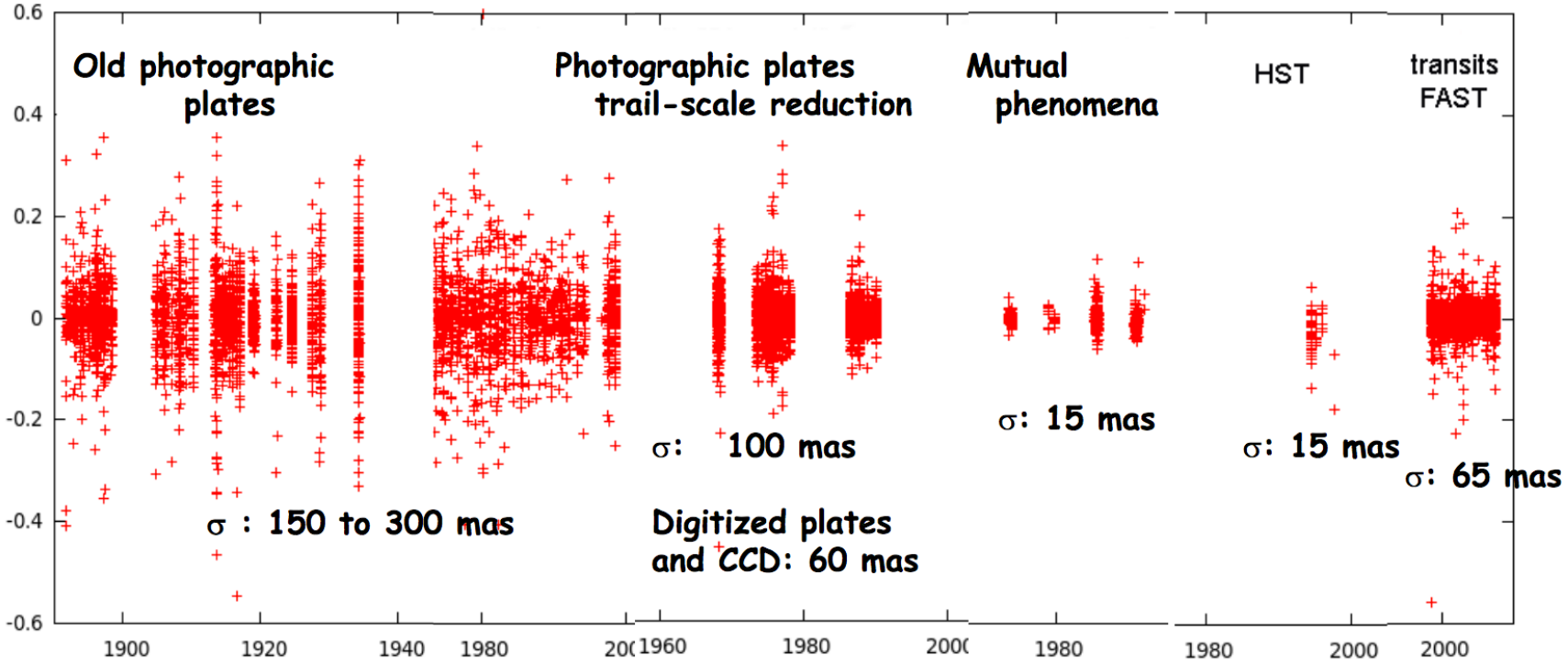
Occultations par des satellites naturels (et autres)

Josselin Desmars

IPSA/IMCCE/Obs.Paris

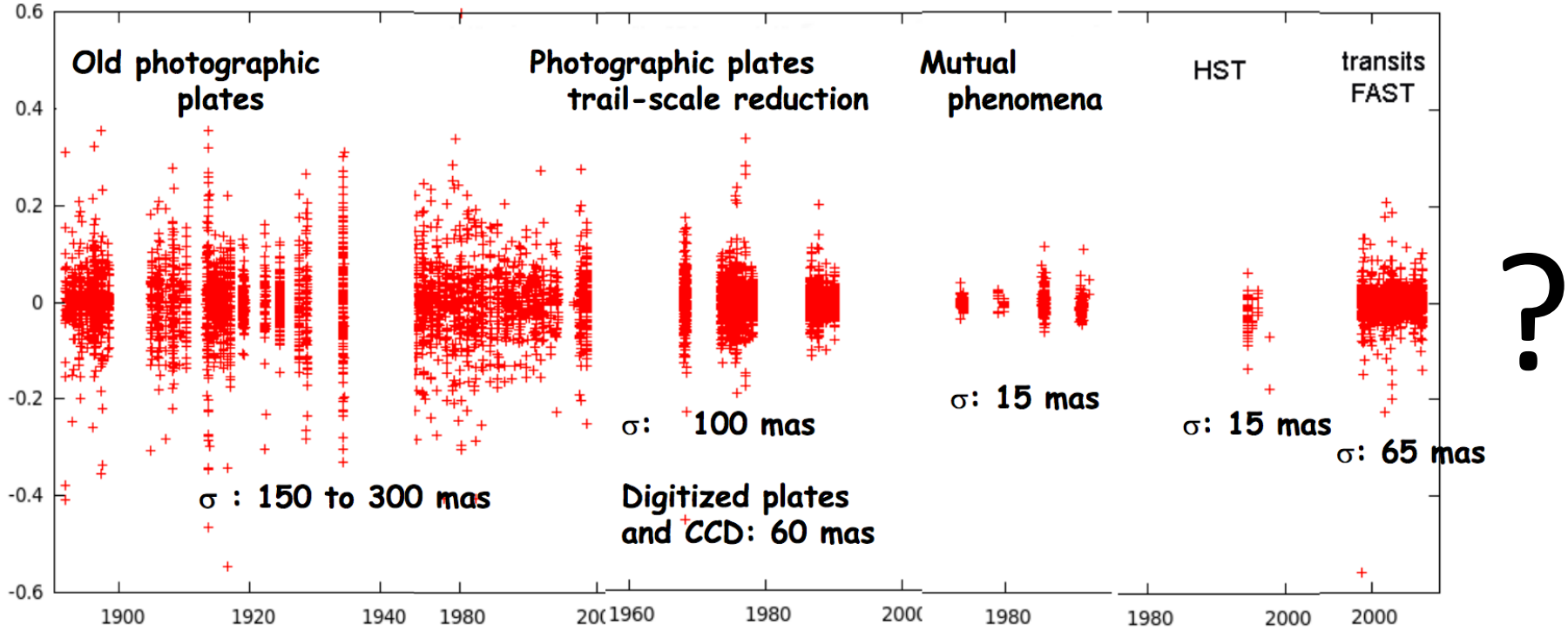
Atelier Phesat (2024.03.16)

Astrométrie pour les satellites naturels



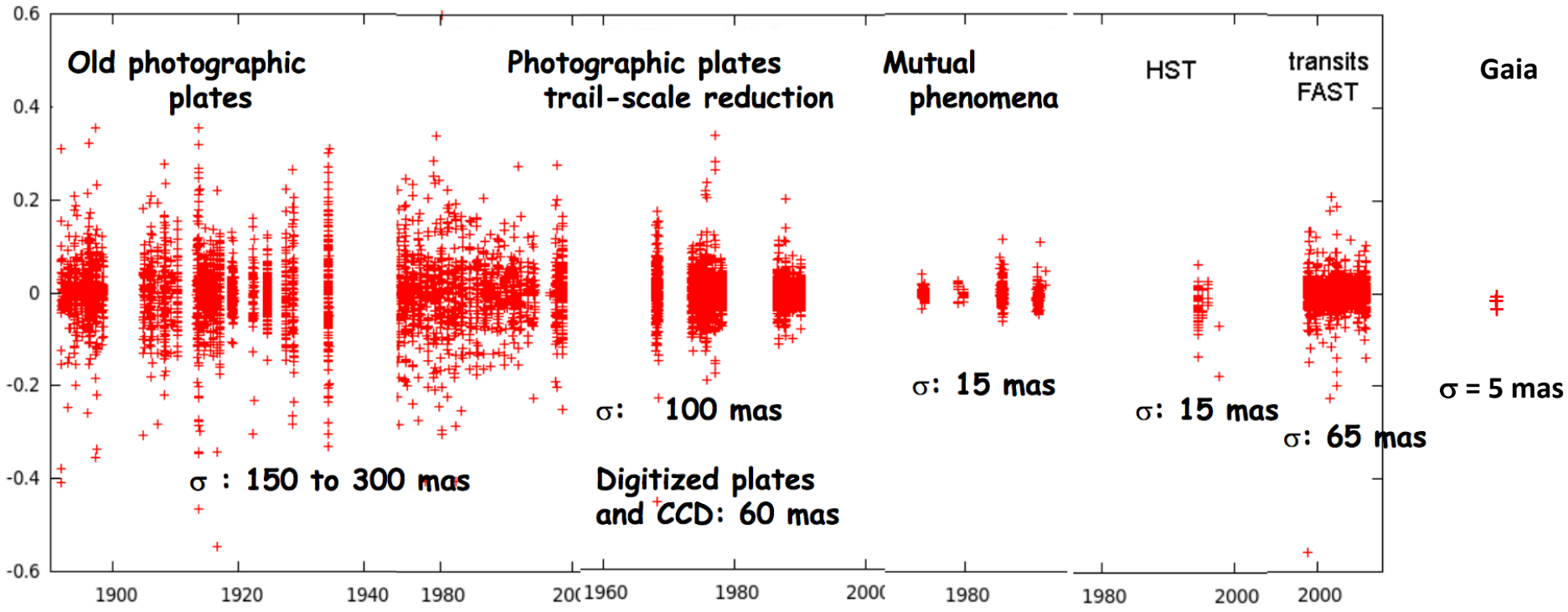
Précision des différentes sources d'observations astrométriques de satellites naturels (source: JEA)

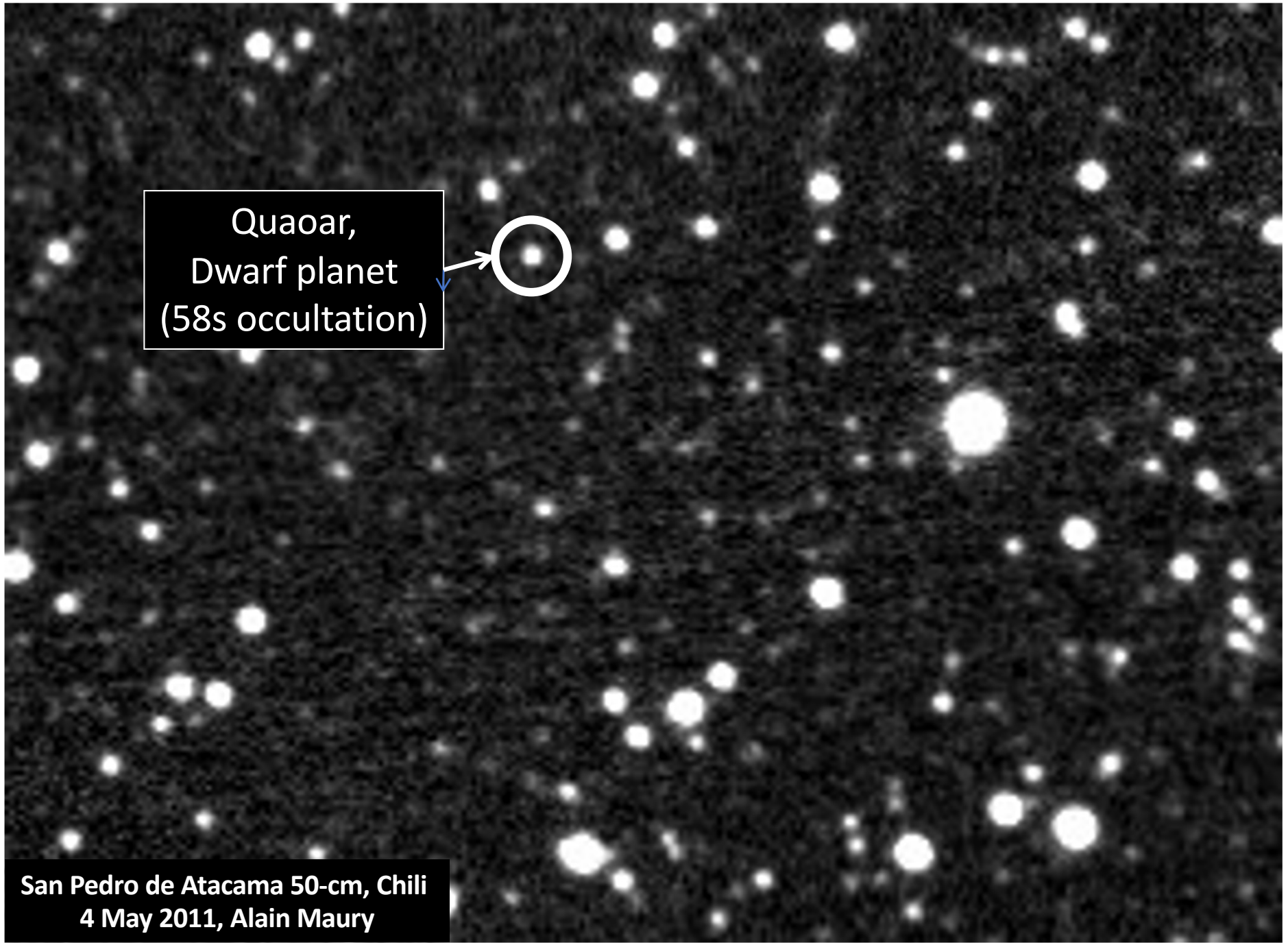
Astrométrie pour les satellites naturels



