

Satellites Naturels

Astrometrie et Orbite

Roberto Vieira-Martins⁽¹⁾, J.I.B. Camargo⁽¹⁾, M. Assafin⁽²⁾, A. Dias-Oliveira⁽¹⁾,
G. Benedetti-Rossi⁽¹⁾, F.P. Magalhães⁽¹⁾, A. Ramos Gomes Jr⁽²⁾, F. Braga-Ribas⁽¹⁾,
A.H. Andrei⁽¹⁾, D.N. da Silva Neto⁽³⁾

(1) Observatório Nacional – Rio de Janeiro – Brésil

(2) Univesidade Federal do Rio de Janeiro – Rio de Janeiro – Brésil

(3) Universidade Estadual da Zona Oeste – Rio de Janeiro - Brésil

MOTIVATION

**positions précises des
satellites naturels**



**fixent les modèles
dynamiques qui déterminent
les orbites**



**donnent renseignements sur
l'évolution et la formations des
satellites**

CE TRAVAIL

**20 ans d'observations CCD - Brésil
satellites naturels**

**satellites
proches – régulières - externes
planètes
Jupiter – Saturne - Uranus - Neptune**

**types d'observations
astrométrique - photométrique**

OBSERVATIONS

période d'observation:	1992 – 2012
observatoire:	Itajubá (IAU: 874)– Brésil ($\phi = -22^\circ$)
télescopes:	1.6m (P-E), 0.6m (B&C), 0.6m (Zeiss)
échelles:	13"/mm, 25"/mm, 27.5"/mm
tailles du champ:	5' x 5', 10' x 10'
détecteurs:	CCDs
réductions:	PRAIA + coronagraphy
référence astrométrique:	aujourd'hui - UCAC2 (2MASS)

DIFFICULTÉS DE L'ASTROMÉTRIE SATELLITES PROCHES ET RÉGULIERS

origine

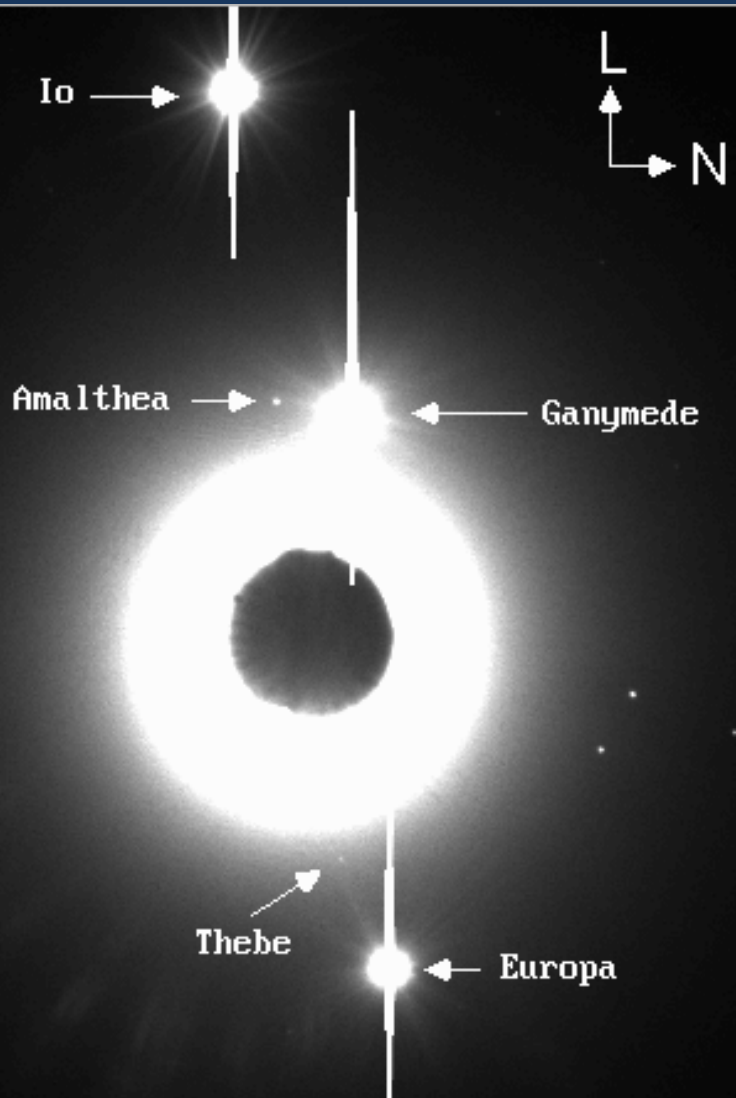
différence de magnitude - planète x satellite

solutions

coronographie - filtres - phénomènes mutuels

DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS



Jupiter (1993)

télescope: 1,6 m

temps de pose: 5 s

masque sur la fenêtre du CCD

magnitudes (V)

Jupiter - 2.3

Io 5.6

Europa 5.8

Ganymède 5.2

Almalthée 14.5

Thébé 16.1

DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

Jupiter (2009)

télescope: 1,6 m
temps de pose: 1 s
filtre méthane



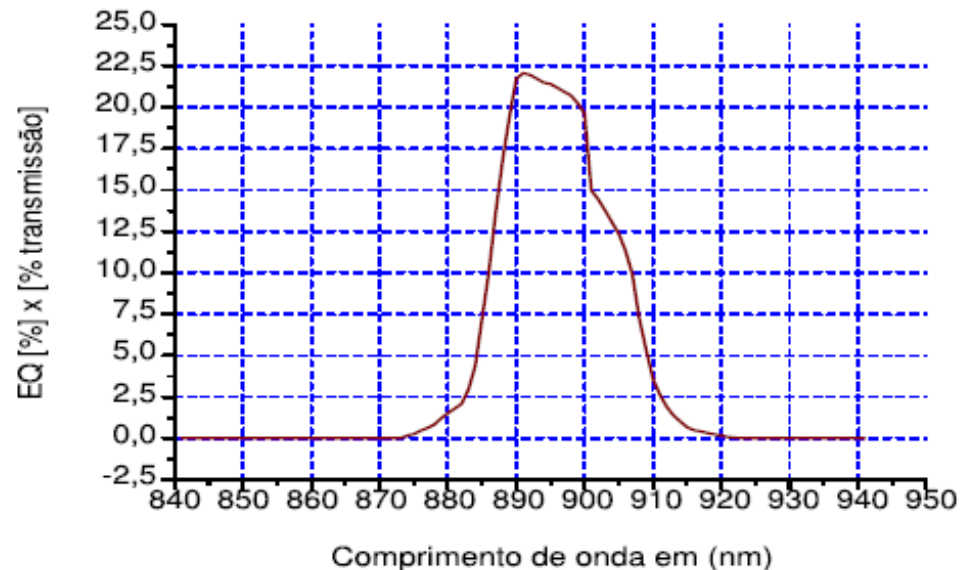
Callisto →



Io ↗



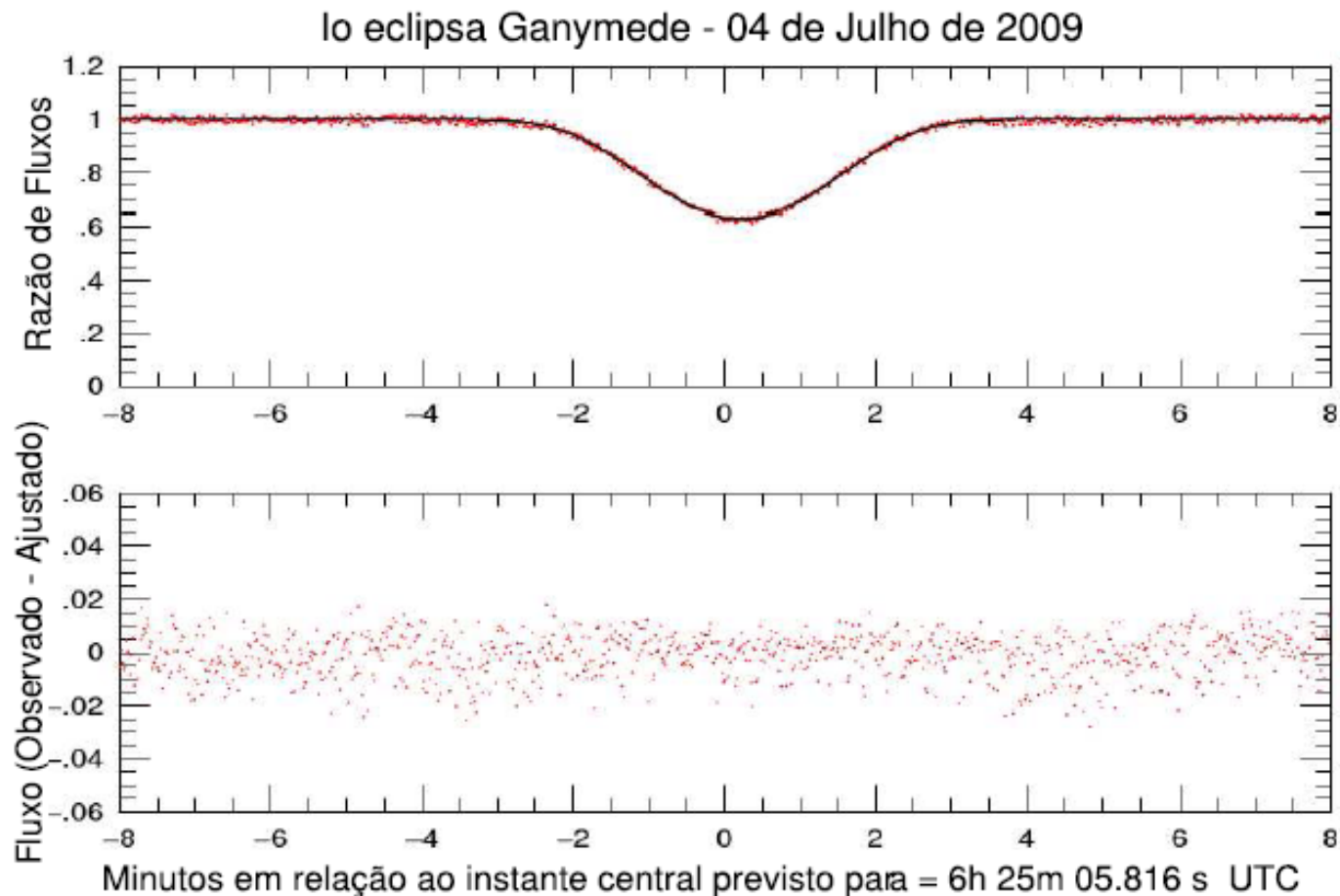
Eficiência Quântica - CCD301 x %Transmissão Filtro de Metano



