Photometric characterization of exoplanets using ADI and SDI in SPHERE/IRDIS

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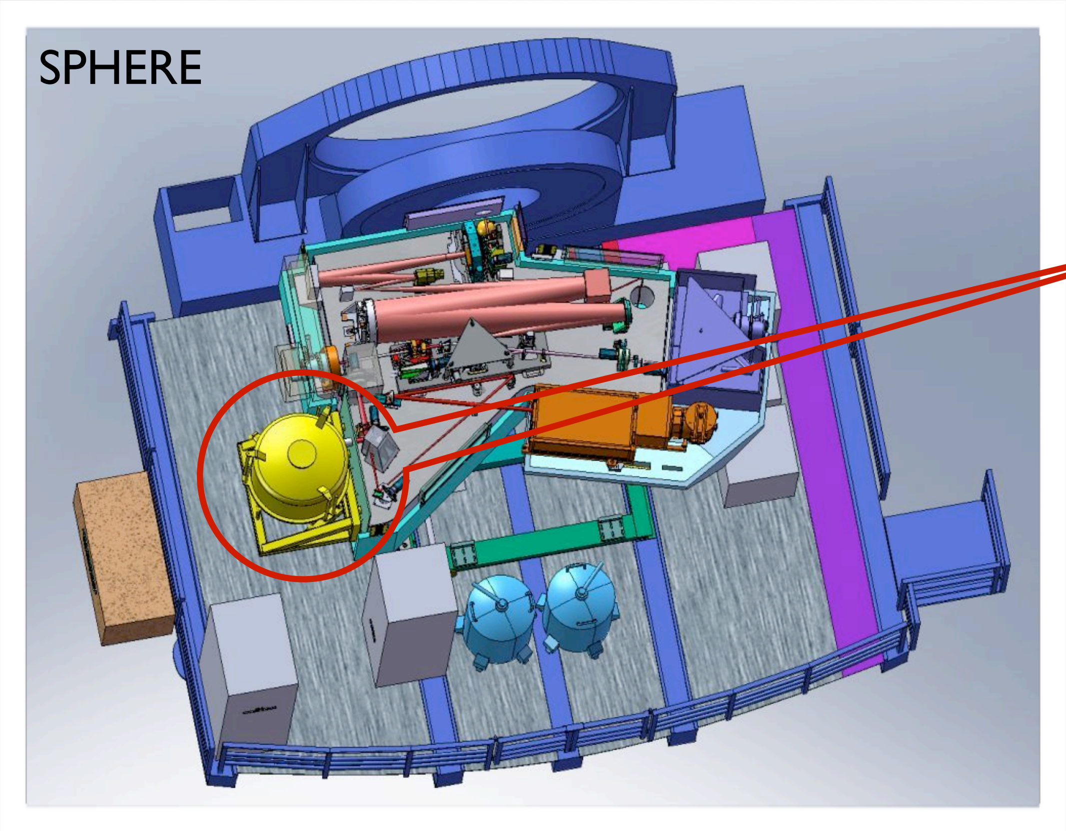
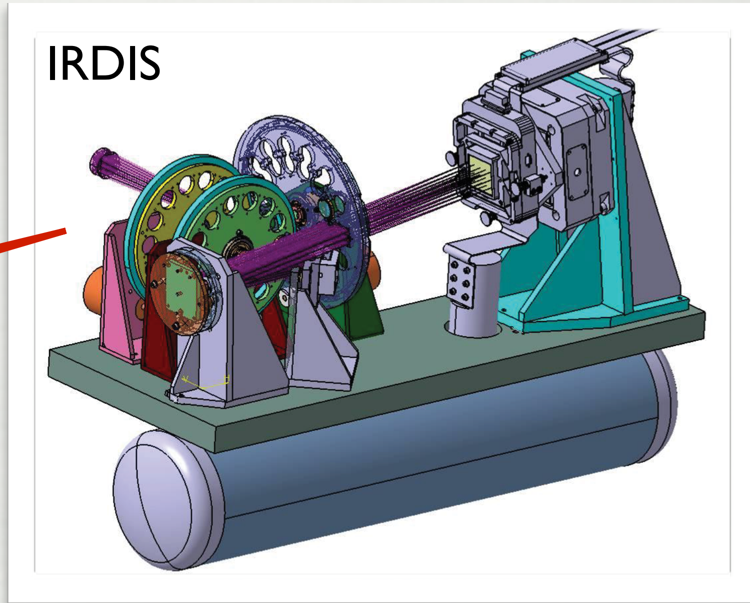
In the Spirit of Lyot 2010 - Paris - 28/10/2010

