Occultation astrometry for NEA study

Final project review
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ACROSS

Asteroid Collaborative Research via Occultation Systematic Survey

ACROSS partnership

- Project manager / leading institute: P. Tanga (OCA/CNRS, Nice, France)
- Partner manager: K. Tsiganis (AUTh, Thessaloniki, Greece)
- Hired personnel:
  - Damya Souami, CNRS / Observatoire de la Côte d'Azur, starting from 4/2022, to 9/2022
  - Joao Ferreira, AUTh, starting on 10/2021
- Main collaborators
  - François Colas (IMCCE/Obs. de Paris)
  - Josselin Desmars (IPSA / IMCCE / Observatoire de Paris)
  - Alexander Siakas (AUTh)
  - Federica Spoto (Minor Planet Center)
  - Sébastien Bouquillon (SYRTE/ Observatoire de Paris, FCLA Santiago, Chile)

Goals

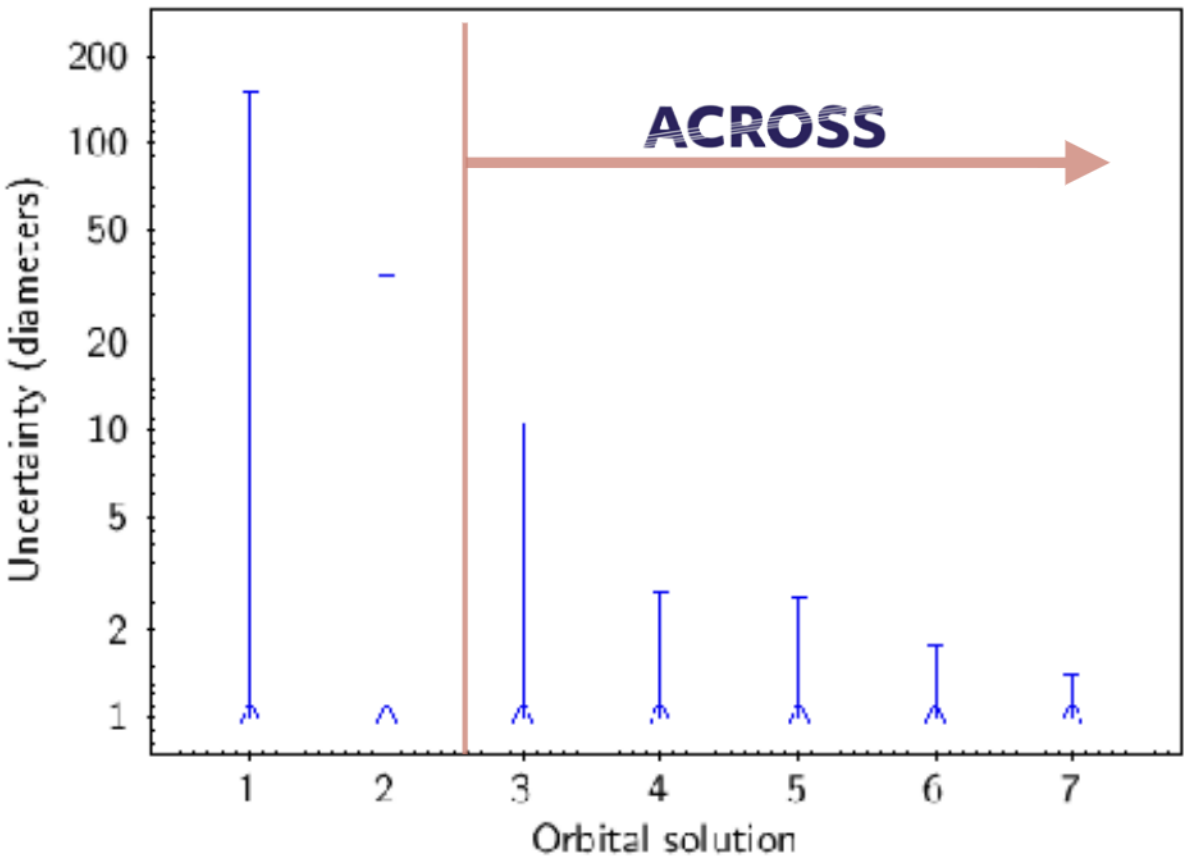
- Tackle the challenge of predicting asteroid occultations by NEAs
  - Assess the accuracy of the existing tools and identify possible limitations
  - Develop new tools to overcome limitations
  - Acquire new astrometry by validated instruments / data reduction
- Focus on 65803 Didymos, and secondary targets of the Hera mission
  - Before and after the DART impact
- Organise a community of citizen scientists into network for targeted campaigns
  - Exploit existing networks of observers
  - Provide visibility to ACROSS by appropriate platforms
  - Provide support and advices to potential observers
- Support the logistics of the campaigns
  - Grant the presence of observers when required, for main occultation opportunities
  - Provide telescopes and suitable GPS cameras when required
  - Assist with the deployment

Tackle the challenge of predicting asteroid occultations by NEAs

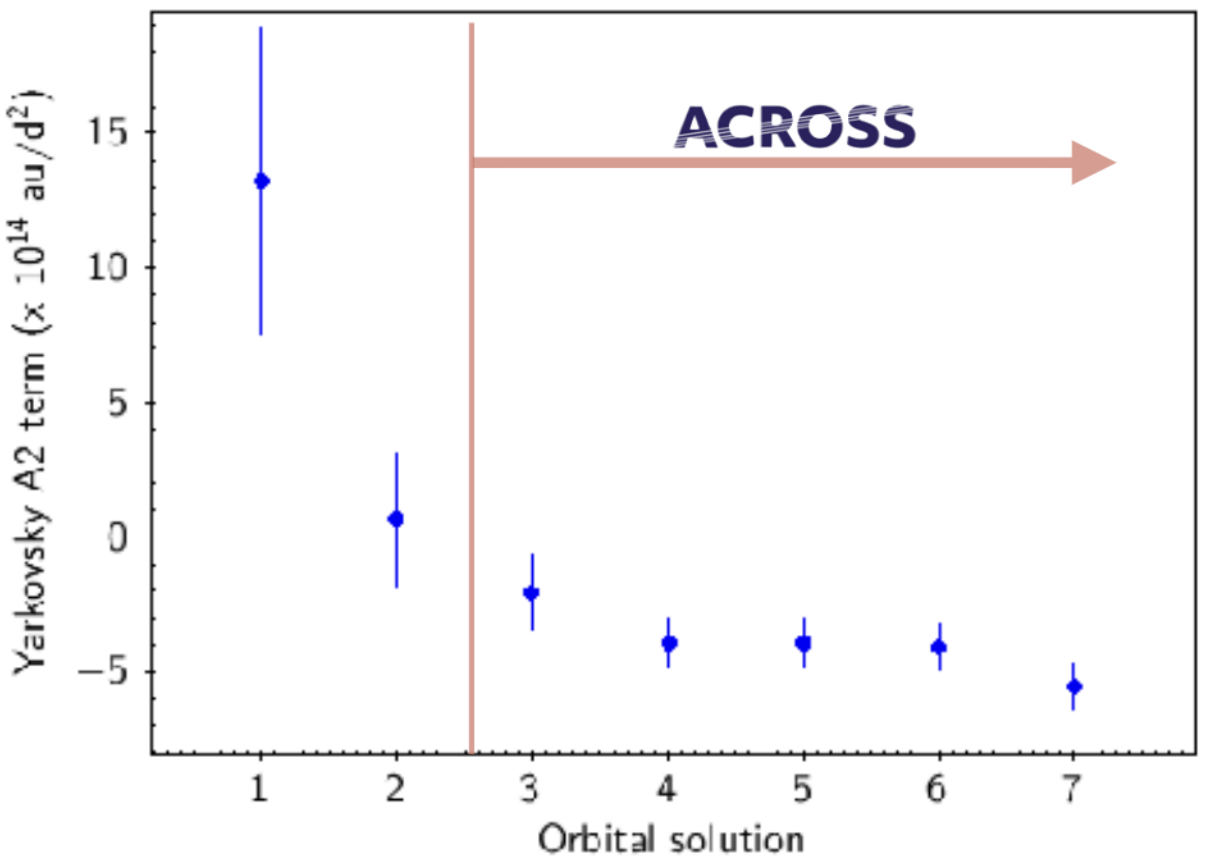
- Orbital fitting: orbfit
  - Developed by a consortium (expertise by F. Spoto, MPC)
  - Optimised in 2022 to ensure full consistency with JPL dynamical models and reference systems (two major updates)
  - Enormous amount of tests to asses the details of orbit propagation, choice of perturbers, reference frame, weighing scheme, biased data…
  - Validation by comparison with NIMA (J. Desmars, Obs. Paris) and JPL
- Occultation prediction
  - Two independent softwares: Occult (amateur community, solidly tested, constantly updated) and SORA (professional, less mature, open source, flexible)
  - Development of a tool to take into account topography details in the prediction of occultation paths on the ground
- New optimised astrometry
  - Reduced by the GBOT (Gaia) pipeline (resp. D. Souami, S. Bouquillon, Obs. Paris)
  - Several observatories, participants to the DART/Hera ground based campaigns
  - New observations obtained and reduced, by TNG, LCO, Kryoneri

