

Observación y análisis de ocultaciones estelares por cuerpos menores del Sistema Solar

Luis Eduardo Salazar Manzano

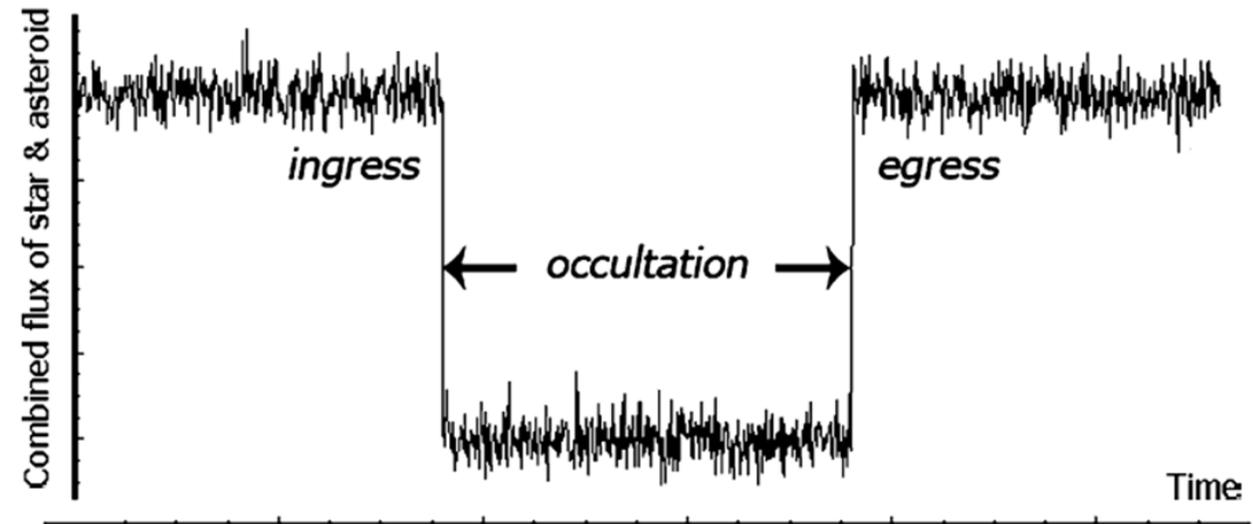
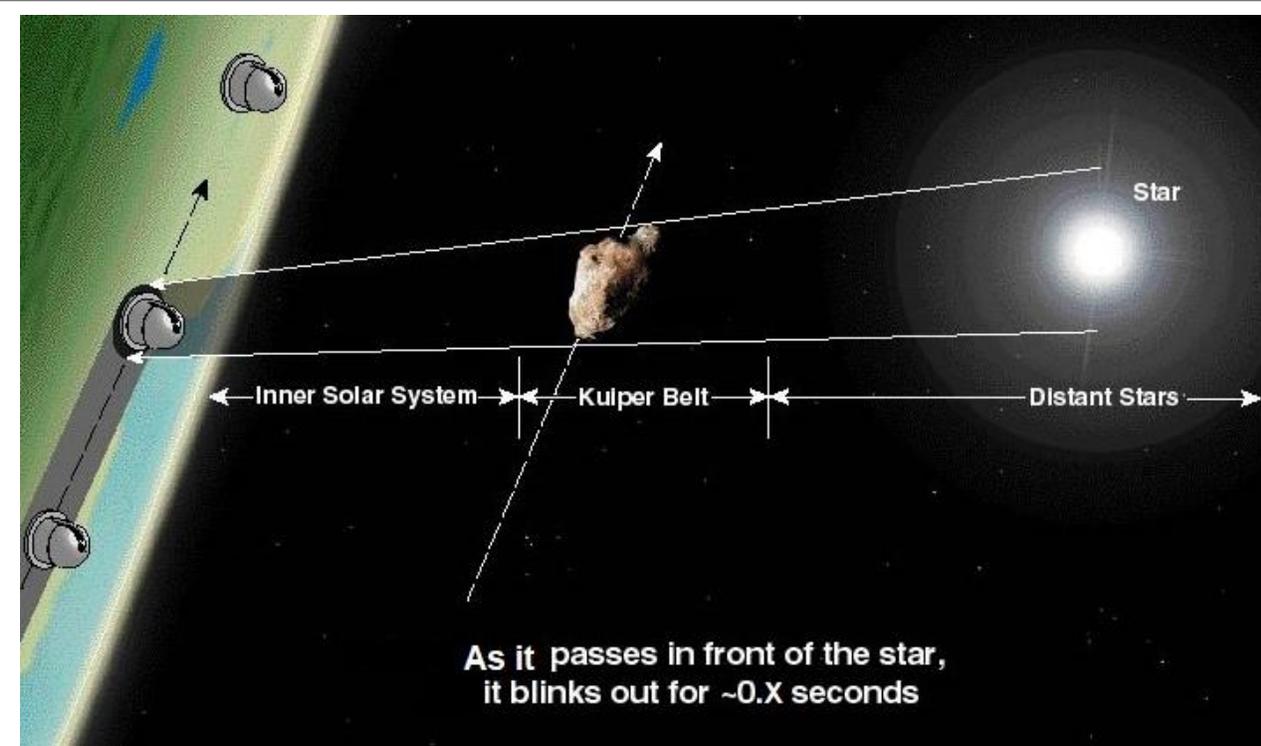
Observatorio Astronómico de la
Universidad Tecnológica de Pereira

18 de Mayo, 2021



¿Qué es una ocultación estelar?

Esta técnica consiste en el registro de la extinción de la luz dada por el paso de un cuerpo frente a una estrella de fondo desde la perspectiva de la Tierra



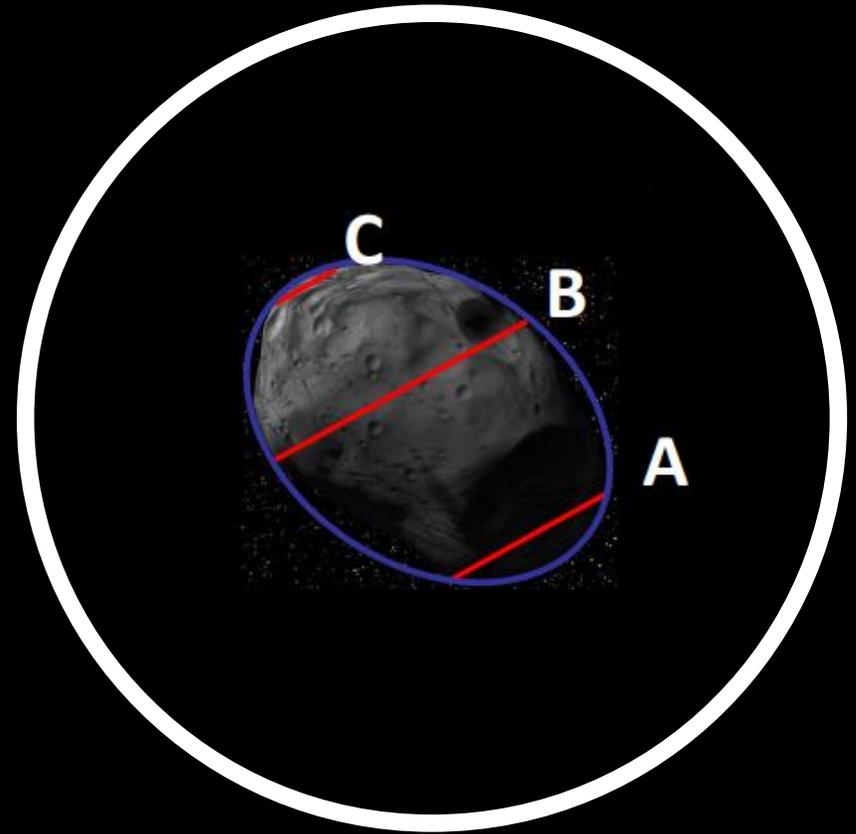
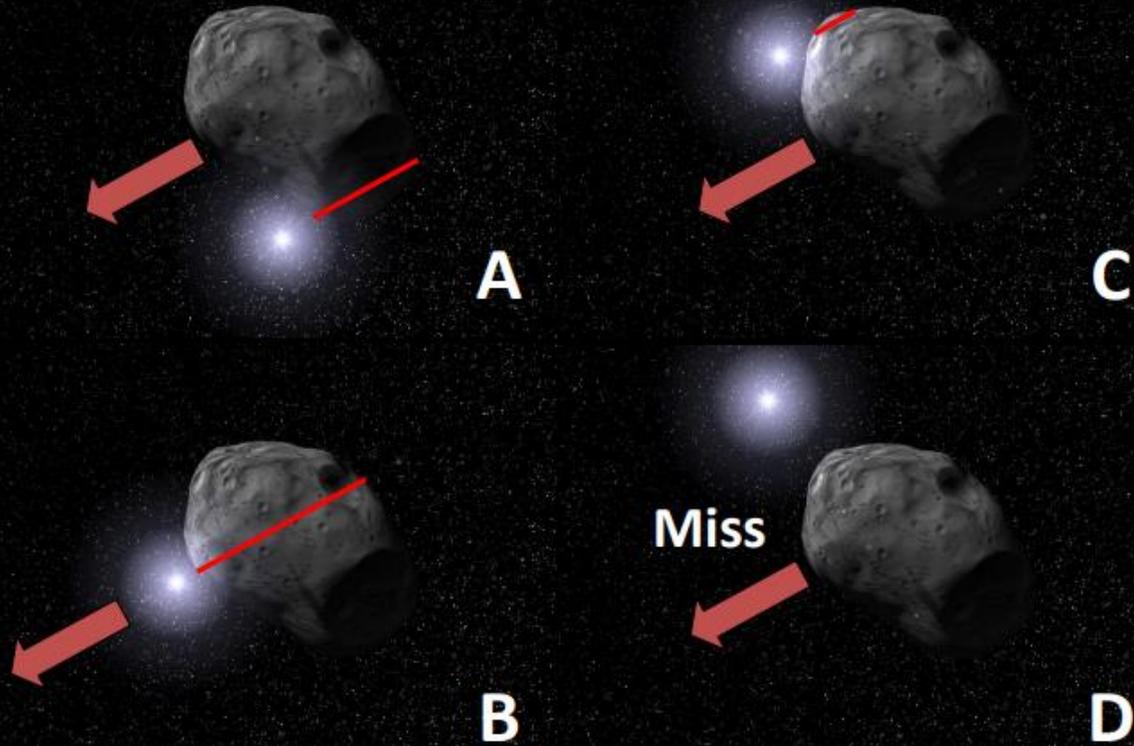
¿Por qué utilizar ocultaciones estelares?



Observables	Observación directa	Ocultaciones estelares
○ Órbitas.	Sí	Sí
○ Masa.	No	No
○ Colores.	Sí	No
○ Diámetros.	No	Sí
○ Formas.	No	Sí
○ Características superficiales.	No	Sí
○ Presencia de satélites.	Sí	Sí
○ Presencia de anillos.	No	Sí
○ Presencia de atmósferas.	No	Sí

¿Cómo es posible?

Fuente: Time Box



Dos características importantes en la observación de ocultaciones estelares son la **sincronización** y la **colaboración**.

A continuación
algunos antecedentes

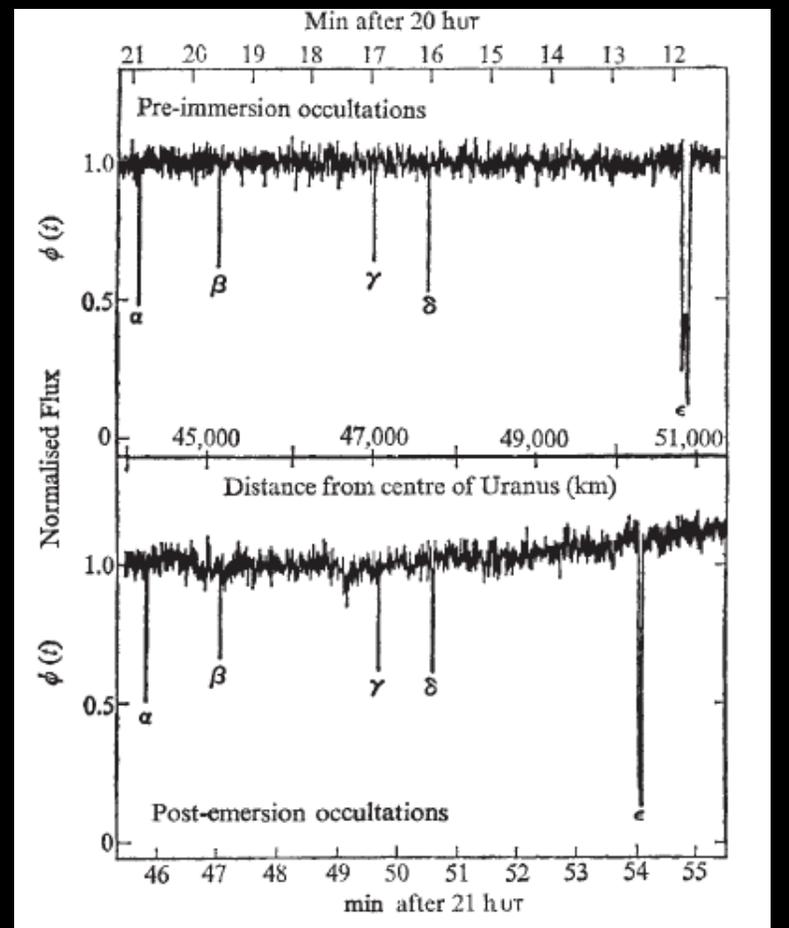


letters to nature

The rings of Uranus

At least five rings encircle the planet Uranus—as indicated by five brief occultations of the star SAO 158687 that

position of the star and Uranus determined by Franz and Wasserman¹. We then continued our observations in expectation of recording more brief occultations. Five such events were recorded before the data recording was stopped at

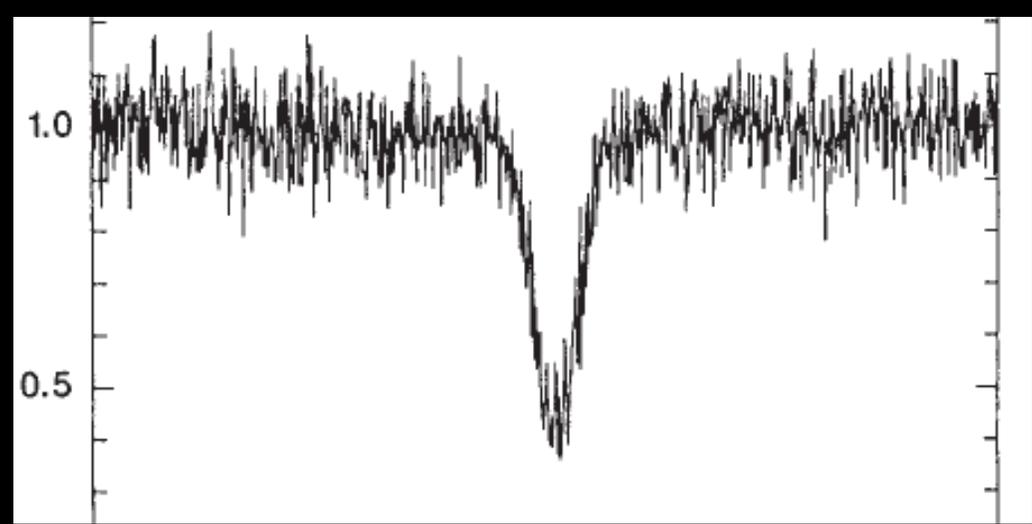


Occultation evidence for an atmosphere on Pluto

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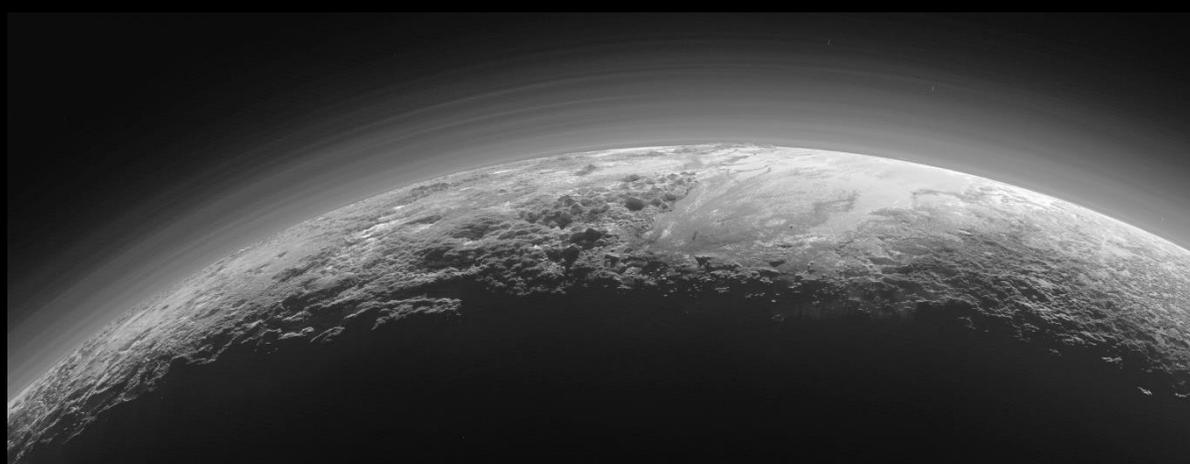
† Department of Physics, University of Tasmania, Hobart,
Tasmania 7001, Australia



