satoshi; Takahashi, Jun; Kim, Yoonyoung; Lee, Myung Gyoon; Choi, Young-Jun; Kim, Myung-Jin; Vaubaillon, Jeremie J.; Miyaji, Takeshi; Yanagisawa, Kenshi; Yoshida, Michitoshi; Ohta, Kouji; Kawai, Nobuyuki; Fukushima, Hideo; Watanabe, Jun-ichi, Monitoring Observations of the Jupiter-Family Comet 17P/Holmes during its 2014 Perihelion Passage, The Astrophysical Journal, Volume 818, Issue 1, article id. 67, 9 pp. (2016)

18. Ishiguro, Masateru; Sarugaku, Yuki; Kuroda, Daisuke; Hanayama, Hidekazu; Kim, Yoonyoung; Kwon, Yuna G.; Maehara, Hiroyuki; Takahashi, Jun; Terai, Tsuyoshi; Usui, Fumihiko; Vaubaillon, Jeremie J.; Morokuma, Tomoki; Kobayashi, Naoto; Watanabe, Jun-ichi, Detection of Remnant Dust Cloud Associated with the 2007 Outburst of 17P/Holmes, The Astrophysical Journal, Volume 817, Issue 1, article id. 77, 9 pp. (2016).

19. Koten, Pavel; Vaubaillon, Jeremie; Margonis, Anastasios; Toth, Juraj; ?uri?, Franticek; McAulliffe, Jonathan; Oberst, Jürgen, Double station observation of Draconid meteor outburst from two moving aircraft, Planetary and Space Science, Volume 118, p. 112-119 (2015)

20. Rudawska, Regina; Vaubaillon, Jeremie, Don Quixote-A possible parent body of a meteor shower, Planetary and Space Science, Volume 118, p. 25-27

21. Soja, R. H.; Sommer, M.; Herzog, J.; Agarwal, J.; Rodmann, J.; Srama, R.; Vaubaillon, J.; Strub, P.; Hornig, A.; Bausch, L.; Grün, E., Characteristics of the dust trail of 67P/Churyumov-Gerasimenko: an application of the IMEX model, Astronomy & Astrophysics, Volume 583, id.A18, 11 pp (2015)

22. Ishiguro, Masateru; Kuroda, Daisuke; Hanayama, Hidekazu; Takahashi, Jun; Hasegawa, Sunao; Sarugaku, Yuki; Watanabe, Makoto; Imai, Masataka; Goda, Shuhei; Akitaya, Hiroshi; Takagi, Yuhei; Morihana, Kumiko; Honda, Satoshi; Arai, Akira; Sekiguchi, Kazuhiro; Oasa, Yumiko; Saito, Yoshihiko; Morokuma, Tomoki; Murata, Katsuhiro; Nogami, Daisaku; Nagayama, Takahiro; Yanagisawa, Kenshi; Yoshida, Michitoshi; Ohta, Kouji; Kawai, Nobuyuki; Miyaji, Takeshi; Fukushima, Hideo; Watanabe, Jun-ichi; Opitom, Cyrielle; Jehin, Emmanuel; Gillon, Michael; Vaubaillon, Jeremie J., Dust from Comet 209P/LINEAR during its 2014 Return: Parent Body of a New Meteor Shower, the May Camelopardalids, The Astrophysical Journal Letters, Volume 798, Issue 2, article id. L34, 6 pp., 2015

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Scientific section

Contents

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1 Introduction

Meteoroids are the pieces that formed the bodies of the Solar system, around 4.5 billion years ago. From sub-micron grains to a few decametres they are also the witnesses of today collisions and comet outgassing processes. Their relative short lifetime expectancy limits the time during which they can be studied. Fortunately, the Earth encounters many meteoroid streams today, providing us with an insight of their dynamical and chemical origin. In addition, sporadic meteors allows us to pinpoint the lifetime expectancy of streams in general as well as meteoroids themselves.

When I started my PhD, back in year 2000, Wu and Williams (1996), as well as McNaught and Asher (1999) had published the first correct prediction of a Leonid meteor storm. This was the very beginning of an era when meteor showers would no longer be a complete surprise at each and every of their appearance. Fifteen year down the road, although many predictions did work extremely well, we are still surprised by meteor showers.

During the Leonid MAC workshop (Mountain View, USA, Aug. 2003), when observers showed their measurement of the Leonid meteors, I almost raised my hand to point that there was a big flaw with the measurements. Indeed, the spread of semi-major axis was way too high to be dynamically plausible. However, being a young researcher, and most of all, having a very short experience with meteor observation, I decided not to say anything. Gladly so. I also promised myself that, if possible, I would build a network of cameras able to accurately measure the velocity of meteors. This idea became the "CABERNET" project, almost 10 years later, and it paved the way for the today FRIPON project.

French research does not exist, in the sense that research is done at an international level, with collaborations with people around the globe and this translates into publications written in English in the international scientific papers. The meteor science gathers a rather small scientific community (compare to the field of asteroids or comets for example). The danger in such case is isolation from the rest of the community: for example the poor usage of tools otherwise extensively used in the astrophysics community. Such tools deal with: de-biasing, calibration, often accompanied with extensive numerical simulations. Two of my PhD candidates have successfully applied such method to demonstrate the lack of meteoroid orbit accuracy in most of today measures (Egal et al., 2017) as well as the need for strong statistical study to establish the parenthood between a shower and an asteroid (Guennoun et al., 2019). As a consequence, more bridges must be created between the meteor community and the rest of the world, being both for data acquisition, reduction and validation. Otherwise the risk is to use outdated methods at best, or to miss the big picture.

Section 2 deals with "the need for speed", i.e. the dynamics of meteoroids and emphasizing the determination of the meteor velocity. Included is a section on the methods needed to be developed or used in a more systematic way in meteor sciences. Section 3 present different observation projects.

2 The need for speed: Towards a reconciliation between observations and theory.

To quote Aristotle: let us save the phenomena.

2.1 The great Leonids years.

A few months after I started my PhD, a researcher asks me what was the topic of my research, and I obviously mentioned the prediction of the Leonids meteor showers. He literally said: "it never works!". Instead of not replying (as in 2001), today I would say: "that's exactly what research is: when it does not work, it means something is to be found!".

One of the biggest failure in the history of astronomy happened in 1899, when the Leonids did not appear as expected (Kronk, 1988). It happened again in 1998, at a time when computers allowed us to perform accurate computations of the trajectory of comets. Because these later predictions were 16 hours early, some people reported saw the Leonids the night before the predicted peak, and went to bed with high expectation for the following night (Hainaut et al., 1998). And they all experience high disappointments.

However, in the late 90s, researchers started to realise that the orbit of a comet might not be exactly the same as the one of a meteoroid. Wu and Williams (1996) as well as McNaught and Asher (1999) pointed out such difference, and the 2000 Leonids were correctly predicted, before the timing of the shower outburst. There were still some room to link the photometry of the parent comet and the level of the shower, which was the topic of my PhD, with the help of Laurent Jorda (LAM). The correct predictions of the 2002 Leonids was a huge relief and success, as well as a booster to perform the forecasting of almost all "easy cases" meteor showers for the coming 50 years. Many results are published in Jenniskens (2006).

During this time, the differences between the measurements and the prediction of meteoroid orbits during an observed and predicted meteor shower on Earth appeared (to me) too large to be real. An example of Draconids meteoroid stream semi-major axis spread from observations is provided in Fig 2. During the Leonid MAC workshop 2003, some scientists were presenting measurements of Leonids semi-major axis, that seemed extremely small. The authors were trying to find a

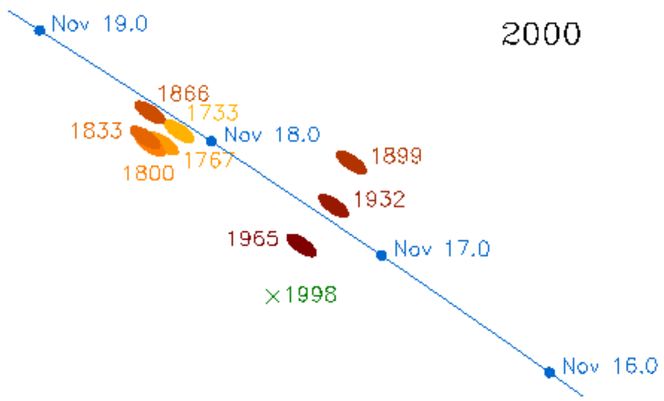

Figure 1: One of the first correct prediction of meteor shower, by McNaught and Asher (1999).

physical process to change the size of the orbit, without changing any other orbital elements, invoking some kind of collisions (energy loss). There are indeed mechanisms able to decrease the semi-major axis of an orbit. However, it takes a fair amount of time (a few hundreds or thousands of years Wiegert et al., 2009). Meanwhile, the other orbital elements also change, because of the precession, close encounters etc. As a consequence, it seemed unlikely that a Leonid meteoroid would end up on such an small orbit, in such a small amount of time (a few hundred years). I suspected that there was probably a problem with the measurements of the semi-major axis, but without any experience of the matter it was better to play it down. This is when the idea of what would become the CABERNET project came to my mind (see also sec. 3.1).

2.2 Meteoroid velocity

Considering a typical semi major-axis of a Leonid meteor of a few hundred million kilometres, and sampled over a few dozen kilometres at best it is no surprise that the measured semi major-axis uncertainty is high. In the case of the Leonid, this effect is exemplified because the measurement happens close to perihelion: a small change in velocity translates into a large change in semi-major axis.

This naturally led to the idea to build the most accurate camera dedicated to meteor observation, in order:

1. to measure the most accurate orbits (ever possibly), and

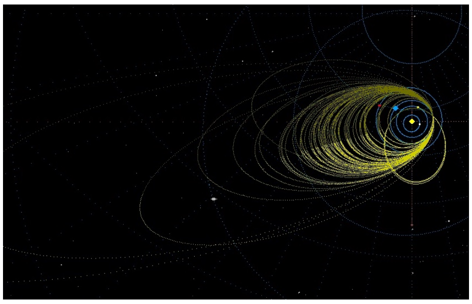

Figure 2: Orbit size distribution of the 2011 Draconids, from ground based video camera observations and the SonotaCo data reduction software suite (A. Leroy).

2. to show that there was a huge problem either with the measurements of semi-major axis, or from the theory itself.

This was the birth of the "CABERNET" project (CAmera for BEtter Resolution NETwork). I decided to take a few years to build the whole project, acquire enough data, and then hire a PhD candidates that will process the data, and publish the first measurements of the most accurate meteor orbits ever published so far.

The good news is that, in 2016, Egal et al. (2017) demonstrated the limits of the methods used so far to measure the semi-major axis of meteor orbits. While conducting her thesis, Auriane also realized how little details authors are providing about the method they use. Another surprise was that even a simple coordinate transformation (geographic to Earth-Centered Intertial) was performed with different methods depending on authors, and, naturally led to rather different results in terms of semi-major axis. The main result was that many published semi-major axis uncertainties happen to be way more optimistic than the method allows to be. In other words: most semi-major axis are not as accurate nor as precise as published.

Denis Vida (U.W.O) performed the logical following step that we did not have time to perform ourselves: he considered all known methods to compute the meteor velocity, and compared all of them step by step, pinpointing the strengths and weaknesses (Vida et al., 2020b,a). He developed a Monte Carlo approach (Vida et al., 2018) that performs similarly to Egal et al. (2017). It took him and Pete Gural more than 3 years to perform this work, underlying the great difficulty to compute the velocity of a meteor. It took at least two years for the scientific community to realise the implication: mainly that most of today orbits are far less accurate than claimed in the articles. In practice, it happened at the IMC2017 (Peznikov, Slovakia) when P. Spurny (Ondrejov Obs, Czech Republic) and M. Hajdukova (Comenius U., Sovakia) publicly and independently from us, announced that the published orbits were not correct, or at least not as accurate as claimed. This was, I believe, a direct consequence of two years of publications (paper and conferences) claiming the flaw in the determination of meteoroid velocity. I dreamt of this back in 2003, and Auriane did it 15 year later. This is actually the perfect scenario for a PhD candidate: the goal is set, and (s)he becomes internationally known for the method and the result, and the whole community is aware of the need for such a new method.

