7th IDPASC PhD school

# Astrophysics in Padua

(overview of what you will not hear about)

Massimo Turatto

## University

DFA

- G.Galilei + Specola + Asiago
- degree + PhD
- 20 staff researchers (for Aph)

Center G. Colombo

- DFA, DEI, DII, Geo, ...
- PhD
- 10 sta
- S vs Applied vs Ind Research

## CNR - IFN

- technology (optics, ...)

## INAF

- reference Institute for Aph (int'l relations with ESO, FGG-Canarie, LBT, SKA, ...)
- 17 Institutes
- 1000 people, 550 researchers + 250 associati
- Astronomical Observatory Pa go)
- 50 staff rese

x 1.5 including PhD students, postdocs, ...

## INFN

- Nataional Institute for Nuc. Phys
- 4 Nat. Labs + Sections
- PD: LNL + Section@DFA
- 10-15 staff researchers (for Aph)

# Fields of activity

- teaching (Phys/Aph + PhD)
- fundamental and applied research
- technology (ground/space, opt/detect/electr/..)
- outreach (PD & AS)

# Asiago

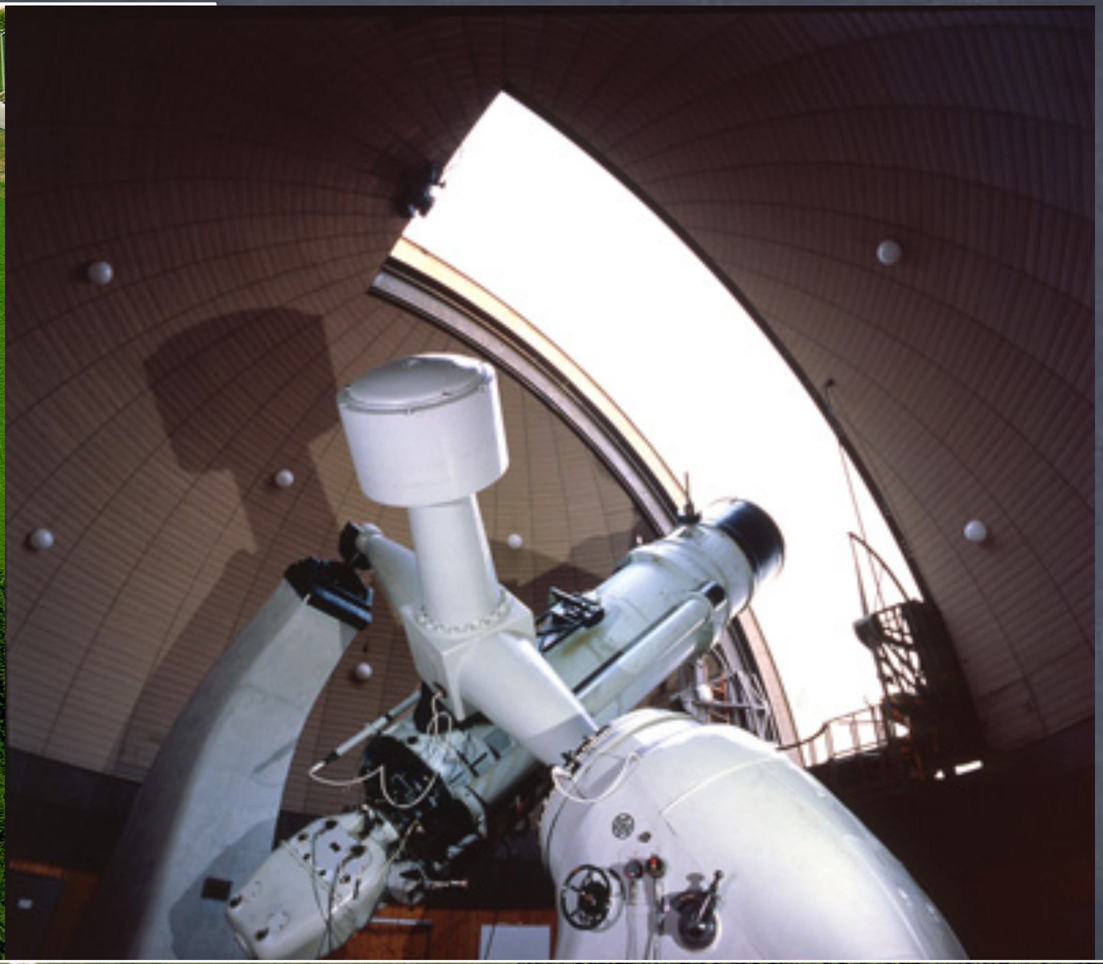
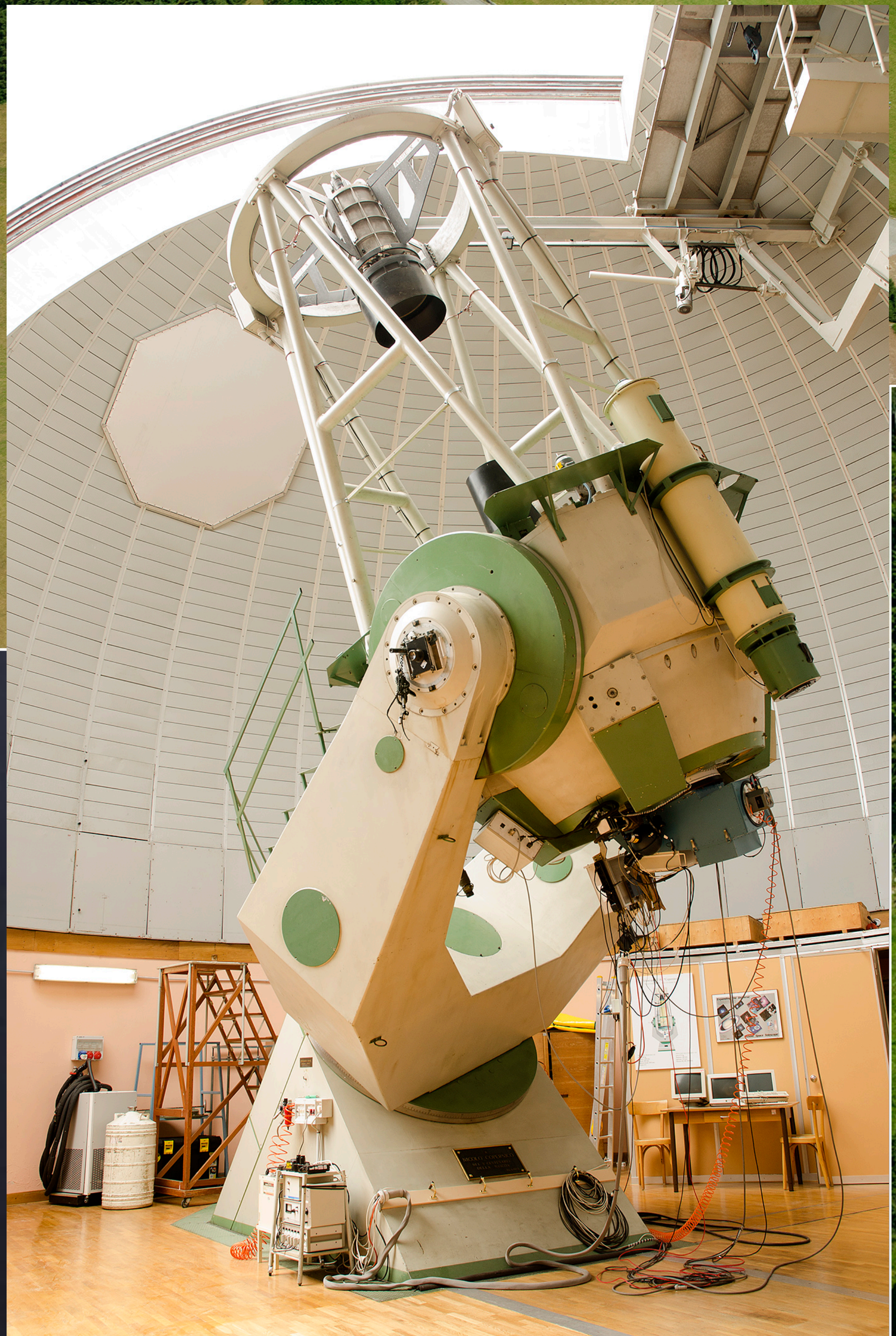
telescopes:

- 1.8m opt phot+low-res spec
- 1.2m low-res spec
- 0.67/0.92 Schmidt, WF Imaging
- joint control room

offices and classrooms:

- Pennar site (DFA)

- fully efficient
- not-ideal location but flexibility (!!)


# Major challenges in Astronomy over the next decade

- Solar, interplanetary and magnetospheric physics
- The Solar System
- Extrasolar Planetary Systems
- Star Formation (local and global)
- Stellar Evolution
- Relativistic astrophysics and astroparticles
- The Milky Way and the Local Group
- Formation and Evolution of Galaxies and Cosmic Structures
- Cosmology and Fundamental Physics
- Enabling Technologies

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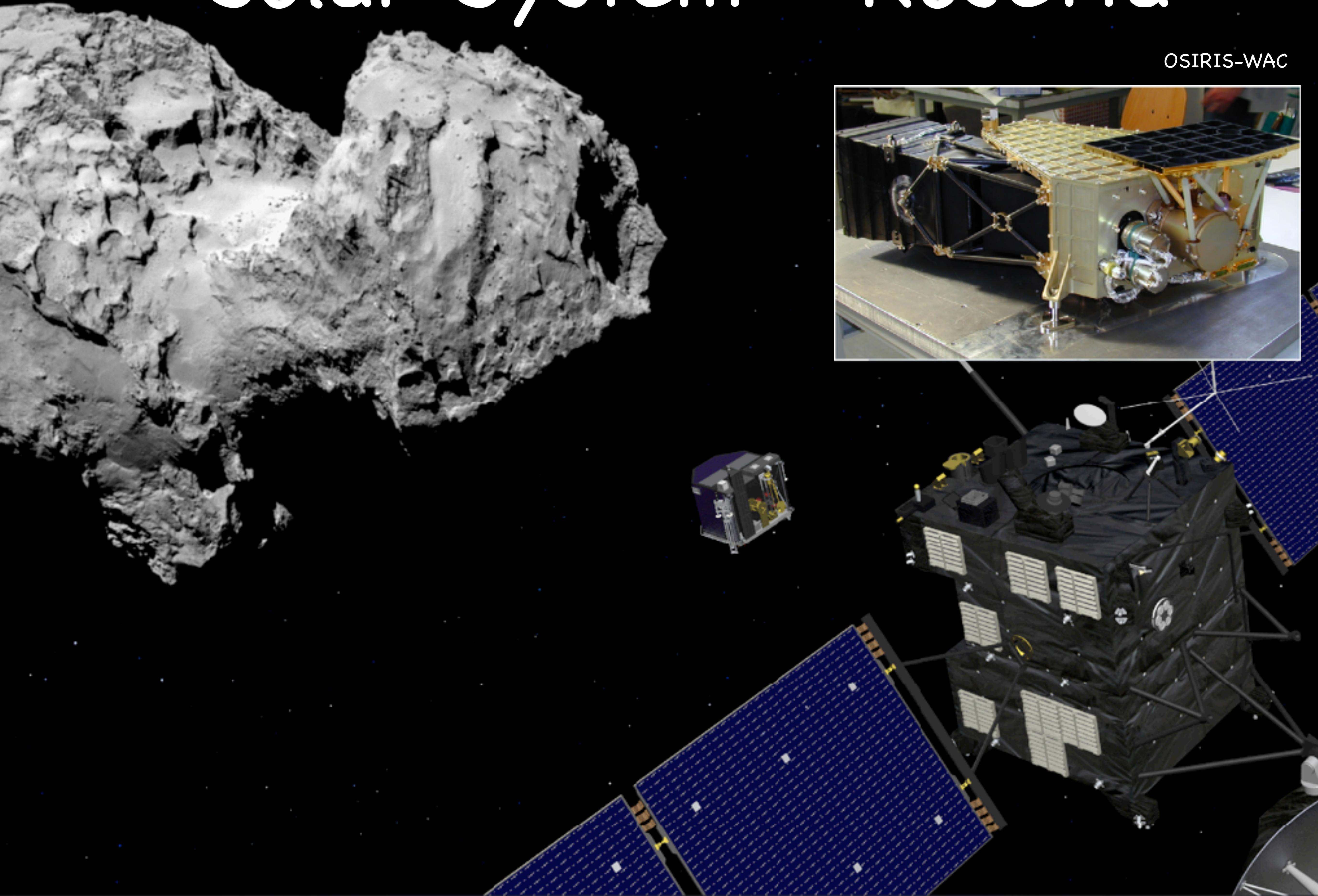
in Padua