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

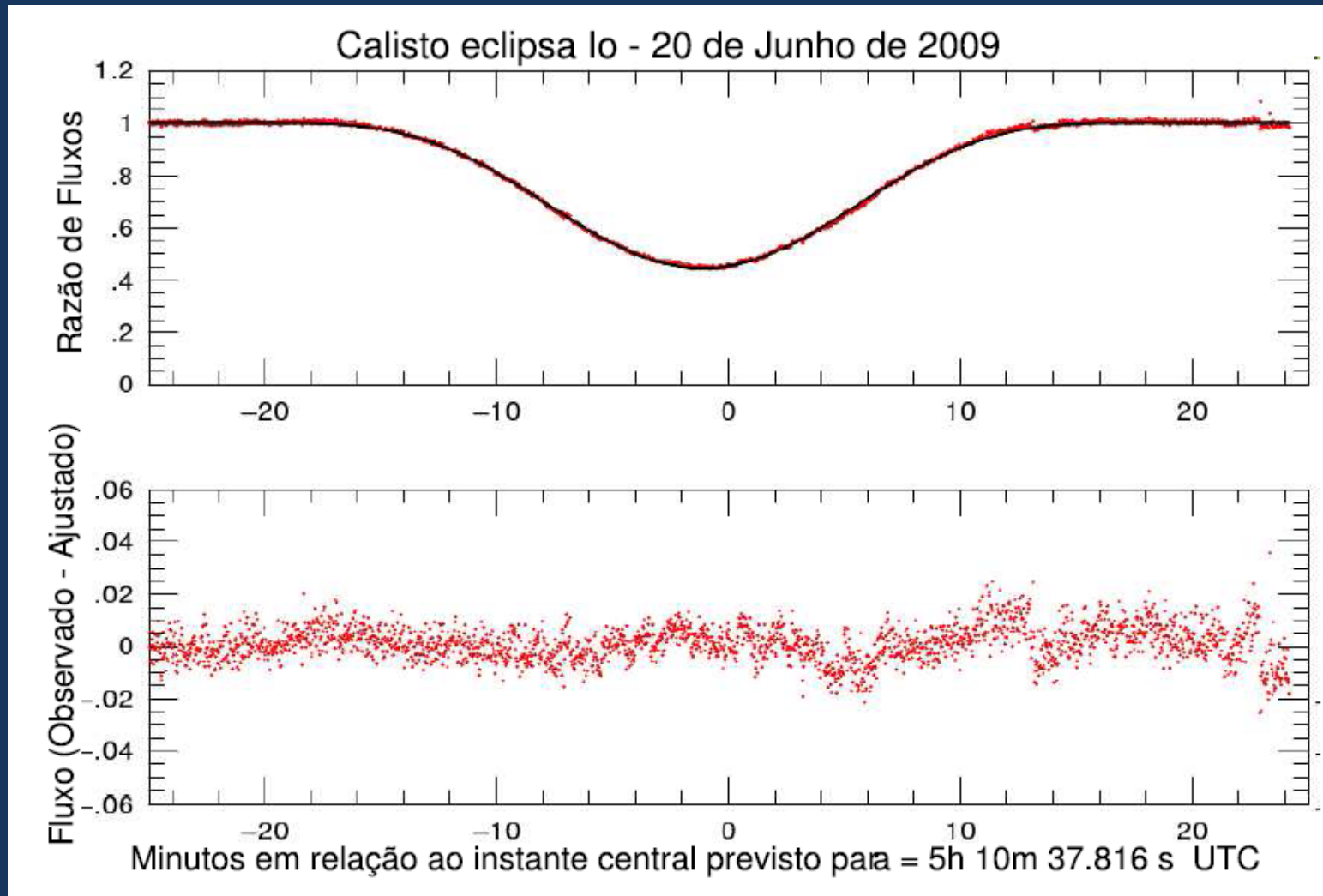
PHÉNOMÈNES MUTUELS - JUPITER



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

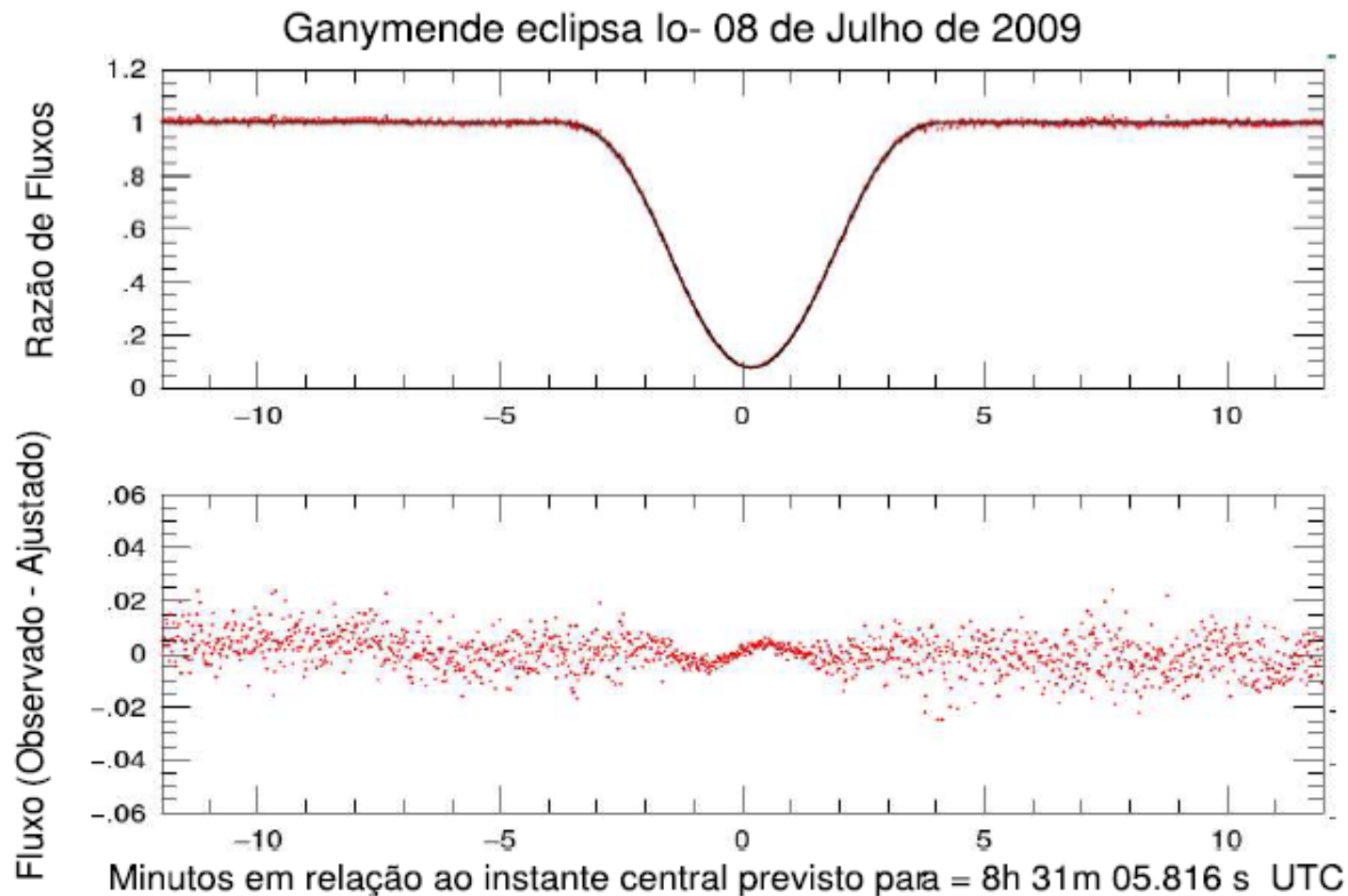
PHÉNOMÈNES MUTUELS - JUPITER



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

PHÉNOMÈNES MUTUELS - JUPITER



DIFFICULTÉS DE L'ASTROMÉTRIE

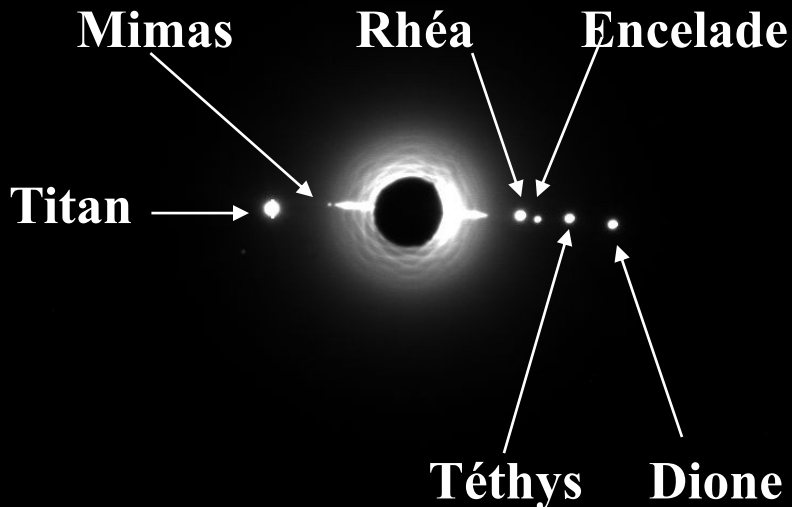
SATELLITES PROCHES ET RÉGULIERS

Saturne (1995)

télescope: 1.60

temps d'exposition: 10 s

masque sur la fenêtre du CCD



magnitudes (V)

Saturne 0.9

Titan 8.5

Mimas 13.0

Rhéa 9.9

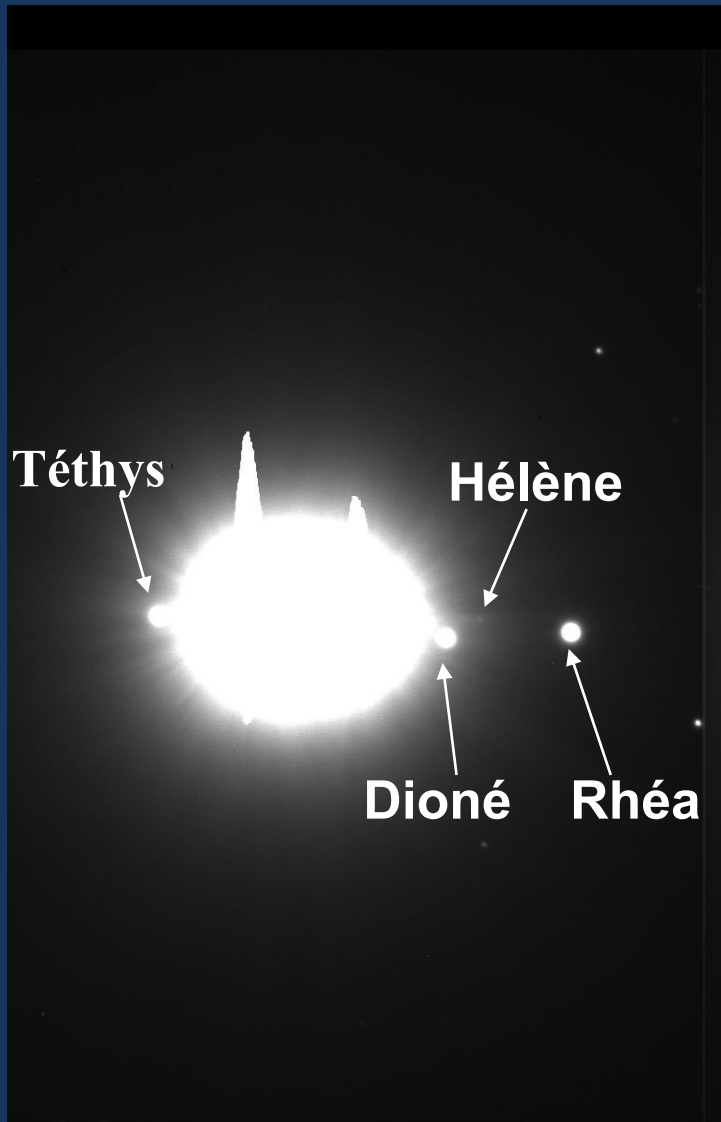
Encelade 11.9

Téthys 10.4

Dioné 10.6

DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS



Saturne (1996)

télescope: 1.60

temps de pose: 20 s

masque sur la fenêtre du CCD

magnitudes (V)

Saturne 0.9

Rhéa 9.9

Dioné 10.6

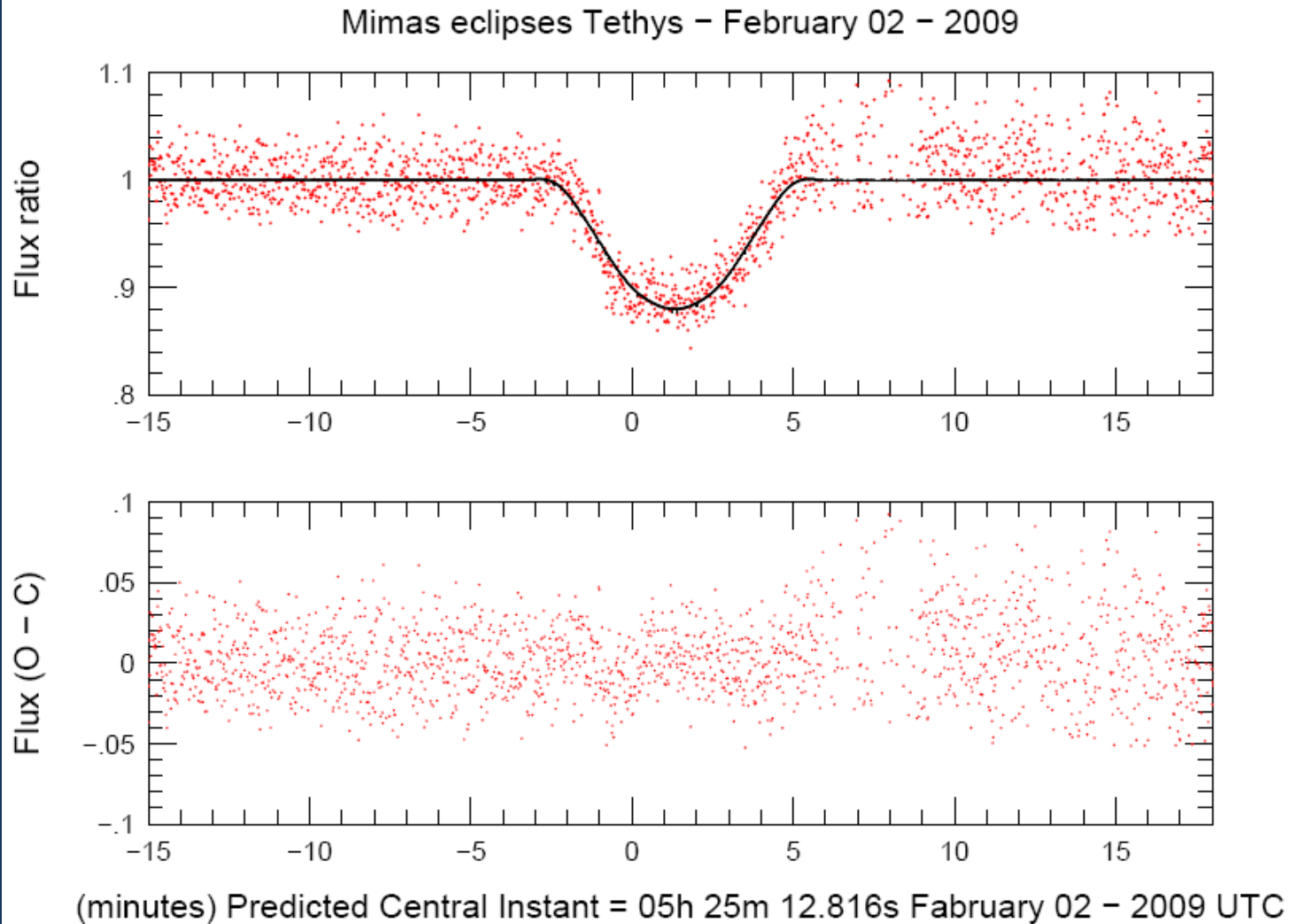
Téthys 10.4

Hélène 18.0

DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

PHÉNOMÈNES MUTUELS - SATURNE



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS



URANUS (2000)

télescope: 1.60

temps de pose: 10 s

coronographe de goutte de Hg

magnitudes (V)

Uranus 5.7

Miranda 16.5

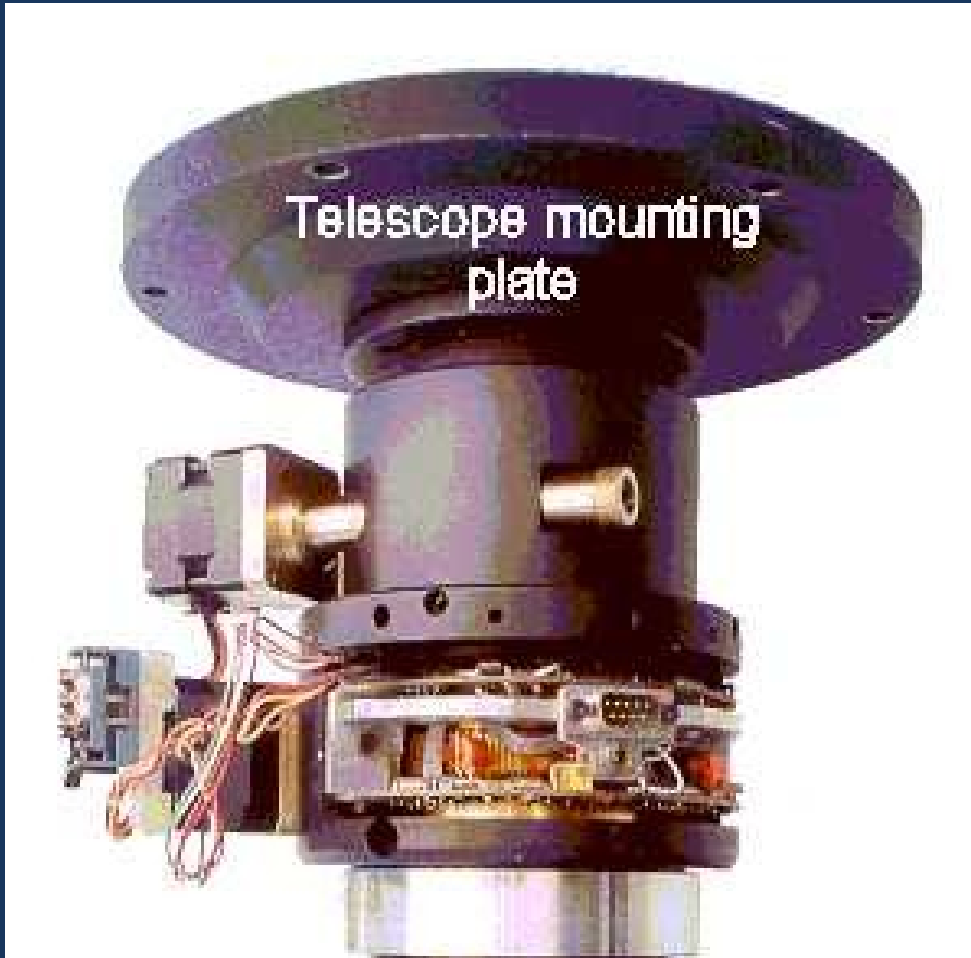
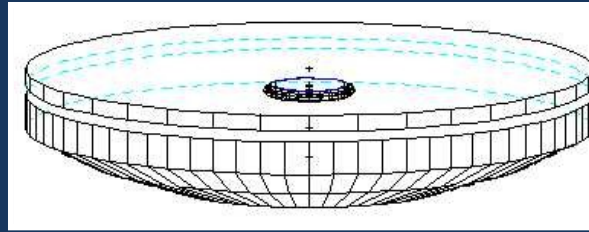
Ariel 14.4

