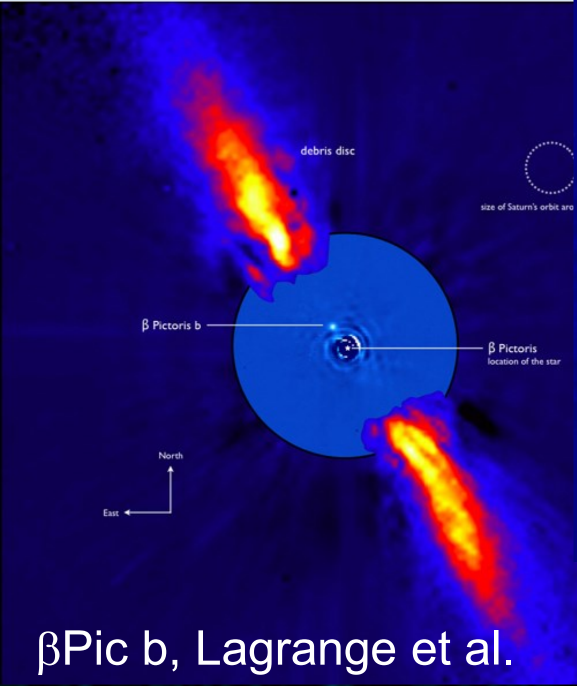
VLT XAO, next steps?

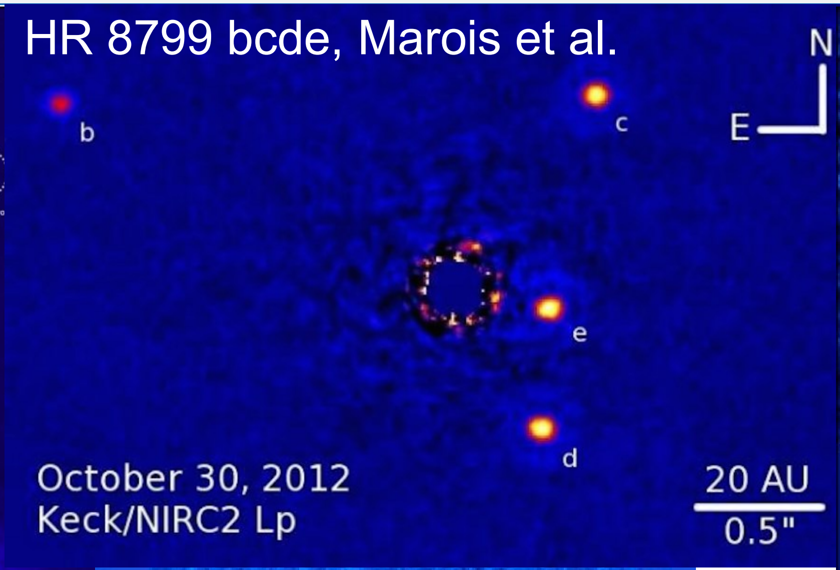
Markus Kasper (ESO)