2.3 The Velocity accuracy dynamicist dream of.

What accuracy is actually needed for the measurement of the velocity? In the past, people tried to measure the ejection velocity a meteoroids from a comet, from the spread of velocities measured during a meteor shower. Further work Ryabova (2013) has demonstrated that this is unfortunately hopeless, for two reasons. Firstly because the ejection velocity is a few 10 m/s, whereas the orbital velocity is a few dozen $km.s^{-1}$. So the needed relative accuracy is about one hundredths to one thousands. Practice has shown it to be almost impossible with today techniques and computation methods (even using the methods developed by Egal et al., 2017; Vida et al., 2020b). Second, the gravitational perturbations of the planets are changing the velocity of the particles. As a consequence, it is extremely hard to recover the memory of the ejection velocity when measured many revolutions after their ejections. This is even true for simulated particles (Rudawska et al., 2012).

Ideally, one would also like to outline the presence of resonances in meteoroid streams, from meteor observations, rather than only theoretical considerations. Here again, the needed accuracy is about one hundredth of an astronomical unit. This is way beyond the measurable uncertainties of meteor velocity (with optical means only). Is the quest for the measurement of meteoroids trapped in resonance hopeless? Theoretical considerations can show that a meteor shower can only happen when particles are trapped in a specific resonance. So in a sense, this has already been done in the past (Taurids Spurný et al., 2017; Asher et al., 1993). The progress of techniques might make it possible in the near the future. The FRIPON project is interested in combining radio (Doppler) and optical observations, in order to make the most of the two techniques. The problem is that few meteors are detected both in optics and radio. However the idea is elegant and worth further investigations. Similarly, in situ observations such as Rosetta has directly measured the ejection velocity of meteoroids in the vicinity of a comet nucleus, showing that it is much less than expected, and of a few meters per second (Ott et al., 2017). So, by tackling the problem with completely different techniques and approaches, we are making progress as well.

2.4 The dynamics of meteoroid streams.

There are two main goals for dynamical considerations of meteoroid streams in the solar system. The first is extremely practical: to predict the meteor showers and outbursts at Earth. The applications range from purely scientific considerations (to plan and optimise observation campaigns, to make sure that every outburst is exhaustively observed, recorded and published, to fully characterize every shower and every outbursts and compare them with other showers and so on), to extremely practical ones (the protection of artificial satellites, the explanation of past space probe failure (Dev, 1992), the awareness for the public of a fantastic astronomy show). The second goal is to acquire a broader picture of the Solar System, to determine the origin, age, lifetime expectancy of meteoroid in the solar system, as well as meteoroid streams structures, how they evolve, how they end up in our atmosphere, what is their fate. Ultimately, since meteorites carry organic molecules (including amino acids), what role have meteoroids played in the apparition of life on Earth about 4 billion years ago. These are all extremely broad questions common to the filed of planetary science.

My input (thanks to the help of L. Jorda) was to link photometry observations of comets, with the predicted amount of meteoroids that would fall on the earth. In the following years, and in collaboration with of Peter Jenniskens, the method was applied to all the "easy" cases: the predictions of meteor shower outbursts were performed for all known parent bodies, leading to a important contribution to Jenniskens (2006). Since then, all the harder cases need are being addressed.

The IAU maintains a list of more than 1200 meteor showers, among which more than 400 are confirmed. In other words, we understand the top of the ice-berg only! The hunt for new meteor shower parent body is taking a new interest nowadays, considering the huge databases of meteor orbits provided by the several years of systematic observations performed by different networks. The possibility to average the data over several years allows us to outline the existence of showers that would otherwise be completely unnoticed (Andreić et al., 2013; Segon et al., 2017).

However, this also leads to contradictions. With nearly half a million meteor orbits (all publicly available databases: EDMOND, SonotaCo, CAMS Kornoš et al., 014a; Jenniskens et al., 2011; SonotaCo, 2009, 2016), the probability to find a bunch of "similar" orbits is high. It all comes down to the similarity criterion and a robust statistical analysis. Similarity criteria have been defined since the 60s (Southworth and Hawkins, 1963; Drummond, 1981), but none is actually working perfectly (Moorhead, 2019). There is therefore room for the definition of a satisfying method to define a meteor shower. Robust statistical analysis are unfortunately seldom performed in meteor science. A collaboration between my former PhD student, Pavel Kotena and David Capeck (Ondrejov obs), we have showed that when it is used, most suspected meteor shower association are mere artifact due to high number of orbits and NEOs Guennoun et al. (2019). The consequence is that:

- many (most?) meteor showers might not exist: this must be proven with a thorough method.
- the association between an established shower and a parent body might as well be apparent only, and should be demonstrated with a rigorous method in the future.
- if all suspected showers are real, we need a scenario to explain how so many stream do exist toady in the Earth environment, given their relative short lifetime expectancy.

These are a few ideas for future PhD studies.

Recent techniques to prove the parenthood relationship is not only to find similar orbits between a stream and an asteroid or comet, but also to perform (past)-predictions of shower outburst. This is waht we did in Segon et al. (2017). However, the time duration during which the association is searched for can only be short, given the duration a given meteoroid stream stays in the Earth vicinity (Abedin et al., 2015, 2017).

Encouraging results are obtained for recurrent meteor shower outburst. If reasonable hypothesis regarding the orbital period of a lost parent bodies can be drawn, shower outburst can be predicted, successfully observed and therefore the knowledge of a given shower greatly increased. This was the case e.g. of the Aurigids (Jenniskens and Vaubaillon, 2008) and recently the alpha-Monocerotids (Jenniskens, 2019). This mainly deals with Halley-type or Long Period orbit streams.

Even a robust and convincing demonstration of the existence of a shower might not be enough to derive its origin: some comets and even asteroids no longer exists because of a disruption event (outgasing, braking, collision Ishiguro et al., 2011, 2016). Following Valsecchi et al. (1999) the best we might achieve is to put constrains on the age and plausible parent bodies. For this, a global picture of the middle to long term dynamics is needed (over up to half a million years typically, for long period streams). In particular the quantification of chaos might be one tool (however might not be enough, or hard to interpret, A. Egal, personnel communication). All in all, the study of long term dynamics of meteoroid stream must be examined thoroughly at some point. Preliminary study should focus on the following questions: How long back in time can we trace back the parent body ? How long in the past does it make sense to search for the origin of a meteoroid stream, given the chaos in a specific orbital space? A. Egal (my former PhD student) and

L. Maquet have developed a tool to determine when the integration of the parent body back in time ceases to make sense (for meteor shower predictions at least). Difficulties arise when one realizes that, even for perfectly known orbits (generated by numerical simulations), it is impossible to go back to the initial time and location of the ejection of the meteoroid (Rudawska et al., 2012). Although greater accuracy orbital measurements are required, dynamics sets the limits of how far back in time we might look for the origin of meteoroids.

2.5 The need for bridges.

A question of flux A question that I keep receiving from different scientific communities is: "how many meteoroids fall on such place during such period of time?". Space agencies want to protect the artificial satellites in case of meteor shower outburst. Insight space mission scientists want to know how many small asteroid will hit planet Mars during the space mission operation. The scientific community interested in micro-meteorites trapped in the ice of the southern pole want to know what is the amount of sporadic meteoroids reaching our planet, versus the number falling during a major meteor shower outbursts such as the Leonids (Duprat et al., 2001b,a, 2007). The natural satellite scientific community want to know what is the contribution of deposition of organic molecules by comets on their surface. Lunar impact flashes scientific community want to have an estimate of the number of events to be observed during the year. Generally speaking, remembering that all the ages of the solar system bodies are computed are computed from crater counting, and calibrated things to the moon missions sample return, the determination of fluxes as well as its variation in the past is a primordial interest.

To compute the total amount of meteoroids falling on our planet on average per year took my colleagues and myself more than a year to compute, and the use of more than hundred thousand CPU hours at a supercomputer (Wiegert et al., 2009), and still, this study benefited from years and terabytes of radar observation provided by the Canadian team. A few years later, David Nesvorny took into account observations of the zodiacal light from infrared space base Observatory in order to perform a similar work. In order to answer the InSIGHT team, I was inspired by what is currently being performed for near Earth objects and adapted the Neslusan et al. (1998) code for this planet. Lunar impact flashes can presumably be predicted directly from the earth backgrounds impact rates. The identification of observed impact with a given meteor shower is possible but suffers from lack of 3D measurement of the velocity (Avdellidou and Vaubaillon, 2019). The determination of major impact cratering rates implies to examine the evolution of near Earth object over a time span of 1 million years typically. It is not enough to compute the evolution of several thousand meteoroids over a few thousand years to derive the fluxes at a specific point of the solar system. A study of the meteoroid environment in the whole solar system also took us years to develop, even with the use of parallelized computers (Soja et al., 2019). In other words, a serious study of such a kind needs inputs resulting from decades of observations and efforts. Needless to say that such an enterprise is never finished! Although we have an idea of the earth environments in meteoroids as well as the flux of near Earth object as a function of their size since (Grün et al., 1985), new observations as well as new models allow us to constantly revise such numbers(Soja et al., 2016; Ott et al., 2019).

The need for high numbers The need for a high number of meteor detection and orbit measurements is obvious when one realizes that a meteor shower might be so weak it might be unnoticed by people observed during one of two years only. With a ZHR less than five (that is, comparable to the sporadic background), it is extremely hard to notice the presence of a meteor shower if observed only once. Now, if several hundred cameras observed the same event, and orbits are measured, then the shower can be recognized from the background. To accumulate data over several years, is another way to highlight the presence of the meteor shower from the background (Jenniskens et al., 2011; Segon et al., 2017). Alternatively, one can simply gather observations performed all around the globe, and put them all in one gigantic database (e.g. EDMOND Kornoš et al., 014a). The presence of such huge number of orbits and observations in general, allows one to start new fields of research. We have started to look for a coincidence of several meteors, in order to quantify the frequency a given meteoroid self fragments in space. Such a natural destruction was suspected for many years but it was not until the observation performed by the Czech team that the definite proof was brought (Koten et al., 2017). This has huge consequences in terms of the very structure of meteoroids and the lifetime expectancy of a given stream, as well as for the prediction of future meteor showers on planets (Soja et al., 2016, 2019).

Is meteor science isolated? To some extent, it might be easy for meteor researchers to be stuck in their own domain. One way this can be measured is the following:

- very few meteor science papers are uploaded on http://arxiv.org. However, this is a usual habit in astrophysics today.
- the computation of the trajectory and the velocity, performed by many groups in the world, was first tested against simulated data by Pete Gural in 2012, and followed by Auriane Egal in 2016. However, such method is been widely used in astrophysics for many years now.

- The objects, instruments and methods used by many meteor scientist are in a sense, way different from the ones used in other fields of astronomy. As a consequence, it might be hard to communicate with other fields of planetary astronomy.

- Some tools used in the meteor science reinvent the wheel in sometimes less performing ways: SExtractor and SCAMP for source extraction and astrometry. Granted, SCAMP was never intended to work with allsky field of view...

The OPENMET project I observe that too often when a team starts to work in meteor science, they have to reinvent the wheel. For example: to write an acquisition software, a pipeline, a method to debias the data, to write a code that computes the trajectory of meteoroids in the Solar System etc. The value of doing things yourself is that you grasp all the subtleties, difficulties and limits of the tools you are using. The drawback is that it takes years to develop, and no one is at the mercy of making a subtle mistake that changes the results compare to another code (all methods being the same). For example: the conversion of to ECE to ECI might lead to different results from one code to another, leading to different semi-major axis of a meteoroid (Ceplecha, 1987; Egal et al., 2017; Vida et al., 2020b). When looking for resonances, this has big consequences (see sec 2.3). The problem is that, too often, the method is either not described in the paper, or the code is not accessible, preventing any comparison, thus raising doubts regarding the uncertainty (and accuracy) of a published result.