no mention

no mention

# Solar System - Rosetta

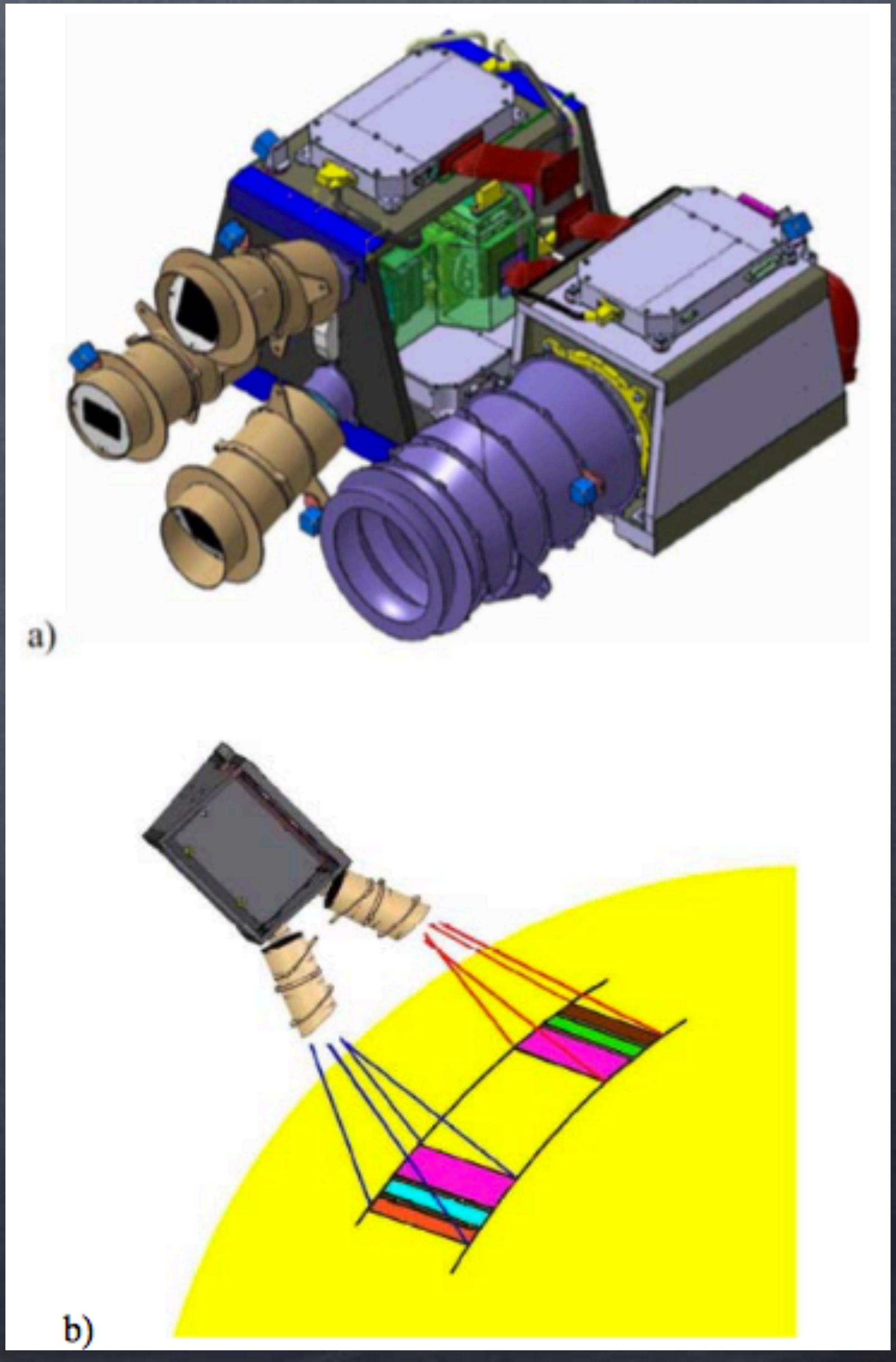


OSIRIS-WAC

# other SS missions

INAF - Cisas - DFA - CNR

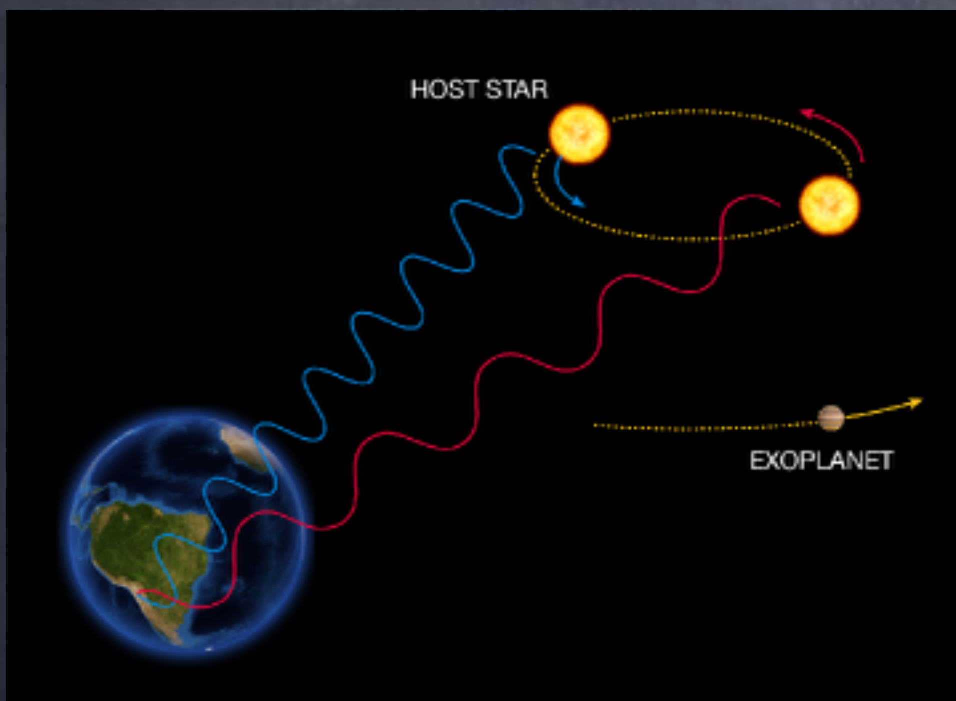
- Exomars (2016-2020)
- Bepicolombo (2018=>2025)
- Juice (2022=>2030)
- Solar Orbiter (2018)
- Joint Lab Deep Space Robotics