Umbriel 15.3

Titania 13.9

Obéron 14.2

coronographe de goutte de Hg (Pierre Bourget)



disque
occulteur

diaphragme
de Lyot
} optique

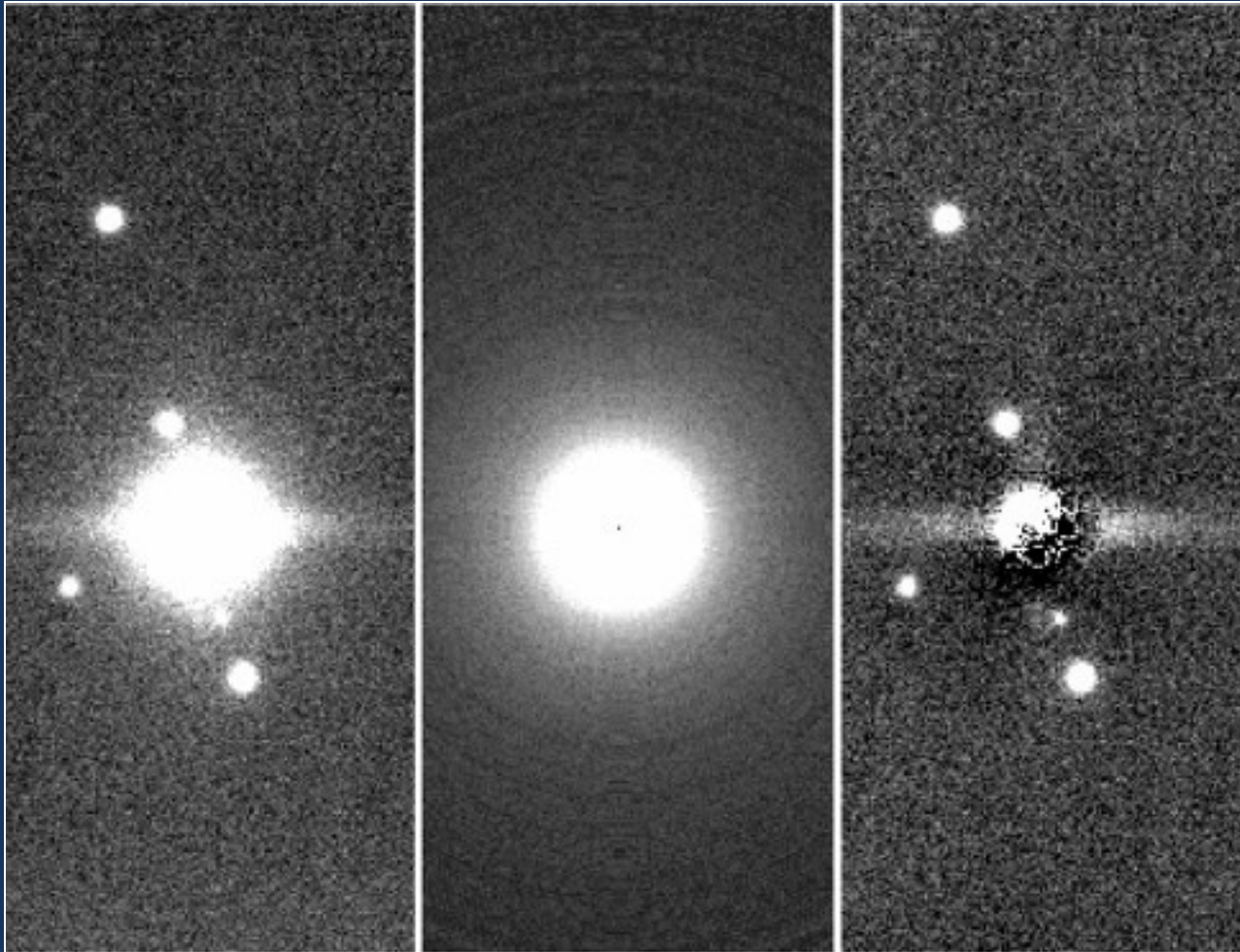
filtre

détecteur

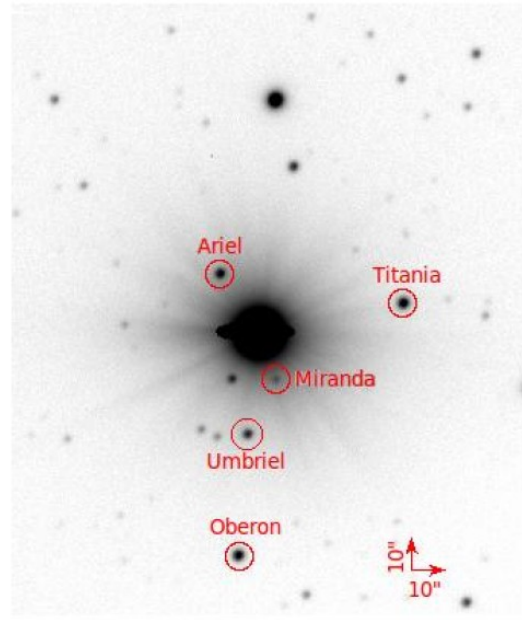
CORONOGRAPHIE DIGITALE

Uranus (2007)

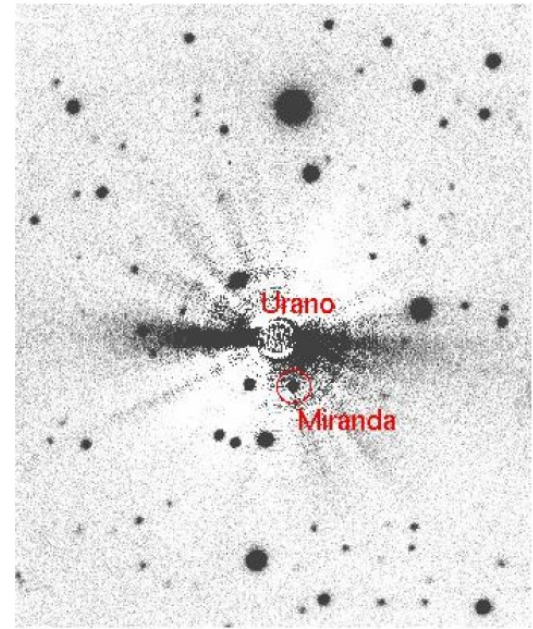
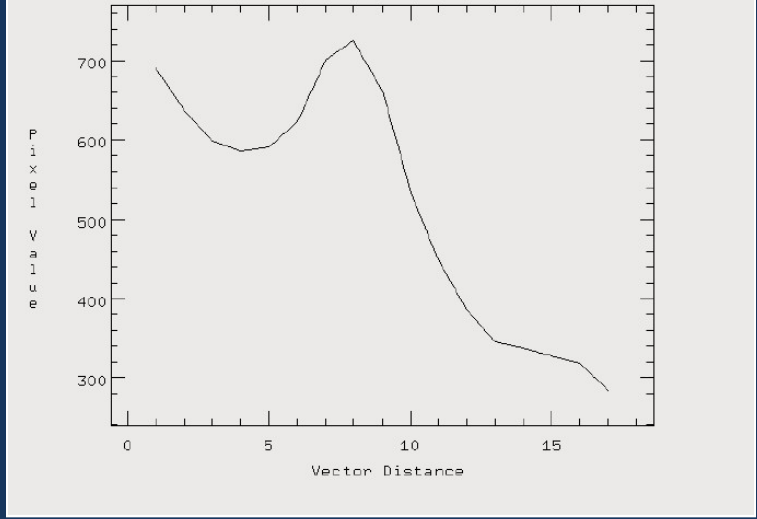
Titania
↓
Ariel
↓
Uranus
↓
Miranda
↓
Umbriel+Oberon



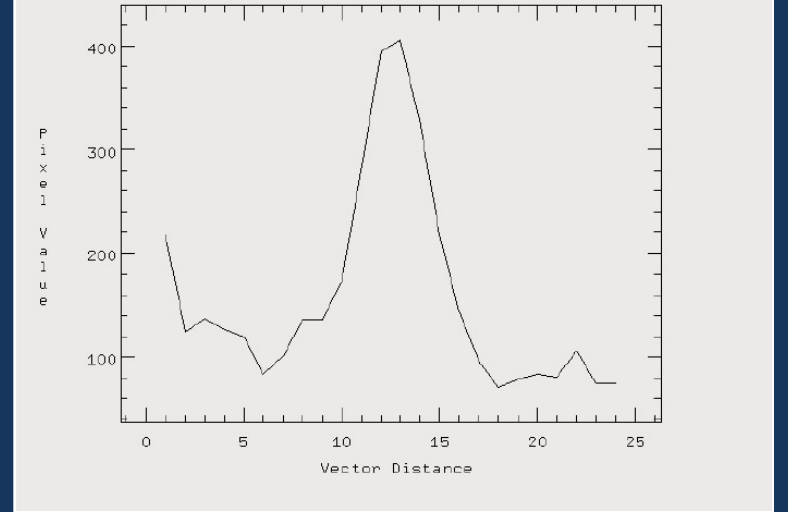
CORONOGRAPHIE DIGITALE



2012 NOAO/IRAF V2.14EXPORT camargo@localhost.localdomain Thu 16:14:20 26-Jan-19079205ut.fits: Vector 330.7,543.0 to 316.0,536.5 naverage: 1
Urano



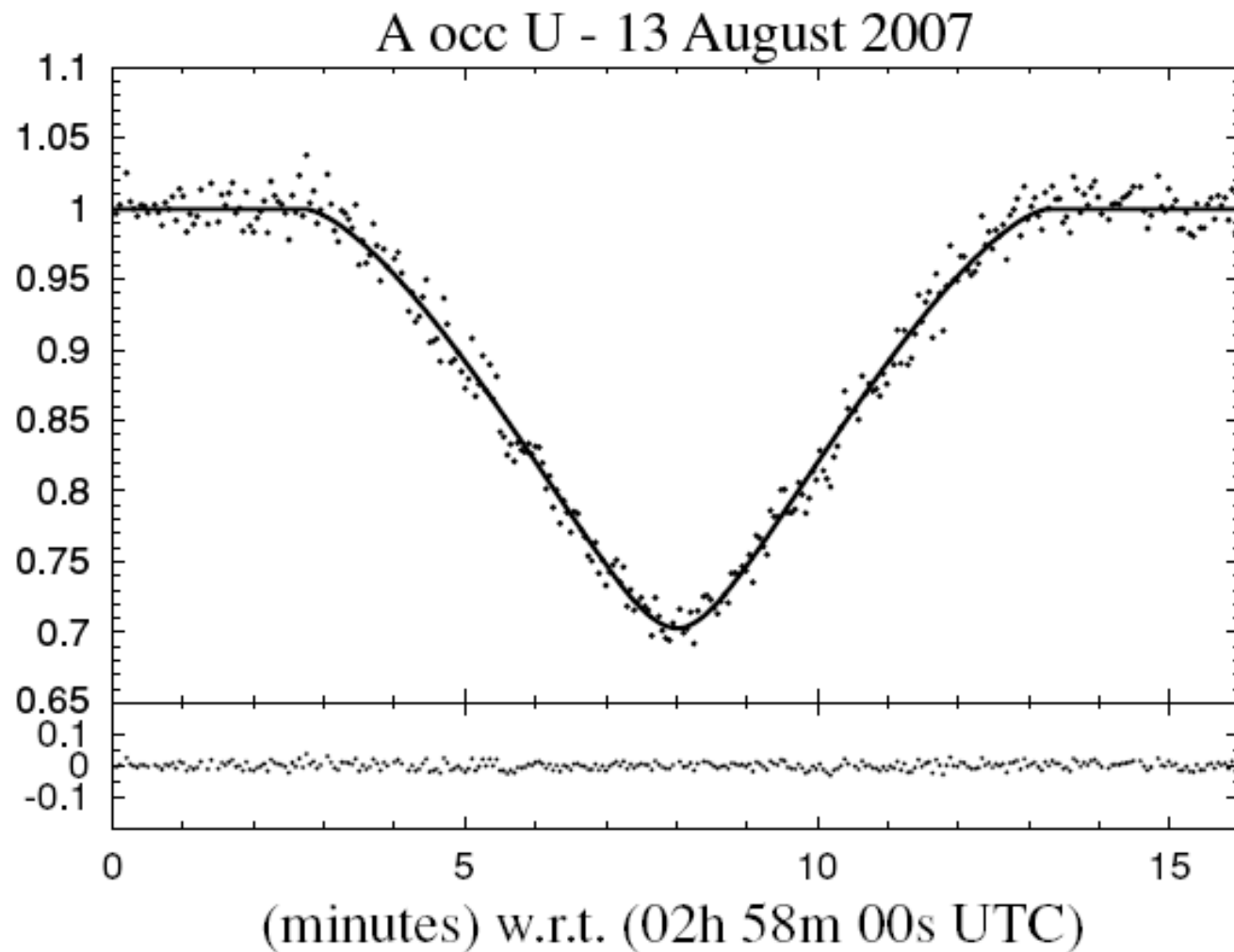
2012 NOAO/IRAF V2.14EXPORT camargo@localhost.localdomain Thu 16:21:33 26-Jan-19079205ut_c4.fits: Vector 335.2,544.5 to 312.7,537.0 naverage: 1
Urano