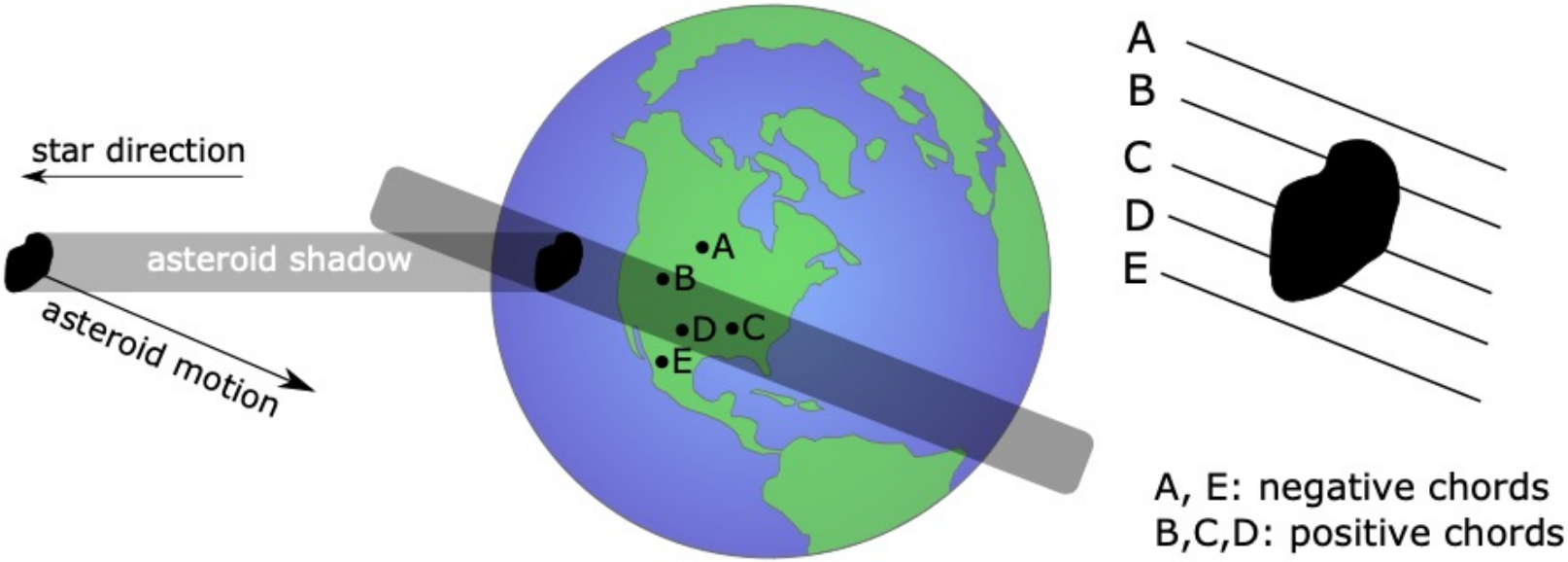
Précision des différentes sources d'observations astrométriques de satellites naturels (source: JEA)

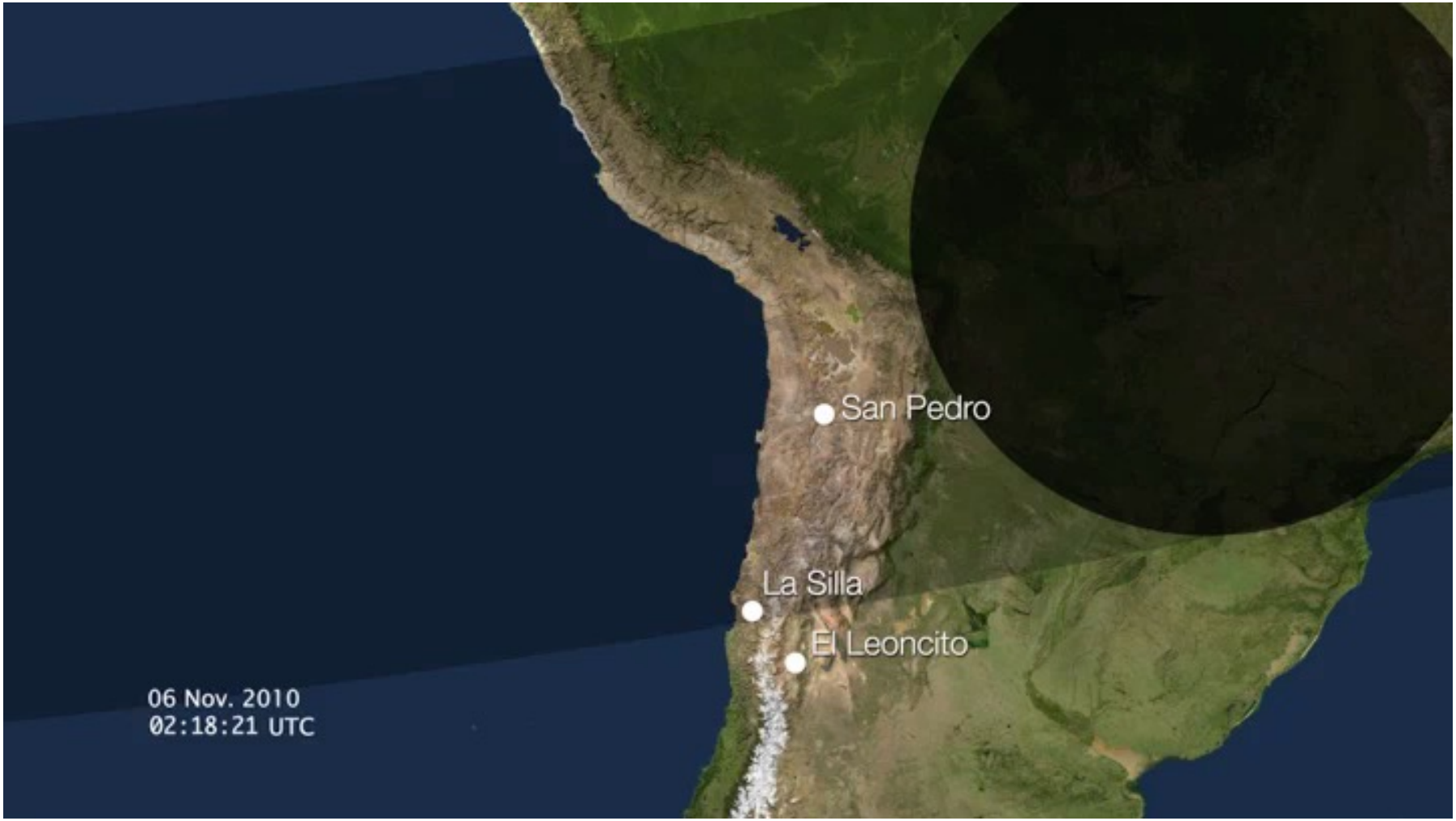
Astrométrie pour les satellites naturels




Quaoar,
Dwarf planet
(58s occultation)
San Pedro de Atacama 50-cm, Chili
4 May 2011, Alain Maury

Occultations

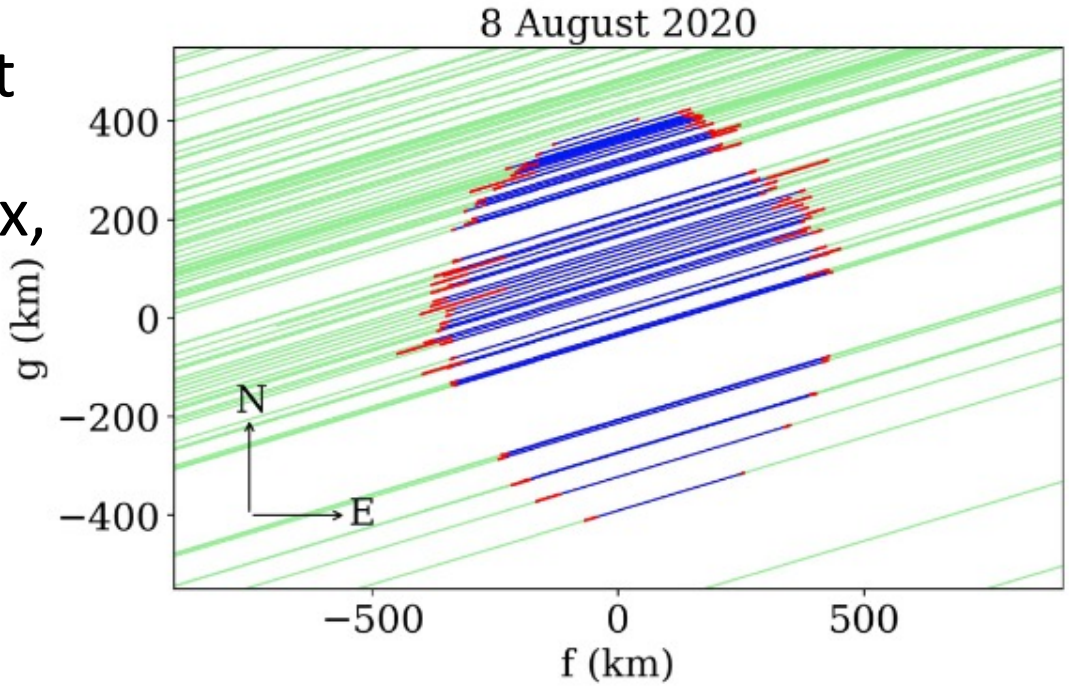



San Pedro
La Silla
El Leoncito
06 Nov. 2010
02:18:21 UTC


San Pedro
La Silla
06 Nov. 2010
02:18:21 UTC

Astrométrie des occultations

- Les occultations fournissent des détails précis sur la forme, la taille, des anneaux, l'atmosphère, etc.
- Elles fournissent aussi une position relative entre l'étoile et l'objet à l'instant de l'occultation
- Grâce à Gaia, la position de l'étoile est connue à 0.1 mas près donnant une précision extreme sur la position de l'objet



Rommel *et al. AA* (2023)

Astrométrie des occultations

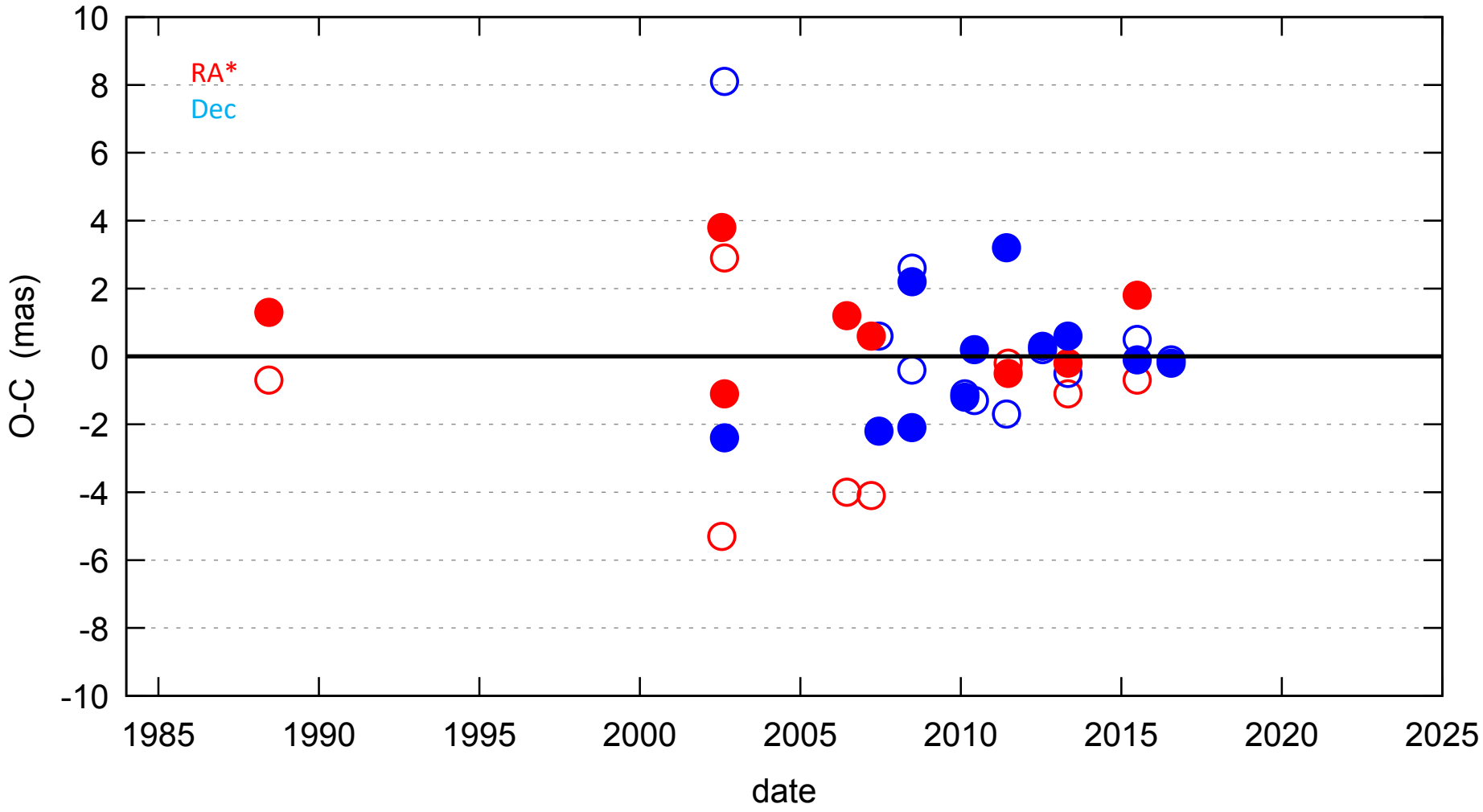
La précision de la position astrométrique dépend de :

- La précision astrométrique de l'étoile occultée (~0.1 mas avec Gaia DR3, 2 mas pour 1980s)
- La précision de la datation (de 0.1s à 1s, … 10s)
- La précision de la réduction et de la reconstruction géométrique (qqs kms -> qqs mas pour des multi-cordes, qqs dizaines de km -> ~10mas pour corde unique)

- **Conclusion** : occultation multi-cordes & recent : 1-2 mas

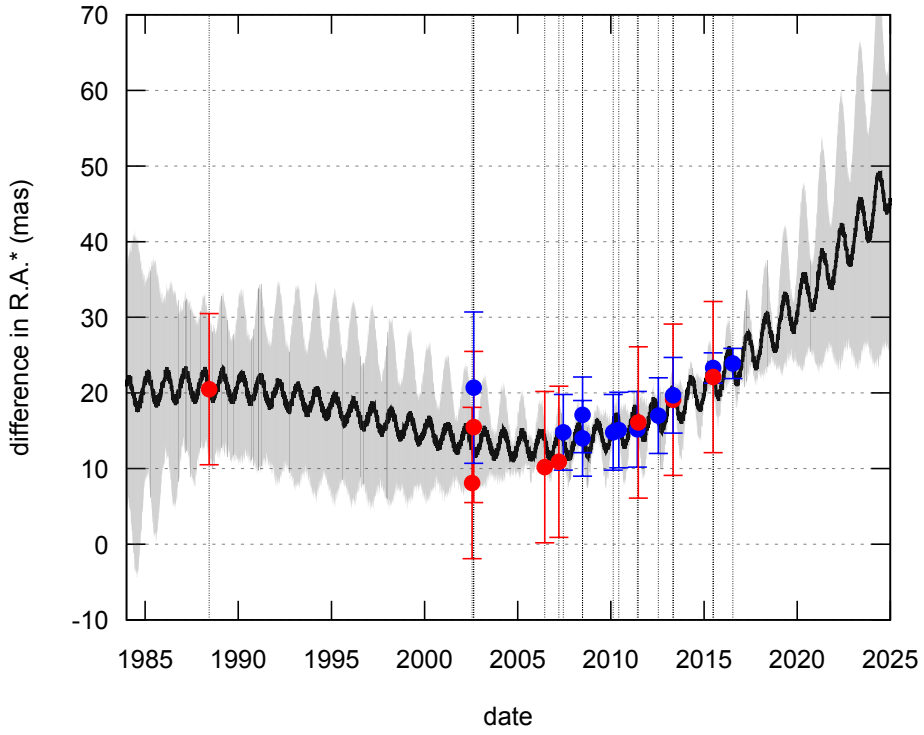
  occultation corde unique et ancienne : 5-10 mas