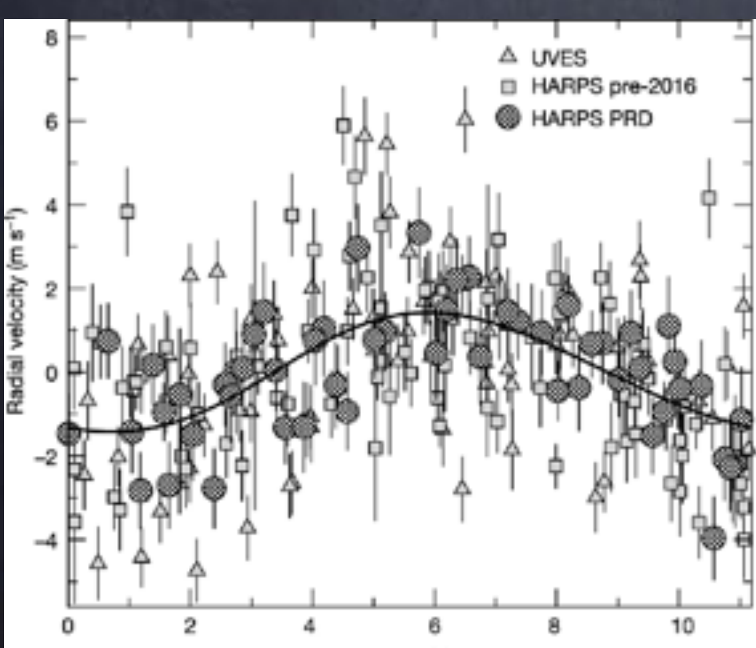



Simbio-Sys
stereo-camera

# Exoplanets

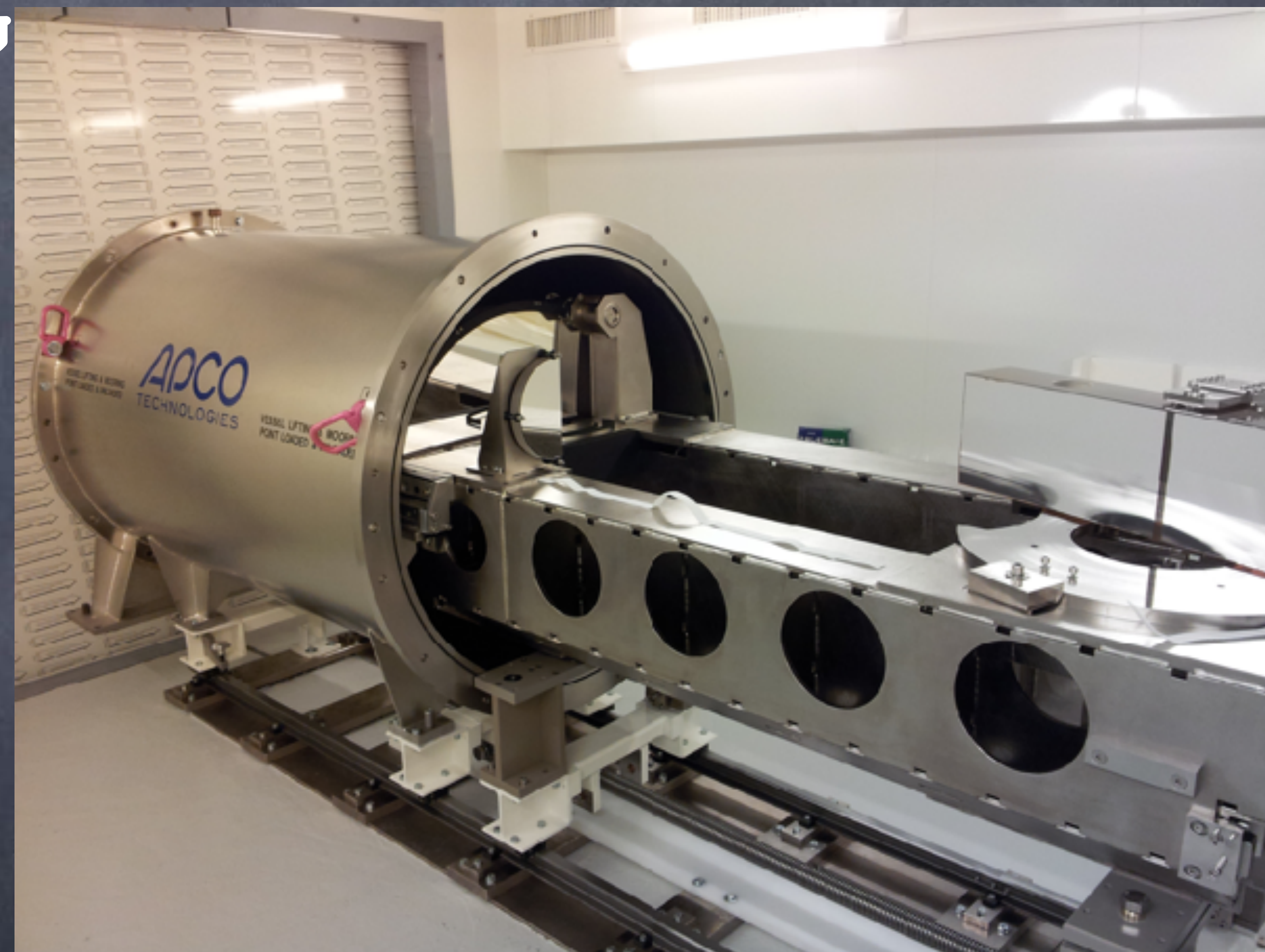
## Harps-N@TNG




Proxima Cen B

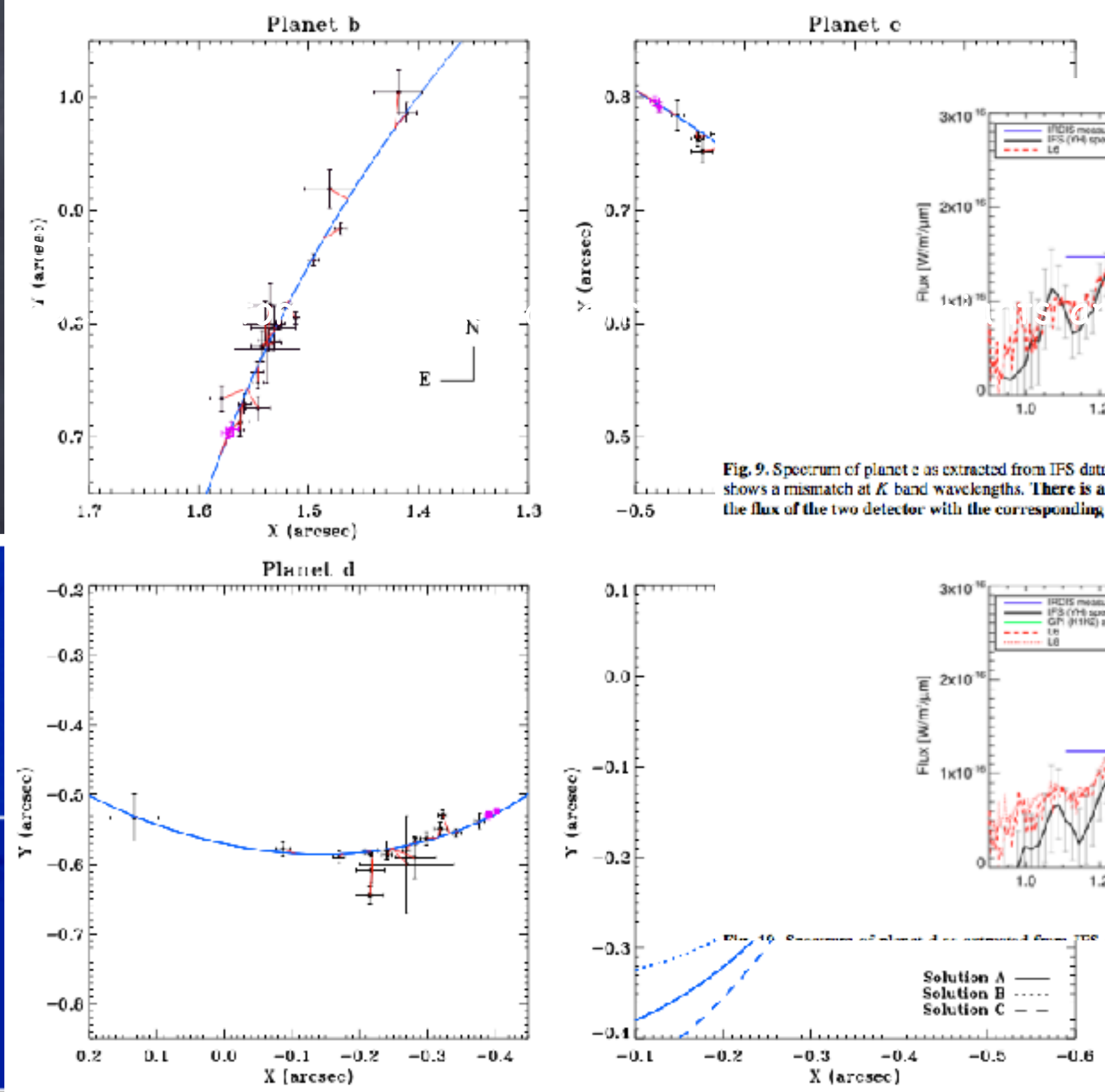
Harps-S




best achievable accuracy (0.3 m/s)

stability: mechanical, thermal, pressure

# Exoplanets



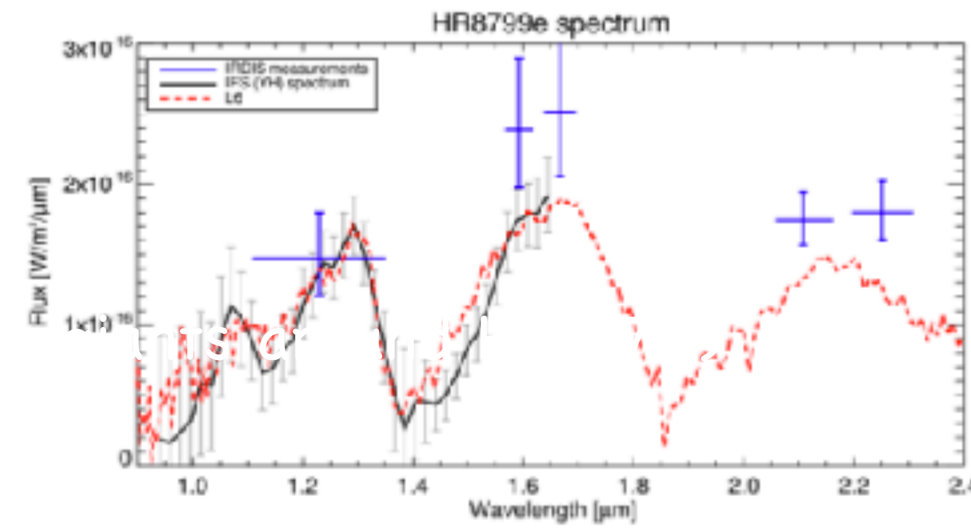
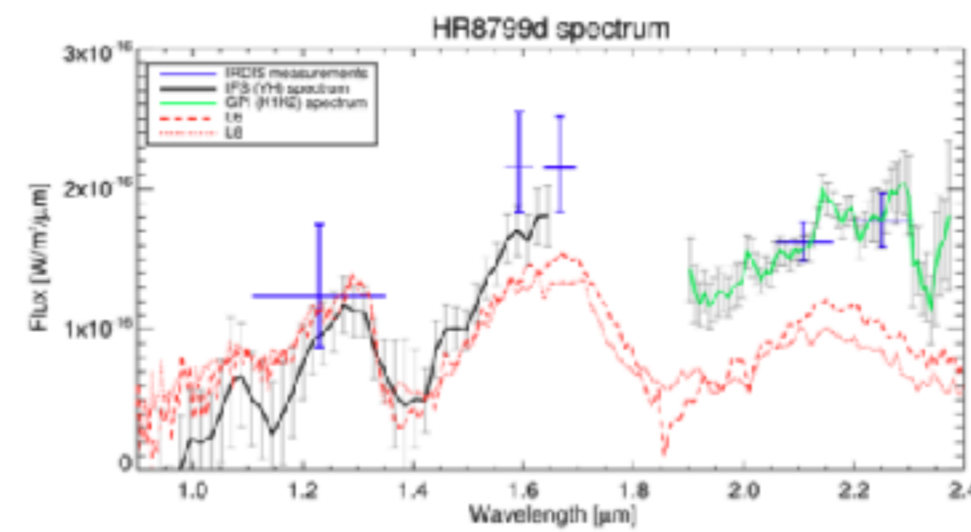




Fig. 9. Spectrum of planet e as extracted from IFS data. IRDIS photometric points are overplotted. A comparison with an L6 isolated brown dwarf shows a mismatch at $K$ band wavelengths. **There is a slight mismatch between IRDIS and IFS measurements, as we normalized separetely the flux of the two detector with the corresponding PSF, the offset could be induced by another variable.**



