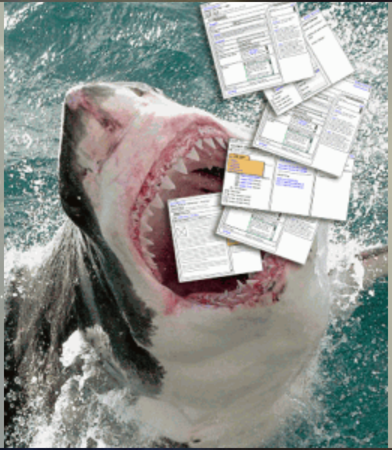

Feeding the beast: science cases for SHAR(K)-NIR@LBT

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ADONI 2016, Firenze, April 12 2016

Exoplanets: detection and characterisation

Discs around young stars and their jets

Extragalactic science: AGN and QSO

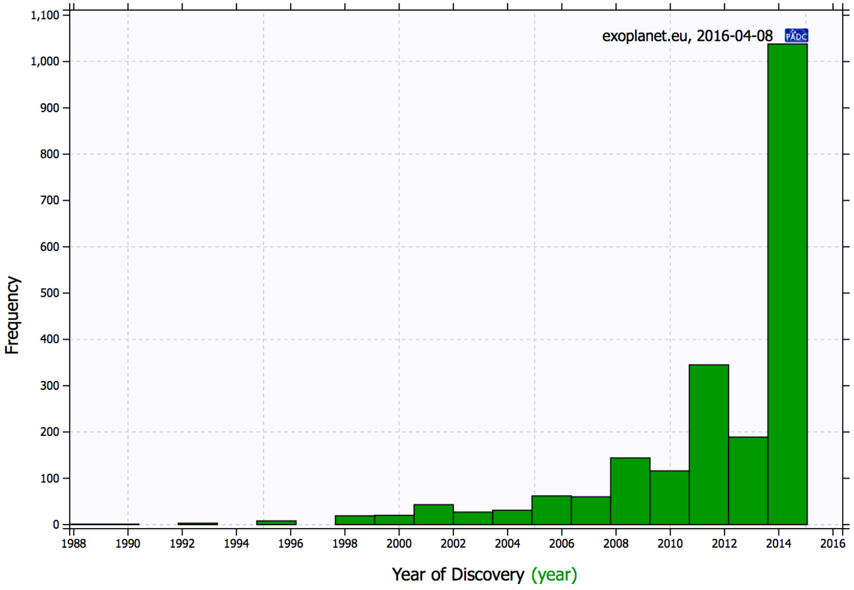
The search for other worlds has been since always one of the fundamental inquiry for the human being.

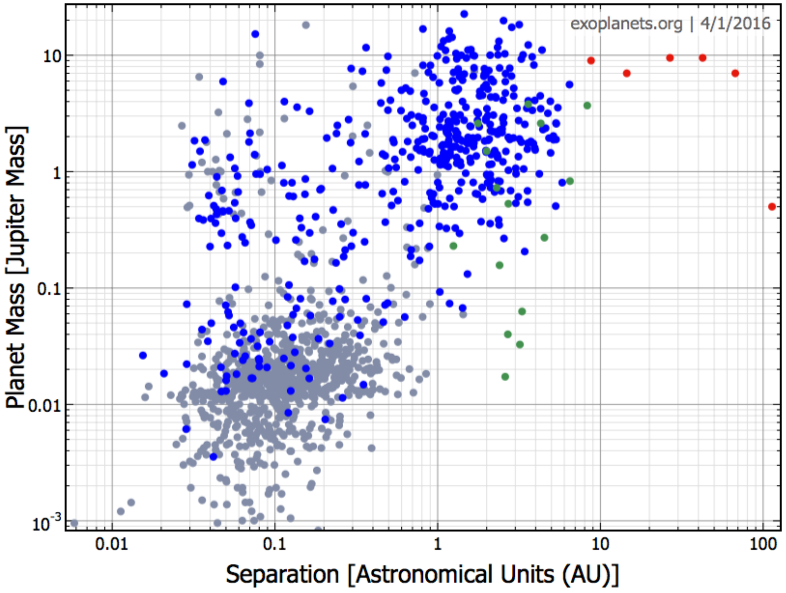
“There are infinite worlds both like and unlike this world of us. We must believe that in all worlds there are living creatures and planets and other things we see in this world”

Epicurus, 300 BC

First discovery by Mayor & Queloz (1995) of a planet orbiting the solar analog 51 Peg, followed soon thereafter by the detection of planets around 47 UMa (Butler & Marcy 1996) and 70 Vir (Marcy & Butler 1996)

→ Outstanding efforts in detecting exoplanets: to date 1642 confirmed planets + 3786 unconfirmed Kepler candidates have been discovered (source http://exoplanet.org, April 2016).

