OBSERVATIONS DES PLANETES ET SATELLITES EFFECTUEES AVEC LA LUNETTE MERIDIENNE DU LABORATOIRE D'ASTROPHYSIQUE DE BORDEAUX (LAB) (2007-2014)

G. Dourneau [1,2], **J.F. Le Campion**[1,2], **S. Bontemps**[1,2], **C. Ducourant**[1,2], **S. Raymond**[1,2], **F. Selsis**[1,2], **C. Soubiran** [1,2], **V. Wakelam**[1,2], **W. d'Anna**[1,2], **J.M. Desbats**[1,2], **M. Soulette**[1,2]

[1] **Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France**
[2] **CNRS, LAB, UMR 5804, F-33270, Floirac, France**

1. INTRODUCTION

Nous présentons ici les résultats des observations astrométriques des planètes du système solaire et de leurs satellites effectuées durant les 8 dernières oppositions, de 2007 à 2014, avec la lunette méridienne CCD automatique du Laboratoire d'Astrophysique de Bordeaux (LAB).

Ce travail fait suite à celui de Dourneau et al. (2007) qui présentait, dans la Note Scientifique et Technique de l'IMCCE S089, les observations de ces mêmes objets effectuées avec le même instrument, de 1997 à 2006, et jusqu'en 2007 pour les satellites de Saturne seulement.

Sur les 8 dernières oppositions, nous avons effectué plus de 1500 observations de planètes et satellites. Le rythme de nos observations méridiennes de ces objets du système solaire s'est très significativement accru au cours de ces 7 dernières années puisque nous avions effectué un peu moins de 900 observations durant les 10 précédentes oppositions de 1997 à 2006, comme il est indiqué dans la Note S089.

Une analyse des observations méridiennes de planètes et satellites présentées dans la Notre S089 a été effectuée par Arlot et al. (2008). Elle a montré que ces observations sont d'une très grande utilité pour la maintenance et l'amélioration de la qualité des éphémérides des objets ainsi observés. En conséquence, une convention a été signée entre le LAB et l'IMCCE début 2012 afin que se poursuive l'effort observationnel du LAB afin de contribuer à l'amélioration du service de la maintenance des éphémérides de l'IMCCE.

2. OBSERVATIONS

Les coordonnées locales du LAB (code UAI=999) sont les suivantes :
Longitude = 0° 31' 39 '' W
Latitude = 44° 50' 7'' N
Altitude = 73m

La lunette méridienne du LAB a un diamètre de 20 cm et une longueur focale de 2,7m, conduisant à une échelle de 8,7''/mm dans le plan focal. Cet instrument est totalement automatisé depuis 1996 et il est équipé d'une cellule CCD Thomson 7896M de 1024x1024 pixels carrés de 19μm de côté, correspondant à un champ de 1,7''x1,7''.

Les observations se font en mode TDI qui consiste à laisser défiler le ciel devant l'instrument immobile, positionné à une hauteur choisie. Les bandes de ciel ainsi observées ont une hauteur de 28' et leur longueur est limitée à 1h. Dans ces conditions, le temps de pose correspond au temps de transit qui est égal à 112s/cosδ, pour un objet de déclinaison δ. La magnitude des objets observables dans de bonnes conditions est comprise entre 8,5 et 16.

Le nombre total d'observations que nous présentons ici est de <u>1519</u>, ainsi réparties pour chacun des objets observés:

A. Planètes
- Uranus : 205 observations de 2007 à 2013
- Neptune : 225 observations de 2007 à 2013
- Pluton : 143 observations de 2007 à 2014

B. Satellites des planètes
- Saturne :
  - Dioné : 3 observations de 2011 à 2014
  - Rhéa : 22 observations de 2008 à 2014
  - Titan : 127 observations de 2008 à 2014
  - Hypérion : 120 observations de 2008 à 2014
  - Japet : 159 observations de 2008 à 2014

  Cela représente un total de 429 observations des satellites Dioné, Rhéa, Titan, Hypérion et Japet effectuées de 2008 à 2014. Les observations des satellites de Saturne effectuées en 2007 ne sont pas présentées ici car elles ont été déjà publiées par Dourneau et al. (2007) dans la Note S089.