The OPENMET project has the following goal:

- accelerate the development of meteor science codes so that researchers can focus on the science, not the beguging process (how many scientists have reinvented the wheel but are unable to compare their results with another method?)

- explicitly present the method and assumptions of the chosen method, so that everyone knows what is considered (example: Solar System dynamical model: number of planets and non-gravitational forces ; method to compute the orbital velocity)

The today way to achieve this is to write codes that obey international standards in terms of documentation, and make them publicly available. I observe that, generally speaking, the young generation is more keen to do so than the older one. In other words, the goal of the OPENMET project might not be of interest for everyone. Nevertheless, in absence of world coordination (doomed to stay at the utopia level), this page is a summary of all meteor science codes I am aware of: www.imcce.frrechercheequipespegasemeteorsc.

One can see that the codes I have developed are not (yet) publicly available. One reason is that until the code is ready, it is rather hazardous to make it publicly available (since the web is highly Darwinian). Another reason is e.g. the multiplicity of language (IDL, python, F90) that makes the code not as easy to install, unless one has the skills to create packages (which is not my case, but IMCCE engineers might help of course).

3 Observation of meteoroids in the Solar System

The observation of meteors has been widely expanded in the last decade thanks to the democratization of electronic devices as well as tools to process the data Colas et al. (2014); SonotaCo (2009); Jenniskens et al. (2011); Hankey and Perlerin (2015). Some scientific goals of such observations and the means to achieve them are summed up in table 1. From a dynamicist view point, double-station observations are the most useful.

Goal	Mean	Recquirement
ZHR, flux, SFD	count	Wide FOV camera
meteoroid property	Tensile strength	3D-trajectory (double station), light curve
origin, parent	orbit	3D-trajectory and velocity (double station)
Age	orbits dispersion	3D-trajectories and velocities (double station)

Figure 3: Goals and means of meteor observations (from Vaubaillon et al., 2020).

3.1 CABERNET

Shortly after coming back to Paris Observatory, the "CAmera for Better Resolution NETwork" was started. The scientific goal was to demonstrate the existing flaw in the current measurement of meteoroid semi-major axis (at least as published in the literature) by 1) performing the most accurate measurements or meteoroid orbit and 2) developing a way to test the accuracy of the measurements. For this, we needed a high spatiotemporal resolution camera. The technical goal was to perform 10 times better than the average existing device. We chose a camera LHeritier full frame 11Mpix camera. Back in 2010, video frame rate with so many pixels did not exist. The manufacturer tuned the image acquisition and provided a way to perform "long" exposure (1 sec is long in meteor science) with an electronic shutter able to cut the signal at a frequency up to 200 Hz. With $40x27\,\mathrm{deg}^2$ of field of view, if the astrometry reach 1/10 pixel, the space accuracy would be of 3.6 arcsec and the time accuracy of 200Hz at most. Compared to a usual all sky video camera the space resolution is 18 times higher and the time resolution is 3 times higher (fixed at 100 Hz). The only comparable device is the Canadian CAMO system (Weryk et al., 2013). An example of a meteor recorded by the three CABERNET cameras is given in Fig 4.

What I did not know when I started the CABERNET project (from my own experience):

- instrumentation projects are far more complicated and time consuming than numerical integration projects

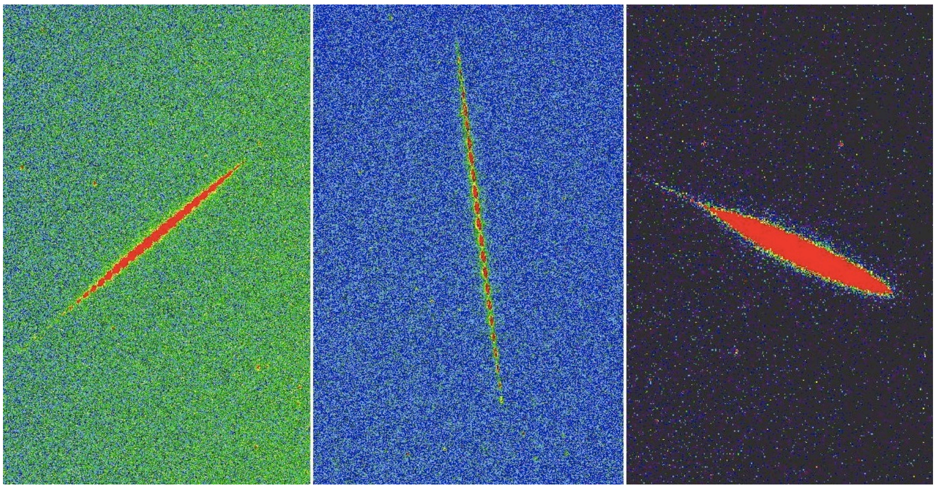

Figure 4: Example of meteor triple detection with CABERNET cameras. Images are subtracted from previous frame (thus removing stars and background).

- people management plays a huge and crucial role in such instrumentation project (see also the section that deals with management), and may lead to a feeling of mixed helplessness, loneliness and/or anger I would never have suspected
- instrumentation project, when they finally work, provide a huge sense of accomplishment, and the satisfaction of gathering your own data I would not have suspected either! And this, by far, outweighs negative feelings and make such project worth to conduct.
- pipeline development is a never-ending process (and ideally, should only be performed by trained and dedicated software engineers who know how to properly write software)
- unexpected items (including software and OS) will potentially (but temporarily, i.e. until you fix it) ruin the whole project. It might take months (up to 1 year in our case) to fix it.
- Windows OS should not exist... we are using it because, linux camera drivers did not exist for the LHeritier camera, back in 2010...
- compromise on the material to save money on the short run might cost much more in the long run

- the measurement of velocity is far more complicated than I expected, partly explaining why nobody really focused on this problem before

- the CAMO Canadian system was already providing very accurate orbits. However, the method to compute it as well as uncertainties was still to be refined.

The choice the of future installation station, the building of the camera box (performed by GEPI), the installation of the 3 cameras, and the following maintenance works were and are still today hard to achieve. The development of the pipeline seems to be a never ending process (Atreya et al., 2012; Rudawska et al., 2012; Egal et al., 2017) It uses common astronomy tools such as SExtractor (source extraction), SCAMP (astrometry) and PSFex (PSF fitting for more accurate source extractor) (Bertin and Arnouts, 1996; Bertin, 2006, 2011).

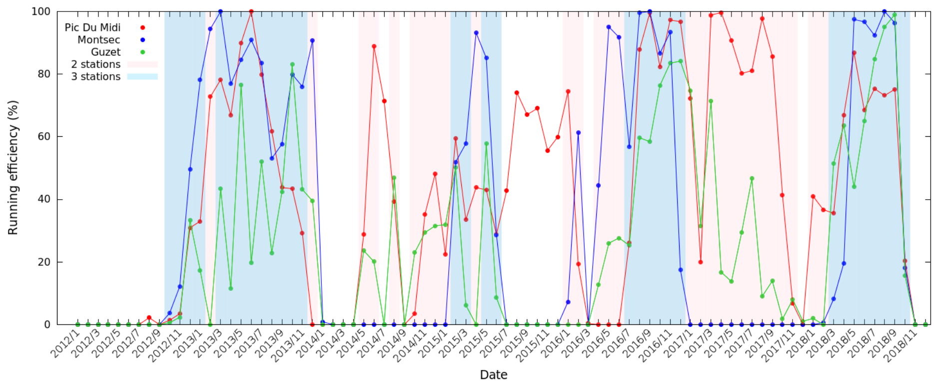

Figure 5: Running efficiency as a function of time for the Pic Du Midi (red), Montsec (blue) and Guzet (green) stations. Highlighted regions indicate periods with two (salmon) or three (blue) stations with a non-zero efficiency value (Credit: A. Egal, 2019).

What I dreamt of (i.e. to demonstrate the flaw in the measurement of meteor semi-major axis) was performed by Auriane Egal during her PhD thesis. The CABERNET pipeline would take much longer to finish than expected, but nevertheless, she developed a way to simulate meteors (known as fakeors, from Barentsen et al., 2007, 2010), inspired by Pete Gural work (Gural, 2012). She extended Guralś work to the computation of the velocity. The idea (very common in astrophysics, but less common in meteor science so far) was to create artificial data to be ingested in a meteor orbit determination software and quantify the accuracy of the different methods used in meteor science. The problem proved to be far more complex than expected. A simple coordinate conversion (ECE to ECI) proved to be a nightmare to compare, from one author to another. Auriane proved that even with the most accurate measurement, the very method used to compute the orbit would not allow one to get the accuracy one would claim to compute. She also developed her own method to decrease such a limit. The CABERNET project is still running today, and the pipeline is still under development, with recent adds-on, such as the measurement of artificial satellite position as a function of time, for Earth enviromnent dynamics applications.

3.2 The FRIPON project

The Fireball Recovery and Inter-Planetary Observation Network aims at locating meteorite fall location as well as their origin in the Solar System. For this, the whole team developed the largest and densest meteor camera network in Europe. Figure 6 shows the state of the network in early 2020.

It is worth mentioning that other networks exist e.g. in Central Europe (Oberst et al., 1998; Srba et al., 2016), Poland (Wiśniewski et al., 2017), Spain (Trigo-Rodríguez et al., 2004), Canada (Brown et al., 2010), USA (Jenniskens et al., 2011), Australia (Devillepoix et al., 2019). FRIPON uniqueness resides in its combined density and covered area. As of early 2020, only 31 meteorites have been both recorded during their atmospheric flight and recovered for analysis[1]. I did participate to the development of the pipeline (several 1000 lines of python) and am still involved in the scientific discussions and coming data calibration and exploitation.

What I learned with the FRIPON project:

- pipeline development for such an ambitious project quickly becomes a nightmare, unless handled by professionals. Fortunately, the project benefited from such people.
- management is essential
- to find a meteorite is much harder than expected

January 2020 marked the first meteorite fall recovery in Italy, showing the principle of finding the origin of meteorites is clearly feasible with the FRIPON means!

3.3 The Draconids 2011 (and other aircraft based endeavours)

Theoretical works allowed us to predict an exceptional Draconids outburst in 2011, observable from Europe (Vaubaillon et al., 2011). Such an opportunity would not

[1] www.meteoriteorbits.info

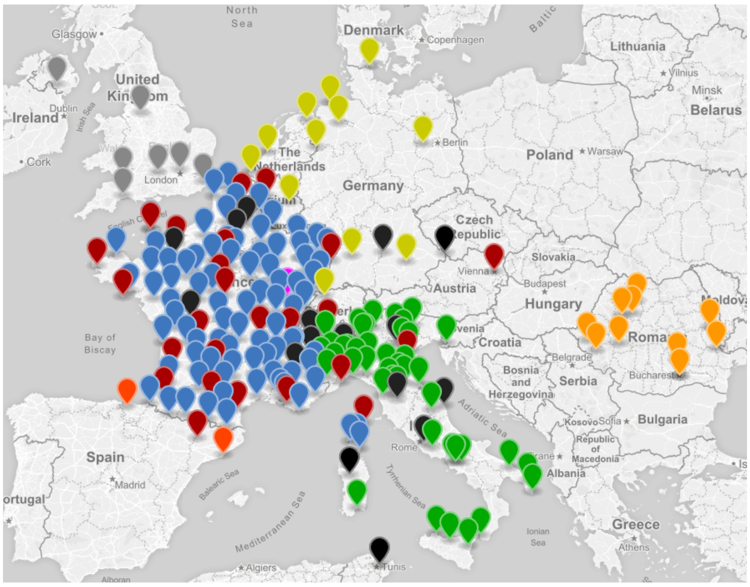

Figure 6: The FRIPON network in early 2020.

be seen again in the coming 50 years at least. It was therefore mandatory to guarantee the success of the observation of such event. The usual way is to spot clear skies thanks to weather maps and be as mobile as possible to deploy small meteor cameras at the best location. However, in early October weather statistics over Europe are not fantastic. Another way is to setup the cameras above the clouds, by putting and operating them from a jet aircraft (not a propeller because of the altitude of the clouds). In the past, I did participate to such campaign organized by Peter Jenniskens: the 2004 Genesis space probe reentry, 2007 Aurigids, 2008 ATV-reentry and the 2008 Quadrantids. CNRS has scientific jet capabilities[2] and Europe also provides scientific jet services[3]. Ideally, one wants to deploy the same jets so the relative velocity is the same, and double-station observation is made possible. However, the usage of a second jet was denied by EUFAR under the reason that France already has a research jet.Therefore I sent a copy of the application to Pavel Koten (Ondrejov observatory) in the Czech Republic, knowing his country does not have research jet. His request was granted, and we were able to conduct the first European airborne meteor observation campaign (see Fig 7 Vaubaillon et al., 2015; Koten et al., 2015; Rudawska et al., 2014).