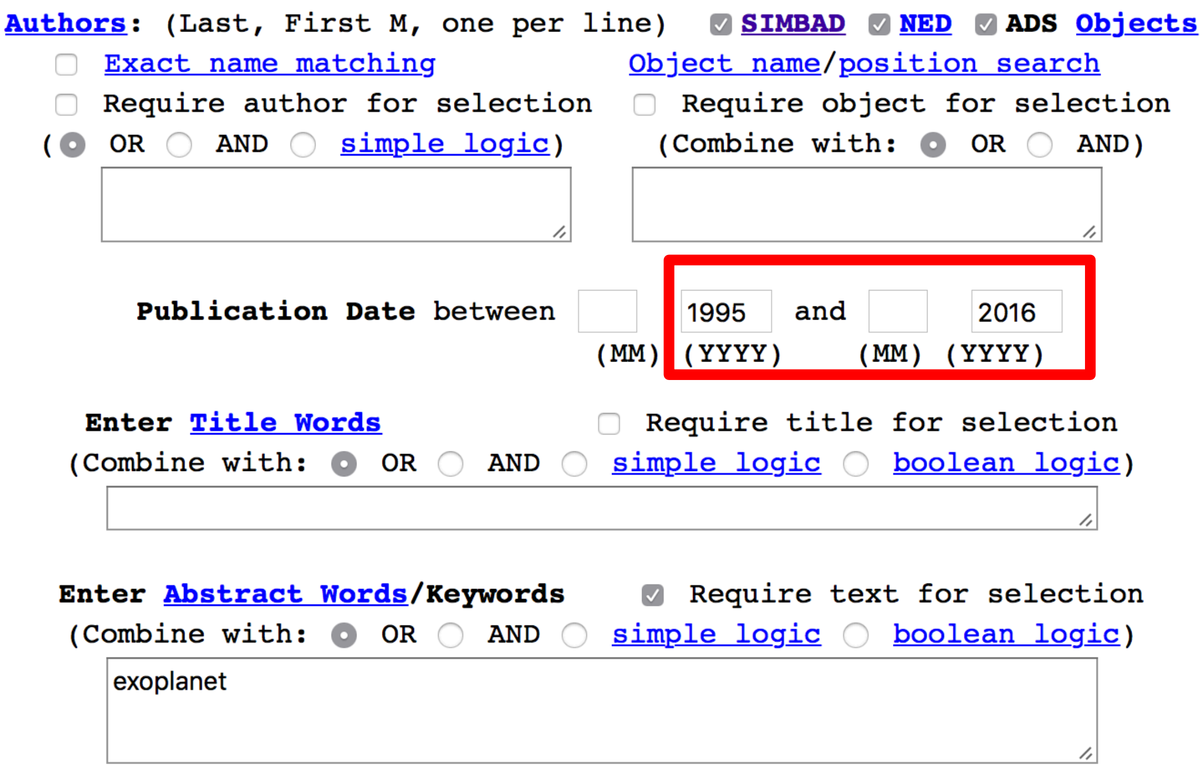




Different detection techniques →

Radial velocity Direct imaging Microlensing Transits

Surfing through NASA ADS database



Authors: (Last, First M, one per line) ☑ **SIMBAD** ☑ **NED** ☑ **ADS** **Objects**

☐ Exact name matching

☐ Require author for selection

(● OR ○ AND ○ simple logic)

Object name/position search

☐ Require object for selection

(Combine with: ● OR ○ AND)

Publication Date between (MM) 1995 (YYYY) and (MM) 2016 (YYYY)

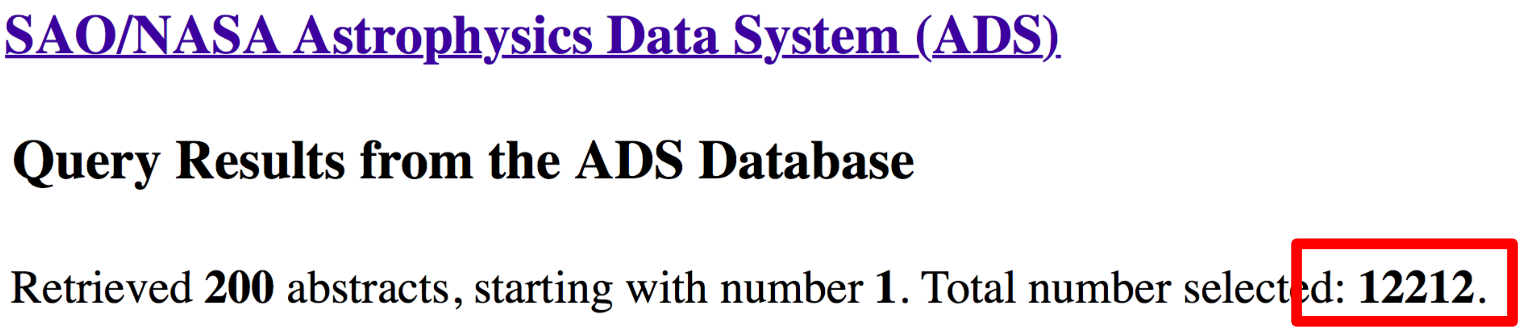
Enter **Title Words** ☐ Require title for selection

(Combine with: ● OR ○ AND ○ simple logic ○ boolean logic)

Enter **Abstract Words**/**Keywords** ☑ Require text for selection

(Combine with: ● OR ○ AND ○ simple logic ○ boolean logic)

exoplanet

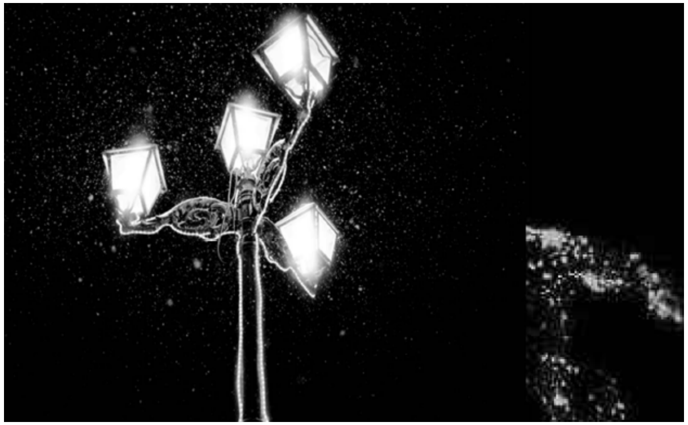


SAO/NASA Astrophysics Data System (ADS)

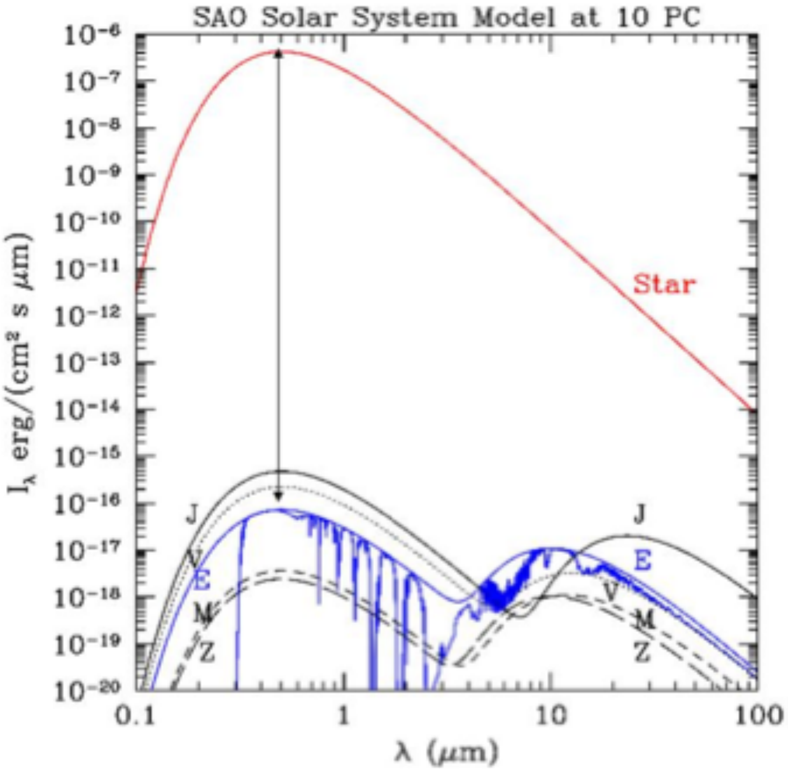
Query Results from the ADS Database

Retrieved **200** abstracts, starting with number **1**. Total number selected: **12212**.

