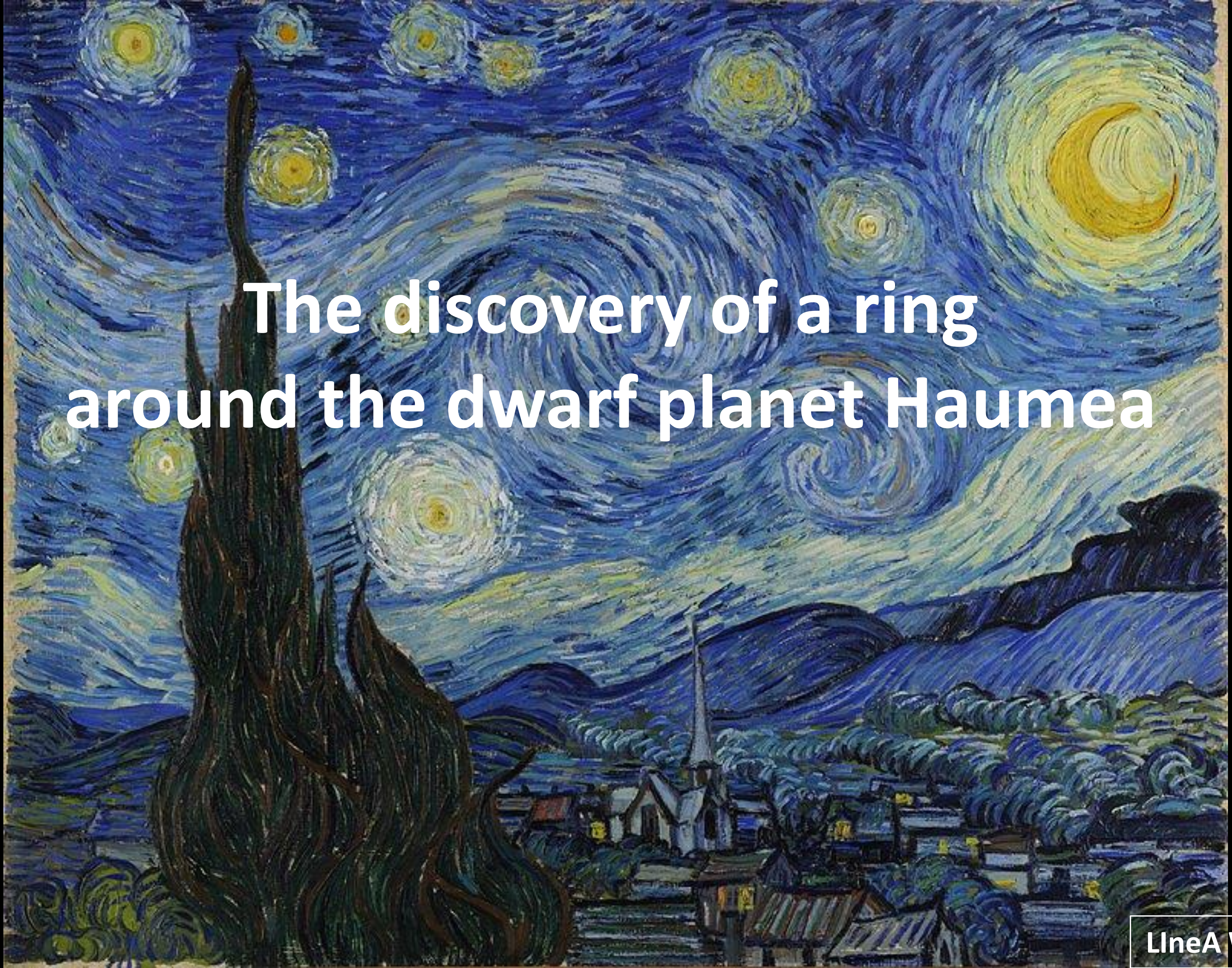

The discovery of a ring around the dwarf planet Haumea

The discovery of a ring around the dwarf planet Haumea

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Laboratório Interinstitucional de e-Astronomia
(support: INCT e-Universo, Lucky Star, CNE-Faperj, CNPq)

LETTER

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The size, shape, density and ring of the dwarf planet Haumea from a stellar occultation

J. L. Ortiz[1], P. Santos-Sanz[1], B. Sicardy[2], G. Benedetti-Rossi[3], D. Bérard[2], N. Morales[1], R. Duffard[1], F. Braga-Ribas[3,4], U. Hopp[5,6], C. Ries[5], V. Nascimbeni[7,8], F. Marzari[9], V. Granata[7,8], A. Pál[10], C. Kiss[10], T. Pribulla[11], R. Komžík[11], K. Hornoch[12], P. Pravec[12], P. Bacci[13], M. Maestripieri[13], L. Nerli[13], L. Mazzei[13], M. Bachini[14,15], F. Martinelli[15], G. Succi[14,15], F. Ciabattari[16], H. Mikuz[17], A. Carbognani[18], B. Gaehrken[19], S. Mottola[20], S. Hellmich[20], F. L. Rommel[4], E. Fernández-Valenzuela[1], A. Campo Bagatin[21,22], S. Cikota[23,24], A. Cikota[25], J. Lecacheux[2], R. Vieira-Martins[3,26,27,28], J. I. B. Camargo[3,27], M. Assafin[28], F. Colas[26], R. Behrend[29], J. Desmars[2], E. Meza[2], A. Alvarez-Candal[3], W. Beisker[30], A. R. Gomes-Junior[28], B. E. Morgado[3], F. Roques[2], F. Vachier[26], J. Berthier[26], T. G. Mueller[6], J. M. Madiedo[31], O. Unsalan[32], E. Sonbas[33], N. Karaman[33], O. Erece[34], D. T. Koseoglu[34], T. Ozisik[34], S. Kalkan[35], Y. Guney[36], M. S. Niaei[37], O. Satir[37], C. Yesilyaprak[37,38], C. Puskullu[39], A. Kabas[39], O. Demircan[39], J. Alikakos[40], V. Charmandaris[40,41], G. Leto[42], J. Ohlert[43,44], J. M. Christille[18], R. Szakáts[10], A. Takácsné Farkas[10], E. Varga-Verebélyi[10], G. Marton[10], A. Marciniak[45], P. Bartczak[45], T. Santana-Ros[45], M. Butkiewicz-Bąk[45], G. Dudziński[45], V. Alí-Lagoa[6], K. Gazeas[46], L. Tzouganatos[46], N. Paschalis[47], V. Tsamis[48], A. Sánchez-Lavega[49], S. Pérez-Hoyos[49], R. Hueso[49], J. C. Guirado[50,51], V. Peris[50] & R. Iglesias-Marzoa[52,53]