- Uranus :
  - Umbriel : 45 observations de 2007 à 2013
  - Titania : 131 observations de 2007 à 2013
  - Oberon : 150 observations de 2007 à 2013

  Cela représente un total de 326 observations des satellites Umbriel, Titania et Oberon effectuées de 2007 à 2013.

- Neptune :
    - Triton : 189 observations de 2007 à 2013.

La répartition des observations des planètes et satellites pour chaque opposition de 2007 à 2014 est donnée dans la Table 1.

Table 1. Nombre d'observations de planètes et satellites par opposition de 2007 à 2014

	2007	2008	2009	2010	2011	2012	2013	2007-2013	2014	2007-2014
Saturne										
Dioné	0	0	0	0	1	0	1	2	1	3
Rhéa	0	3	8	2	3	0	2	18	4	22
Titan	12*	33	27	12	11	11	15	109 (121#)	18	127 (139#)
Hypérion	11*	28	25	12	14	6	14	99 (110#)	21	120 (131#)
Japet	14*	38	33	15	18	13	19	136 (150#)	23	159 (173#)
Uranus	60	27	32	21	21	29	15	205		205
Umbriel	11	11	3	7	3	8	2	45		45
Titania	36	15	19	16	11	21	13	131		131
Oberon	40	20	23	15	16	24	12	150		150
Neptune	53	32	53	15	17	37	18	225		225
Triton	50	27	45	14	12	27	14	189		189
Pluton	13	30	33	13	10	12	21	132	11	143
Total	263 (300#)	264	301	142	137	188	146	1441 (1478#)	78	1519(1556#)

(*) Observations des satellites de Saturne de 2007 déjà publiées par Dourneau et al. (2007)
(#) Nombre incluant les observations (*) déjà publiées par Dourneau et al. (2007)

3. REDUCTION ASTROMETRIQUE

La réduction astrométrique des bandes de ciel de 28' de hauteur et d'environ 1h de longueur a été décrite de façon détaillée Dourneau et al. (2007). Vous pouvez vous reporter à ce travail, mais rappelons simplement que le catalogue de référence que nous utilisons est Tycho-2 et que la précision des observations que nous présentons ici est d'environ 60 mas pour les positions et de 4 10^{-4} pour les magnitudes. Aucune correction d'effets chromatiques a été effectuée, ces effets ayant été évalués négligeables en comparaison de la précision des observations par Arlot et al. (2008).

4. PRESENTATION DES POSITIONS ET MAGNITUDES OBSERVEES

Les positions observées que nous présentons ici sont les coordonnées astrométriques topocentriques des planètes et satellites rapportées à l'ICRF. Les magnitudes observées sont données en bande V. Ces positions et magnitudes observées sont données dans des fichiers disponibles sur le site web de l'IMCCE, à l'adresse : ftp://ftp.imcce.fr/pub/misc/bordeaux/2007-2013.

Ces fichiers portent le nom de la planète ou du satellite dont ils contiennent les positions et les magnitudes, suivi de « -data.txt ». Leur contenu est donné en Annexe ci-dessous. Ils comportent 8 colonnes successives, comme indiqué dans l'exemple suivant pour le fichier « uranus-data.txt » :

```
2455039.645977  23 47 22.4542  -2 13 24.826  6.808
2455040.643196  23 47 18.0618  -2 13 55.050  6.969
2455041.640414  23 47 13.5159  -2 14 26.805  6.499
```

La première colonne fournit la date julienne d'observation (temps moyen de la pose), exprimée en Temps Universel. L'ascension droite observée, exprimée en heures, minutes et secondes décimales, est donnée

dans les colonnes 2 à 4. La déclinaison observée, exprimée en degré, minute et secondes décimales, est donnée dans les colonnes 5 à 7. La 8ème colonne indique la magnitude observée.