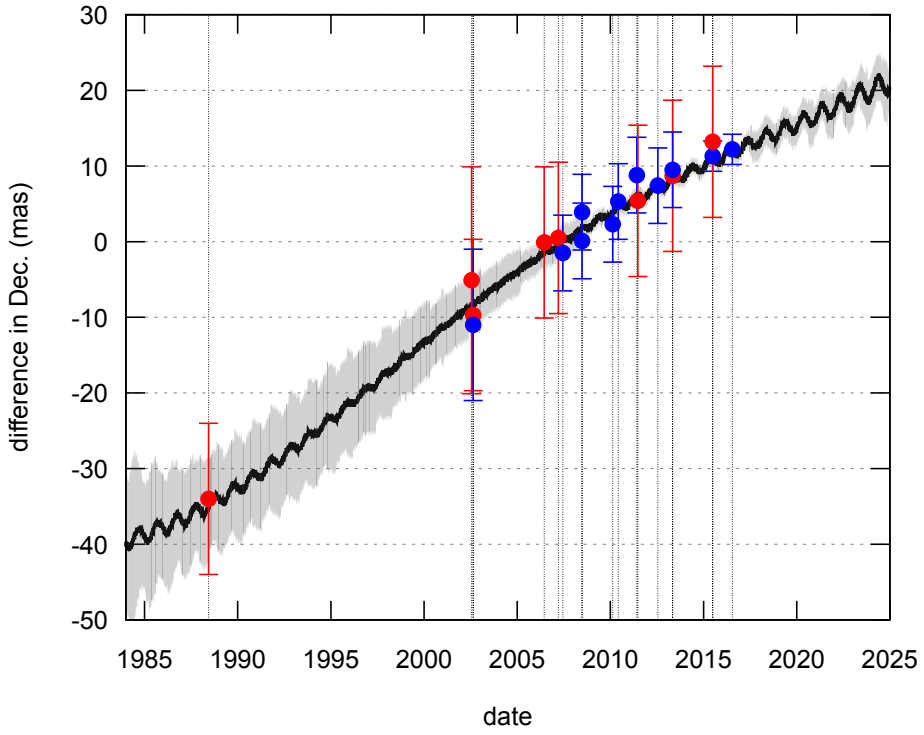
Exemple : Pluton (1988-2018)



Post-fit residuals of occultation positions (Desmars *et al.* 2019)

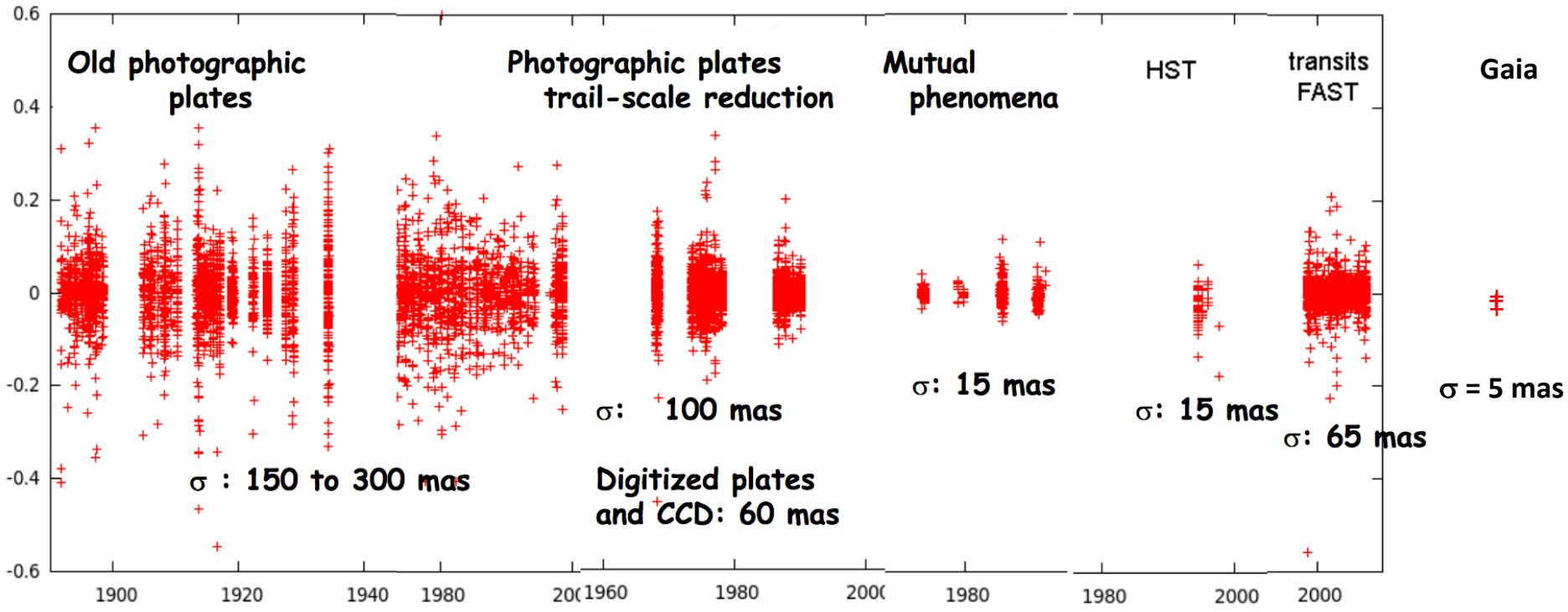
Exemple : Pluton (1988-2018)



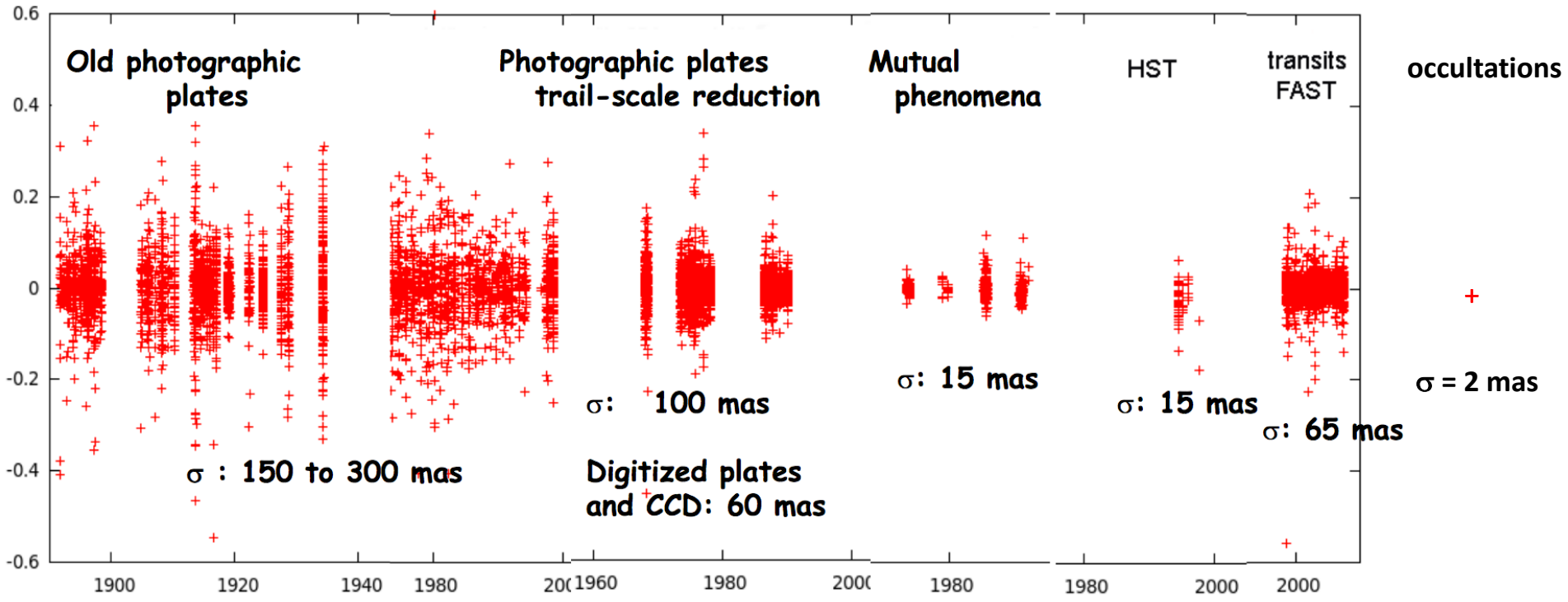


Comparison with NIMAv8-JPLDE436

Astrométrie pour les satellites naturels



Astrométrie des occultations

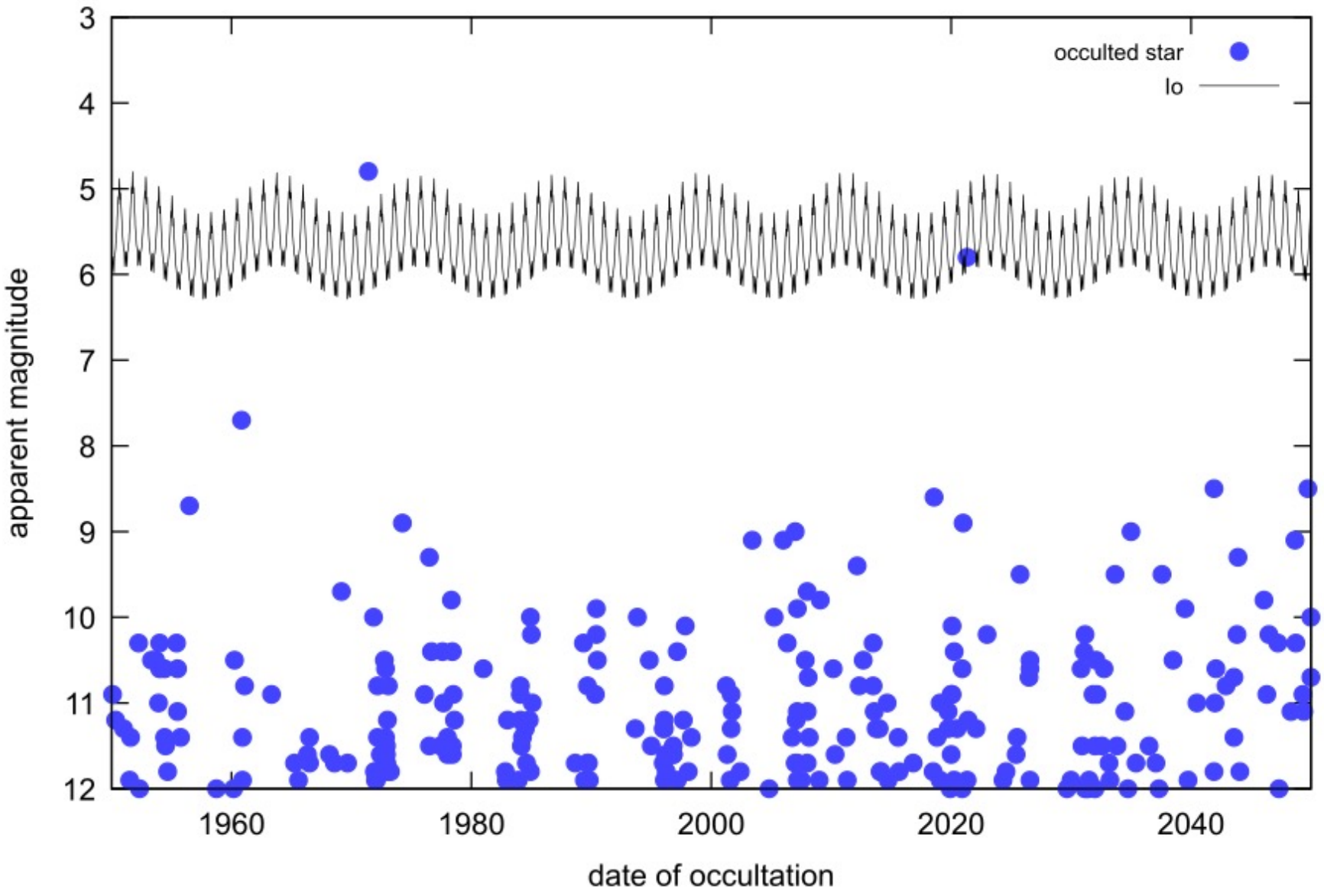


Occultations par des satellites naturels

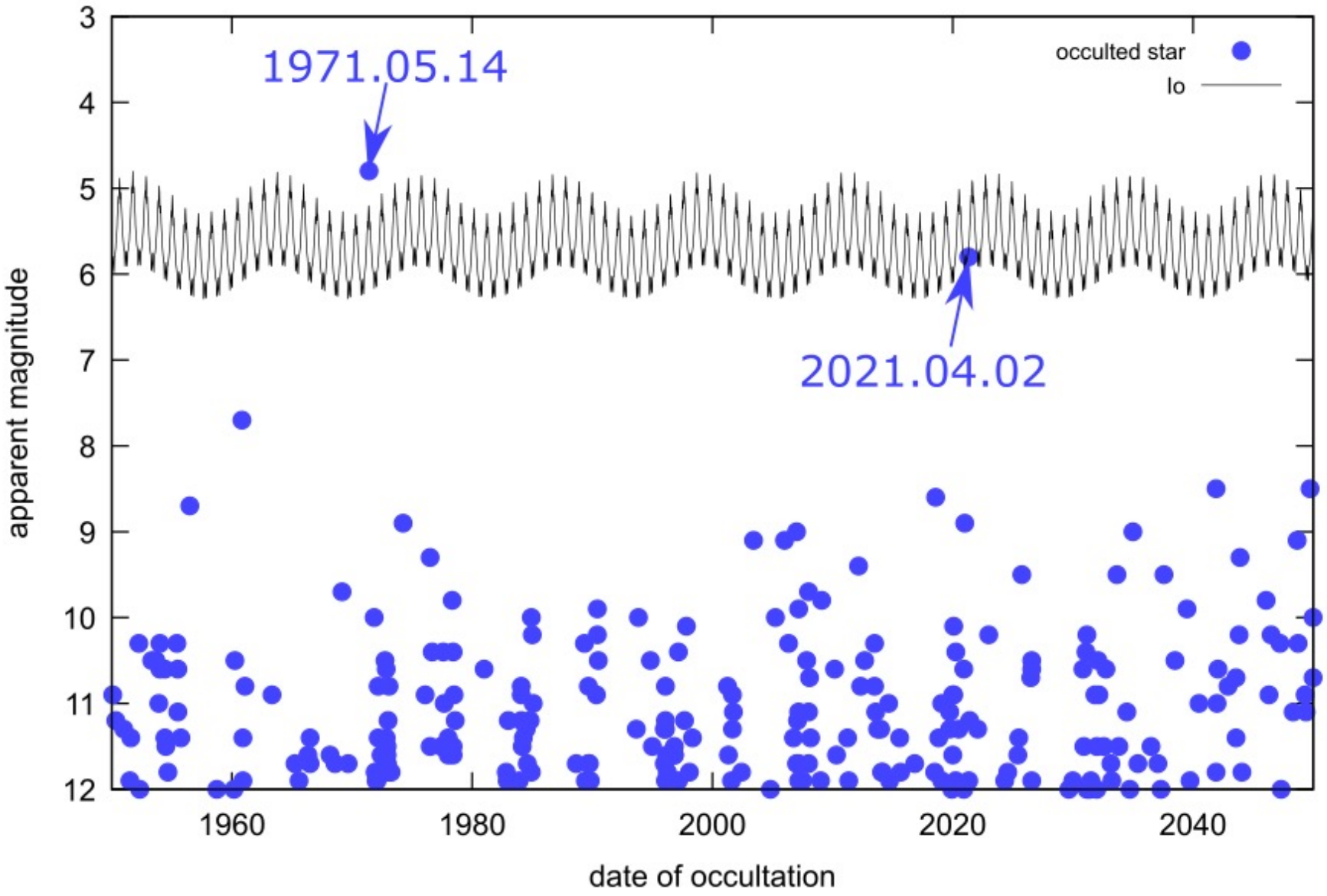
- **Jupiter**: Io (1971), Europe, Ganymede, Callisto, Himalia, Lysithea
    - -> Europe: astrometrie ~1mas (Morgado et al. 2019)
- **Saturne** : Phoebe, Titan, Tethys, Rhea
- **Uranus** : Titania, Miranda, Umbriel
- **Neptune** : Triton