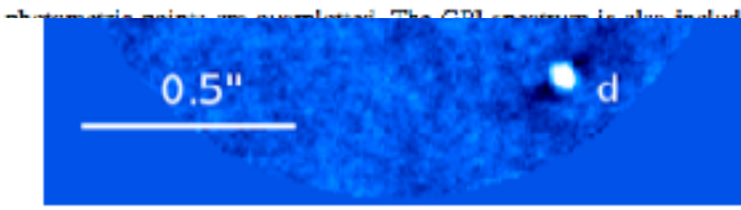



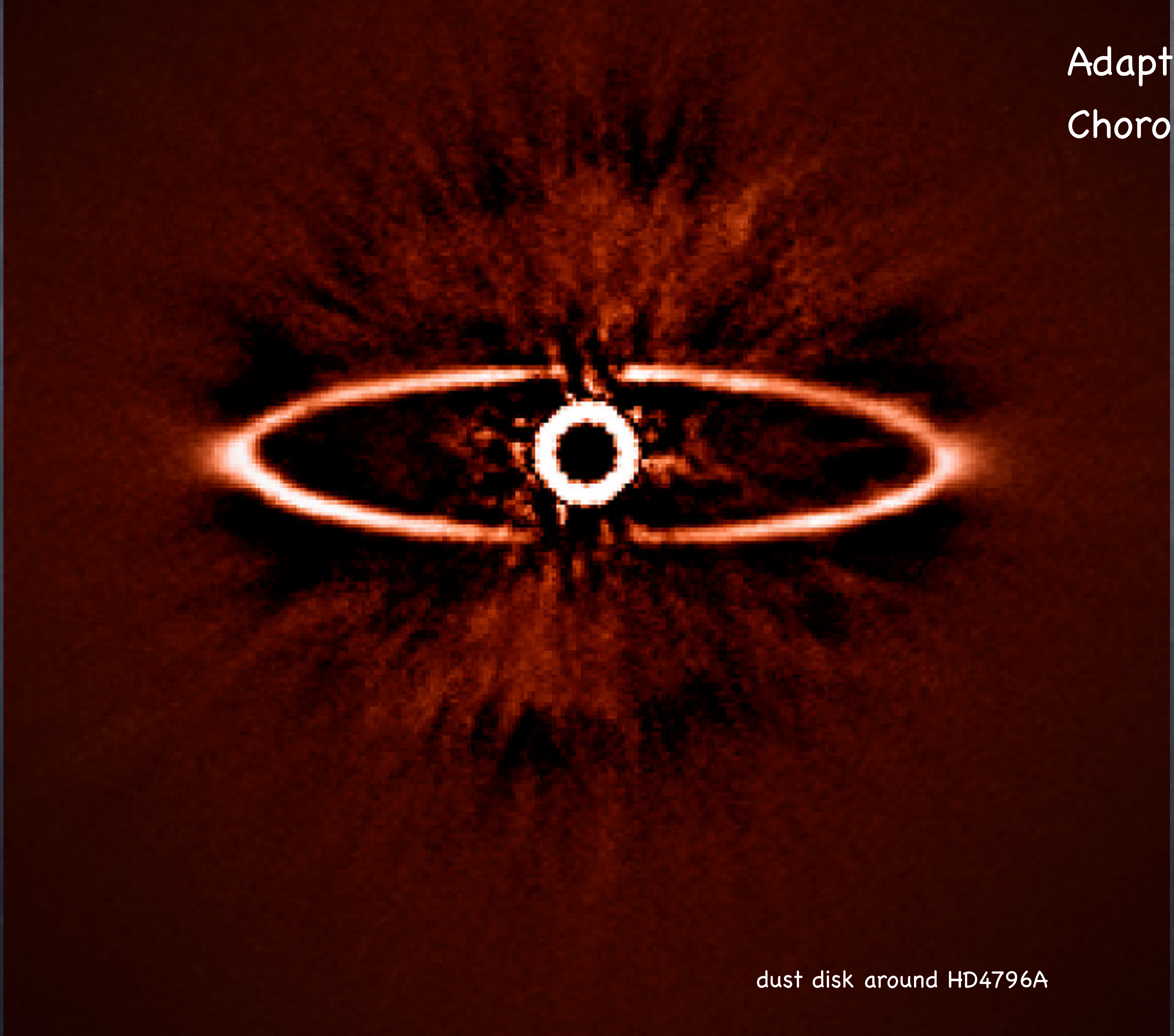

Fig. 2. Image of the 38th IFS spectral channel (1.63 $\mu$m) with planets HR 8799 de obtained with KLIP reduction.

Fig. 5. Relative astrometry for the planets around HR 8799. The points available from the literature are represented in black filled circles, while new SPHERE measurements are represented in purple filled squares. The solid blue lines represent the orbital solution labeled "A" in Table 5. Red lines connect the predicted and observed positions for all the data points. The dotted and dashed lines in the panel for HR 8799 e indicate the orbital solutions labeled "B" and "C" in Table 5, respectively.

# VLT - SPHERE

Adaptive Optics

Choronography



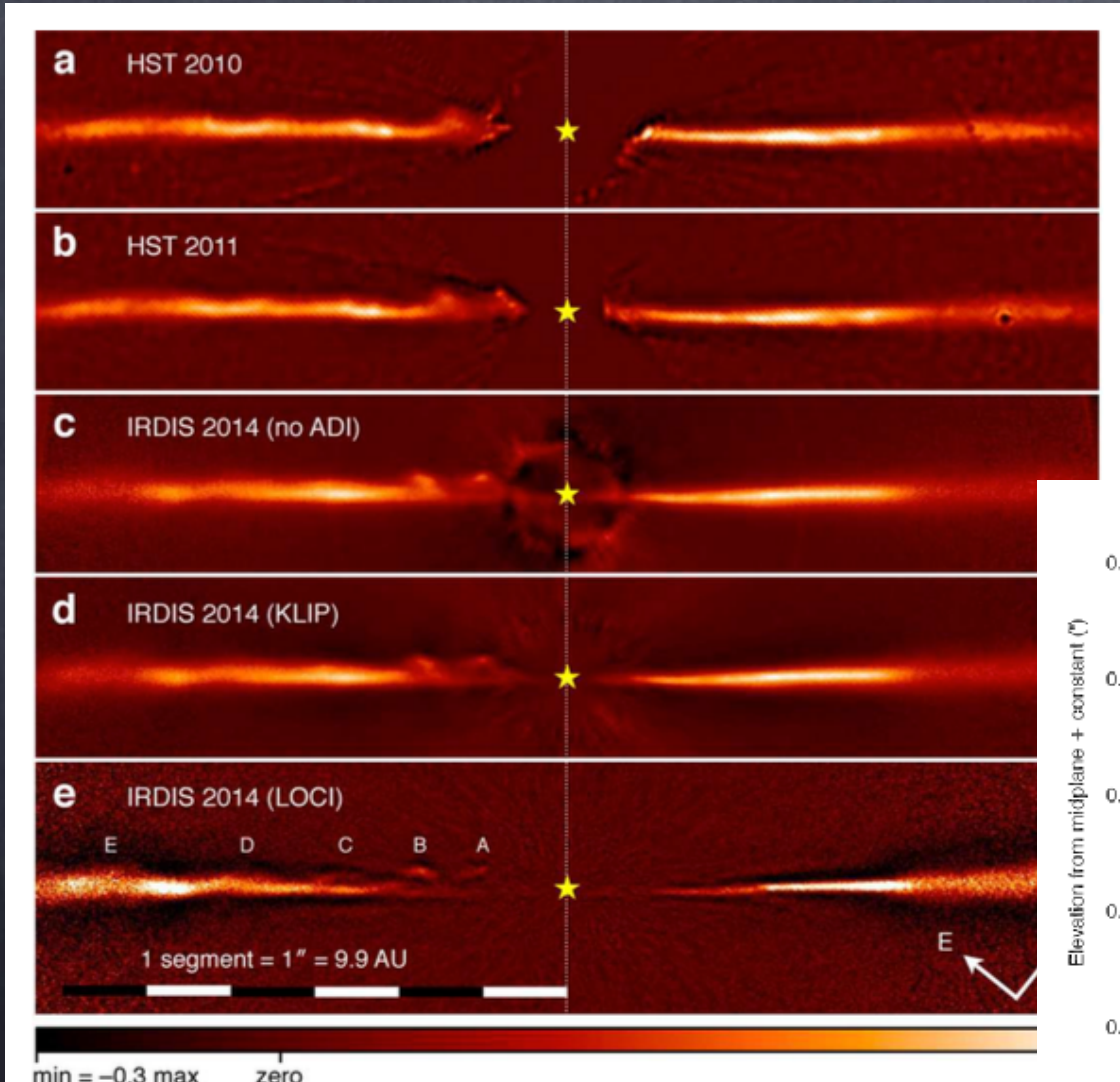
dust disk around HD4796A

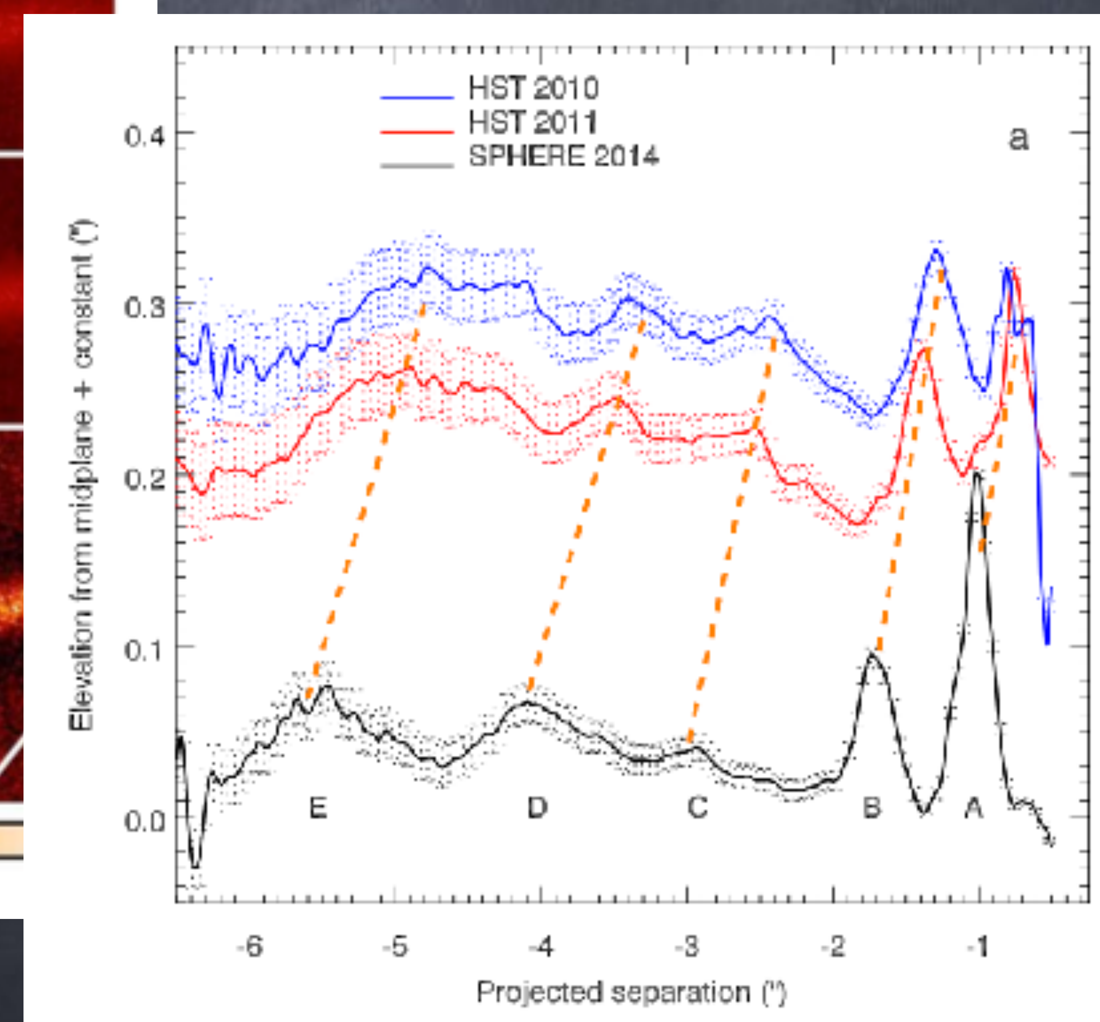
# Dusty disk around AU Mic

Boccaletti et al. Nature, 2015

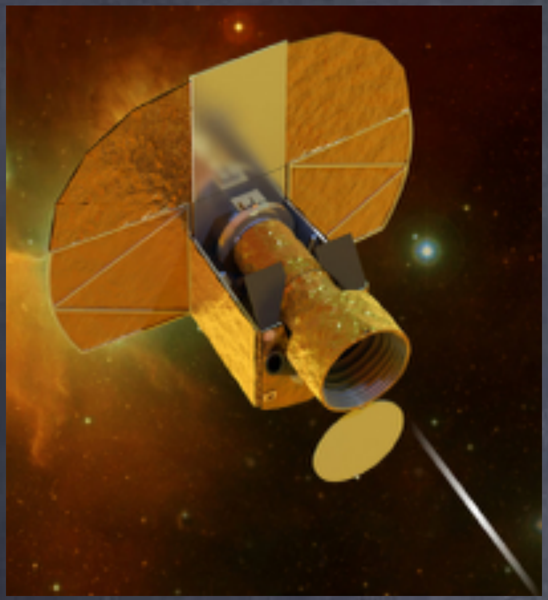
- Beta Pic group
- M1Ve flaring
- $P_{rot}$ =4.9d
- D= 9.9 pc
- age = 12 Myr

- HST (2 epochs)
- Sphere J-band ==> 0.17 arcsec
- 5 knots
- coherent evolution
- invisible planet at about 10-15 AU ?



