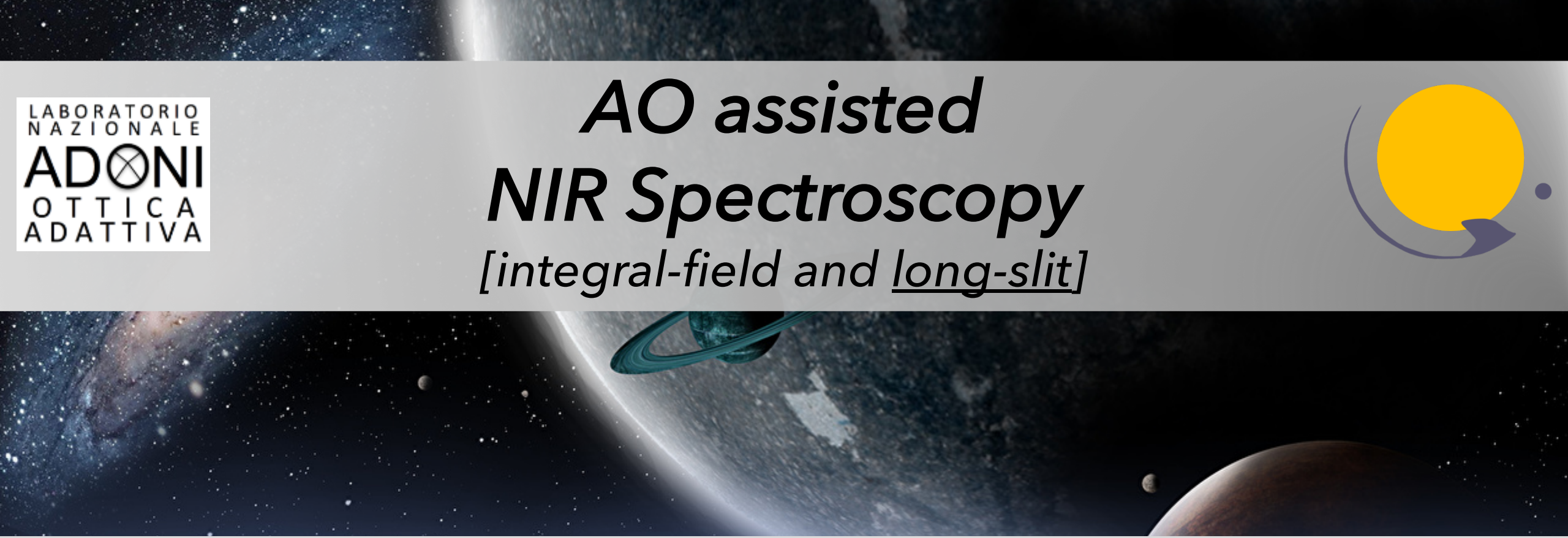

AO assisted NIR Spectroscopy

[integral-field and long-slit]

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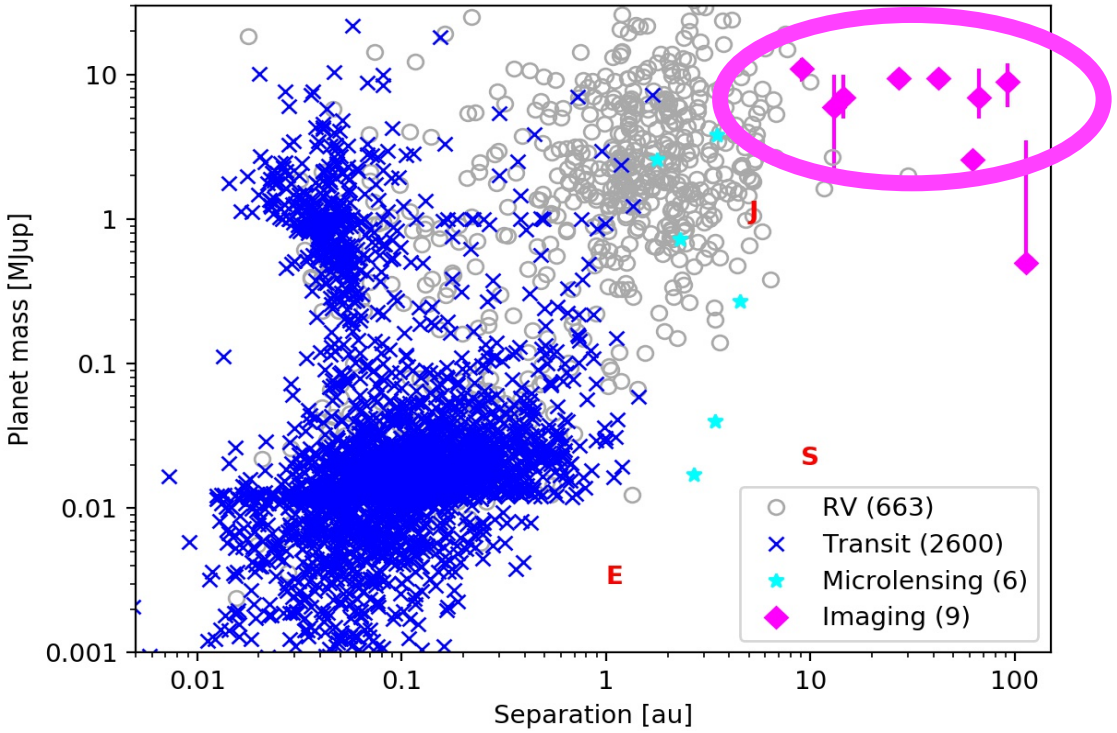
INAF Osservatorio Astronomico di Padova