http://occultations.ct.utfpr.edu.br/results/

Occultations par des satellites naturels



Occultations par des satellites naturels

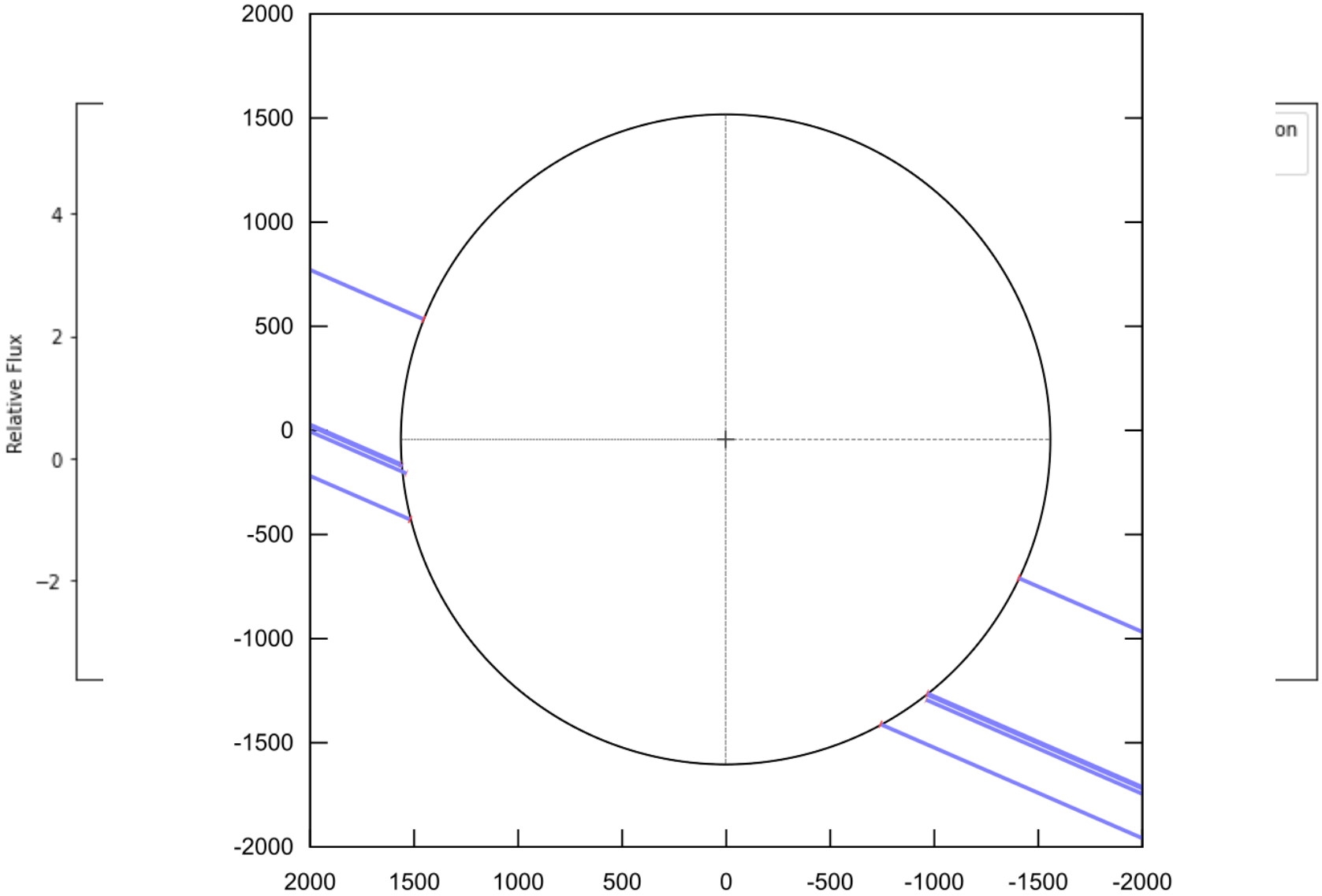


Exemple: Europe 2022.06.19

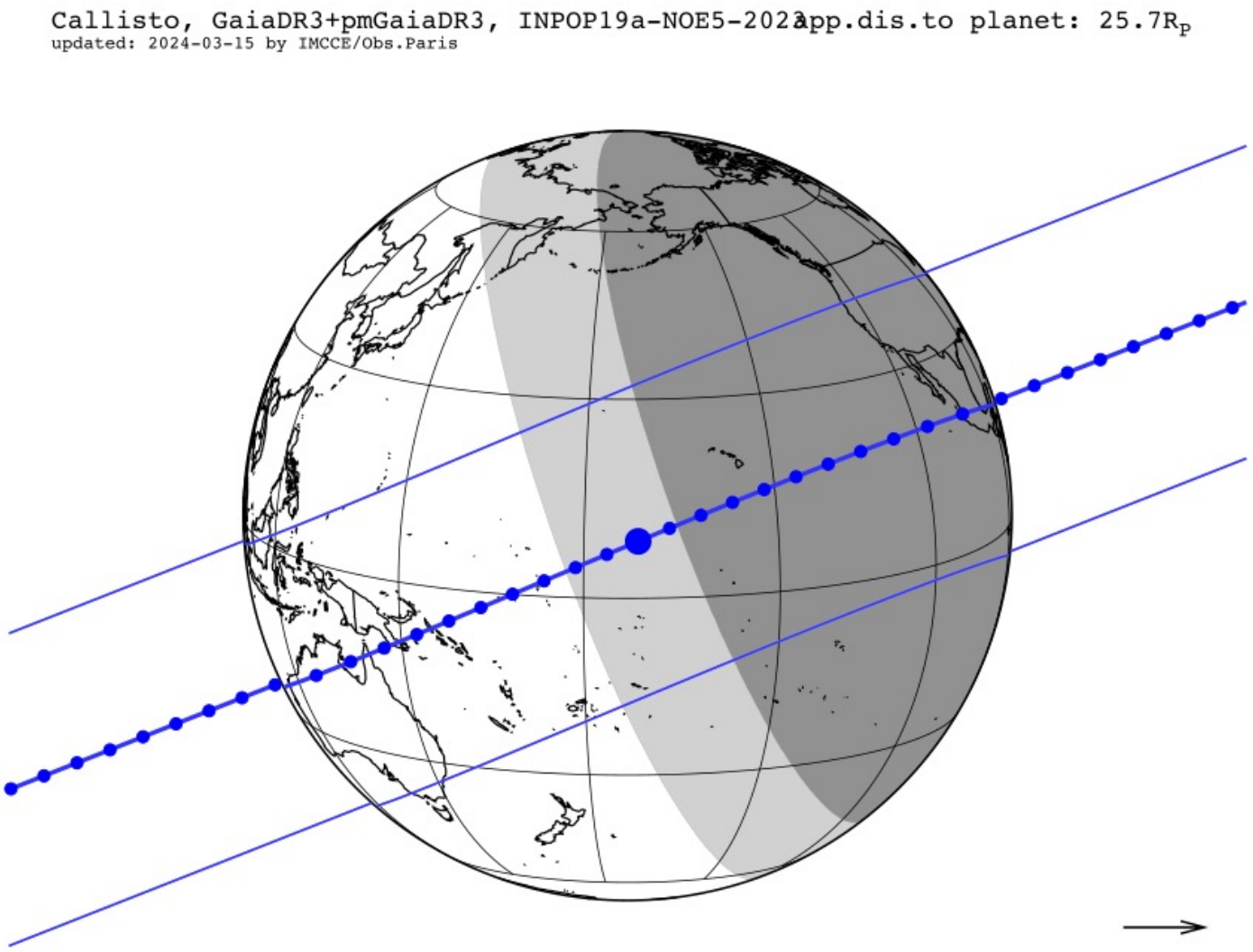
Europa, GaiaDR3+pmGaiaDR3, INPOP19a-NOE5-2023 app.dis.to planet: 2.2R_p
updated: 2024-03-16 by IMCCE/Obs.Paris eclipsed

yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2022-06-19 03:06:08.9	00 23 46.5267	+01 13 18.922	0.262	156.79	31.25	5.0145	9.7	9.0	7.7

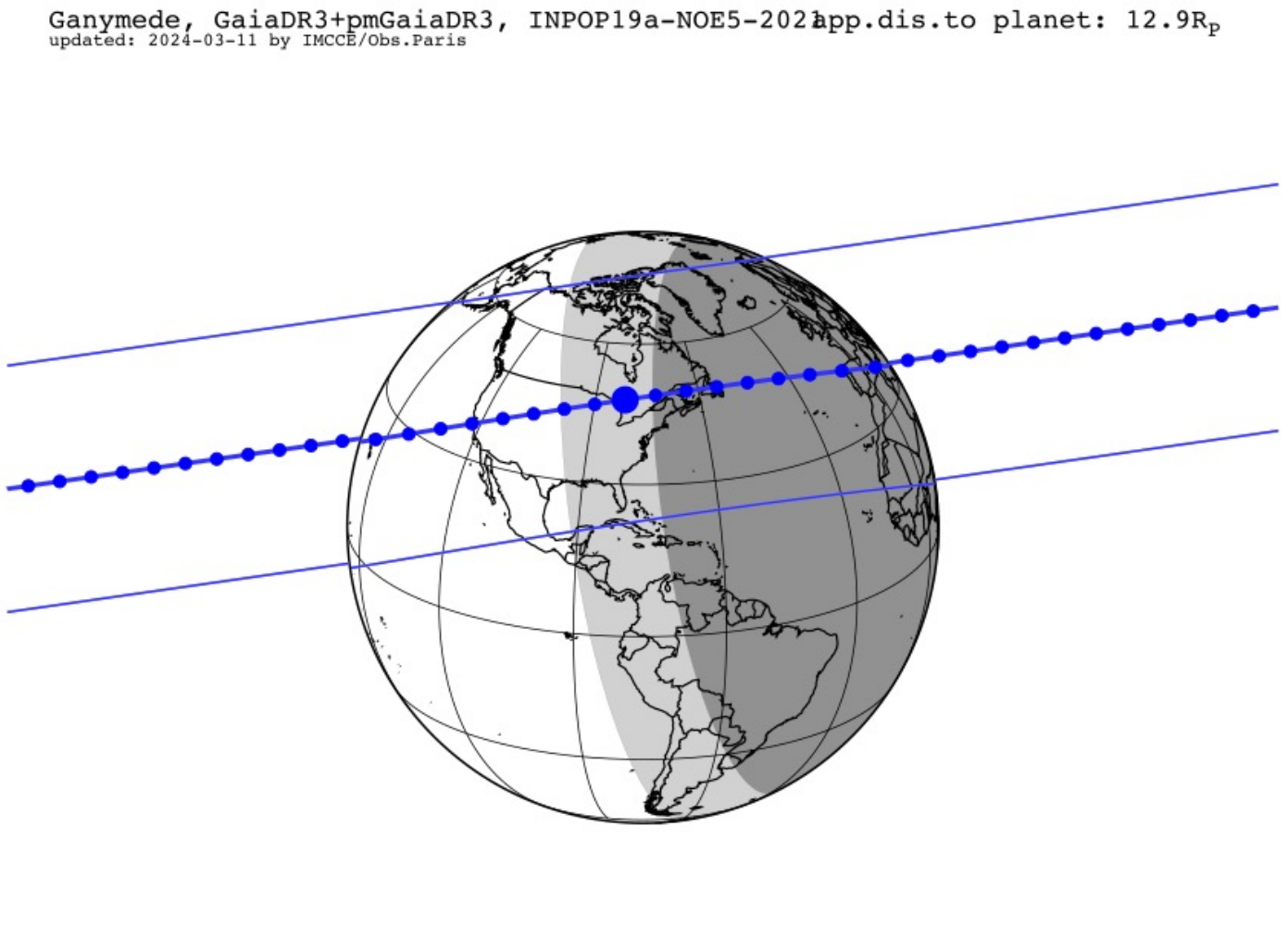
Exemple: Europe 2022.06.19



Exemple: Callisto 2024.01.15

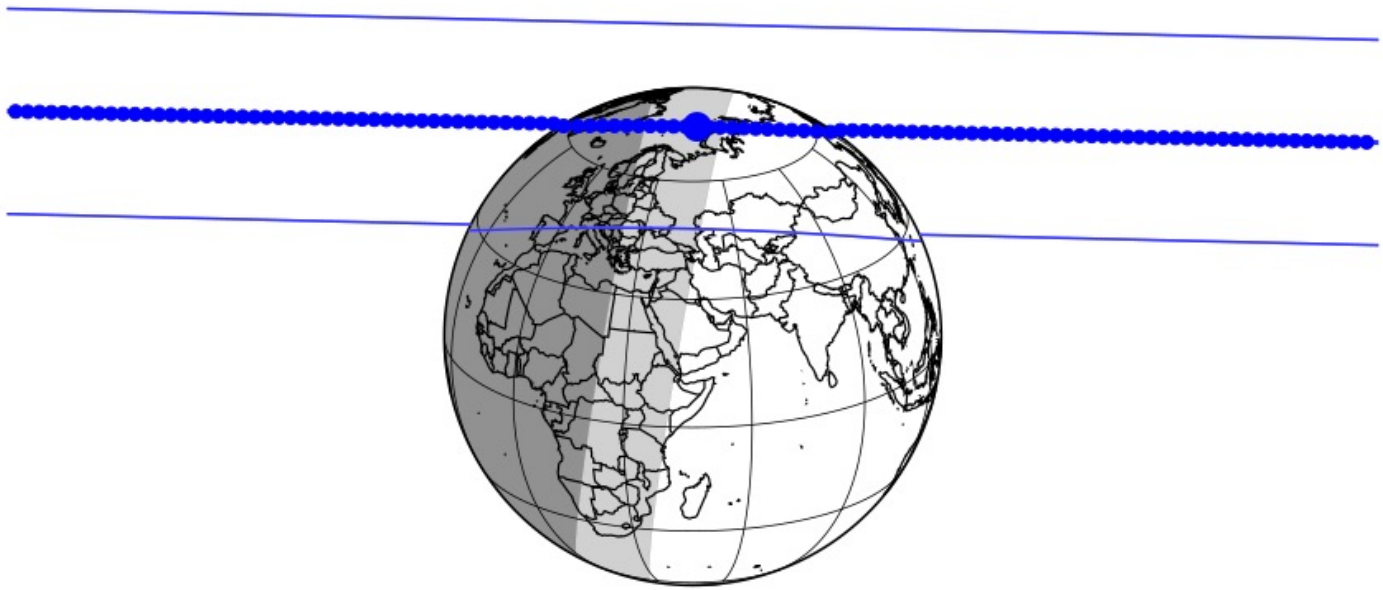


Occultation Ganymede (2025.02.15)



