Scientific applications of AO instrumentations for exoplanets

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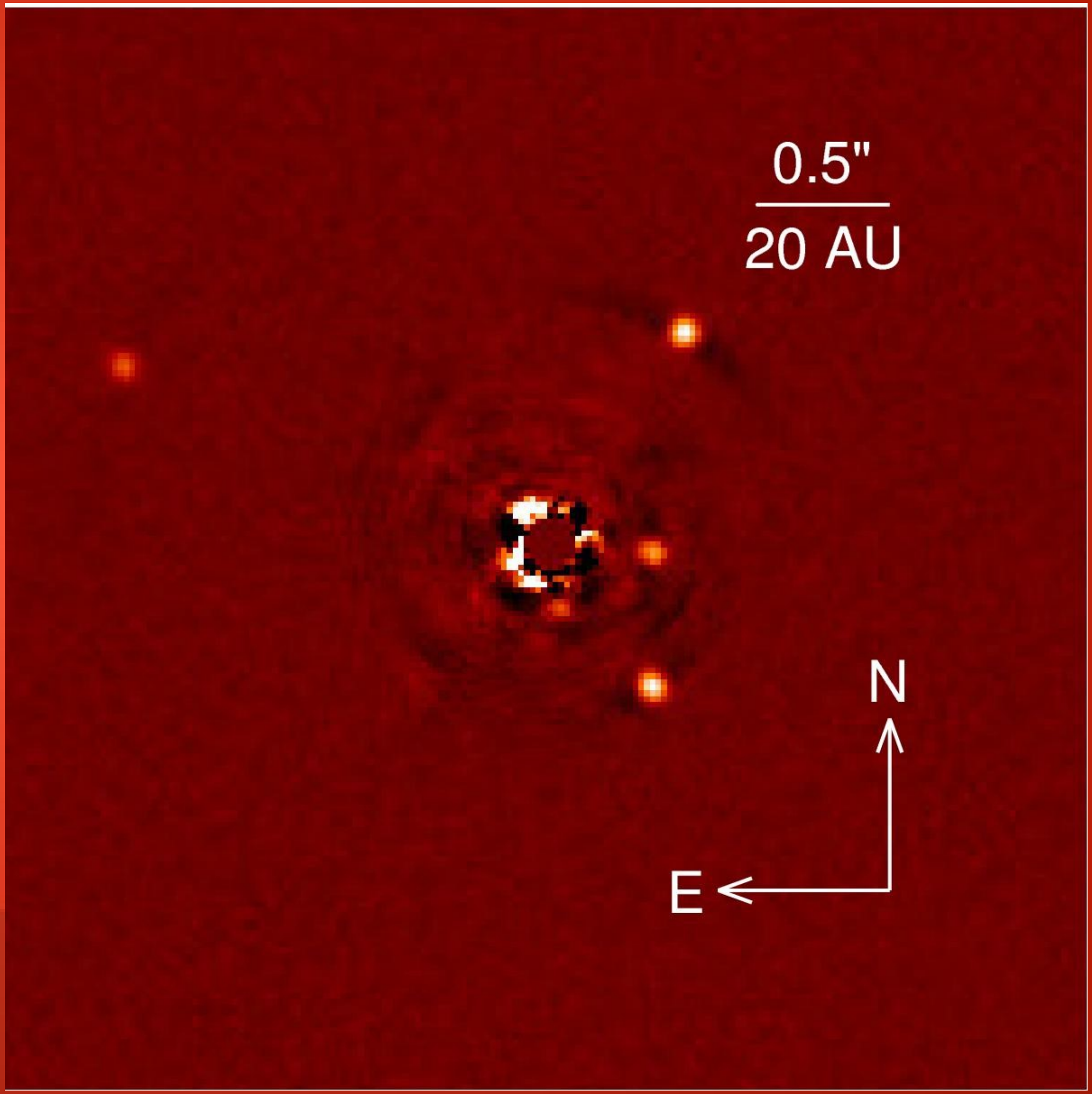
Direct imaging: discovery

Direct imaging is the most powerful method to identify planets at wide separation from their stars.