Orbit improvement for 65803 Didymos

Uncertainty on position, for a given date



Yarkovsky acceleration

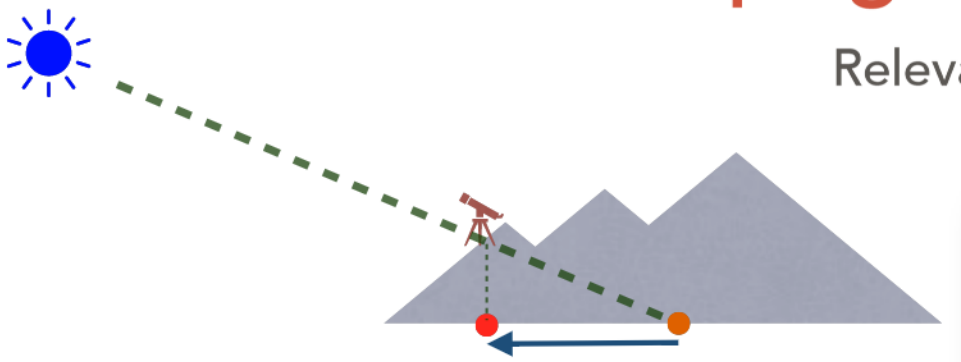


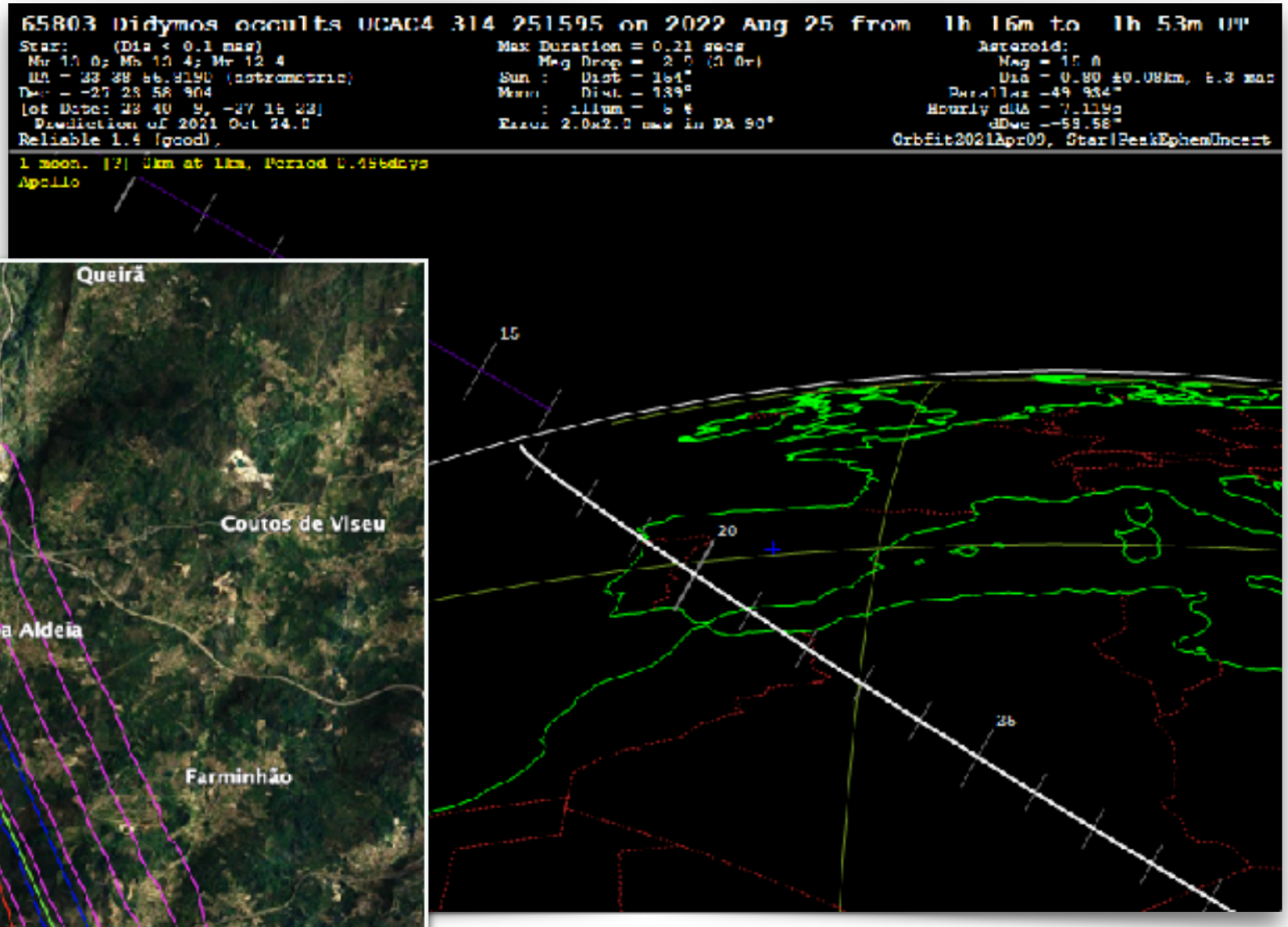
1 - data from 1996 to 2015
2 - … to 2019
3 - … to 2021
4 - …to July 2022
5 - to now (including DART NAV data)
6, 7 - different weighting of 4, 5