Outer Solar System

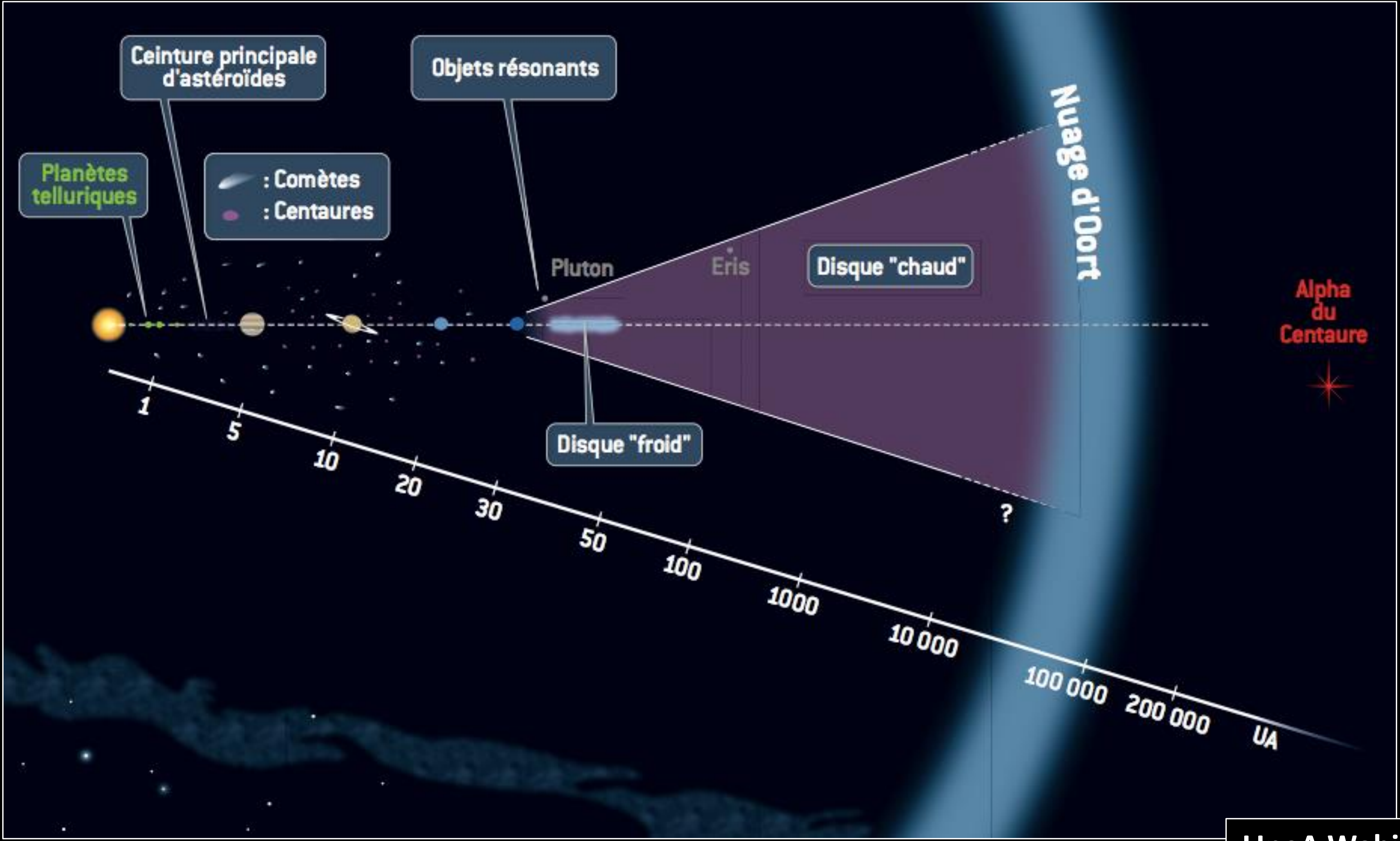
Stellar Occultations

Haumea

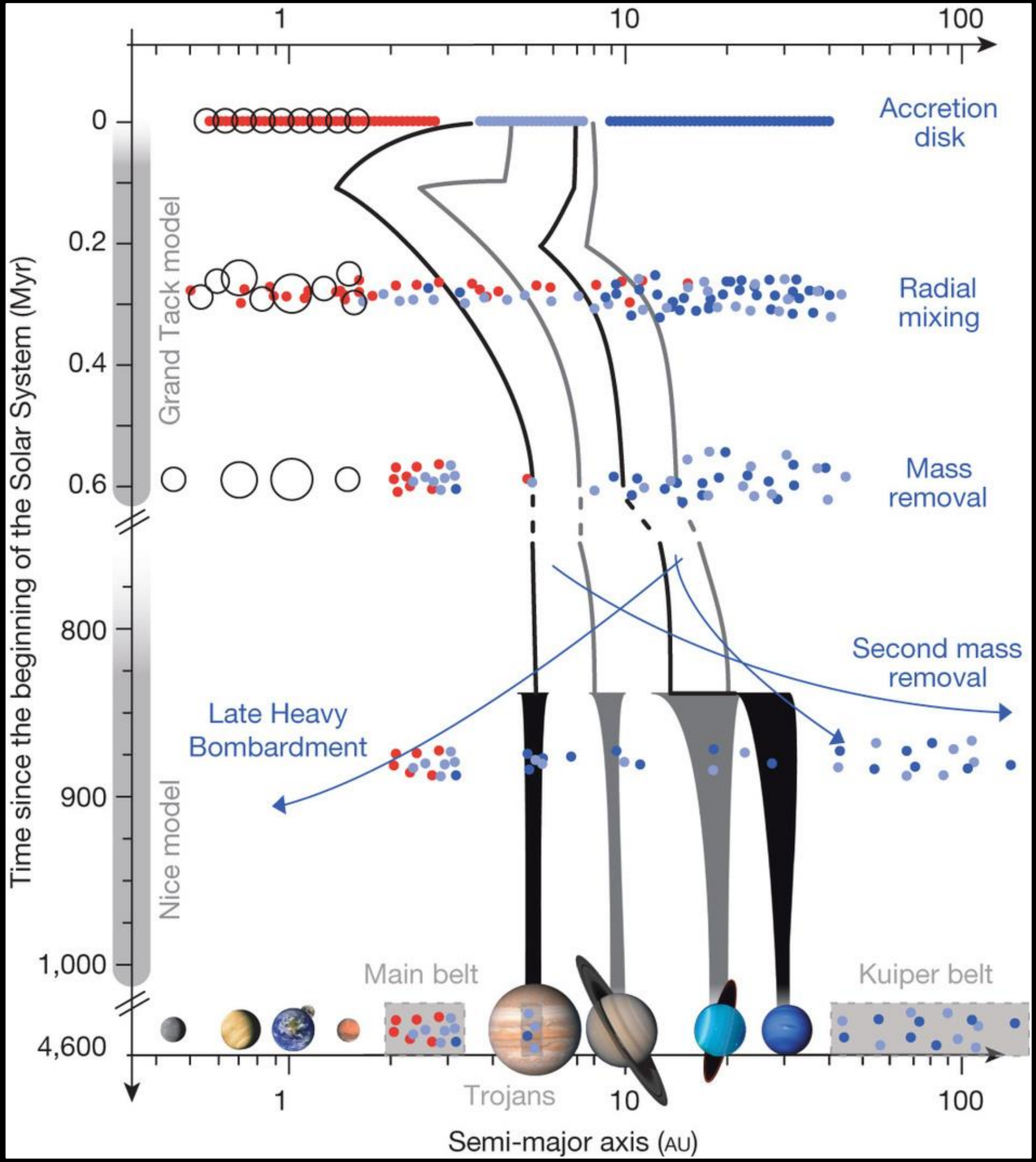
Haumea Stellar Occultation

Future

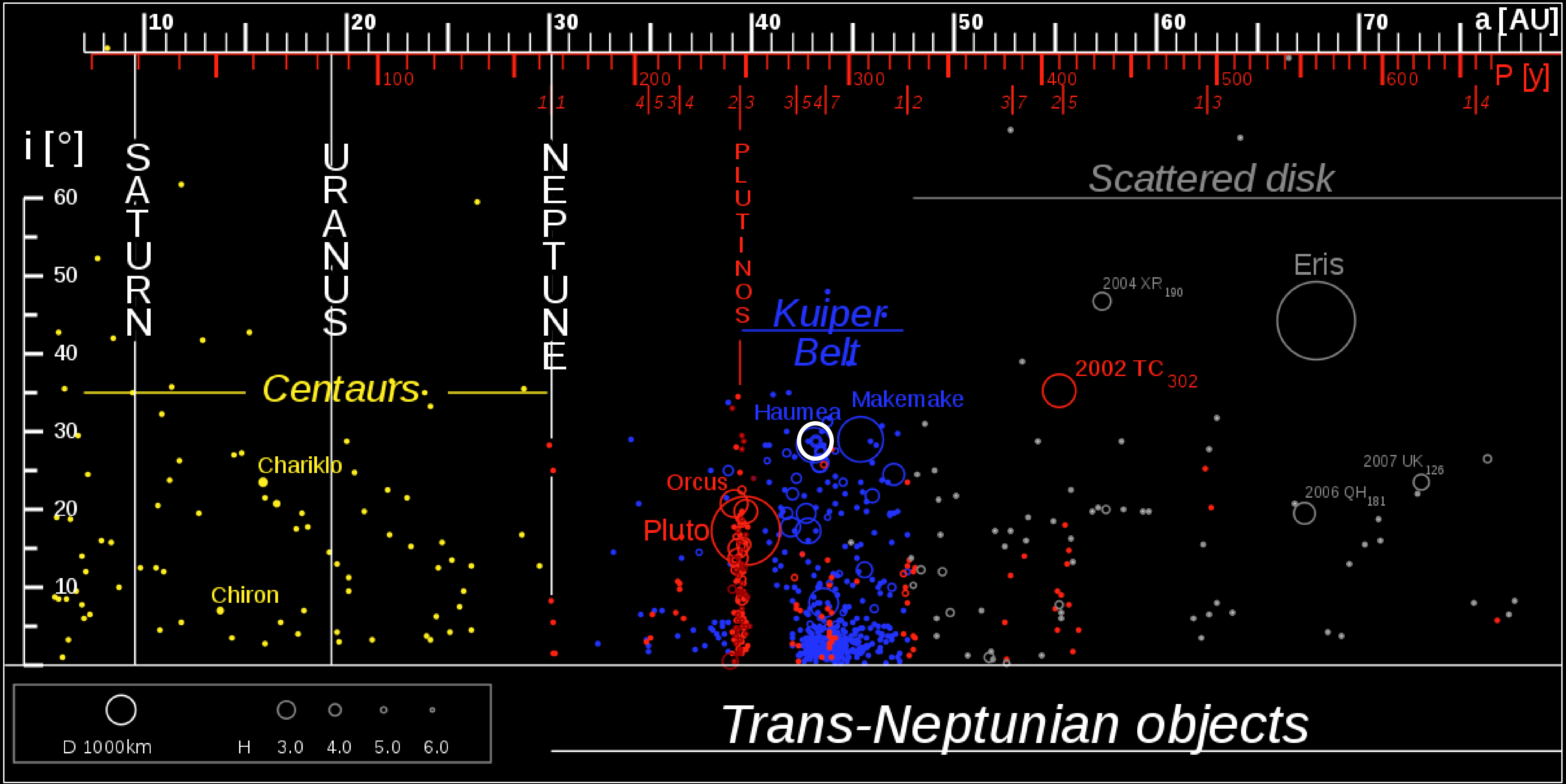
Research Field: Outer Solar System



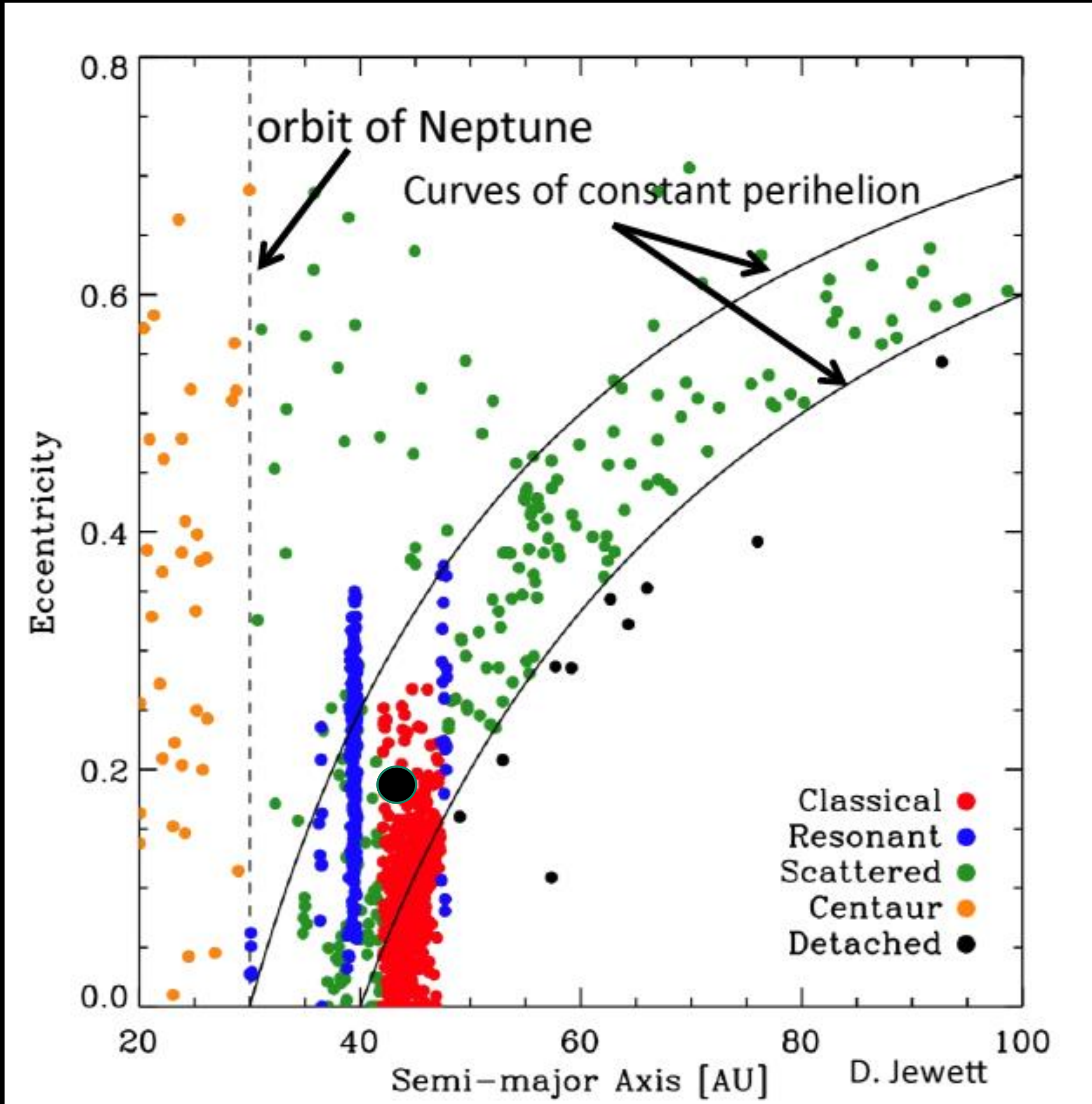
Outer SS: physical parameters + dynamics => SS primordial evolution



The Outer Solar System



The Outer Solar System



per = a (1 – e)

The Outer Solar System – dwarf planets

IAU Resolution - 2006

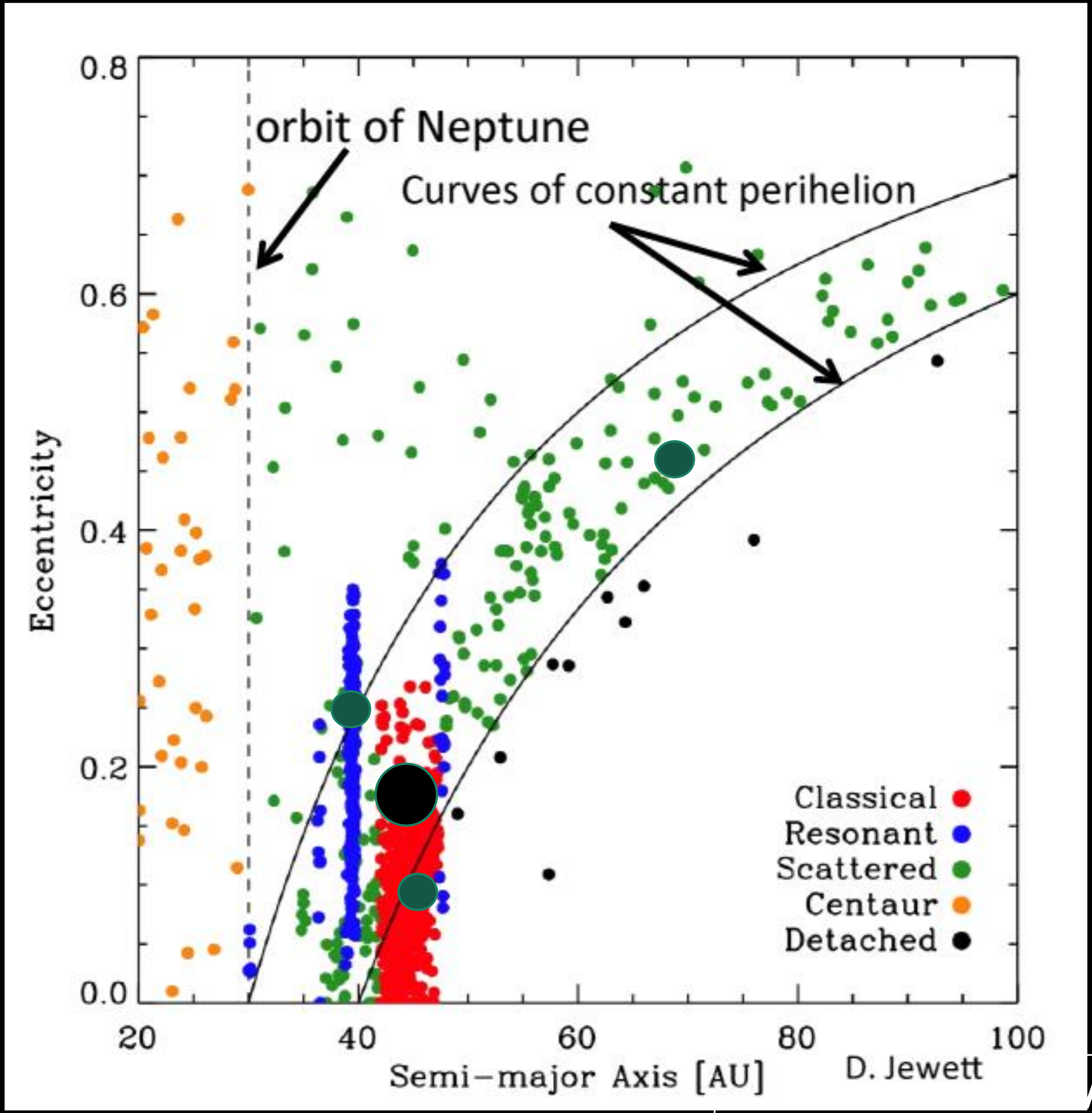
<u>A "dwarf planet" is a celestial body that</u>

(a) is in orbit around the Sun;

(b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape;

(c) has not cleared the neighborhood around its orbit;

(d) is not a satellite.