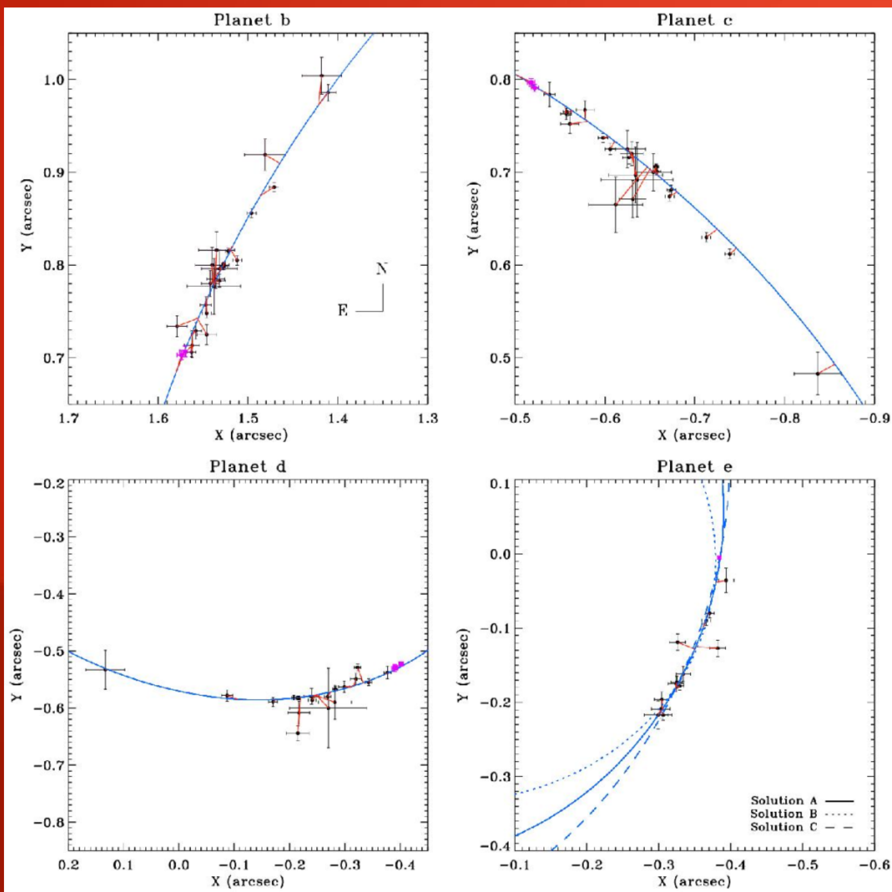
See D. Mesa talk for results with SPHERE; talk on SHARKs



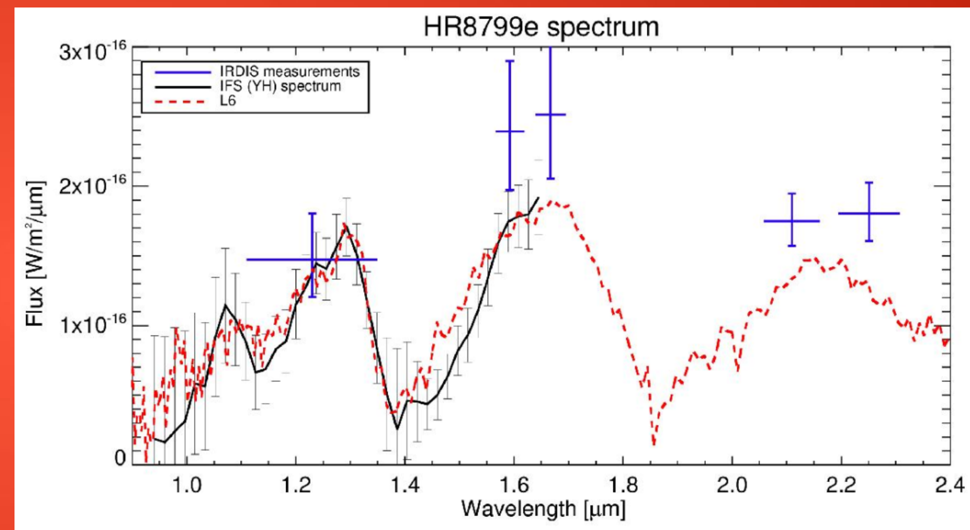
Maire et al. 2015 HR 8799 with LBT-FLAO+ LMIRCam

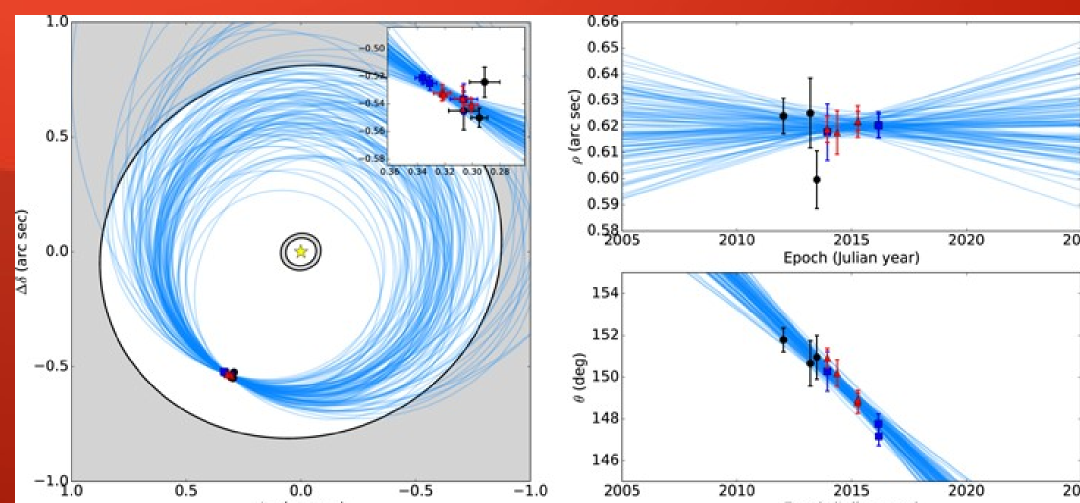
Direct imaging: characterization

Direct imaging as a tool for planet characterization: photometry, spectra, orbits, link with disks, etc.