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

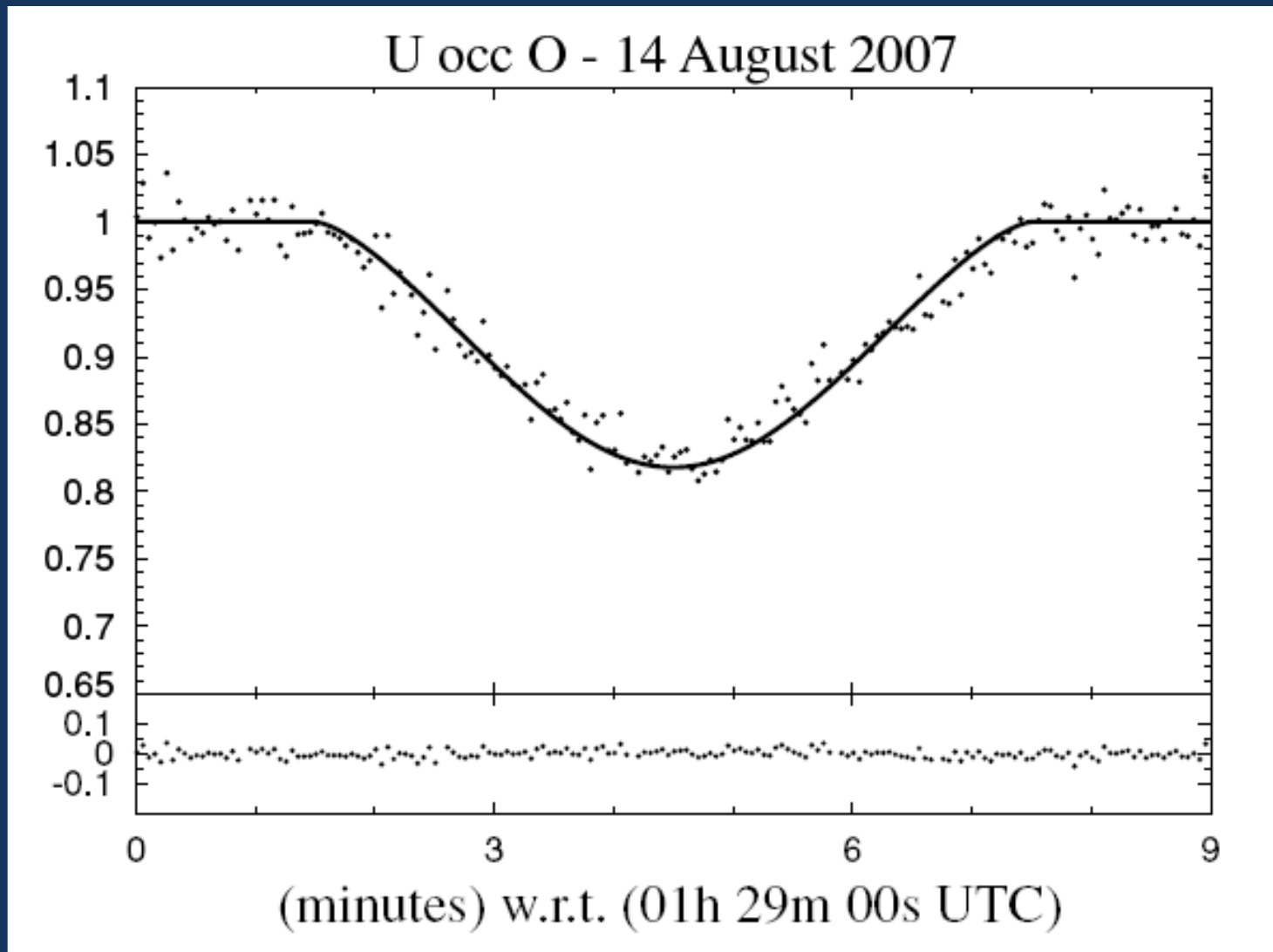
PHÉNOMÈNES MUTUELS - URANUS



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

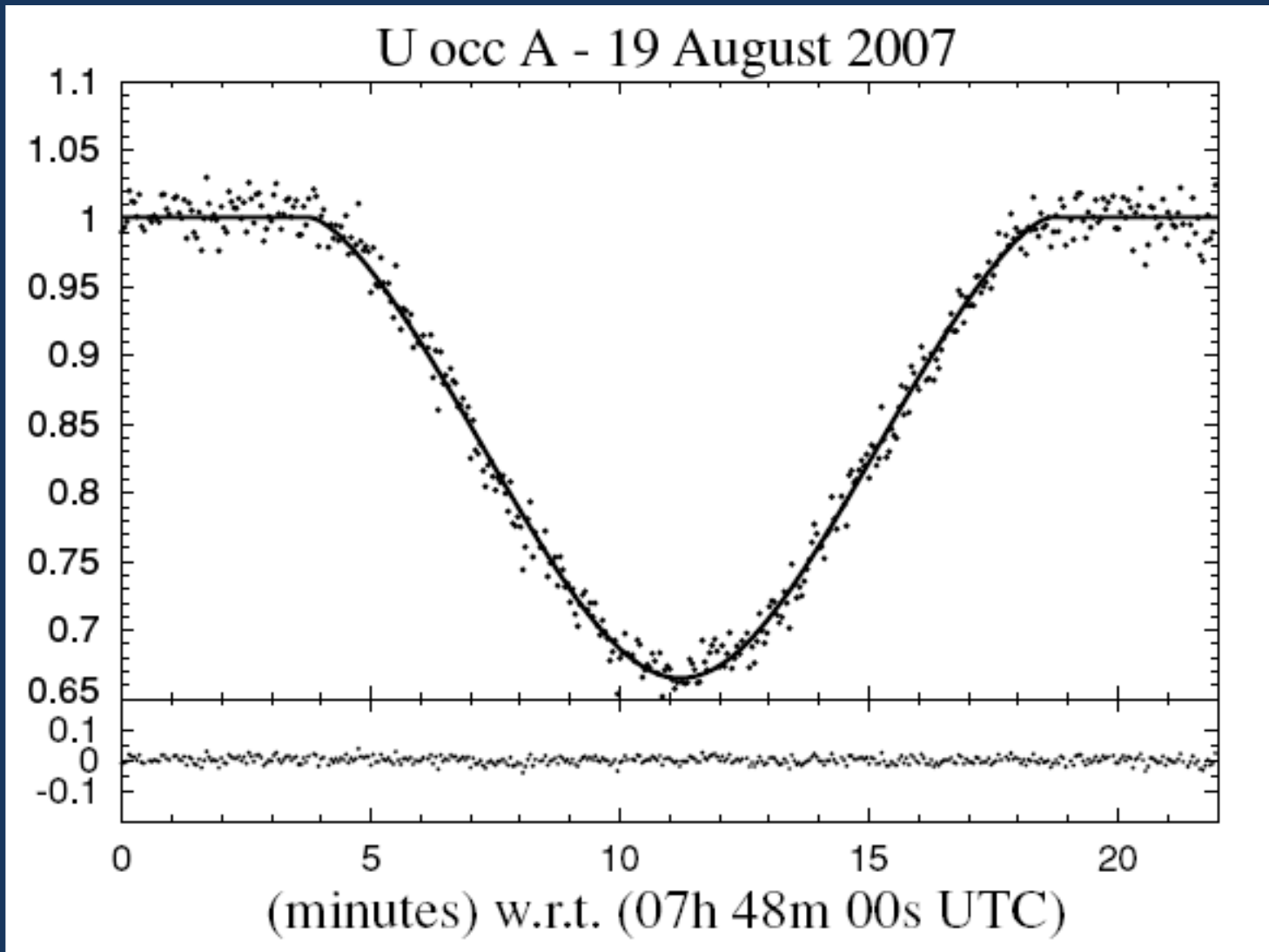
PHÉNOMÈNES MUTUELS - URANUS



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS

PHÉNOMÈNES MUTUELS - URANUS

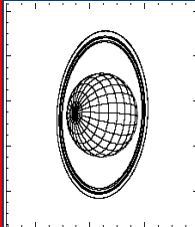


RÉSULTATS

POSITIONS DES SATELLITES D'URANUS RELATIVES À OBERON

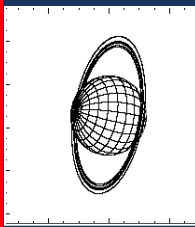
1992-2001

Telescópio 1,60 m					
$\Delta(O - C)_\alpha$ (mas)	$\Delta(O - C)_\delta$ (mas)	$\sigma_{(O-C)_\alpha}$ (mas)	$\sigma_{(O-C)_\delta}$ (mas)	Observações (usadas/total)	satélite
-0.006	0.004	0.054	0.045	471/535	Miranda
-0.001	0.000	0.023	0.024	715/802	Ariel
-0.001	-0.003	0.022	0.024	695/817	Umbriel
-0.001	0.001	0.022	0.023	684/802	Titânia

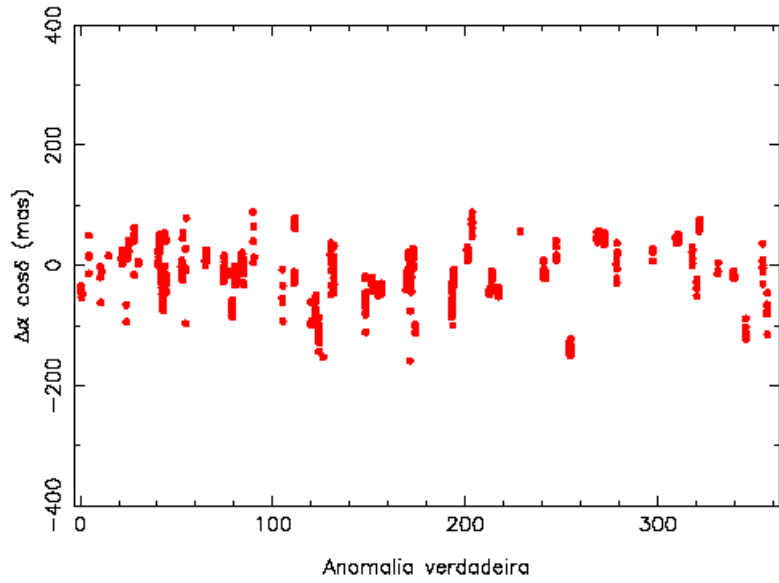


1995-2009

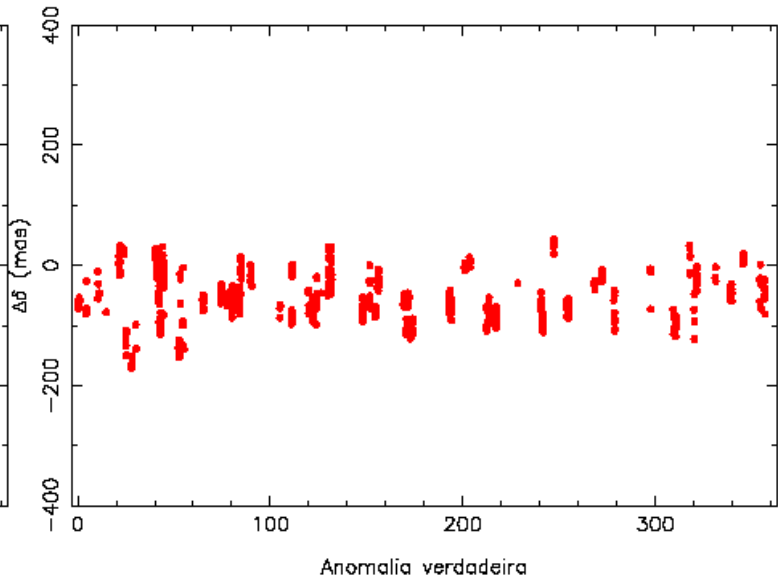
Telescópio 0,60 m					
$\Delta(O - C)_\alpha$ (mas)	$\Delta(O - C)_\delta$ (mas)	$\sigma_{(O-C)_\alpha}$ (mas)	$\sigma_{(O-C)_\delta}$ (mas)	Observações (usadas/total)	satélite
0.126	0.173	0.928	0.790	66/66	Miranda
0.020	-0.005	0.069	0.049	305/352	Ariel
0.002	-0.009	0.042	0.041	414/492	Umbriel
0.005	-0.012	0.039	0.040	672/738	Titânia



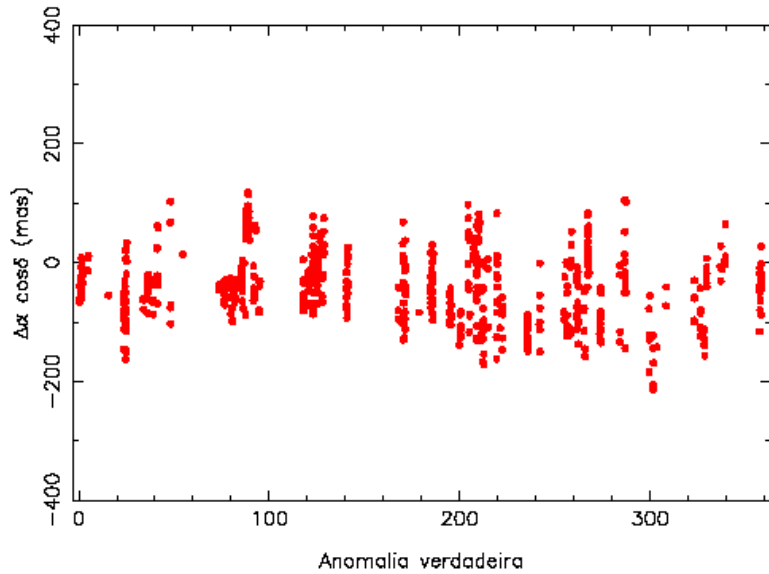
Titania (Perkin-Elmer)



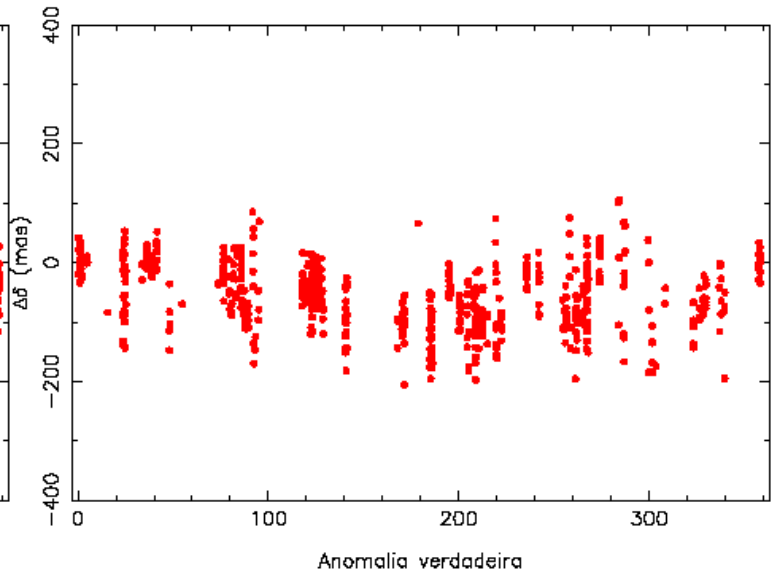
Titania (Perkin-Elmer)



Titania (Boller&Chivens)

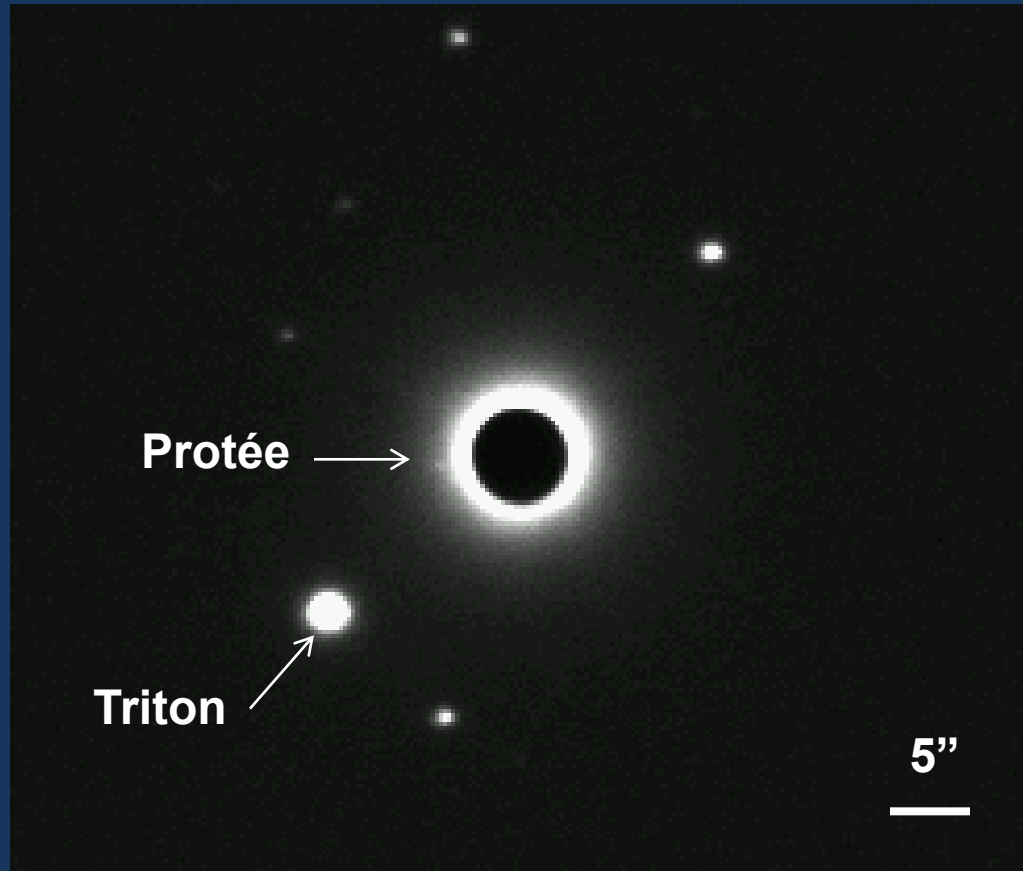


Titania (Boller&Chivens)



DIFFICULTÉS DE L'ASTROMÉTRIE

SATELLITES PROCHES ET RÉGULIERS



Neptune (2000)

télescope: 1.60

temps de pose: 10 m

coronographe de goutte
de Hg

magnitudes (V)

Neptune 7.7

Triton 13.6

Protée 20.3

3 PROBLÈMES DE L'ASTROMÉTRIE DES CORPS DU SYSTÈME SOLAIRE

- CATALOGUES DE RÉFÉRENCE
(ERREURS ET DENSITÉ)
- RÉFRACTION CHROMATIQUE
- CONTAMINATION DU FOND DU CIEL

Analyse basée sur une réduction astrométrique de Pluton

15 ans => 160 nuits => 5 500 images

Pour quoi Pluton?