TNO physical parameters to be determined

size, shape, albedo, color, density, atmosphere, rings, relief

Problems to determine the physical parameters

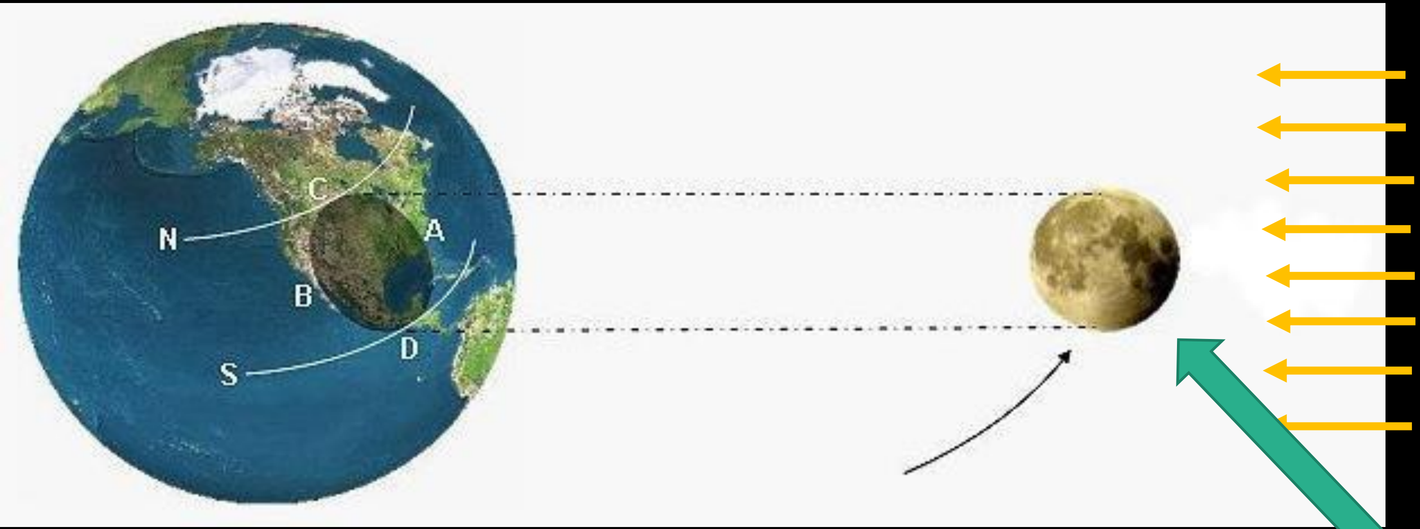
faint objects => determination of parameters is strongly model dependent

small sample => the models are poorly constrained

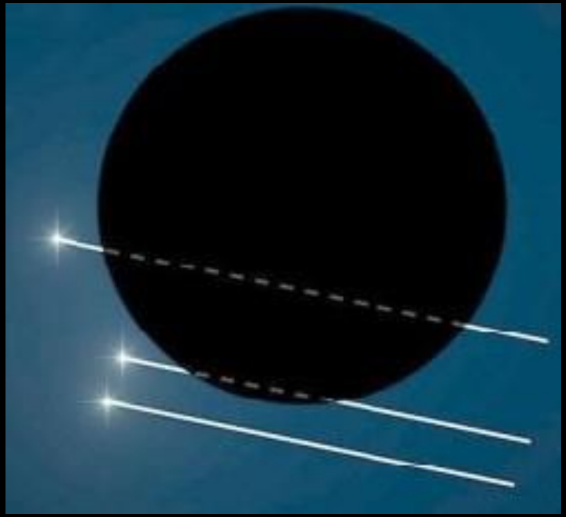
Solution

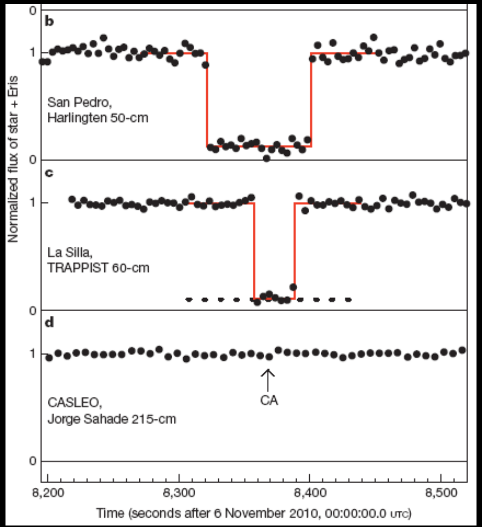
stellar occultation

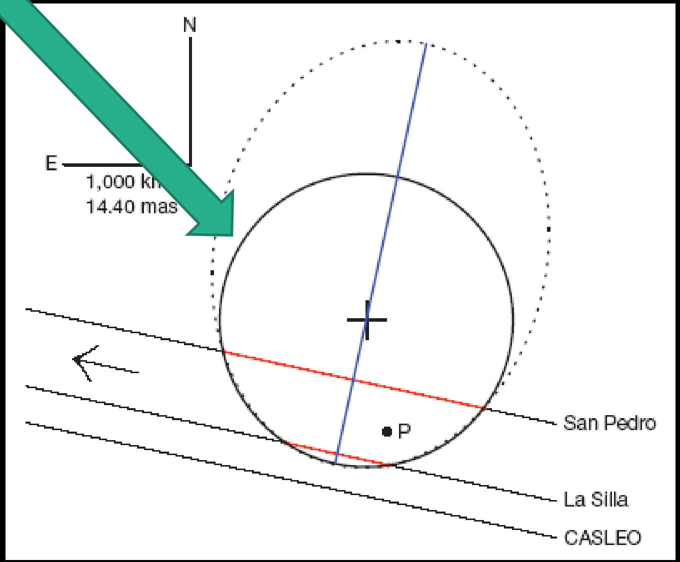
Stellar Occultation Procedure



star light

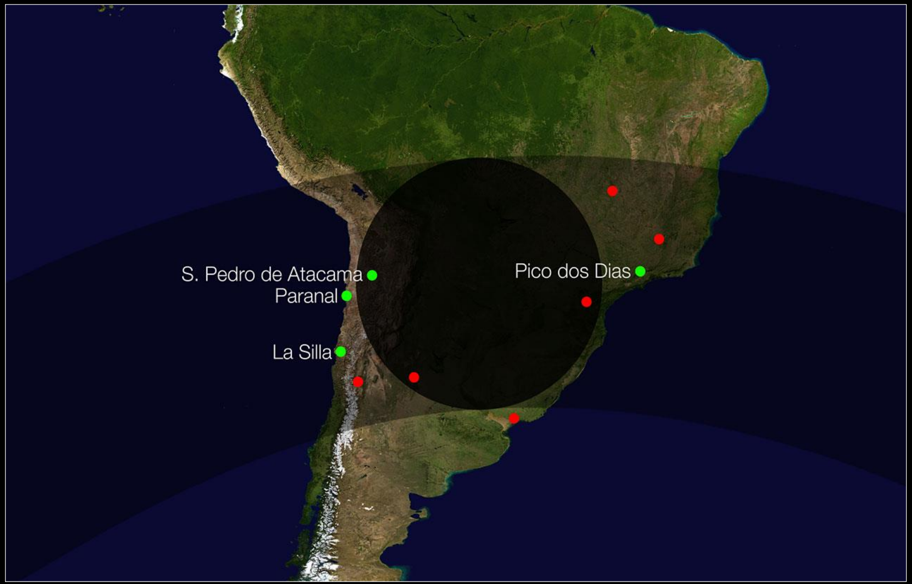






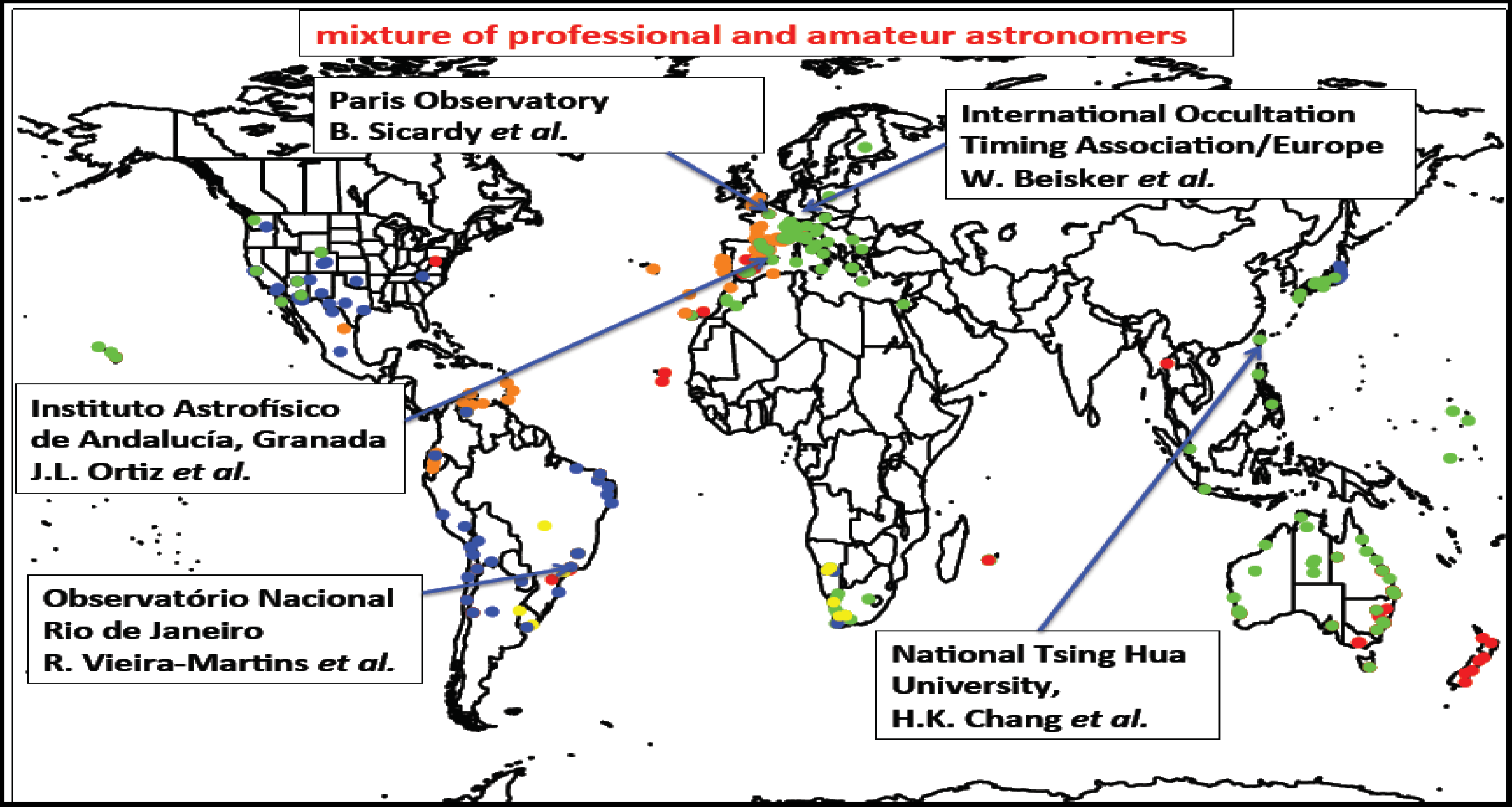
Occultation advantages:

- shadow size = object size
- no dependence on the object’s magnitude
- may be observed with small telescopes
- the spatial resolution comes from the temporal resolution
- observational technique = differential photometry



Occultation disadvantages => Solutions

- few events => observational network
- difficult prediction => GAIA + large surveys (LSST)
- events occur at fixed instants => chance



100 km

HAUMEA

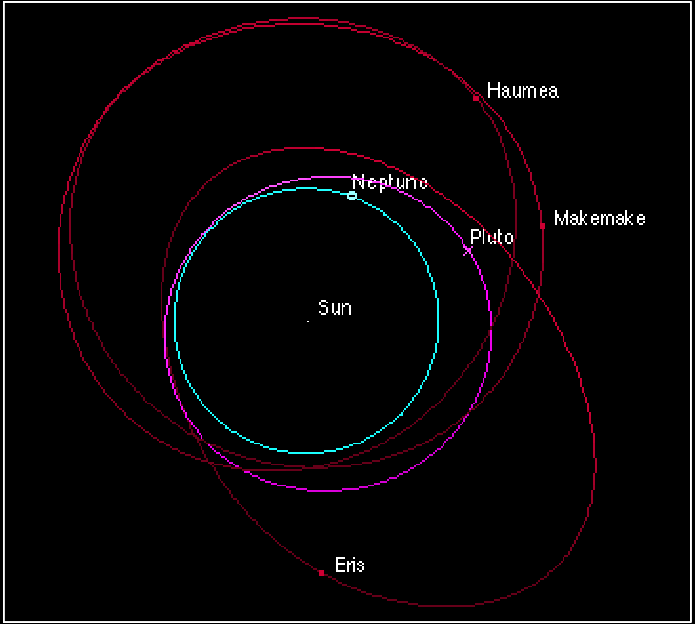
Discovery: 2004 -2005

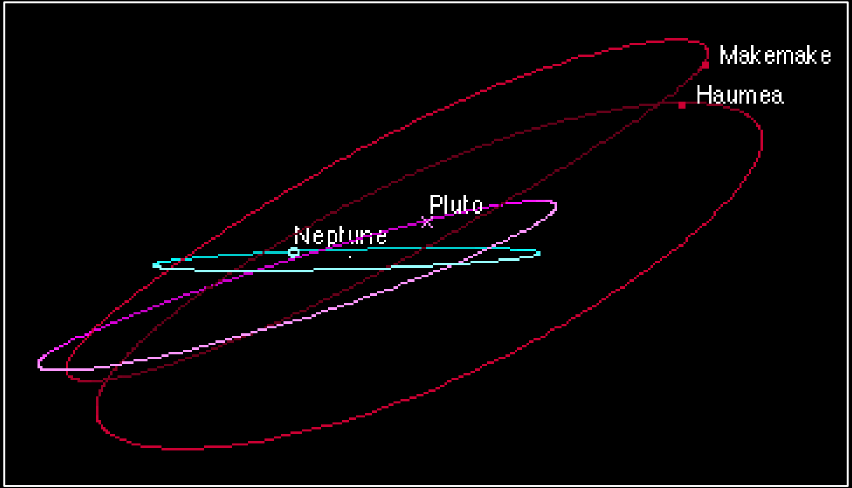
Keck (9m) and Sierra Nevada (1.5m), m_V = 17.5