5. CONCLUSION

Les observations des planètes et satellites présentées ici ont été comparées aux éphémérides disponibles à ce jour sur le site de l'IMCCE. L'analyse détaillée de ces résidus a fait l'objet d'un travail indépendant (Arlot et al., 2012) qui montre notamment que ces positions observées présentent un niveau de précision élevé, avec des erreurs standard inférieures ou égales à 100 mas pour Uranus, Neptune et leurs satellites, ainsi que Pluton. Pour les satellites de Saturne, la précision est encore meilleure, avec des erreurs standard de l'ordre de 50 mas. Par ailleurs, les dérives systématiques qui avaient été mises en évidence par l'analyse des observations de 1997 à 2006 par Arlot et al. (2008) semblent persister, notamment pour Uranus et Neptune et leurs satellites. Par contre aucune dérive significative n'affecte les positions de Pluton et des satellites de Saturne.

Pour terminer, ajoutons que les positions observées des satellites planétaires permettent de déduire de pseudo-positions de leur planètes respectives, par l'intermédiaire des positions théoriques des satellites. Les positions observées des planètes ainsi obtenues, via les positions observées de leurs satellites, présentent une meilleure précision que celle issue de l'observation directe, notamment pour Saturne.

Il en résulte que les observations méridiennes effectuées au LAB présentent un intérêt scientifique certain pour leur contribution au service de maintenance des éphémérides des objets du système solaire de l'IMCCE. Cet effort observationnel devra donc se poursuivre durant les années à venir.

6. REFERENCES

Dourneau G., Le Campion J.F., Rapaport M. et al., « Observations des planètes, satellites et astéroïdes avec la lunette méridienne de l'observatoire de Bordeaux (1995-2007) » 2007, Note Scientifique et Technique de l'IMCCE, S089

Arlot J.E., Dourneau G. and Le Campion J.F., « An analysis of Bordeaux meridian transit circle observations of planets and satellites (1997-2007» 2008, A&A, 484, 869

Arlot J.E., Dourneau G. and Le Campion J.F. « Analysis of meridian circle observations of planets and satellites made at LAB (2007-2013) » 2014, en préparation

ANNEXE

Nous présentons dans cette Annexe le contenu des fichiers suivants qui fournissent les positions et les magnitudes observées des planètes et satellites, les observations de chaque opposition successive étant séparées par un interligne. :

- Planètes : « uranus-data.txt », « neptune-data.txt » et « pluto-data.txt »
- Satellites : « dione-data.txt », « rhea-data.txt », « titan-data.txt, « hyperion-data.txt », « iapetus-data.txt », « umbriel-data.txt », « titania-data.txt », « oberon-data.txt » et « triton-data.txt ».

Ces fichiers sont également disponibles électroniquement sur le site web de l'IMCCE à l'adresse : ftp://ftp.imcce.fr/pub/misc/bordeaux/2007-2013