Zurlo et al. 2016





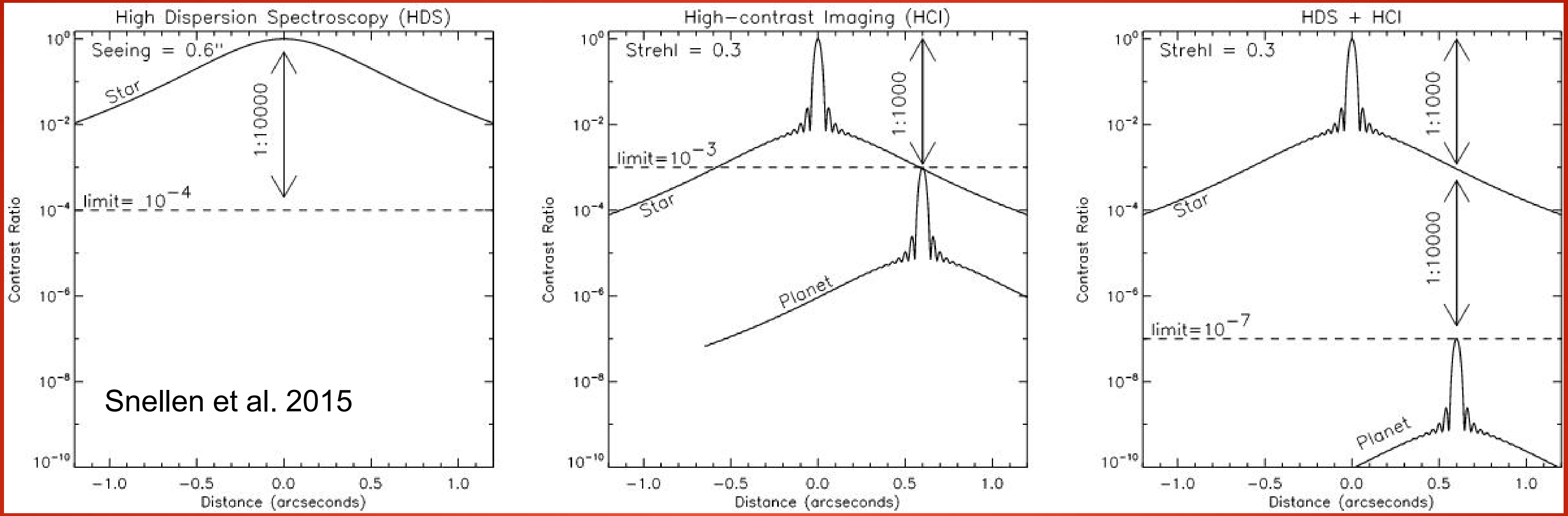
Rameau et al. 2016

Additional cases

- Coupling high-contrast AO imaging and high-resolution spectroscopy for planet atmosphere characterization
- AO as a supporting tool to validated transiting planet candidates

