First science results from SPHERE and future perspectives

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The field of extrasolar planets today

- At the moment 2017 planets have been discovered. Of these, 666 have been discovered by Radial Velocity, 1300 by transiting, 46 by microlensing and just 65 by direct imaging.
- Direct imaging is a very challenging method because of the large contrast (~10^{-6} for a young Jupiter-like planets and down to 10^{-8}-10^{-9} for an old Jupiter-like planets arriving to 10^{-10} for an Earth-like planets) and of small angular sepation (of the order of few tenths of arcsec for a planet at a a distance up to 100 pc and a separation of 10 AU) from the hist star.
- Direct imaging is however important because it can give us the possibility to determine the planetary orbit, to obtain spectro-photometric data from the planet (so information about its composition), to obtain information about interaction between planets and disks and then about the evolution of planetary systems. Moreover, coupling direct imaging with indirect technique could allow a precise characterization of the planets.

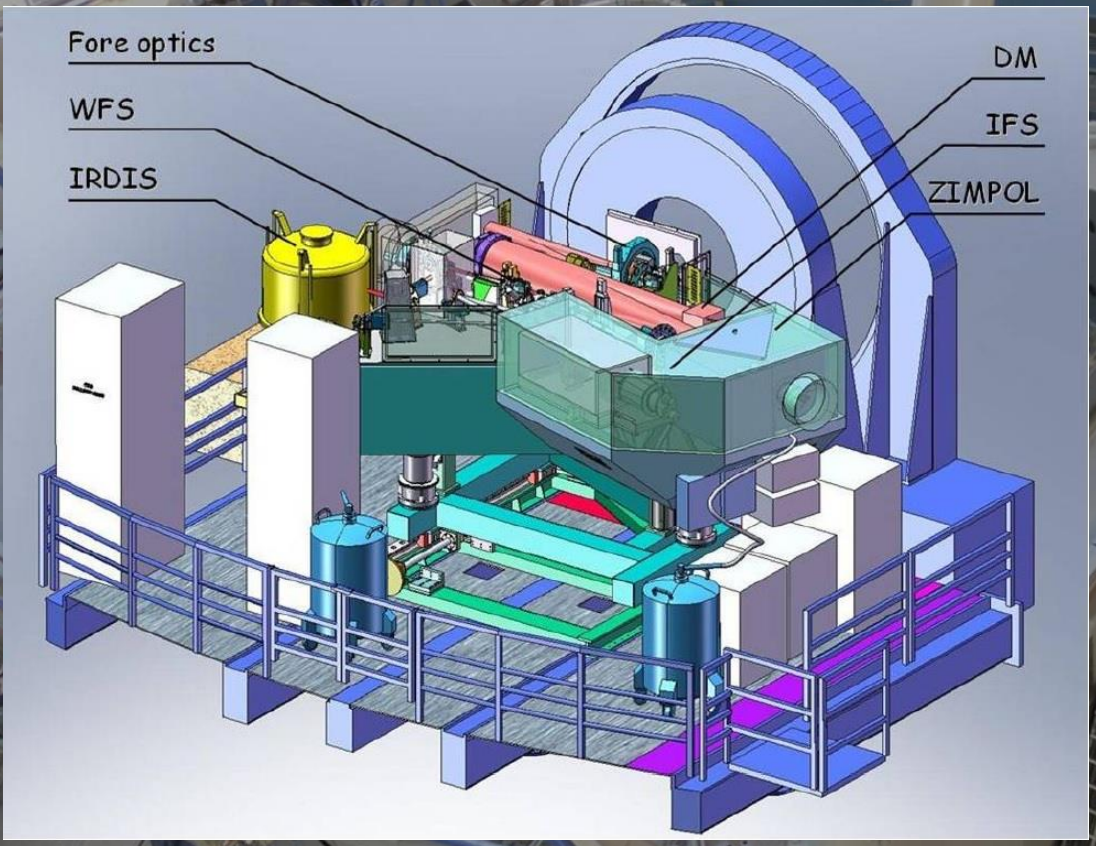
Tools needed for successful direct imaging of extrasolar planets

To be able to image an extrasolar planets we need the following tools:

1. High efficiency coronagraphy to strongly attenuate the light from the host star.
2. Extreme Adaptive Optics (XAO) systems able to provide high Strehel ratio (~90%)
3. Effective methods for the reduction of the speckle noise that can mimick the presence of a planet. The main methods are:
   - Angular Differential Imaging (ADI) that exploits the rotation of the FOV diring the observing time
   - Spectral deconvolution (SD) that exploits the scaling of the speckle pattern with different wavelengths.
   - Spectral Differential imaging (SDI) that exploits different structures in the sepctrum of the star and in the spectrum of the planets (e.g. absorbing bands of the methane in the T-type spectra)

   Various algorithms has been implemented to fully exploit these techniques (e.g. PCA or T-LOCI)

What is SPHERE

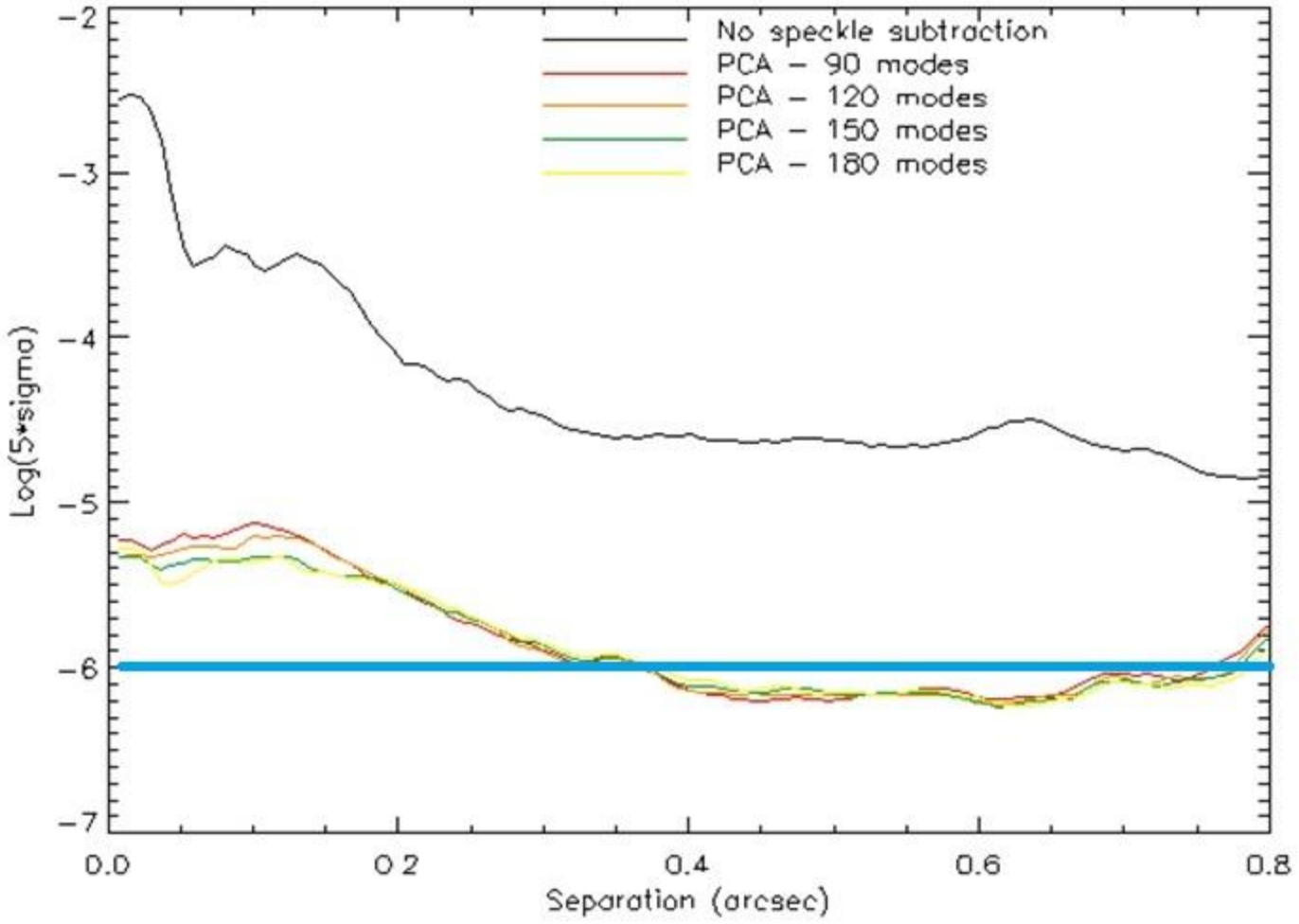


SPHERE is a VLT isntrument aimed to the direct imaging of extrasolar planets. It is composed by three scientific modules :

- IFS a low resolution (R=30-50) integral field spectrograph) operating between 0.95 and 1.65 μm. FOV=1.7x1.7 arcsec
- IRDIS an infrared (0.95-2.32 μm) imager mainly aimed to use the SDI. FOV=11x11 arcsec.
- ZIMPOL is a direct and differential polarimetric imager operating in the visible (0.5-0.9 μm). FOV=3.5x3.5 arcsec.