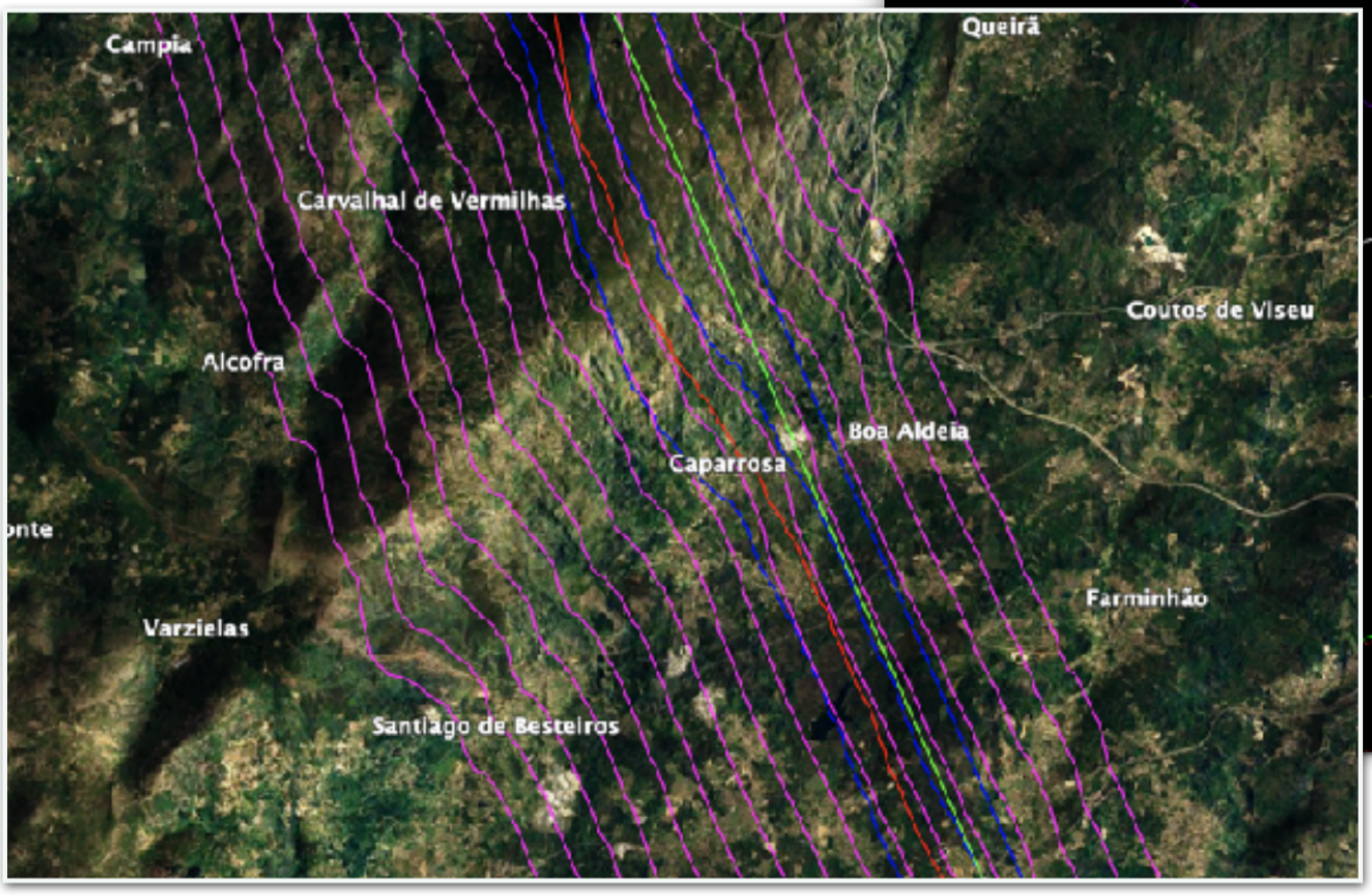
FIRST MEASUREMENT OF YARKOVSKY FOR DIDYMOS

Predictions: topography correction

Relevant for low star elevation and ground altitude comparable to object size







Targets

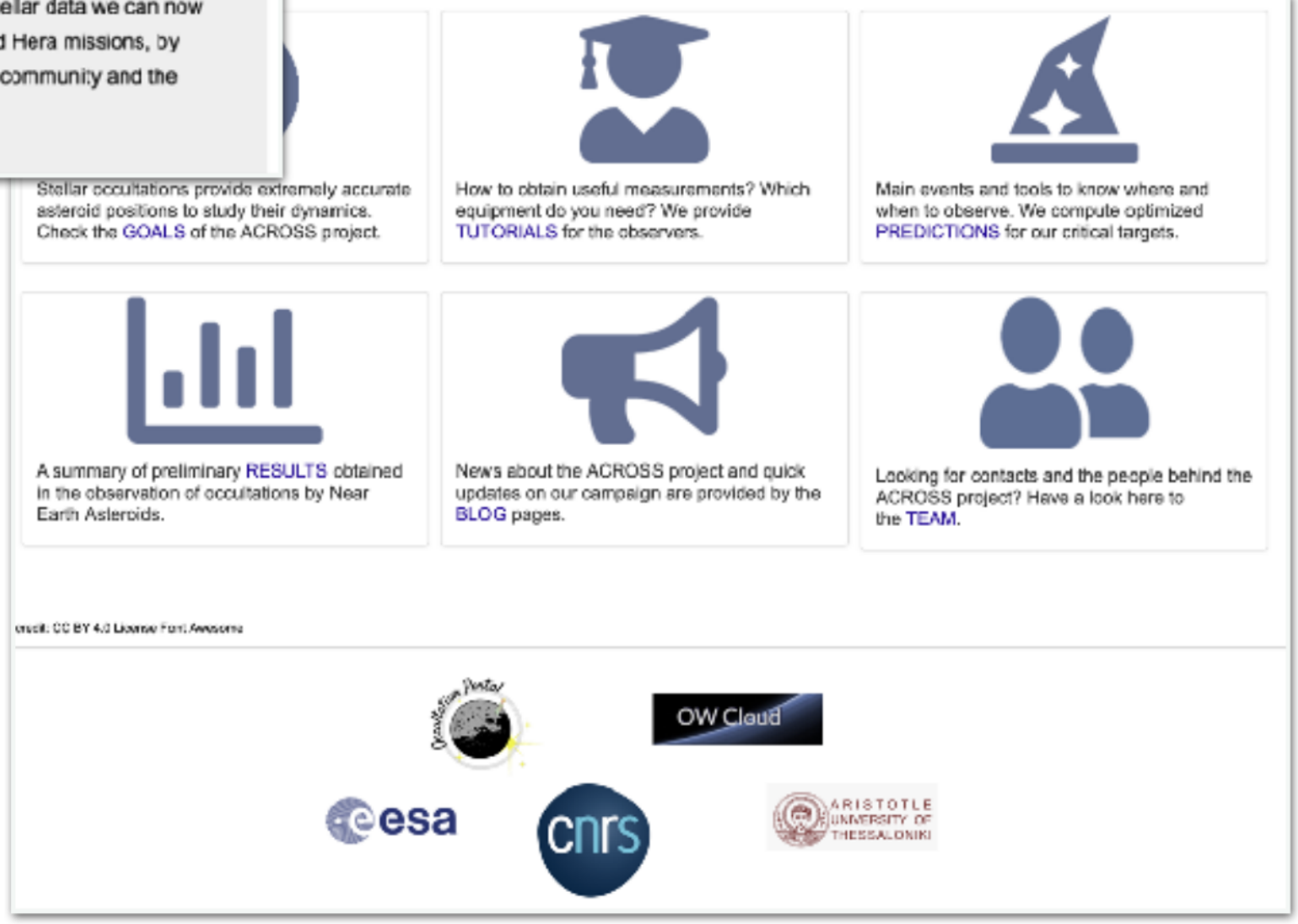
- (65803) Dydimos
- (29 886) Randytung
- (42 532) 1995 OR
- (54 212) 2000 HJ89
- (65 803) Didymos
- (88 992) 2001 TJ72
- (95 802) Francismuir
- (122 764) 2000 SX69
- (169 549) 2002 EG105
- (188 708) 2005 TR99
- (477 416) 2009 WW1

+30 NEAs with good orbital quality (σ < 1e-9 au), size (D > 0.5 km) and astrometry in Gaia DR3