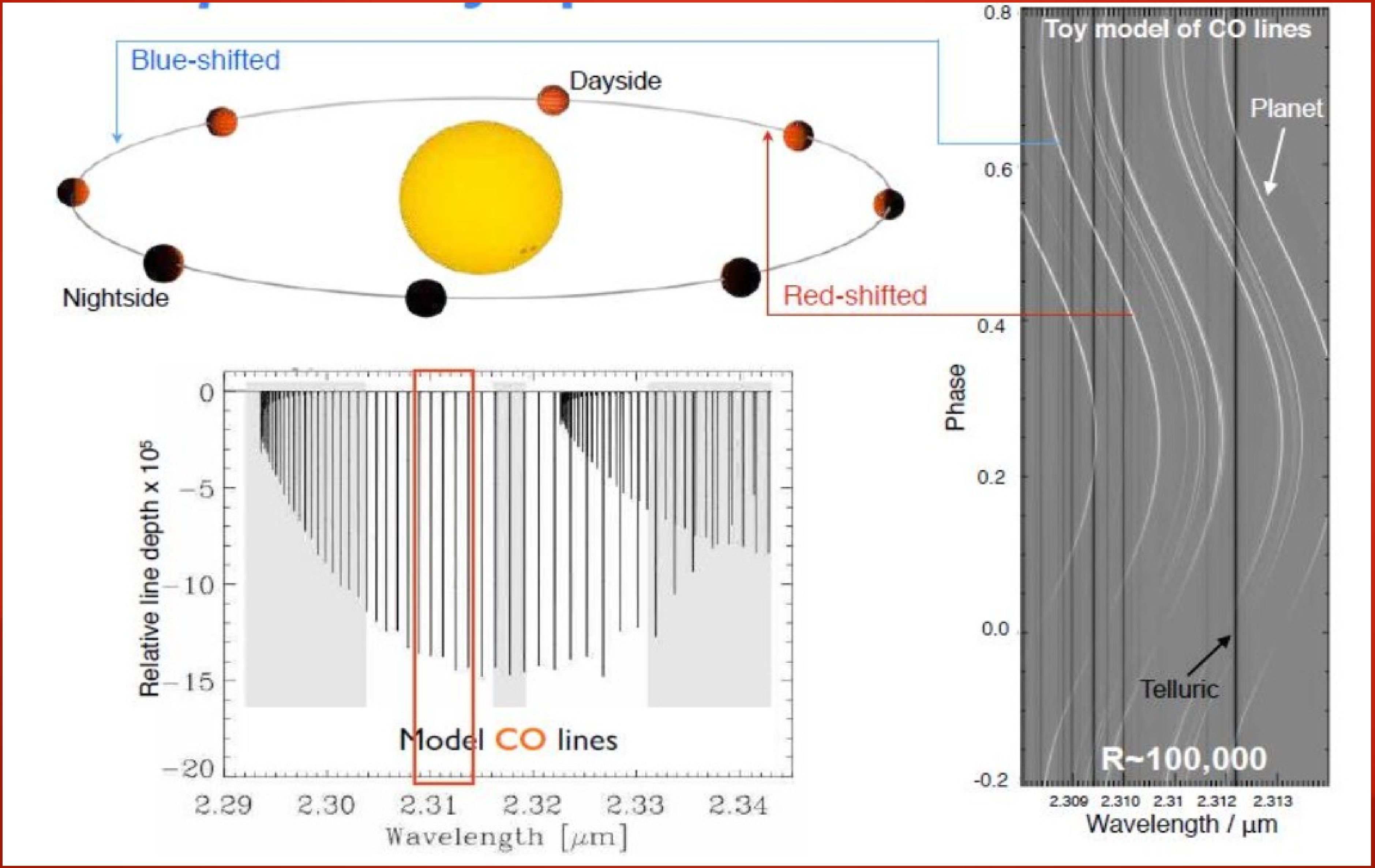
AO + High resolution spectroscopy

The concept: 2 step- approach



- Use AO system to make star-planet- contrast smaller
- Use high res. spectroscopy to disentangle planet vs stellar features on the basis on the different spectra lines/bands and radial velocity