Workshop Laboratorio Nazionale di Spettroscopia, Monte Porzio Catone , June 10 – 11 2019

The context: high-contrast spectroscopy (imaging) of exoplanets

Direct technique: planet's photons → Targets: Giant Planets on wide orbits around young, nearby stars



Orbital & Physical properties:

- *L, a , e, i*
- *Multiple: Architecture & Stability*
- *Planet – disc connection*

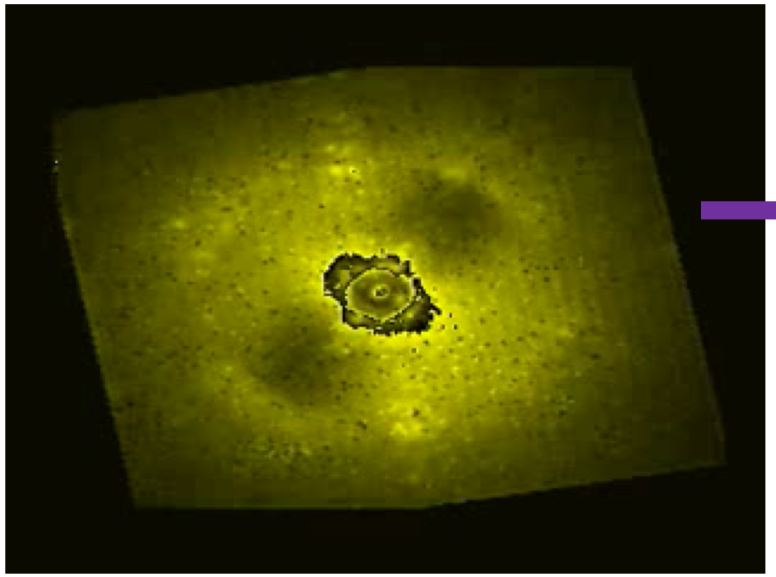
(Chauvin et al. 2005, 2010, 2017; Lafrenière et al. 2007; Soummer et al. 2011; Vigan et al. 2012)

High-contrast spectroscopy:

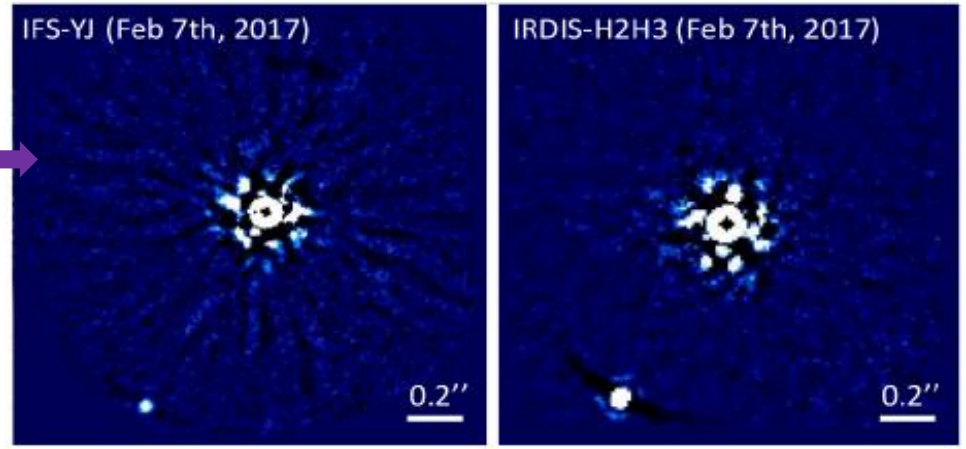
(Low) gravity, composition, non-LTE chemistry, cloud coverage...