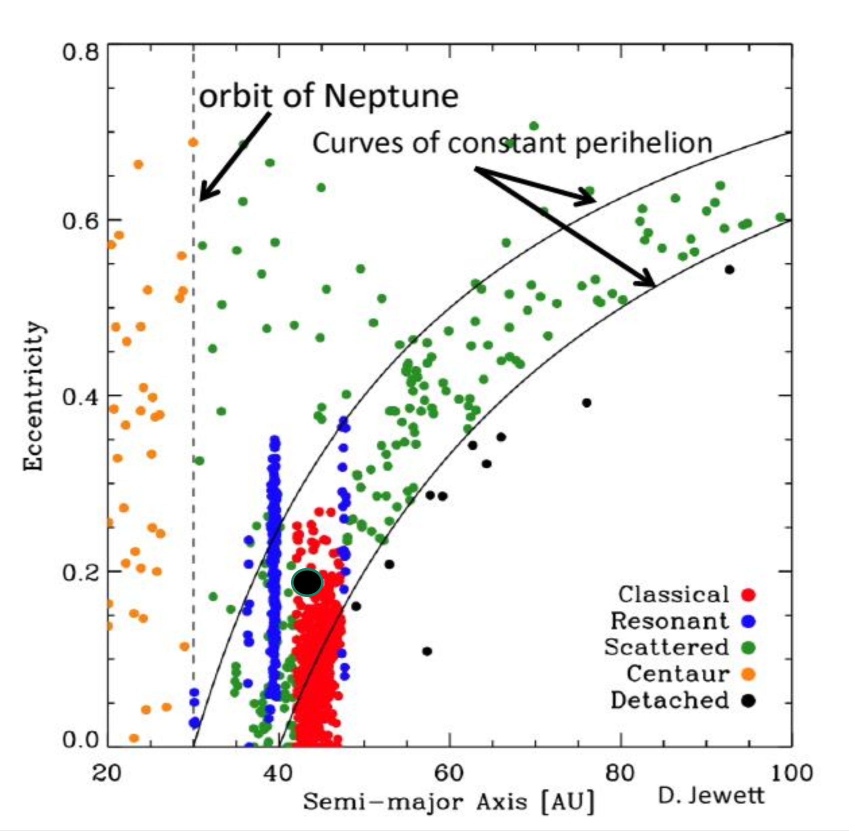
Orbital parameters

a= 34,9 ua e = 0.2, i = 28º , P = 284 years

per. = 35 ua, aph. = 51.5 ua





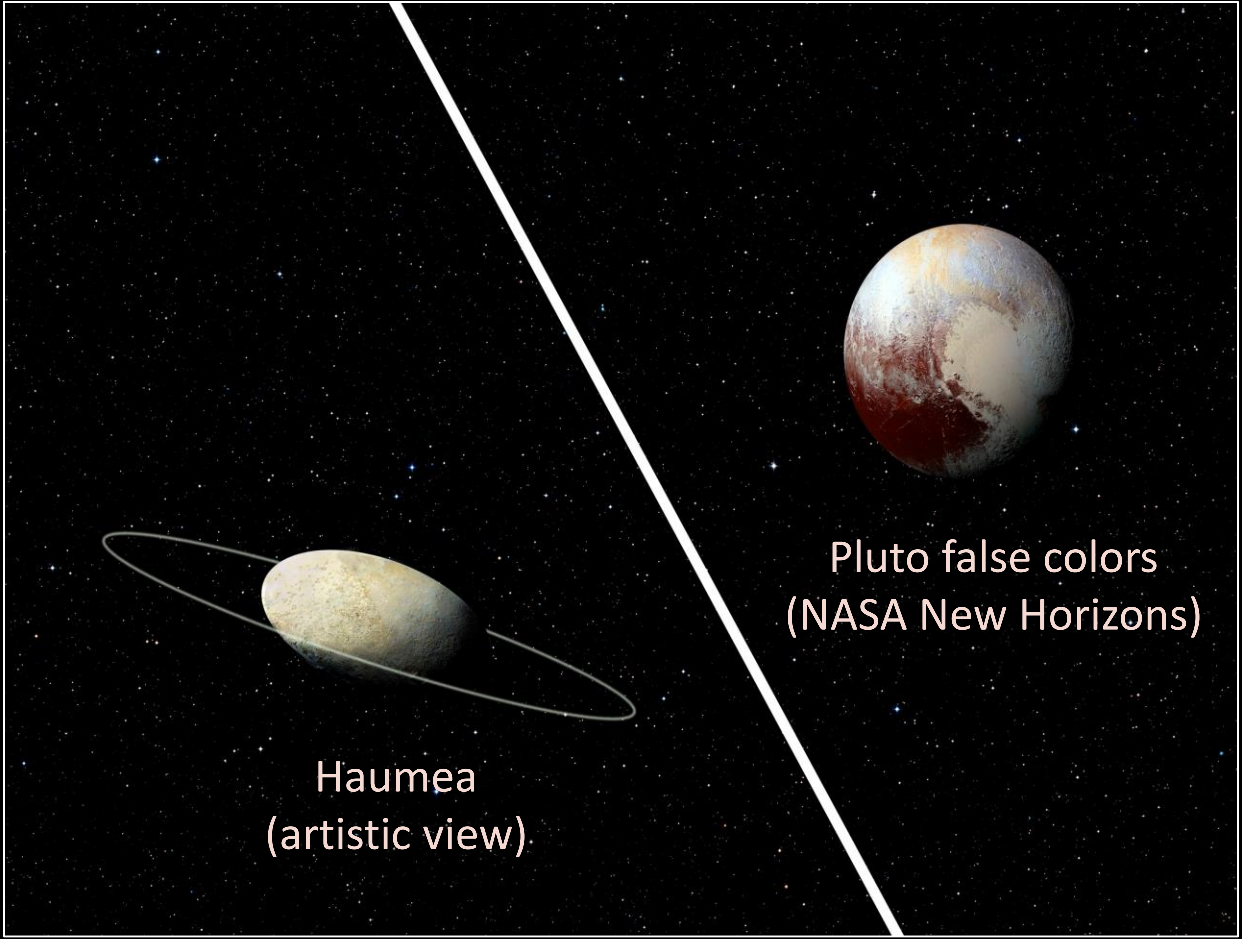


HAUMEA

Physical parameters

Dimensions = 2322 x 1704 x 1026 km
Rotational period = 3.9 hours
Density = 1885 kg/m^3
Albedo = 0.5

Ring
radius = 2 287 km
Width = 70 km
Opacity = 0.5



Artistic view. Credit: A. Crispim, UTFPR-Curitiba

HAUMEA

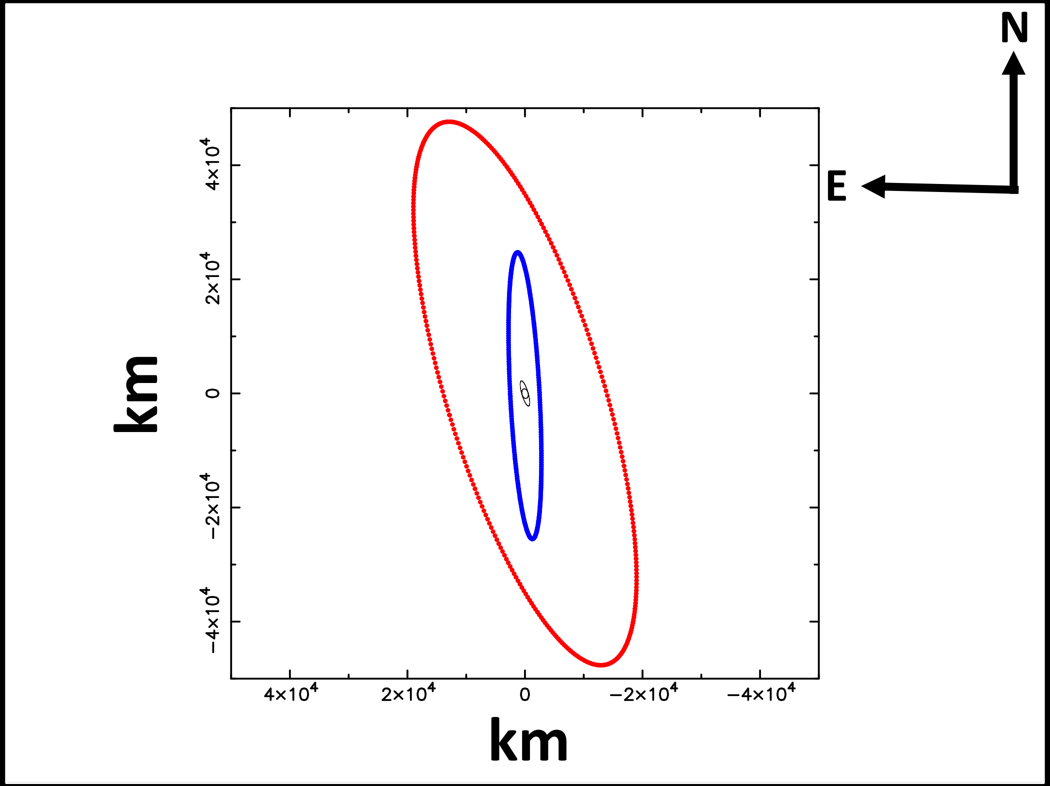
Satellites

Hi'iaka => a = 48 880 km, P = 49.5 days
D = 320 km

Nimaka => a = 25 650 km, P = 18.2 days
D = 160 km

Collisional Family

Haumea + 5 TNOs + 2 satellites



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Haumea Stellar Occultation

Prediction

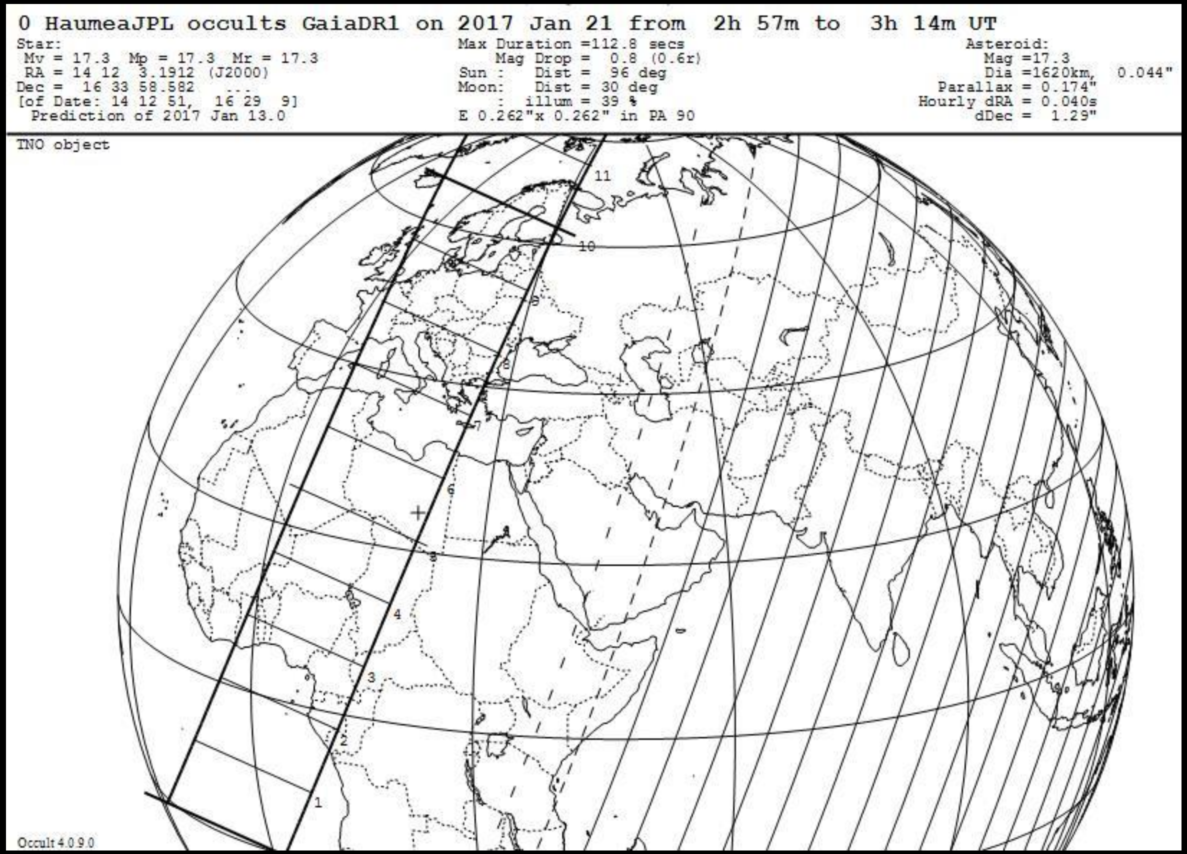
Date: January 21, 2017 – 03:00 UTC

Local: Central Europa

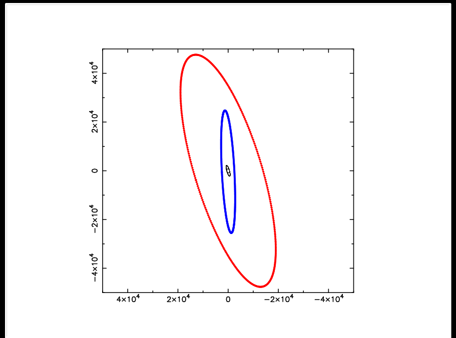
Star magnitude: 18 (V), 15 (J)