[2] www.safire.fr
[3] www.eufar.net

Figure 7: The participants to the first European airborne meteor observation campaign, in Kiruna before going back home. The DLR and SAFIRE Mystere 20 (a.k.a. Falcon 20) are visible in the background.

Once again it proved to be much more complicated (and tiring) than expected. Nevertheless, the campaign was a success, and the following data reduction workshops allowed to transform the experience into scientific papers. What I learned was:

- preparation more than one year in advance is mandatory
- checklist are mandatory
- French work regulations must be taken into account (e.g. we wanted to work a whole night on the ground for tests purpose, but we never got the clearance)
- such endeavour ends up being more expensive than expected
- help and enthusiasm from everyone involved in the campaign: jet staff are delighted to participate to an astronomy project, astronomers are delighted to fly, journalists have great stories to tell
- the satisfaction to organize or participate to such airborne campaign are worth all the efforts!

The Draconids 2011 taught us that airborne double station meteor measurements are possible (Koten et al., 2015). It was followed by 2 workshops and involved more scientists than just those participating to the airborne observations. The first peak was observed, showing the meteor shower outburst help to determine the dynamics of a comet before its discovery (Vaubaillon et al., 2015). The level was lower by a factor of 2 compared to predictions. The latest were based on past observation of the same encountered trails (in 1933 and 1946 Vaubaillon et al., 2011). This implies that either 1) past observation are wrongly calibrated or 2) meteoroids are naturally lost by e.g. self disruption of collision. Hypothesis 1 is plausible, since eyewitness observations are subject to high uncertainties, but this should be better proven for this specific case. Hypothesis 2 has been suspected for a long time (Jenniskens et al., 2008), but the definite proof was provided by (Koten et al., 2017), when several September epsilon Perseid were detected within less than 2 seconds. However in the case of the Draconids, such a decrease within such a short time scale (50 years) is doubtful (IMHO). Collisions usually takes longer to have such significant effect on meteoroid streams, as we have showed (Soja et al., 2019).

3.4 The MALBEC project

Is there any astronomer who never cursed the clouds or the Sun for interfering with his optical observations? The 2009 Leonids observation campaign (Jenniskens et al., 2009) was conducted in Nepal thanks to the participation of Prakash Atreya (postdoc working at the CABERNET project). We spent the whole night watching the sky between the clouds that the wind was moving above our heads. Robust conclusion were hard to draw because of lost observation time due to clouds. The most disappointing was that the clouds were only a few hundred meters above our heads. At that time, I thought that a stabilized nacelle below a Helium inflated balloon might have saved the day (and the night...). Two years later, Remi Caillou (SAFIRE, CNRS) told me during the 2011 Draconids campaign, that such a gondola was certainly feasible. This opened new ideas for meteor observations.

Because of the day / night cycle only half of the meteor showers only are observable by optical means. Many intense meteor showers happen during the day (e.g. June Arietids, beta Taurids, September Sextantids). They have been studied by radio techniques mainly (Lovell, 1954; Sekanina, 1976; Brown et al., 2008). However, radar observations are strongly biased towards slow and tiny meteoroids, so that even the famous Perseids and Leonids are hard to detect. As a consequence, the only known intense daylight meteor showers are the slow ones and it is hard to know if strong and fast daylight meteor showers do exist today. Moreover, even when such meteoroids are detected, their velocity vector has already been changed by the atmospheric drag by a non-negligible amount (up to $2\,km.s^{-1}$ Abedin et al., 2017), making it complicated (if not impossible) to retrieve the exact origin of the initial body. Bruzzone et al. (2015) demonstrates one of the limits of the radar data: 10 years of observations and several millions of bad quality orbits were required to study the shape of the daytime Arietids stream. They published orbital data with $1-\sigma$ error bars because of the poor quality of the measurements[4].

The scientific goal of the MALBEC project is to fully and accurately characterize daytime meteor showers, representing 50% of interplanetary matter entering our atmosphere, and so far known only through radar observations providing very poor orbit solutions. Double station optical observations will be performed to determine the orbit, parent bodies, age, mass distribution, bulk density and the fragility of the meteoroids. In addition we aim to guarantee the successful observation of any meteor shower, regardless of the weather and the Moon, so often the cause of unsuccessful observation trips. In addition, we will develop a fast and easy way to observe natural and artificial meteors, that can be used for scientific and engineering aspects of space debris risk assessment.

In order to bypass the restriction of optical observations caused by daylight, we plan to put a double station cameras at high altitude (>20km) thanks to stratospheric balloons, where the sky is dark (in red wavelengths especially). In practice, we are currently building a stratospheric nacelle equipped with meteor observation camera, mounted on an automated attitude stabilized gondola able to fly in a coordinated constellation mode. CNES granted us with a few k€starting in 2017 to build a demonstrator. However, such a task proved to be much harder than expected (at this point of the document, no-one should be surprised of such statement...). The challenges we had to face dealt with:

- work with CNES (specification, deadlines, security aspects, etc.)
- fly and stabilize a light stratospheric nacelle (<3kg)
- recover stratospheric nacelle in trees and corn fields...
- deal with material not conform to manufacturer claim (here: onboard computer)
- deal with electromagnetic incompatibility

Most of these challenges result in delayed operation, or unmatched technical goals. We have showed that:

- to fly above 15km of altitude decreases the sky brightness by a factor of 100, for unfiltered optical wavelength

[4] who else outside of meteor science publishes $1-\sigma$ error bars results? In itself it is a confession that measurements are affected by strong uncertainties

- gondola stabilization and onboard meteor data recording is possible (for the whole duration of the flight)
- trajectory prediction is possible with an engineering model
- double station stratospheric observation is possible, under usual wind conditions
- provided the gondola is a glider, nearly any flight can be guaranteed thanks to the choice of the landing point.

Other application to the MALBEC nacelle include:

- 70th anniversary of the "Paris Match" journal, nO 3657, 19 June 2019
- Stellar occultation of natural Satellite : an exception 4 occultations event will happen on 2nd April 2021 (under study).
- possibly: high rate communication between stratospheric nacelle, or tropospheric drones
- coordinated stratospheric constellations (for e.g. atmospheric, weather or climate science)

3.5 The METEORIX project.

Carbon emission lines might be detected in meteors, under the conditions that a system can isolate them. A known line is at 248 nm. Because of the UV extinction by the atmosphere, an obvious way to detect C is to put a spectra-imager in space able to detect meteors. When Nicolas Rambaux (IMCCE) told me he wanted to start a student-Cube sat project and was in need for a scientific project, I immediately answered about the detection of C in meteors. This project became the Meteorix project, and has involved dozens of students, and still involve several labs (LIP6 in particular). Unfortunately, what is easily feasible from the ground is much harder from a 3U-cubesat! Very quickly, specialists told us about the impossibility to build a 3U spectro-imager. Today, the scientific goal is to observe 100 m-size object rentries within one year of operation. Note that the the "basic" meteor detection from the ground becomes a nightmare from space for 2 main reasons: 1) the computing power available on board a 3U is extremely limited (a few Watts at most), and 2) unlike from ground, the image background if full of moving light sources (cities, night glow, lightnings, Moonshine reflection on clouds etc.). The biggest challenge today for this project is to find the money to pass phase B. What the Meteorix project told me:

- if ground based instrumentation is complicated, it is nothing compared to space
- scientist versus engineer point of view (still learning...)

Other meteor observation programs include: infraread obseration (with Spitzer, 2006-2008), the MUSCAT project (high resolution meteor spectroscopy). Theoretical work include: ADMIRE (meteoroid entry model considering fragmentation).

4 Conclusion and future projects of the scientific section

As of today, the priority is first to finish what has been started: CABERNET and MALBEC in particular. In the following year, data calibration and exploitation is a natural followup. All in all, the loop is closed: theoretical considerations of the dynamics of meteoroid streams, development of observation means, data reduction and interpretation leading to dynamical works etc.

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List of Tables

List of Figures

A few thoughts about the word “Diriger” (to lead) in the “HDR” acronym.

I was once asked by a researcher in human sciences: "if my science is called human science, is your science inhuman?”.

List of PhD candidates I have supervised as co-supervisor:

Auriane Egal, IMCCE, Paris Observatory, France, 2014-2017, The determination of meteoroid velocity from meteor observations ; 80% of PhD management task ; co-director: William Thuillot, François Colas, IMCCE, France

Meryem Guennoun, University of Marrakech, Morocco, 2013-2019, Setup of a Morocco meteor network and the search for meteor shower parent ; 80% of of PhD management task ; co-director: Zouhair Benkhaldoun, University of Marrakech, Morocco

Theresa Ott & Esther Drolshagen, University of Oldenburg, Germany, 2017-2020 Measurement of large meteoroid flux at Earth ; 5% of of PhD management work ; co-director: Björn Poppe, University of Oldenburg, Germany, Detlef Koschny, ESA, Noordwijk, The Netherlands

1. Introduction.

In the world of what is called "hard sciences", the hierarchy of the different disciplines considered as the hardest to study to the easiest (the later being sometimes even regarded as non-science) goes like this: mathematics, physics, chemistry, biology, and last but not least, the so-called human sciences. Even if every star, every asteroid, every comet is unique, the work of the astronomer is to actually find common features between each body, find general law that are to be applied to all the bodies and to reproduce their different features, in particular by understanding their formation process and conditions. In other words, the work of the researcher is to find the big picture. Presumably, human sciences seek similar goals: to derive common features to be drawn for many human being, remembering that every one of them is unique and might not perfectly fit the derived generality. During an astrobiology course (in 2002…), I was taught that life is defined with a complexity: even the most complicated crystal is still a lot more simple than the simplest living cell. Consequently, a human being being composed of more than 37 trillion cells (source: wikipedia), is arguably one of the most complex entity astronomers have to deal with. I am of course not talking here about medical science, but rather psychology, sociology and the likes.

Researchers are supposed to be up-to-date with different techniques, at least in their domain. Otherwise, they take the risk to find something that was already known. This is the reason why a new research work starts with a full search of all the works that were performed before. This is called bibliography. Surprisingly, at least in what I've seen in astronomy, researchers do not care at all to have a look into human sciences and management references. Chances are then that they reinvent the wheel, or worse, spend a whole career repeating the same mistakes over and over again.

A few years ago, I took some times to list all the tasks and skills that today researchers need to perform in order to survive the academic world.

Figure 1: the non-exhaustive list of the skills of the new scientist. Green color denotes what is taught at physics or astronomy university level. Red is what astronomers do, but were never taught to do.

In short, nowadays in the academic world, you need to be able to sell yourself (in order to get grants, or even present your work during international conferences), which also means to compete with each other (should we like it or not), communicate with your peers, but also with the students, engineers, recruit people, manage a whole scientific team, communicate with space agencies, funding agencies, answer to media, communicate with the public, manage conflict within the team, manage the different egos within the team, and a lot more.

Ideally, for all these reasons:
-a PhD advisor should be highly trained in communication and people management, both from theoretical knowledge, as well as it is from personal experience.
-in order to manage people, one is supposed to have a decent enough emotional intelligence (EI).