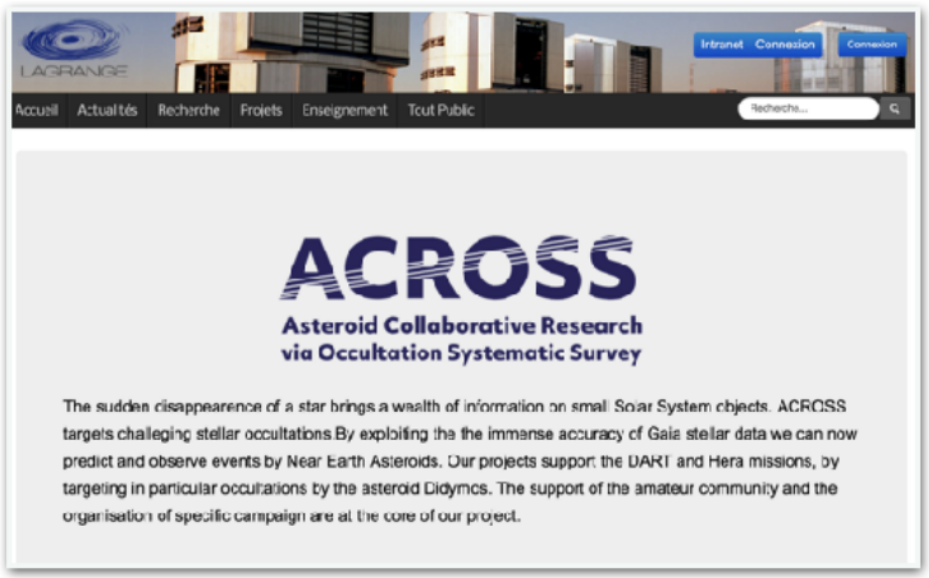
ACROSS: the portal



https://lagrange.oca.eu/fr/home-across



The ACROSS: connected platforms and visibility

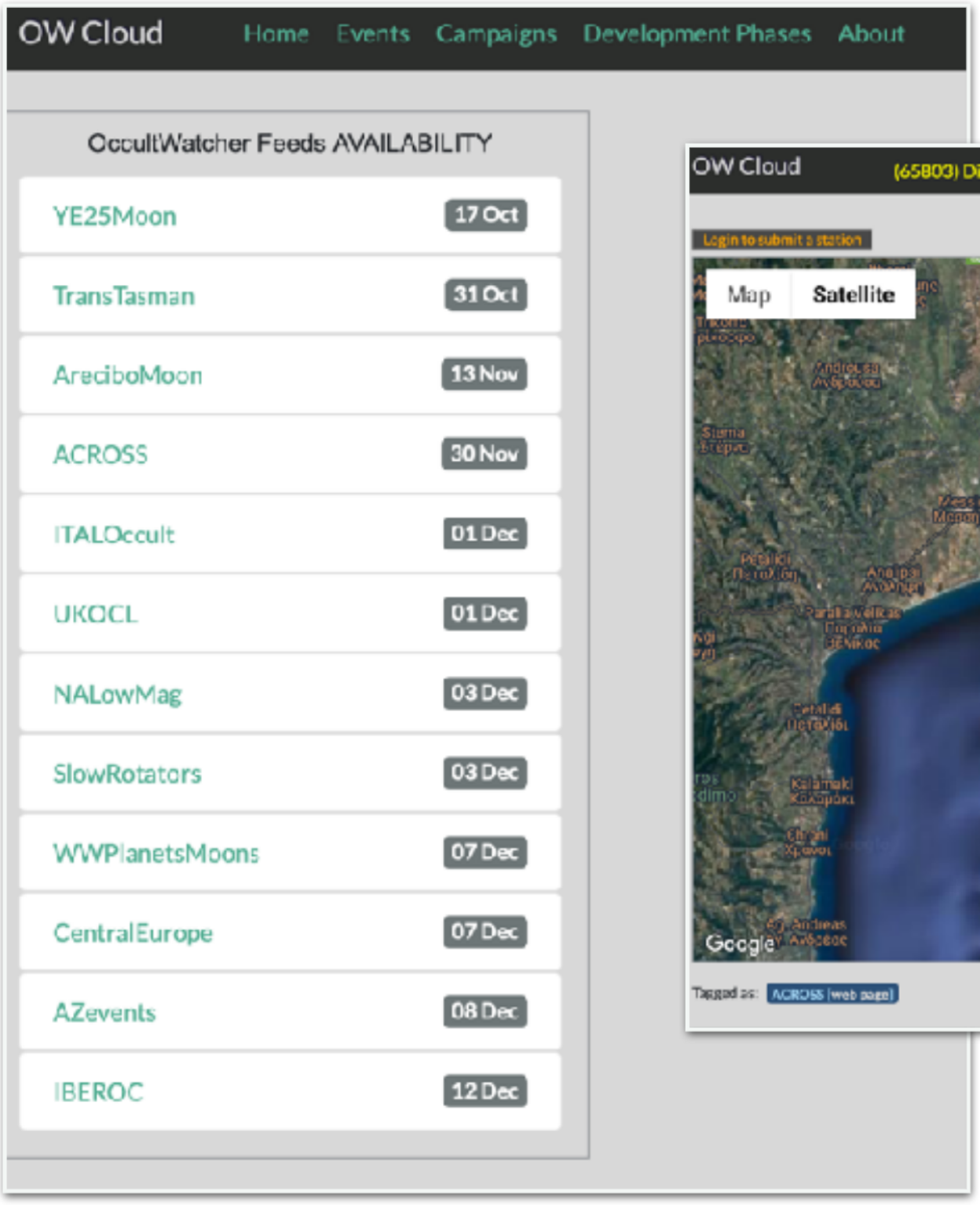


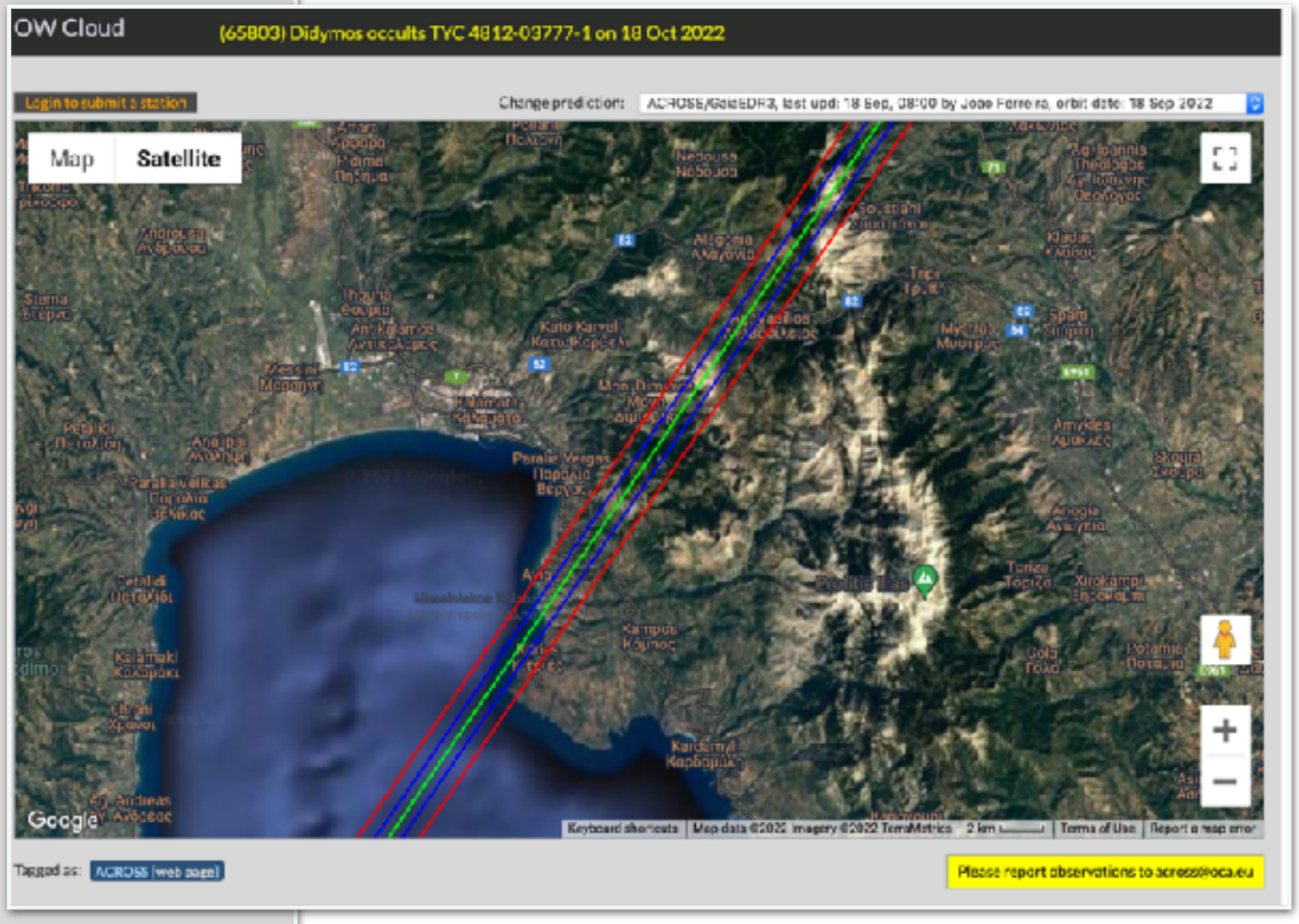




Mailing lists
- Occult (EU)
- IOTA
- IOTA-ES
- IOTA-Asia

Occult Watcher Cloud: support to campaign deployment





Campaign organisation - preliminary actions

- Team of students/staff for conducting the observations trained both in AUTh and OCA/CNRS.
- AUTh and OCA/CNRS : 6 x 16” Dobsonian GoTo telescopes
- 6 x QHY174M/GPS global-shutter GPS-enabled cameras + laptops and battery packs.
- Several collaborators with more equipment (including fixed observatory telescopes).

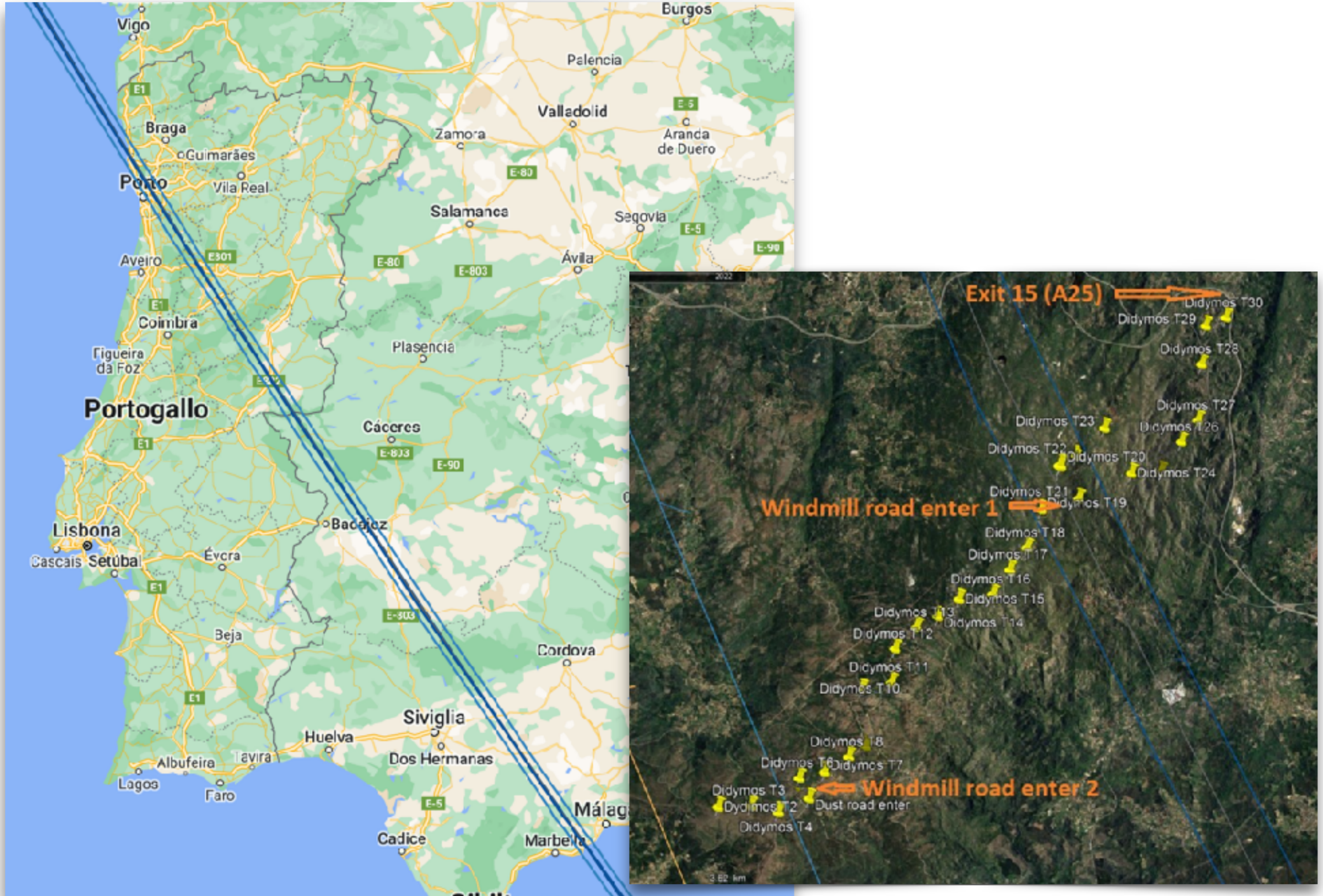
Campaigns

- June 25, 2022 (Arizona, USA), 7 stations deployed (clouds, technical problems, only 2 worked)
- July 24 (Montana, Georgia, USA), 14 stations, clear negative (path was N of the chosen areas)