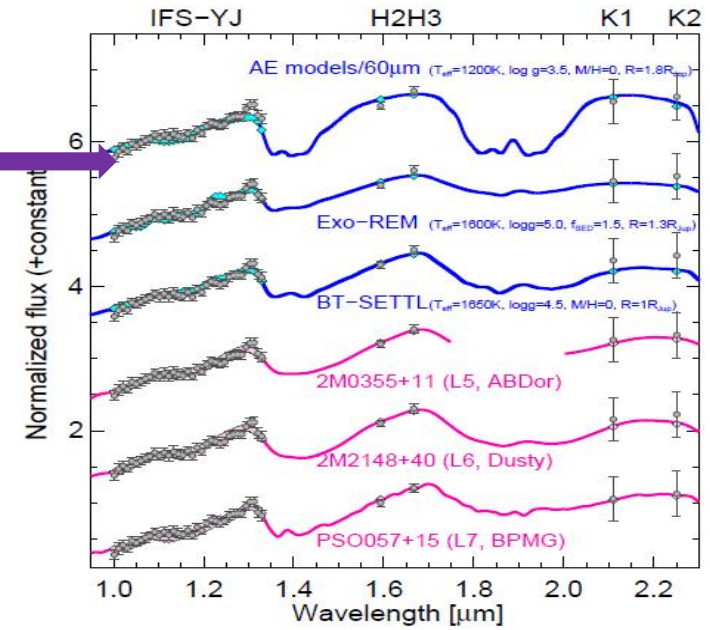
(Janson et al. 2010; Bonnefoy et al. 2009, 2012, 2018 ; Bonavita+ 2017)

SPHERE IFS

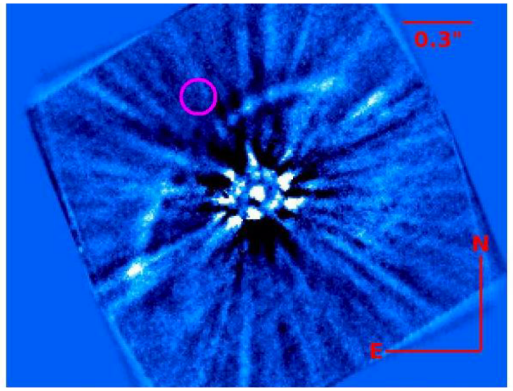


HIP 65426 (Chauvin+ 2017)

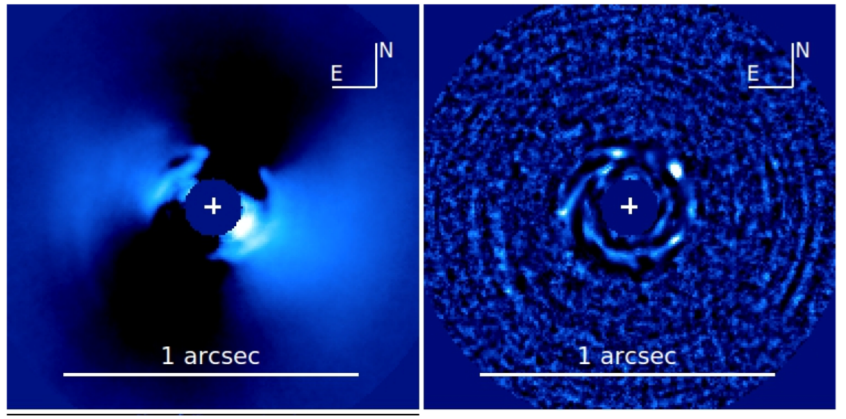




From the spectral datacube
To extraction and determination
of the atmospheric properties



HD 163296 (Mesa+ 2019, in press)



HD 169142
(Gratton+ 2019)

The long-slit coronagraphic spectroscopy

The problem

The main issue in high-contrast imaging is given by the speckle noise $\theta_{speckle} = \lambda/D$.

The planet (unresolved point source) image has FWHM that is approximately equal to the diffraction limit.

Distinguishing a faint planet PSF from a speckle is therefore impossible with a single image, and without using a temporal sequence or other spectral information.

The solution

The position and size of a speckle is wavelength-dependent: as the wavelength increases from λ_1 *to* λ_2, *the FWHM of a single speckle and its angular separation from the star increase by a factor* λ_2/λ_1.