...Main Difficulties with Planets....



We aim at seeing a moth flying around a street-lamp from a satellite at 500 km height



Contrast:

Jupiter/Sun = 10^{-8} = 20 mag

Earth/Sun = 10^{-10} = 25 mag

Angular Separation:

Jupiter = 0.5 arcsec @ 10 pc

Jupiter = 0.1 arcsec @ 50 pc

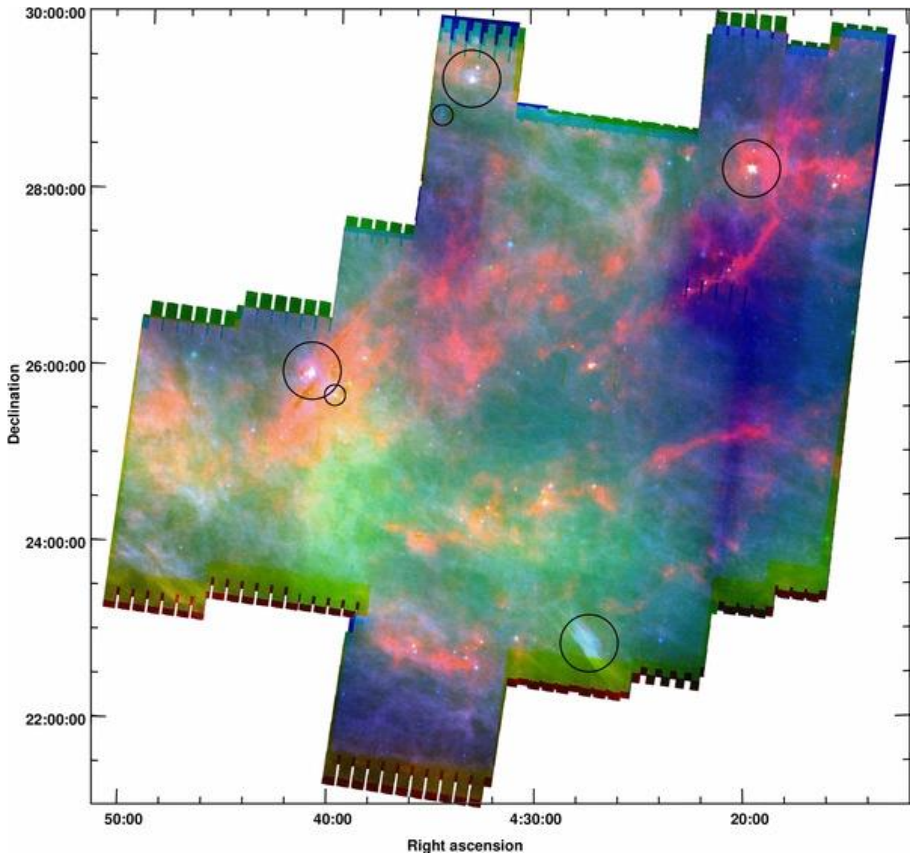
Planets in wide orbits of low-mass stars

A special niche for SHARK is offered by the LBT AO at faint mag, especially with AO upgrade: wide planets orbiting low-mass stars (e.g., K/M dwarfs in young associations and SFRs like Taurus)

Giant planets in Star Forming Regions

Taurus-Auriga: ages of about 1-2 Myr, at a distance of about 140 pc. About 350 members were identified, 130 of which brighter than R=15.

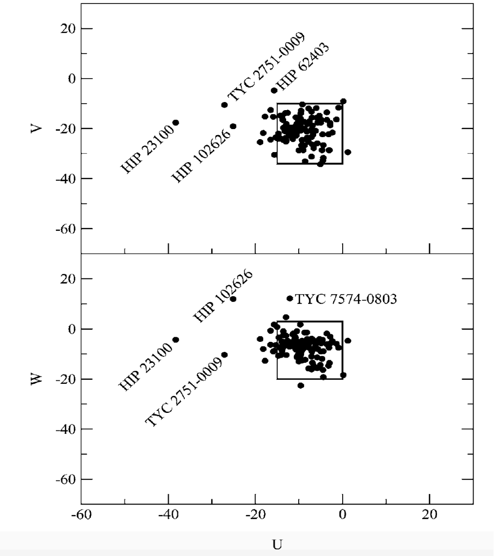
The search for planets in star-forming regions represents a program capable of fully exploits the potential of SHARK@LBT.
The NIR channel will be used to reveal planet thermal emission.



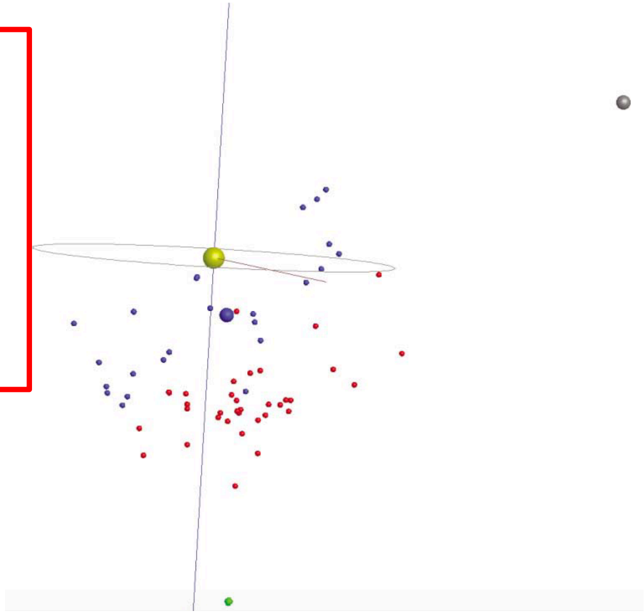
Planets around K/M type stars in young (loose) associations