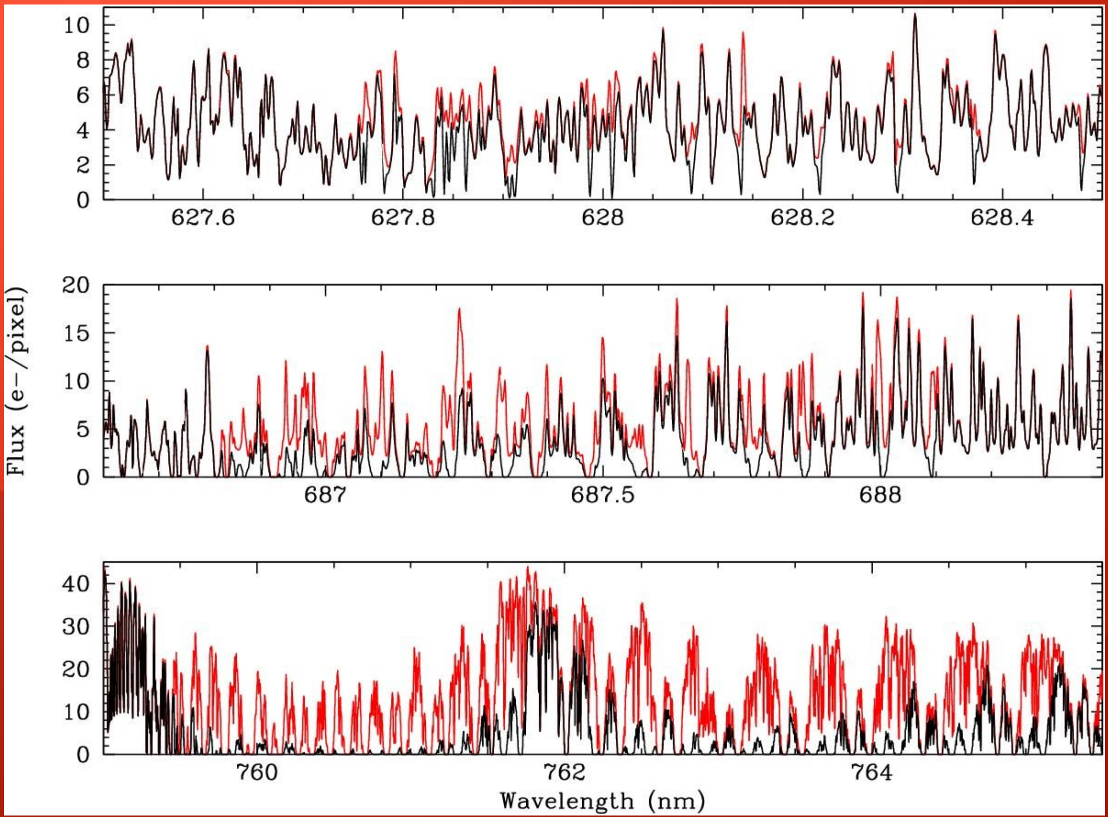
Exploit the planet orbit motion



Snellen et al. 2015

Scientific aims

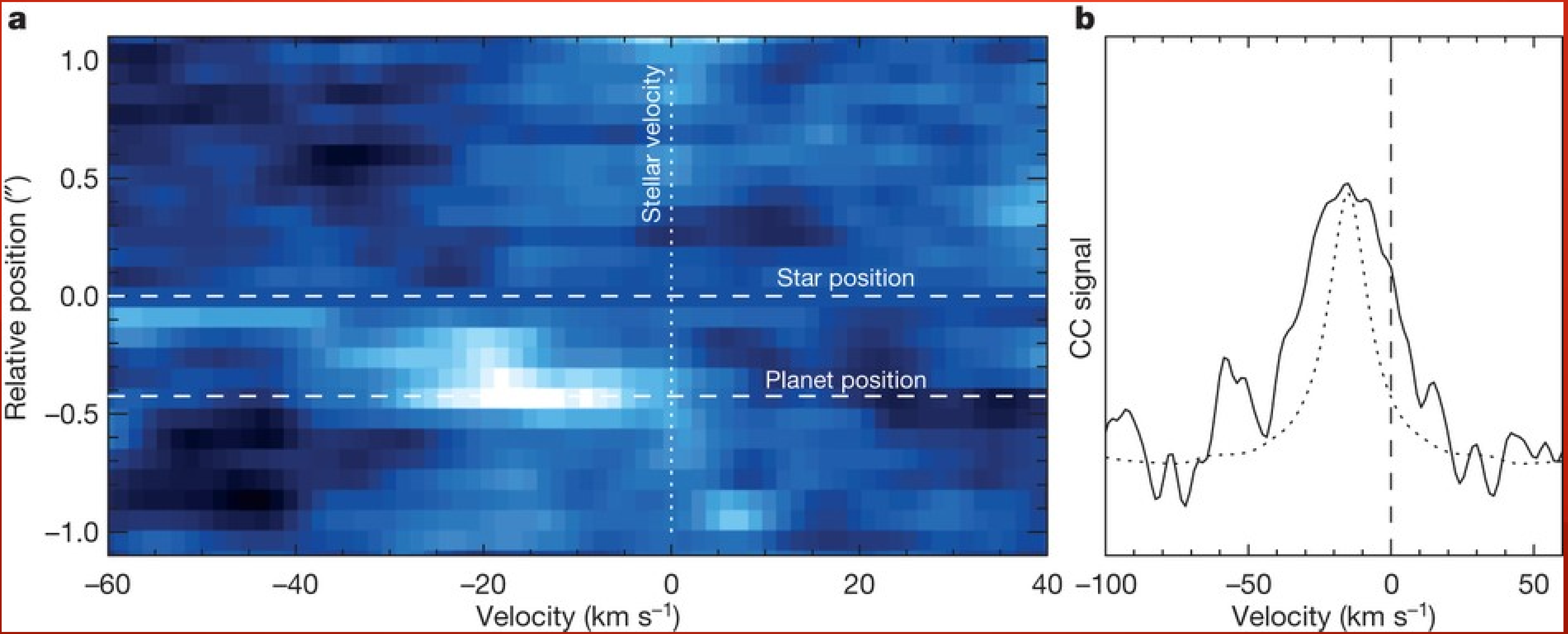
- Will depend on type on planets (shining by instrinsic vs reflected light)
- Atmospheric planet characterization (identification of molecules present in the atmosphere)
- Planet mass
- Albedo
- Planet RV
- Planet vsini



Simulation of Proxima Cen b for atmosphere with/without O2
Lovis et al. 2017 SPHERE + ESPRESSO 60hr

First on-sky application

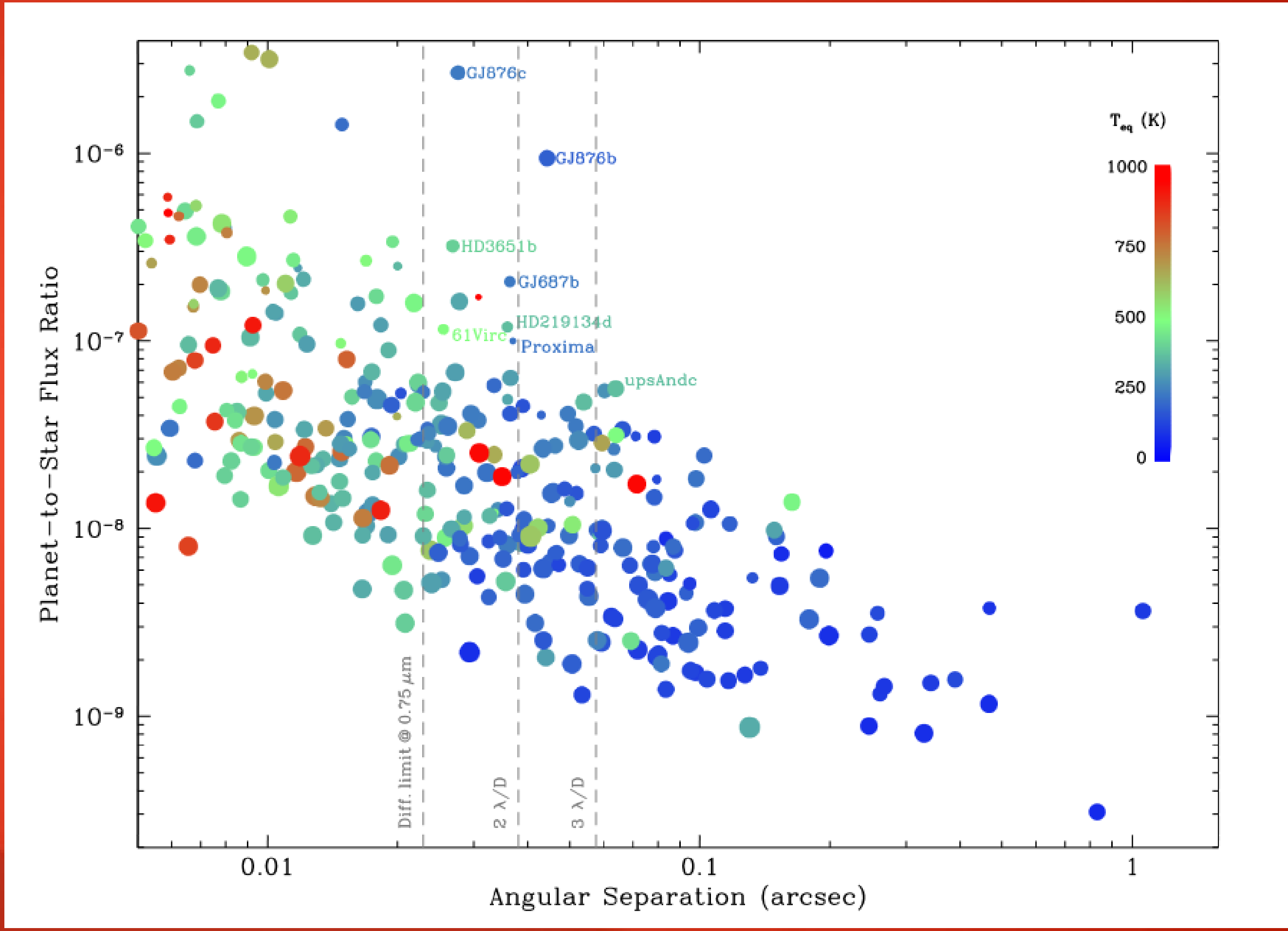
- MACAO+CRIRES observations of beta Pic b
- rotation and radial velocity of the planet