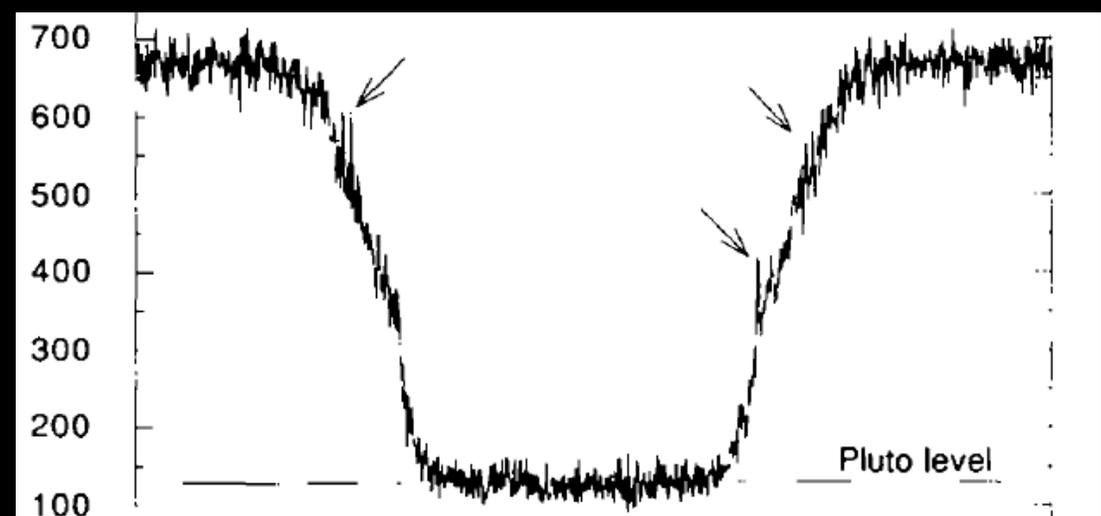
Pluto's Atmosphere

J. L. ELLIOT,*† E. W. DUNHAM,* A. S. BOSH,* S. M. SLIVAN,*
L. A. YOUNG,* L. H. WASSERMAN,‡ AND R. L. MILLIS‡

**Department of Earth, Atmospheric, and Planetary Sciences, and †Department of Physics,
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; and ‡Lowell Observatory,
Flagstaff, Arizona 86001*

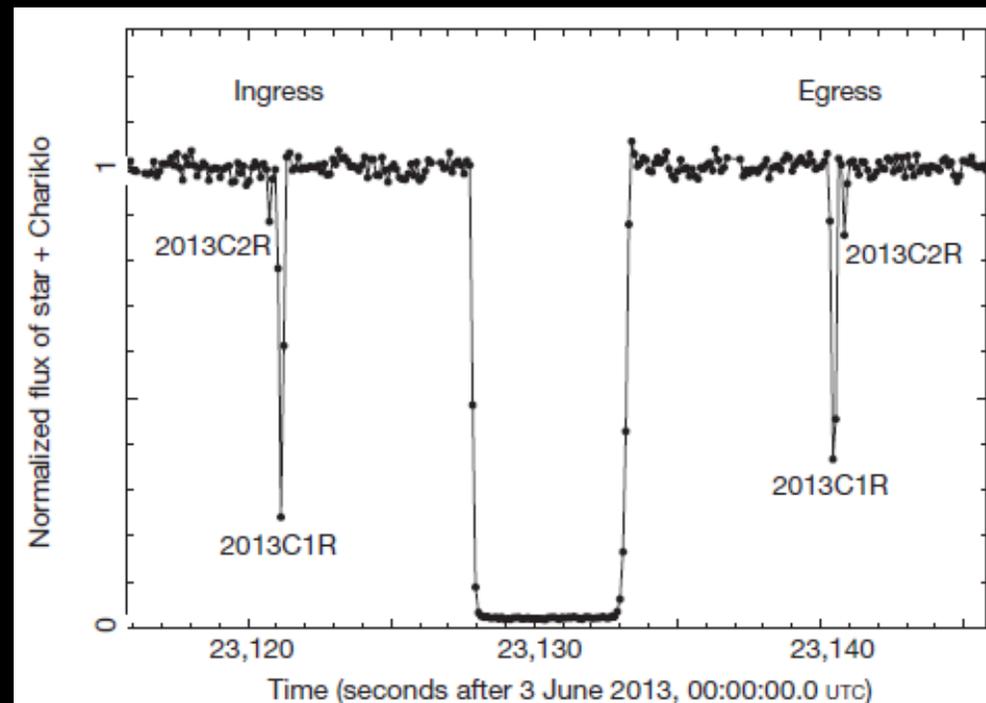
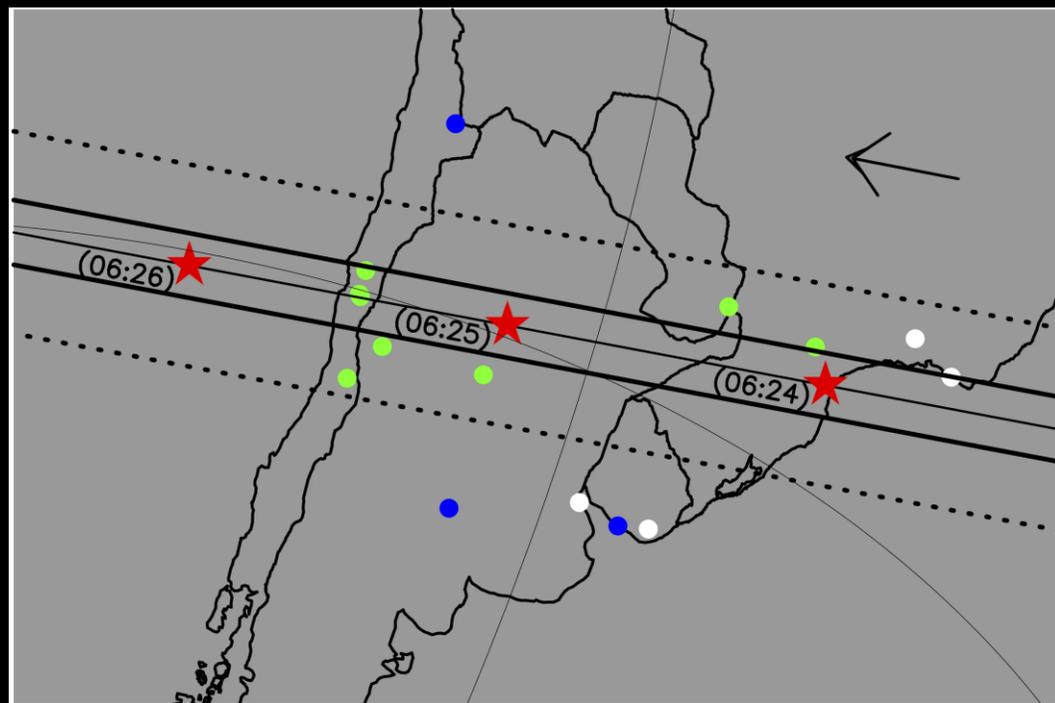


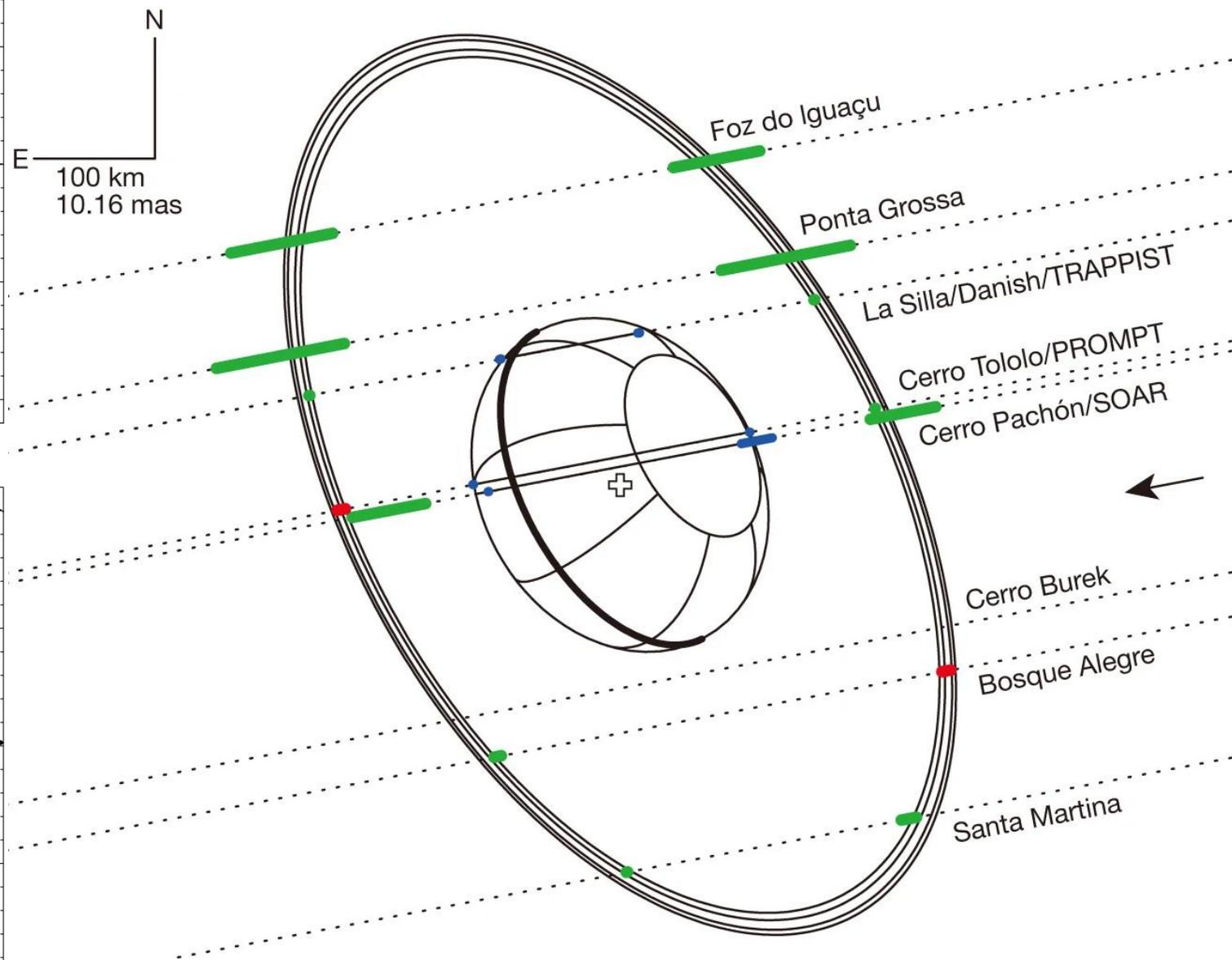
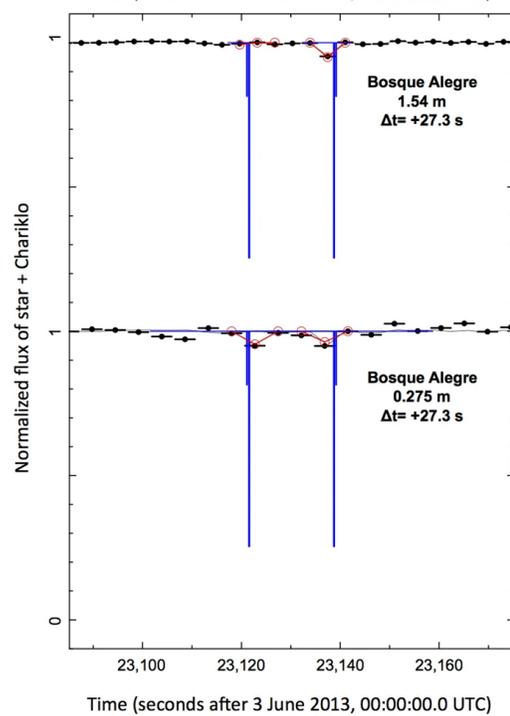
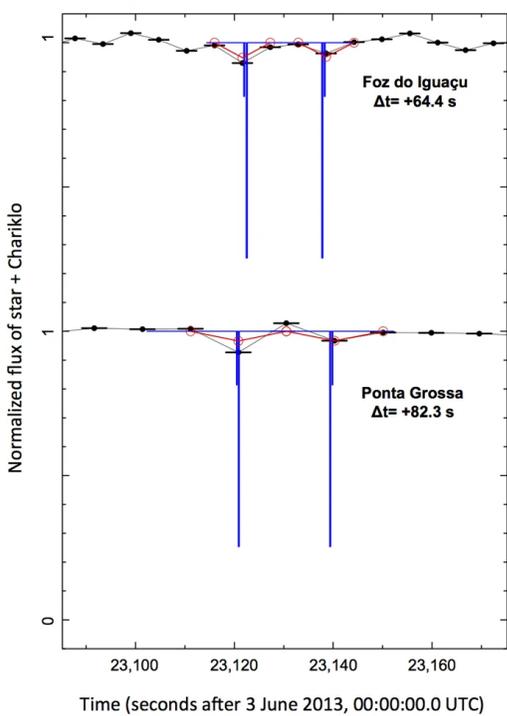
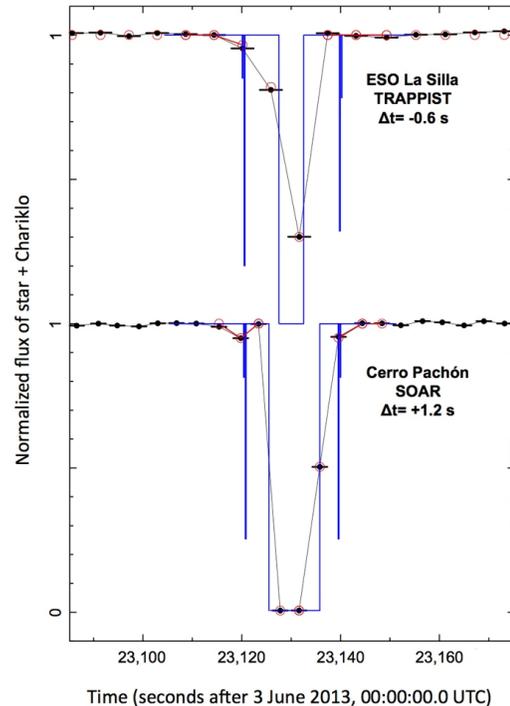
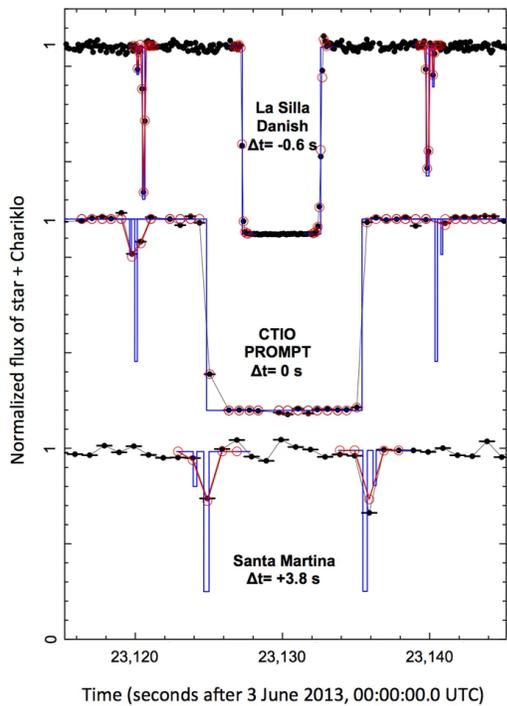
NASA/New Horizons