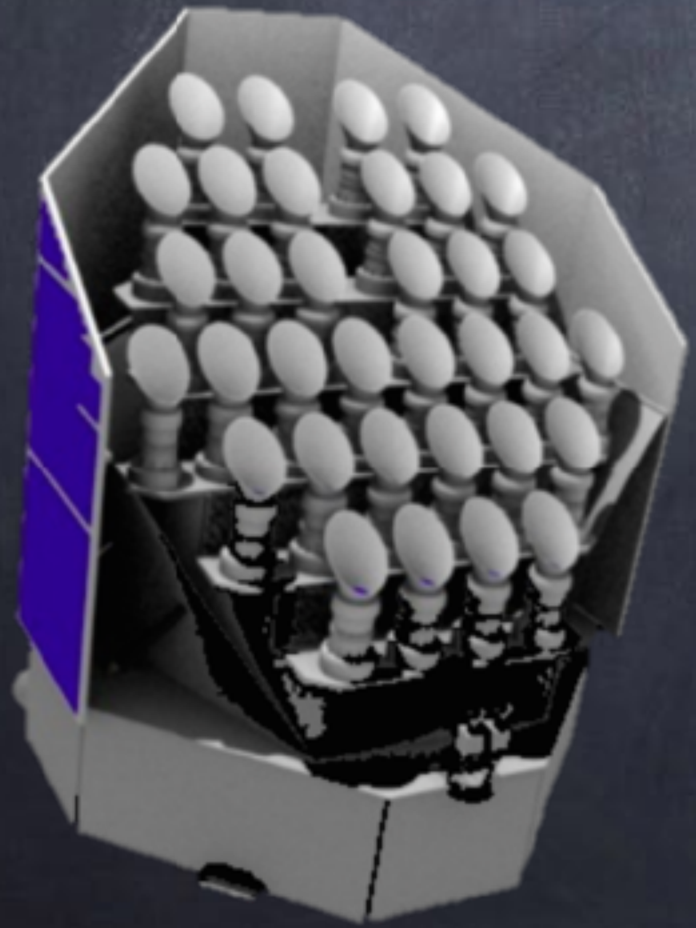



# Exoplanets



## Cheops (2018)

- ESA S-class in Low-orbit
- characterisation of ExoPl (atmosph, radii, II eclipse for superEarth)
- design of mirror & focal plane, science



## Plato (2025)

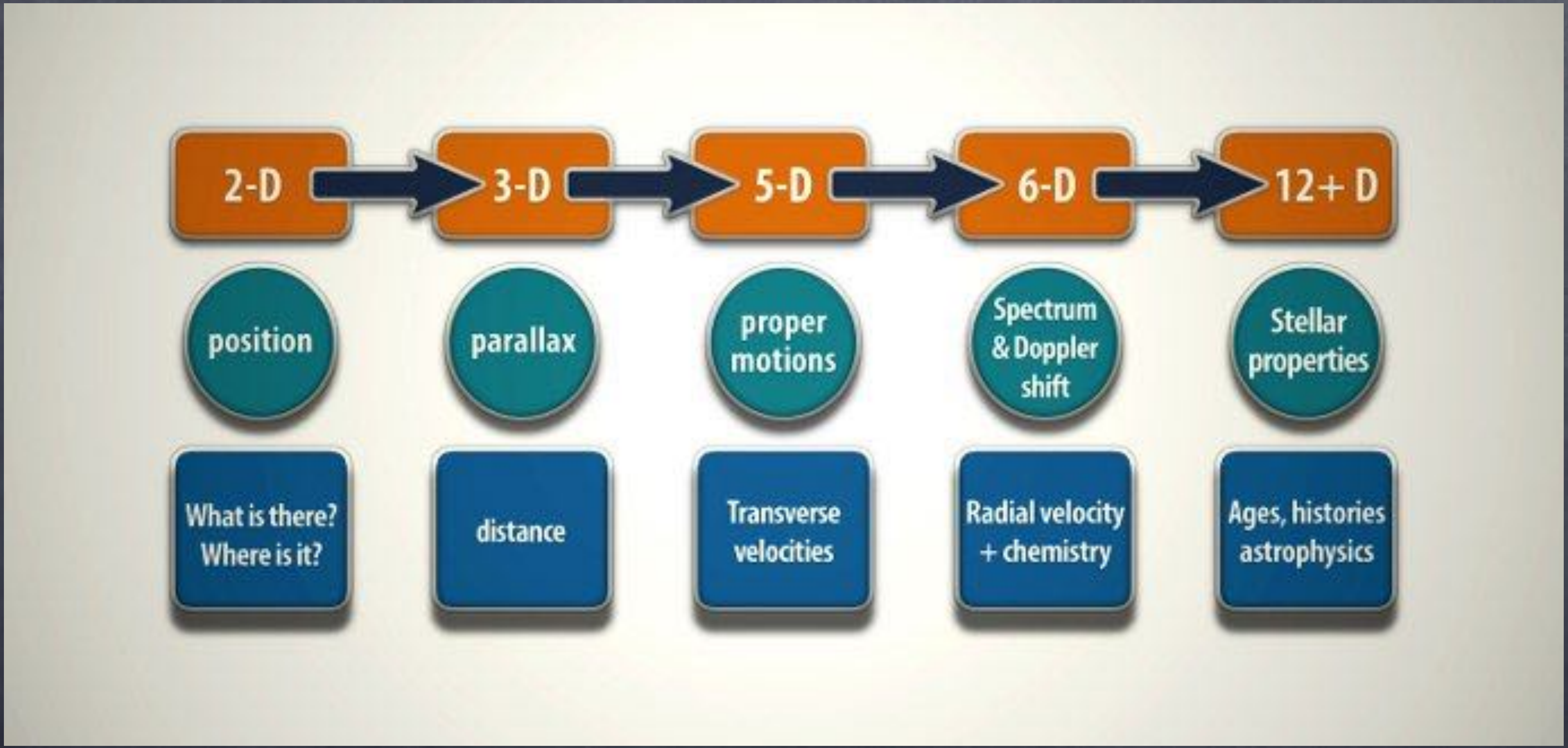
- ESA M-class in L2
- 24 telescopes. Super-Kepler
- search/characterisation of Earth-like in the habitable zone
- design of mirror & focal plane, science

http://www.cosmos.esa.int/web/gaia/presentations

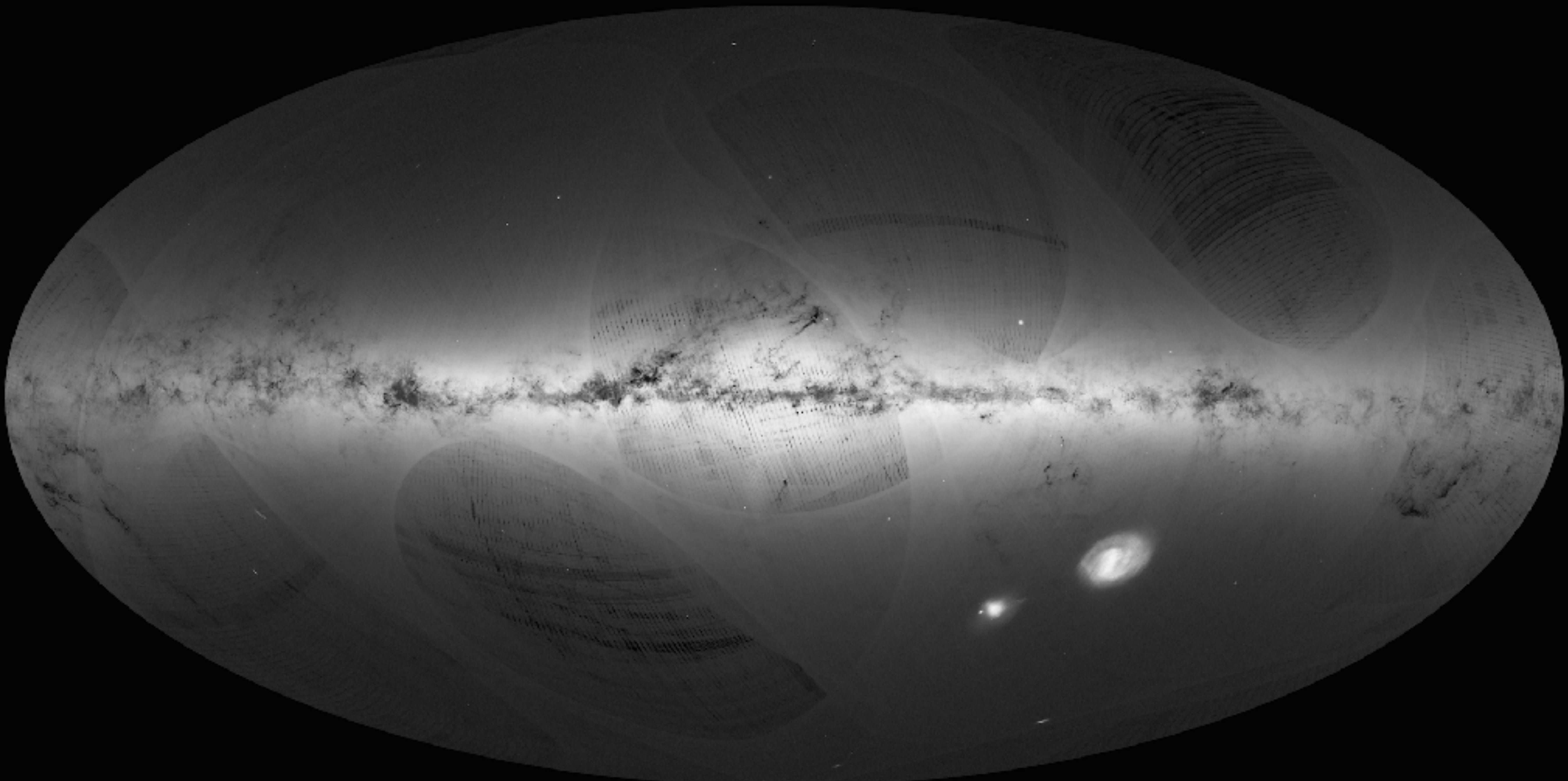
# ESA-Gaia (2013)

- Astrometry (G < 20 mag):
  - completeness to 20 mag (on-board detection) ⇒ $10^9$ stars
  - accuracy: 26 μarcsec at G=15 mag (Hipparcos: 1 milliarcsec at 9 mag)
  - scanning satellite, two viewing directions
    ⇒ global accuracy, with optimal use of observing time
  - principle: global astrometric reduction (as for Hipparcos)
- Photometry (G < 20 mag):
  - astrophysical diagnostics (low-dispersion photometry) + chromaticity
    - $\Delta T_{eff}$ ~ 100 K, log g, [Fe/H] to 0.2 dex, extinction (at G=15 mag)
- Radial velocity (GRVS < 16 mag):
  - accuracy: 15 km s-1 at GRVS=16 mag
  - application:
    - third component of space motion, perspective acceleration
    - dynamics, population studies, binaries
    - spectra for GRVS < 12 mag: chemistry, rotation
  - principle: slitless spectroscopy in Ca triplet (845-872 nm) at R = ~10,800

# Milky Way in 6/12 D




How big? How old? What mass? Which shape ? How fast they move? Where different stars are located?...