Star position: 14h 12m, +16º 33'

Star apparent diameter: 0.007 mas



Haumea Stellar Occultation Prediction

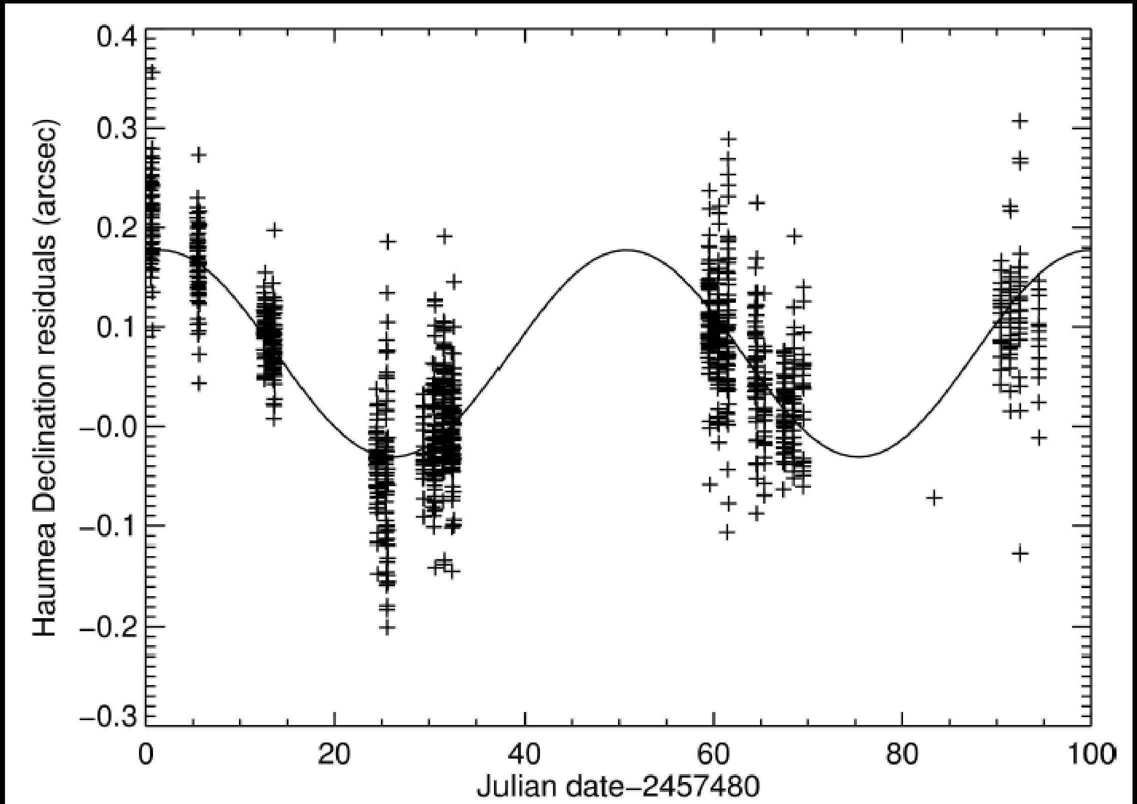


Haumea magnitude : 18.2 (V)

Haumea apparent size: 0.06”

Shadow direction: south to north

Shadow speed: 13.1 km/s



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Haumea Stellar Occultation

Observations

Duration < 2 minutes

Observatories: 10

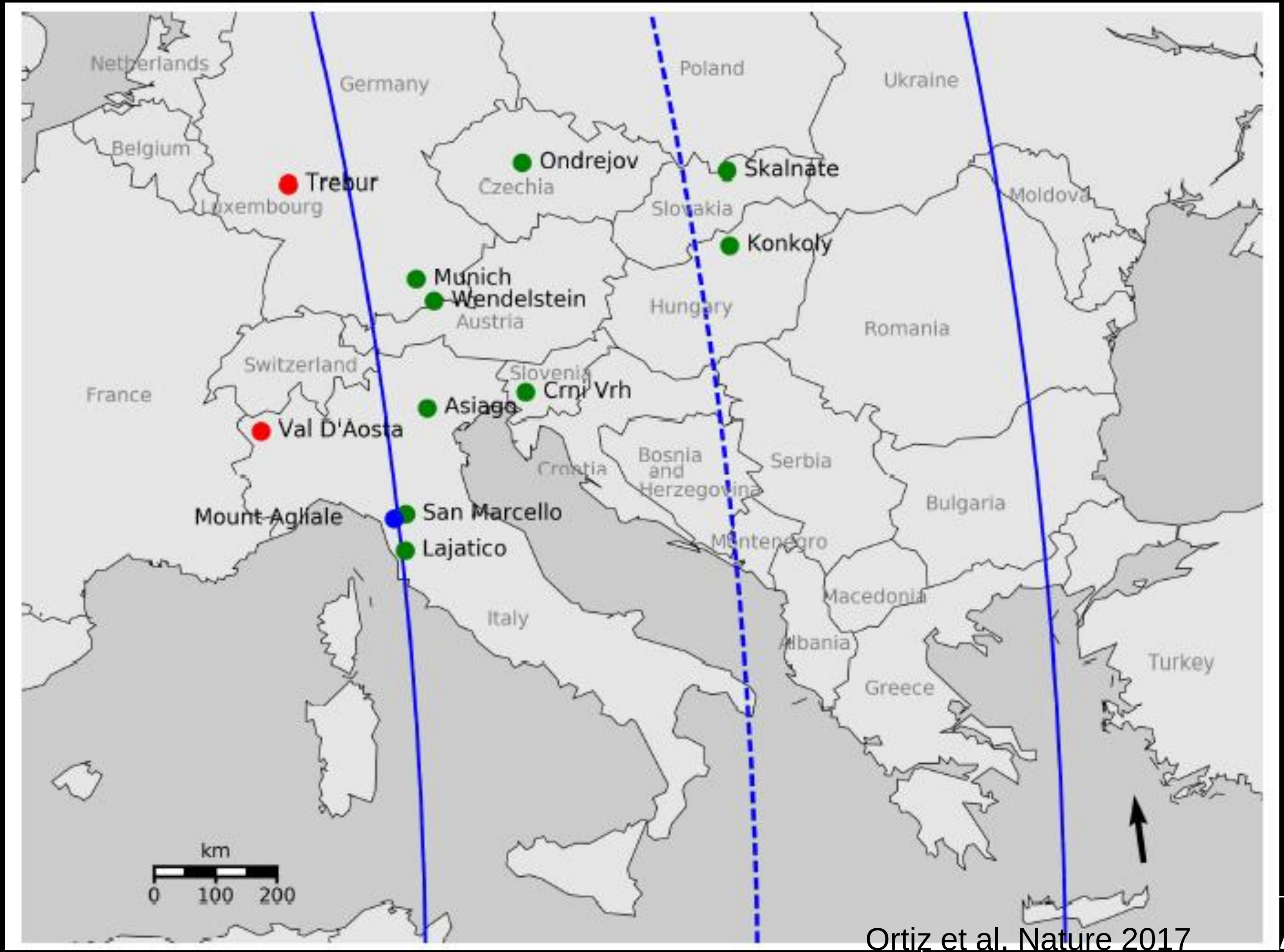
Telescopes: 12

Telescopes diameters:

0.4m to 2.0m

Countries:

Slovakia - 1 (1.3)
Hungary - 2 (1.0, 0.6)
Czech R. - 1 (0.65)
Slovenia - 1 (0.6)
Germany - 3 (2.0, 0.8, 0.4)
Italy - 4 (1.8, 0.6, 0.5, 0.5)



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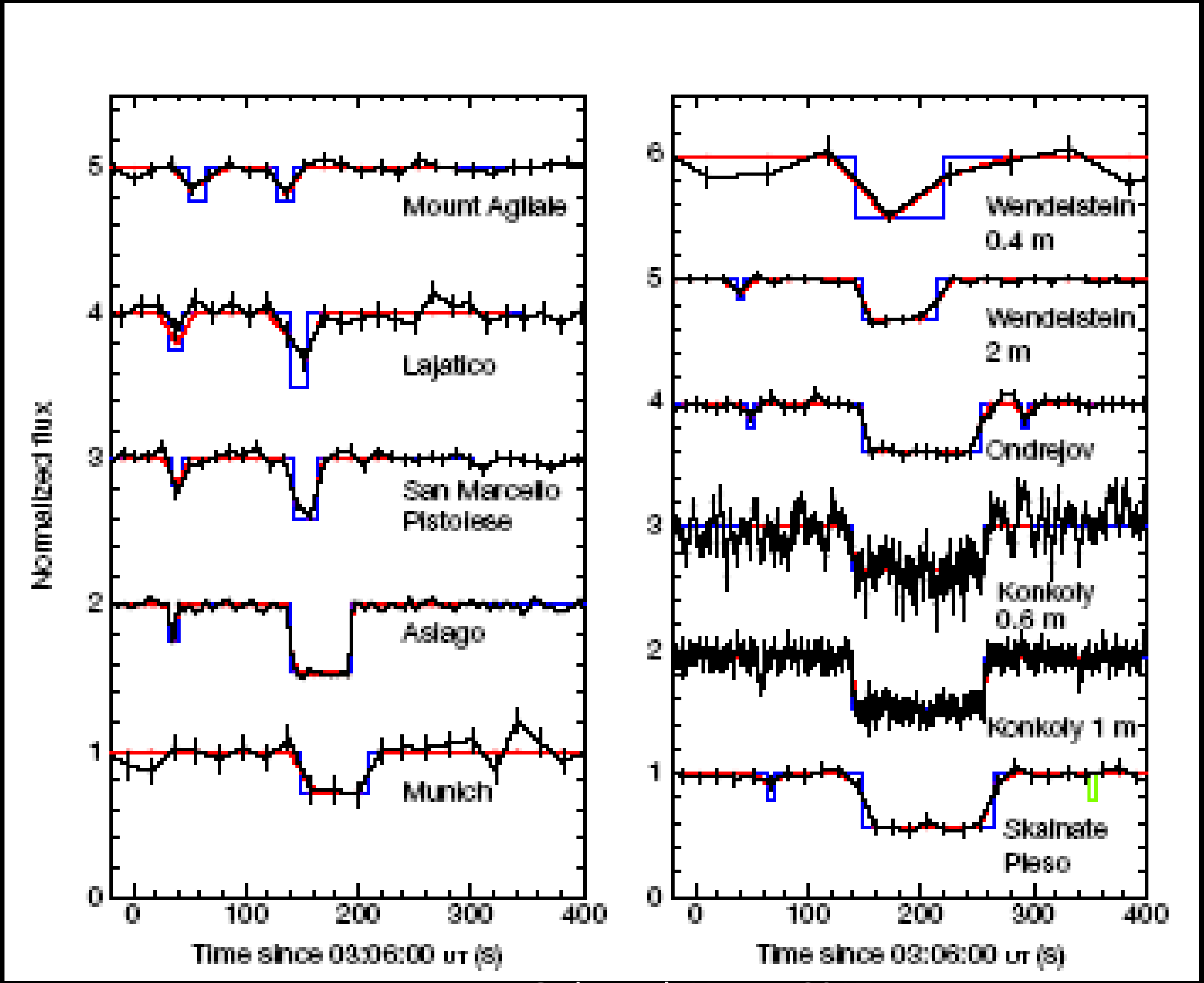
Haumea Stellar Occultation