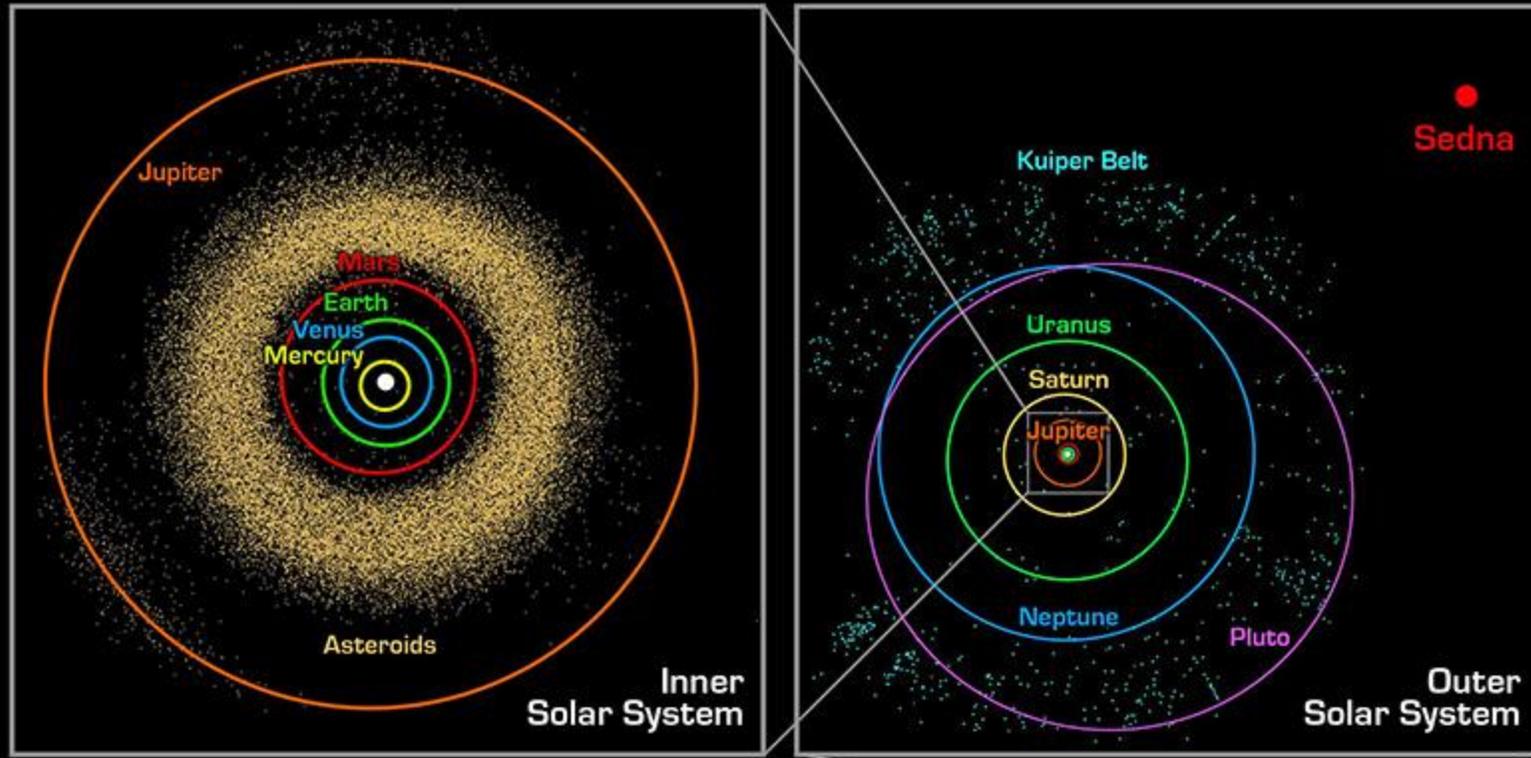
A ring system detected around the Centaur (10199) Chariklo

F. Braga-Ribas¹, B. Sicardy², J. L. Ortiz³, C. Snodgrass⁴, F. Roques², R. Vieira-Martins^{1,5,6}, J. I. B. Camargo¹, M. Assafin⁵, R. Duffard³, E. Jehin⁷, J. Pollock⁸, R. Leiva⁹, M. Emilio¹⁰, D. I. Machado^{11,12}, C. Colazo^{13,14}, E. Lellouch², J. Skottfelt^{15,16}, M. Gillon⁷, N. Ligier², L. Maquet², G. Benedetti-Rossi¹, A. Ramos Gomes Jr⁵, P. Kervella², H. Monteiro¹⁷, R. Sfair¹⁸, M. El Moutamid^{2,6}, G. Tancredi^{19,20}, J. Spagnotto²¹, A. Maury²², N. Morales³, R. Gil-Hutton²³, S. Roland¹⁹, A. Ceretta^{20,24}, S.-h. Gu^{25,26}, X.-b. Wang^{25,26}, K. Harpsøe^{15,16}, M. Rabus^{9,27}, J. Manfroid⁷, C. Opitom⁷, L. Vanzi²⁸, L. Mehret¹⁰, L. Lorenzini¹¹, E. M. Schneider^{14,29,30,31}, R. Melia¹⁴, J. Lecacheux², F. Colas⁶, F. Vachier⁶, T. Widemann², L. Almenares^{19,20}, R. G. Sandness²², F. Char³², V. Perez^{19,20}, P. Lemos²⁰, N. Martinez^{19,20}, U. G. Jørgensen^{15,16}, M. Dominik³³, F. Roig¹, D. E. Reichart³⁴, A. P. LaCluyze³⁴, J. B. Haislip³⁴, K. M. Ivarsen³⁴, J. P. Moore³⁴, N. R. Frank³⁴ & D. G. Lambas^{14,30}

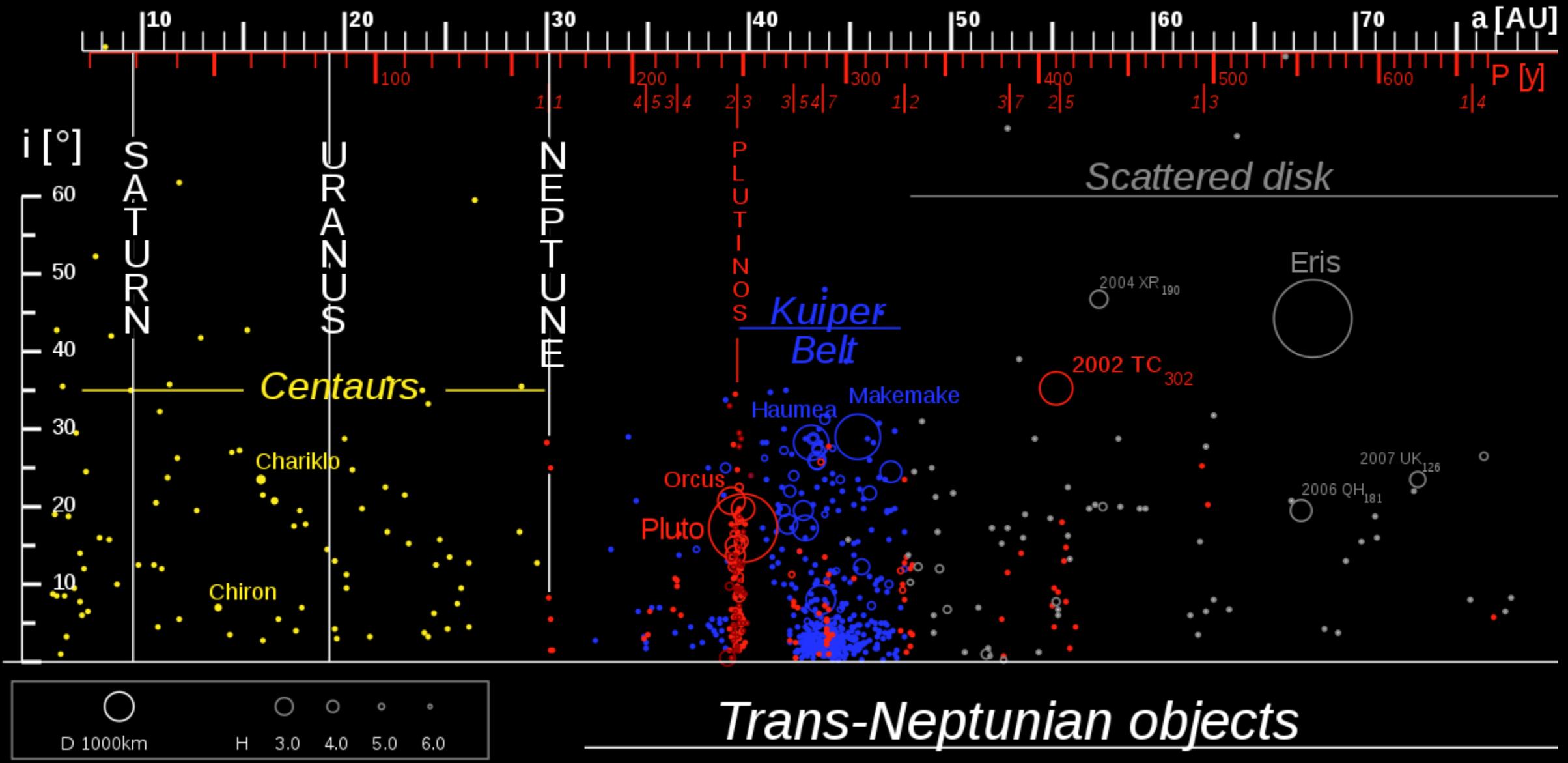


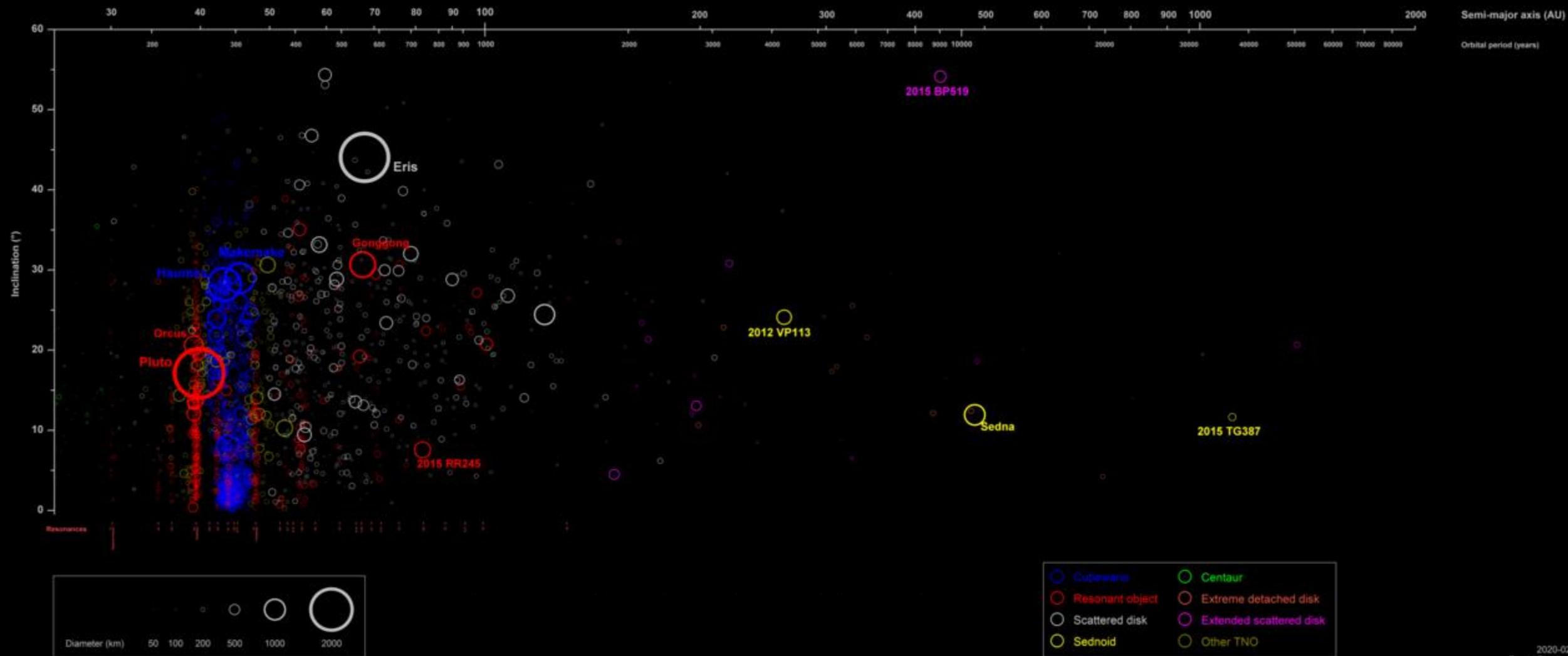


Un breve repaso de los cuerpos menores del Sistema Solar



NASA/Caltech

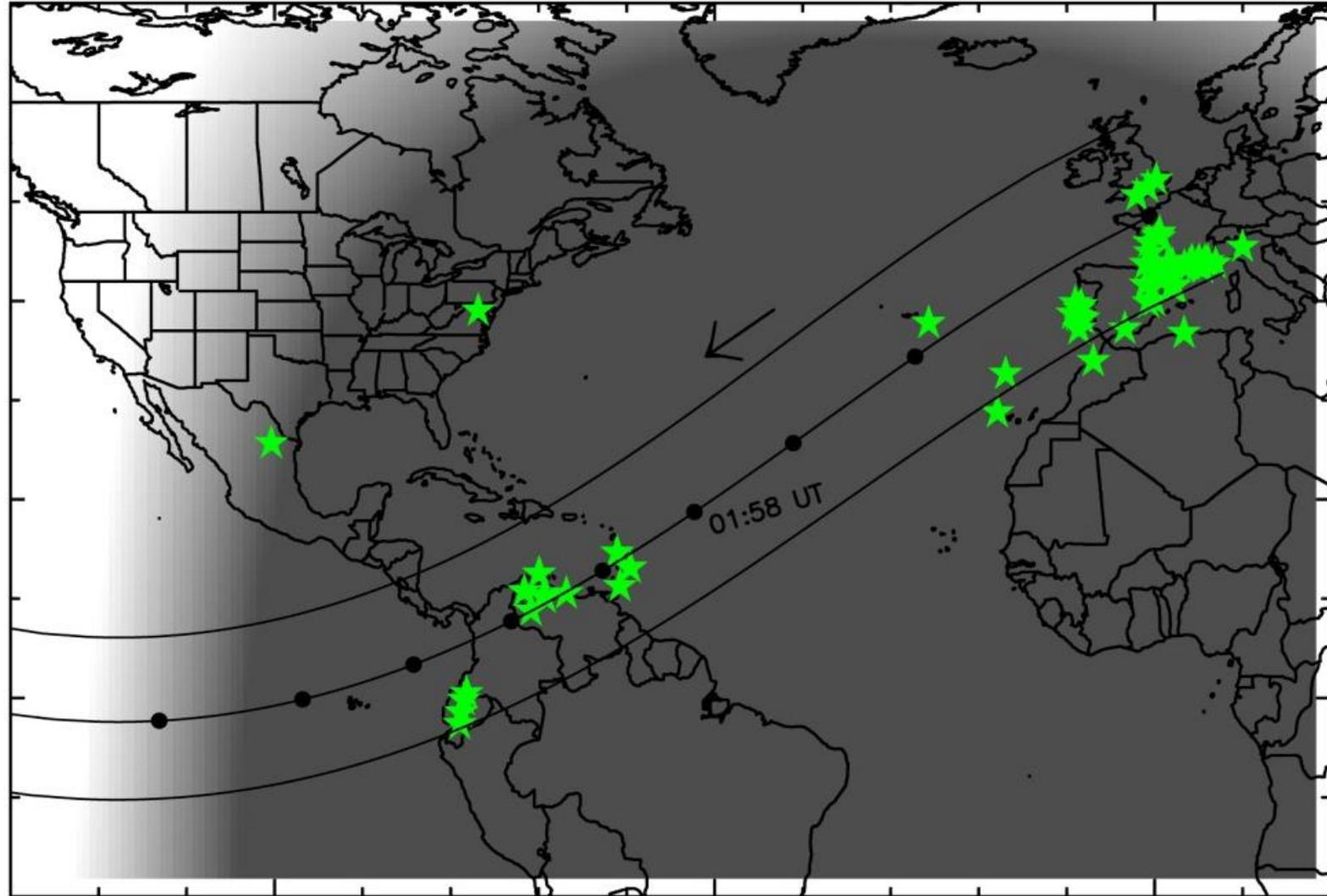




Planeación de las observaciones

Las fuentes de predicciones están a cargo de redes de colaboración internacional:

- Research and Education Collaborative Occultation Network (RECON).
- Proyecto Lucky Star.
- **International Occultation Timing Association (IOTA).**
 - ✓ Sección EEUU.
 - ✓ Sección Europea (IOTA/ES)
 - ✓ Sección Australia y Nueva Zelanda (RASNZ).
 - ✓ Sección India (IOTA/India).
 - ✓ Sección Medio Oriente (IOTA/ME).
 - ✓ **Sección Sudamérica (LIADA/SETO).**



(Widemann et al. 2009). Titania's radius and an upper limit on its atmosphere from the September 8, 2001 stellar occultation. *Icarus*, 199(2), 458-476.