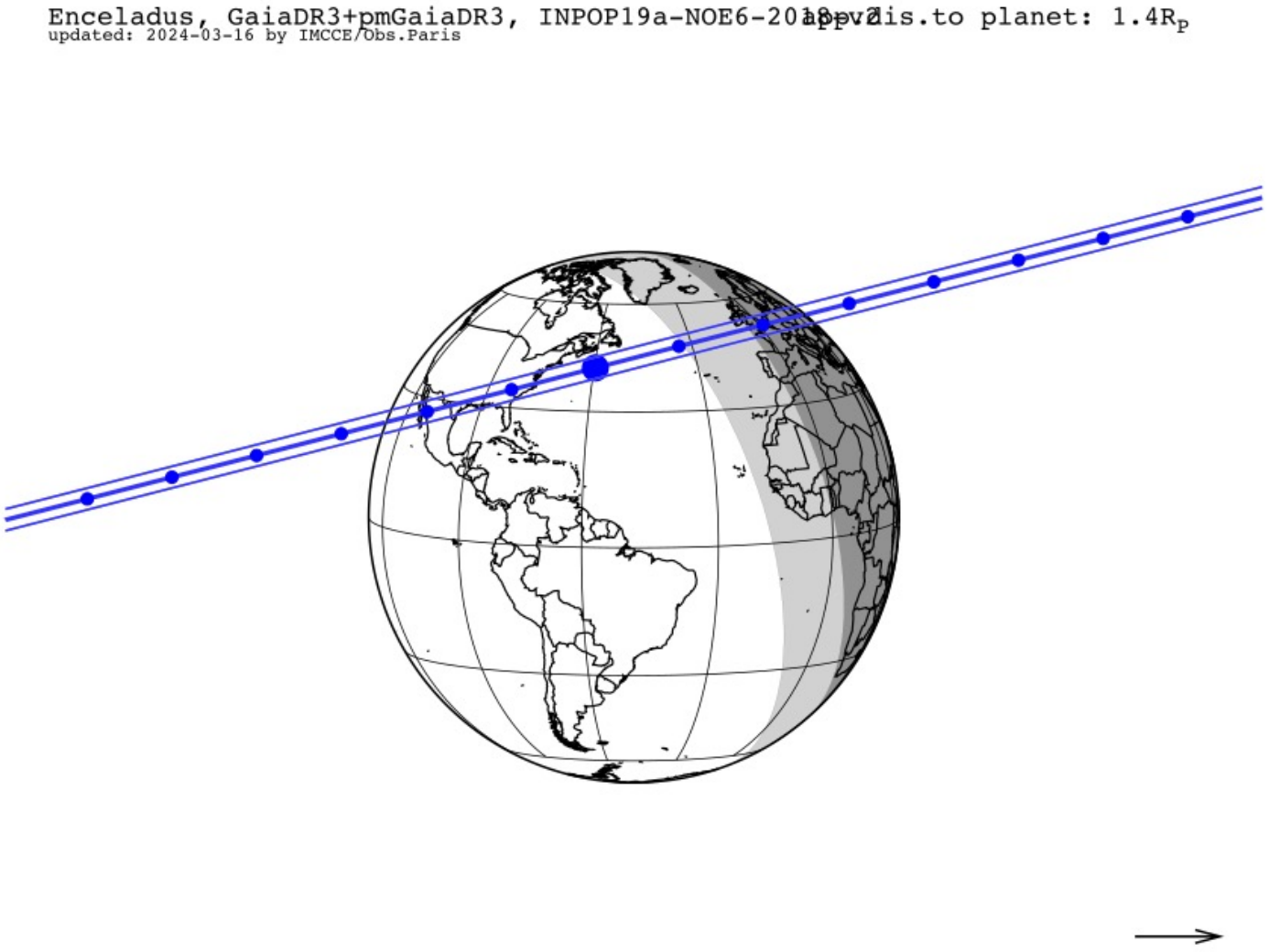
Occultation Ganymede (2025.10.14)

Ganymede, GaiaDR3+pmGaiaDR3, INPOP19a-NOE5-2021app.dis.to planet: 9.3R_p
updated: 2024-03-11 by IMCCE/Obs.Paris



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2025-10-14 03:04:44.5	07 41 12.7200	+21 26 47.821	1.444	1.42	5.12	5.1298	7.5	6.8	5.3

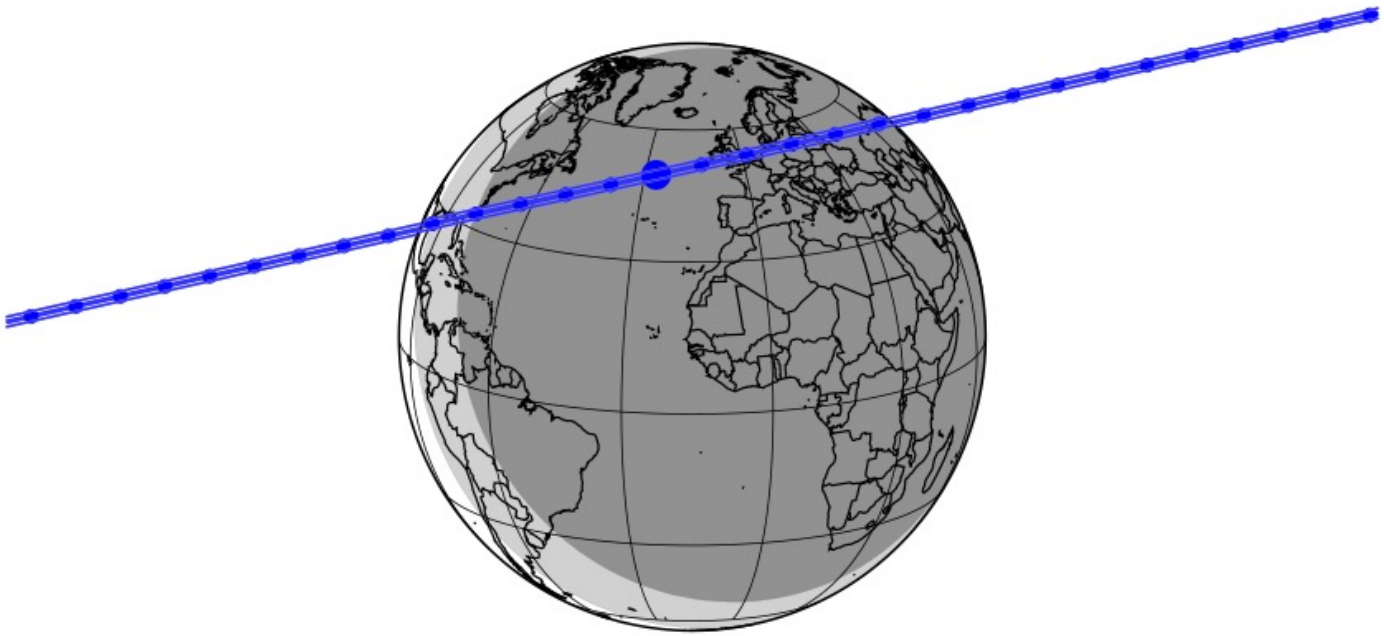
Occultation Encelade (2028.02.10)



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2028-02-10 19:20:23.3	01 27 35.2551	+06 37 57.828	0.524	345.68	35.04	9.7197	14.0	13.4	12.5

Occultation Phoebe (2029.12.01)

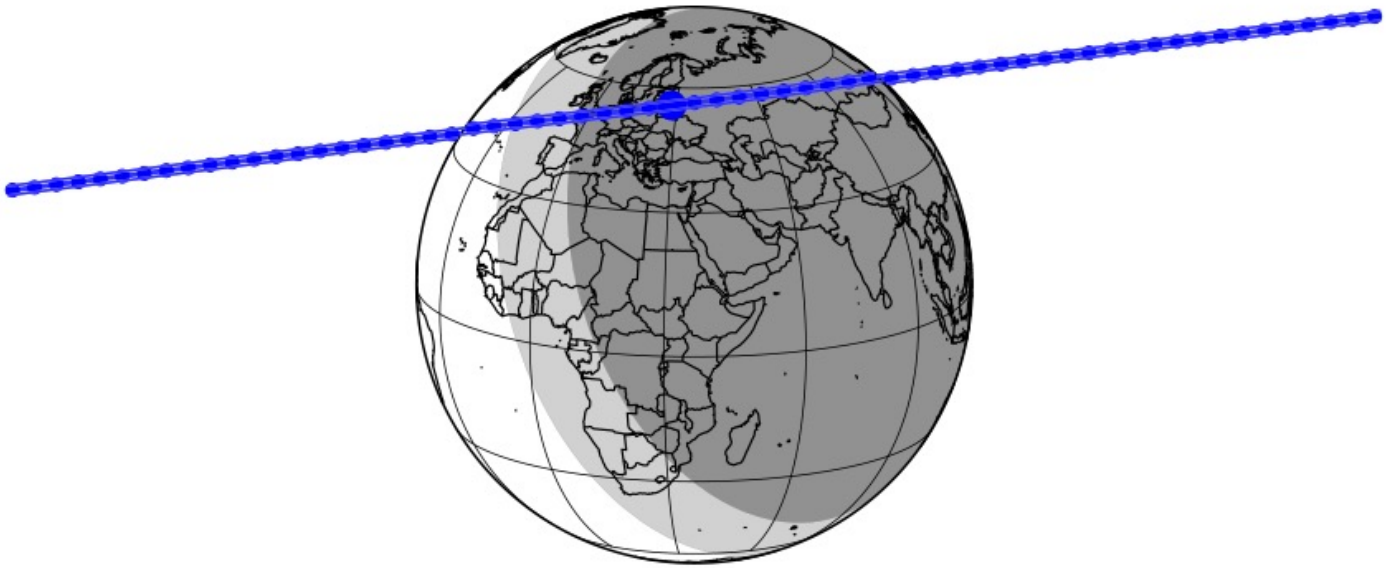
Phoebe, GaiaDR3+pmGaiaDR3, INPOP19a-PH20 app.dis.to planet: 104.9R_p
updated: 2024-03-16 by IMCCE/Obs.Paris



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2029-12-01 23:30:01.7	03 10 23.8779	+15 12 31.265	0.608	347.46	-16.58	8.1366	14.2	13.6	12.3

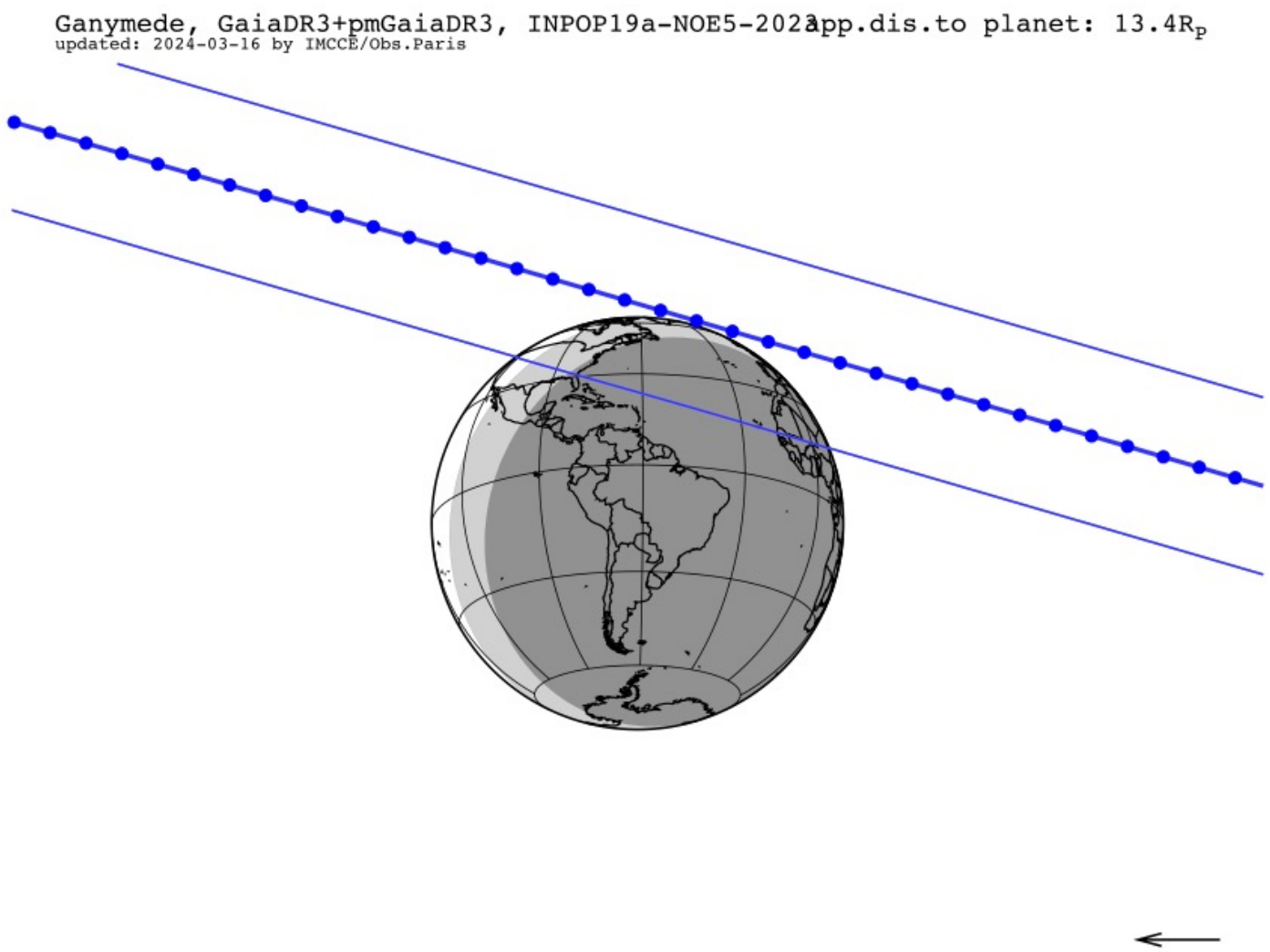
Occultation Phoebe (2029.12.27)