The VLT/SPHERE instrument





Main goals:

- 5σ contrast ≥12.5 mag
- Angular separation ≥ 0.10”
- Masses down to ~1 M_{Jup} at short separation

Main characteristics:

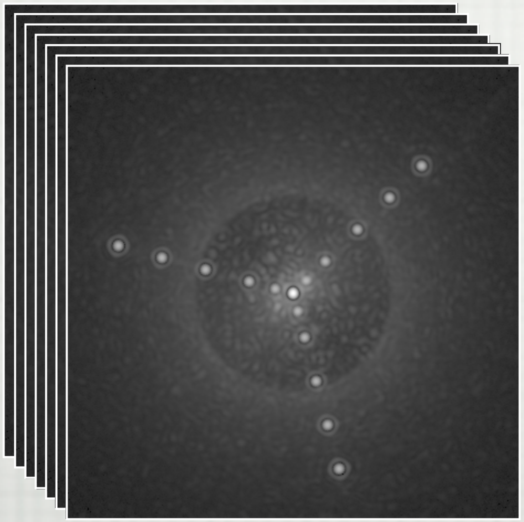
- Differential imager: YJHK bands
- Long slit spectrograph:
  - R = 60 and R = 420
- Polarimeter
- Imager
- 11” FoV with 12.25 mas/pix

SPHERE consortium:
LAOG, MPIA, LAM, LESIA, Laboratoire Fizeau, INAF, Observatoire de Genève, ETH, NOVA, ONERA, ASTRON

Data simulation for DBI mode

Realistic simulations with IDL+package SPHERE (Carbillet et al. 2008):

- atmosphere + AO + coronagraph + aberrations
- temporal variations (seeing, wind, optics rotation, ...)
- Y2Y3 / J2J3 / H2H3 / K1K2 filter pairs
- 4 h observing sequence for a star at $\delta = 45°$