- July 29 (Japan), 11 stations, 2 failed, path was S
- August 25 (Portugal, Spain) ACROSS
- September 20 (UAE, Oman) ACROSS
- More coming…

Porto, Portugal - August 24, 2022



More than 45 people involved. 21 sites in Portugal, 7 in Spain, 3 in Algeria


Vigo
Burgos
Palencia
Valladolid
Zamora
Aranda de Duero
Braga
Guimarães
Porto
Vila Real
Salamanca
Segovia
Aveiro
Ávila
Coimbra
Figueira da Foz
Plasencia
Portogallo
Cáceres
Lisbona
Cascais
Setúbal
Évora
Badajoz
Beja
Cordova
Siviglia
Huelva
Tavira
Albufeira
Dos Hermanas
Lagos
Faro
Málaga
Cadice
Marbella
E1
E-80
E-803
E-90
E-5
E-503
Exit 15 (A25)
Didymos T30
Didymos T29
Didymos T28
Didymos T27
Didymos T23
Didymos T26
Didymos T22
Didymos T20
Didymos T24
Didymos T21
Didymos T19
Windmill road enter 1
Didymos T18
Didymos T17
Didymos T16
Didymos T15
Didymos T13
Didymos T14
Didymos T12
Didymos T11
Didymos T10
Didymos T8
Didymos T6
Didymos T7
Didymos T3
Windmill road enter 2
Didymos T2
Dust road enter
Didymos T4