Sept. 2016: $1^{st}$ data release

1yr observations

$10^9$ stars (largest cat to date)

(artefacts due to scanning)

# Transients


- Novae
- Symbiotic stars
- X-ray binaries
- Thermonuclear Supernovae
- Core-Collapse Supernovae
- Interacting Supernovae
- SN impostors
- EM counterparts of GW

activity:

- identification
- classification
- ph. characterisation (energetics, M, T, ...)
- physical nature (exp. mechanism, ..)
- instrumentation (SoXS, ...)

# GASP GAs Stripping Phenomena in galaxies

IFS survey with MUSE

114 galaxies in various environments

$z=0.04-0.07$

$M= 10^{9.2}-10^{11.5} M_\odot$

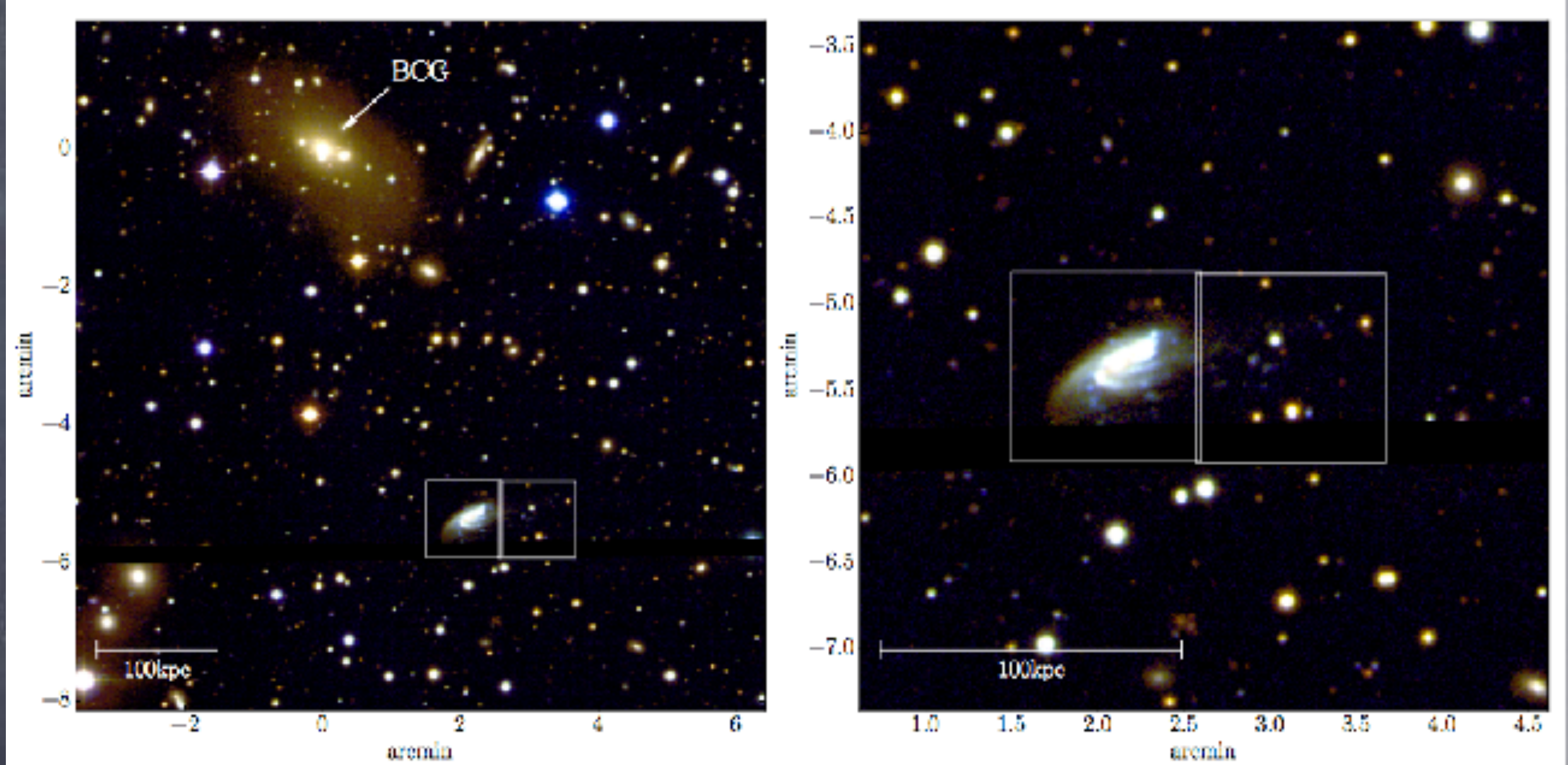



Figure 3. Left. RGB image (OMEGAWINGS u, WINGS B and V) of the central region of the cluster IIZW108, with the forming BCG and the two MUSE pointings for JO206 highlighted. North is up, and east is left. Right. The same RGB image zoomed on JO206.

Goal:

- time-scale and the efficiency
- amount of stars formed in the stripped gas
- speed of the galaxy in IGM
- physical process/es responsible for outflow
- evolution of the galaxies
- galaxy velocity and velocity dispersion maps

# Theory and Modelling

- stellar evolution
- population synthesis
- hydrodynamic models of stellar systems
- NS-NS merging
- N-body simulations of cosmic structures
- primordial fluctuations
- modified gravity
- N-body simulations for evolution of planetary systems
- ...

# Thermally Pulsing AGB stars

stellar evolution
nucleosynthesis
pulsation
stellar winds
dust formation
dust growth

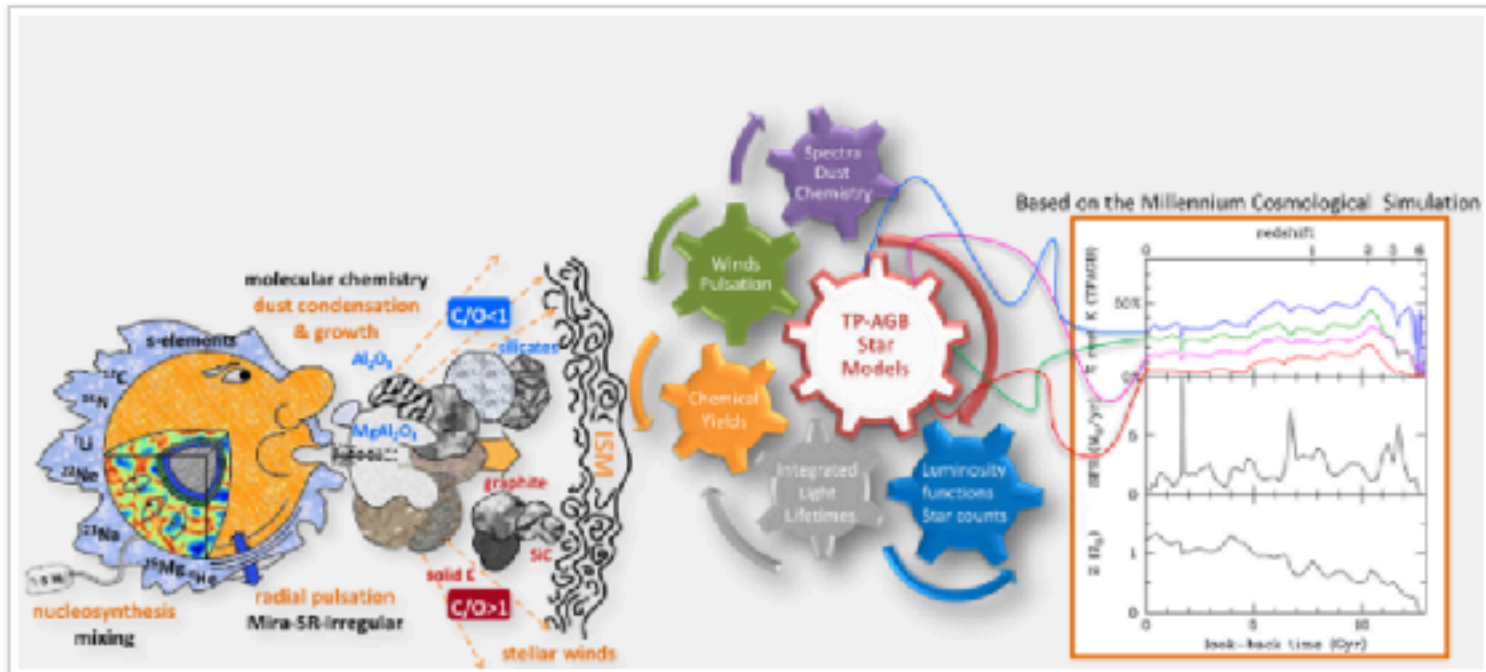
VS

high-quality data
of clusters & galaxies

HOME

## Solving the TP-AGB STAR Conundrum: a KEY to Galaxy Evolution

The impact of the Thermally Pulsing Asymptotic Giant Branch (TP-AGB) stellar evolutionary phase is widespread across astrophysics, impinging on a plethora of aspects, from the chemical composition of meteorites belonging to the pre-solar nebula up to the derivation of galaxy's properties in the high-redshift Universe.
In spite of its importance, the modelling of TP-AGB is still affected by large uncertainties that propagate into the field of extragalactic astronomy, degrading the predicting power of current population synthesis models of galaxies.