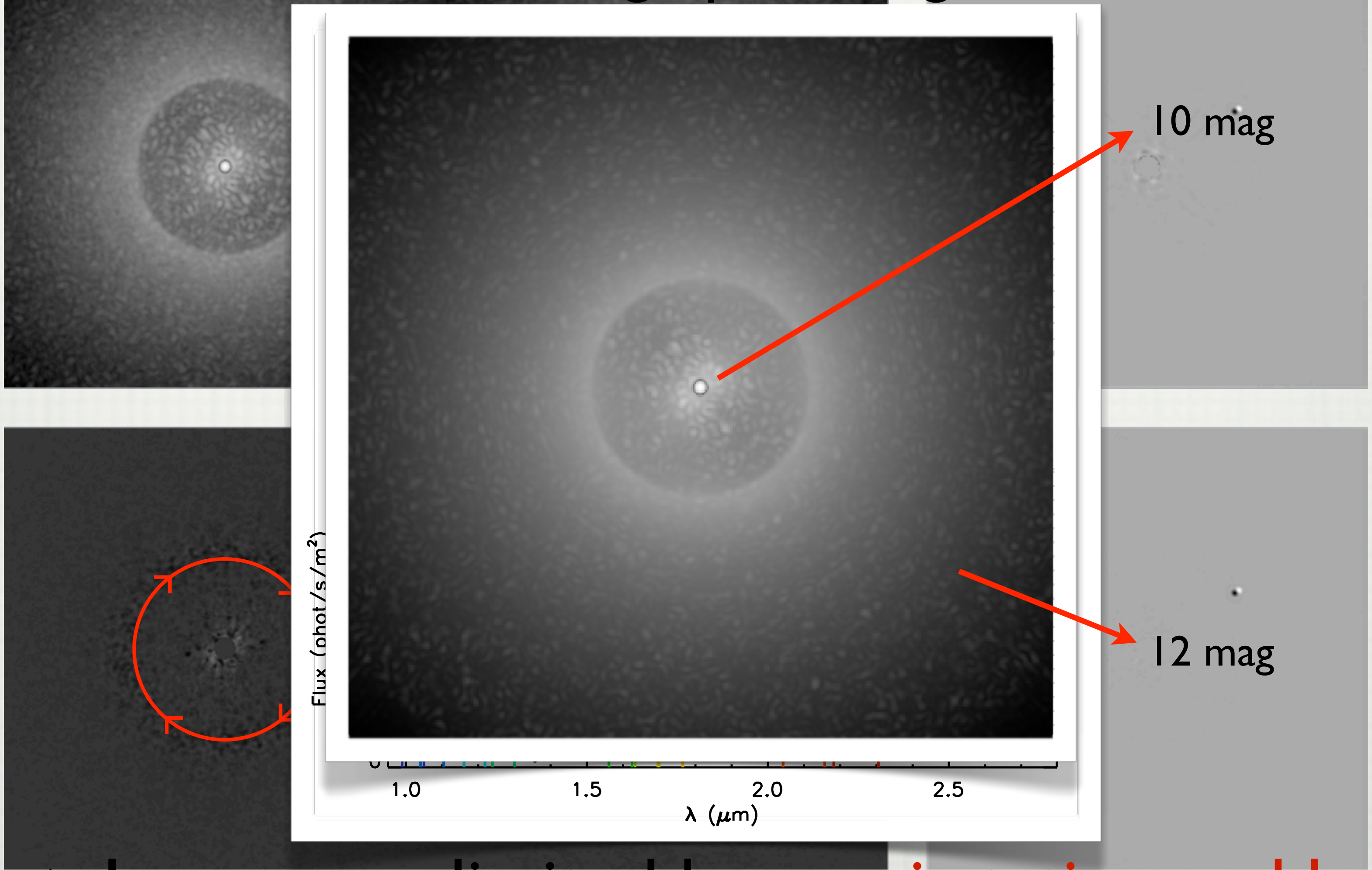


- 3 series of planets
- 5 angular separations
- stars from F0 to M2
- planet T_{eff} from 500K to 2500K
- contrast from 5 to 16.5 mag

Data analysis methods

λ_0 λ_1 SDI (Racine et al. 1999)

Coronagraphic image

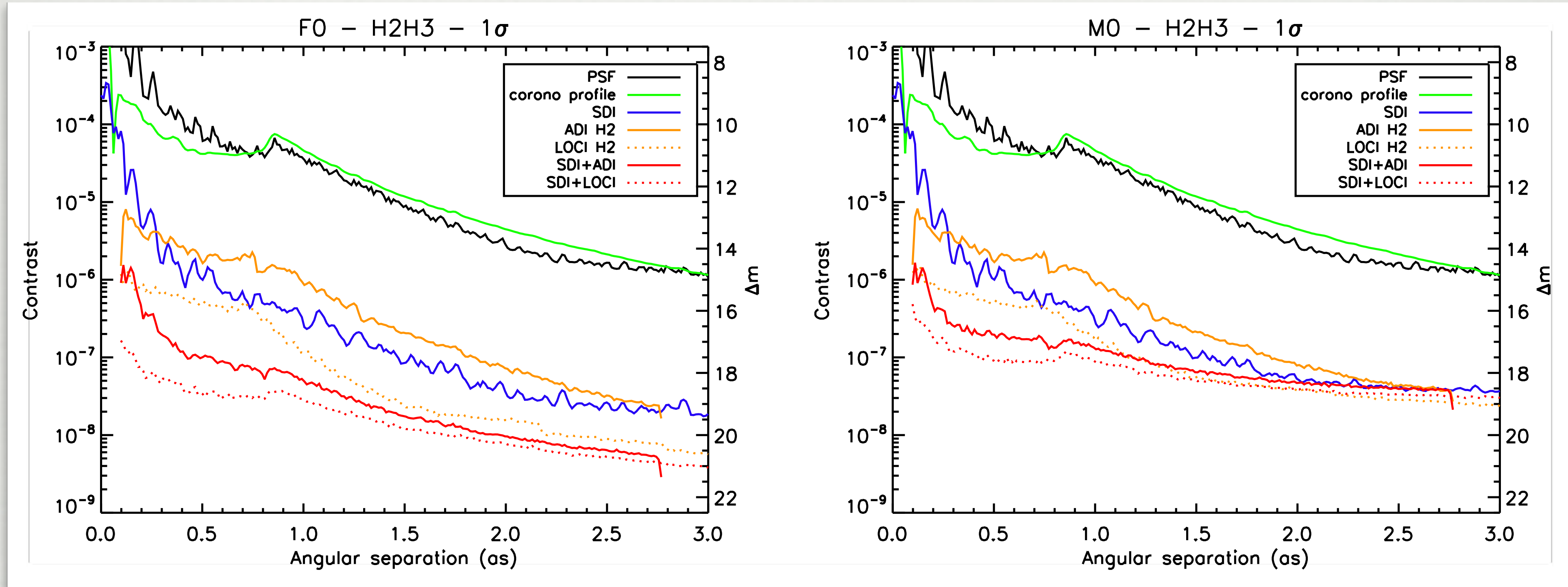


→ Images are limited by quasi-static speckles

ADI λ_0 ADI λ_1 SDI+ADI

(Marois et al. 2006)