Several members of young moving groups (age~10-100 Myr) were recently identified, with special effort for low-mass stars.
→ stream of stars with common age and motion through the Milky Way and with no overdensity of stars discernable in any region (e.g., the Ursa Maior, AB Dor, Beta Pic)

Why did it take so long for astronomers to identify the closest coeval associations of young stars? Because these groups are sparse and spread over large regions of the sky, usually there is no clustering, whereby a stellar over-density can be picked out against the background stars



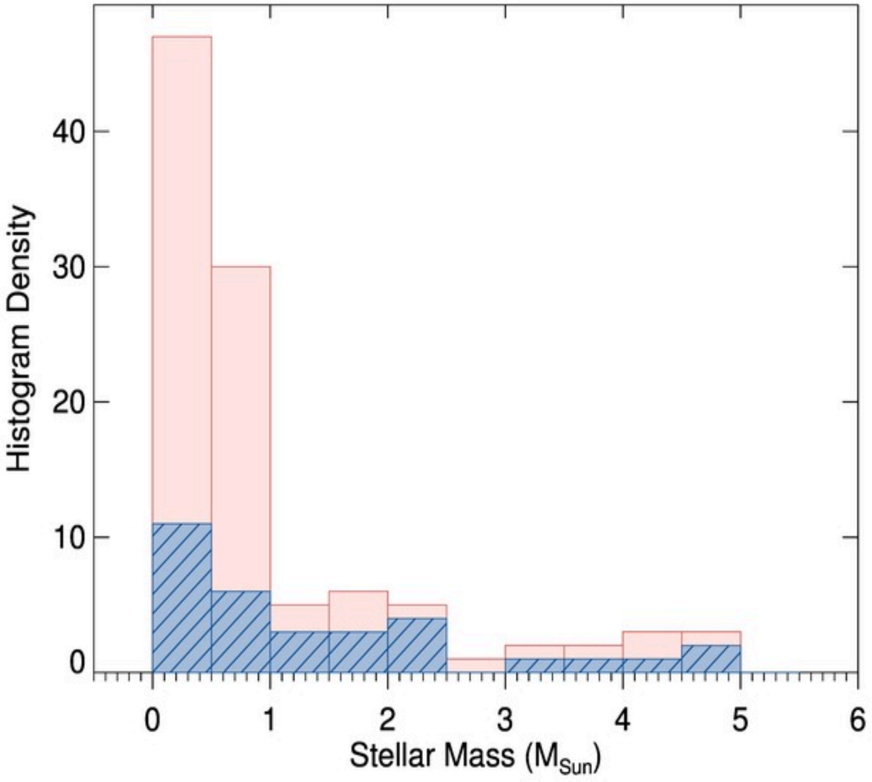
Zuckerman & Song (2004)



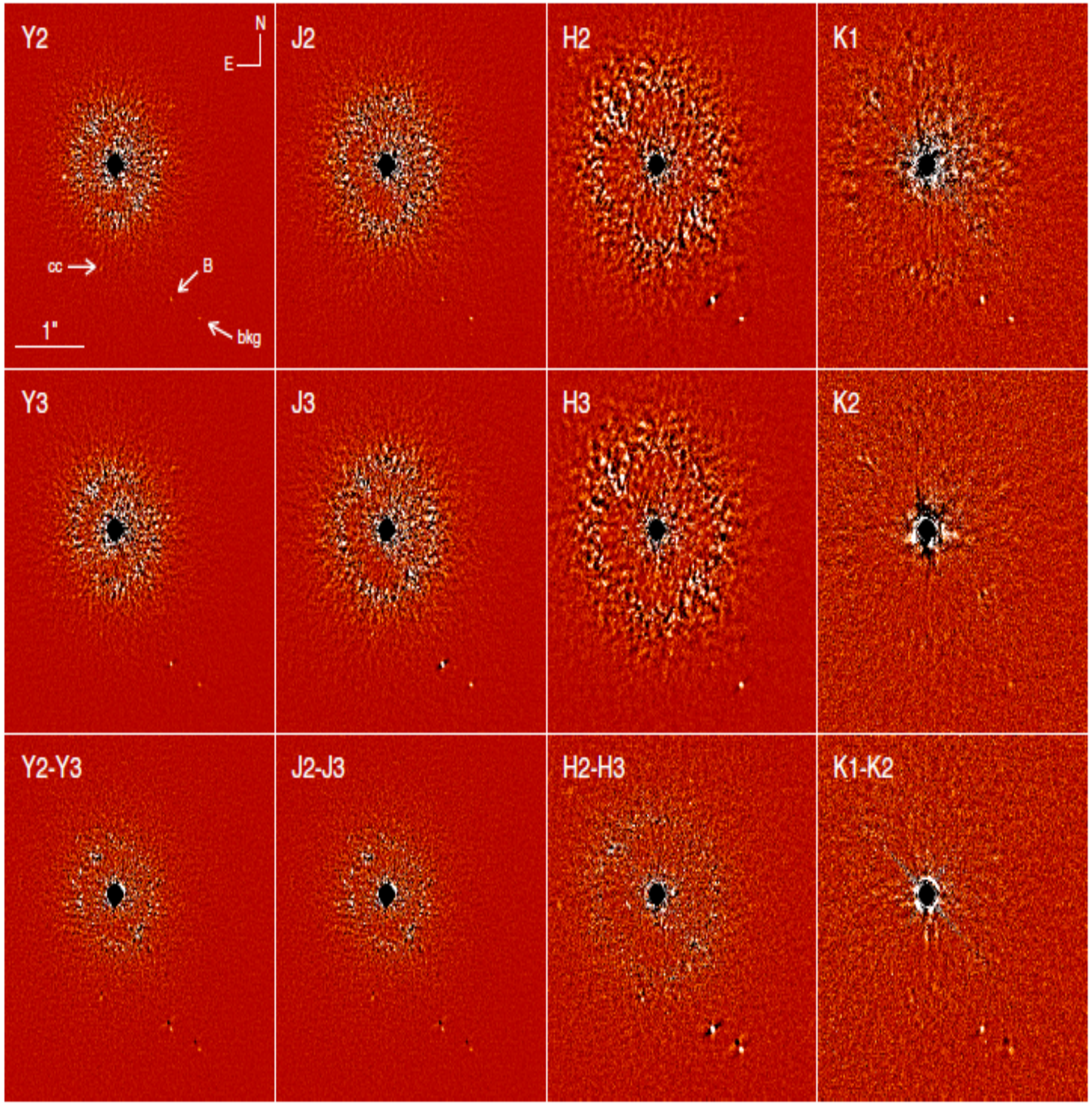
Observational investigations of planetary system and theoretical studies indicate that giant planets form in < 10 Myrs and Earth-like terrestrial planets in ~30 Myrs.
→ **Thus, local, post T Tauri stars promise to reveal the story of the formation and early evolution of planetary systems.**