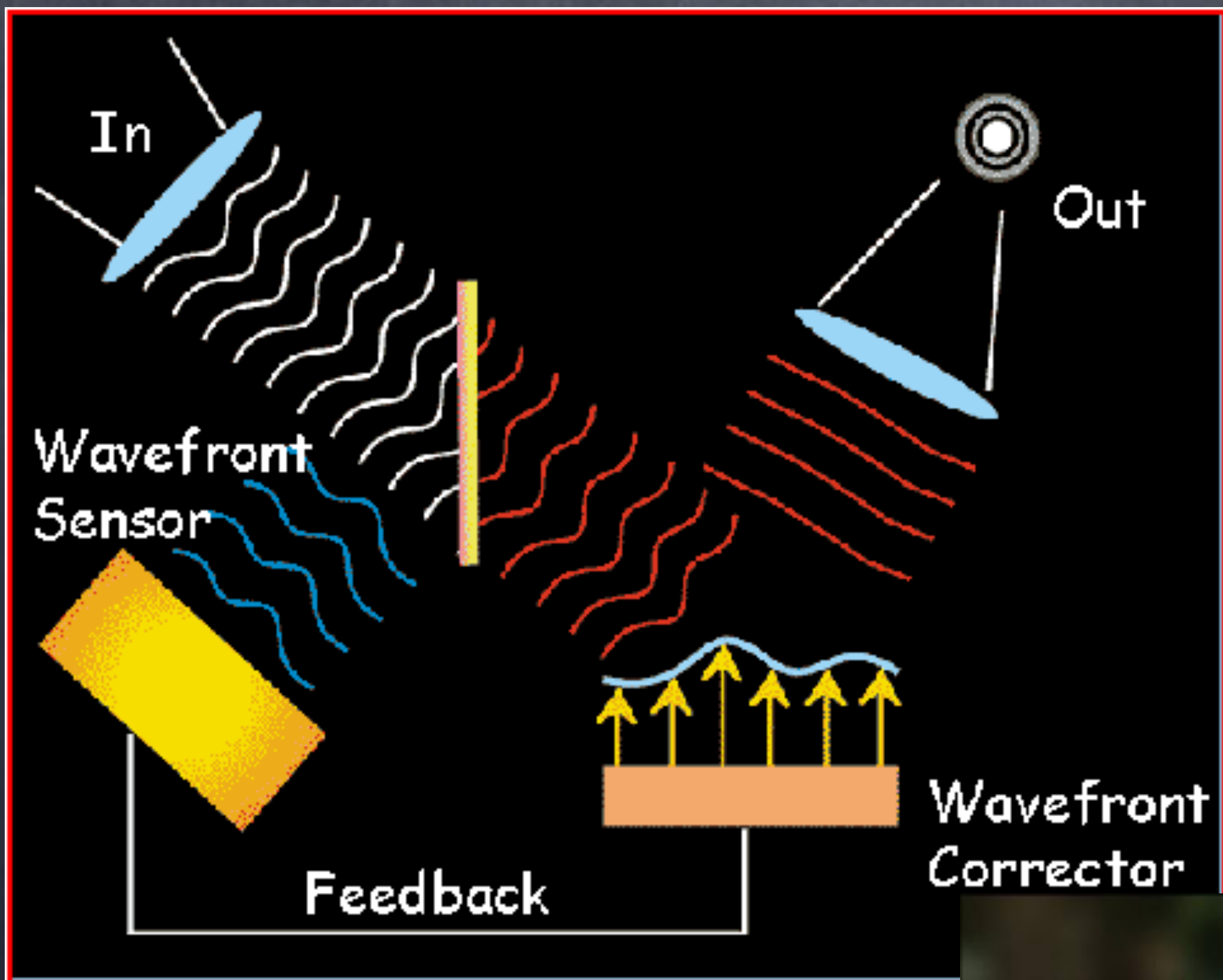



The major goal of the **STARKEY** project is to remedy this persistent condition of uncertainty and controversy. The solution to the TP-AGB star conundrum will be provided by a new approach, which stands on the optimised integration of a) state-of-the-art theoretical tools to account for the complex physics of TP-AGB stars (evolution, nucleosynthesis, pulsation, winds, dust formation, etc.), and b) exceptionally high-quality observations of resolved TP-AGB stellar populations in stars clusters and nearby galaxies (Magellanic Clouds, M31, M33, dwarf galaxies) with reliable measurements of their star formation histories.

The **STARKEY** project adopts a global calibration method, in which TP-AGB evolution models are required to simultaneously reproduce a set of well-defined observational constraints (star counts, distributions of luminosities, colours, pulsation periods, dust mass-loss rates, expansion velocities of dusty envelopes, etc.).

**STARKEY** aims to provide the community with wide-spread deliverables. We will publicly release well-tested 'TP-AGB products', including stellar tracks, libraries of stellar spectra (both static and dynamic), isochrones in all photometric systems, and chemical yields for both gas and dust. Eventually these products will be embedded in the stellar population synthesis models that are routinely used to analyse the integrated galaxy observables that probe the extragalactic Universe.