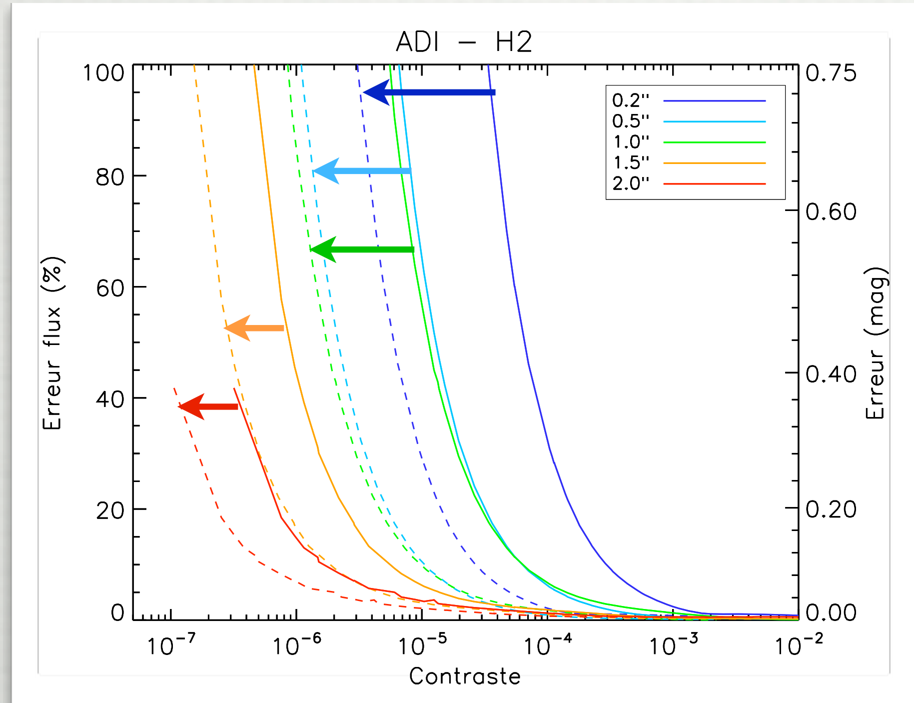
Detection limits



- Attenuation of
  - 4 to 5 mag with ADI or SDI
  - 6 to 7 mag with SDI+ADI
- LOCI really improves at small separation
- Similar results at other wavelengths
- Limiting sky and instrument background (K band)