La representación de la **IOTA** en Sudamérica esta a cargo de la *Liga Iberoamericana de Astronomía* (LIADA) a través de la **Sección de Eclipses Tránsitos y Ocultaciones** (SETO). El Observatorio Astronómico de la UTP asumió esta coordinación el 2020.

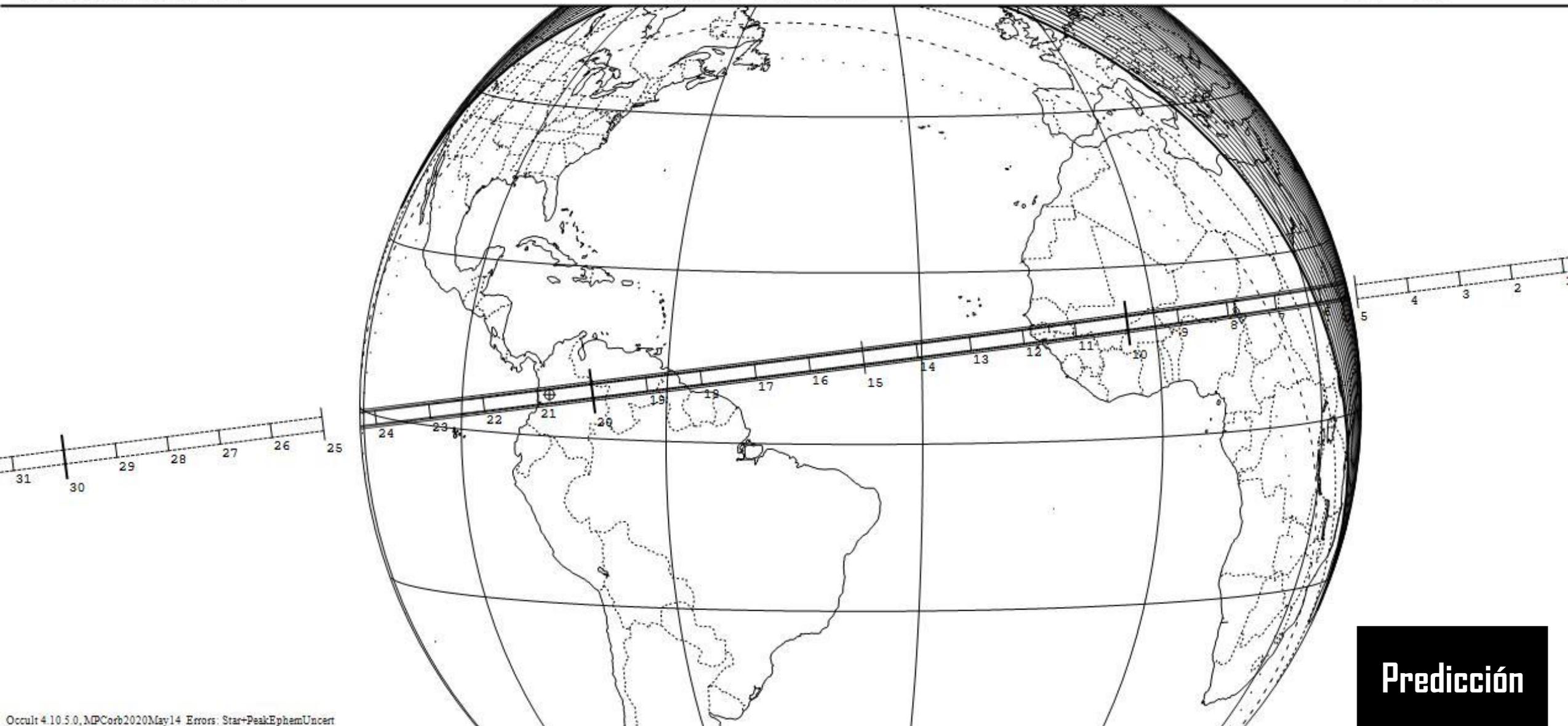


386 Siegena occults TYC 473-03890-1 on 2019 Jun 29 from 3h 5m to 3h 24m UT

Star:
Mag V = 11.4; B = 12.5; R = 10.9
RA = 19 24 18.2636 (astrometric)
Dec = 4 25 10.425
[of Date: 19 25 17, 4 27 33]
Prediction of 2020 May 28.0

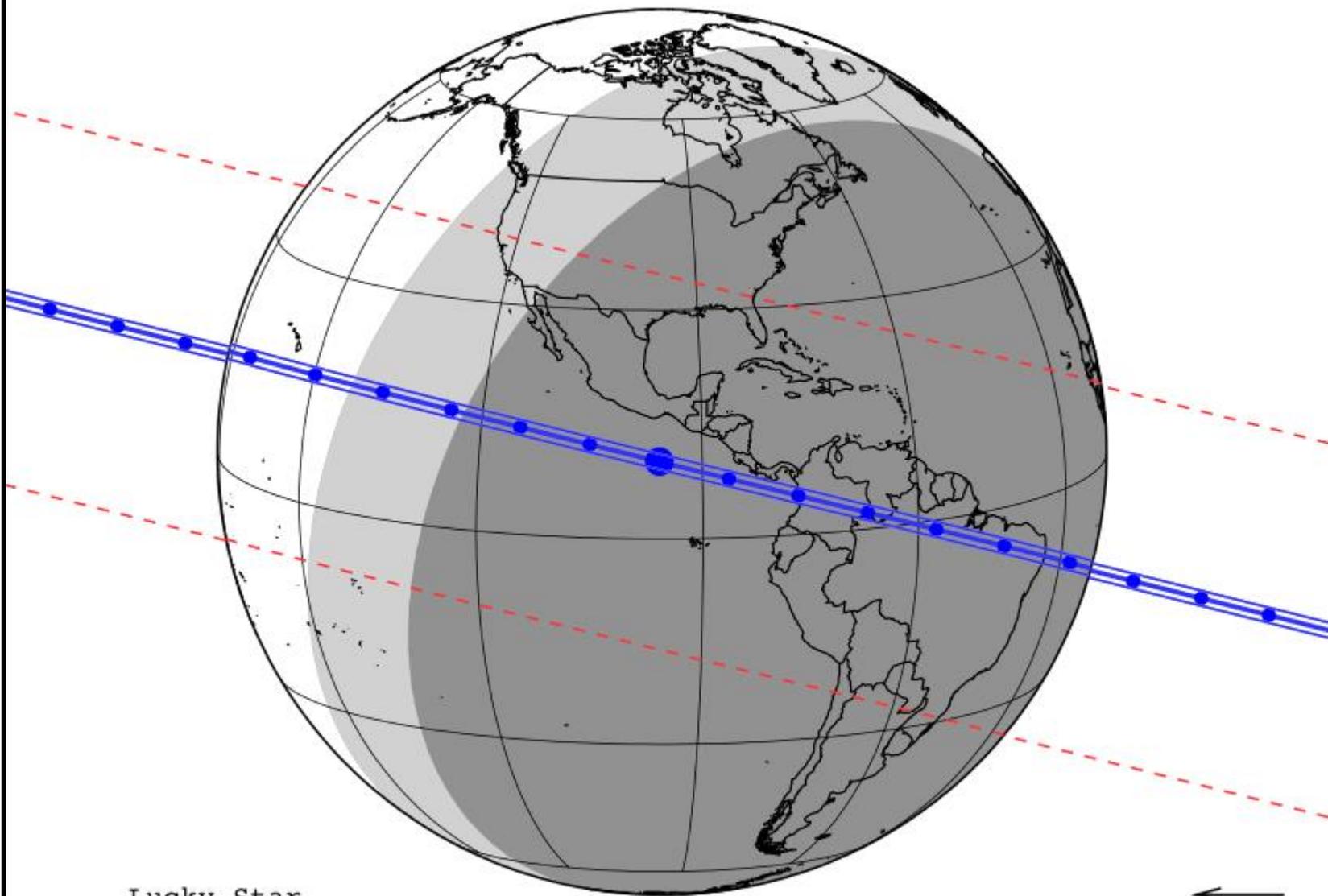
Max Duration = 16.2 secs
Mag Drop = 1.2 (1.3r)
Sun : Dist = 149°
Moon: Dist = 116°
: illum = 16 %
E 0.022"x 0.022" in PA 90

Asteroid: (in DAMIT, ISAM)
Mag = 12.2
Dia = 179 ±18km, 0.124"
Parallax = 4.417"
Hourly dRA = -1.829s
dDec = -3.51"



Predicción

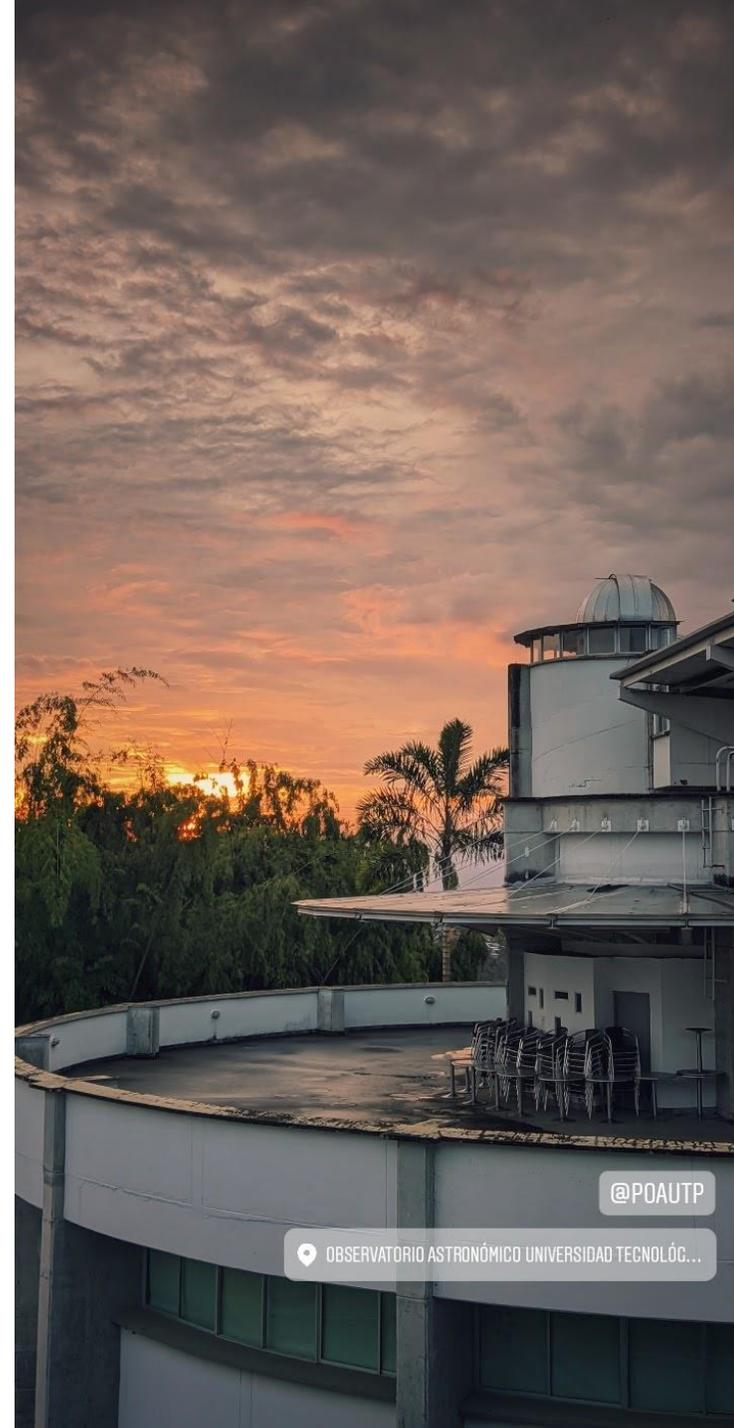
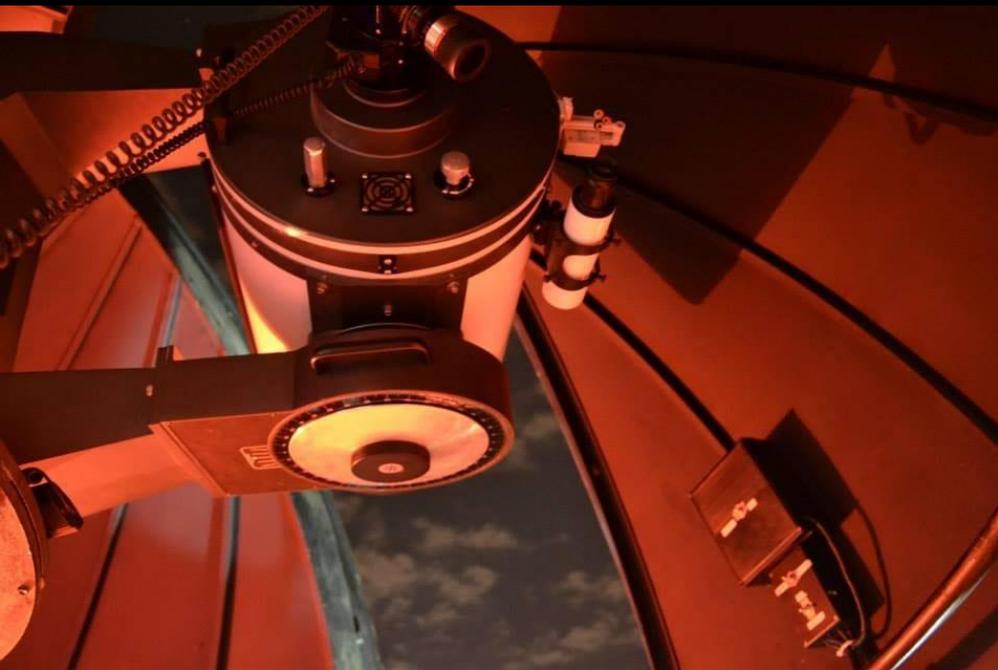
Las ocultaciones estelares por **Objetos Trans Neptunianos (TNOs)** se caracterizan por presentar grandes incertidumbres en sus predicciones.