PLANETES

uranus-data.txt

```
2454306.632323   23 17 50.8056   -5 24 10.449   6.617
2454307.629532   23 17 45.5531   -5 24 45.497   6.743
2454308.626740   23 17 40.1630   -5 25 21.726   6.748
2454312.615555   23 17 17.2561   -5 27 54.018   6.694
2454315.607150   23 16 58.7081   -5 29 56.745   6.668
2454316.604345   23 16 52.2684   -5 30 39.276   6.727
2454320.593114   23 16 25.3538   -5 33 36.039   6.590
2454321.590303   23 16 18.3375   -5 34 22.170   6.260
2454322.587491   23 16 11.2164   -5 35  8.095   6.757
2454337.545179   23 14 13.5032   -5 47 48.848   6.094
2454343.528205   23 13 22.2098   -5 53 15.861   6.222
2454344.525374   23 13 13.5202   -5 54 11.075   6.312
2454345.522543   23 13  4.7828   -5 55  6.652   6.228
2454346.519712   23 12 56.0220   -5 56  2.094   6.287
2454348.514048   23 12 38.4206   -5 57 53.427   6.185
2454349.511216   23 12 29.5843   -5 58 49.409   6.324
2454350.508384   23 12 20.7350   -5 59 45.199   6.072
2454351.505551   23 12 11.8697   -6  0 41.262   6.117
2454352.502718   23 12  2.9990   -6  1 37.118   6.179
2454353.499886   23 11 54.1299   -6  2 32.820   6.035
2454354.497053   23 11 45.2487   -6  3 28.761   6.300
2454355.494220   23 11 36.3808   -6  4 24.473   6.279
2454356.491387   23 11 27.5104   -6  5 20.116   6.045
2454359.482890   23 11  0.9932   -6  8  6.209   6.000
2454362.474395   23 10 34.6698   -6 10 50.320   5.706
2454363.471564   23 10 25.9626   -6 11 44.622   6.410
2454364.468734   23 10 17.2949   -6 12 38.740   6.410
2454385.409461   23  7 29.8317   -6 29 45.863   6.599
2454386.406650   23  7 22.8416   -6 30 27.860   6.393
2454387.403840   23  7 15.9623   -6 31  9.524   6.739
2454388.401032   23  7  9.1985   -6 31 50.248   6.444
2454389.398225   23  7  2.5638   -6 32 30.006   6.391
2454390.395419   23  6 56.0539   -6 33  8.766   6.626
2454392.389812   23  6 43.4124   -6 34 24.618   6.551
2454393.387011   23  6 37.2870   -6 35  1.028   6.515
2454394.384212   23  6 31.3002   -6 35 36.531   6.911
2454395.381414   23  6 25.4487   -6 36 11.235   6.710
2454397.375822   23  6 14.1562   -6 37 17.763   6.555
2454398.373029   23  6  8.7387   -6 37 49.522   6.709
2454400.367448   23  5 58.3200   -6 38 50.547   6.747
2454401.364660   23  5 53.3381   -6 39 19.648   6.528
2454405.353526   23  5 34.9549   -6 41  5.787   6.577
2454412.334112   23  5  9.0496   -6 43 31.280   7.302
2454414.328584   23  5  3.1885   -6 44  3.070   7.064
2454420.312047   23  4 49.8933   -6 45 11.078   6.739
2454421.309298   23  4 48.3132   -6 45 18.400   6.976
2454422.306552   23  4 46.9241   -6 45 24.537   6.803
2454426.295586   23  4 43.2145   -6 45 37.488   6.758
2454429.287385   23  4 42.3986   -6 45 34.615   6.691
2454432.279204   23  4 43.2769   -6 45 21.402   6.812
2454433.276481   23  4 43.9424   -6 45 14.474   7.254
2454438.262900   23  4 50.1341   -6 44 22.692   6.805
2454445.243978   23  5  6.7903   -6 42 20.551   6.666
2454446.241284   23  5  9.9287   -6 41 58.351   6.695
2454447.238592   23  5 13.2459   -6 41 34.896   7.141
2454448.235902   23  5 16.7584   -6 41 10.531   7.127
2454449.233214   23  5 20.4460   -6 40 44.913   6.881
2454451.227844   23  5 28.3857   -6 39 50.114   7.001
2454452.225162   23  5 32.6275   -6 39 20.915   6.851