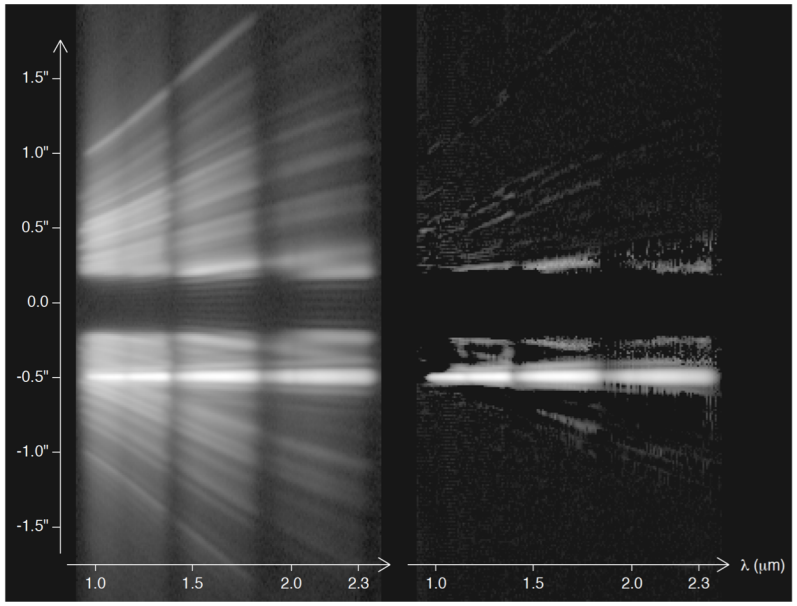
However, a fixed physical object (e.g., a planetary companion) will not change its position with wavelength: only its FWHM will be multiplied by that factor λ_2/λ_1.

Speckle removal and planet spectrum (for free!)

The concept

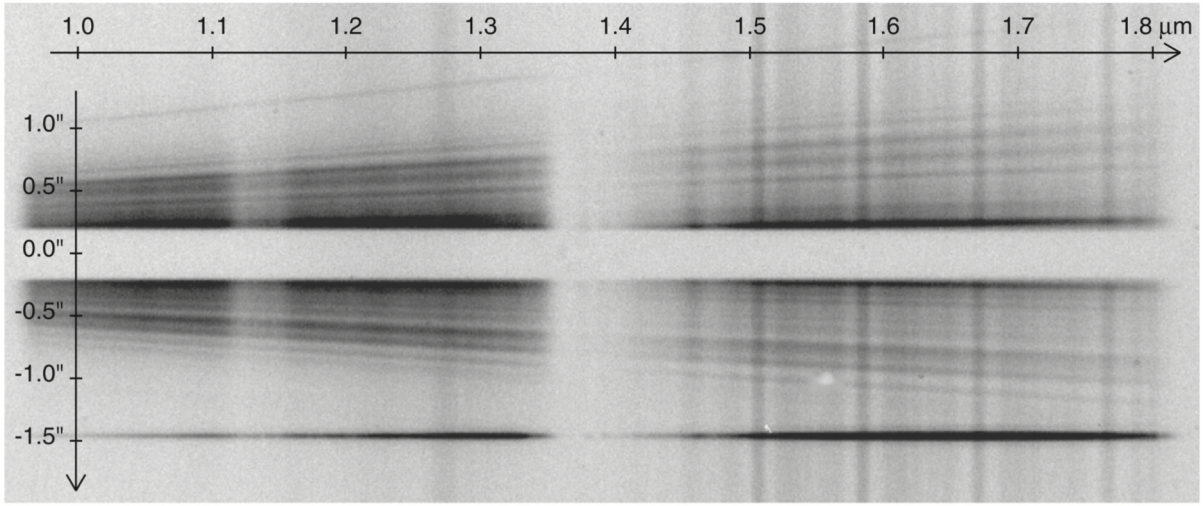
the slits and coronagraphic masks have been merged into a single device →
The obscured part between ±0.2″ corresponds to the position of the opaque coronagraphic mask.

Vigan+ (2008)



LRS data obtained on PZ Tel (H=6.5) →
The spectrum of the companion PZ Tel B is visible as a straight line at an angular separation of ~0.5″

Hinckley+ (2015)



MRS data for 2MASS J01225093-2439505 (H=9.5)
The spectrum of the companion is visible at 1.45″

Why ? *Spectroscopic characterisation of (known) planets/BDs*

The implementation of a long-slit coronagraphic mode furnishes spectral classification if $R \gtrsim 30$ and molecular band + atomic feature identification if $R \gtrsim 100$

High-quality (SNR) spectra are FUNDAMENTAL as to determine physical properties:

(1) Gravity (age)

(2) Clouds

(3) Chemical composition (with higher resolution)