Phoebe, GaiaDR3+pmGaiaDR3, INPOP19a-PH20 app.dis.to planet: 39.9R_p
updated: 2024-03-16 by IMCCE/Obs.Paris



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2029-12-27 18:13:43.9	03 04 56.3377	+14 57 10.449	0.682	352.89	-8.47	8.3624	11.5	10.9	9.8

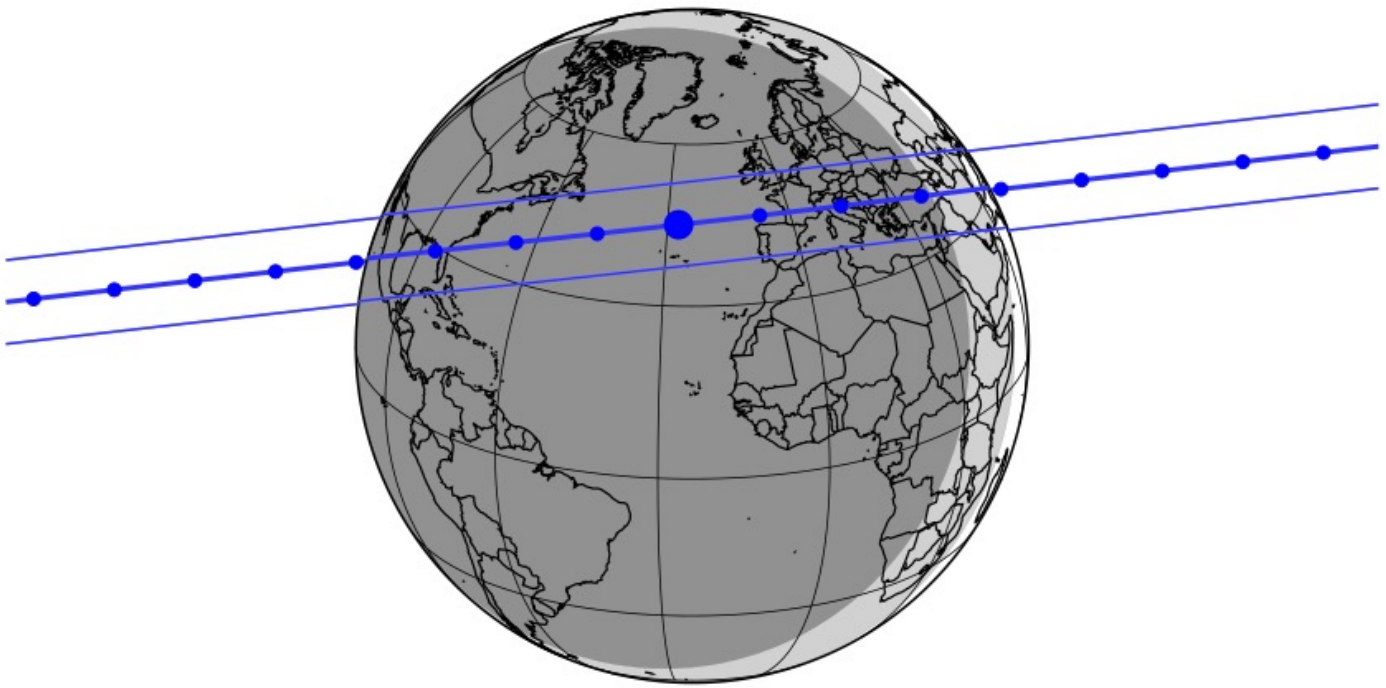
Occultation Ganymede (2030.06.06)



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2030-06-06 02:17:37.0	15 09 50.3463	-16 31 51.130	2.021	16.09	-19.32	4.4535	11.0	10.3	9.1

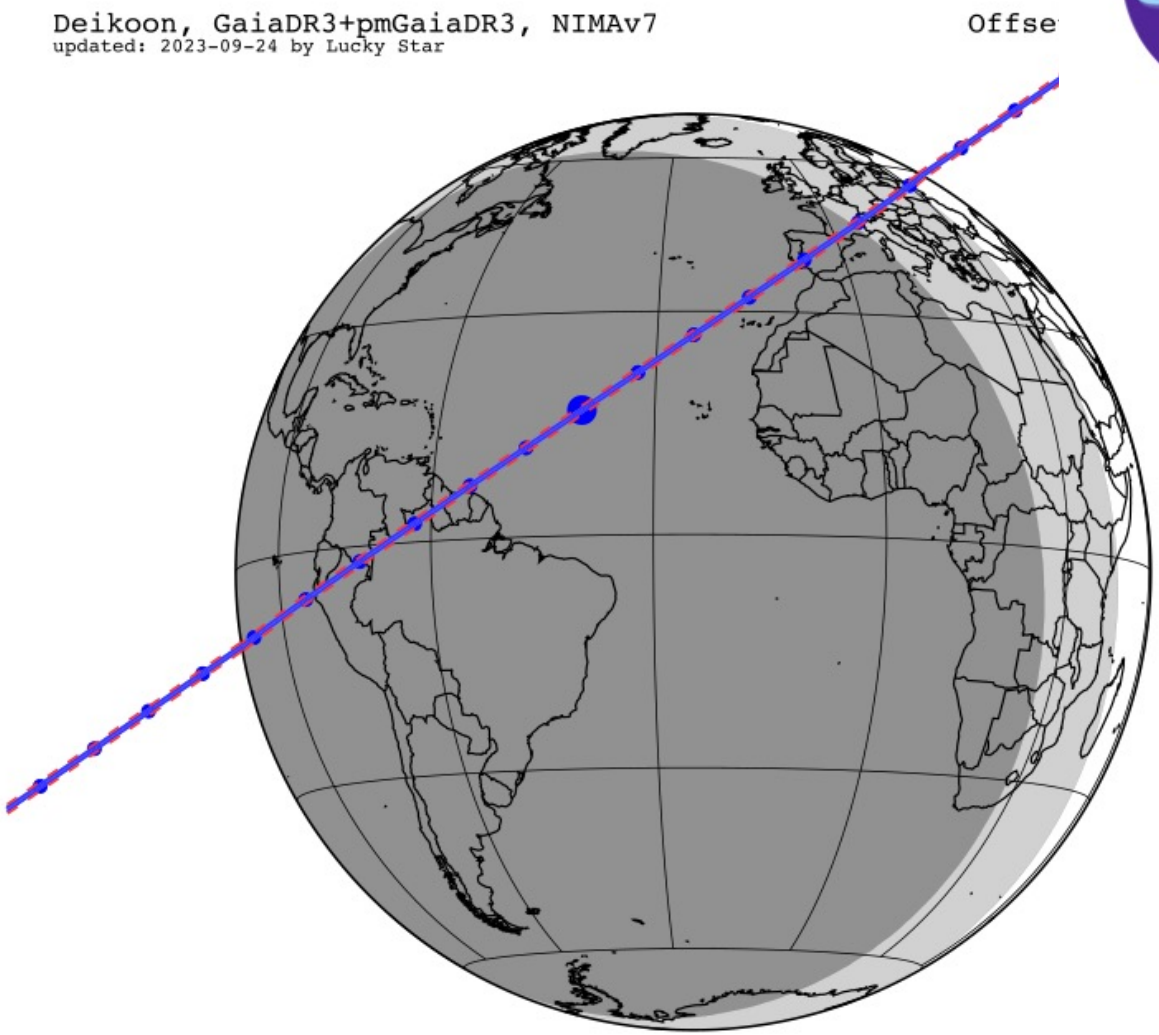
Occultation Titania (2030.11.27)

Titania, GaiaDR3+pmGaiaDR3, INPOP19a-URA111 app.dis.to planet: 17.1R_p
updated: 2024-03-16 by IMCCE/Obs.Paris



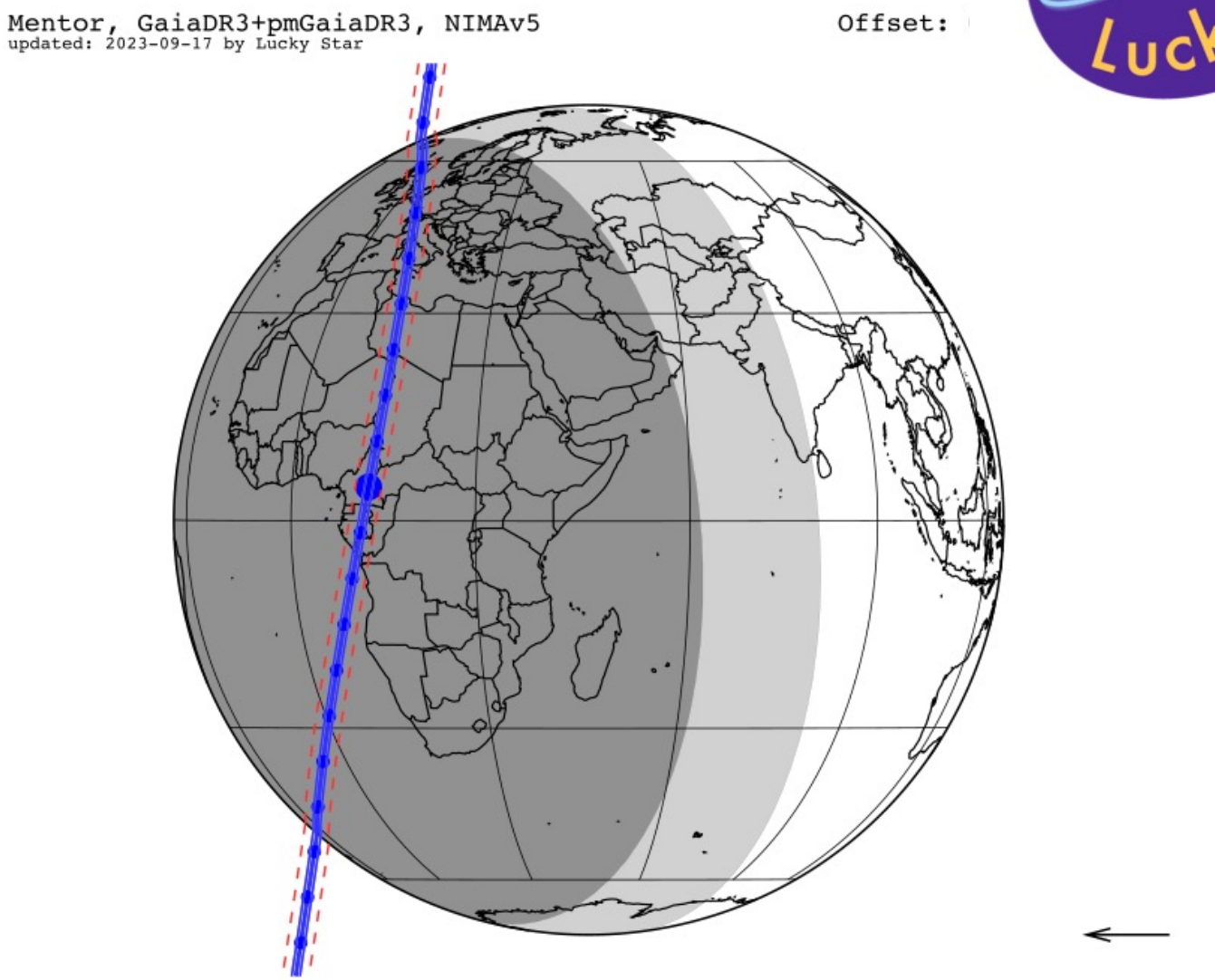
yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2030-11-27 02:33:21.8	05 21 07.0458	+23 14 06.887	0.173	353.70	-25.63	18.2108	14.3	13.3	11.0

Programme Lucky Star



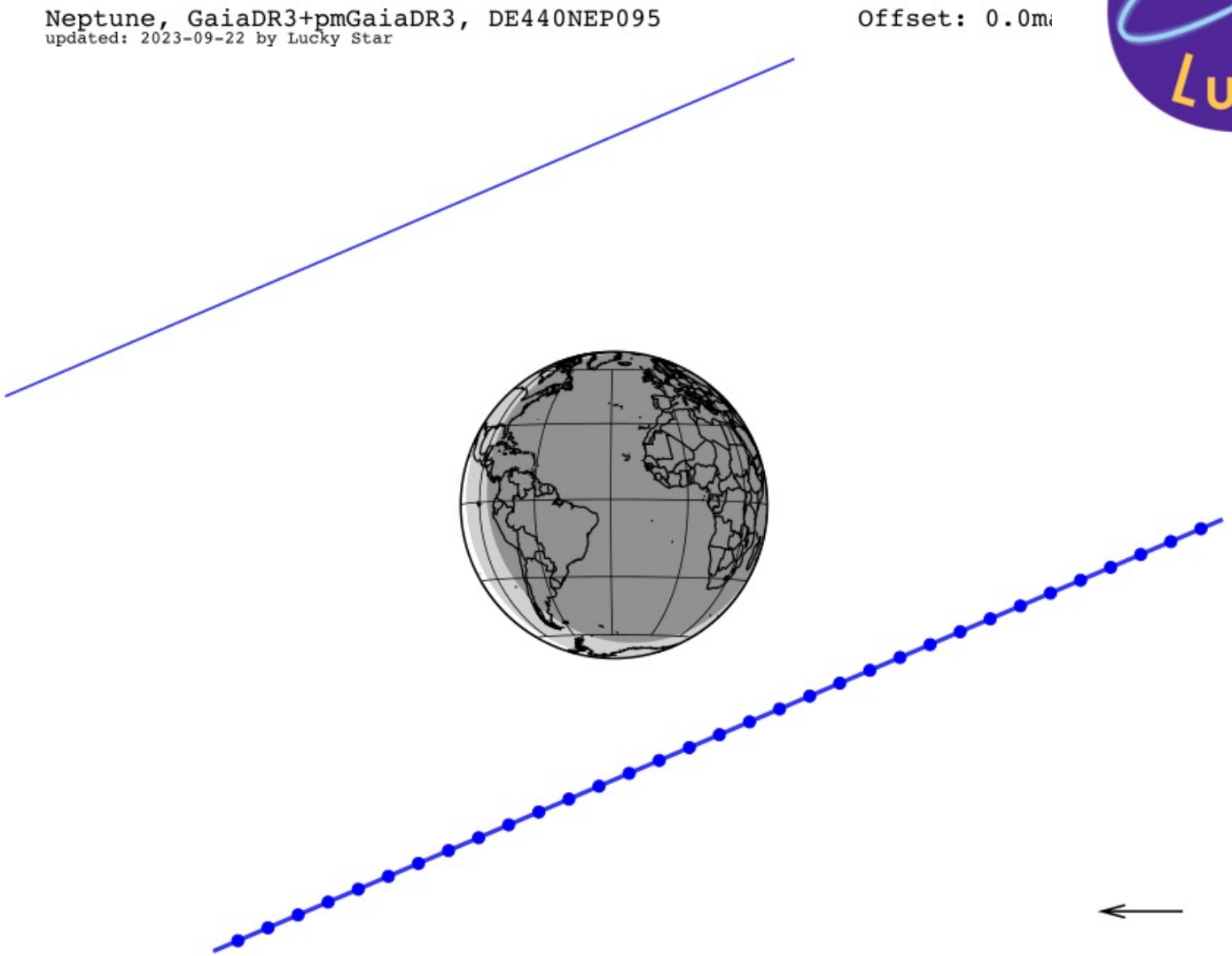
yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-08-28 03:08:52.6	23 56 14.7100	-04 42 45.920	0.861	325.33	-15.31	4.3701	13.7	13.0	11.7