Lucky Star

yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2019-05-01 03:42:19.4	11 55 17.5301	+11 23 50.807	0.005	194.15	-16.70	34.7255	9.6	8.3	5.3

Instrumentación



@POAUTP

📍 OBSERVATORIO ASTRONÓMICO UNIVERSIDAD TECNOLÓGICA DE PANAMÁ

Instrumentación

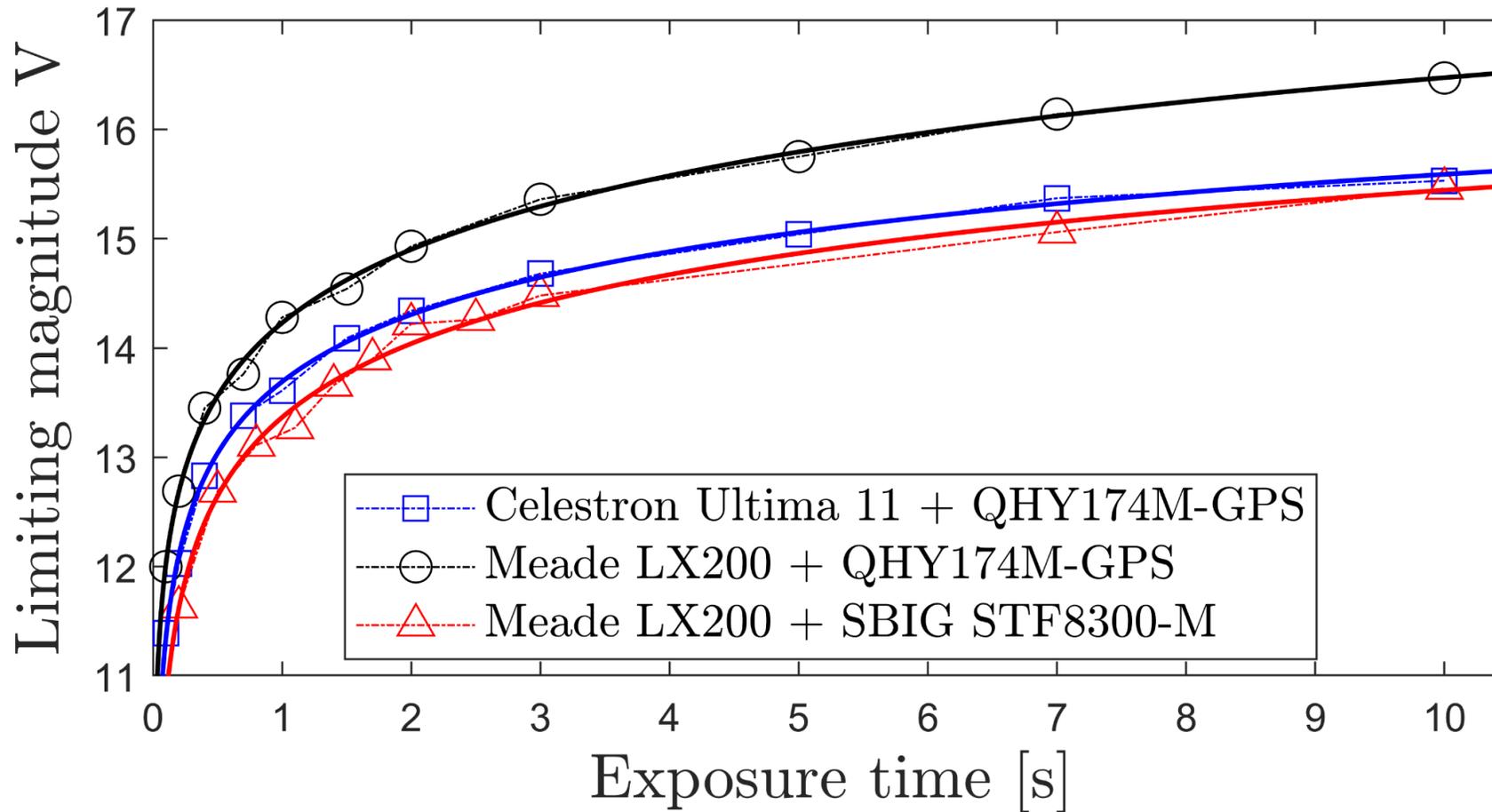
- Si la montaña no va a Mahoma, Mahoma irá a la montaña: **estación fija vs estación móvil.**
- Como la resolución temporal se traduce en resolución espacial, se utilizan **detectores con mínimo tiempo muerto.**

Telescope	Meade LX200-ACF	Celestron Ultima 11	
Aperture (inch)	16	11	
Focal length (mm)	4,064	2,800	
Focal ratio	f/10	f/10	
Camera	SBIG STF-8300M	QHY174M-GPS	
Sensor	KAF-8300	SONY IMX174	
Pixel array	3,326 × 2,504	1,900 × 1,200	
Pixel size (μs)	5.4	5.86	
Fullwell capacity (e ⁻)	25,000	32,000	
Peak quantum efficiency (%)	56	78	
Cooling delta (°C)	45	40	
Stations	Fixed station		Mobile station
Telescope	Meade	Meade	C11
Camera	SBIG	QHY	QHY
Field of View (arcmin)	15 × 11.4	9.6 × 6	13.8 × 8.4
Pixel scale			
Binning 1 × 1 (arcsec/pixel)	0.27	0.3	0.43
Binning 2 × 2 (arcsec/pixel)	0.55	0.59	0.86
Binning 3 × 3 (arcsec/pixel)	0.82	-	-



Capacidades instrumentales

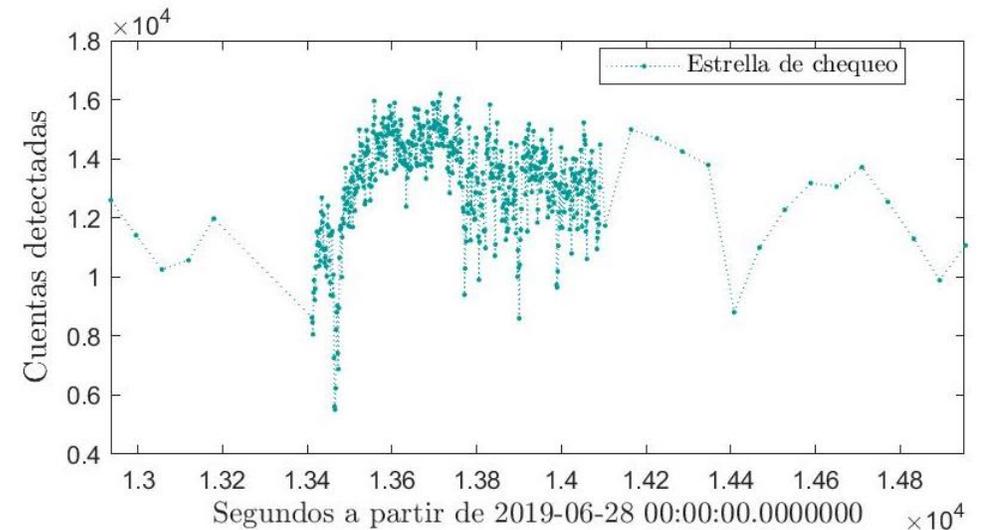
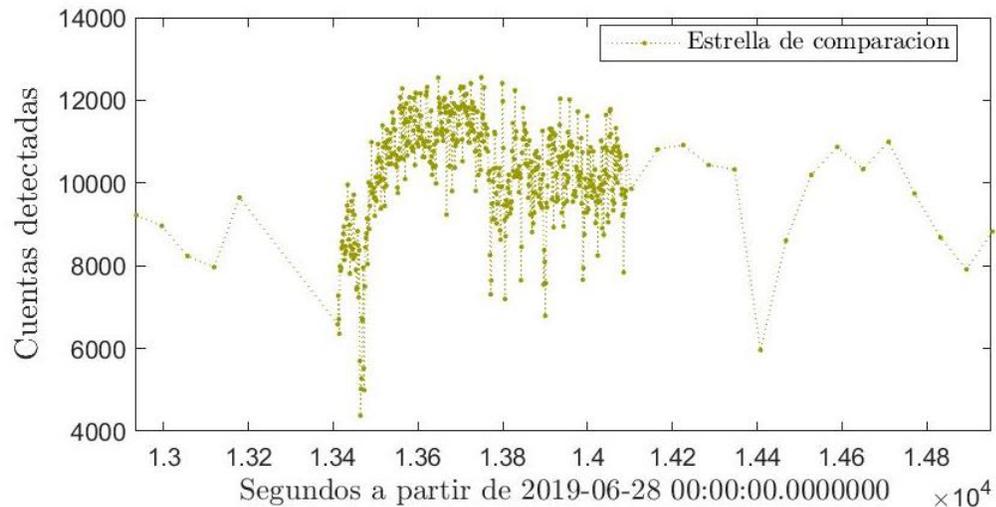
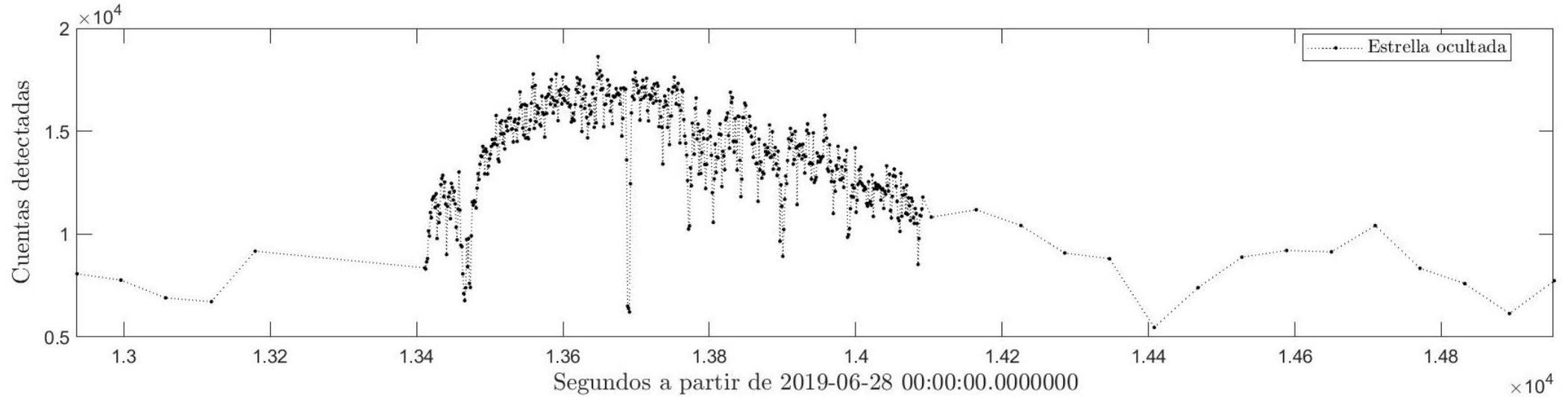
Las capacidades instrumentales son importantes para definir las ocultaciones observables.



Análisis de las observaciones

Fotometría apertura

Curvas de luz de la ocultación de la estrella UCAC4 311-202944 por el asteroide (257) Silesia del 27 de junio del 2019, positivamente detectada desde el Observatorio Astronómico de la UTP.



Fotometría diferencial y ajuste a modelo

$$\Phi(t, \Delta A, t_c, \delta t) = 1 - \Delta A \varphi(t, t_c, \delta t)$$

where:

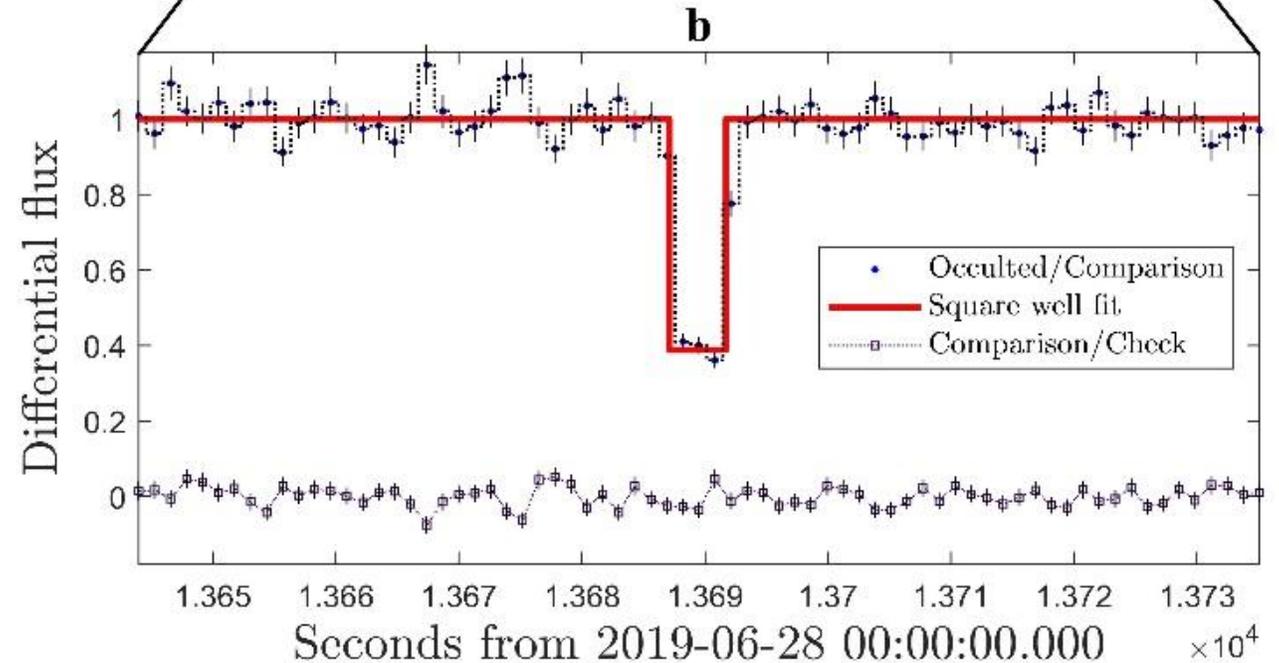
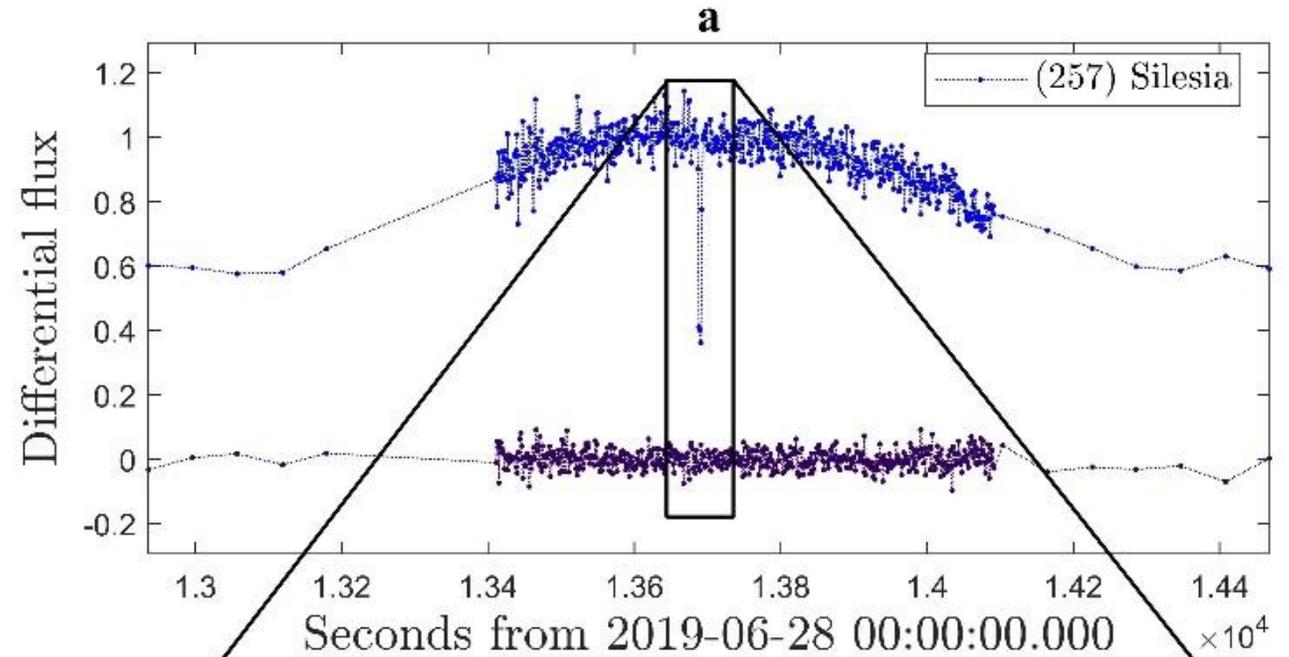
$$\varphi(t, t_c, \delta t) = \begin{cases} 1, & \left| \frac{t - t_c}{\delta t} \right| \leq \frac{1}{2} \\ 0, & \left| \frac{t - t_c}{\delta t} \right| > \frac{1}{2} \end{cases}$$

Fitting

ΔA (flux)	0.61 ± 0.03
t_c (UTC)	03:48:09.414
δt (s)	4.608 ± 0.09

Calculations

Δm_i (mag)	1.03 ± 0.03
t_i (UTC)	03:48:07.110
t_e (UTC)	03:48:11.718
D (km)	64.4 ± 1.3
d_{lim} (km)	63.1