Smiles were then totally hidden by fogs…

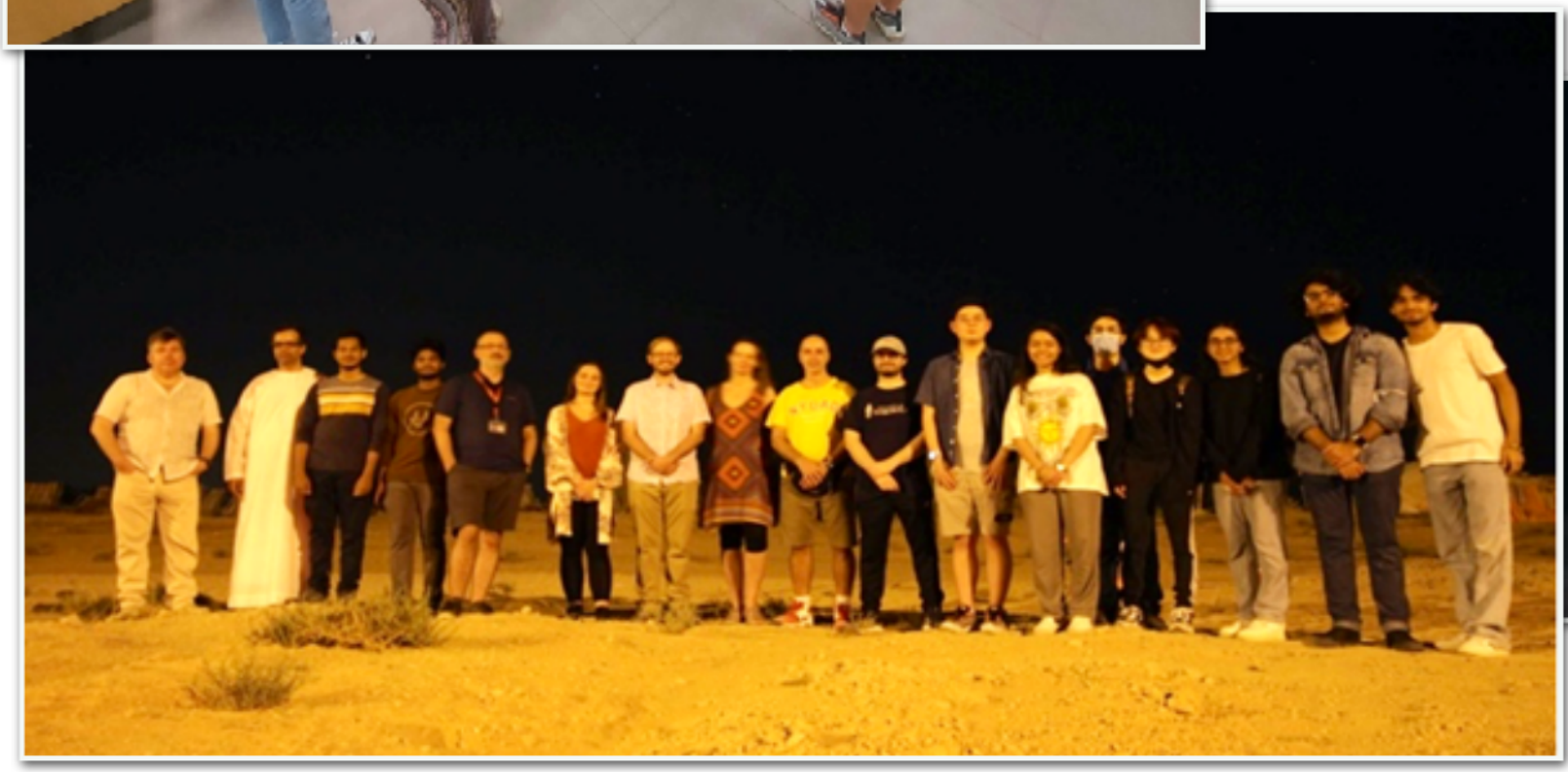


Dubai / Oman, September 20, 2022



Bright star event (V=9.8) - 10 stations deployed.
Collaboration with:

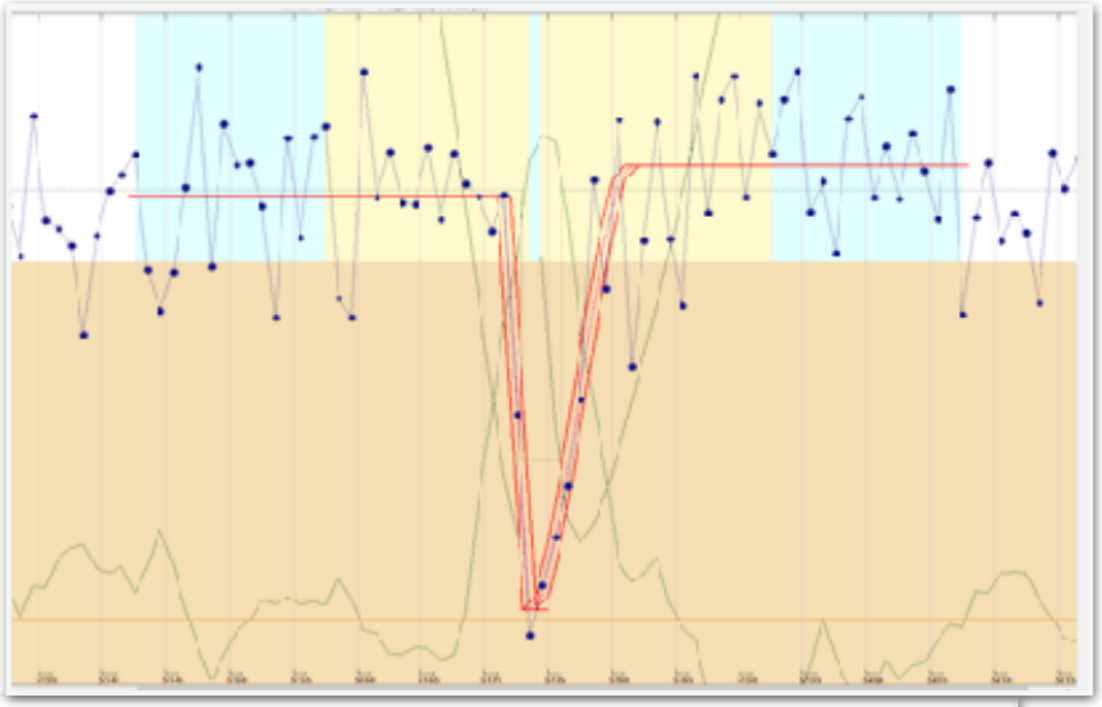
- Unistellar/SETI Institute
- New York University Abu Dhabi
- Mohammed Bin Rashid Space Centre, Dubai
- Sultan Qaboos University in Oman





The outcome of ACROSS - 1

- Dramatic improvement in the orbit accuracy, by a solidly tested procedure, from astrometry to prediction
- Occultation success by the asteroid (385186) 1994 AW1