There are several tens of potential targets, depending on exact magnitude limit of the instrument, accessible for a deep search for planets in wide orbits

In particular, with the current limit at R<10.5 our sample comprises 33 targets (basically FGK-type stars), whereas adopting R=12.5 as a magnitude limit we would gain more than a factor of three in sample size (that is 108 objects)

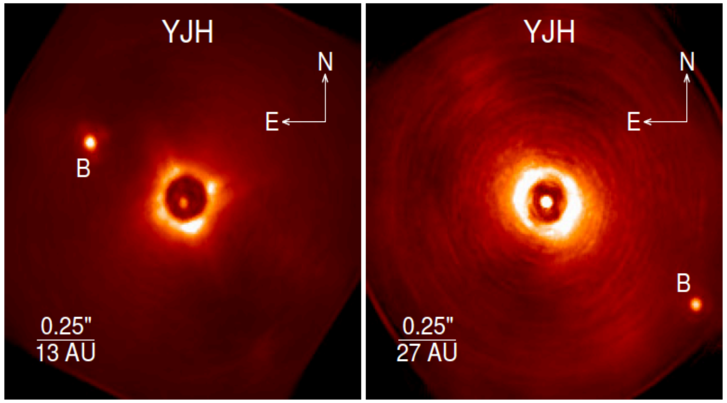


SPHERE and GPI will be mostly limited to solar-type and early-type stars (in the Southern hemisphere)

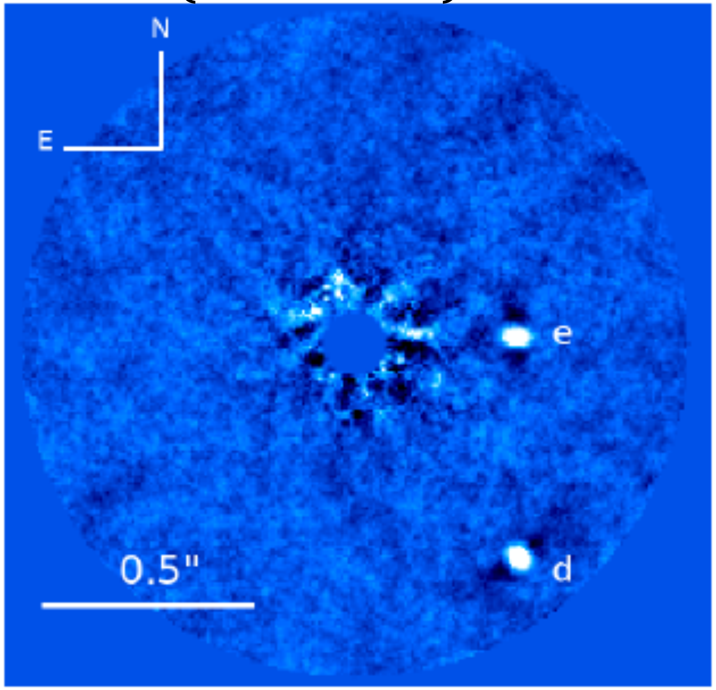


IRDIS GJ758 system (Vigan+ 2016)

Pz Tel & HD 1160 (Maire+ 2016)



IRDIS (left) and IFS (right)
HR8799 (Zurlo+ 2015)



What does this kind of science require?

Coro IWA required: minimum 4 λ/D, goal 2-3 λ/D

Contrast : 10^{-6} (goal 10^{-7}) in the range IWA=300-500 mas,
10^{-5} (goal 10^{-6}) for IWA<300 mas

→ A contrast of 10^{-6} ($\Delta M=15$), assuming a distance for the system of 140 pc and ages of 10 Myr and 100 Myr, would correspond to mass limits of $M=4.24\ M_{jup}$ and $M=5.29\ M_{jup}$, respectively (employing models by Allard and collaborators).

synergy with LMIRCAM : extension to thermal infrared for SED determination and broad spectral coverage to remove degeneracies affecting NIR photometry

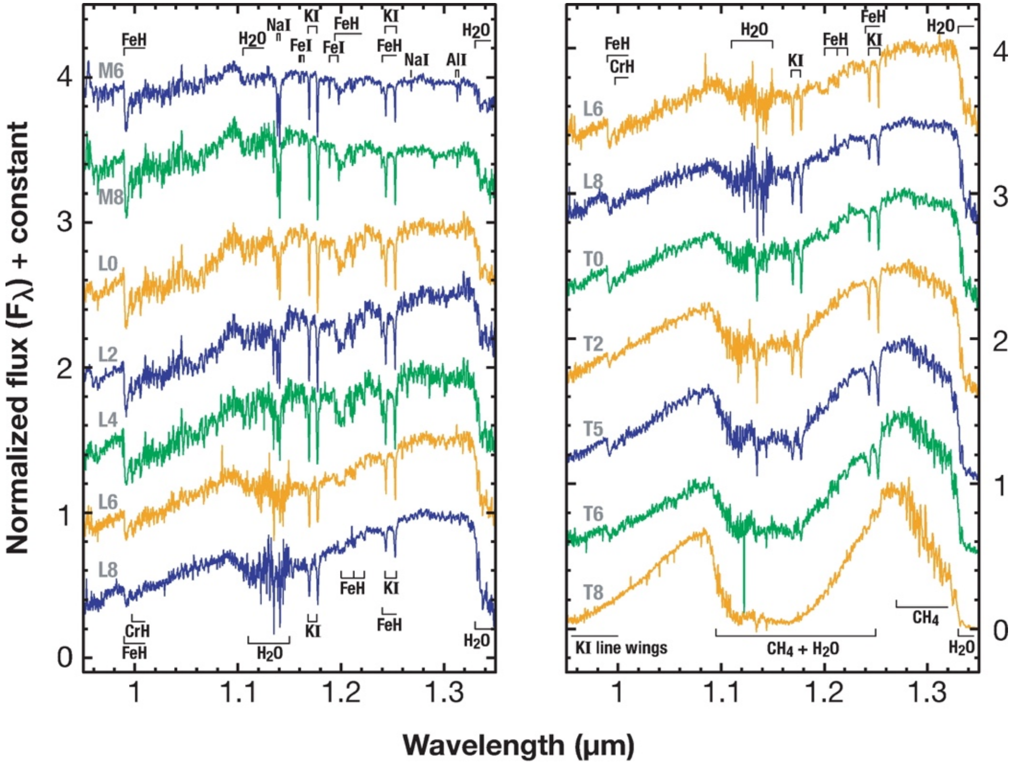
synergy with VIS Channel : feature Hα and accretion mechanisms