Surprisingly, at least in my experience:
-astronomers rarely care for human sciences

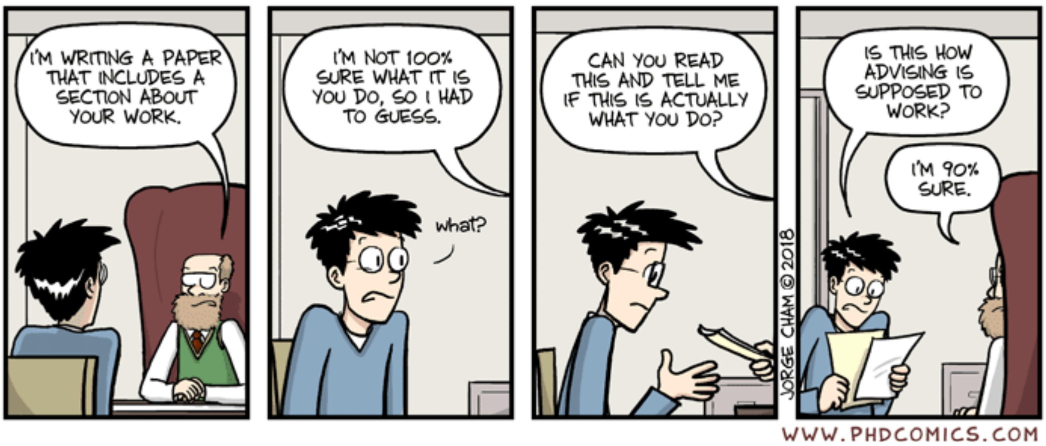
-human qualities are never assessed nor even questioned when one applies for a job position in research (at least for CNAP or CNRS recruitment in France)
-management was never taught, nor even mentioned during the 8 long years of academic studies, although the human factor might arguably account for the majority of astronomy project delays or even failures.

Not surprisingly and in other words, astronomers do not know they do not know much about human science and management. Fortunately, in most cases, "it works"! That is, PhD candidates end up defending their theses, and astronomy science is progressing. They become postdocs and end up laying a job in academia. Some of us, because of their own story, are actually pretty good or even excellent at managing people! I feel however that, most of us are not really good, to say the least.

The point of this introduction section is the following: PhD candidates management is presumably the most complex task an astronomer has to deal with, because of the very nature of the work. However, never in her/his career as (s)he even been aware of the great difficulty of the task, unless this topic is of interest to her/him. A question that is stuck in my mind for the past few years, and for which I would tend to answer "yes" is the following: is the lack of even the slightest interest in human sciences one of the reasons for some failures when it comes to people management in astronomy research?

Now, one difficulty is the following: some people spend years studying management, human behaviour and similar topics, and astronomer cannot afford to study all those topics in the same time as studying astronomy. In addition, the theoretical knowledge of management is not enough at all! Practice and experience play a preponderant role. In the following, I first share some observations and thoughts in sections 2, and then in section 3 I describe the knowledge and practices of my own management style.

Note : the expression “PhD student” has been revised in France to “doctorant” and translated in this document by “PhD candidate” (by lack of exact English word). So called “PhD students” are put at the edge of Human knowledge and asked to move forward. I do not think this is a task for a student, but rather for a well trained person in a particular field of science. Some argue that a “PhD student” is called “student” because (s)he must learn many things before being granted the degree. However I consider that, because of its very nature, the research work leads to a learning process that is lasting for the whole duration of the researcher’s career. I might even argue that a researcher who no more learns anything is no more doing research, since, by definition, every new finding generates new knowledge, which implies a learning process.



From: http://phdcomics.com.

2. Observations

I started to be interested in the topic of people management, shortly after laying a position in my lab at Paris Observatory. However, as a PhD candidates, I have also heard many stories: some of them are pleasant, and some are not. Below is a non-exhaustive list of a few observations I have made in the past years. The goal of this section is to lay down my own picture of a small fraction of the management (or lack of) in my surrounding, and the consequences I have witnessed directly or indirectly.

Management resources.

-In France, there is an online “guide for PhD students”, but I did not find (yet…) any regarding the management of PhD candidates, beside generalities. Update: in Nov 2019 I found a MOOC on this topic[1].
-there is a huge discrepancy between what we learned at school and what we do at work (especially management-wise, see also Fig 1).
-there is a kind of disdain or mockery or even aggressive behaviour against anything that deals with management or human sciences in general
-there is a sort of fusion in the eyes of many researchers, between the PhD candidate and her/his advisor: the success of one is often taken as a consequence of the work of the later. I can partially understand that: some PhD candidates are fine being completely alone, thanks to a good amount of knowledge and maturity and independence. However, many of them do need some sort of guidance (especially the first year), so, being ill advised (or not advised at all) naturally leads to missing the point and/or wasting some precious time. However, this is only part of the equation. Another case, can simply be the lack of scientific and/or management skills from the new PhD candidates, from what I have witnessed.

The good, the bad and the ugly.

The bad
The most frequent complaint I have witnessed are:
-my advisor is absent
-my advisor does not provide me with any feedback regarding my manuscript or article.
Less frequent complaints include:
-my advisor has no idea of what I am doing
-my advisor's feedback is useless because it is irrelevant
-we agreed to do something, but we end up doing the exact opposite.
-I have to manage my boss.

The ugly
Below are the worse stories that I have heard, read or witnessed (in order to preserve the anonymous character on the stories, the masculine gender has been used). The reason why I take the time to describe these situation is to highlight the need for management awareness.
-An article is submitted several months late just because the advisor has not replied to the students request to proofread it; in the end, the paper was rejected for poor scientific content; all in all many months were wasted.
-Repeated disputes, gossips, the PhD candidate ends up quitting research
-A PhD candidate can not officially start his second or third year of his PhD, simply because the advisor has not signed an official document
-A PhD candidate is not taken seriously because of the bad reputation of his advisor
-Sufferance at work, harassment, all coming from micromanagement from the advisor
-The PhD candidate ends up managing his own boss, instead of the opposite
-Researchers are put in the position of mediator between a PhD candidate and his advisor. Unfortunately, researchers have very little management nor communication skill. The result is that the conflict has now reached other persons, instead of being calmed down.
-Project team member ends up quitting violently.
-Halfway through a multi years long project, a key person threatens the PI to stop the whole projet in order to get a promotion, when the PI has no power on such a promotion.

[1] https://www.fun-mooc.fr/courses/course-v1:enseignementsup+131001+session03/about

-A collaborator finishes his contract, but the work is not 100% finished. As a consequence, because it takes so long to fix the remaining tasks, the results are never published.
-A manager realises that the hired person is definitely not the one he wanted. Too bad this is a permanent position in France, meaning that this person is now hired for the coming 42 years…
-Plane crash because the pilot did not listen to the copilot; surgeon ends up cutting the wrong leg of patient because the nurse did not dare to speak up (from "Crucial conversations" book, see references section)

The good
Here are the best stories I have witnessed:
-Conflicts involving harassment were ended after a few months of adapted management
-A conflict between a PhD candidate and his advisor is ended within two hours only, thanks to the intervention of a professional of mediation
-"My postdoc years are by far and in all regards, the best of my years as a single person" (me)
-A PhD candidate is able to significantly progress and even goes way beyond what was expected, even excels and ends up brilliantly defending his thesis
-Long-lasting conflict get resolved
-It only takes 5 to 10 minutes for a trained manager to understand how each and every of the 15 persons of a team works (or is sensitive to), and talk to each other in a way that is appropriate, understandable, and suitable for every situation (from ASCEO PhD advisor training courses).
-Plane accident is avoided because the pilot listens to co-pilot ; the higher hierarchy people is not offended by the remark of a subaltern (from the book "Crucial conversations")

The point of this section is: if the lack of awareness among astronomers accounts for some sad stories, there is hope since other people in human science research are actually working hard to make it possible for nearly anyone to learn at least the basics of management, and experience shows that it can work a great deal.

Preconceived ideas that I have witnessed, partly as a "correspondant doctoral" (PhD career advisor) in my lab.

The goal of this section is actually to present preconceived ideas that some PhD candidates might have, and, more important, that might prevent them from being successful. These observations were collected when I was "correspondant doctoral" at IMCCE.
Here are the three main preconceived ideas I have witnessed.
-**"A good sales man is a liar; in order to sell a work or an idea, you have to lie".** If some salesmen use such techniques, this is not a fatality! An excellent result or idea can be sold with the appropriate speech, with no reason whatsoever to lie. What is certain, and what I have seen, is that if someone cannot talk properly in order to convince the audience, then the chances that the idea is accepted are thin. I have witnessed the story of someone extremely talented when it came to equations, but definitely not trained to give a speech. As a consequence, he had a hard time to communicate with many people, and to write scientific papers. The result is that, after a few years as a postdoc, he realised that he would never make it into the academic research. Well, this is good for him that he realised this early enough. However, this illustrates the need for high communication skills in today's research. Again, this does not mean that you have to lie in order to be convincing! Maybe you just need to have great ideas and learn how to communicate! Shall we conclude that the people claiming that you have to lie in order to be convincing do not have good ideas? Not necessarily of course. A PhD candidate can and should sell her/himself, <u>without</u> having to lie. The fundamental value of telling the truth, can and must be preserved, but this does not mean or imply that one cannot be a good salesman. My experience also shows that the most successful scientists are excellent sales(wo)men.
-**"In order to be successful, you need to step on others toes"**. Again, why should a great result coming from a great work performed by a great team necessarily be the result of someone suffering from being abused? Should we conclude that the people supporting such claim have never been successful? Probably not, and I am convinced that by all means they do not want to step on others toes. This demonstrates that to be successful does not imply to abuse others.
-**"When a student fails, it is the advisor's responsibility"**. This might be true in parts, but in part only! In the previous section I have showed the importance of even the mere existence of management process, otherwise leading to sad stories. So yes, failure might be the advisor's

responsibility. But, again, this is not a fatality. Suppose you have a great advisor but a very bad student who does not follow the advisors guidance: why would the advisor take the responsibility for someone else not following the guidance? In psychology, this is called a fusion. The opposite is the differentiation, which is highly desirable, in my opinion. Granted, the advisor and the students are tied together. Ideally, this is for the better: the scientific articles written by the student and cosigned by the advisor will be highly beneficial to both of them. In case of failure from the student, the people claiming that this is all coming from the advisor probably forgets the time and energy that it takes to manage a person. As the proverb says: if you have never failed, you might never have tried anything new.

-**“Nonacademic job are awful, surrounded by people looking after money only and having no other interest whatsoever ; everyone is under high pressure”**. Of course, I strongly exaggerate this statements! However, I have witnessed so many times very similar ideas in the mind of PhD candidates, who have never worked in non-academia structures. I believe this perpetuates the dichotomy between academy and non-academy realms. I am always struck to hear sci statement in the mouth of PhD candidates who have never work for the non-academy entities, and still claiming to be openminded. My short experience with nonacademic world is that there are good people everywhere, and that to face economic realities naturally leads to differences of goal and about the way the work is performed. I must also say, that a decent amount of pressure helps people stay focused and efficient. Similarly, the absence of competition might be reflected by a lack of motivation, having a great influence on efficiency. I have also noticed that there are a lot of similarities between academic and nonacademic daily tasks. For this purpose, I have created in appendix A and "academia versus non-academia dictionary". The point is that, after all, the two worlds are not that different. This observation also comes from reading the French “Management" monthly magazine, dealing with entrepreneur and management works.

From these observations and reading, I now describe what I have taken out and wish to cultivate.