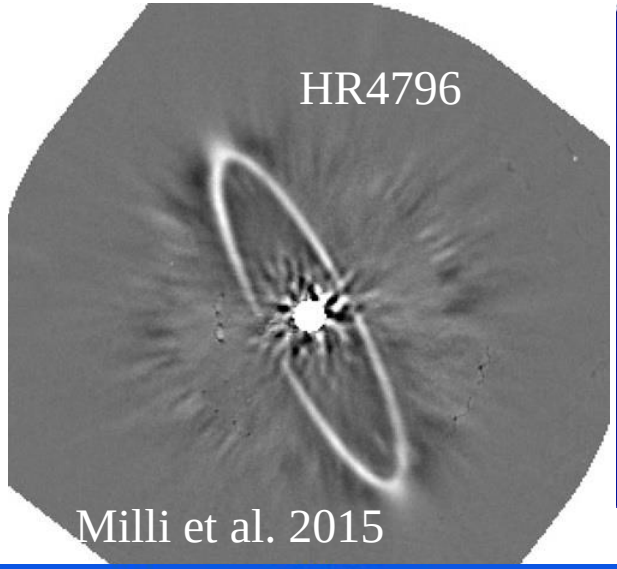
In its common path, it has a set of different high performance coronagraph (both Lyot and 4 quadrant) adapted for different observing bands and the extreme AO system called SAXO (Sphere AO for eXoplanets Observations)

Results with SPHERE: contrast

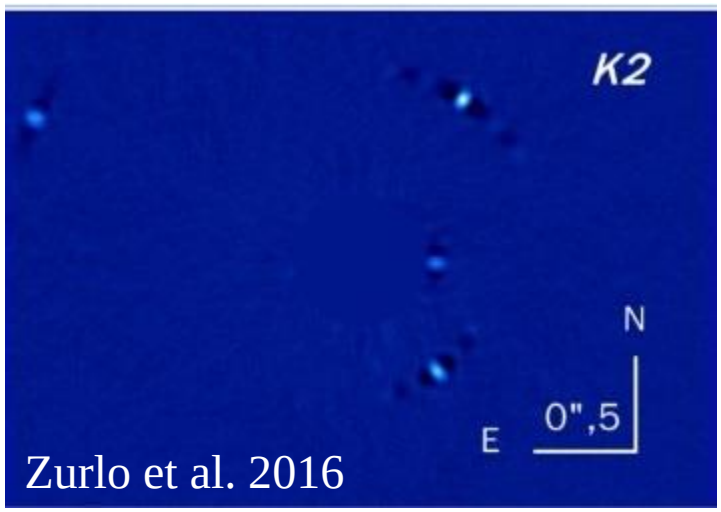


IFS 5σ contrast at 0.3 arcsec ~10^{-6} for Tau Ceti (R=2.88)