2454453.222483   23  5 37.0569   -6 38 50.892   6.874
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2454675.632206   23 32 26.3039   -3 50 37.407   6.659
2454676.629416   23 32 21.1171   -3 51 12.771   6.758
2454677.626624   23 32 15.7964   -3 51 48.720   6.926
2454680.618240   23 31 58.9906   -3 53 42.266   6.375
2454683.609842   23 31 40.9964   -3 55 42.950   5.917
2454687.598624   23 31 15.2505   -3 58 34.781   6.867
2454711.530941   23 28  8.3894   -4 18 57.777   6.816
2454717.513957   23 27 16.1583   -4 24 34.372   5.822
2454725.491299   23 26  5.5607   -4 32  5.688   6.144
2454726.488467   23 25 56.7421   -4 33  1.901   6.100
2454729.479971   23 25 30.3699   -4 35 49.413   5.985
2454730.477140   23 25 21.6225   -4 36 44.932   6.153
2454731.474309   23 25 12.9048   -4 37 40.103   5.821
2454733.468648   23 24 55.5613   -4 39 30.010   6.047
2454735.462989   23 24 38.3622   -4 41 18.419   5.773
2454736.460160   23 24 29.8340   -4 42 12.174   6.316
2454738.454504   23 24 12.9250   -4 43 58.597   5.917
2454739.451677   23 24  4.5512   -4 44 50.963   6.683
2454744.437553   23 23 23.6894   -4 49  6.562   7.104
2454746.431910   23 23  7.8668   -4 50 45.120   7.397
2454750.420635   23 22 37.2807   -4 53 54.994   6.169
2454757.400948   23 21 47.6489   -4 59  0.534   6.049
2454758.398141   23 21 41.0062   -4 59 40.921   6.029
2454759.395336   23 21 34.4889   -5  0 21.006   6.285
2454762.386927   23 21 15.6854   -5  2 15.095   5.881
2454763.384127   23 21  9.6768   -5  2 51.645   6.113
2454765.378532   23 20 58.0687   -5  4  1.501   6.201

2455039.645977   23 47 22.4542   -2 13 24.826   6.808
2455040.643196   23 47 18.0618   -2 13 55.050   6.969
2455041.640414   23 47 13.5159   -2 14 26.805   6.499
2455044.632056   23 46 59.0032   -2 16  6.655   6.204
2455047.623683   23 46 43.2037   -2 17 54.513   6.320
2455053.606895   23 46  7.9785   -2 21 52.277   6.150
2455057.595674   23 45 41.9792   -2 24 47.029   5.978
2455069.561893   23 44 13.6963   -2 34 33.297   6.017
2455072.553424   23 43 49.6309   -2 37 11.832   5.868
2455073.550600   23 43 41.4741   -2 38  5.233   5.775
2455074.547775   23 43 33.2533   -2 38 59.307   5.975
2455080.530810   23 42 42.7158   -2 44 29.562   6.036
2455082.525150   23 42 25.4942   -2 46 21.816   6.093
2455085.516658   23 41 59.4107   -2 49 11.418   6.134
2455088.508164   23 41 33.0880   -2 52  2.197   6.072
2455097.482675   23 40 13.7528   -3  0 33.301   6.154
2455099.477012   23 39 56.2574   -3  2 25.546   5.838
2455104.462862   23 39 13.0477   -3  7  1.471   5.893
2455107.454377   23 38 47.6326   -3  9 43.011   6.094
2455111.443073   23 38 14.5557   -3 13 12.897   5.694
2455117.426143   23 37 27.1019   -3 18 12.234   6.481
2455119.420507   23 37 11.9557   -3 19 47.164   5.964
2455121.414876   23 36 57.2066   -3 21 19.387   6.052
2455123.409249   23 36 42.8632   -3 22 48.703   6.040
2455130.389599   23 35 56.2983   -3 27 36.721   6.063
2455131.386797   23 35 50.1492   -3 28 14.569   5.853
2455132.383997   23 35 44.1174   -3 28 51.358   6.126
2455134.378402   23 35 32.4988   -3 30  2.426   6.021
2455145.347749   23 34 39.0200   -3 35 23.132   6.195
2455154.322837   23 34  9.8107   -3 39  9.578   6.054
2455160.306320   23 33 58.2767   -3 39  8.415   6.056
2455177.259942   23 34  1.8756   -3 38  0.117   6.087