HCI Targets, now

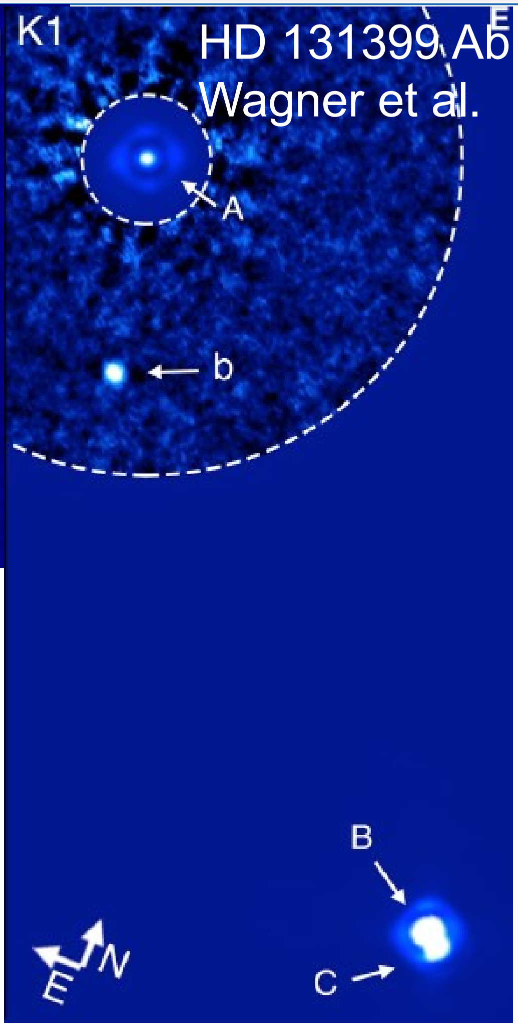


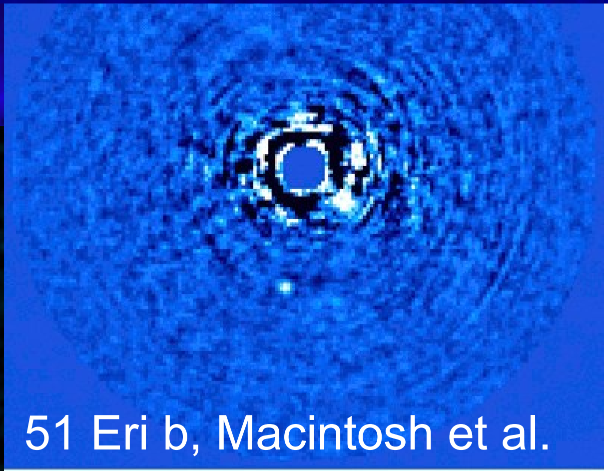
βPic b, Lagrange et al.

HR 8799 bcde, Marois et al.

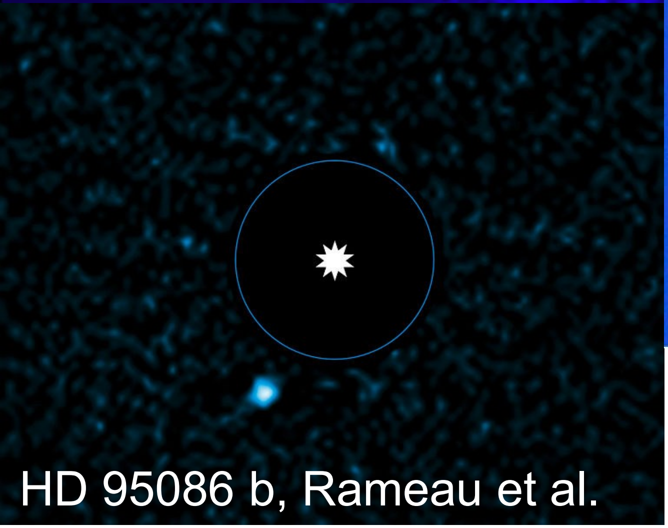


HD 131399 Ab
Wagner et al.