Results with SPHERE: images

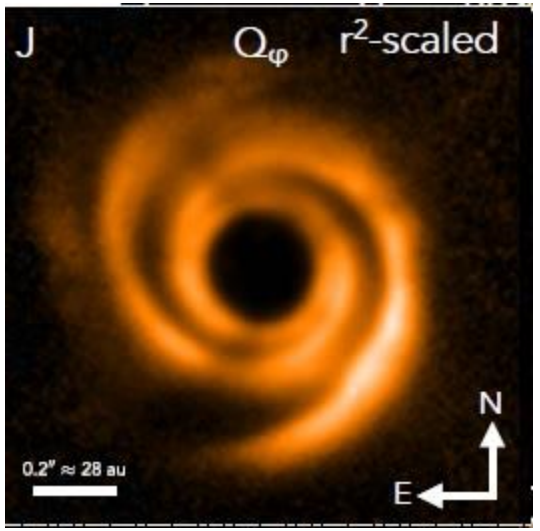


Milli et al. 2015

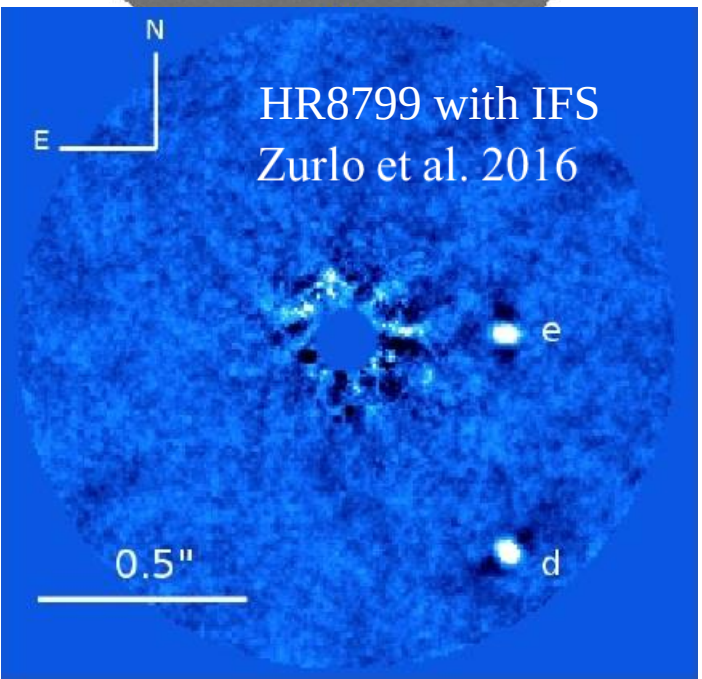


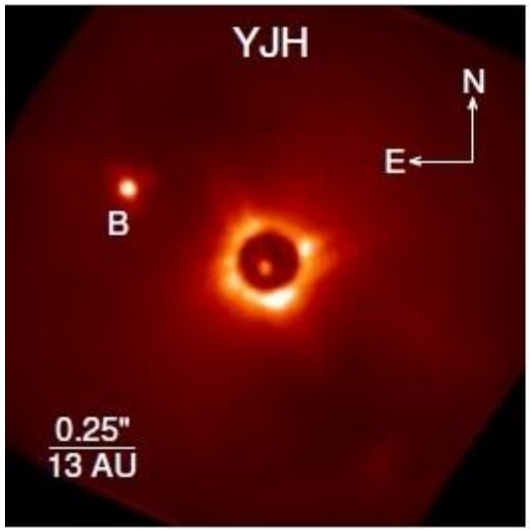
Zurlo et al. 2016

HR8799 with IRDIS



HD135344B (Stolker et al 2016





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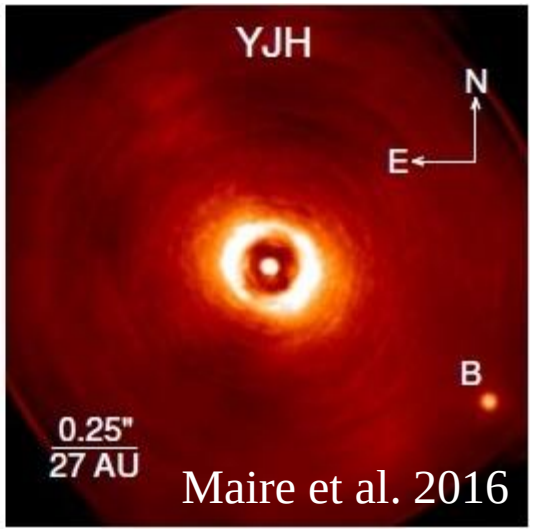
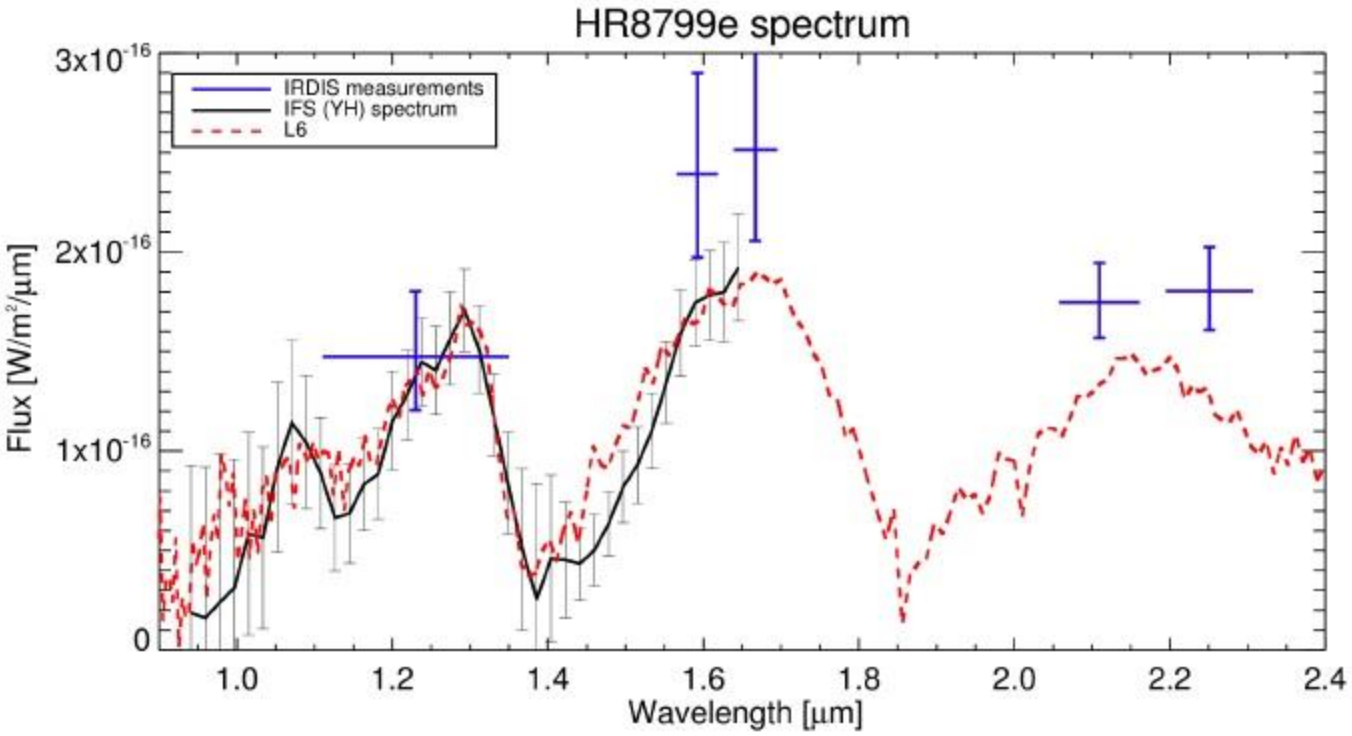


HD1160

Not only nice images …



Zurlo et al. 2016

Spectral retrieving and classification (with IFS)

And moreover: precise astrometry ➔ orbit determination

photometry ➔ companion characterization (mass, T_{eff})

Planets statistic with SPHERE

From the statistical point of view SPHERE will allow to determine the frequency of giant gaseous planets at medium and large separation (that is, beyond the snow line) from the host stars. This goal will be fulfilled through the SHINE survey that search for these objects in young systems (less than 100 Myr) in the Near Infrared (0.95 – 2.32 μm) using both the scientific subsystems of the IR branch (IFS and IRDIS).

This work will allow to complement the informations on the distribution of giant planets coming from RV and transit methods that are normally limited to small separations.

Work in progress with SPHERE

SPHERE is not only a planet finder. Indeed it allow:

- Characterization of known or new companion (BDs or giant planets) allowing to determine their mass, radius, T_{eff} (using theorical models) and to obtain a spectral classification.
- Experimental work are just now under developments to define the time variability of the brightness of the planets of HR8799 so being able to define e.g. a model for the clouds of these objects.

Future perspectives

The work now performed on SPHERE is not stand alone. It is indeed a milestone for the development of instrumentation for the future ELT (e.g. PCS for the E-ELT). While with SPHERE we are limted to young giant planets, these new instruments will allow to image (and characterize) older giant planets (Jupiter like) and arrive probably to image super-Earth or neptunian.

Conclusion

- SPHERE is now working since more than one year.
- Its performance until now are as expected allowing us to obtain contrast never obtained until now.
- It allows to characterize substellar companions with unprencented precision (e.g. HR8799) .
- Further, SPHERE is a test case for future instrumentations for the ELT telescope (e.g. PCS for E-ELT).