Validación del modelo

Effects	
r (au)	2.398
F_s (km)	0.34
θ (km)	0.07
Integration (km)	18.2

Difracción de Fresnel

$$F_s = \sqrt{\frac{\lambda r}{2}}$$

Diámetro de la estrella

$$\theta_{V=0} = \theta 10^{V/5}$$

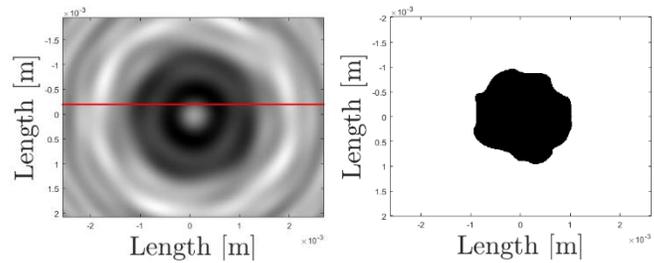
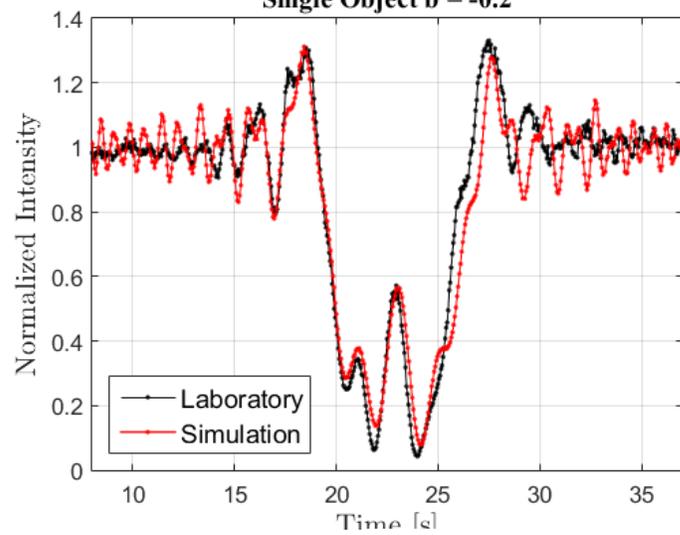
Resolución espacial

$$d = r \tan(\mu t)$$

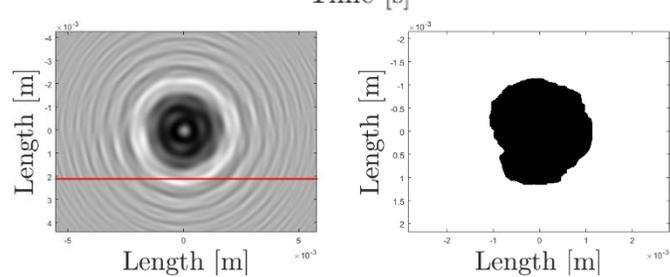
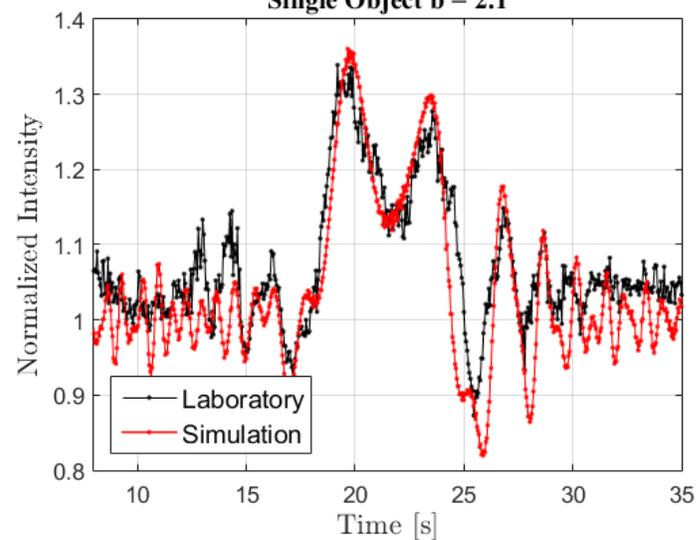
La difracción es un efecto a considerar en las ocultaciones por TNOs:



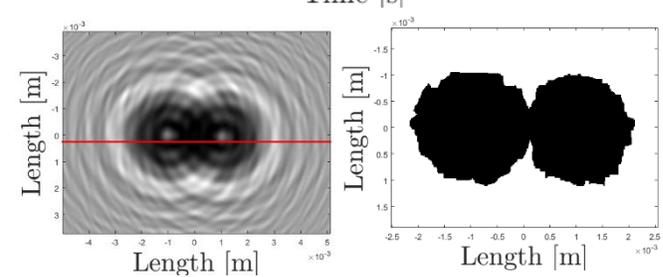
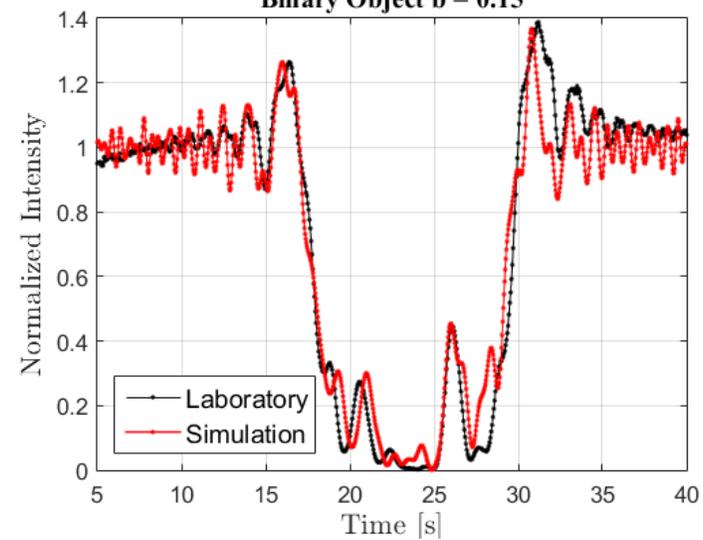
Single Object $b = -0.2$



Single Object $b = 2.1$

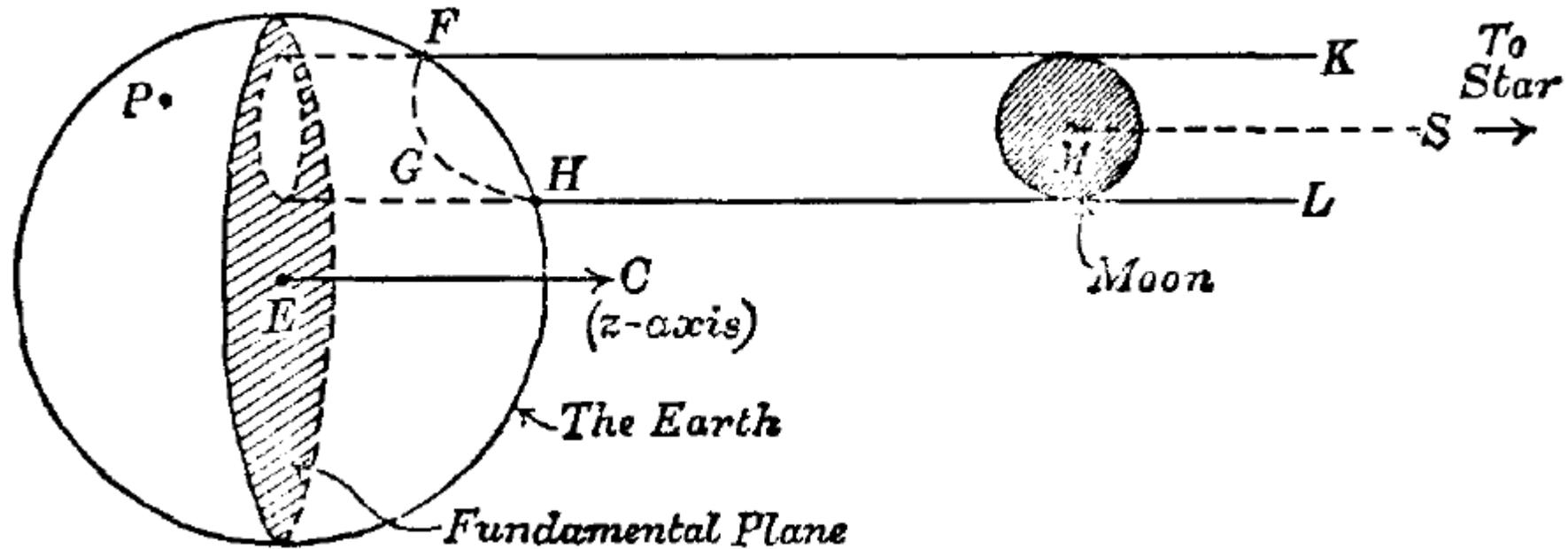


Binary Object $b = 0.15$



Medición astrométrica

Al proyectar la detección de la ocultación estelar en el plano del cielo se puede determinar una corrección a la efeméride.



Proyección en el plano del cielo

Coordenadas del observador:

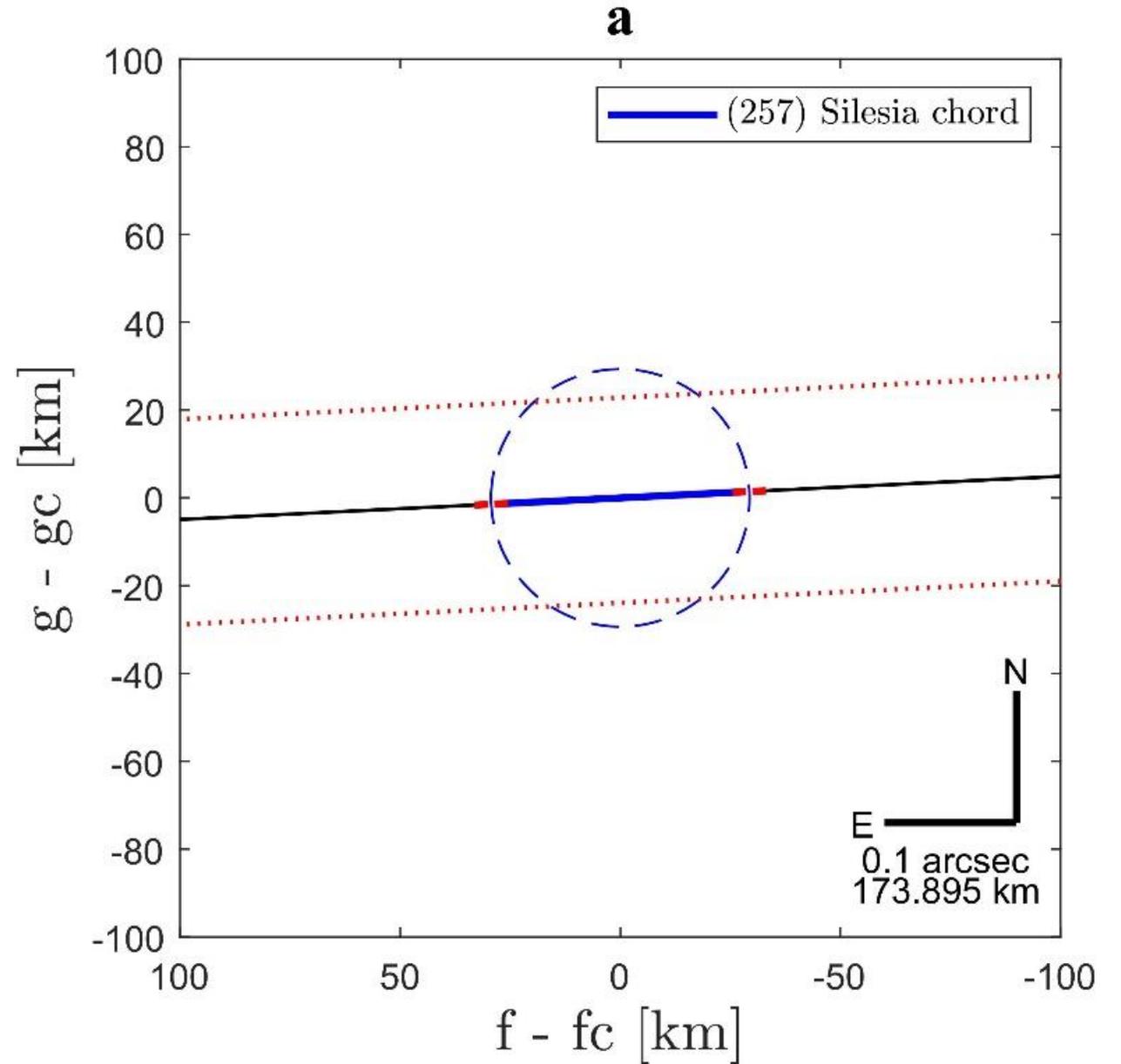
$$\xi = (\rho + z) \cos\phi' \sinh_*$$

$$\eta = (\rho + z)[\sin\phi' \cos\delta_* - \cos\phi' \sin\delta_* \cosh_*]$$

Posición del objeto:

$$x = r \cos\delta_o \sin(\alpha_o - \alpha_*)$$

$$y = r [\sin\delta_o \cos\delta_* - \cos\delta_o \sin\delta_* \cos(\alpha_o - \alpha_*)]$$