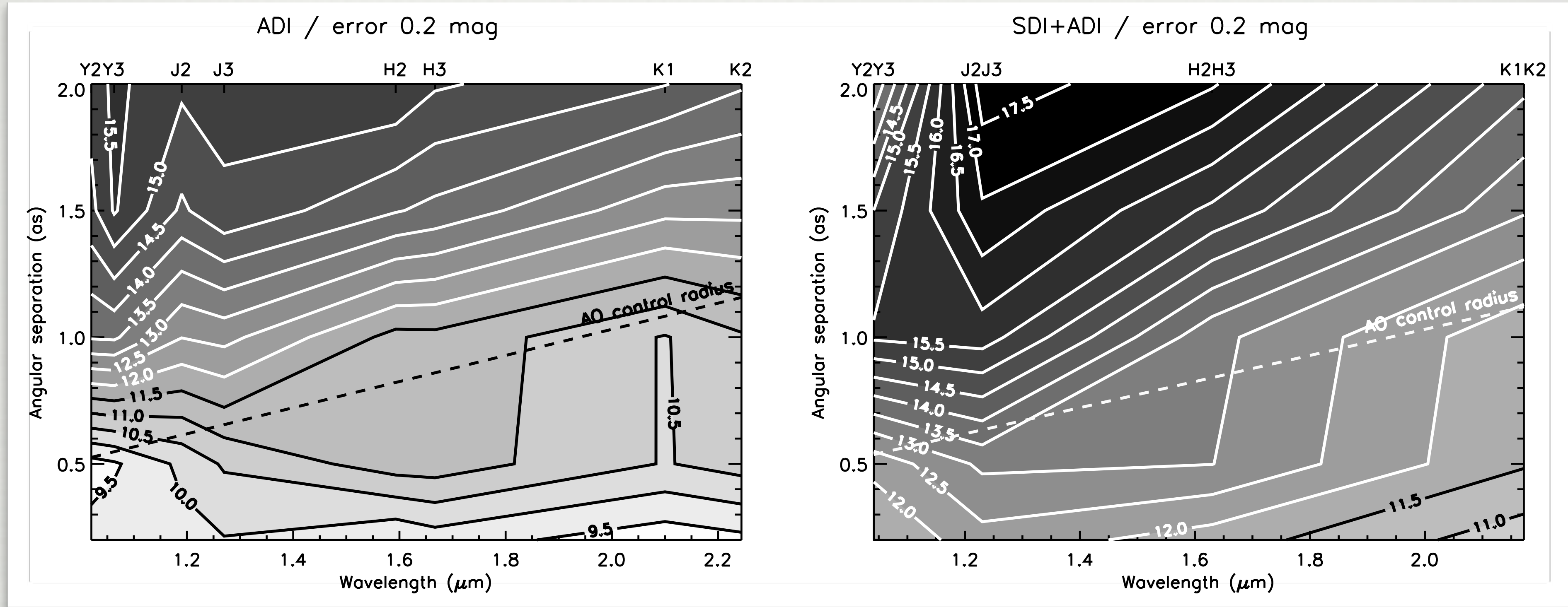
Photometric accuracy

- How precisely can the planet flux be retrieved?
- Estimation of the photometric precision:
    - for all planets detected at 5σ
    - using aperture photometry (diameter = 2.44 λ/D)



- SDI+ADI brings a significant improvement
- Variation with angular separation
- Factor 2 to 12

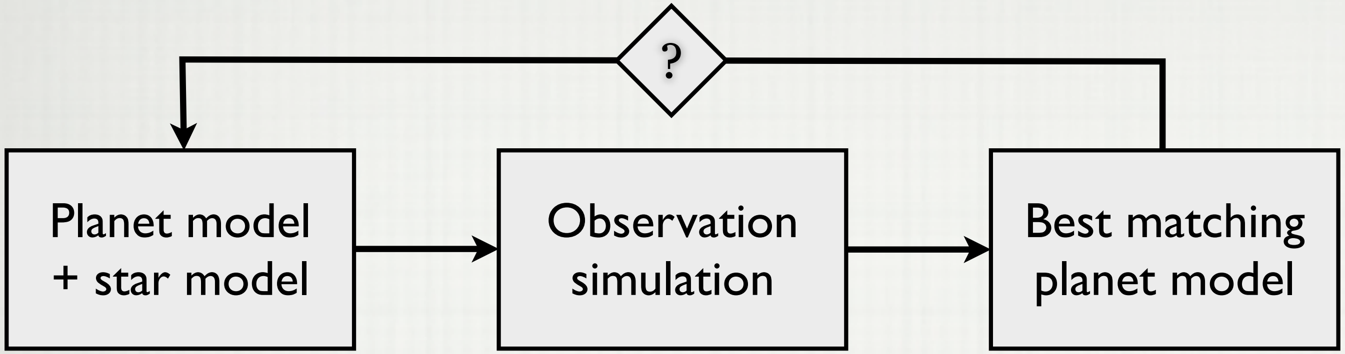
Dependance on wavelength



Vigan et al. 2010

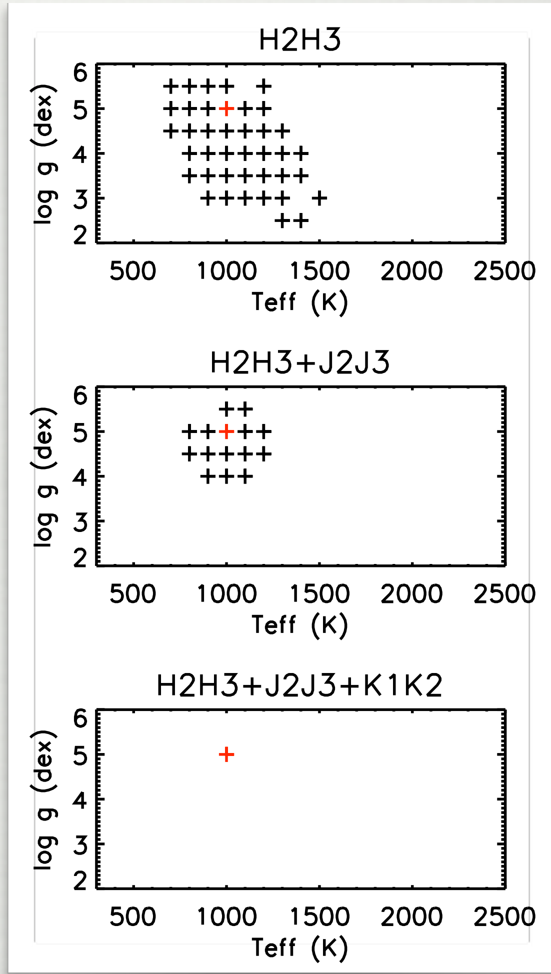
- 0.2 mag precision → ~30 K precision on T_{eff}
- Performance depends on:
  - wavelength (chromaticity of the PSF)
  - AO correction region (inside/outside)