Il passe dans la Voie Lactée et alors il a une couleur différente de celle des étoiles de référence.

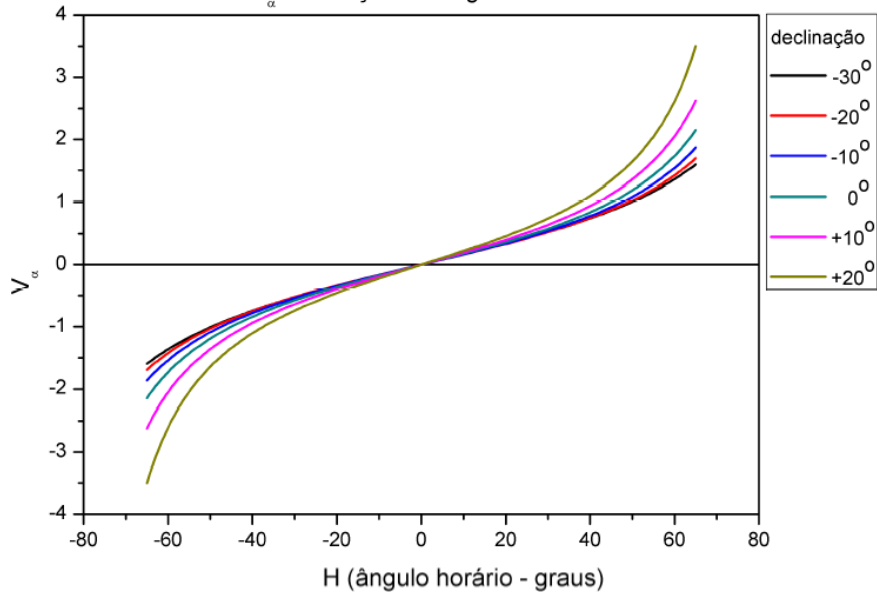
Il a un satellite proche en distance et en magnitude (distance $< 1''$, et différence de magnitude de $\sim 1,5$).

La réfraction chromatique

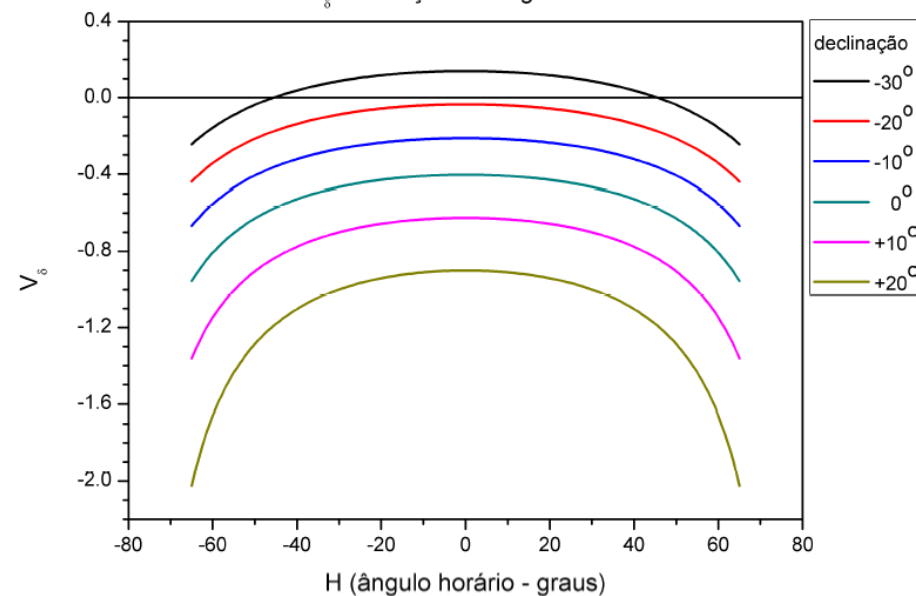
$$\Delta\alpha_{ref.} = \alpha - \alpha' = B_1 \frac{\sec^2\delta \sin H}{\tan\delta \tan\varphi + \cos H} = B_1 V_\alpha(H)$$

$$\Delta\delta_{ref.} = \delta - \delta' = B_1 \frac{\tan\varphi - \tan\delta \cos H}{\tan\delta \tan\varphi + \cos H} = B_1 V_\delta(H)$$

V_α em função do ângulo horário

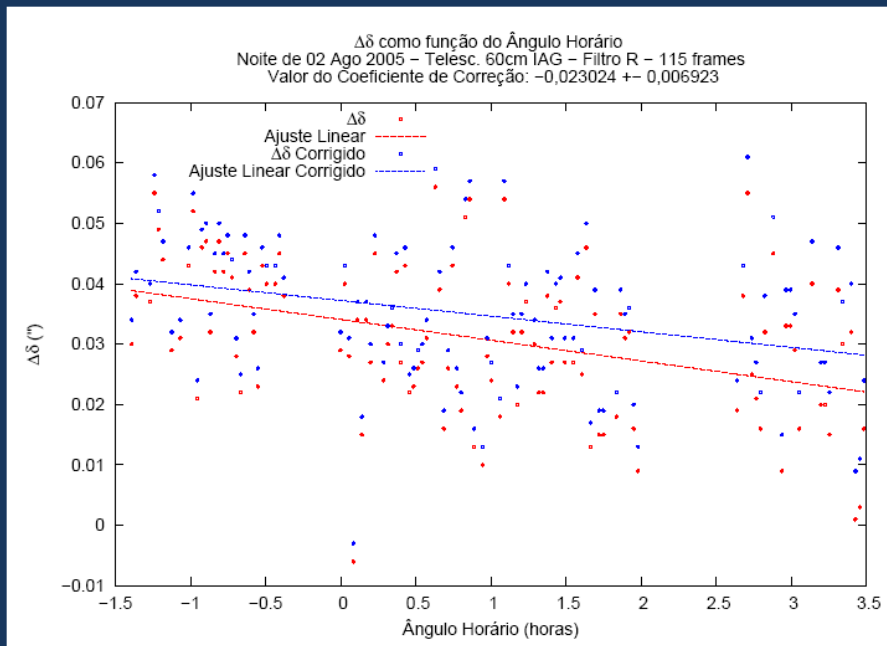
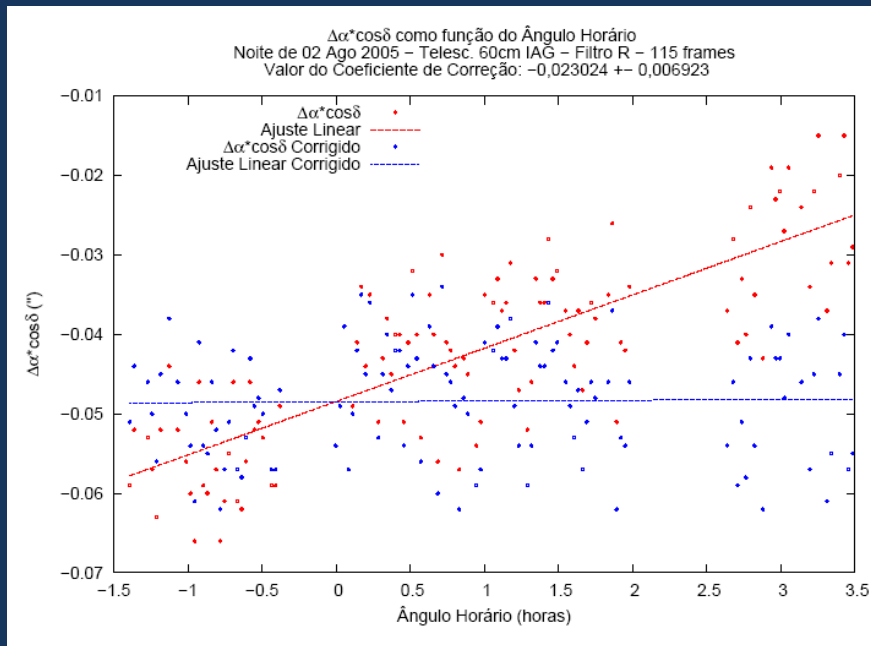
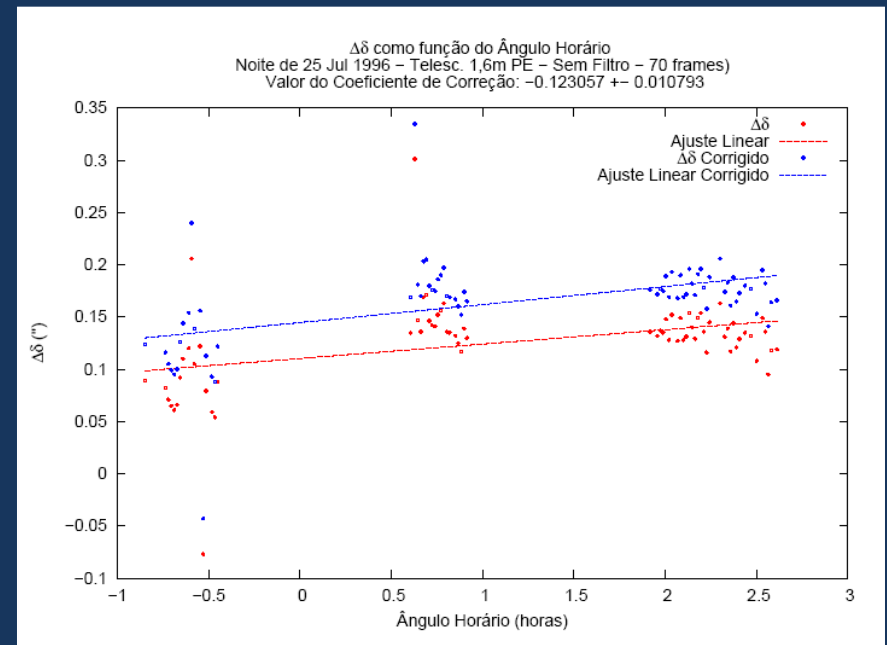
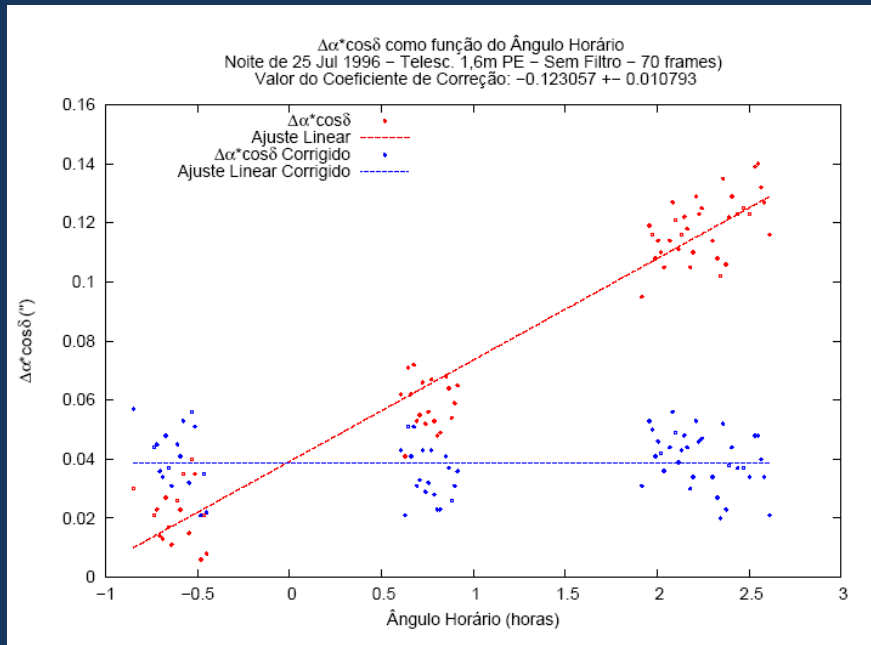