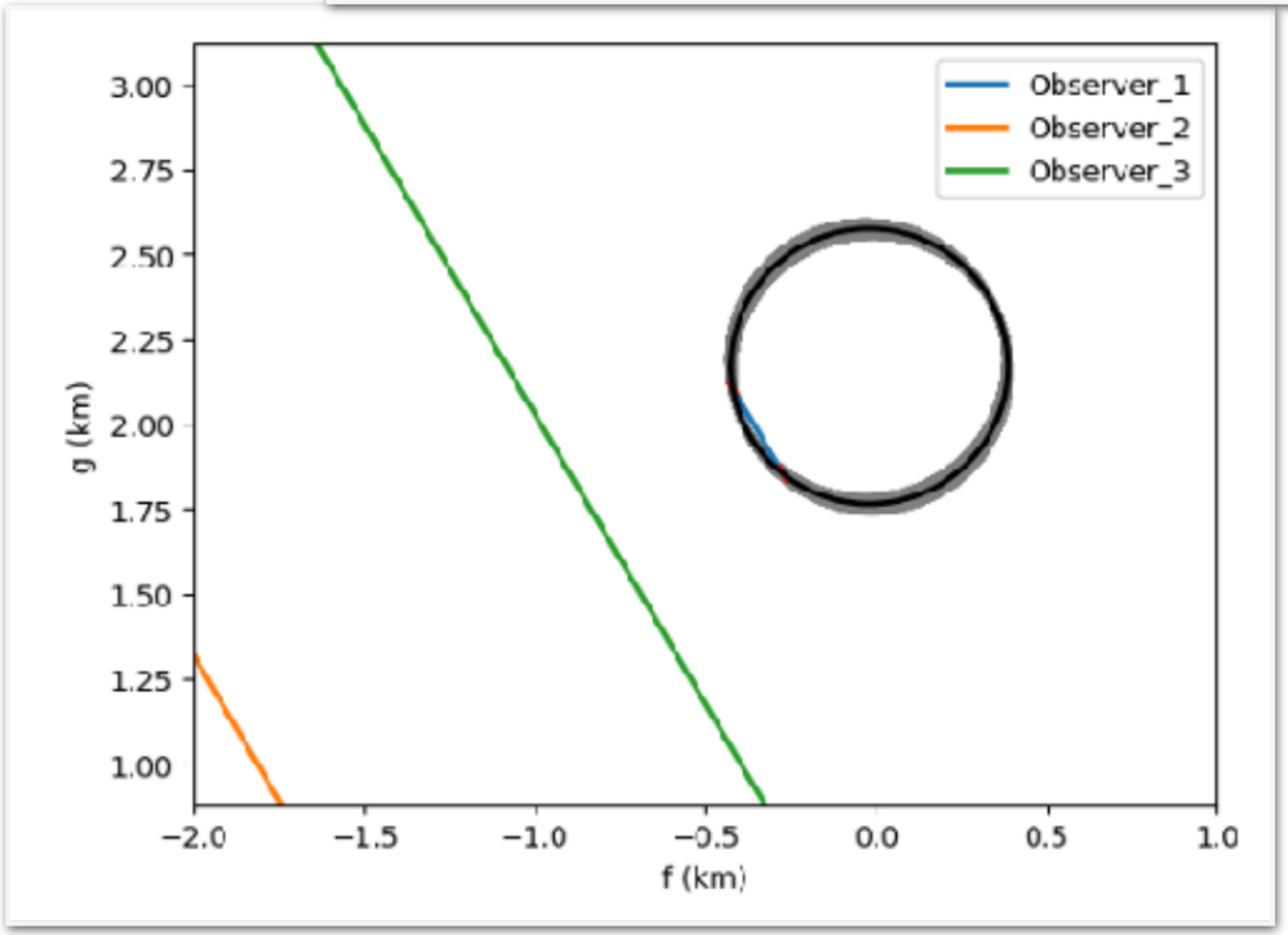
Prediction errors (path widths)

Number	2022/04	2022/07	2022/10
29886	4,39	2,97 *	2,55
42532	5,93	2,48 *	2,66
54212	22,35	9,94	8,29
88992	17,50	8,06 *	6,67
95802	8,33	4,63 *	4,67
122764	18,00	9,56	8,22
169549	25,75	9,32	9,79
188708	47,00	21,00	13,58
477416	54,45	40,05	39,51