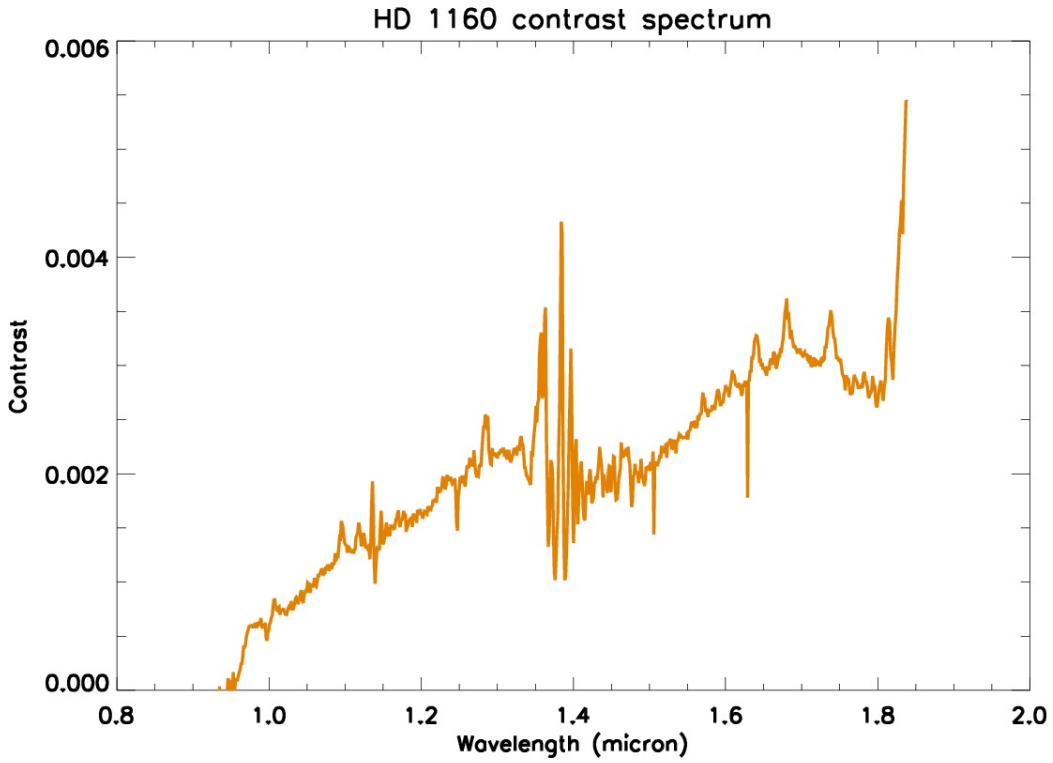
NIR photometry suffers degeneracy !

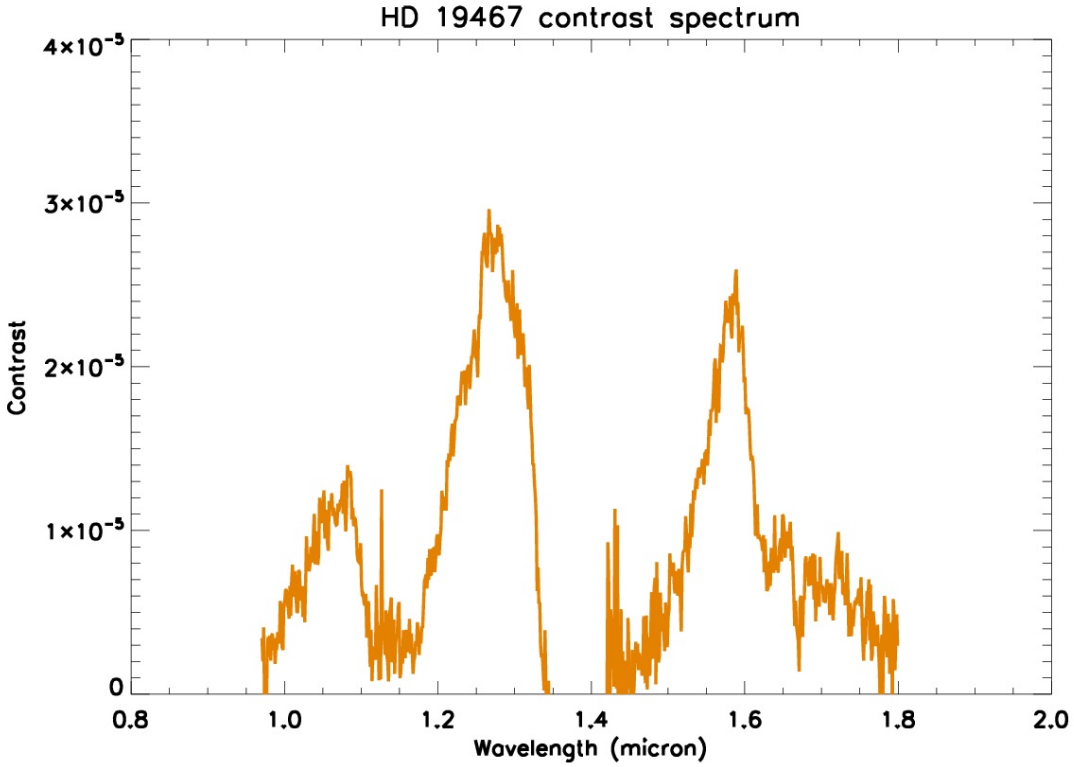
Limited number of sub-stellar objects with accurate spectra because of:

- *very few planets observed with high-contrast imaging*
- *high-contrast (at least 10^{-3} - 10^{-4})*
- *small angular separation (currently limitations to 200 mas)*

References & Work in progress

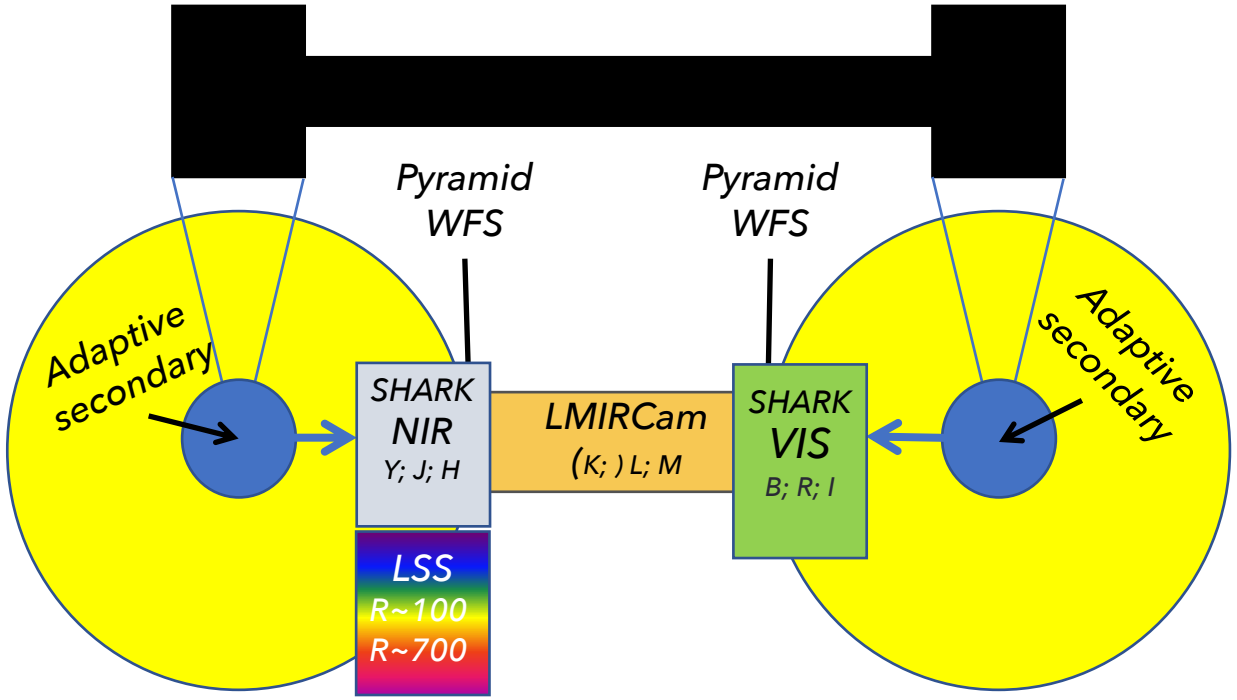
Vigan+ 2016
Bonavita, D'Orazi, Mesa+ 2017