V_δ em função do ângulo horário



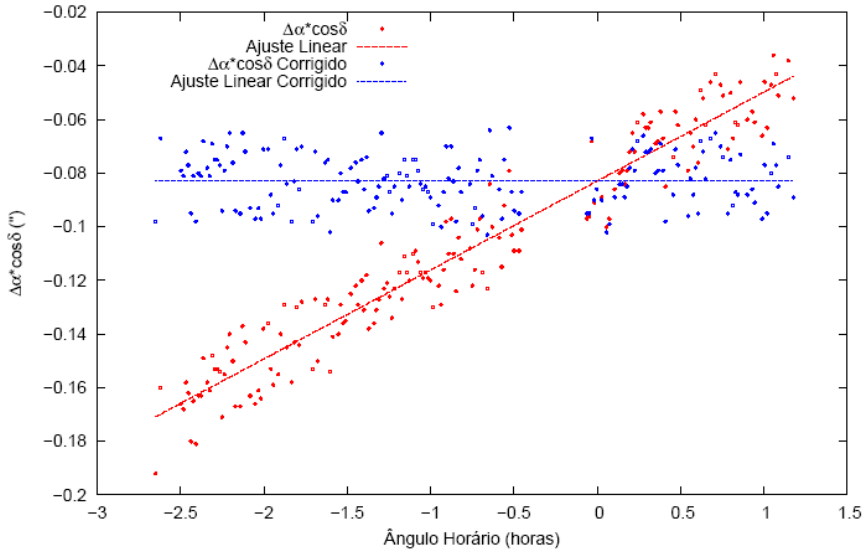
le B_1 est fonction de: météo + couleur

Réfraction chromatique par nuit

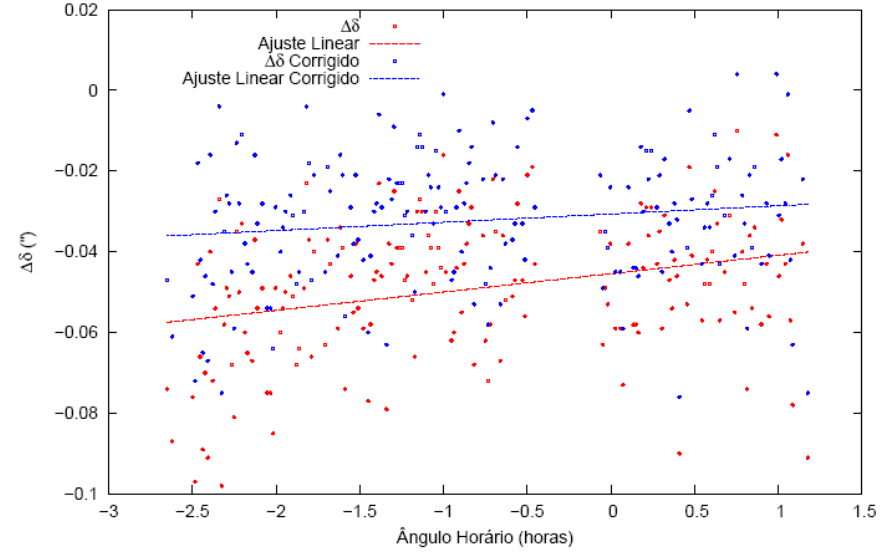


Réfraction chromatique par nuit

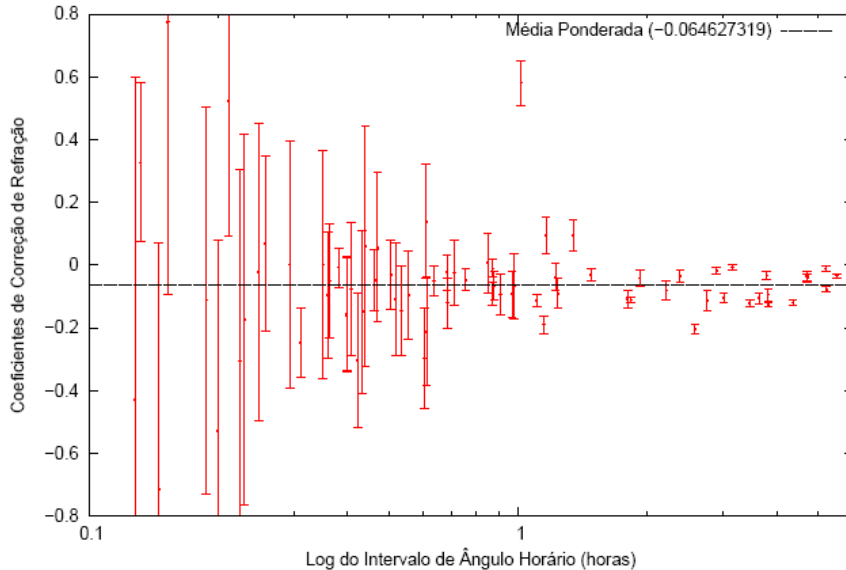
$\Delta\alpha^*\cos\delta$ como função do Ângulo Horário
Noite de 18 Abr 2007 - Telesc. 60cm IAG - Filtro Desconhecido - 171 frames
Valor do Coeficiente de Correção: $-0,126130 \pm 0,007860$



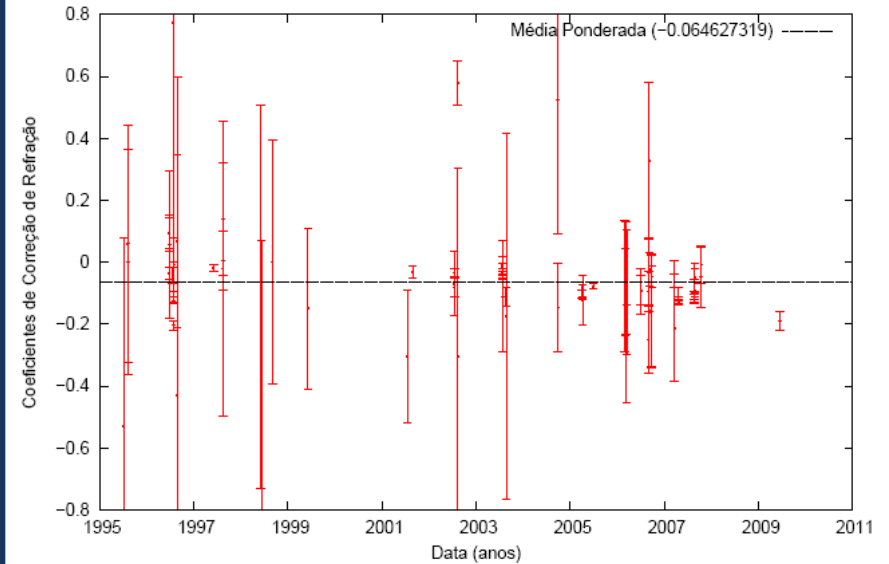
$\Delta\delta$ como função do Ângulo Horário
Noite de 18 Abr 2007 - Telesc. 60cm IAG - Filtro Desconhecido - 171 frames
Valor do Coeficiente de Correção: $-0,126130 \pm 0,007860$



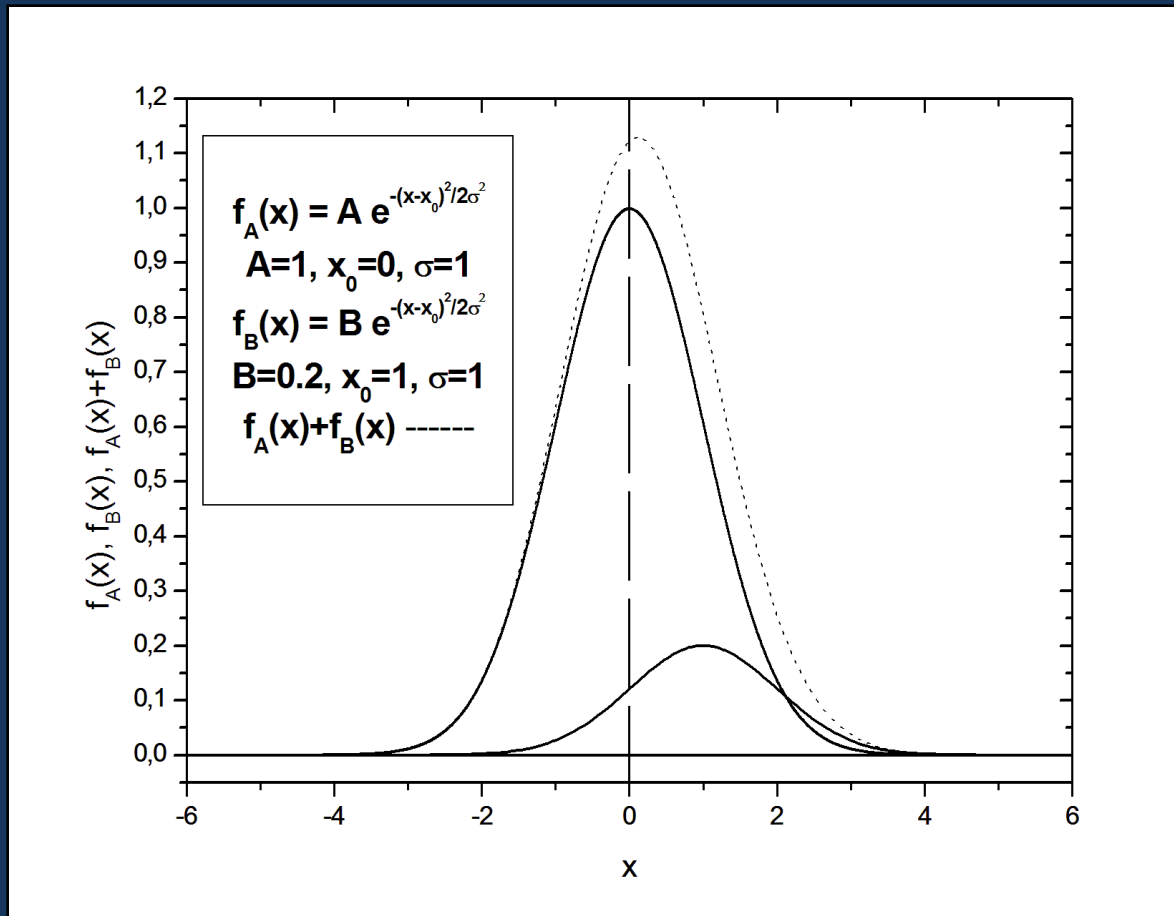
Coefficientes de Correção de Refração em Função do Intervalo de Ângulo Horário
Observações sem Filtro



Coefficientes de Correção de Refração em Função da Data de Observação
Observações sem Filtro



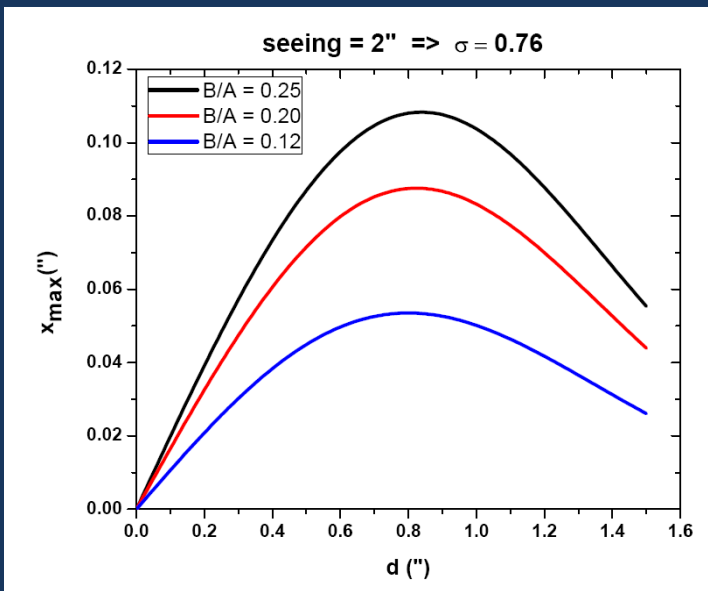
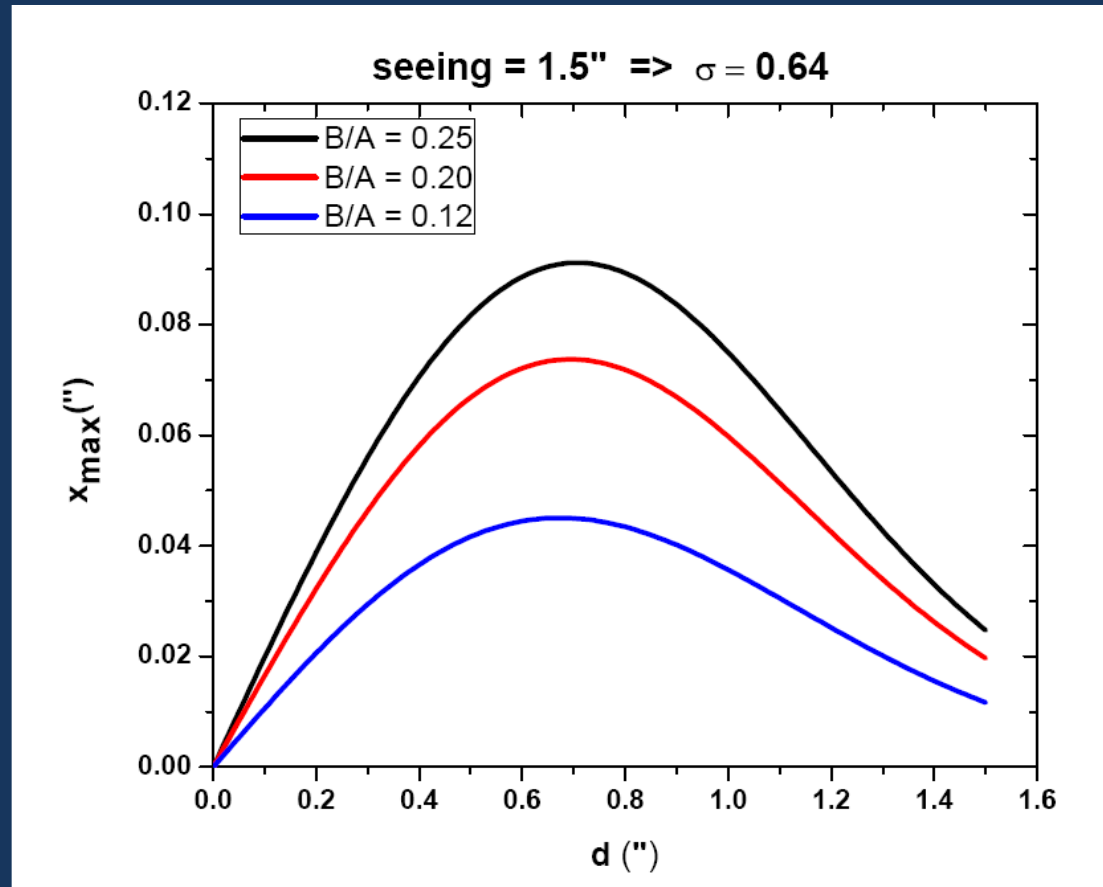
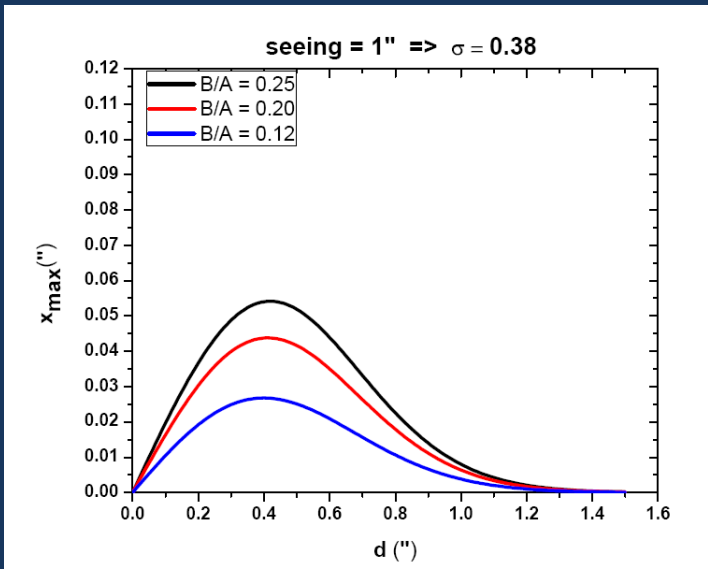
Superposition de deux gaussienne = changement de photocentre