Programme Lucky Star



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-09-10 00:37:38.6	02 59 15.4122	+00 10 03.417	1.052	278.56	-11.80	4.4803	15.7	15.0	13.5

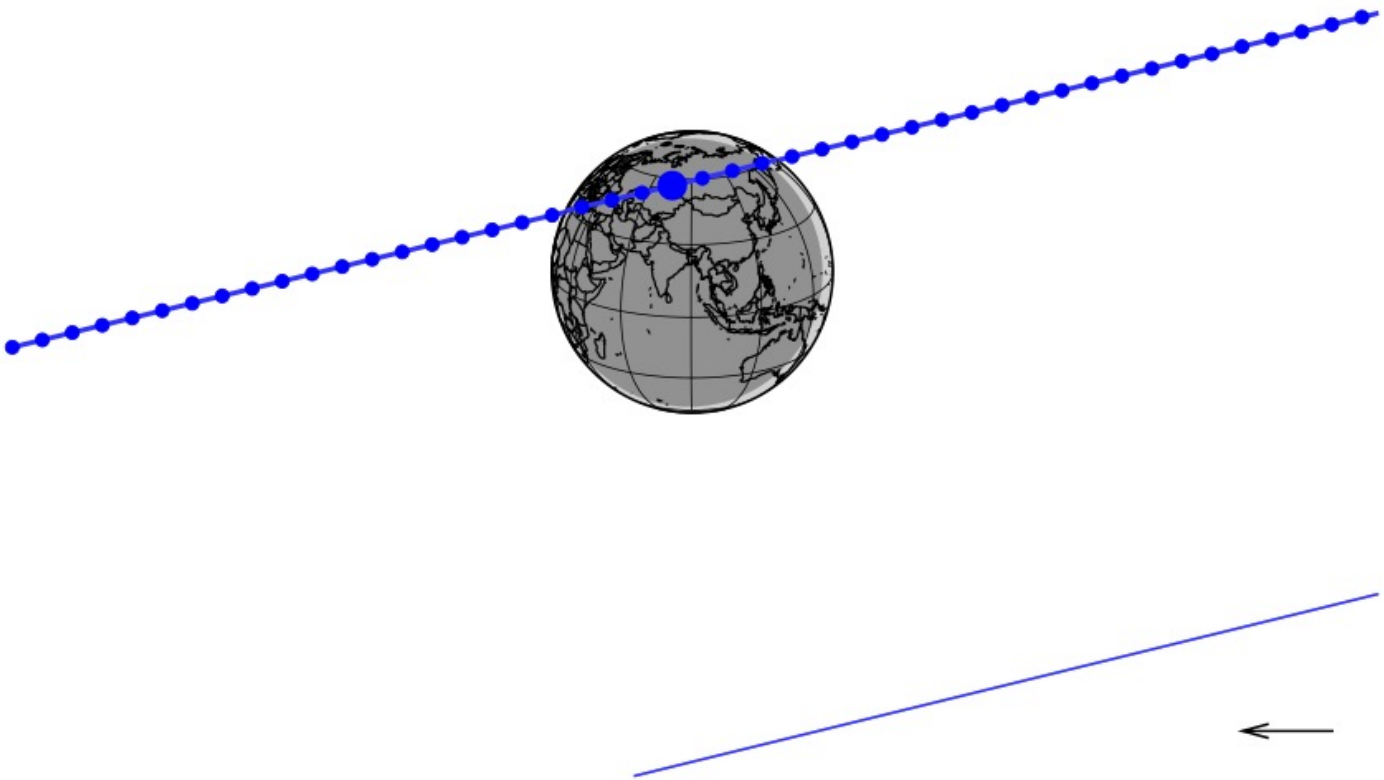
Programme Lucky Star



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2024-10-09 00:36:11.5	23 53 34.8065	-02 08 27.136	0.493	156.85	-22.69	28.9462	11.6	10.8	9.3

Programme Lucky Star

Uranus, GaiaDR3+pmGaiaDR3, DE440URA115 Offset:
updated: 2023-09-22 by Lucky Star



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G	RP	H
2024-11-12 17:59:43.6	03 31 09.6519	+18 46 26.755	0.302	346.39	-23.34	18.5749	12.9	12.4	11.4

Programme Lucky Star

yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-11-29 03:45:06.0	10 30 41.8618	+16 09 03.589	0.583	31.47	9.68	5.0496	13.0	12.6	11.7

https://lesia.obspm.fr/lucky-star/predictions.php

Projet GaiaMoons (OCA, Obs.Paris)

- Etude des astéroïdes binaires par occultations

  -> Thèse R.Lallemand (oct 2023)

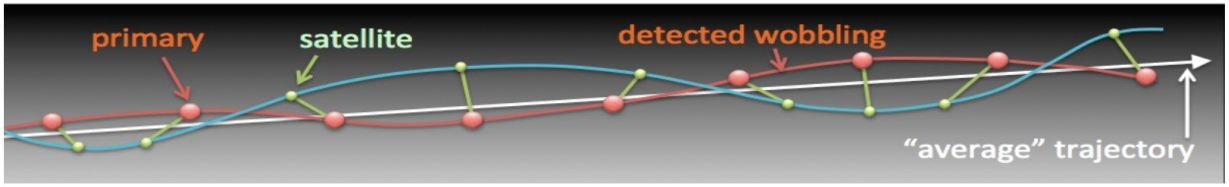


Figure 1 - Schematics of the astrometric method to detect moons around asteroids. The red trajectory is the « signature » of the satellite presence, relative to the unperturbed trajectory (white) that would be followed by the asteroid in the sky.

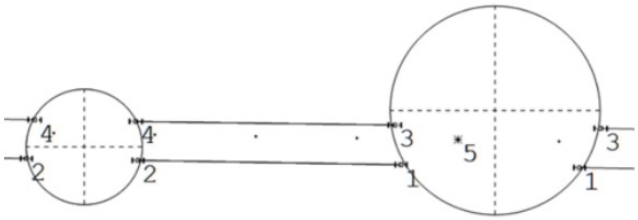


Figure 3. Occultation chords by two independent observers of a stellar occultation by (4337) Arecibo on June 9, 2021. The double extinction of the star light correspond to the interruption of the segments, to which a preliminary model of the two components of the binary is fitted (D. Gault, D. Herald, private comm.).

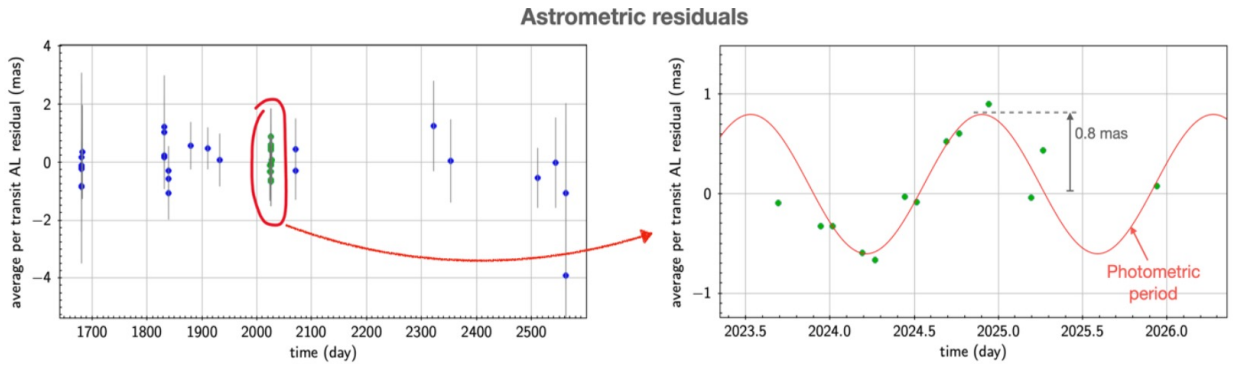
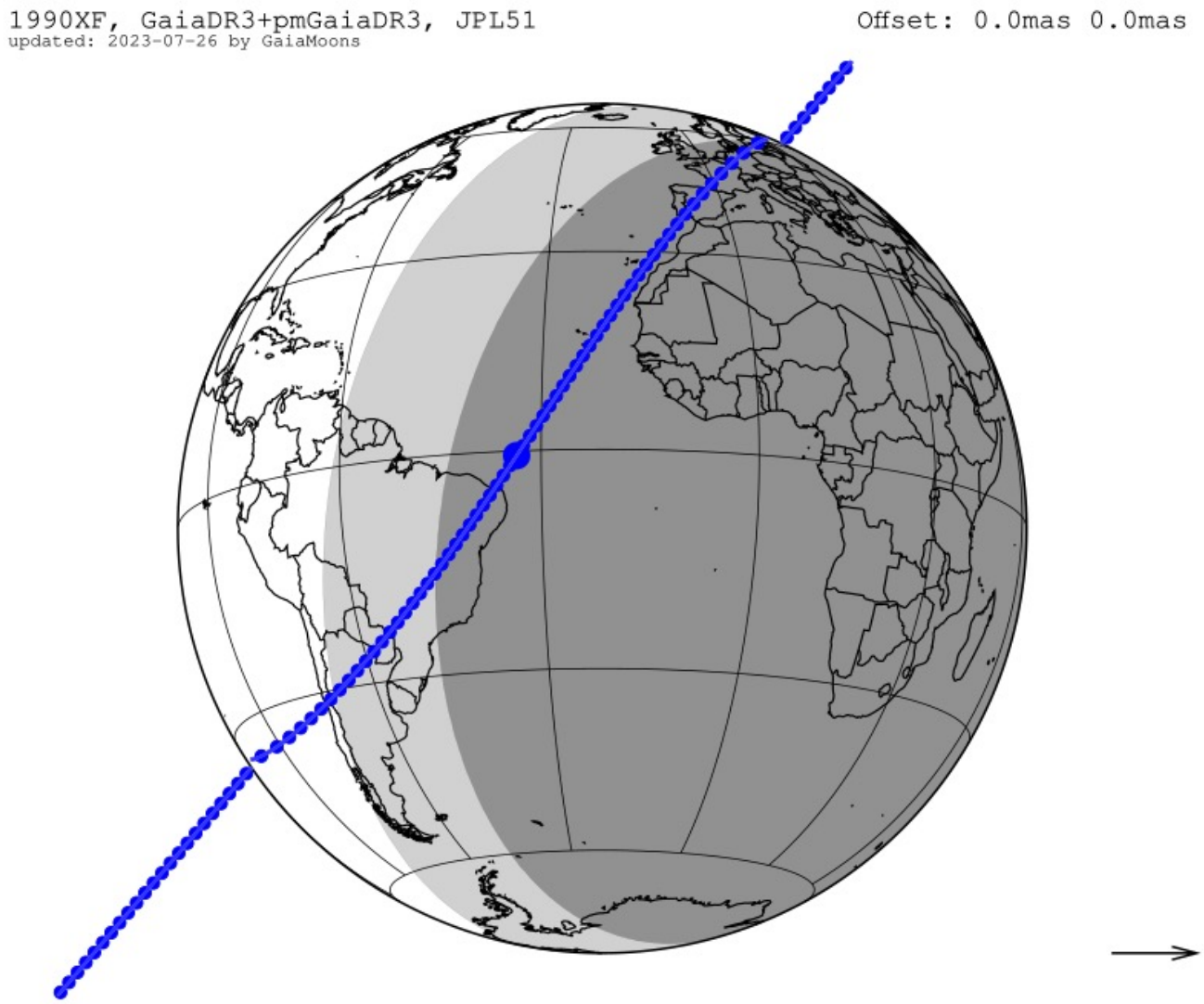


Fig. 4. The first astrometric wobbling detected during the validation of DR3 astrometry of asteroids, for the recently discovered binary 4337 Arecibo. The plot on the right is a zoom on the longest sequence of data, which shows the astrometric signature . The vertical scale is in milli-arcsec (P. Tanga, Gaia DPAC/ESA).