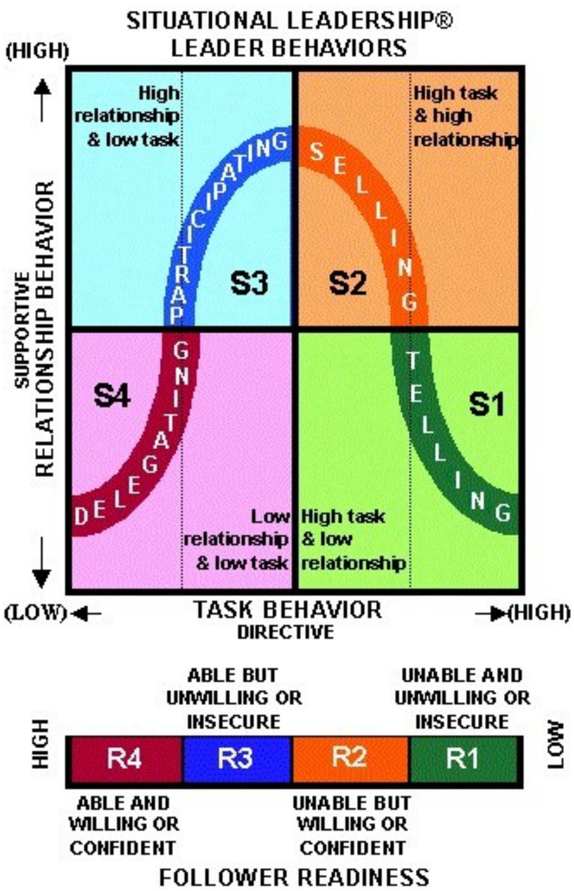
3. What I have (hopefully) learned and what I still work to be better at

“Culture is what remains once you have gotten everything" (authorship contested).

This section is an unsorted collection of thoughts and practices from my own experience with people management in general and PhD candidates in particular. It portrays what I am used to do, either consciously or unconsciously (thanks to habit). At the end of the section, I draw a short list of the skills I am (slowly) working at.

Four management styles

(Acknowledgements: J. Goursat, personal communication).
Quoting my colleague Benoit Carry: “there is no good or bad management, however there is an adapted management for every person and situation”. The figure below presents the four different management styles that human sciences researchers have observed.



The four management styles.

Like many researchers, my default management style is “participating”. Again, there is no good or bad management style, but it is counterproductive for example to ask a newcomer his opinion about a project that he knows very little of. Most fragile people might even be stressed by their absence of insight into the project, when asked as a newcomer. Consequently, to be directives is probably more appropriate in such a case. And this can be achieved without adopting a military style! One can simply say: "since you are new in this project, you must absolutely read the documentation we have written regarding such and such aspect that you will be working at later on".

Actually, probably my biggest weakness regarding the management style, is my natural tendency not to verify what people are doing or providing, assuming that, if they said they will do it, they actually will. Similarly, to do what I promised to do is sometimes quite a challenge.

"Purposes defines success"

(from "Getting things done", D. Allen.).

What is the motivation to be interested in human sciences and management in general? I can list the following items:

-Efficiency! Avoid to waste time and (emotional) energy
-optimise the work between partners
-avoid to reinvent the wheel (in terms of management) or to keep repeating the same mistake.
-take the most and the best about human sciences research, similarly to an orchestra conductor[2].

The difference between goal and result.

During my years as a "career advisor" for PhD candidates, I have noticed that there is a confusion, in the head of PhD candidates as well as advisors, between the purpose of a PhD work and the results the research will produce. I interviewed many PhD candidates every year and asked them to describe me their work, which they usually did with pleasure for five to ten minutes. Then I asked them "what is the purpose of your work"? Most of the time, I noticed by the way they looked at me that they were wondering if I was either stupid, or if I had not listened to anything they just said. During a scientific council, a researcher even told me that it is useless to define a goal for any research work, since you do not know in advance what you will find, by definition of research. He kept going explaining that if you do know what you want to find, then this is not research.

In both cases, I had to explain the difference between the goal and the results of a research work. The result is indeed what will be found during or at the end of the research process. But the goal is what drives you to conduct this research. Quoting David Allen, the goal is the answer to the question: "how will you know at the end [of the PhD] that you were successful, that you have performed the work that you actually wanted to?" In order to better explain myself, I always give some examples. The goal of a PhD work might be to create a new model. At the start of the PhD, of course, you do not know what the model will look like, but you know that you are successful when the model is built. Alternatively, the goal of the PhD work might simply be to explore a brand-new field. Even if no great scientific discovery is made, the goal is reached at the end of the PhD, because the field has now been explored widely enough to show that it is pointless to keep searching it. Another goal might simply be to exploit data (which is quite common in astronomy). Again in such a case, you do not know what will be found, but you know that you are successful when the data are exploited.

How to make the soup?

(Acknowledgements: J. Goursat, personal communication).

A manager wants a newcomer to make the soup for the whole team. However, he did not specify how many persons were there in the team, or what kind of flavours he wanted for the soup. Did he want a carrot soup or tomato soup? Was there three persons or 15? What is for dinner or supper? Without further instructions, the newcomer's soup is made, but it was not at all like the manager wanted to. Is it surprising? Not at all! This short story illustrates the need for a management that is adapted. A method to provide appropriate guidance is called "SMART": it is described in appendix C, and I complemented it to fit my needs.

Speak, write, do.

(Acknowledgements: Jean-Louis Rault, former project manager at Thales, permanent invited member of the FRIPON project core team).

There is a well-known methods for project management, that is simple to express, but not as simple to apply on a daily basis.

-Say what you do
-Write what you say
-Do what you write

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2 https://www.ted.com/talks/benjamin_zander_on_music_and_passion starting at 17 min.

This simple idea can help a great deal not to redo over and over again the same task, and might simplify the communication between members of a team. Now the difficulty I have encountered is to actually write down what was said, and to double check it on a regular basis to make sure to be on the agreed track.

“With great power comes great responsibility”

(Acknowledgements : Arielle Santé - ASCEO)
At the end of a course on how to manage a PhD candidate (14-15 May 2013), A. Santé (ASCEO) provided us with collection of ressources (property of ASCEO). Without revealing the content, I can say that a very useful tool is to define at the very start of the PhD project, the responsibility of both the PhD candidate and the advisor. This allows later to pin point who is supposed to do what. For example, contrary to some of my colleagues belief, I am persuaded that it is the PhD candidate’s task to find a postdoc. Now the advisor’s role is to introduce the PhD candidate to other research teams (especially during international conferences).
Similarly, within a project, my short experience shows me that conflicts arise easily when it is either not clear who does what, or when boundaries are not respected.

Table 1 is my own view of the responsibilities for the PhD candidate and the advisor.

Advisor	PhD candidate
Define the topic, goal and pertinence, feasibility of the PhD project	get acquainted with the scientific context and double check the goal, pertinence and feasibility
Communicate bibliography resources, set time for paper discussions, ask for candidate’s opinion	Read and search relevant articles, discuss the papers with advisor and provide opinion
Define report frequency with PhD candidate	Report at agreed frequency
Help brainstorm to overcome scientific problems	Brainstorm to overcome scientific problems
Help decide what to implement to move forward	Implement the solution to move forward
Communicate guidelines regarding writing	Write thesis and scientific papers
Communicates guidelines to make a powerful presentation	Practice and Make the presentation in front of peers
Communicates about conferences	Go to conferences (preferably with advisor for the first one)
Introduce the PhD candidate to other research teams	Interact with other research teams, without the advisor
Communicates the guidelines for the thesis defence	Defend the thesis
Communicates known resources to get a job	Get a job after the PhD defence
Lead until the PhD candidate becomes autonomous, make everything so the PhD candidate becomes a specialist in another field of expertise than the advisor’s	First follow the advisor’s guidance, then acquire autonomy, eventually leads the research project and become a renown researcher in the field

Table 1. My non-exhaustive list of responsibilities for the advisor and PhD candidate.

Three ways to communicate

(Acknowledgements: Frederic Defoy).
There are three different ways someone listens to another. On the first level, one only listens to himself. As a consequence, nobody feels listened to, and this can go on forever or create some frustration. On the second level, one carefully listens to the words that are coming from the mouth of the other person. This is of course much better than the previous case, since the other persons

feels listened to. However, nonverbal communications are at stake too. At the third level, one listens to verbal and nonverbal communications, such as body behaviour or even surrounding.
Practicing the three levels of communication with a volunteer student helped me to understand the three different styles. Nowadays, it still helps me a great deal to either stay focused while interacting with many people (at work in particular but not only) or simply to save time by realising that neither me nor my interlocutor is really communicating.

Only three questions really matter: What? How? Why?

(Acknowledgements : Arielle Santé - ASCEO)
This one comes from a one-week training for future PhD candidate advisors. The fact is, any question that can be answered by “yes” or “no”, will most likely end up being answered by “yes". Most of the time anyway. So in the end, you have no idea of what is really going on. The worst question, in terms of usefulness, is: “is everything okay?". A police officer taught us the exact same idea, during a workshop on UFO witnesses organised by the French space agency (CNES). If the officer would ask: “was the phenomenon you witnessed loud?” the answer has most chances to be “yes”. Now it does not tell us much about the intensity of the sound. Now it is far much better to ask: “how would you characterise the nose you witnessed?” and (most important) let the person answer with her/his own words.
Such questions saved me a huge amount of time, both at work and in the personal realm! It forces the interlocutor to think about the answer and it provided me with so much additional information that I would not even have necessarily thought of asking. It also shows how/if the envisioned plan is feasible. With my coworker, I would generally ask: “what have you done lately?” or “how do you intend to solve this problem?”.

Difference of sexes

(from “Men are from Mars, women are from Venus”, J. Gray).
John Gray in his best seller book made the point that men tend to be solution oriented. On the opposite, women tend to speak out their thoughts as a process for problem-solving. An immediate consequence has happened many times during Auriane Egal PhD thesis: she would come to me explaining her problem, and I would try to find a solution for her, when she had already thought which path to take, and was just seeking for either a word of affirmation or a “go/no go" signal. Fortunately, after a few weeks, I realised that the scheme was repeating itself, so I started to reverse the question to her: "What do you think"? Most of the time, the solution that she envisioned proved to be excellent! Well, to realise that did not always prevent me from falling into such a simple trap at some other occasions, but still, it helped a lot!
Interestingly, Auriane Egal did not have at all the same perception of such conversations. She commented the previous paragraph explaining that she would have talked more about solutions if she was aware of the way I perceived our conversation. However she also added that, overall, it would most probably not have ended up as useful conversations as the ones we had. Moreover, I feel that to fully present the problem rather than a quick fix has the potential to unveil additional otherwise unthinkable solutions. So all in all, it worked one way or another…

“The 5 love languages” (G. Chapman)

According to G. Chapman, people are sensitive to five "love languages”. These are the ways to express gratitude or appreciation, or to help each other. The consequence is that person A might have the impression that (s)he gives a lot to person B, but person B has the impression that person A is not doing anything. In practice it might look like this: person A keeps repeating to person B that (s)he is a good friend, and is working very well and that everybody in the team is extremely glad that B is part of it. In other words, person A’s love language is "words of affirmation". However, person B’s love language is "services", and expect person A to simply do something for the project that is high in the priority list but has been kept delayed. As a consequence, there is a constant misunderstanding between the two people. Everyone feels like the other person is not appreciating the other person’s efforts to move the project forward. In the worse case, such a situation leads to serious verbal fights, stress and eventually someone quits the project.
The point of this section is that it is extremely useful to know what makes person A and person B feel appreciated, in order to maintain good relationship and a friendly ambiance in the team. Now, to grasp someone “love language” requires a decent emotional intelligence (EI), that not

everybody has. In fact, geeks (among which astronomers…) are generally known for having few social skills, and that is why they are geeks. The good news is that EI can be practiced[3]. The bad news in my opinion, is that it takes a long time to learn and/or might end up being expensive.

Positive reinforcement

(from "How to make friends and influence people", D. Carnegie)
Depending on the people and the culture, there is a natural tendency to either point out what is going right or what is going wrong. Experience shows that to systematically point out what is wrong can easily lead to discouragement. According to experiment as well, motivation is greatly stimulated by positive reinforcement, that is to point out what is working well, or what was done right. Having spent a total of about four years in North America, I have witnessed and experienced the fruits of such approach, and the benefits it can reap. However, I would ponder that such methods works best for the people whose "love language" is "words of affirmation" (G. Chapman, see previous section). Otherwise, it might not be as efficient. The French culture, too much of positive reinforcement has the tendency to irritate people as well. There must be a right balance between being factual and being positive.