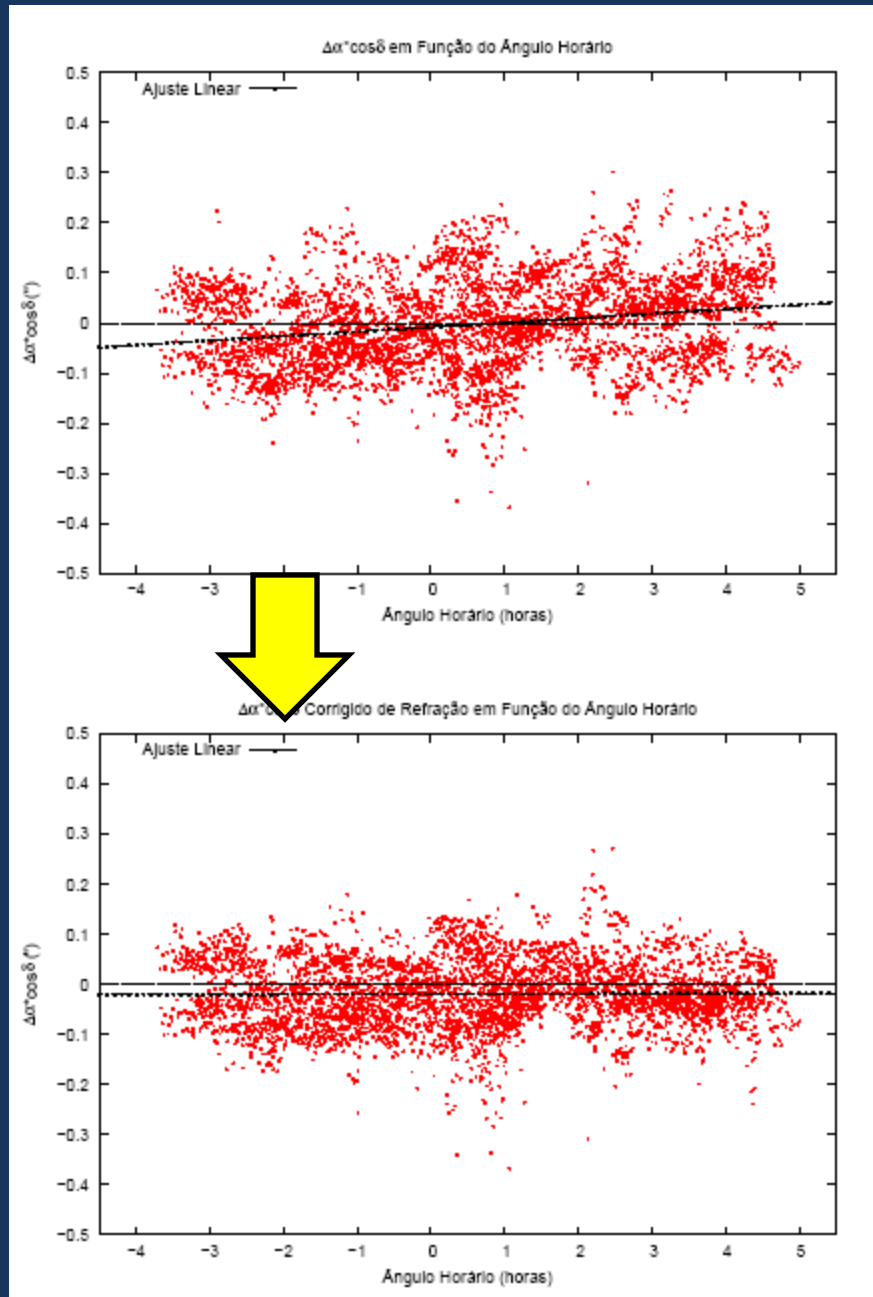
$$f_{A+B}(x) = A \exp\left(-\frac{x^2}{2\sigma^2}\right) + B \exp\left(-\frac{(x-d)^2}{2\sigma^2}\right)$$

$$x_{\max}\left(\frac{B}{A}, d, \sigma\right) = \frac{B}{A} \frac{1}{\exp\left(\frac{d^2}{2\sigma^2}\right) - \frac{B}{A} \left(\frac{d^2}{2\sigma^2} - 1\right)}$$

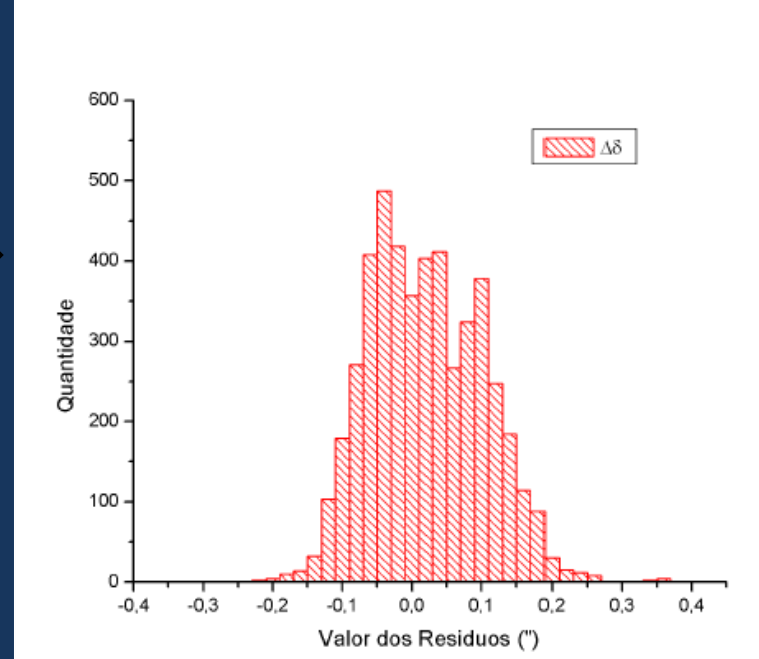
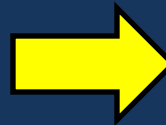
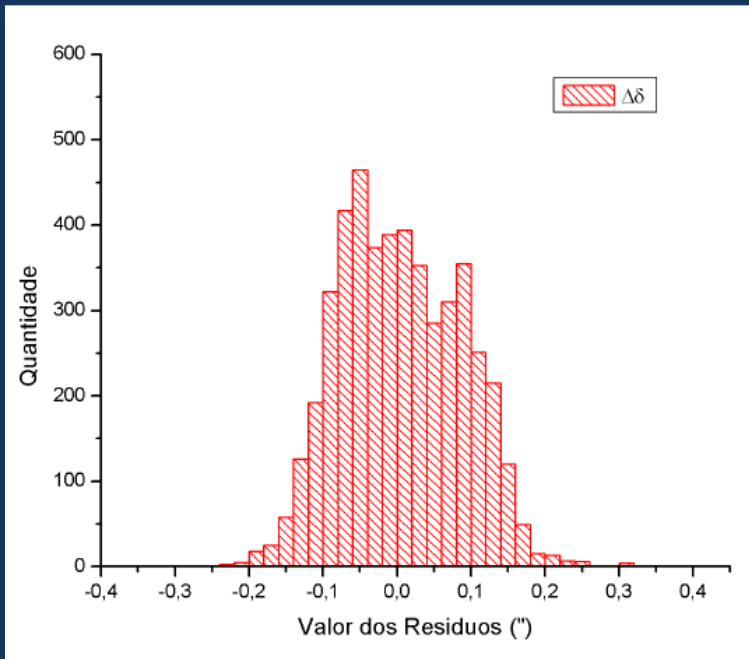
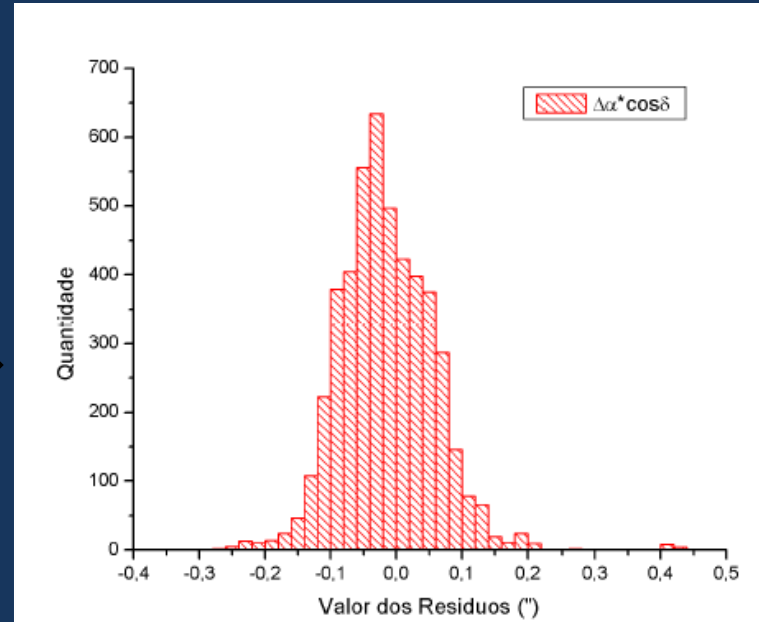
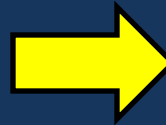
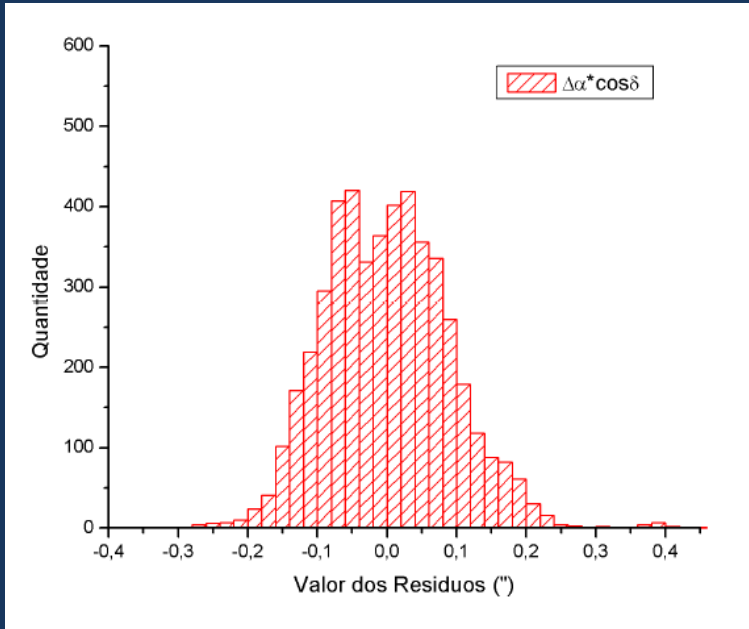
changements de photocentre avec l'albedo et le seeing



Comparaison:
sans correction de la
réfraction
x
avec correction de la
réfraction



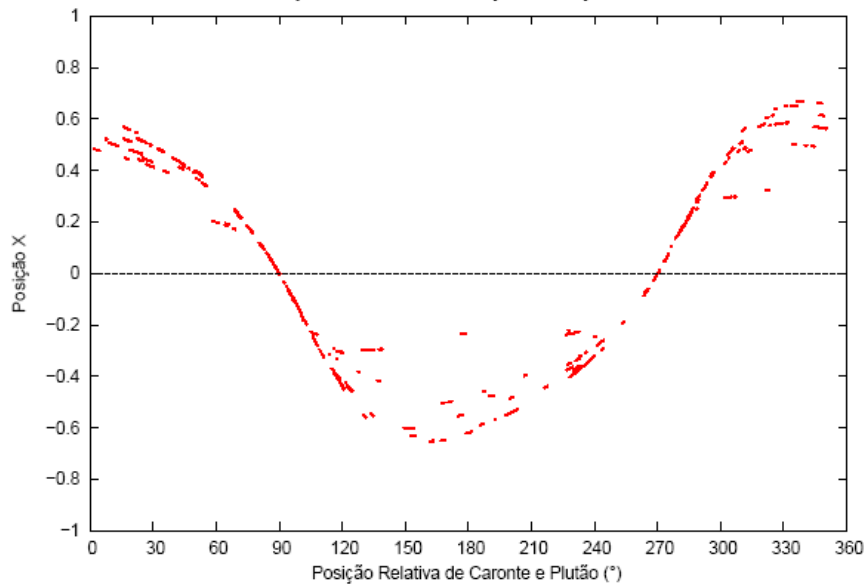
Comparaison: sans et avec la correction de la réfraction



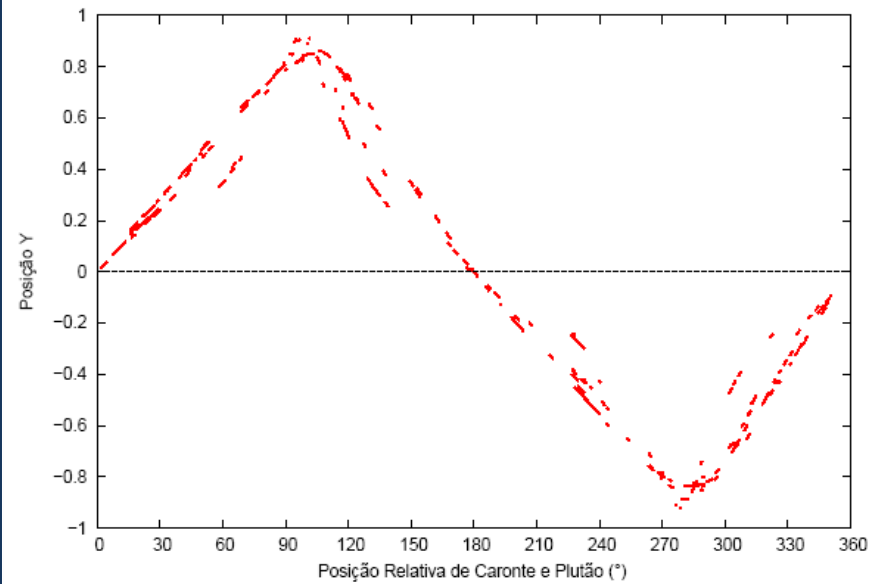
diamètre Charon $\approx \frac{1}{2}$ diamètre Pluton