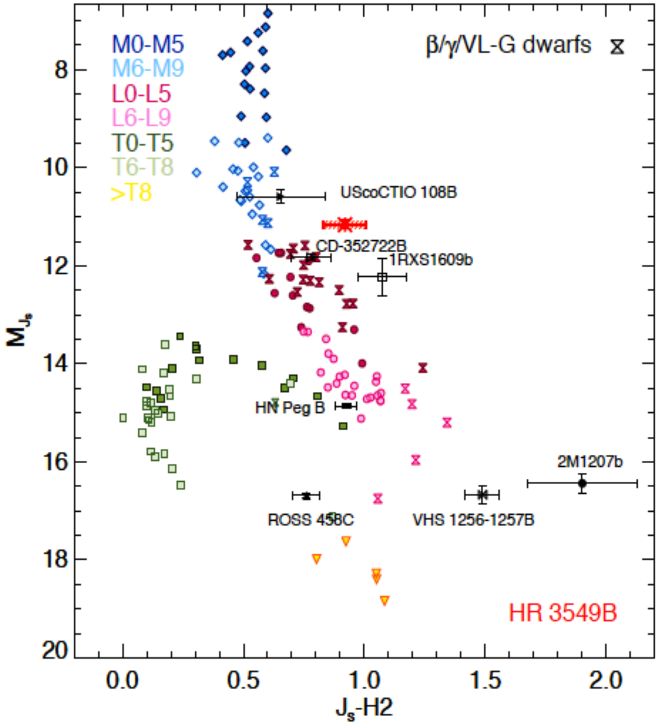
Photometric and spectroscopic characterisation of known planets/BDs

Shed light on L-T transition and on the characteristics of brown dwarfs and giant planets, which are expected to somewhat overlap but also significantly differ in terms of chemistry of the atmospheres and mechanisms of clouds formation (Mandushev et al. 2014).

The L-T transition

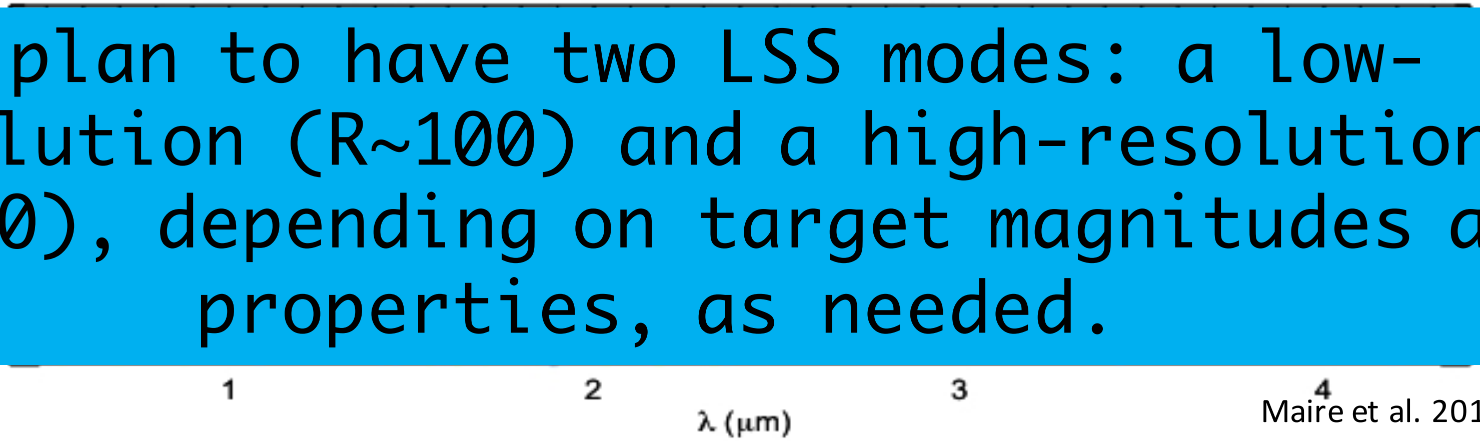
Mesa+ 2016, in prep.





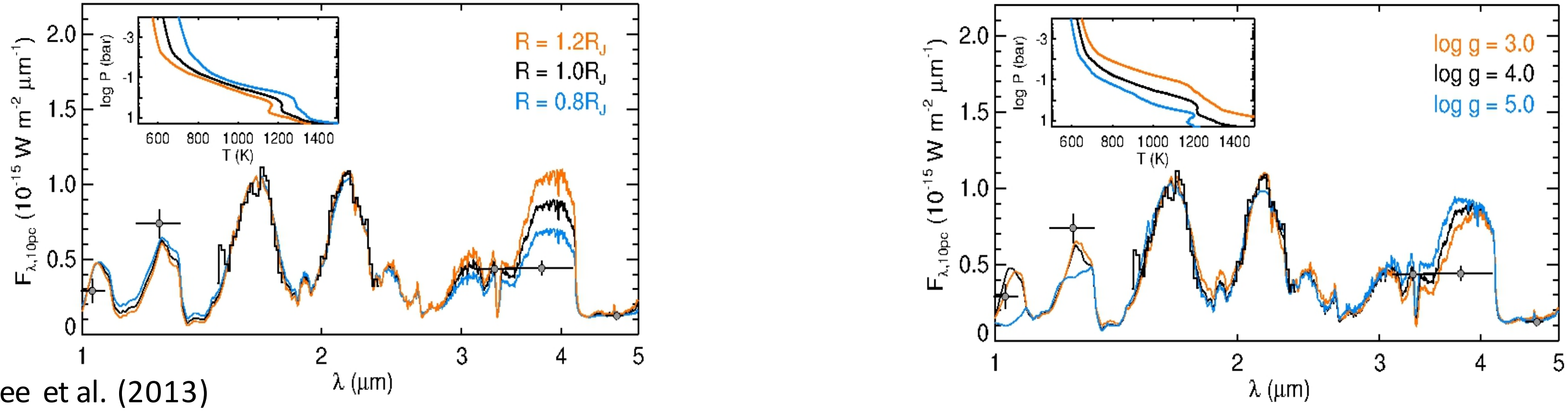
The implementation of a long slit spectroscopic mode will furnish spectral classification (L vs T) if R=30 and molecular band identification if R > 100.