Reduction



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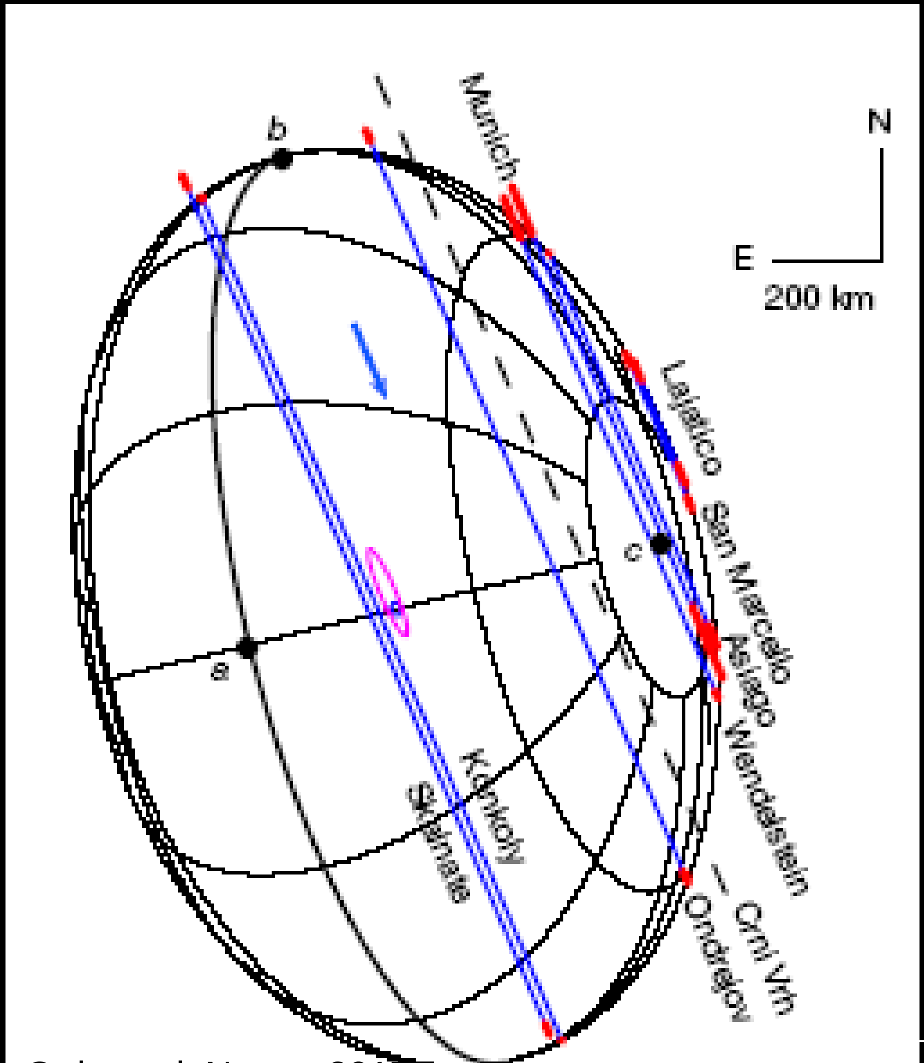

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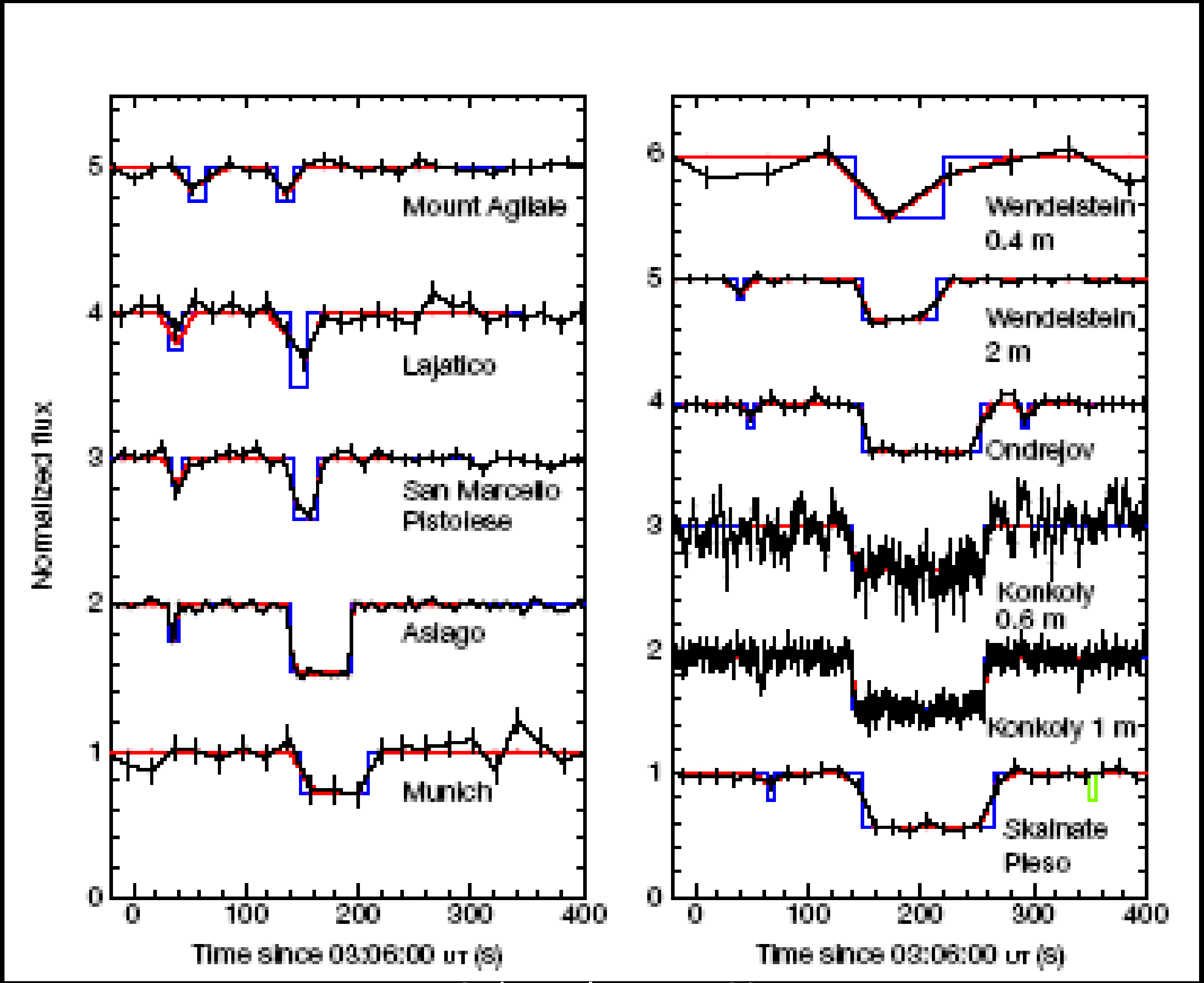
Haumea Stellar Occultation Reduction



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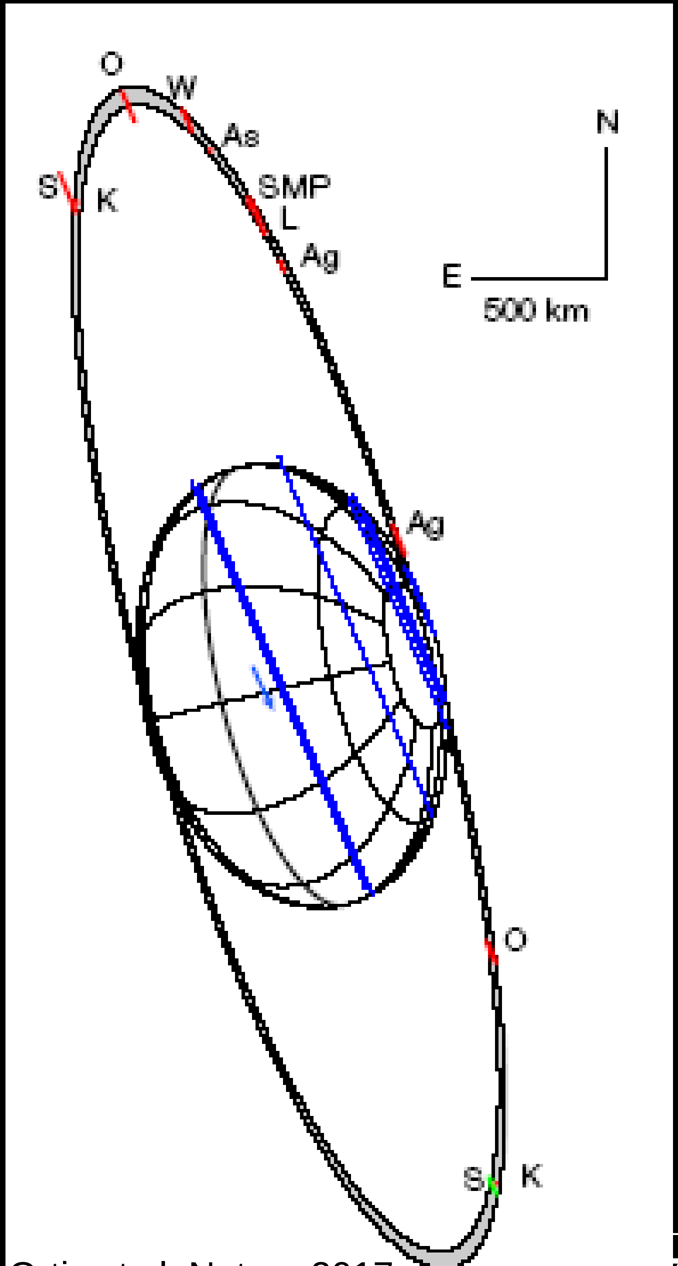

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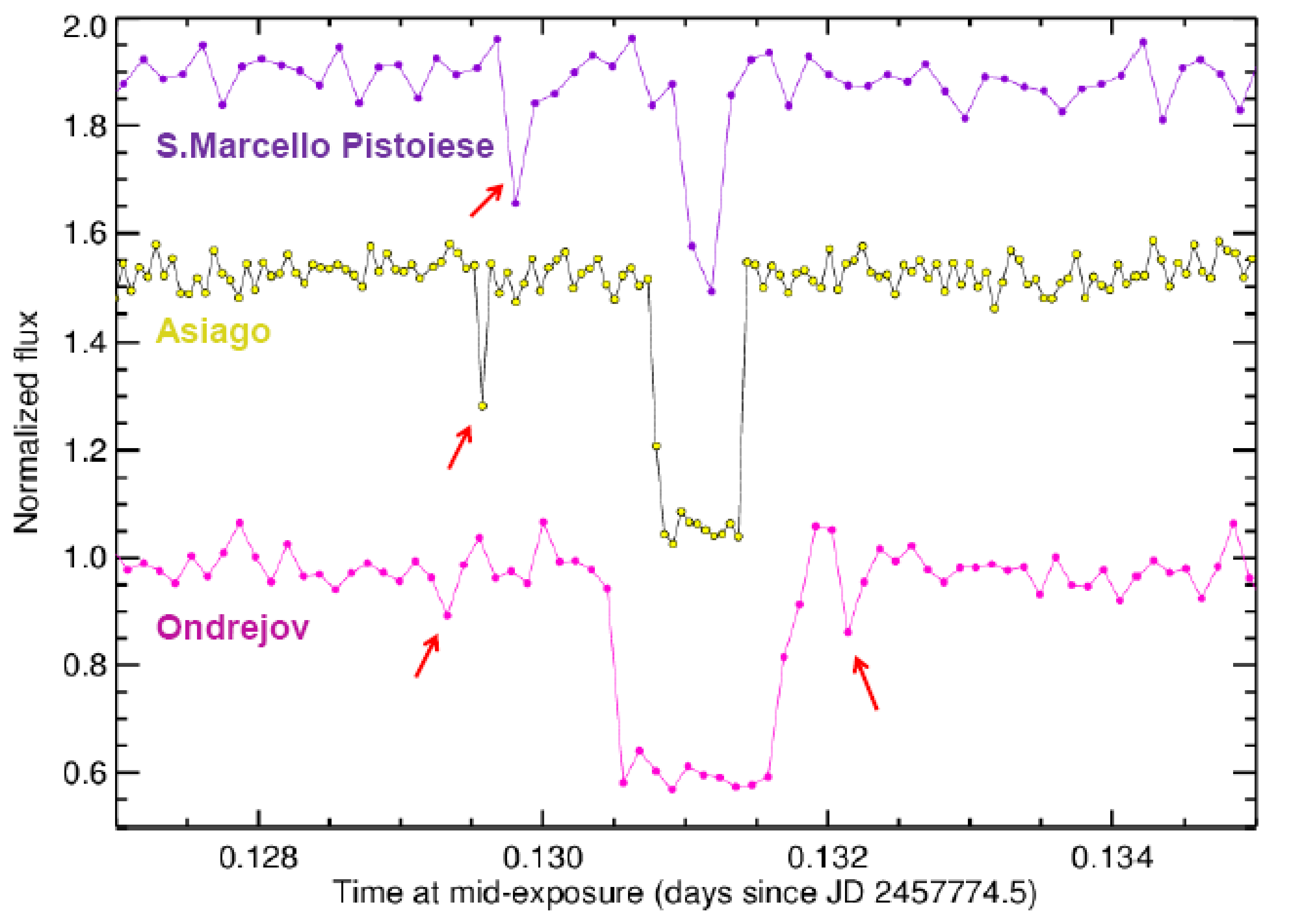
Haumea Stellar Occultation Reduction