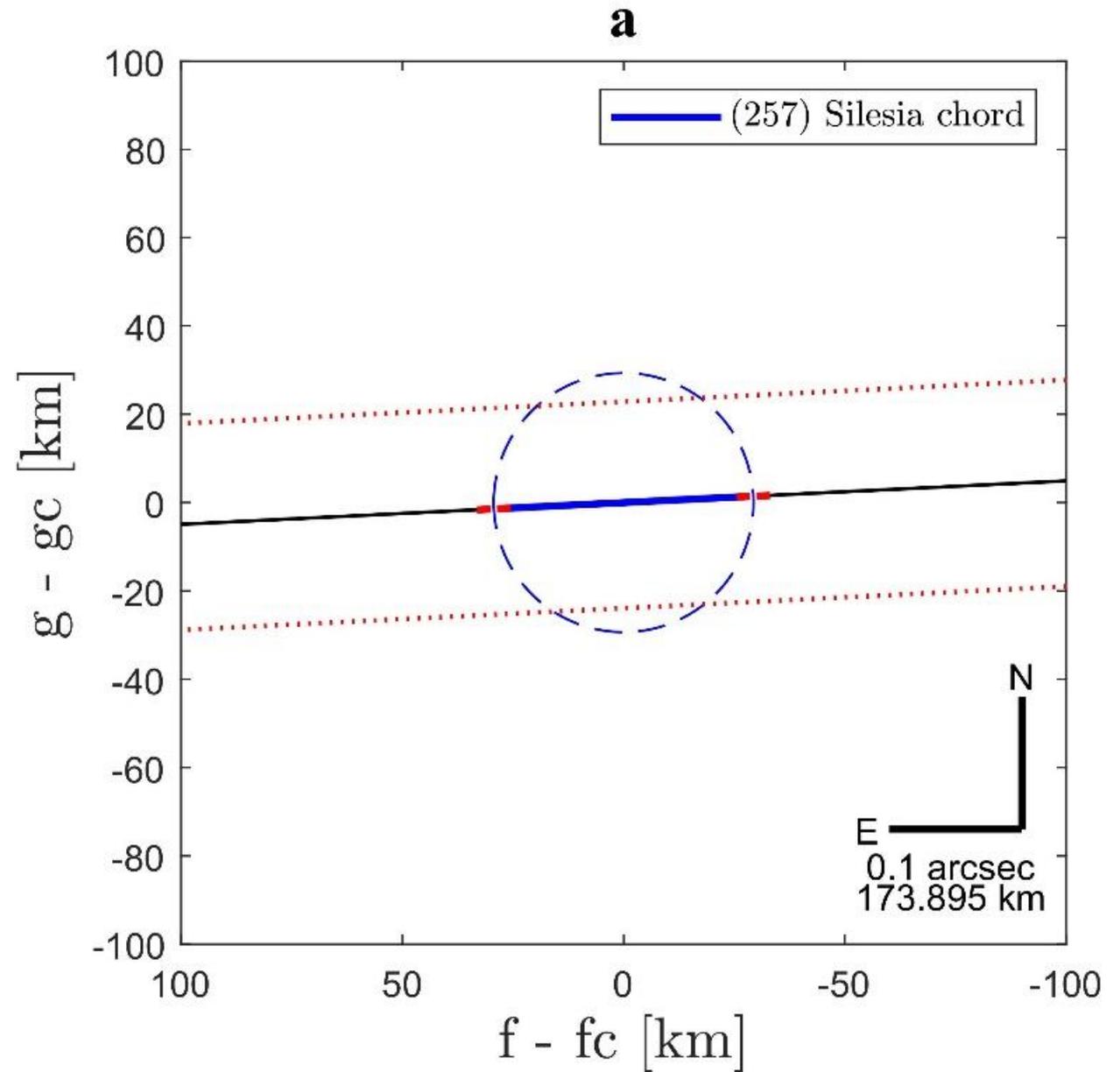
Proyección en el plano del cielo

$$f = \xi - x$$

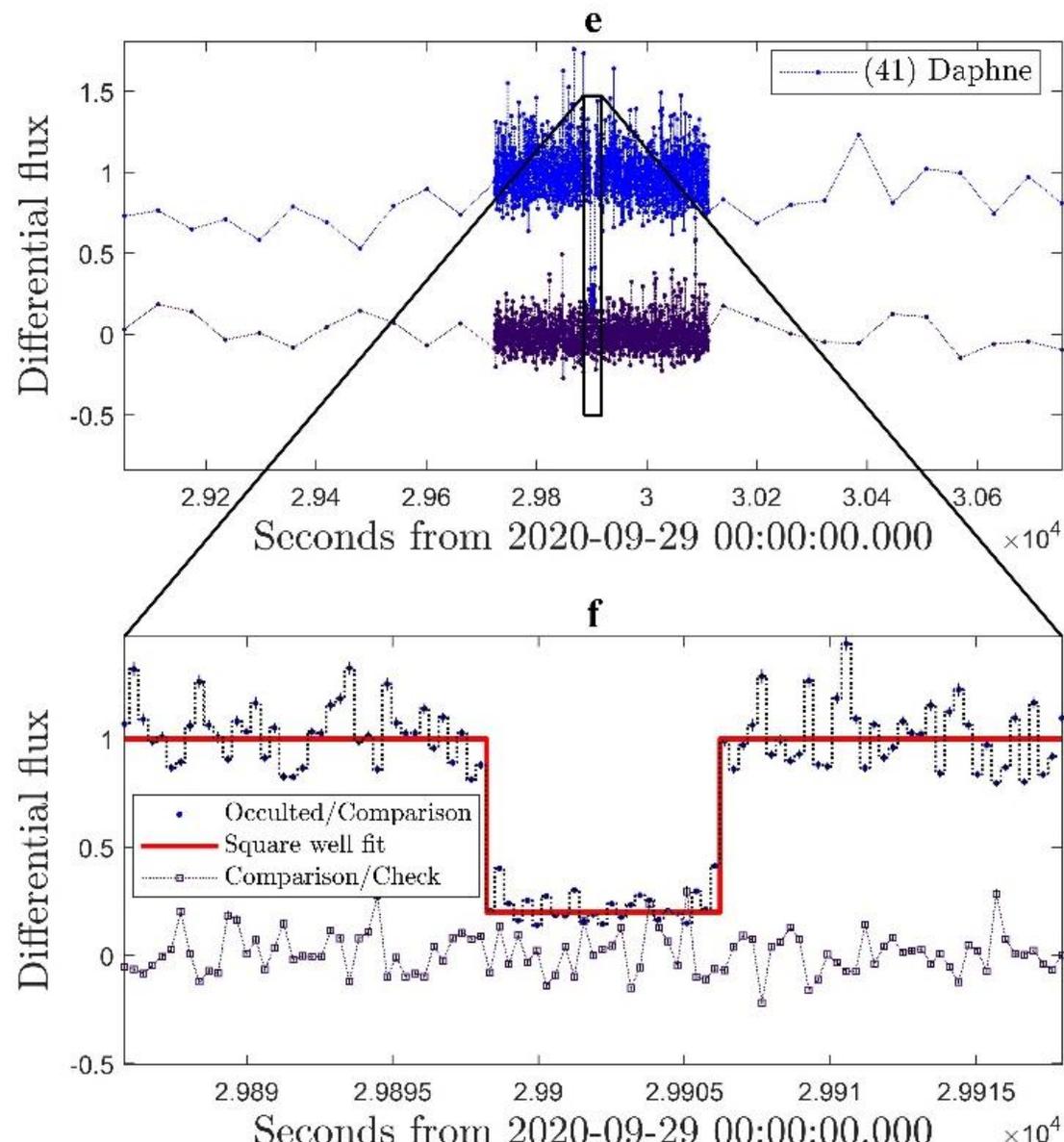
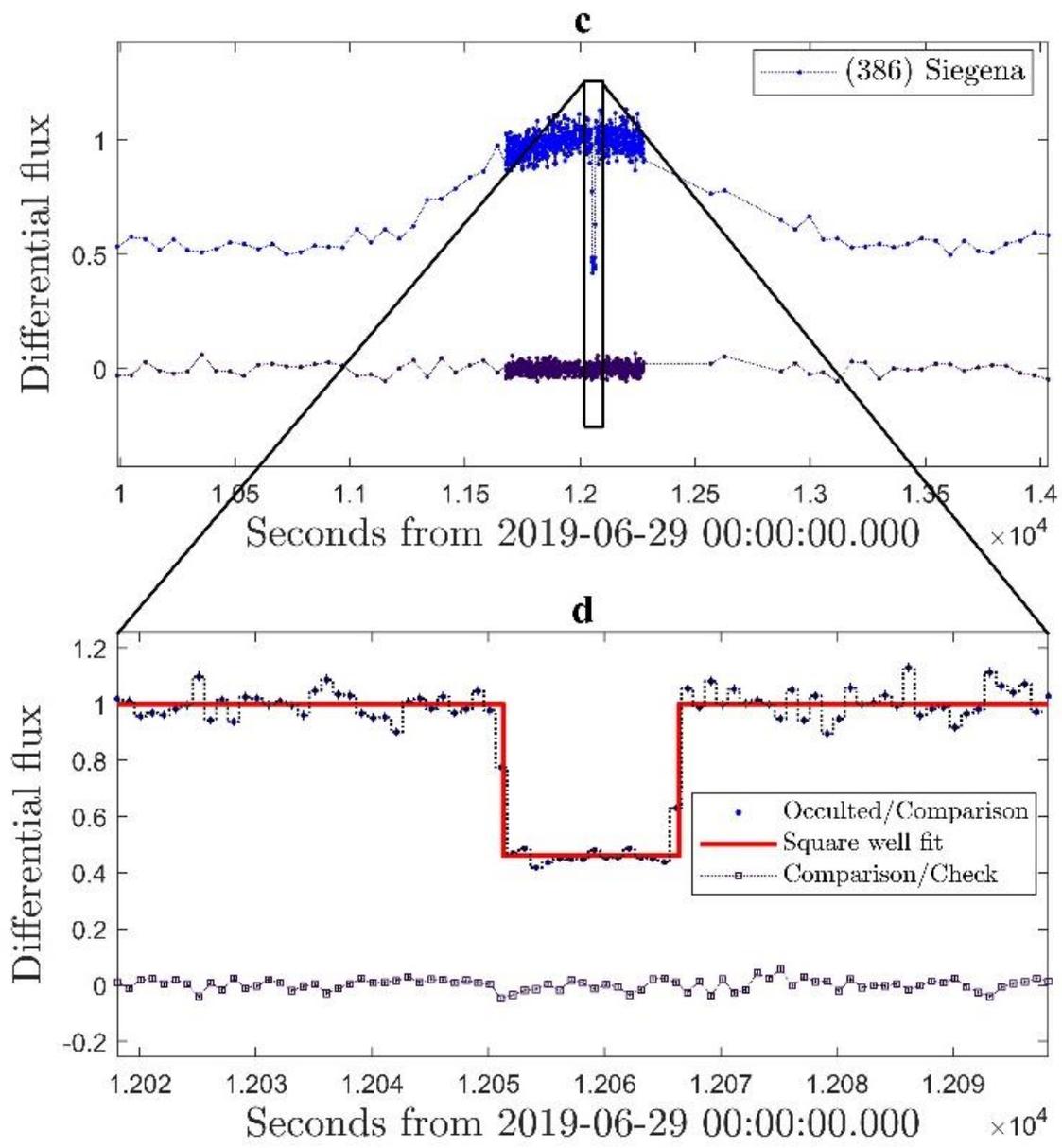
$$g = \eta - y$$

Astrometry

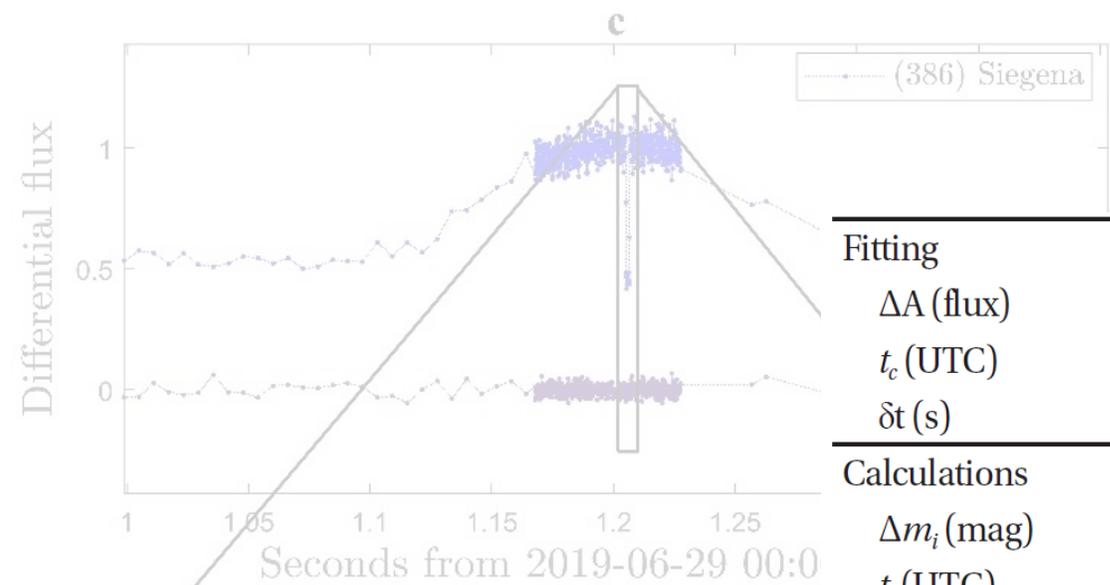
f_c (km)	$1,082.1 \pm 1.4$
g_c (km)	26.5 ± 17.2
$\Delta\alpha_c \cos(\delta_c)$ (mas)	622.30 ± 0.83
$\Delta\delta_c$ (mas)	15.23 ± 9.88



Otras detecciones positivas



Otras detecciones positivas

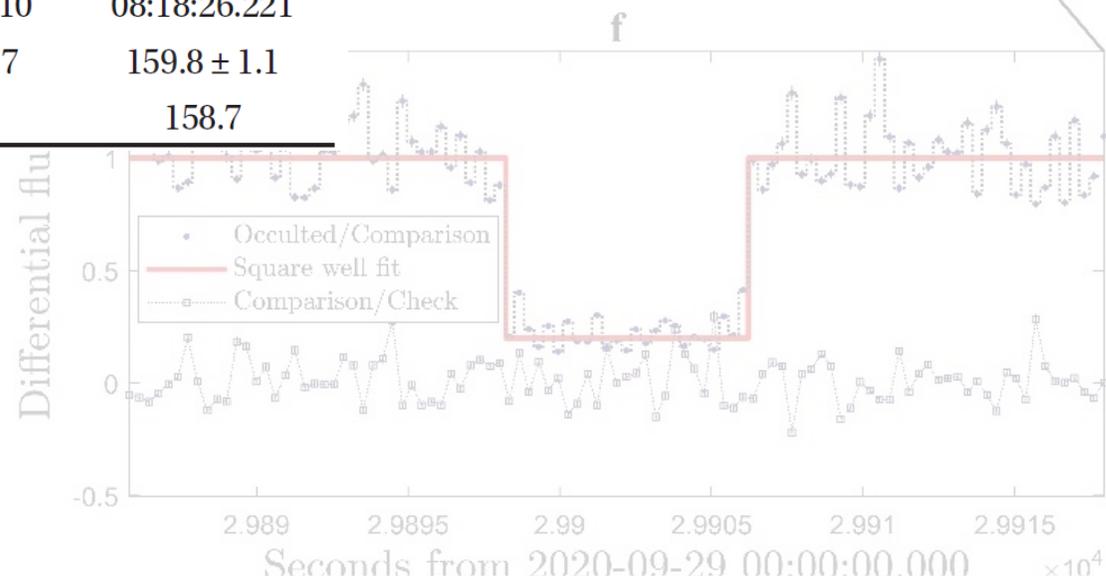
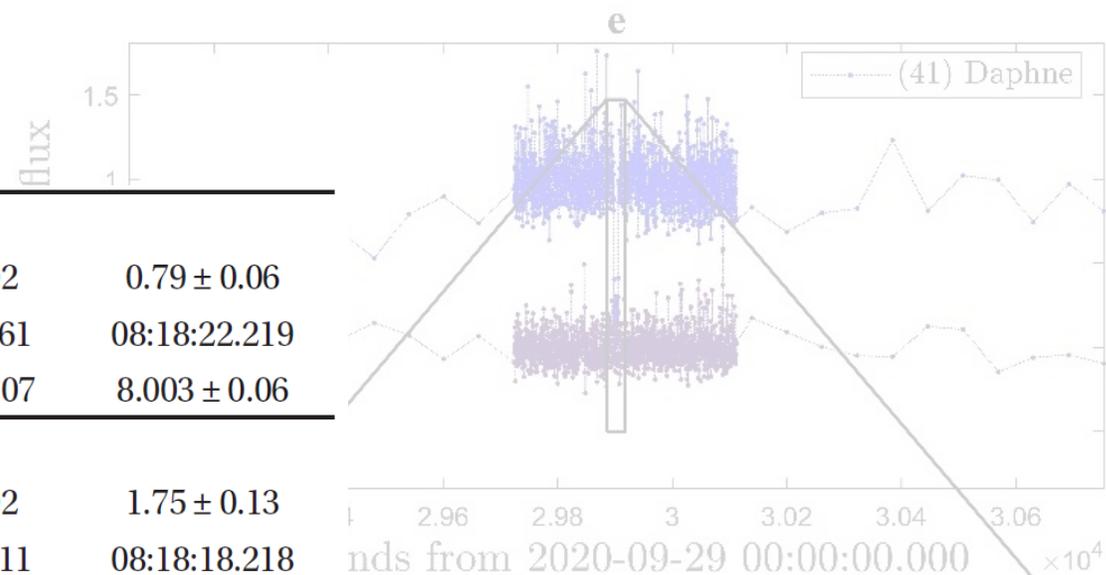
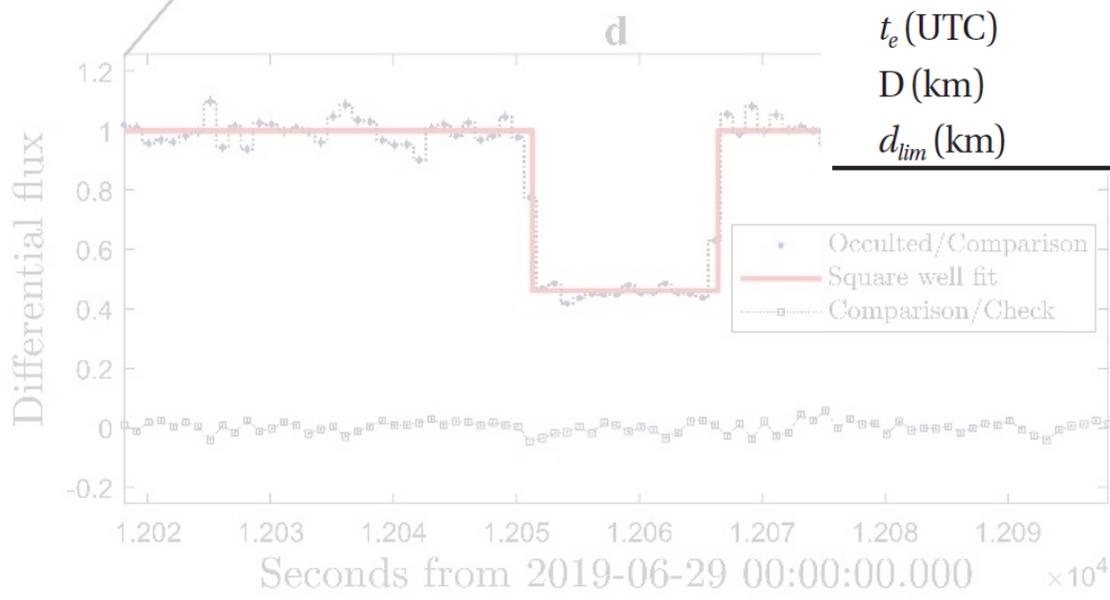