"Forget the popularity poll"

(from "9 Things a Leader Must Do: How to Go to the Next Level--And Take Others With You", Henry Cloud).
In his book, Henry Cloud points out that in order to achieve a given project, leaders should be focused on the envisioned goal, and make everything to reach it. One natural consequence is that the whole process might involve not being popular because of the decisions it requires. It seems to me that this is especially hard for people seeking friendship (or love, or recognition) at work. I have experienced that it is also especially hard when there is no hierarchy. Dr. Cloud points out that it might temporally affect the relationship between the leader and other people, but in the long run, when the project is done and results are reaped, the leader in charge will be praised for his management. In other words, this is most likely going to be beneficial for everybody, generally speaking.
I must say that this is something I still need to get better at, even though I have already witnessed that my popularity has gone down in the realm of certain projects, but that it has affected me much less than what it would have had a few years ago.

To get better at list

Here is a very short list of management skills I want to make progress in:
-"Trust but verify" (Russian proverb, quoted by R. Reagan): especially "verify", since I tend to just trust people
-Say what you do, write what you say, do what you write
-Confront
-Deal with people without having hierarchy position
-Efficiency: this is a never-ending process it seems.
-"I see, I feel, I need, I want" method when having to confront someone.

Conclusion

On the learning curve below, I estimate that I am currently at the "discouragingly realistic". This does not stop me from being interested in the topic of management in general, nor to take over some managing tasks. However, it has led me to be more picky about which task to take and which to leave, depending on my own skills.

[3] example: https://www.mindtools.com/pages/article/newLDR_45.htm

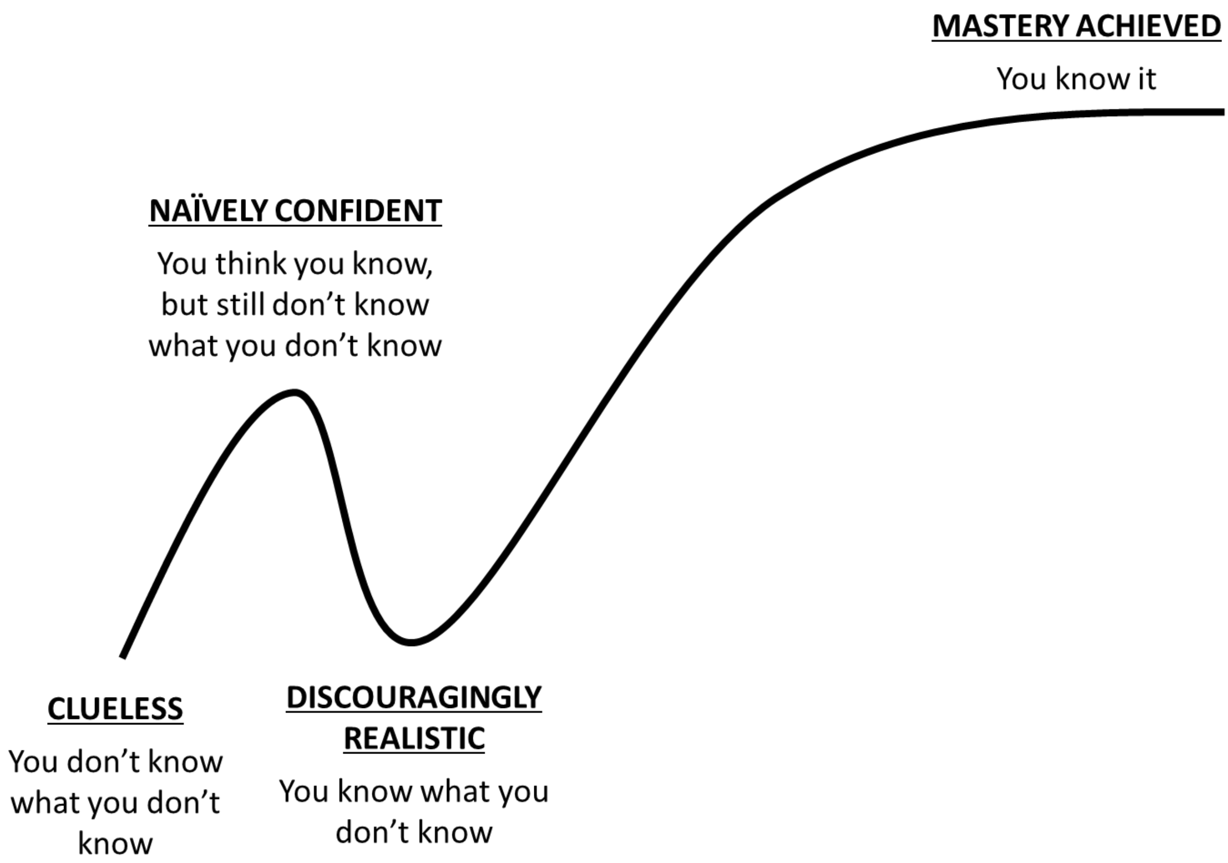

Figure: typical learning curve. In terms of management, I estimate that I am at the bottom of the right hand side of the curve…

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Annex

A. The research vs non-research dictionary.

I have noticed that there are many skills researchers must have, that are just not called the same way between academic and nonacademic worlds. The goal of this table is to provide some ways to communicate with non-academic people, and to show that the world outside research is after all not so different. Below is a non-exhaustive list of the vocabulary used in the two worlds.

Research	Rest of the world
Teaching	people management
scientific team chief	team management
expertise	consulting
to present my work at an international conference	to sell my project or myself
to write a grant proposal	to sell my project, to convince, to be in competition
to create a new research project from scratch, apply for funding, planning the different resources needed for the project, to recruit people, lead the project to its end	to be an entrepreneur
to talk with other researchers in the domain, and particularly to researchers in position to hire you in the future	to network
to find a postdoc position	to find a job
to apply to a permanent position	to sell yourself, to be in competition
to go for lunch or dinner with other researchers who might end up being the future employer	to have an informal interview

B. Questions to PhD candidates

Below is the non-exhaustive list of questions asked to PhD candidates during my years as a "career advisor". This list was initially created by myself, and enriched thanks to my colleague Benoit Carry. The goal of these questions are not necessarily to get precise answers, but rather to **initiate a reflexion** coming from the PhD candidate.

-What's your name? Who is your advisor? When did you start to PhD thesis?
-Why are you doing a PhD thesis? What are your motivations?
-What do you expect from your PhD work for yourself? What skills/status/knowledge/“know how” would you like to acquire during these years? How will you acquire them?
-What are your middle term goals? What would you like to do after your defense? Would you like to stay in academia or to go to private companies? Other plan? Why?
-What is the topic of your research?
-What is the goal of your research?
-How relevant is your work considering the field?
-Have you everything you need in order to perform the tasks that you are currently doing? If not, how can you get them?
-How often do you meet with your advisor? Is it okay with you? If not, what can you do to make it okay for you?

-How many international conferences have you attended? How many will you attend this coming months/years?
-During a conference, how do you approach a researcher working in your field, that may end up being your future employer? What can you do so that (s)he remembers you when time comes for you to lay a job?
-How relevant for your end goal is your current work?
-Have you already submitted a scientific article? If not, when and how do you intend to submit one? (If needed, the PhD candidate is reminded that this is a requirement to get the degree).
-What are the administration steps for your defense? If unknown, informations are provided.
-What are the lab resources for PhD candidates? If unknown, links to the PhD candidates laboratory webpages is sent.
-What are the skills that you are currently developing, or that you will develop, that can be useful for nonacademic position? Advice is given to produce two CVs by the end of the PhD years: one dedicated to academic research and another one for nonacademic structures.
-What do you know about the academic world? What is your experience with nonacademic world? The point of these questions is to make a PhD candidate aware that there is a whole other world outside academia, and that, if (s)he doesn't know it and doesn't want to go into it, it might be because of preconceived ideas. The goal is not to convince the PhD candidate to seek non-academic work, but rather to have a look at other possibilities, in order to have a better opinion, based on her/his own observations and experience. The PhD candidate is reminded that, at least in France, nine out of 10 astronomy PhD awardees do not end up as astronomers in academia.
-Are you becoming your advisor's students? The goal of this question is for the student to realize that (s)he should be known for her/his own work, not that of the advisor. Similarly, (s)he should be known and renowned for his own work, not the one that her/his advisor wants her/him to do.

C. Newcomer

Below is a copy of a document I provide to every newcomer, coming to work with me. The goal is to provide background awareness and tools regarding project or people management in general.

Newcomers guide

Here are a few advise for newcomers to the lab. Note that it is useful to be reminded those simple principles on a regular basis...

Organization.
Every day, set up a time to define what you want to achieve by the end of the day.
Once a week, and preferably NOT on Friday, set up a time to define what you want to achieve in the next week and also to sum up everything you have done for the past week. Do it once a month for one month duration. FYI: this is what I do for the so called "weekly meeting", usually organised on Thursday.
Draw a schedule well ahead for the big tasks, like writing proposals, if you want them to be successful.
Make sure you have a clear idea of the task you are doing, or asked to do. Never hesitate to ask questions on this topic, or on any other technical question! Remember that there is no stupid questions, only stupid people who do not dare to ask ;-)
Similarly, keep in mind the goal of what you are doing, in terms of intermediate and final goal. Having the big picture in your head will help you in everything you do. As a consequence, do not hesitate to take short breaks in order to clear your mind, or to reflect on the big picture.
Finally, remember that to think outside the box is what will get you the furthest in everything you do.
Write down a report on every big step of your work. It will help you to look back at all the things you have achieve and motivate you for the next step.

Stuck in procrastination?
Check the book: “Getting things done”, D. Allen (available at IMCCE library).

Failure.
Stressed to fail? Fearing to disappoint your boss? Check this out:

"If you're not failing, you're not trying enough new things" or the equivalent: "if you have never failed, you have probably never tired anything new"
"Success is the ability to go from one failure to another without loss of enthusiasm"
"Think wrong, fail harder" (M. Zuckerberg)
"Done is better than perfect"
"What would you do if you were not afraid?"
Useful link:
http://thefailcon.com

How to be efficient?
Always keep in mind the goal of what you are doing: it will help you to avoid rabbit trails. Studies show that we are best efficient when we are not interrupted, for a period of 1.5 hours (in general). As a consequence, try to avoid any source of distraction (emails, internet, telephone etc.) we you need to focus. Best is to shut your door, but in order to also be accessible for your coworkers, remember to open it again when you are no more so much in need of quiet time.
Work meeting: contrary to the French culture, the most important time is the END up time! It will help you to focus on what really matters and hopefully avoid rabbit trails. Never leave a meeting without having a TODO list as well as a deadline for each item (and priorities). If the meeting does not end up with a clear decision about what to do, you will feel like you have wasted your time and will be less likely to attend the next meeting. When you are meeting to show some results or updates, remember the KISS principle: Keep It Simple Stupid!
Remember: if you like it, you'll be good at it!

Report.
All of us have to write reports soon or late in our life. As a consequence, it will be very useful to take notes on a regular basis. This is exactly why it is very useful to set up a time every day, every week, and every month to reflect on what you have done and what you will do. Remember also that we are all here to help you in this task, so do not hesitate to ask us about the lab, about the project, and about past works for the project aso.
Do NOT start typing right away! Reflect on the GOAL of the report: what would you like to say? Who is it intended to?
Have a brainstorming session with yourself, draw a mind map, and THEN write down (e.g. by hand) a detailed outline of the report. Put keywords for each idea you will develop in paragraphs. Otherwise chances are you'll get quickly confused about what you want to include in the report.
Remember: KEEP IT SIMPLE STUPID. ESPECIALLY when you write in English (if you're not native English). The structure of your sentences should be: subject, verb, complement AND THAT'S IT! If you're French, forget the way you write at school, that is not the point here. As much as you can, think in English, not in French.