distance Pluton - Charon

Posição X de Caronte em Função da Posição Relativa

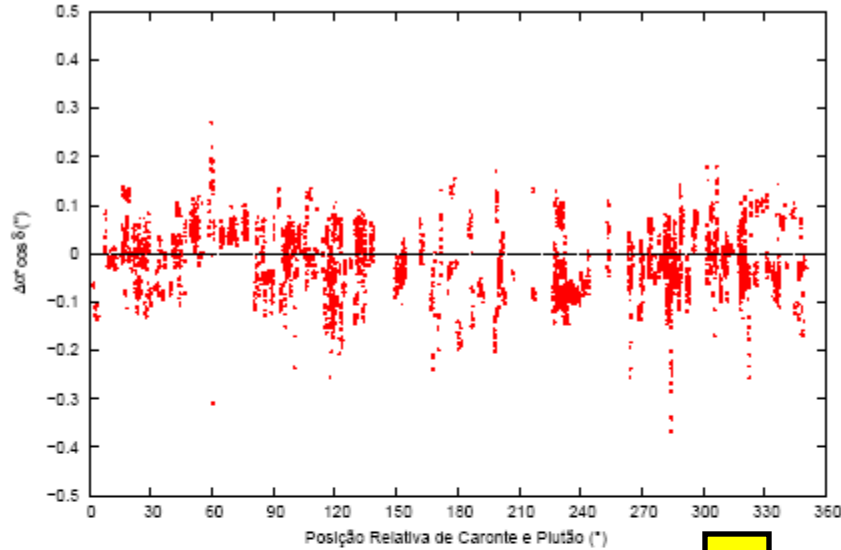


Posição Y de Caronte em Função da Posição Relativa

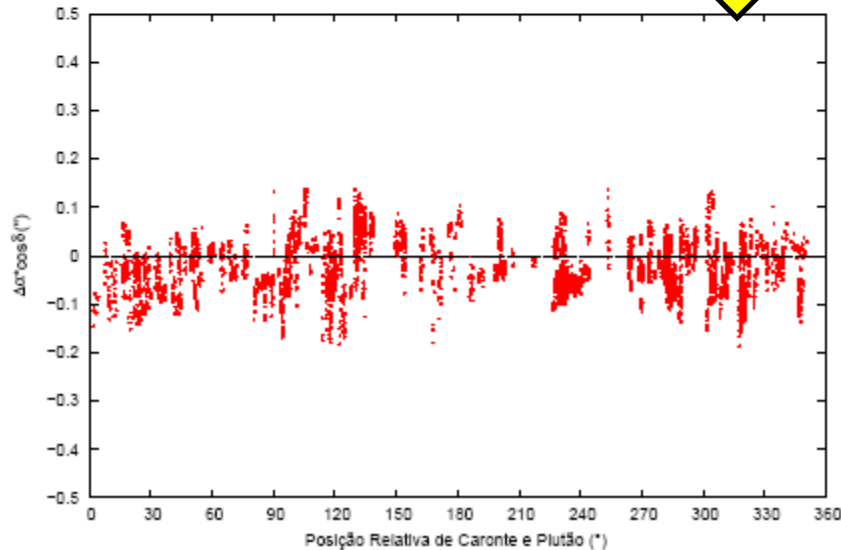


Comparaison: sans et avec la correction du photocentre

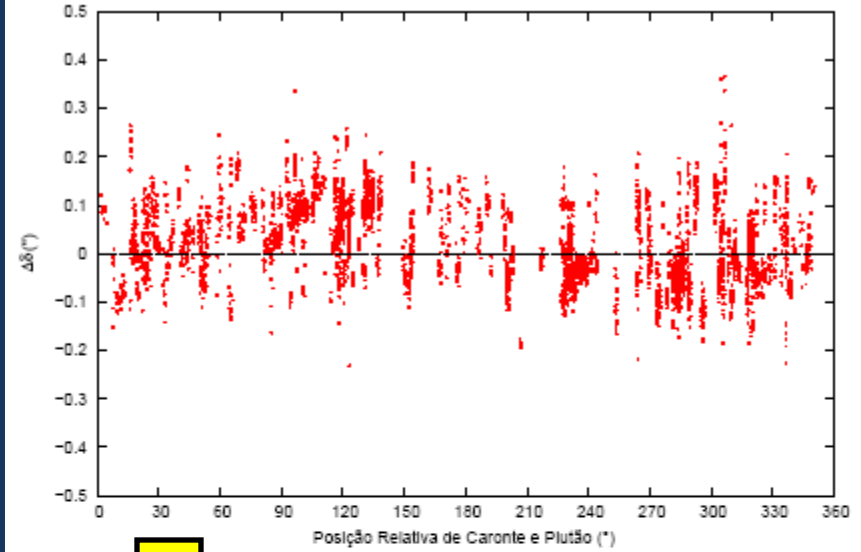
$\Delta\alpha^* \cos \delta^*$ Corrigido de Refração em Função da Posição Relativa de Caronte e Plutão



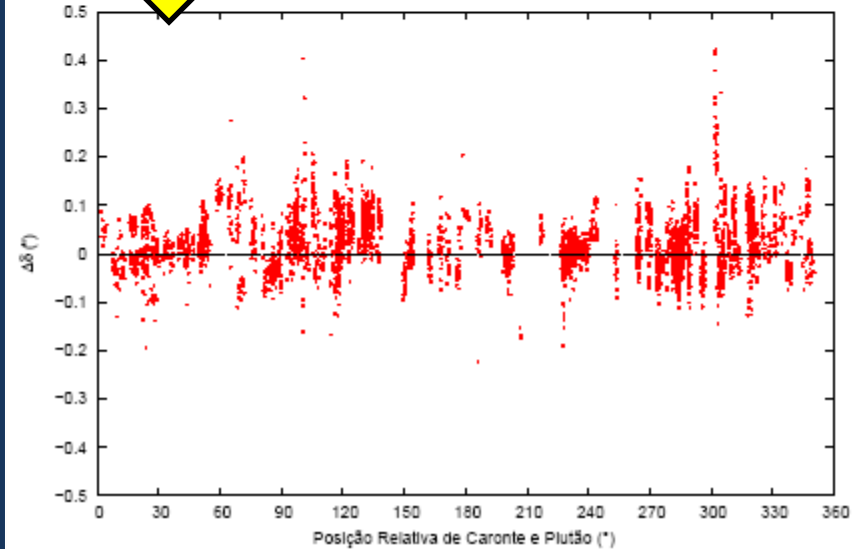
$\Delta\alpha^* \cos \delta^*$ Corrigido de Refração e Fotocentro em Função da Posição Relativa de Caronte e Plutão



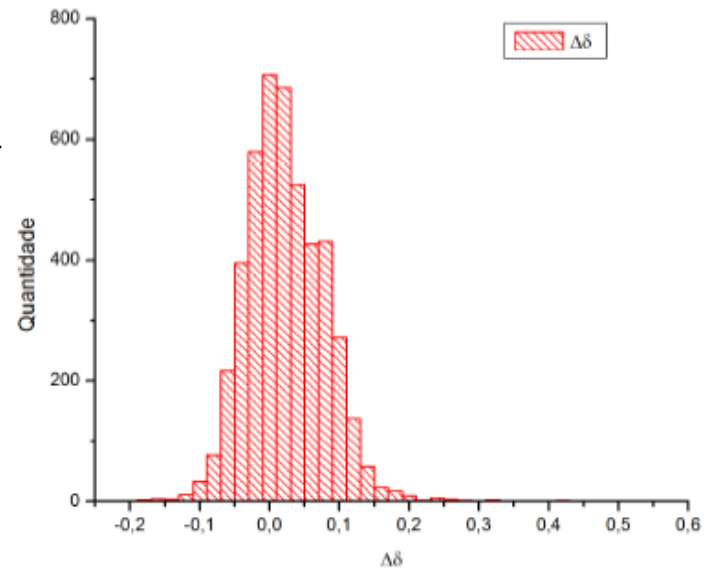
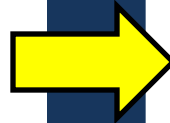
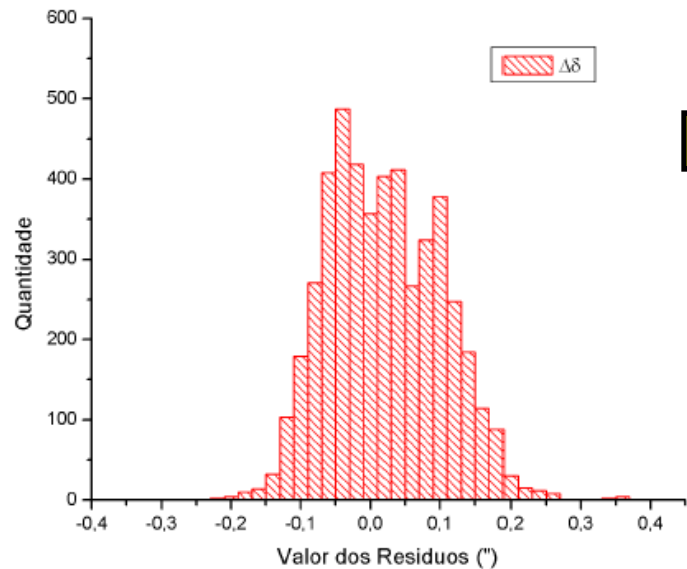
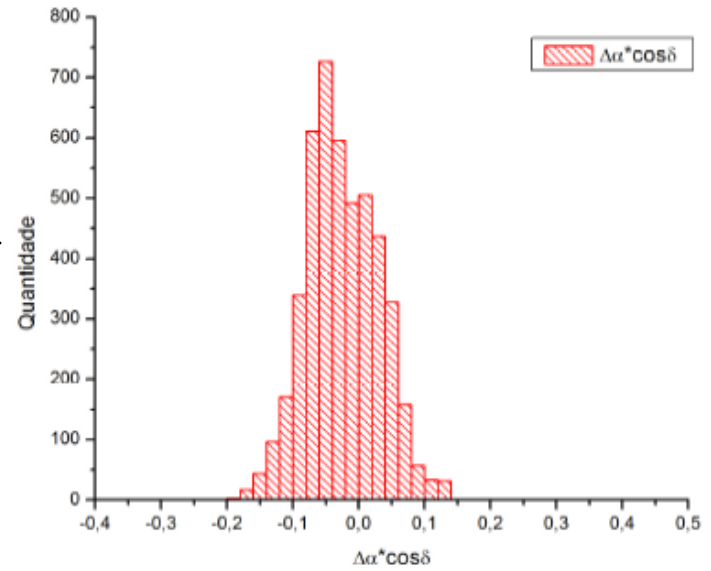
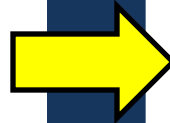
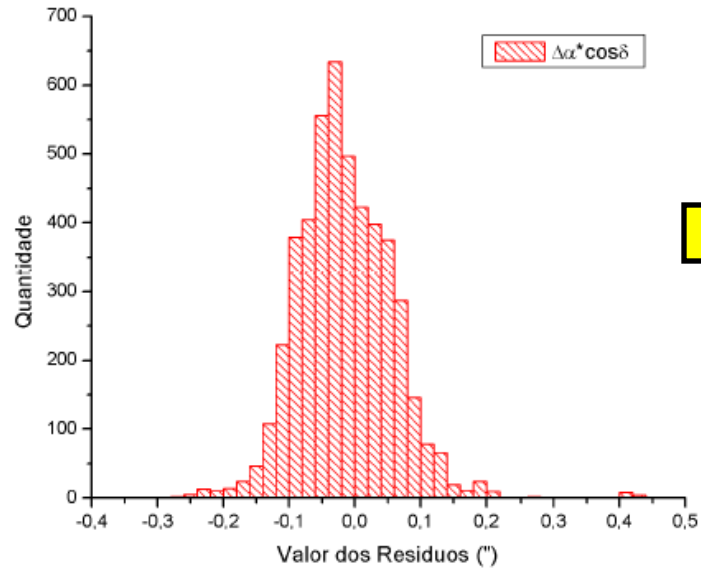
$\Delta\delta$ Corrigido de Refração em Função da Posição Relativa de Caronte e Plutão



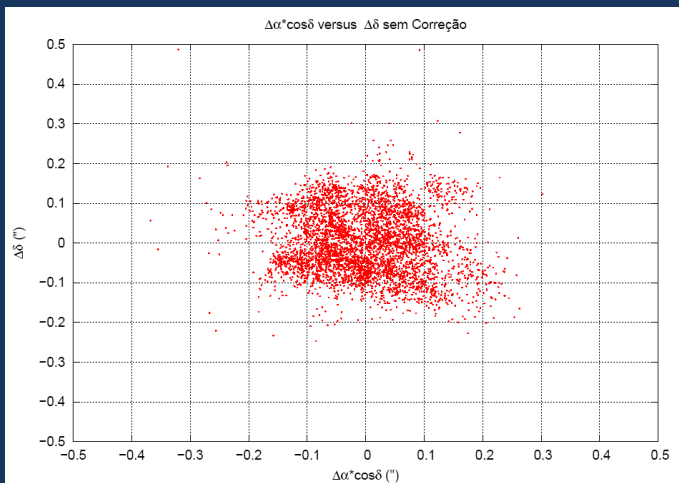
$\Delta\delta$ Corrigido de Refração e Fotocentro em Função da Posição Relativa de Caronte e Plutão



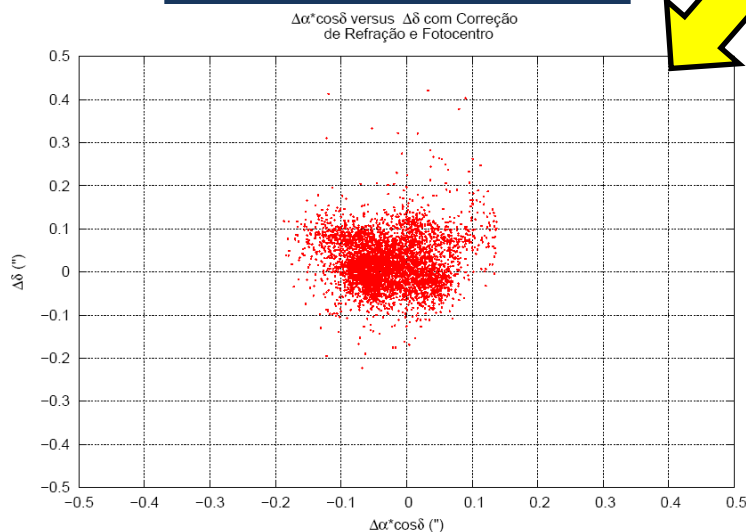
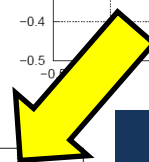
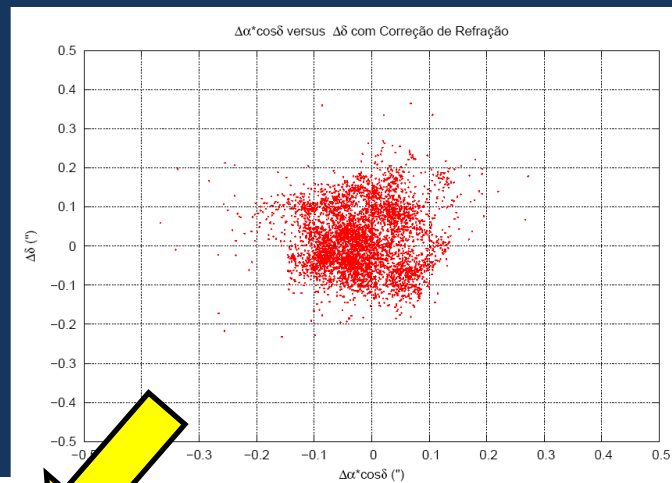
Comparaison: sans et avec la correction du photocentre



		Núm. de Imagens	Média	σ	Mediana	Mínimo	Máximo
Dados iniciais	RA	5474	-0,00534161	0,10486	-0,003	-0,601	0,947
	DEC		0,00175	0,0947	-0,002	-0,886	0,542
Refração e filtro 2σ	RA	4776	-0,01539	0,07319	-0,022	-0,367	0,467
	DEC		0,01985	0,0818	0,016	-0,232	0,487
Fotocentro e filtro 3σ	RA	4645	-0,02524	0,05458	-0,030	-0,187	0,137
	DEC		0,02277	0,05706	0,018	-0,223	0,421



Statistiques



AVEC GAIA

~~- CATALOGUES DE RÉFÉRENCE
(ERREURS ET DENSITÉ)~~

~~- RÉFRACTION CHROMATIQUE~~

~~- CONTAMINATION DU FOND DU CIEL~~

merci

2007

Star

Titania

Ariel

Uranus

Miranda

Umbriel

Oberon

10 arcsec
└──┘