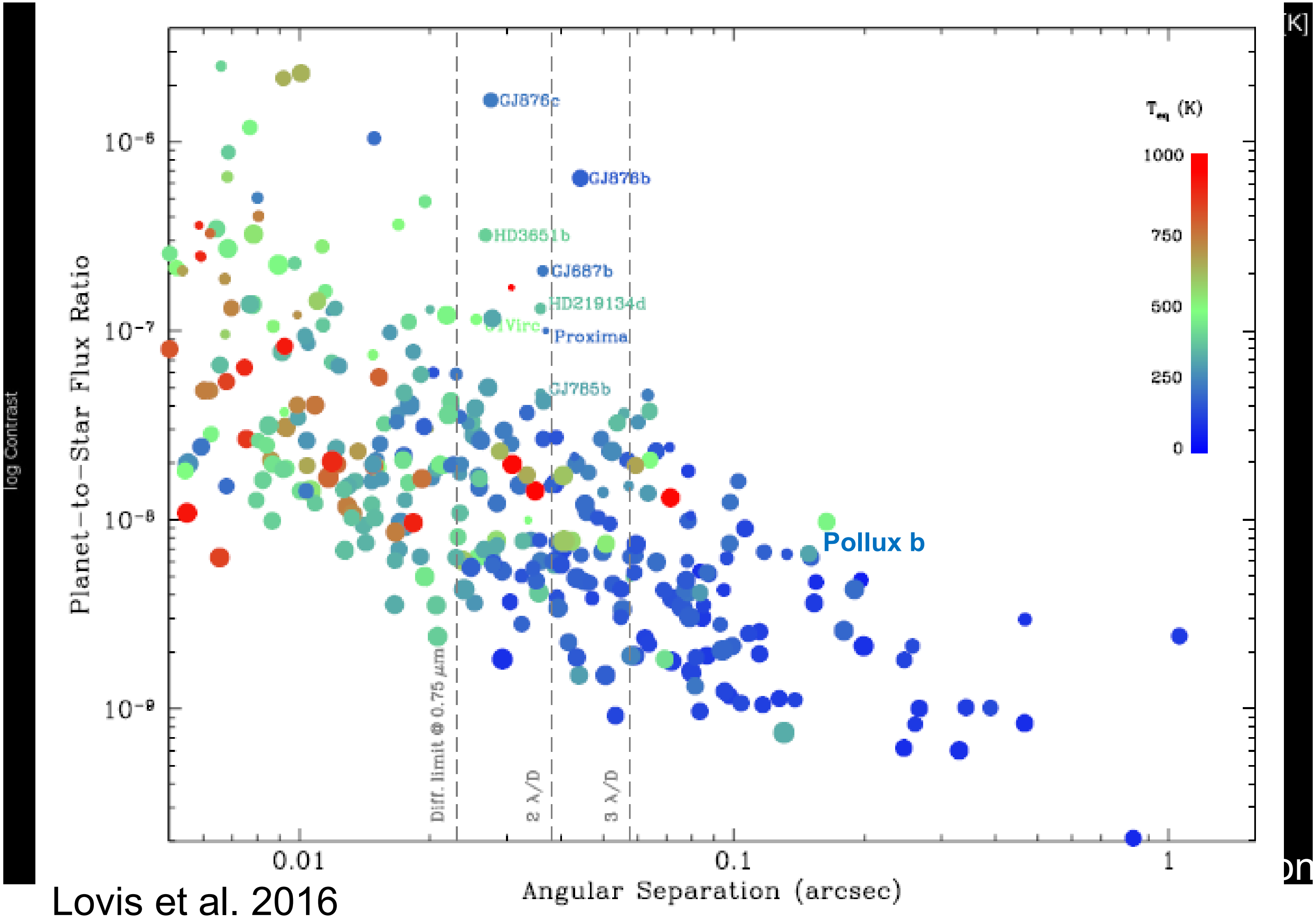
51 Eri b, Macintosh et al.



HD 95086 b, Rameau et al.