Presentation.
To make an efficient presentation is far from being easy. If you think otherwise, you're probably not giving efficient talks.
-First of all: know your audience! Even scientists need to be introduced to your field, so you'll have to explain the basics. Public talks are the hardest because the audience is composed of very different persons, having a very different background. FYI: the Hawaii “Institute of Astronomy” rule specifies that the first HALF of the talk should be about introducing the topic. So never neglect this part or you will loose your audience very quickly.
-Set your goal: You want people listening to you to walk away with new ideas and with the feeling that they have understood something new. The question you HAVE to ask yourself is: what do I want people to learn / know / understand?
-Pin down the key points of your presentations: transitions and what really matters
-How to? The thing with a presentation is that there is always a certain dose of stress inherent to any talk in public. This is exactly why you need to prepare your very first and the very last sentence. This will avoid “Er...”, “well” and embarrassing silent times. In addition, if you start with a joke, everybody, including you, will feel more relaxed. Once your first sentences are done you'll already feel better anyway.
Remember that after 20 minutes, you will have lost half of your audience (at least, this is what statistics say...). As a consequence, after 10 or 15 minutes, you want to put something exciting that will wake up everybody. My suggestion: put a movie, because everybody likes movies, and most of the people are visual and will remember it.

When you prepare your slides, remember again that most other people are visual and only one third need words more than images. Keep in mind also that nobody will read long sentences or equations. My suggestion: in your slides, always put words AND image (in order to touch everybody), and keep your words FEW, focusing on the main ideas. NEVER put a whole sentence! (it's boring to read and to hear...).
Restrict your number of slides to 1 per min approximately. So if you give a 15 min talk you should have 12 to 18 slides.
In your slide, put at MOST 3 colours, otherwise it will be very hardly readable, so nobody will read it.
During your talk, move your hands, NOT your feet, otherwise people will focus on you and get dizzy instead of focusing on your slides and talk. Remember to face the people, not the slides. As much as you can, and as much as it is allowed, try to interact with them to keep their focus.
Putting a question as the main title of your slide will help people keep focusing because they'll ask themselves the question and will fell like they cannot wait for the answer you are about to provide.
The conclusion: 3 sentences maximum: write down and say what you want people to remember / walk away with. This is the short answer to your question: "what do I want people to learn / know / understand?".
Last slide: acknowledgements, accompanied by the last sentence. My suggestion: "Thank you for your attention" will, again, avoid silent and embarrassing time.
Last but not least: practice is the key! Remember again that we are here to help you!

Research resources / advice:
-CDS-ADS web site to find papers:
http://cdsads.u-strasbg.fr/abstract_service.html
-Accepted papers before they are published in journals:
http://arxiv.org
-Subscribe to famous papers (e.g.: Nature, Science, Icarus, Earth Moon & Planets, MNRAS, AJ, AA, ApJ etc.) Table of Content in order to be aware of what is going on.
-Always keep in mind why you are doing what you are doing and why it is interesting and worth the effort (=keep the big picture).

Conferences.
When you go to a conference, go talk with the top 3 researchers in your field (if not top 10...), make contact with people from other countries. Why? because they most likely have a complete different approach and view as the people in your lab. Therefore it will provide you with a complementary view on your research and highlight your strength and weaknesses.
For the same reason, do NOT stick to French people longer than the 1st, or 2nd day of a 1 week conference. Otherwise you're taking the risk to spend a week wanting to talk to someone and never doing it. Force yourself to have lunch with people from other countries.
You think your English is bad? No worry: most of non-native English is bad anyway. You don't understand the words of this guy with a weird accent? No worry: we've all been there at some point, so we know what it feels like and won't blame you for this.
Your model still doesn't work? That's a good occasion to ask others their point of view on this topic! It's ok not to have perfect results, as long as you ask the right question or mention this is preliminary results.
Do you want to best researchers in your field to remember you went job hunting seasons comes? Go ask them for advice! Why? First they will feel honoured that you are asking them their opinion, and as a consequence will pay much attention to you. Second, in order to fully understand your question, they'll probably ask you for more, which will be the perfect occasion to present what you are doing. Finally, they might give you insight or new ideas of what you are doing. All in all, you have everything to gain!

Networking.
It is the art to connecting to other people for whatever purpose, and in particular that of getting you a job in the end.
Let's be frank: most geek/scientists do NOT like this word, mainly because they are usually bad or afraid at social skills.
Things to remember:
-people will be happy to talk to you because they want to pass on what they know to the future generation of scientists

Informal interview: questions to ask:
-what is their job? Company? Do you like it?
-how did you get here? people you met? resume question.
-what should I do to follow your footstep? do NOT ask them to pass it on,
-who else should I talk to?
warning: people are bombarded with requests so make sure to be short.

Project management:
-set up clear goals
-"draw" the big picture of the whole project
-draw an “organisational chart"; who does what?
-draw a functional scheme: what does what?
-identify / anticipate future problems, as much as possible
-manage projects through interfaces
-explore a solution, then draw out the advantages and inconvenient, THEN conclude.
-PLAN, DO, CHECK, ACT
-to trust doesn't mean you don't check!!!
Have a regular meeting (in my case weekly). The goal of this meeting is:
-think of ALL what you have done for the past week so everyone can see your progres
-present it to the other members of the team, in a concise and interesting (for the others not for you) way. Remember to Keep It Simple Stupid (KISS)! Unless you're the PI or have big news, don't speak for more than 5 min. Remember there might we many people also talking. AS A CONSEQUENCE YOU ABSOLUTELY HAVE TO PREPARE YOUR MEETING!!!
-present your intended work for the coming week so everyone can know your plans
-share your keystone problems so you can discuss it with a colleague who can give you an advice AFTER the weekly meeting
-useful books: "7 habits of highly effective people" by Stephen R. Covey ; "Getting things done"
http://www.evancarmichael.com/

People management:
-"Management is doing things right. Leadership is doing the right thing" (P. Drucker & W. Bennis)
-"Great people talk about ideas. Average people talk about things. Small people talk about other people."
-always encourage and point out what has been done ; then you can talk about what's missing or not done the way you thought
-make sure you communicate clearly: evaluate your communication by e.g. asking the other one to reformulate what you've just said. Alternatively, rephrase with your own words what your colleague just told you to make sure you have listened and understood what (s)he means.
-make sure your co-workers have enough tools/knowledge to perform what you have asked them to do
-the SMART(ER-NG) method when setting a project / task:
S Specific : Significant, Stretching, Simple
M Measurable : Meaningful, Motivational, Manageable
A Attainable : Appropriate, Achievable, Agreed, Assignable, Actionable, Ambitious, Aligned, Aspirational
R Realistic : Relevant, Resourced, Resonant
T Time-bound : Time-oriented, Time framed, Timed, Time-based, Timeboxed, Timely, Time-Specific, Timetabled, Time limited, Trackable, Tangible
E Evaluate : Ethical, Excitable, Enjoyable, Engaging, Ecological
R Reevaluate : Rewarded, Reassess, Revisit, Recordable, Rewarding, Reaching
and I would add (from D. Allen):
N Next step : what is the next step towards your goal? If it takes less than 2 minutes, do it NOW!!! (from D. Allen)
G Goal : why are you doing this? Is it really useful? Why does it matter to you? Why does it have to be done now?
-seek a win / win outcome in every situation
-talk about facts, not feelings
-"I see, I feel, I need, I want" principle when something is wrong
-when there's a pb don't delay: talk about it (bluntly or not). Most important: talk about it to the person in charge of the problem, NOT to all your other colleagues!

-take pb / conflicts as a way to improve, move on, learn something, rebound.
-don't talk on people's back. Talk about person's problems with someone you know won't always take your side and knows well both you and the person you have pb with.
-Afraid of having an argument with your colleague? Chances are after the argument things will settle down. Even better: chances are the (s)he will thank you for speaking frankly and not hiding your point of view. Remember: don't be afraid of what you say because “those who mind don't matter and those who matter don't mind”.
-Remember: the wise, the fool and the evil (from H. Cloud, "Necessary endings").
-halfway through the internship, fill in an appreciation form and discuss with the person why you filled it this way and what to change for the second half. Assess the being (personality), knowledge and know how.
-always ask them to grade you: it will highlight your management / communication strength and weaknesses
-regularly go back to your note to remember yourself what / where you need to change/improve.
-Management resources:
Dale Carnegie: "how to make friends and influence people"
Henry Cloud & John Townsend: "Boundaries"
Henry Cloud: "Necessary endings"
Got problems with your boss or colleague & no more know what to do? Here are 2 life-changing resources to help you handle any conversation when stakes are high:
-crucial conversations (REF)
-crucial confrontation (REF)
Other resources :
www.salary.com

How to get a student work for / with you? What to ask during an interview?
-carefully detail the job, highlighting the desired skills and personality ; get the people with a "carrot" like observation trip or money in addition to the subject itself
-hiring someone: evaluate the knowledge, know how and the being (in French: savoir, savoir faire et savoir être)
1st face to face meeting:
-ask why (s)he is here and how her/his CV fits the needs
-test knowledge with respect to the project goals
-evaluate the "know how" based on past experience
-evaluate personality (=ask yourself if you would like to work with this person) and candidate motivation,
-ask about people management skill / experience, ask about how it went with previous advisor
-test autonomous work+thinking abilities: what do you usually do when you're stuck?
-test independence versus autonomy
-ask about personality strengths and weaknesses
-ask about availability time period.
-ask if (s)he has questions about the project, but decide before end what question you really do NOT want her/him to ask. Example: I would hate that someone asks me about vacations as a first question. Not that it does not matter, just that I might conclude the person is more interested in vacation than the job itself, and as such, is not where (s)he would like to be. And if so, (s)he probably won't like being working with us. Remember: if you like it, you'll be good at it!
see also :
http://management.about.com/od/managementskills/a/InterviewQ70204.htm
https://fitsmallbusiness.com/worst-interview-questions/

How to write a proposal?
-the first and probably the most important thing to do is to know exactly what the referee/committee wants/needs. If you do not answer the needs, why would they give you the money? Or why would they hire you if you do not fit the needs?
-put yourself in the shoes of the referee who reads the proposal: if it's not clear and interesting to read, why'd he even continue to read the proposal until the end? Needless to say that if your proposal is boring you won't get the money.
-keep asking yourself why is my idea a good idea and how will I convince that is a good idea?
-keep asking yourself why would I do that? What benefits would I get from it? Is it really new and groundbreaking?

-granted, you think you have a great idea. Now the question is: why does anybody else care? If your scope is too narrowminded, nobody but you is interested in the topic. As a consequence, you need to open up the scope of the research proposal so that the results will really have an impact in your field of research, but also in others.
-if you think that the document you have written is not perfect, why would it be considered, given that there are plenty of others “perfect” proposals in the competition? So get back to work and make it as best as possible! Have at it read by another researcher, preferably not exactly working in your field and ask him/her what (s)he understands and if (s)he would give you the money. If no, ask why. Don't be afraid: it's best to have a negative answer now than once the proposal is submitted! :-)
- important aspects not to neglect: feasibility, timeline (Gantt chart), list of deliverable, who does what and when? Complimentary of the members of the team, management of people and project.

OTHER RESOURCES:
-IMCCE: local resources:
https://intranet.imcce.fr
Paris Observatory and related resources:
http://ecole-doctorale.obspm.fr
https://sympa.obspm.fr/wws/info/astro-jc
http://cjc.jeunes-chercheurs.org
http://associations-jeunes-chercheurs.org/

Career development resources:
https://www.nature.com/careers
http://www.career.caltech.edu/

Job posting
https://dps.aas.org/jobs-list

Meteor Sciences:
subscribe to IMO-news and meteorobs if you haven't done so:
https://www.imo.net/contact-us/mailing-list/
http://arch.lamacchia.us/meteorobs/www.meteorobs.org/
https://www.meteornews.net/

Bibliography:
-the #1 must know/use bibliography tool in astronomy : https://ui.adsabs.harvard.edu/
-the #2 must know/use bibliography tool in astronomy : https://arxiv.org/
-All old WGN articles are in the IMCCE library
-Meteor shower and their parent bodies, P. Jenniskens (available in the library)

List of Astronomy Conferences:
http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/meetings/

Computer science resources:
https://openclassrooms.com

Not English native? Here are some resources to write in English:
http://www.swya.org
http://www.nextscientist.com/writers-block-phd-students