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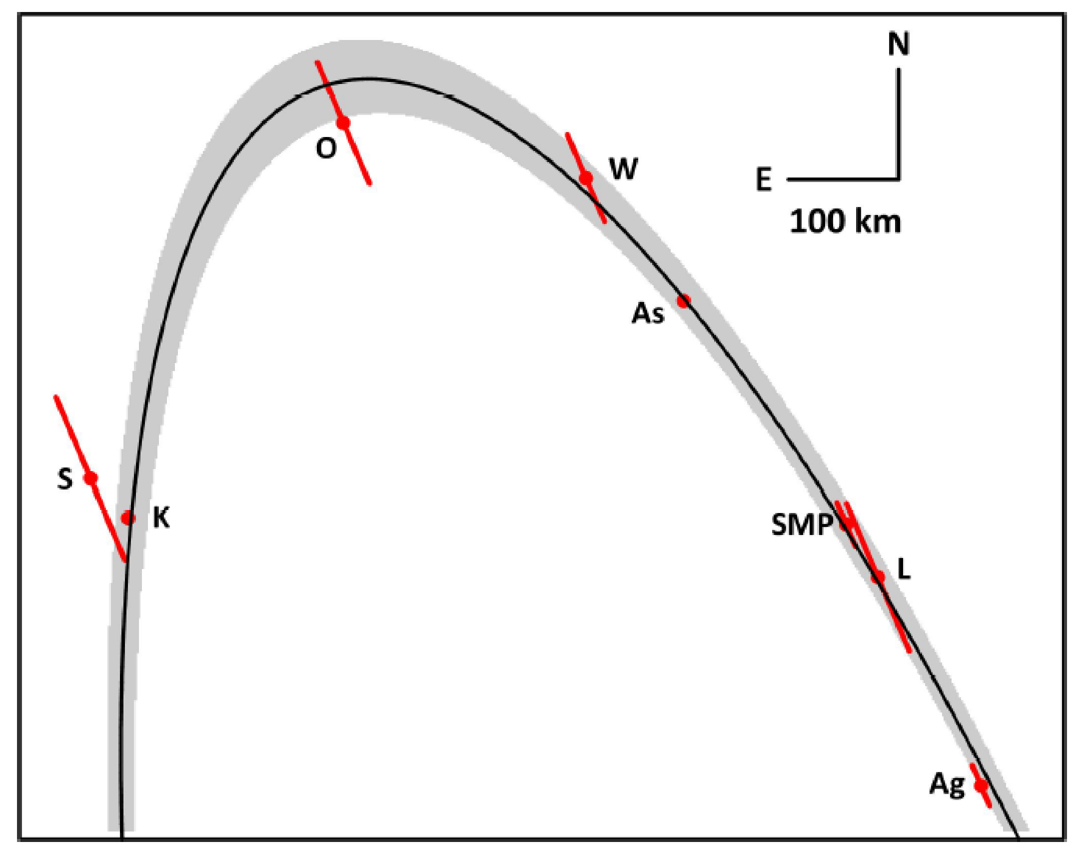


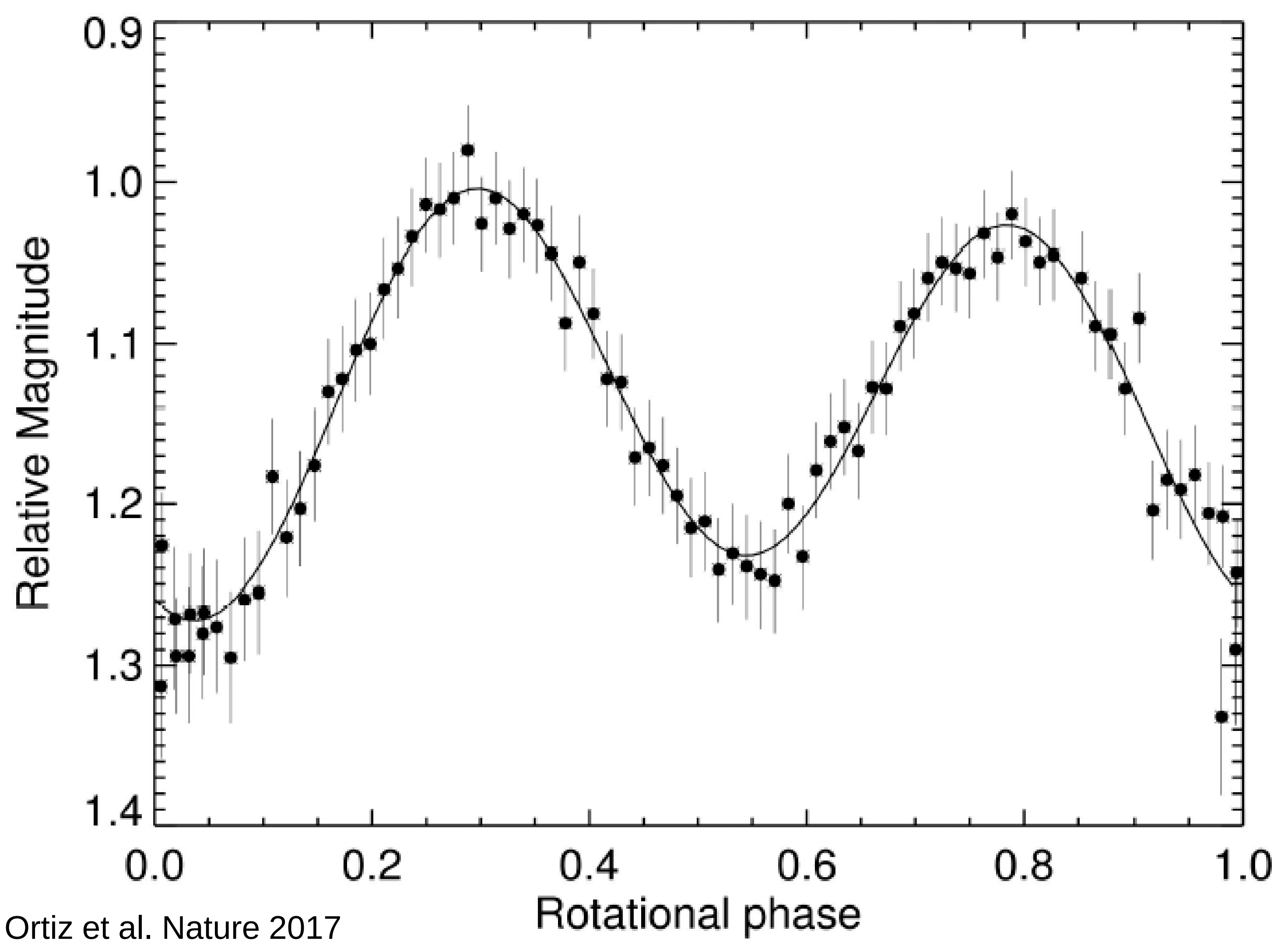
Ortiz et al. Nature 2017

Haumea Stellar Occultation

Reduction

Rotational light curve obtained 2 days after the occultation with the Valle D'Aosta 0.81m telescope.

The zero phase correspond to the time of occultation.



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Haumea Stellar Occultation

Results - Haumea

Haumea's projected limb
1704 ± 4 km x 1138 ± 26 km

Angle = -76.3º ± 1.2º

Albedo (V)= 0.51 ± 0.02

Haumea's 3D shape (km)
2322 ± 60 x 1704 ± 8 x 1026 ±32

Diameter (equivalent volume) = 1595 ± 11 km

Density = 1885 ± 80 kg/m^3

Artistic view. Credit: A. Crispim, UTFPR-Curitiba

Haumea Stellar Occultation

Results - Ring

Narrow and dense ring

R = 2287 (+75, -45) km
<< the Roche limit of a fluid satellite

Opacity = 0.5

Circular and Equatorial ring (assumed)

Close to the 3:1 spin-orbit resonance

Artistic view. Credit: A. Crispim, UTFPR-Curitiba

Haumea Stellar Occultation

Results - Haumea

Before occultation	After occultation
Haumea's 3D shape (km)	
1920 x 1540 x 990	2322 ± 60 x 1704 ± 8 x 1026 ±32
Diameter (equivalent volume) (km)	
1430	1595 ± 11
Density (kg/ m^3)	
2530	1885 ± 80
Albedo	
0.8	0.51 ± 0.02

Haumea Stellar Occultation

Results - Haumea

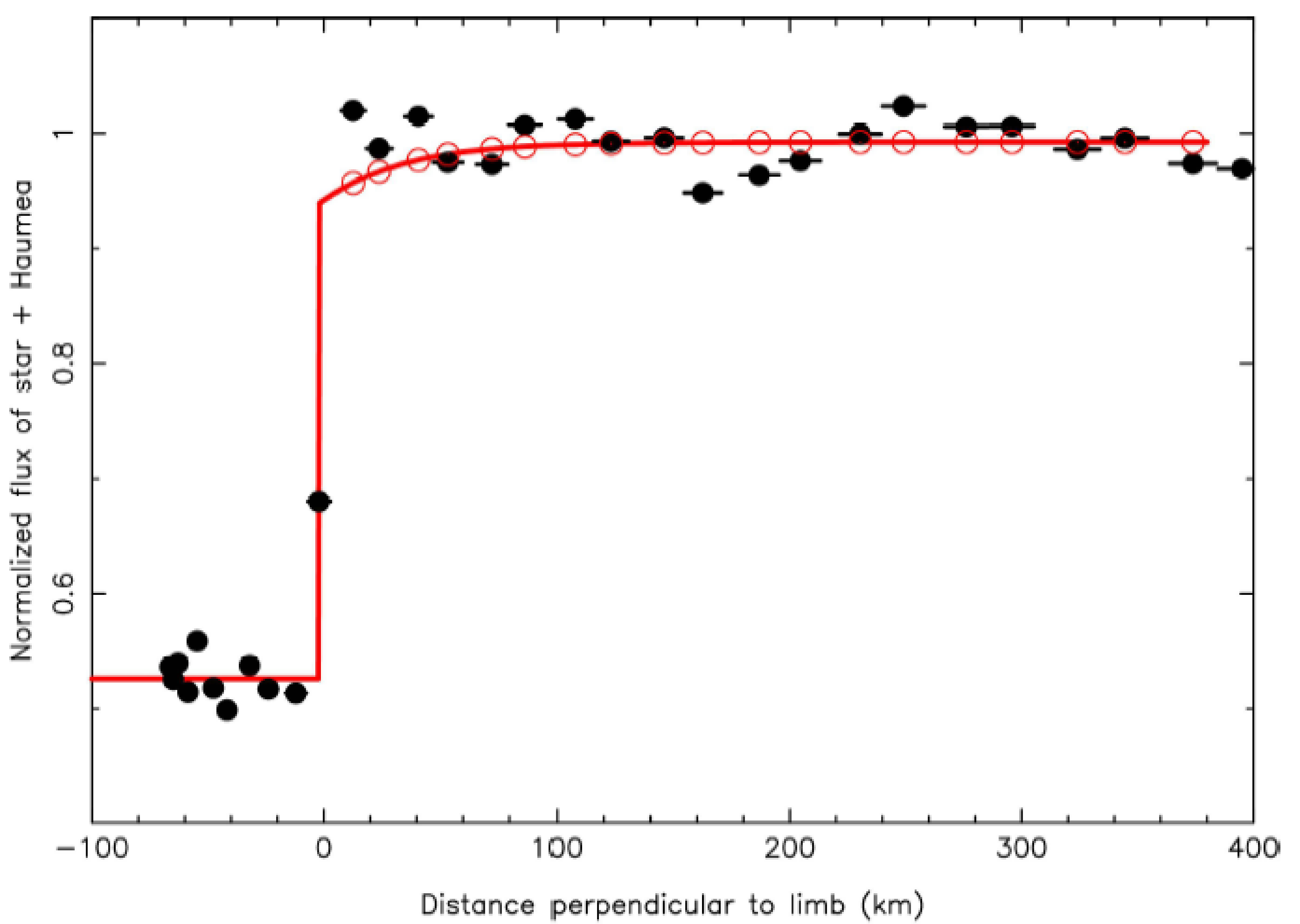
Change in:

3D shape	=>	inconsistent with a homogeneous body in hydrostatic equilibrium (dwarf-planet???)
Density	=>	it is non-homogeneous or granular
Albedo	=>	the non-icy on the surface can be much large than proposed previously.

Haumea Stellar Occultation

Results - Haumea

No global Pluto-like atmosphere detected.