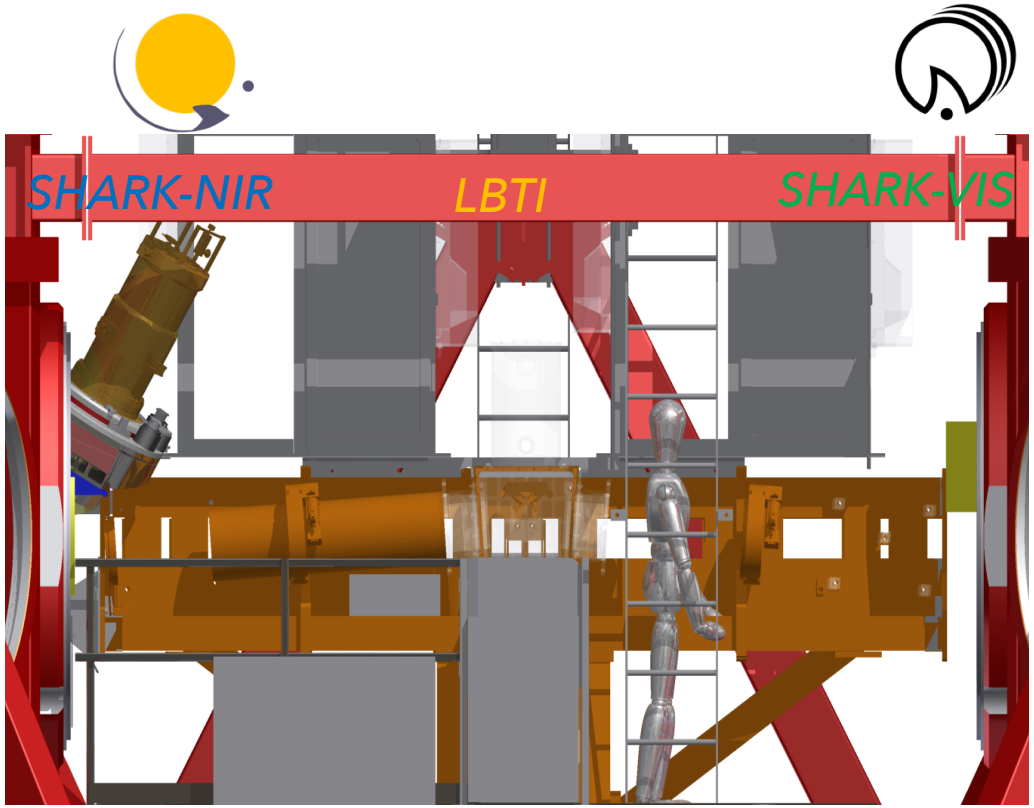




D'Orazi, Mesa, Vigan+ 2019, in prep. (DRS by D. Mesa)

The SHARKs@LBT





Exoplanets detection (GPs on wide orbits)
Discs/jets around young stars
AGN/QSOs
SS bodies (Main belt + trans-neptunians objects)

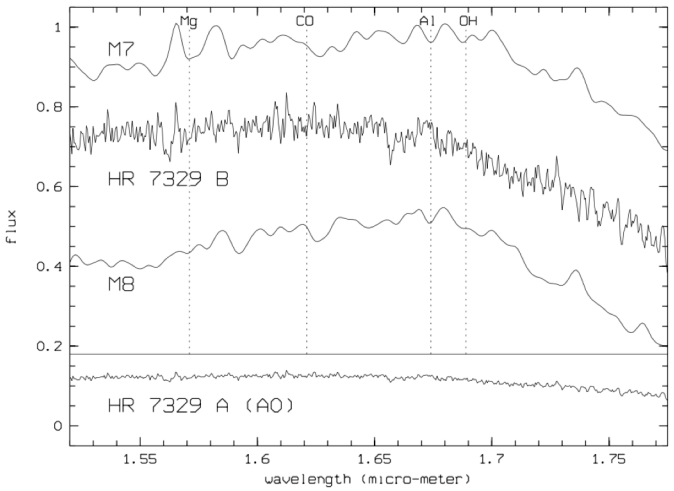
SINERGY IS VITAL: TRINOCULAR OBSERVATIONS

Coro performances similar to SPHERE (hopefully we gain in magnitude limit with SOUL!)
But MULTI-WAVELENGHT observations will be a unique feature !

Looking forward.. MAORY+MICADO

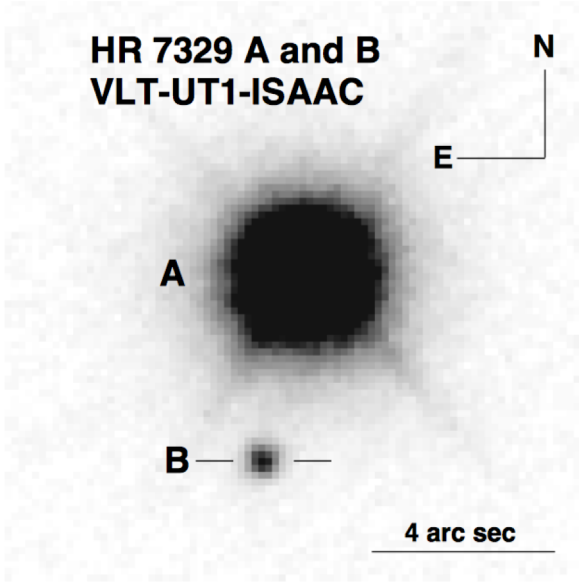
Because of their location sufficiently far away from the host stars (e.g., the Eta Tel system (Lowrance+ 2000), whereby the companion is at ~ 4 arcsecond separation, d=48 pc, Beta Pic moving group [age ~ 20 Myr])

*several of these sub-stellar companions can be studied with no need of **coronagraphs***



Δmag = 5.6
(primary H=5.5)