2455407.648590    0  1 58.0291   -0 37 47.561   6.075
2455414.629105    0  1 25.6046   -0 41 31.534   6.096
2455415.626314    0  1 20.3861   -0 42  7.339   6.026
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2455417.620729   0  1   9.5229  -0 43 21.235   5.982      2454302.571678  21 34 28.6977 -14 42 36.607   8.455
2455418.617934   0  1   3.8872  -0 43 59.536   6.046      2454306.560488  21 34  5.4088 -14 44 34.530   8.253
2455439.558919  23 58 38.3586  -1  0 12.001    7.036      2454307.557689  21 33 59.4691 -14 45  4.511   8.374
2455442.550449  23 58 14.1569  -1  2 51.796    6.877      2454308.554890  21 33 53.4807 -14 45 34.577   7.981
2455443.547624  23 58  5.9556  -1  3 45.616    6.733      2454309.552090  21 33 47.4468 -14 46  5.054   8.118
2455450.527830  23 57  6.8721  -1 10 13.634    6.436      2454312.543688  21 33 29.1335 -14 47 37.063   8.300
2455451.525000  23 56 58.2436  -1 11  9.590    7.050      2454315.535282  21 33 10.5179 -14 49 10.597   8.355
2455452.522170  23 56 49.5841  -1 12  6.190    6.997      2454316.532480  21 33  4.2572 -14 49 41.973   8.299
2455454.516508  23 56 32.1657  -1 13 59.854    7.027      2454320.521267  21 32 38.9851 -14 51 48.150   8.139
2455458.505182  23 55 57.0661  -1 17 48.083    6.949      2454321.518463  21 32 32.6296 -14 52 20.027   8.205
2455461.496685  23 55 30.6144  -1 20 39.829    6.972      2454322.515660  21 32 26.2562 -14 52 51.741   8.177
2455482.437274  23 52 31.0098  -1 39 51.870    6.902      2454337.473604  21 30 50.8528 -15  0 44.362   7.911
2455484.431630  23 52 15.1507  -1 41 32.632    6.646      2454343.456795  21 30 13.9272 -15  3 46.033   7.972
2455514.347586  23 49 10.7384  -2  0 34.376    6.463      2454344.453995  21 30  7.9021 -15  4 15.564   8.079
2455524.319913  23 48 38.8497  -2  3 36.938    6.981      2454345.451196  21 30  1.9186 -15  4 44.915   7.870
2455540.276066  23 48 25.1394  -2  4 24.004    6.980      2454346.448397  21 29 55.9779 -15  5 14.060   8.044
2455542.270624  23 48 26.8039  -2  4  7.745    6.921      2454348.442801  21 29 44.2459 -15  6 11.394   8.153
2455546.259766  23 48 32.4030  -2  3 20.807    6.969      2454349.440003  21 29 38.4486 -15  6 39.772   7.920
                                                          2454350.437207  21 29 32.7174 -15  7  7.841   8.082
2455782.631733   0 16  2.5943   0 54 27.875    6.942      2454351.434411  21 29 27.0357 -15  7 35.631   8.140
2455783.628945   0 15 57.5577   0 53 53.517    6.887      2454352.431616  21 29 21.4119 -15  8  3.117   8.053
2455784.626155   0 15 52.3730   0 53 18.175    6.920      2454353.428821  21 29 15.8521 -15  8 30.260   7.944
2455811.550296   0 12 46.6914   0 32 41.496    6.469      2454354.426027  21 29 10.3496 -15  8 57.033   8.158
2455814.541819   0 12 21.8947   0 29 58.616    6.740      2454355.423234  21 29  4.9178 -15  9 23.518   8.137
2455816.536164   0 12  5.0732   0 28  8.646    6.943      2454356.420441  21 28 59.5590 -15  9 49.472   8.208
2455817.533336   0 11 56.5830   0 27 12.954    7.092      2454362.403705  21 28 28.9149 -15 12 18.634   8.045
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SATELLITES

Satellites de Saturne

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