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Haumea Stellar Occultation

Results - Ring

Narrow and dense ring

R = 2287 (+75, -45) km
<< the Roche limit of a fluid satellite (4.400 km)

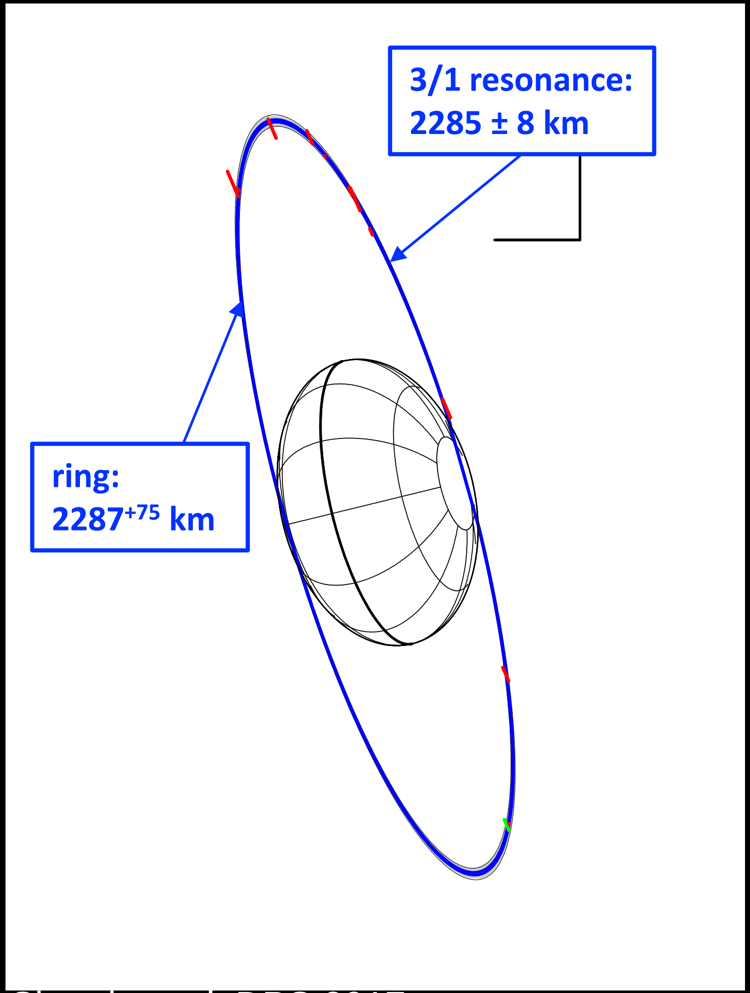
Opacity = 0.5

Circular and Equatorial ring (assumed)

Close to the 3:1 spin-orbit resonance

Stability : may depend on the Haumea internal structure

Origin: related to a catastrophic impact



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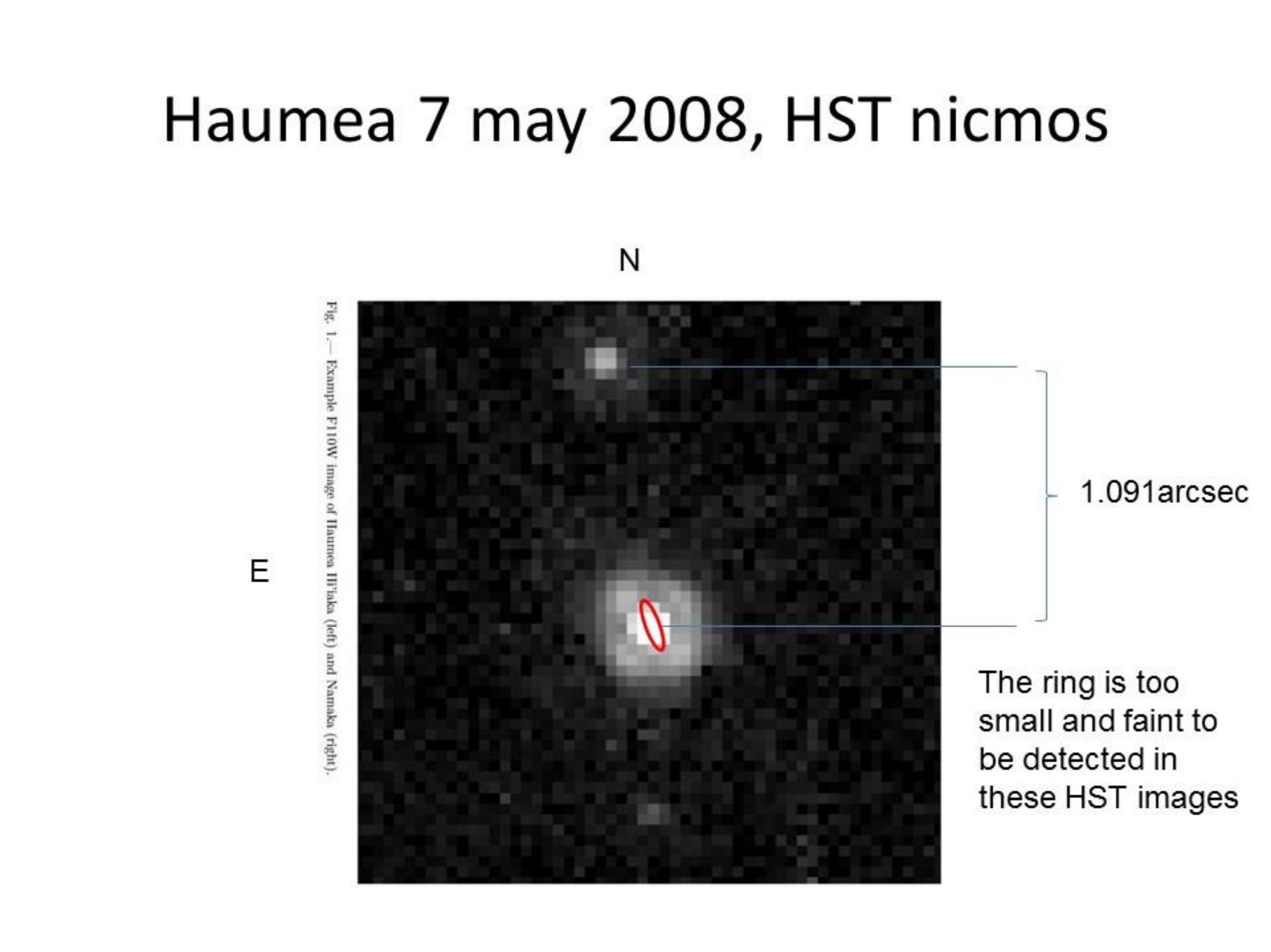
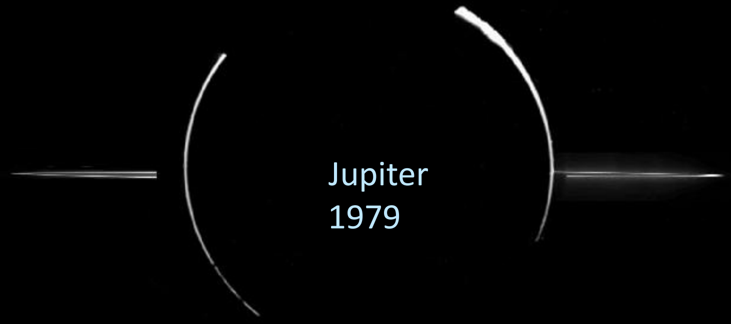
Haumea Stellar Occultation

Future

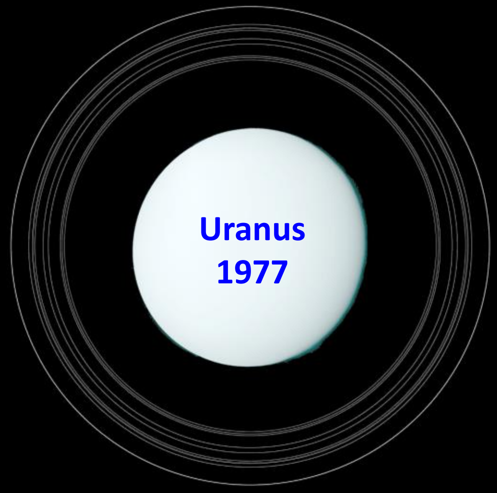


New Haumea stellar occutations

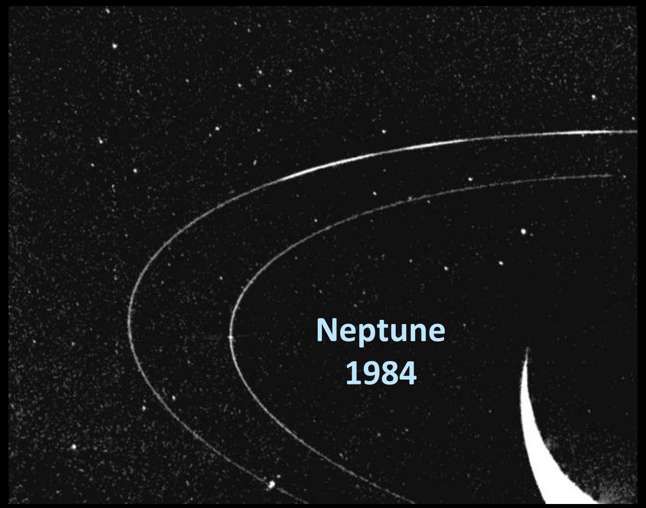
Rings in the Solar System



Haumea 2017



Voyager Image of Uranus Copyright © 2004 Calvin J. Hamilton



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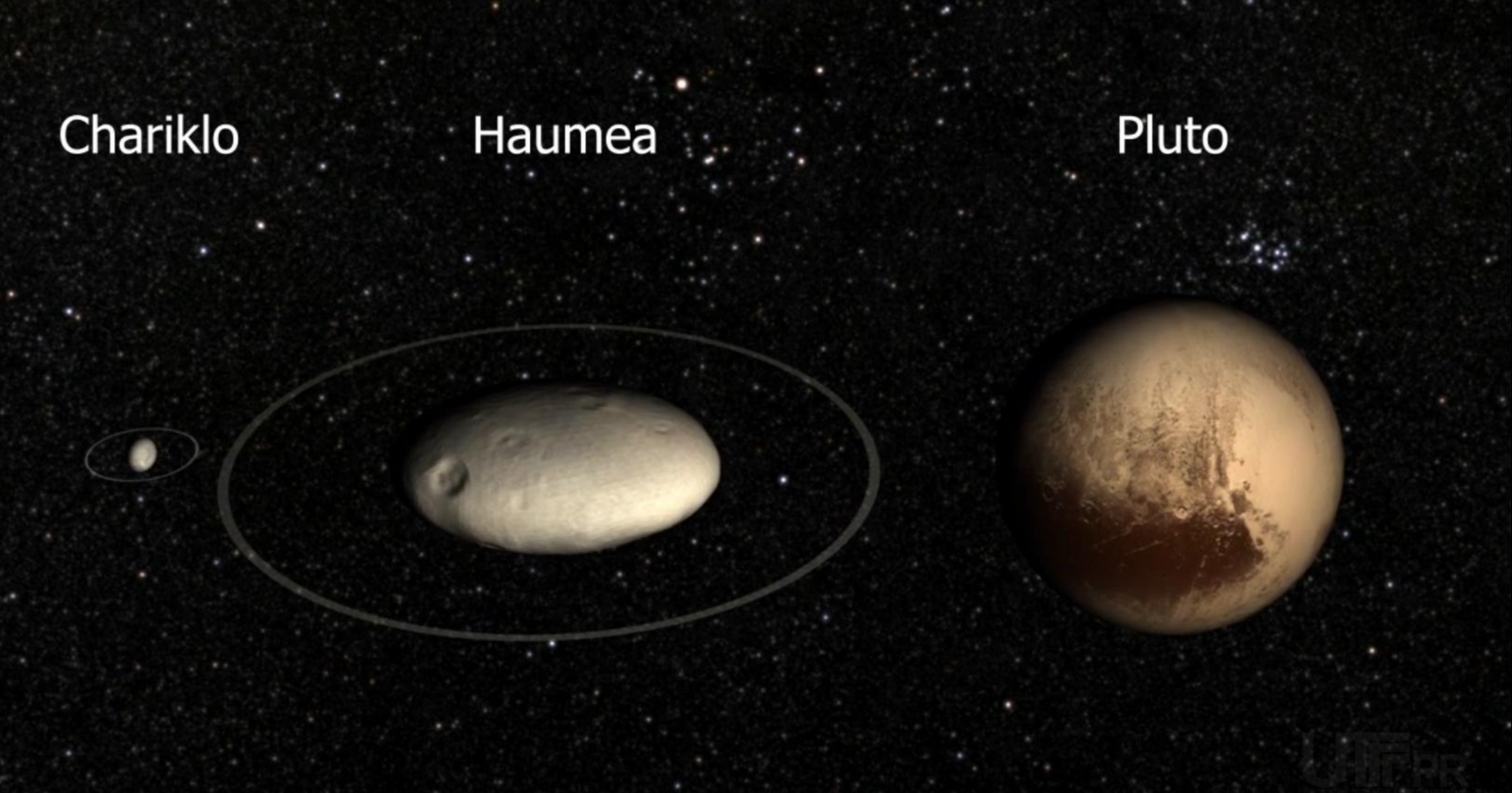
Chariklo 2013



Artistic view. Credit: A. Crispim, UTFPR-Curitiba

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