Cross-correlation signal as function of position along the slit. Snellen et al. 2014

Potential targets for reflected light

- Some cases at 10-6 contrast at 2-3 lambda/D for 8m telescopes
- Easier cases from young and/or massive objects shining by intrinsic light



Lovis et al. 2017

Future implementations under study (at ESO)

- SPHERE+ESPRESSO at VLT
- SPHERE+CRIRES+
- SCAO+HIRES at E-ELT

A&A 599, A16 (2017)
DOI: 10.1051/0004-6361/201629682

Astronomy & Astrophysics

Atmospheric characterization of Proxima b by coupling the SPHERE high-contrast imager to the ESPRESSO spectrograph

C. Lovis[1], I. Snellen[2], D. Mouillet[3,4], F. Pepe[1], F. Wildi[1], N. Astudillo-Defru[1], J.-L. Beuzit[3,4], X. Bonfils[3,4], A. Cheetham[1], U. Conod[1], X. Delfosse[3,4], D. Ehrenreich[1], P. Figueira[5], T. Forveille[3,4], J. H. C. Martins[5,6], S. P. Quanz[7], N. C. Santos[5,8], H.-M. Schmid[7], D. Ségransan[1], and S. Udry[1]

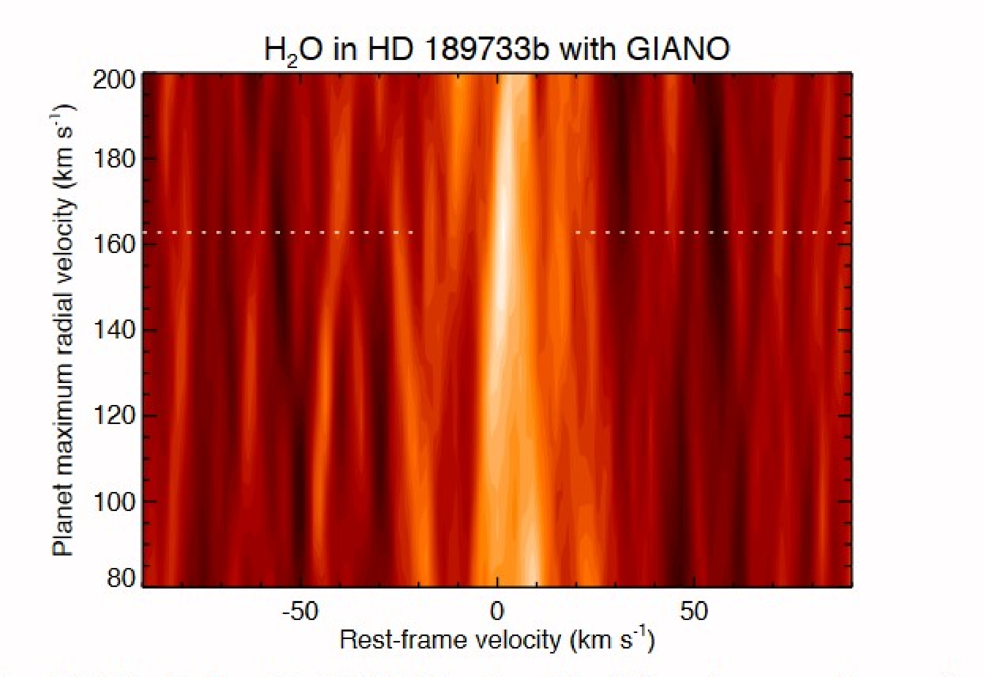
Future implementations under study (at LBT)

- High-resolution IFU mode considered as post-baseline for SHARK-VIS
- R=75000
- Inclusion of oxygen A band (crucial atmospheric diagnostic)

Synergies

- Coupling AO and high-resolution spectroscopy requires synergy between people working on the two aspects
- AO people: you here
- Planet atmospheric characterization using high resolution spectroscopy one of key drivers for GIARPS (GIANO+HARPS-N at TNG). Expertise being developed in the framework of GAPS.