+ Gaia DR3 *

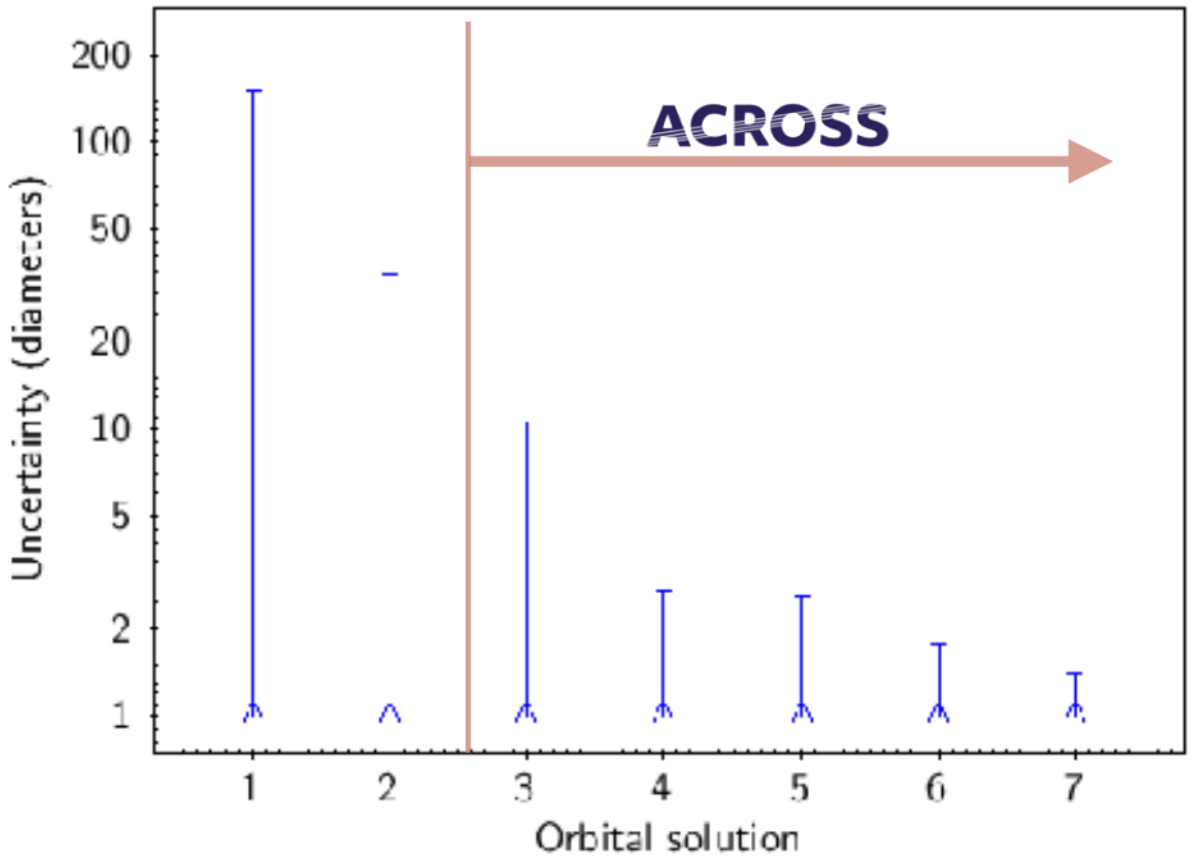
+ ACROSS astrometry

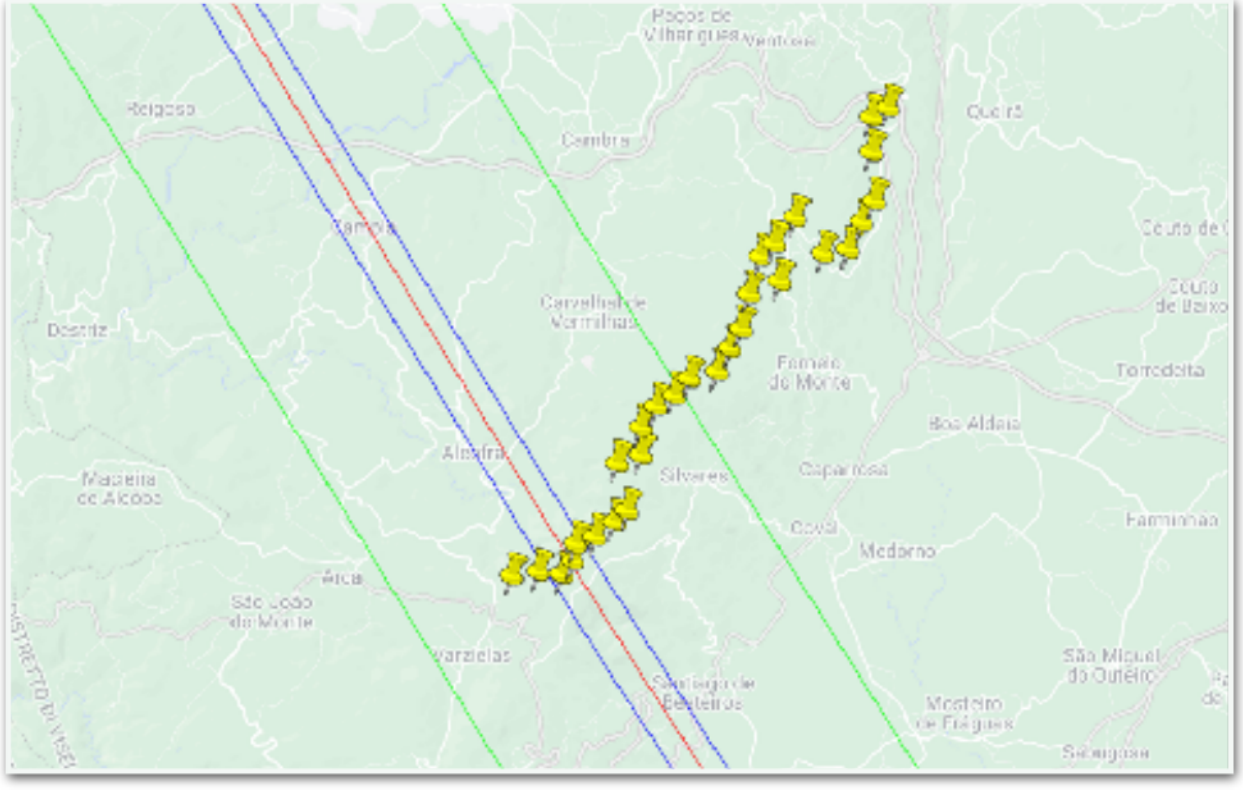
ACROSS



The outcome of ACROSS - 2

- Success for the goal to reach predictability for Didymos
  - Uncertainty nearly = diameter
  - NAV data from DART nicely complement and confirm the quality
- Occultations by Didymos will CERTAINLY be observed
- The campaign in Portugal was candidate to success



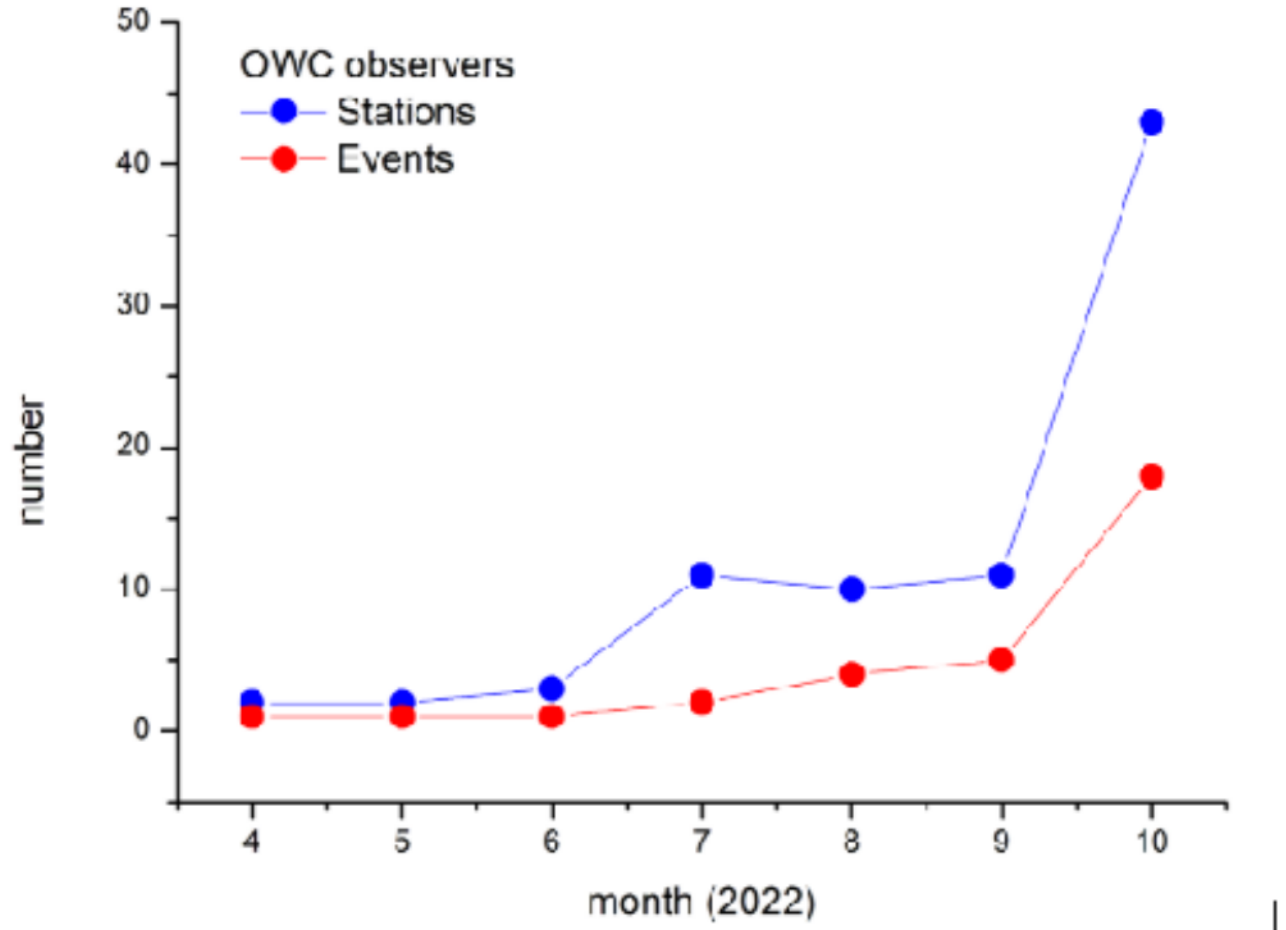


Portugal, August 25 - post-diction

The outcome of ACROSS - 3

A brand, growing motivation, a community of observers

ACROSS



Conclusions - main improvements brought by ACROSS

- Orbit computation
  - Reached the goal of very demanding accuracy on ephemeris error (0.5 km)
  - Full exploration and consolidation of subtle effects
    - In astrometry: differential chromatic refraction, weighting
      - Total of 16 telescopes contributing, 2029 astrometric measurements
    - In orbits: reference systems
- Integrated approach with space missions
  - NASA/DART
  - ESA/Gaia
- Strong visibility for challenging NEA events
  - 100s of observers reached, several 10s active
- New experience on campaign organisation, in situ and remotely
  - Logistic aspects, choice of sites, practical issues
- Enable the observations of occultations by (65803) Dydimos

Summary slides

THE ACROSS SYSTEM

cnrs · OBSERVATOIRE DE LA CÔTE D'AZUR · UNIVERSITÉ CÔTE D'AZUR · ARISTOTLE UNIVERSITY OF THESSALONIKI

ACROSS
Asteroid Collaborative Research via Occultation Systematic Survey

Complementary astrometry



Prediction details and planning

OW Cloud

Orbit improvement
Prediction computation refinement and diffusion
Exploitation of astrometry
Campaign organisation

esa

Results

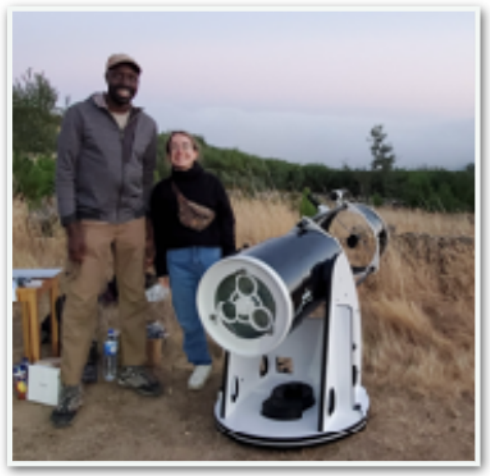


Space missions

DART
Double Asteroid Redirection Test

esa
hera

Observers



Mailing lists

- Occult (EU)
- IOTA
- IOTA-ES
- IOTA-Asia