We plan to have two LSS modes: a low-resolution (R~100) and a high-resolution (R~1000), depending on target magnitudes and properties, as needed.



Maire et al. 2016

Synergy with LMIRCAM will provide us with large and critical spectral coverage that is CRUCIAL as to breaking degeneracies affecting NIR-only spectroscopic observations



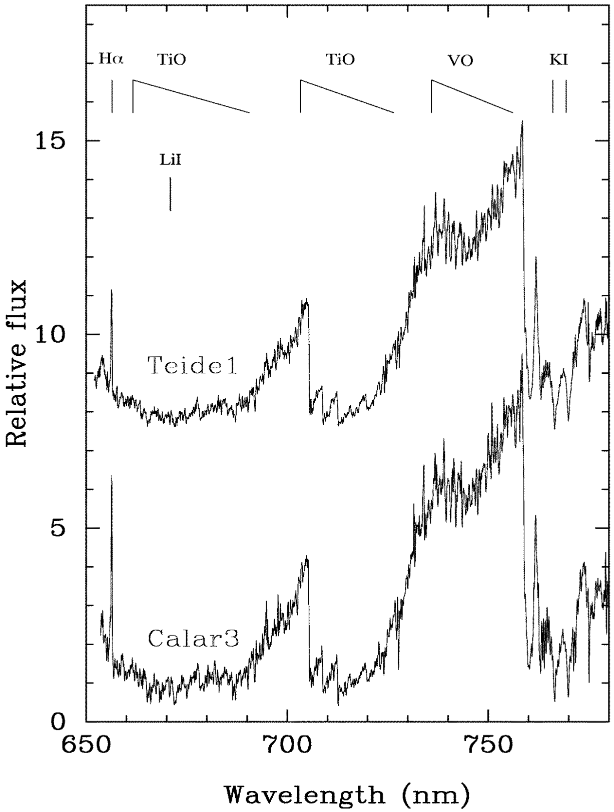
Lee et al. (2013)

Brown dwarfs in open clusters

Brown dwarfs (BDs) –intermediate objects between stars and planets- are still poorly understood, especially in terms of formation mechanisms (star-like, or planetary-like formation??)

Formation of gas-giant planets: core accretion (Jupiter/Saturn mass, up to ~10 AU) and disc instability (up 10 Mjup, 10-100 AU).

→ Two populations of giants planets segregated by orbital distance: the closer planets formed by core accretion and the outer ones by disk instability, showing that stellar and planetary mechanisms overlap in the substellar regime.



→ statistical properties -occurrence, the mass, and the main orbital parameters- should help to identify the dominant mechanism to forming substellar companions.

Objects belonging to moving groups/local associations are preferred objects: they are nearby (20-100pc) and young (several to several hundred Myr), so their substellar objects (planets and BDs) are relatively bright → PLEIADES (known age, distance, metallicity)

Astrometry

Astrometric follow-up allows to constrain the total dynamical mass for short-period systems (≤10 AU typically), and if combined with radial velocity data the individual masses of the components of a system can be derived.

There are two kinds of short-period systems relevant for astrometric monitoring:

1. Low-mass binary systems with components of similar masses, like brown-dwarf binaries

2. A young star primary and a brown-dwarf or giant planet companion (e.g., HR7672, β Pictoris)

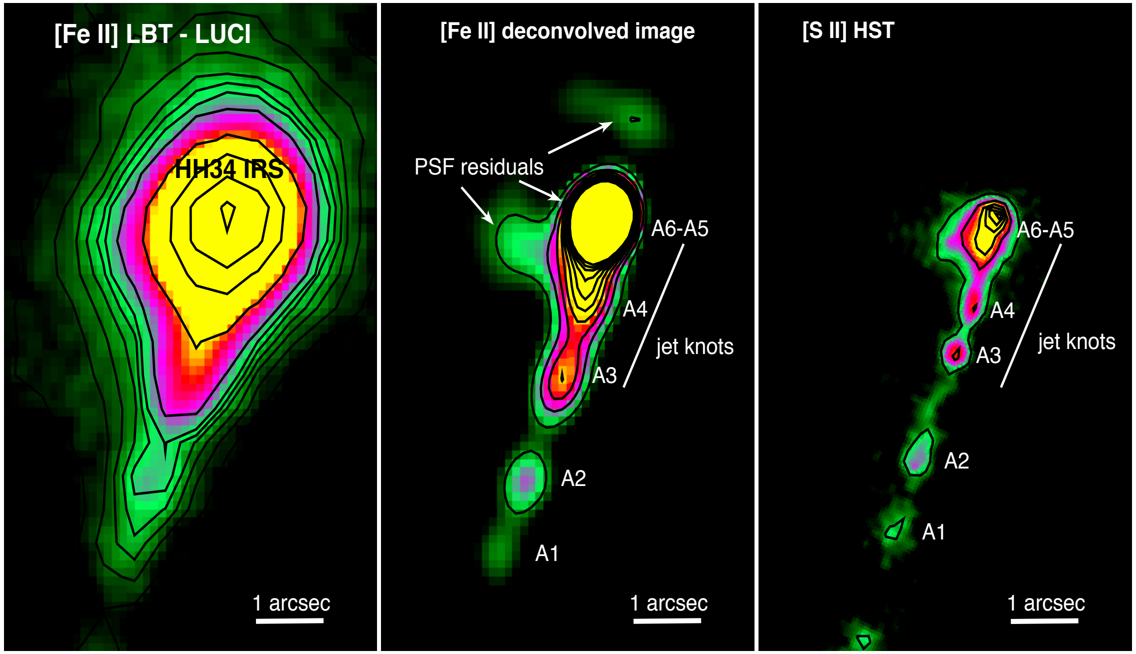
Astrometric performance comparable to that of SPHERE (3-5 mas).