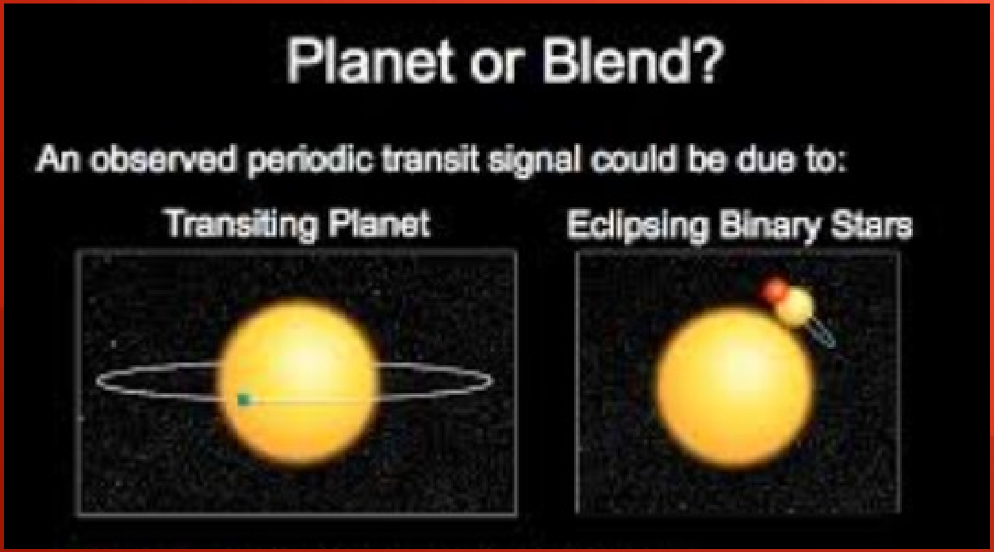
First results with GIANO (pre-GIARPS phase) at TNG
A. Bonomo et al.



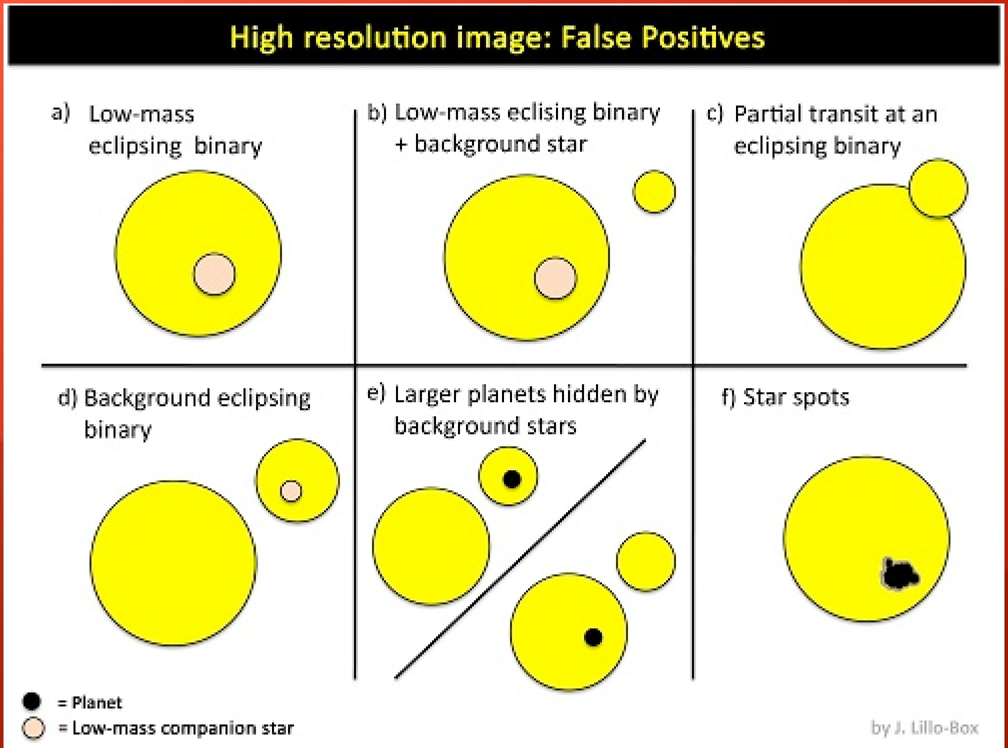
AO as validation tool for transiting planets

Concept

- Photometric dimming interpreted as a transiting planet could also be due to a blended eclipsing binary or more complicated blend configuration
- Even if a true transiting planet, planet radius is biased in case of significant light contribution by other sources