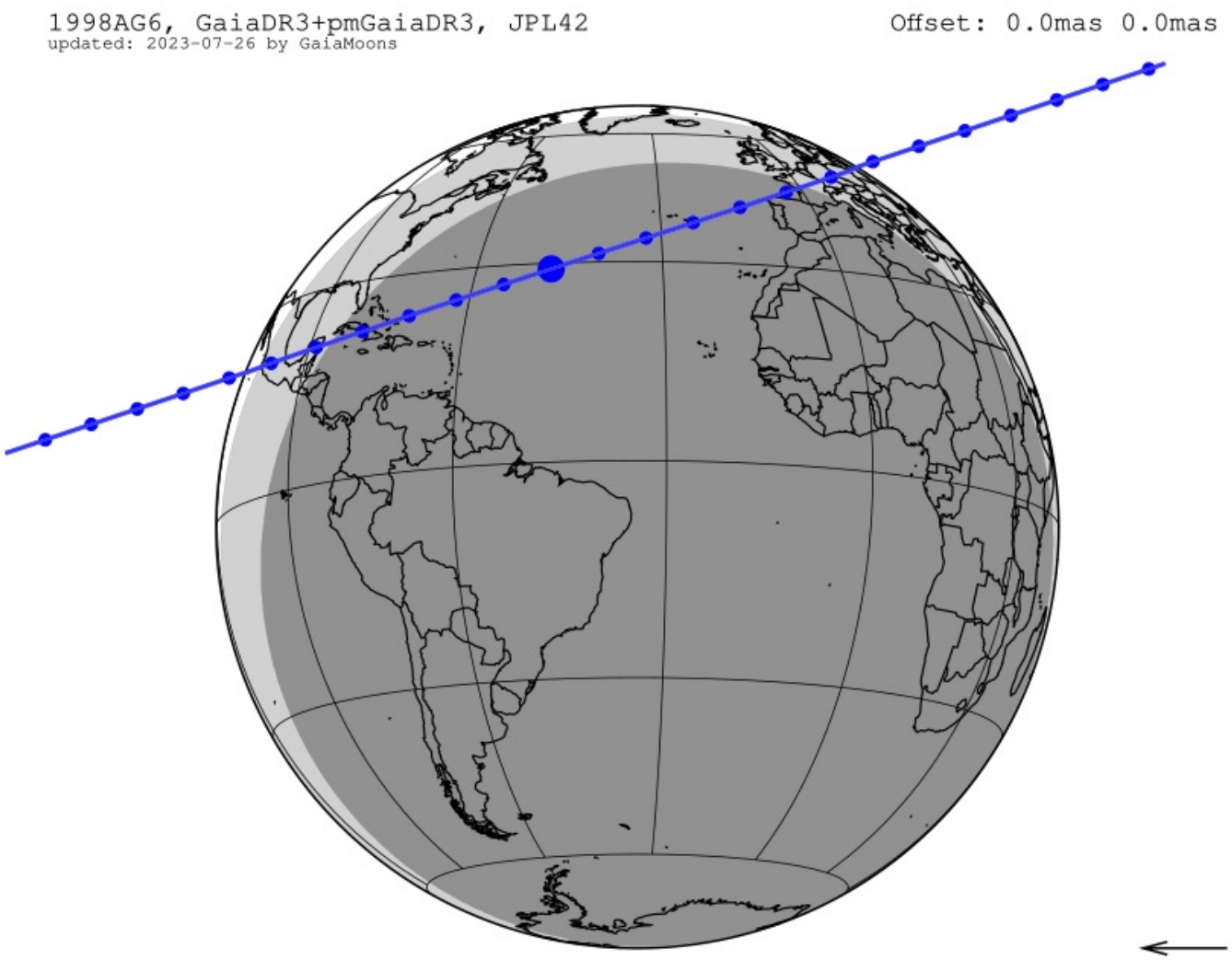
GaiaMOONS

Programme GaiaMoons



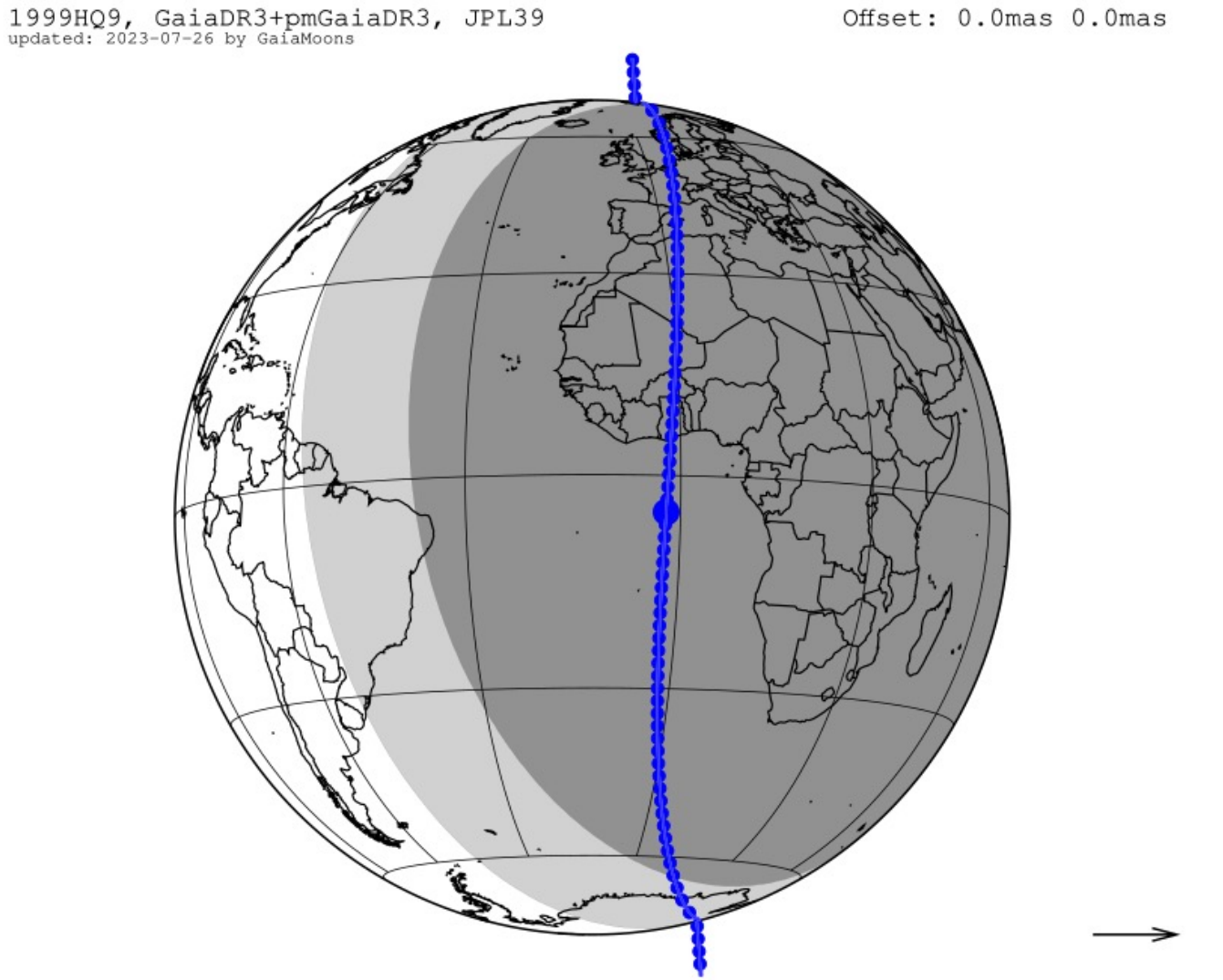
yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-04-23 22:01:24.3	10 44 16.6614	-10 44 15.814	1.801	310.41	3.27	1.2932	11.3	10.7	9.2

Programme GaiaMoons



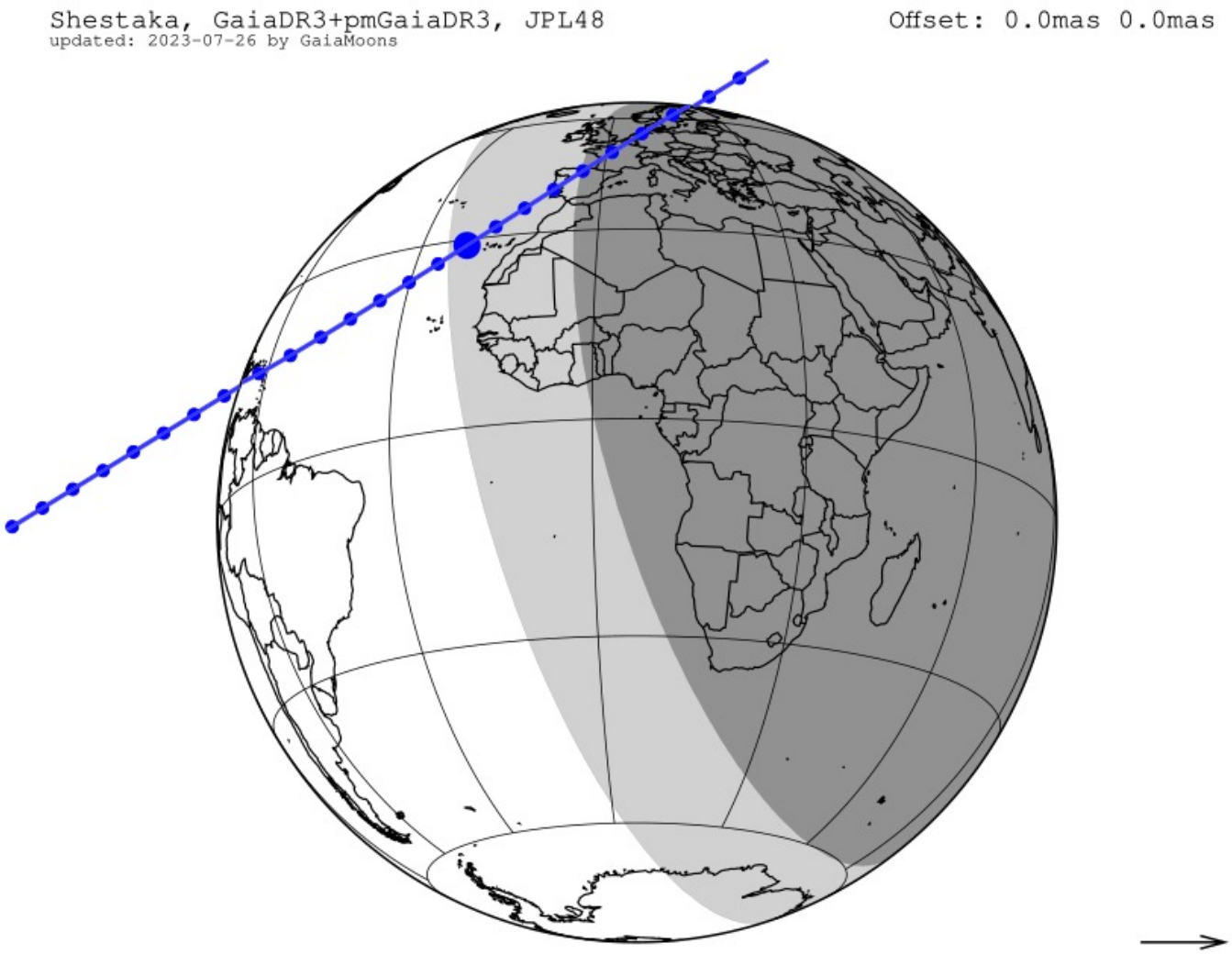
yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-07-17 01:43:25.3	19 09 02.1590	-09 02 52.005	2.982	341.29	-12.24	1.8989	11.2	10.0	7.2

Programme GaiaMoons



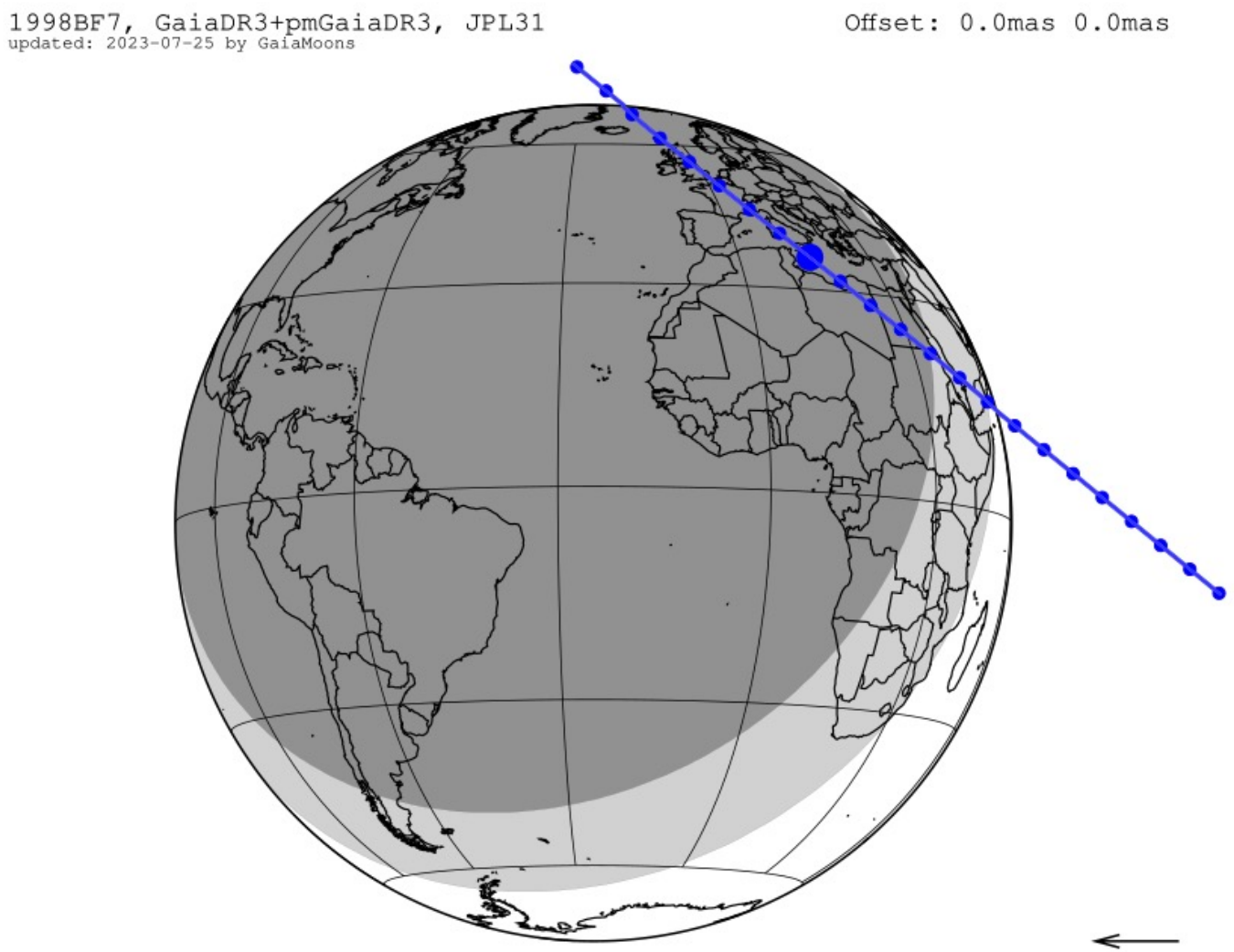
yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-10-07 21:30:26.7	21 49 21.8567	-05 52 22.253	1.025	85.68	3.21	1.5255	11.6	11.1	10.1

Programme GaiaMoons



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-10-23 18:55:15.5	21 30 27.3364	-14 18 30.604	4.562	328.25	9.02	1.4892	9.7	8.9	7.4

Programme GaiaMoons



yyyy mm dd hh:mm:ss.s	RA_star_J2000	DE_star_J2000	C/A	P/A	vel	Delta	G*	RP*	H*
2024-12-21 02:53:40.9	07 13 54.9301	-05 02 18.322	7.805	39.47	-9.59	0.9221	9.5	8.8	99.9