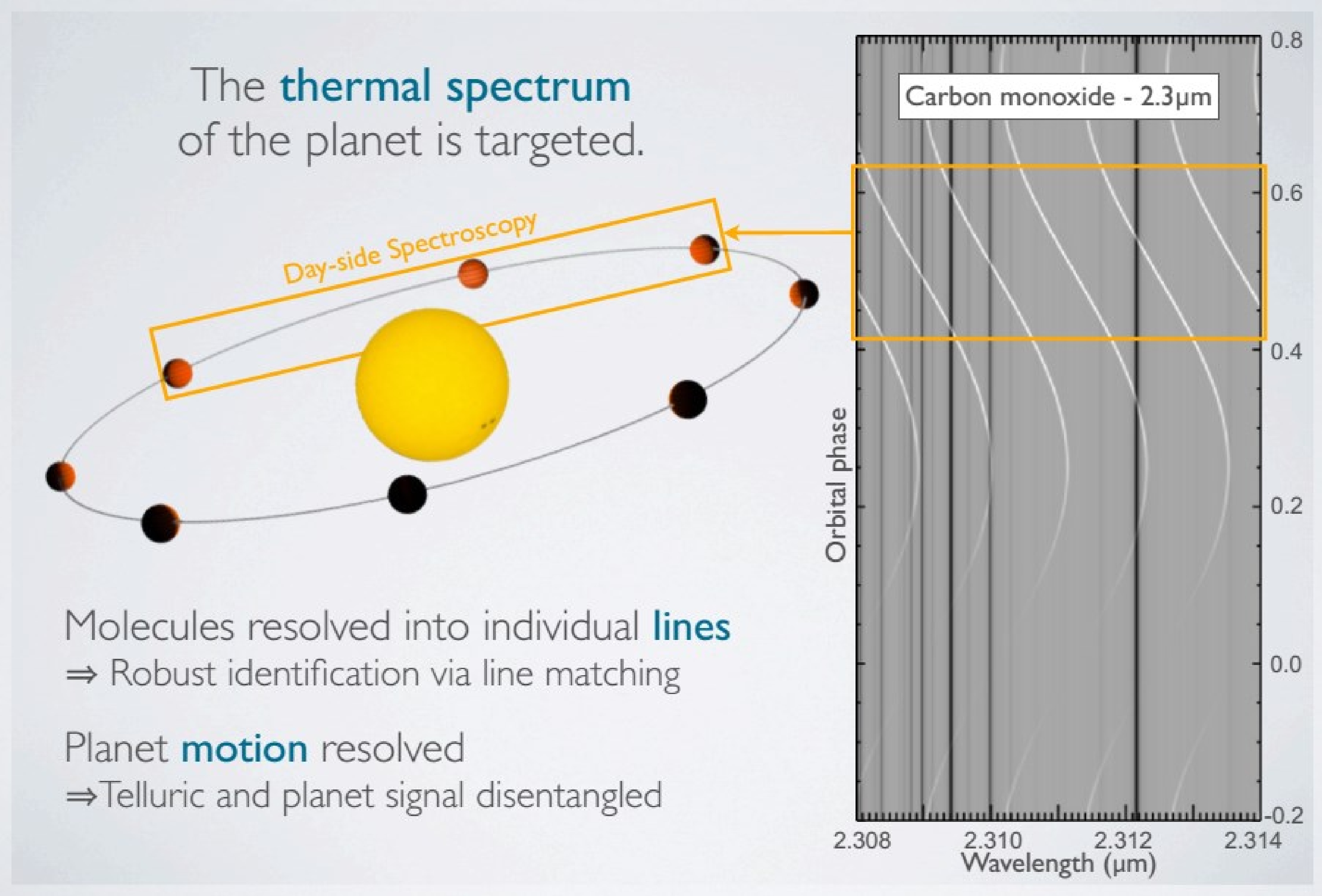
Young, self-luminous planets, 2-10 M_{Jupiter}
Relatively large distance and orbits: tens of pc and AU

… and soon



Lovis et al. 2016

Highres Spectroscopy (R~100.000)