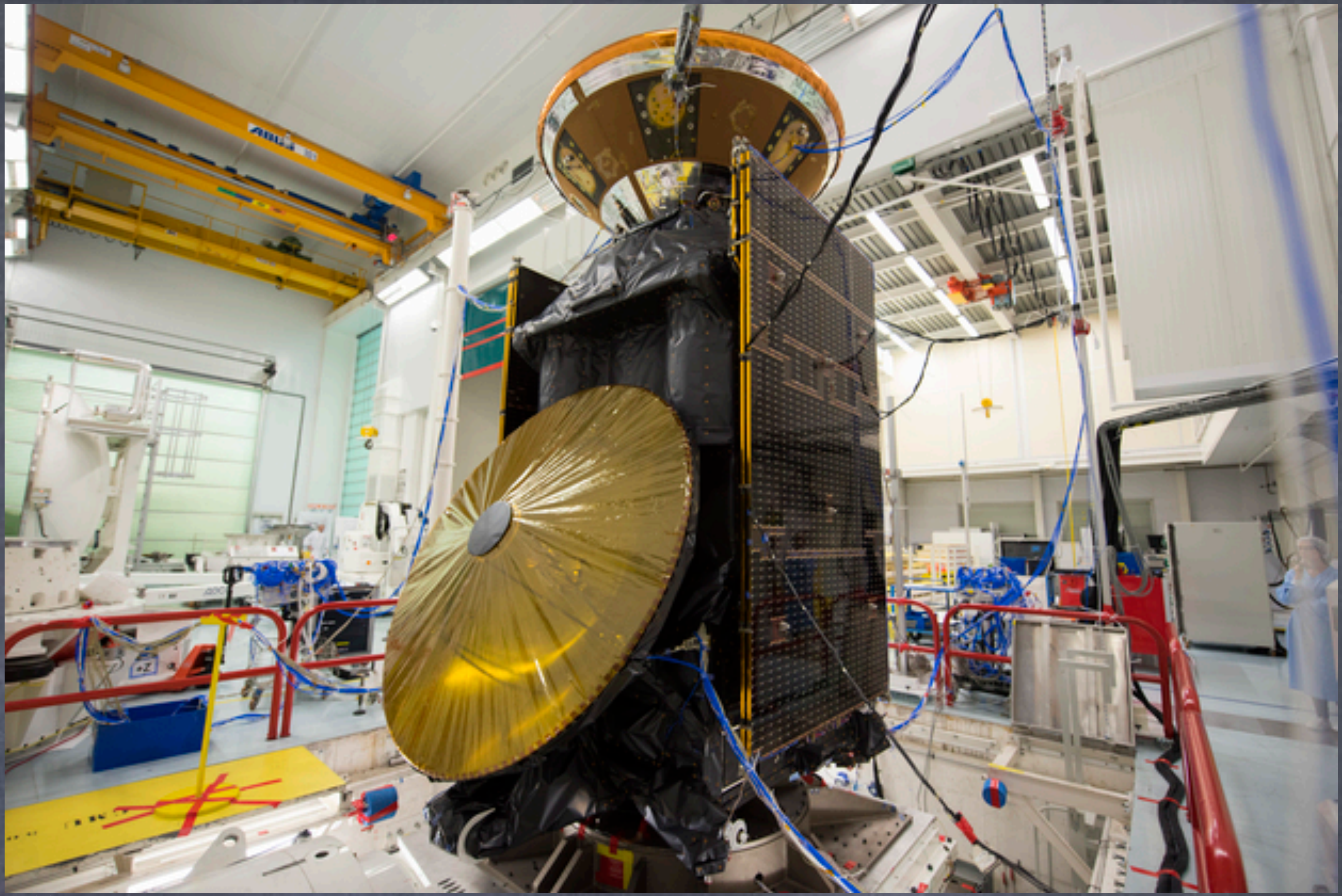
# Enabling technologies



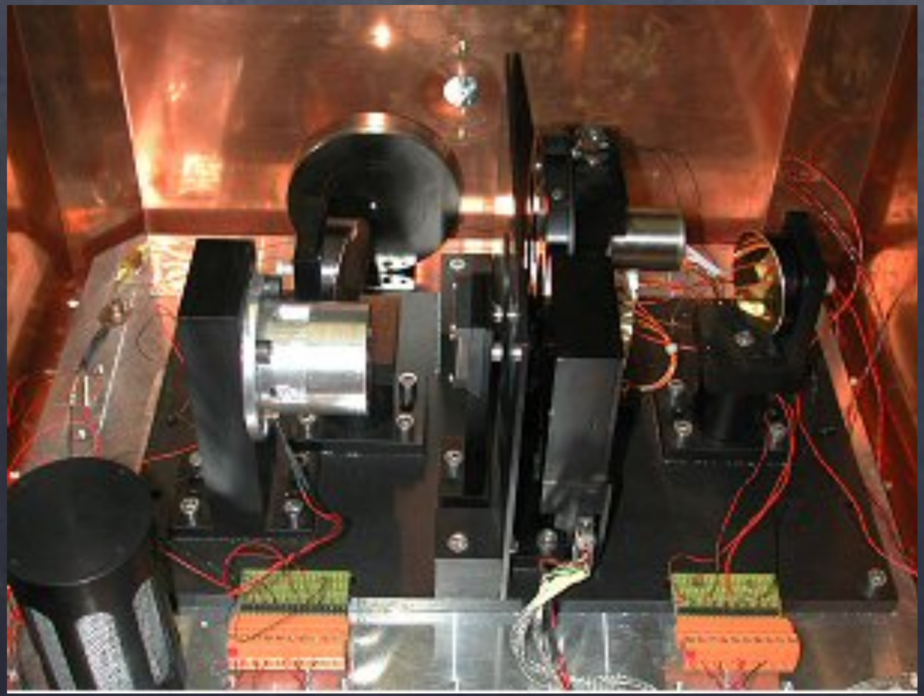

## Adaptive Optics

- pyramid wavefront sensor
- layer-oriented MCAO
- …

Precision electromechanics



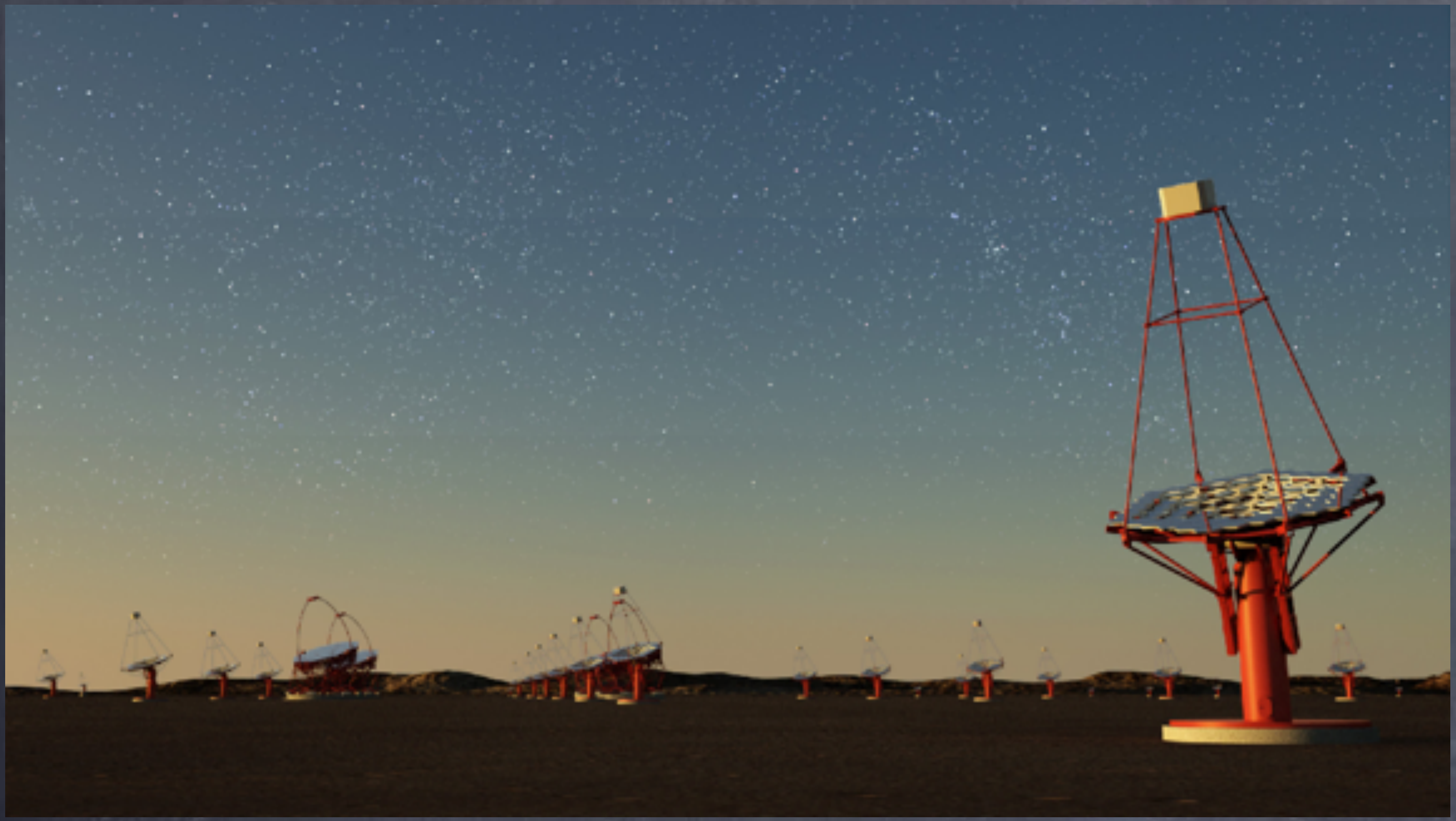
Exomars - Schiapparelli EDM



OPt-IR sensors

EUCLID

# CTA - Cherenkov Telescope Array



very high energy gamma-ray (10s GeV - 100 TeV)

2 sites:
- La Palma
- Paranal

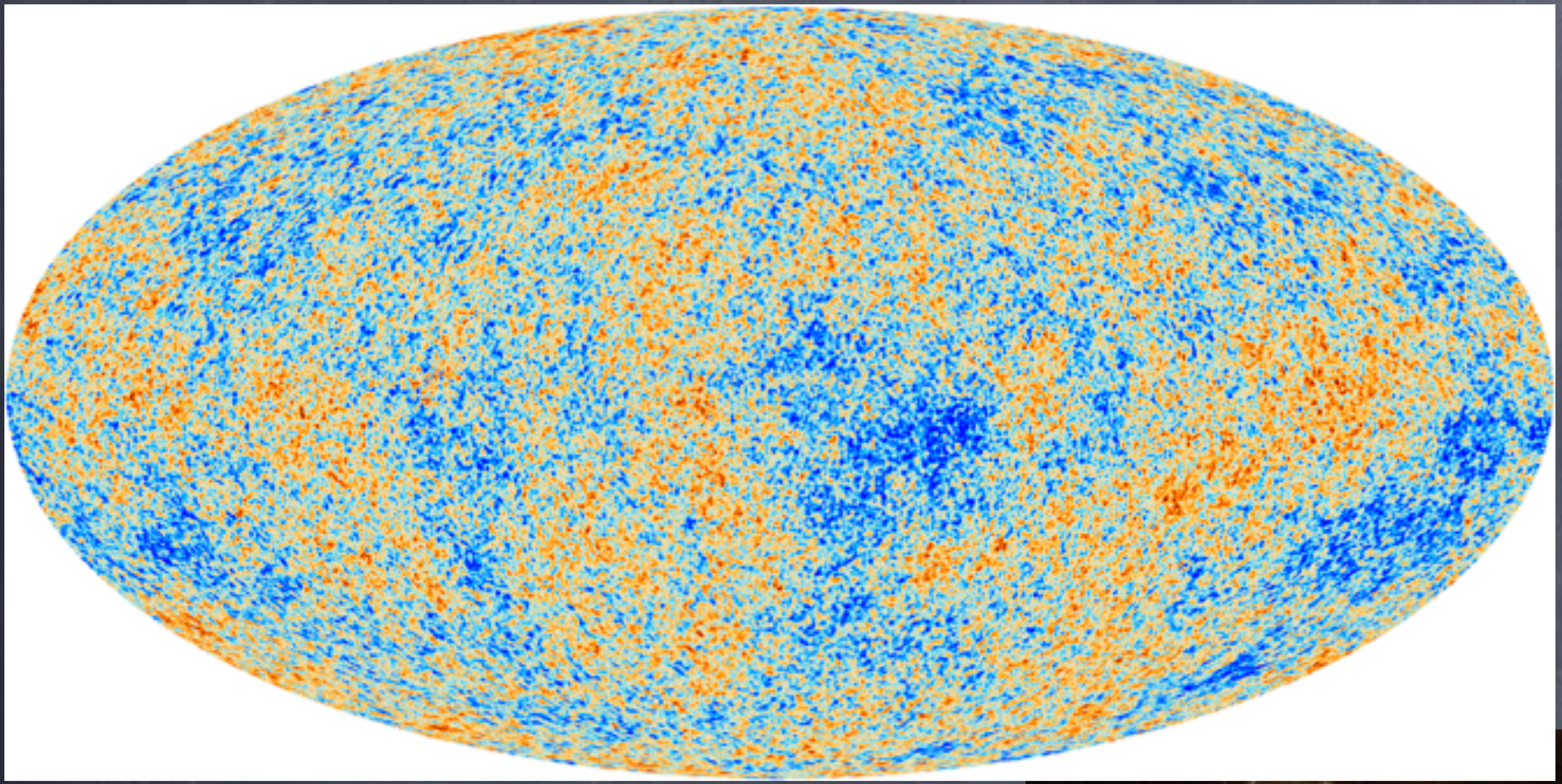
CTA (artistic)

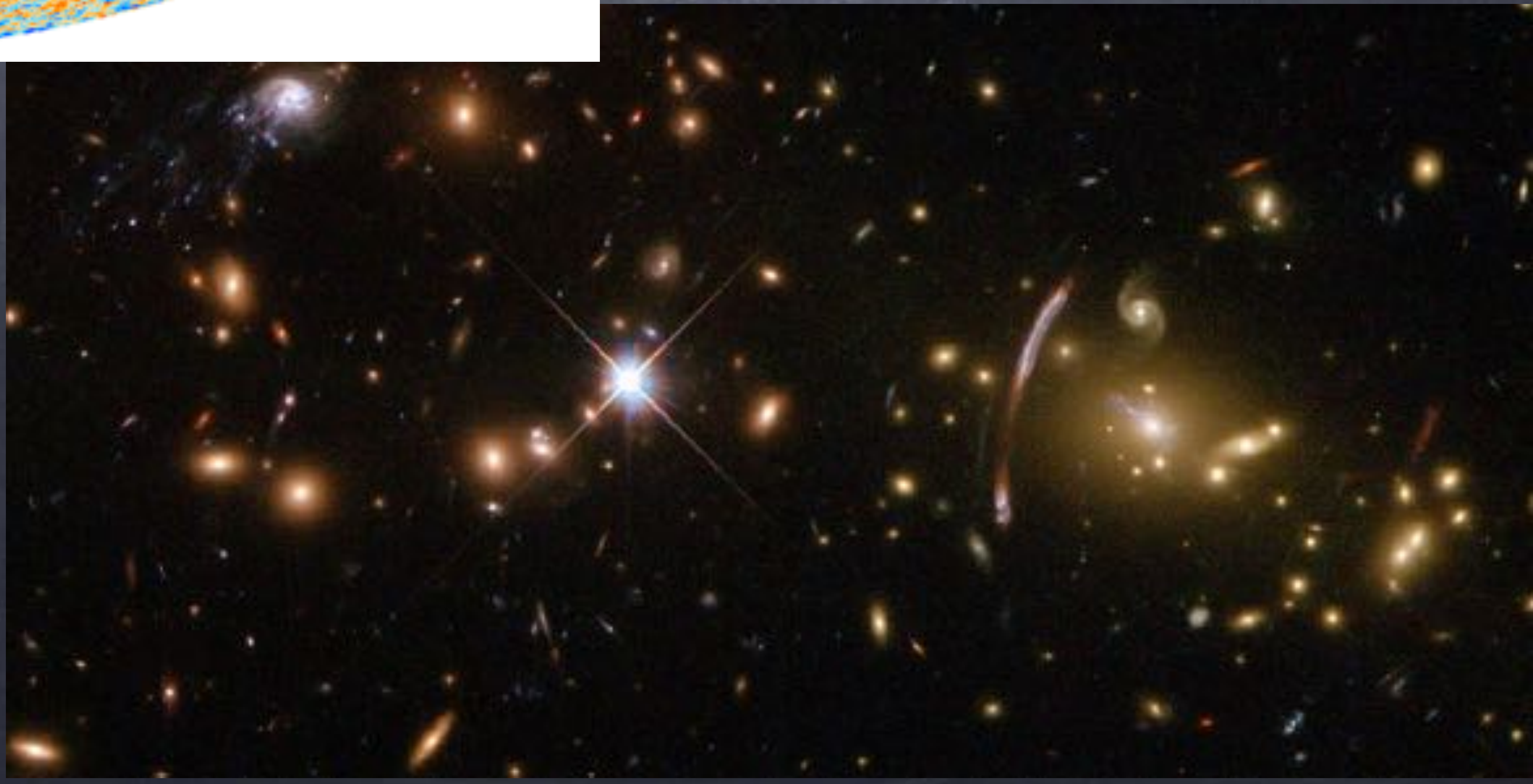
## INAF: mini-array (9 units)

prototype ASTRI

Serra La Nave, Catania

# observational cosmology





# strategic projects (incomplete)

- VLT (2 e 3 gen.)
- TNG+Harps
- LBT
- Gaia
- Fermi
- Exomars

- E-ELT
- CTA
- JWST
- PLato - Cheops
- ATHENA, EUCLID
- JUICE, Solar Orbiter, Bepi-Colombo
- enabling technologies