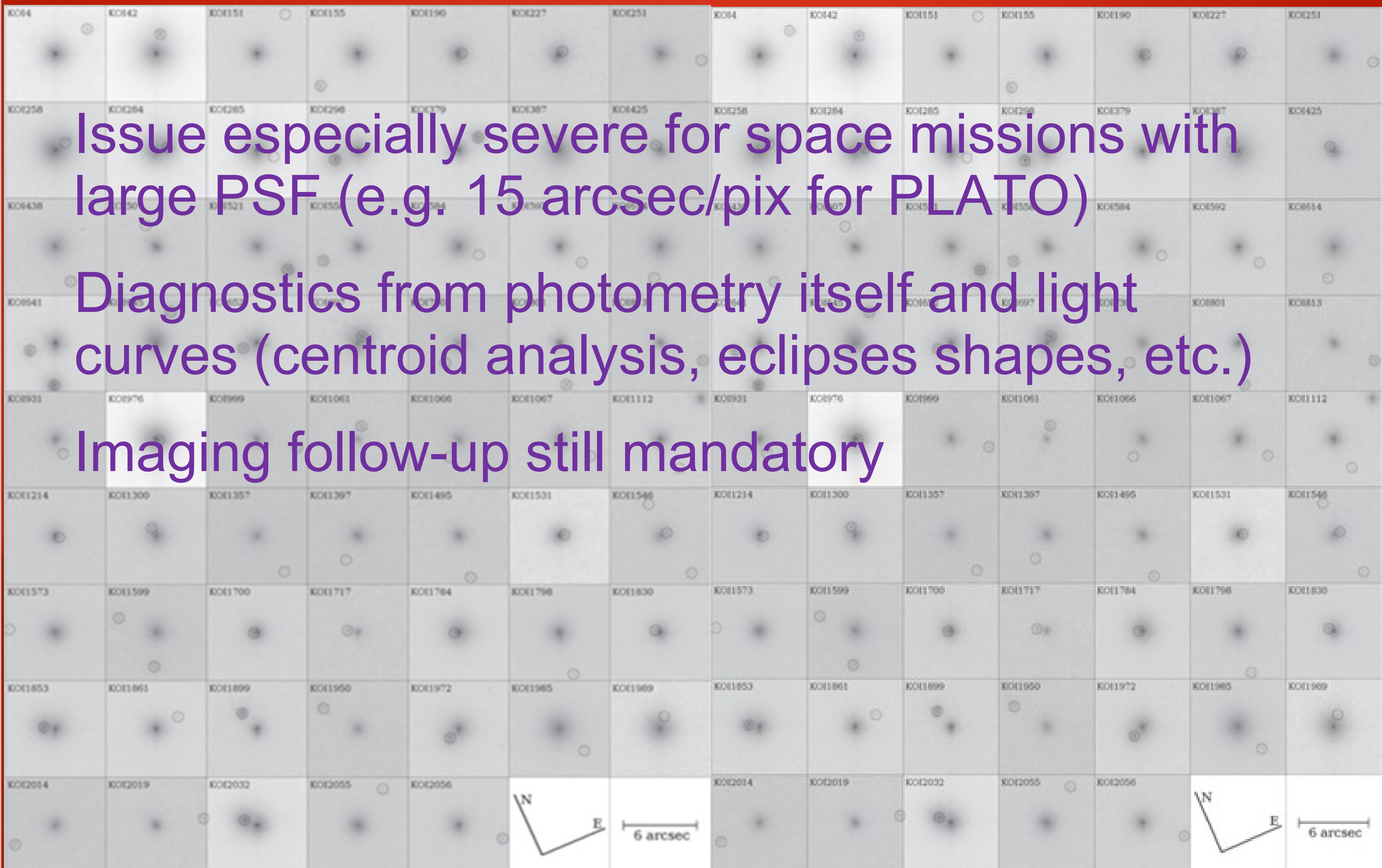


Credits: NASA



J. Lillo Box et al.

The space missions



Issue especially severe for space missions with large PSF (e.g. 15 arcsec/pix for PLATO)

Diagnostics from photometry itself and light curves (centroid analysis, eclipses shapes, etc.)

Imaging follow-up still mandatory

Requirements for AO follow-up

- Thousands of candidates
- Priority ranking: start with a screening phase with moderate contrast
- Go on large telescopes for most important candidates (process similar to RV follow-up)
- Usefulness of color information from imaging observations (to properly estimate light dilution at the wavelength of transit observations and infer physical association vs field object)

Best AO instruments

- Aimed at best contrast; not optimized for large samples
- Significant overheads for target acquisition, AO set-up, coronagraph set-up. Example for SPHERE: about 15 minutes
- To be used only on best candidates (e.g. candidates for habitable planets)
- Rely on shallower observations + appropriate statistical validation methods (BLENDER for Kepler)

Dedicated instrumentation

- This goal greatly benefits from dedicated instrumentation
- Example: ROBO-AO at Kitt Peak 2.1m
- Pointing/AO set-up overheads: 1 min
- 200 targets per night
- Fully dedicated telescope
- Strehl about 10% *i* band

PLATO AO follow-up

- No comparable resource up to now for PLATO follow-up
- Need of a 2-4m-class telescope with ROBO-AO-like instrument accessible to PLATO Community
- Also think at minimizing overheads on existing/planned instruments (dedicated fast mode?)