Simulation of characterization performances



- T_{eff}
- log *g*
- spectral type

- filter pair sequence
- detection limits
- photom. precision



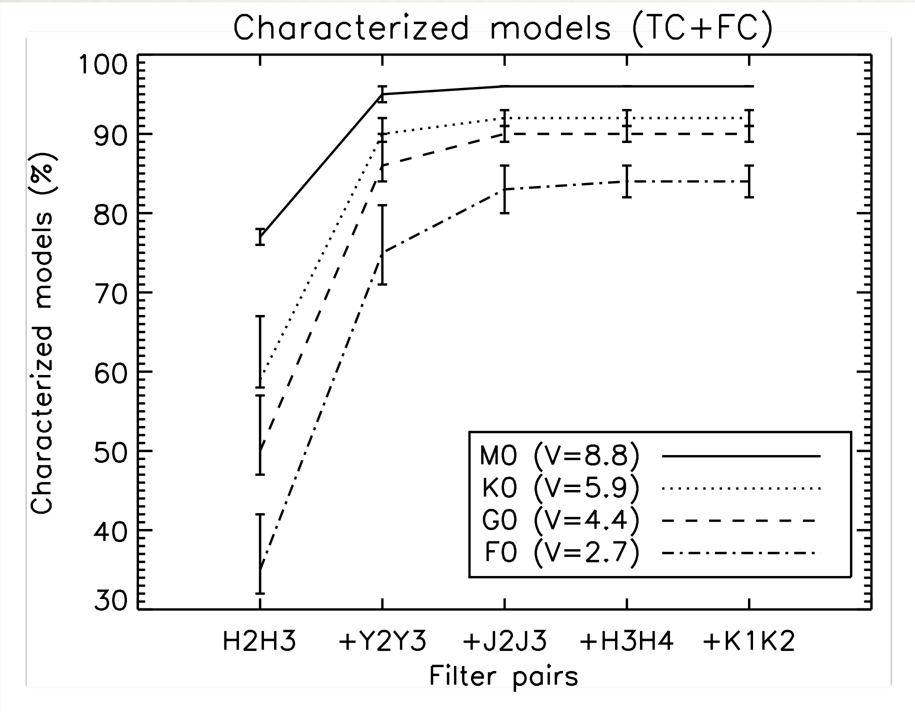
- Statistics on:
  - ~220 planetary atmosphere models
  - 4 stellar magnitudes
  - 5 angular separations

→ Test of all filter pair combinations

Best filter pairs sequence

➙ Priorities on filter pairs for characterization:

1. H2H3 (NIR-Survey)
2. Y2Y3 / J2J3
3. H3H4 / K1K2

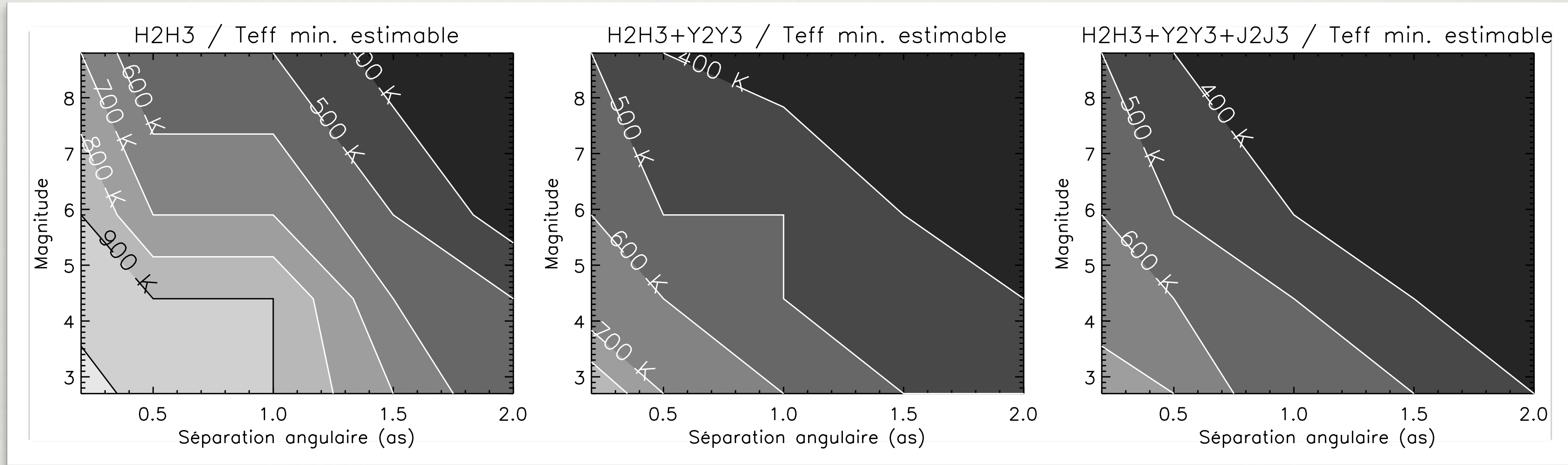


Vigan et al. 2010

- Significant gain with 2 or 3 filter pairs
- H3H4 / K1K2 useful for warmer objects
- No «cross-talk» between the different star magnitudes