Guenther+ (2001)
ISAAC H band (R~ 500)
→ Only Sp. Type from the continuum shape



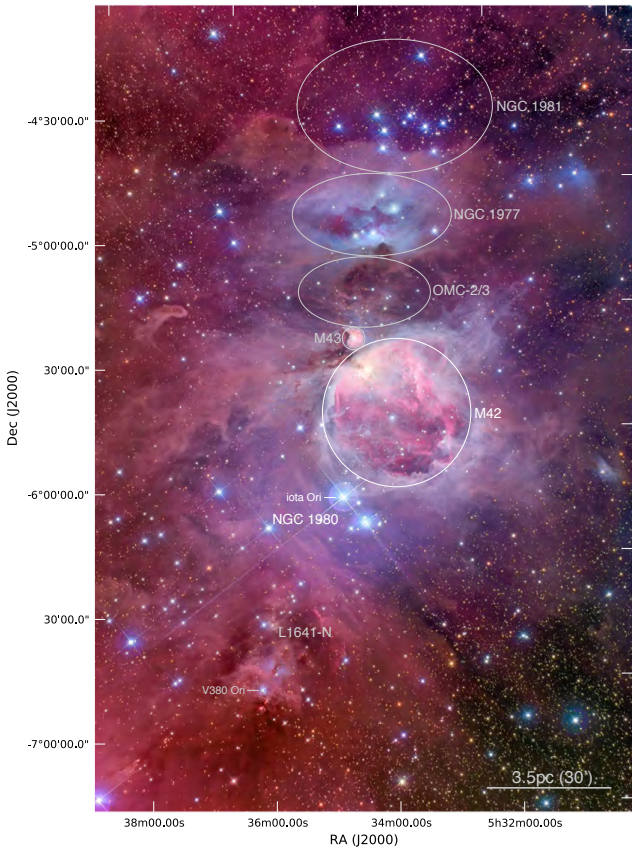
We want to know:

1. *Chemical composition*
2. *Surface gravity (age)*
3. *Clouds*

the long-slit spectroscopy R~18 000 for point sources in IzJ band (and HK), will allow us not only to identify broad molecular bands (e.g., CH_4, H_2O), but also to resolve atomic features, which are critical diagnostics as to atmospheric characterisation (not possible for e.g., JWST due to lower resolution)

SNR=30 in 1 hour of integration for objects with H=21 and SNR=10 for H=23 objects, implying that in very young systems (1-5 Myr) objects less massive than Jupiter will be investigated.

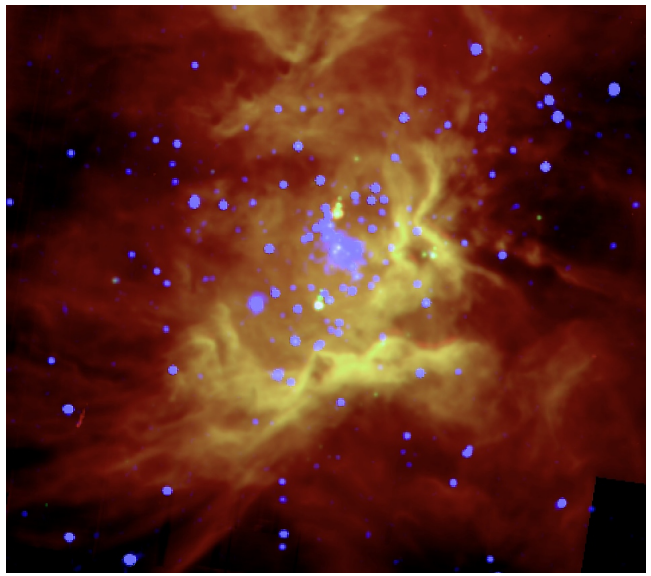
The Orion complex (d=400 pc, age 1 – 10 Myr): ONC, OBIa,b. H=12-13 (suitable for SCAO)



(from Alves & Bouy 2012)

W40 (d=500 pc, 0.8 – 1.5 Myr)

RCW36 (d=700pc, age=1 Myr)



Moving to older ages: Beta Pic moving group, Tucana, IC 2391 supercluster, .. (d< 200 pc and age 20 – 50 Myr)

The sample is (and will be) provided by complimentary facilities, e.g., with SPHERE@VLT or GPI@Gemini in the South and SHARKs in the Northern emisphere

Hot points

This is SPECTROSCOPY, folks!

Is this Laboratorio aimed at dealing ONLY with big MOS spectroscopic surveys ? Then "Laboratorio Survey Spettroscopiche MOS"

How our research field is "seen" by the Laboratorio Nazionale (interaction ?)

The expertise in the Italian community is quite restricted (despite next-coming Italian facility such as e.g., SHARK-NIR)

Tools for data reduction and analysis are very specific and no public software is basically available