Fitting

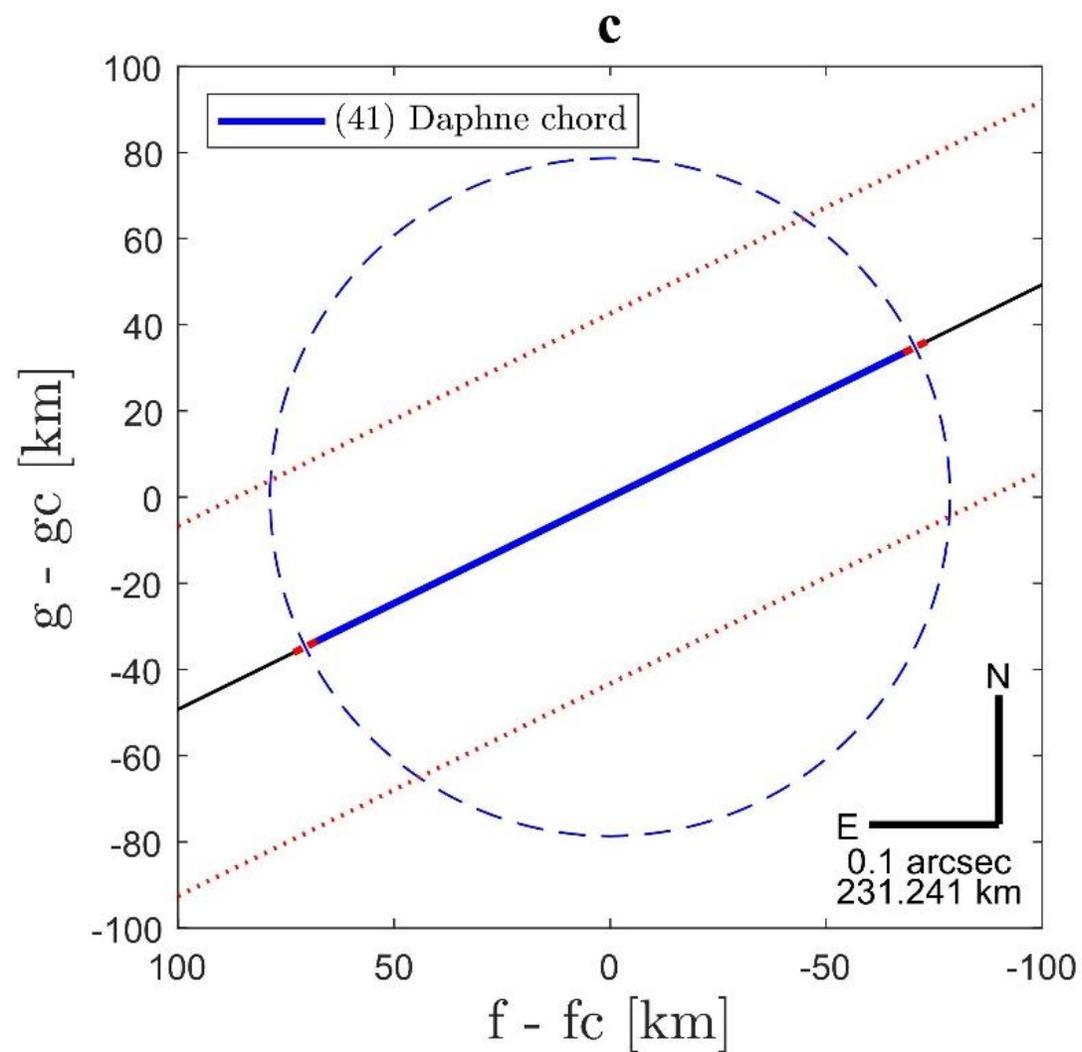
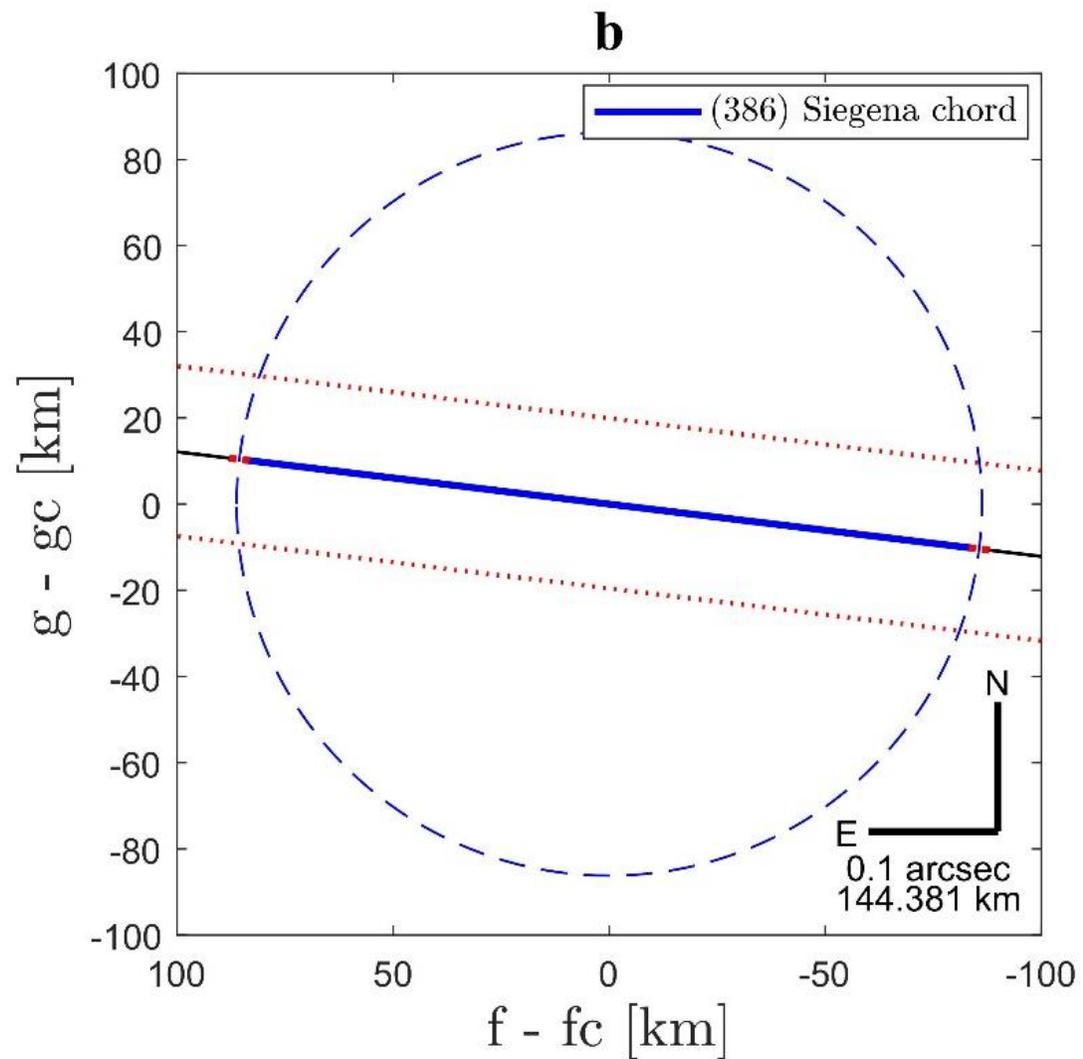
ΔA (flux)	0.54 ± 0.02	0.79 ± 0.06
t_c (UTC)	03:20:58.861	08:18:22.219
δt (s)	15.099 ± 0.07	8.003 ± 0.06

Calculations

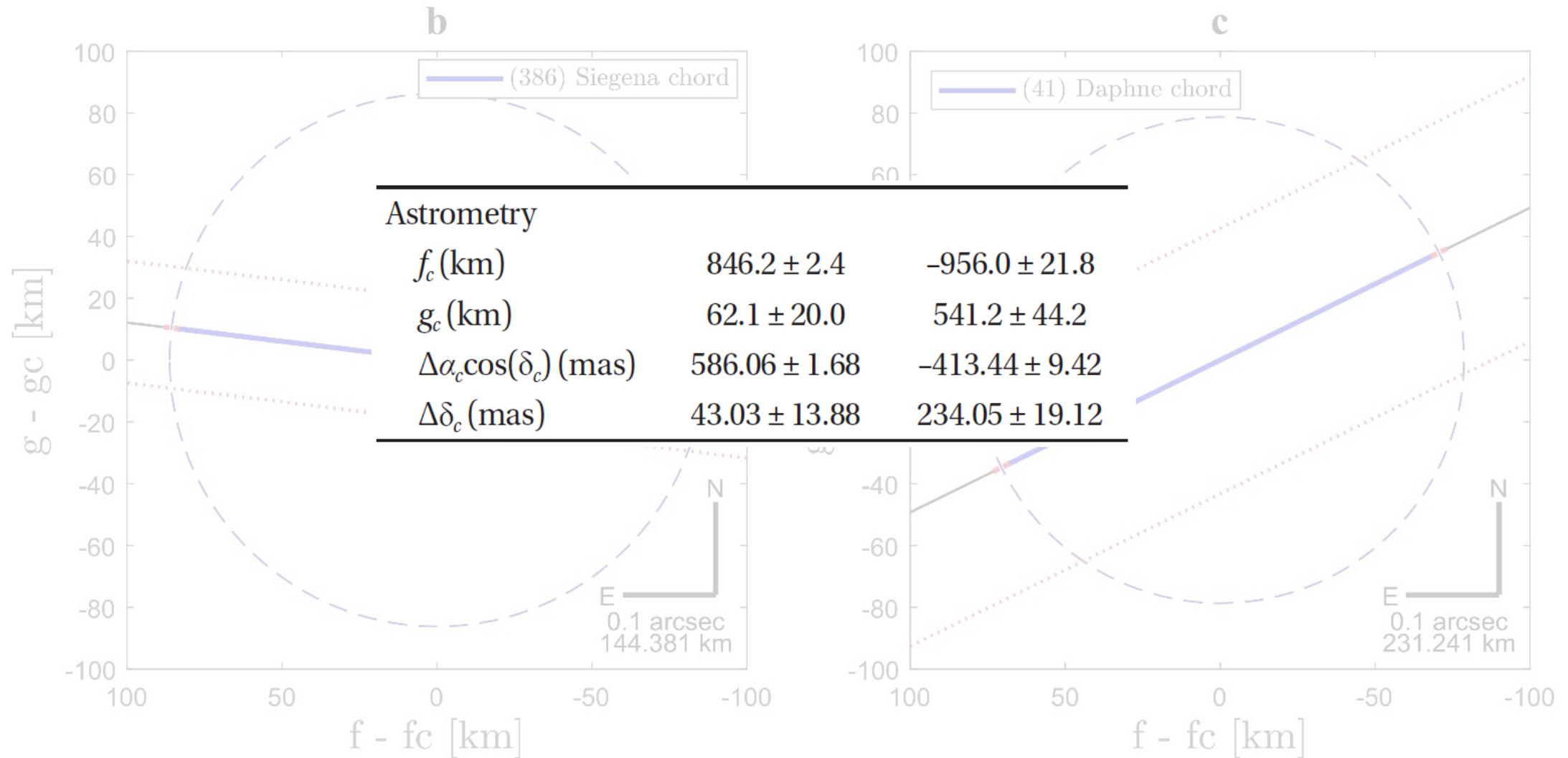
Δm_i (mag)	0.84 ± 0.02	1.75 ± 0.13
t_i (UTC)	03:20:51.311	08:18:18.218
t_e (UTC)	03:21:06.410	08:18:26.221
D (km)	166.9 ± 0.7	159.8 ± 1.1
d_{lim} (km)	166.2	158.7



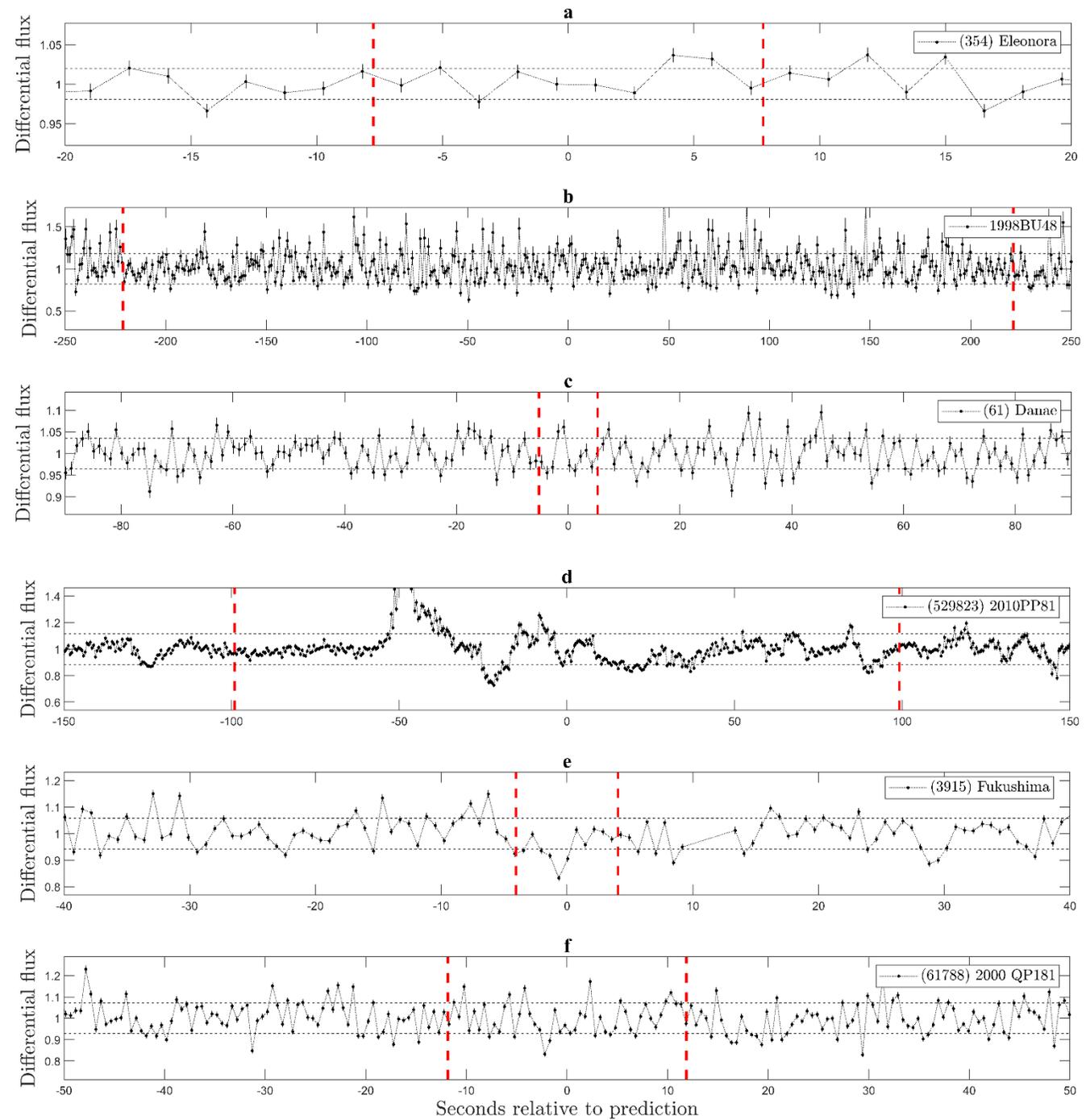
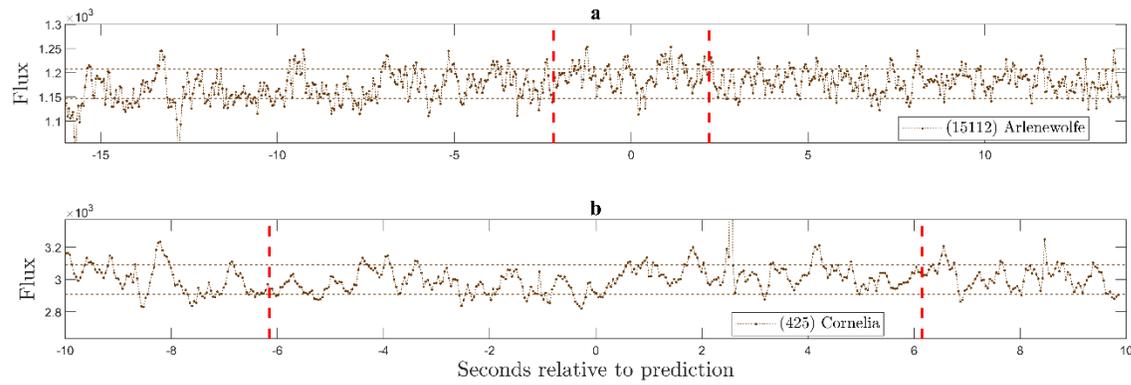
Otras detecciones positivas



Otras detecciones positivas



También detecciones negativas



Mayores detalles

Research Paper

J. Astron. Space Sci. 38(1), 1-21 (2021)

<https://doi.org/10.5140/JASS.2021.38.1.1>



Methodology for the Observations of Stellar Occultations by Small Bodies of the Solar System

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<http://janss.kr/journal/article.php?code=77786&list.php?m=1>

¡Gracias!

Contacto:

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- ✓ obsastronomico@utp.edu.co