Lowest estimations of T_{eff}

Vigan et al. 2010



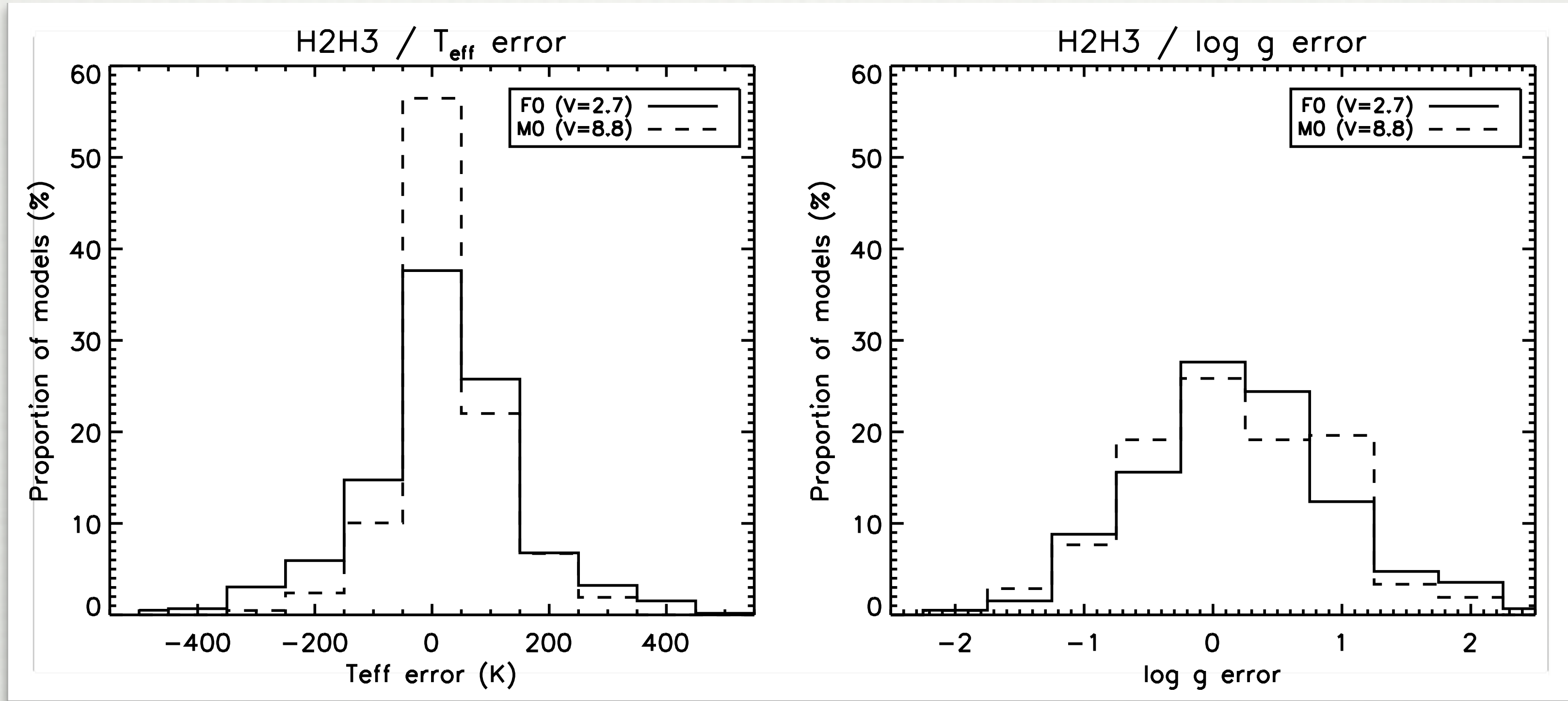
H2H3 H2H3+Y2Y3 H2H3+Y2Y3+J2J3

Estimation of T_{eff}:

- high flux → 700K @ 0.2″ / ~2 M_{Jup} @ 10 Myr
- low flux → 500K @ 0.2″ / ~1 M_{Jup} @ 10 Myr

Error distribution for T_{eff} and log g

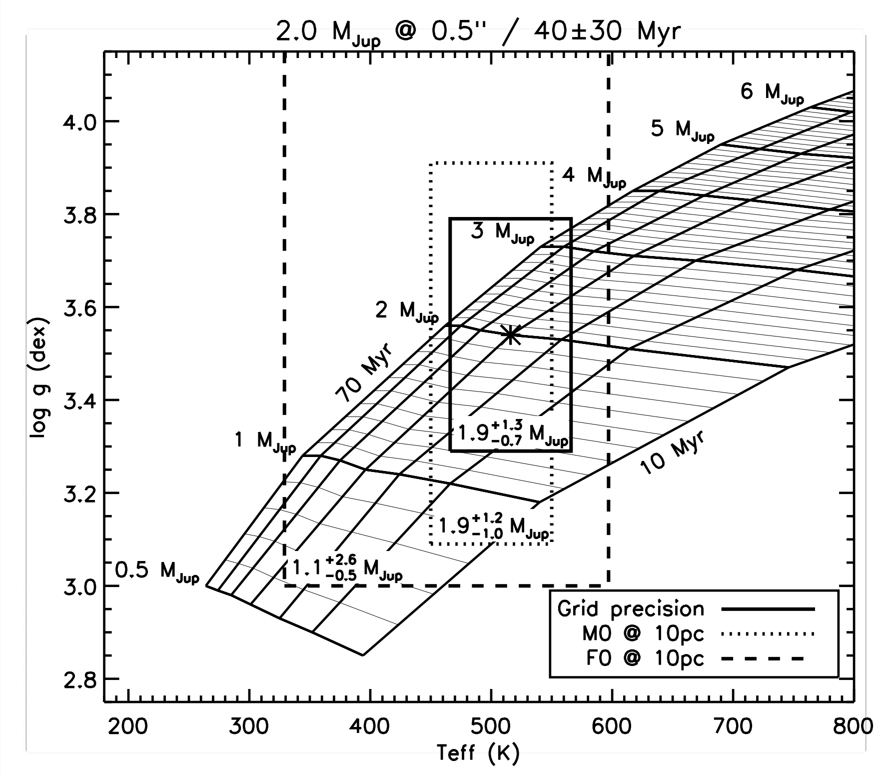
How precisely can we determine T_{eff} and log g?



- Strong dependence with star magnitude for T_{eff}
- Small dependence for log g

→ log g much more difficult to constrain!!

Impact of T_{eff} and log g errors



- Concrete example:
  - M0 and F0 stars at 10 pc
  - 2 M_{Jup} planet @ 5 AU
  - age 40±30 Myr
  - age based on preliminary SPHERE target list

Ideal	M0 @ 10 pc	F0 @ 10 pc
$1.9^{+1.3}_{-0.7}\ M_{Jup}$	$1.9^{+1.2}_{-1.0}\ M_{Jup}$	$1.1^{+2.6}_{-0.5}\ M_{Jup}$

Conclusions

- IRDIS in DBI mode will allow to reach Jupiter mass regime at very small separation
- Speckles strongly limit the photometric accuracy on the planet flux
- Combining different filters helps to constrain a model on the data ➙ definition of a best filter pair sequence
- Characterization of planets down to 1 M_{Jup}
- log g is difficult to constrain and leads to large errors on the planet mass