directly imaged young massive planets and brown dwarfs with SHARK-NIR will be monitored with the objective of detecting the orbital motion of the companions, and the combination with Gaia astrometry of the primaries will allow for very tight constraints to be placed on the actual masses of the imaged objects

Discs around Young Stars and their Jets

- High-contrast imaging of circumstellar discs with NIR coronagraphy.
- Coronagraphic or classical imaging of stellar jets
- 2D kinematical maps of Jets

Narrow-band images of jets reveal the generation mechanism and its feedback on the star/disc



Antoniucci+ (2014)

Goals:

understand dynamic role of jets in shaping the disc structure

Probe the innermost regions of discs and jets in T Tauri stars (Binocular observations VIS+NIR)

H_2 as key tracer: SYNERGY with LMIRCAM

Requirements: **Classical Imaging + CORO** IWA<3λ/D (~100 mas); Contrasts 10^{-4} for discs and 10^{-3} for jets

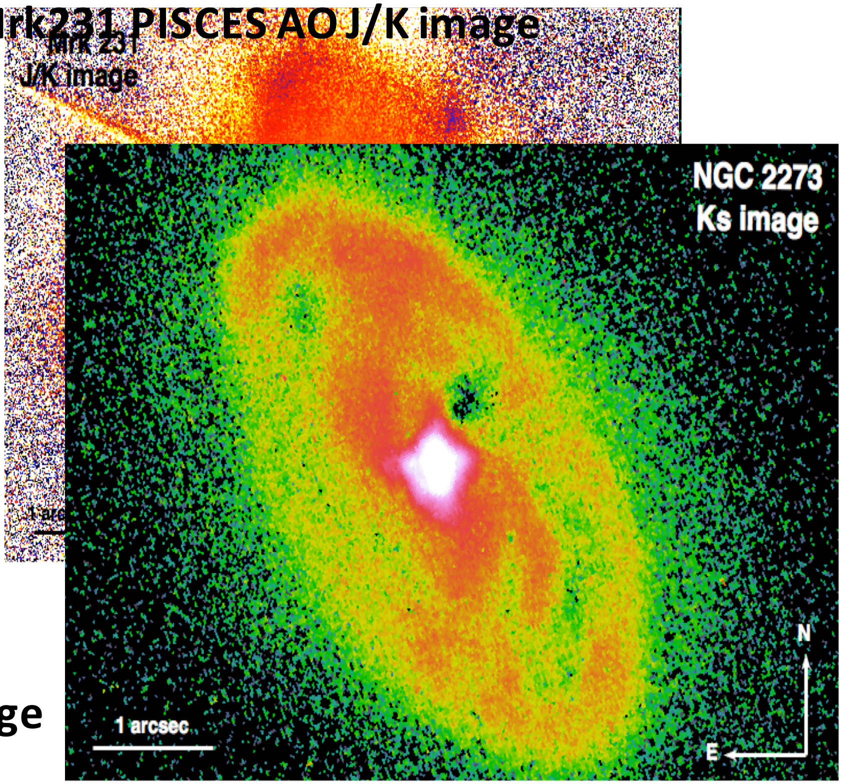
AGNs and QSOs

(1) Discover and fully characterise the AGN close pairs;
(2) Constrain the Black Hole feeding mechanism (e.g., SN driven winds *vs* gravitational asymmetries) in local Seyfert galaxies
(3) Trace, in bright quasars, molecular outflows powerful enough to clean the inner kpc and quench the star formation

- Dust lane maps on scales down to hundreds pc to investigate whether outflows are dusty or rather the AGN driven feedback has already swept the ISM;

- Color maps of SF regions in the galaxy nucleus and disk to constrain the SF rate, the age, and the metallicity.

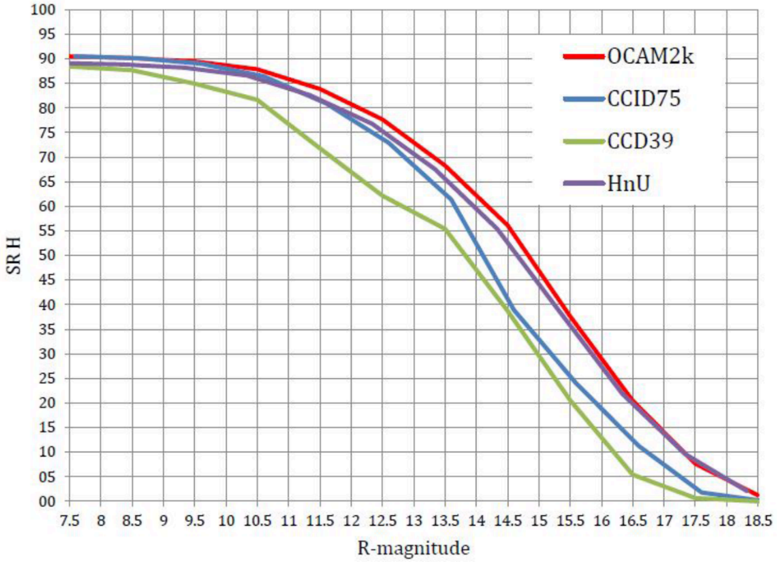
Mrk231 PISCES AO J/K image



NGC 2273 PISCES AO K image

Requirements:
Binocular VIS and NIR both imaging and coro modes. + Synergy with LMIRCAM for H2
Coronagraphs with $2<\lambda/D<8$; FoV of 5”x5” and ~20”x20” for DLAs and AGN inner morphology.

Conclusions: where SHAR(K)-NIR can be unique?



Thanks to the outstanding performances of the AO system (especially with SOUL upgrade) we will be able to target FOR THE FIRST TIME relatively faint targets (planets on wide orbits around K/M type stars, distant QSO/AGNs, etc..), NOT ACCESSIBLE before

Implementing the combination of coronagraphic techniques and long-slit spectroscopy will allow us to derive fundamental properties for giant planets and brown dwarfs, providing crucial information such as e.g., spectral types (and the L/T transition), atmospheric properties and chemical composition.

The utmost synergy of SHAR(K)-NIR with the existing and forthcoming instrumentation at LBT (SHARK-VIS, LMIRCAM..), will result in a very powerful tool that is not currently available for other facilities in the world.