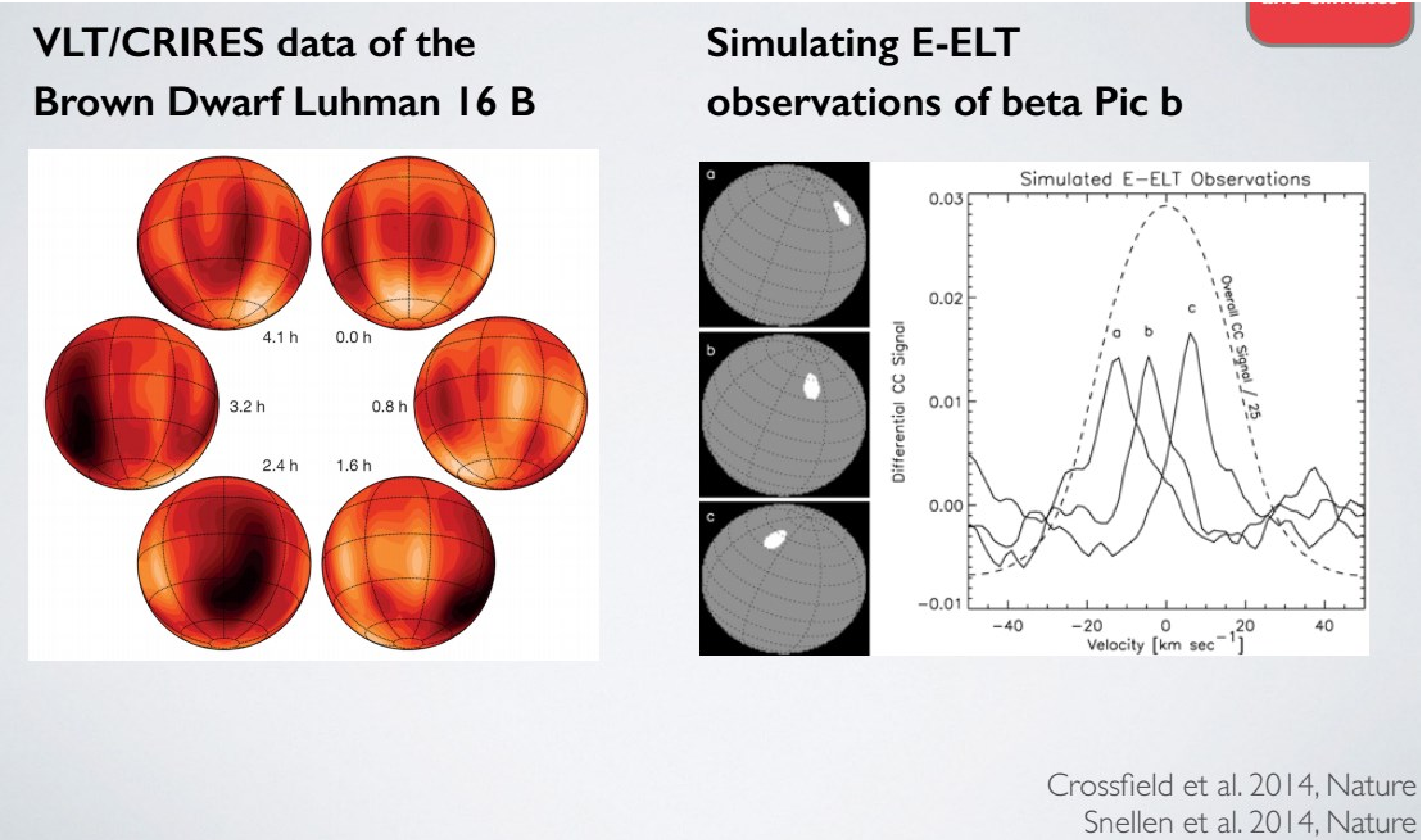


The **thermal spectrum**
of the planet is targeted.

Molecules resolved into individual **lines**
⇒ Robust identification via line matching

Planet **motion** resolved
⇒Telluric and planet signal disentangled

Highres Spectroscopy (R~100.000)

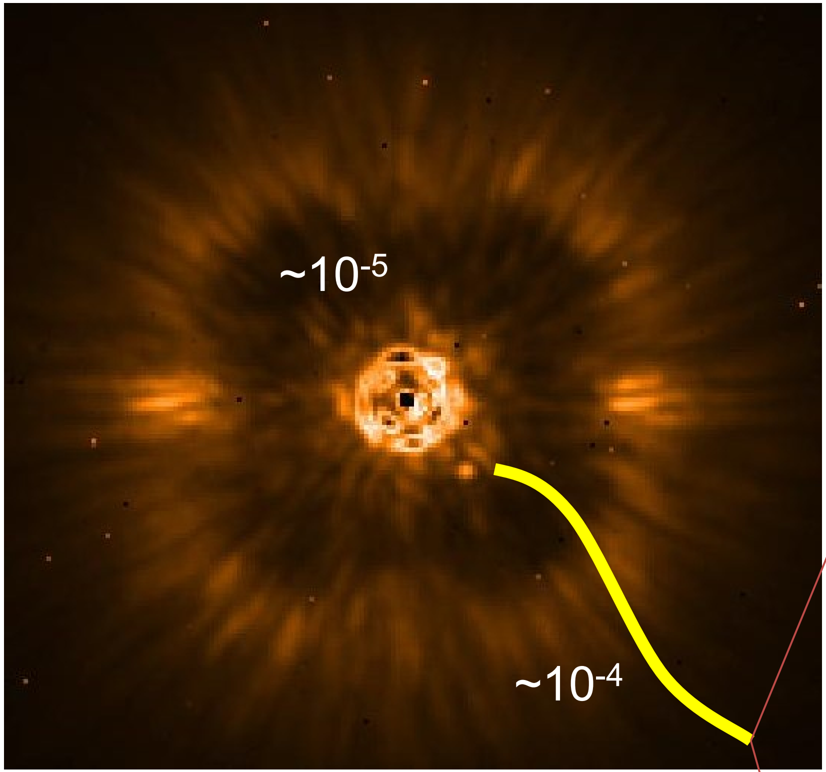


VLT/CRIRES data of the Brown Dwarf Luhman 16 B

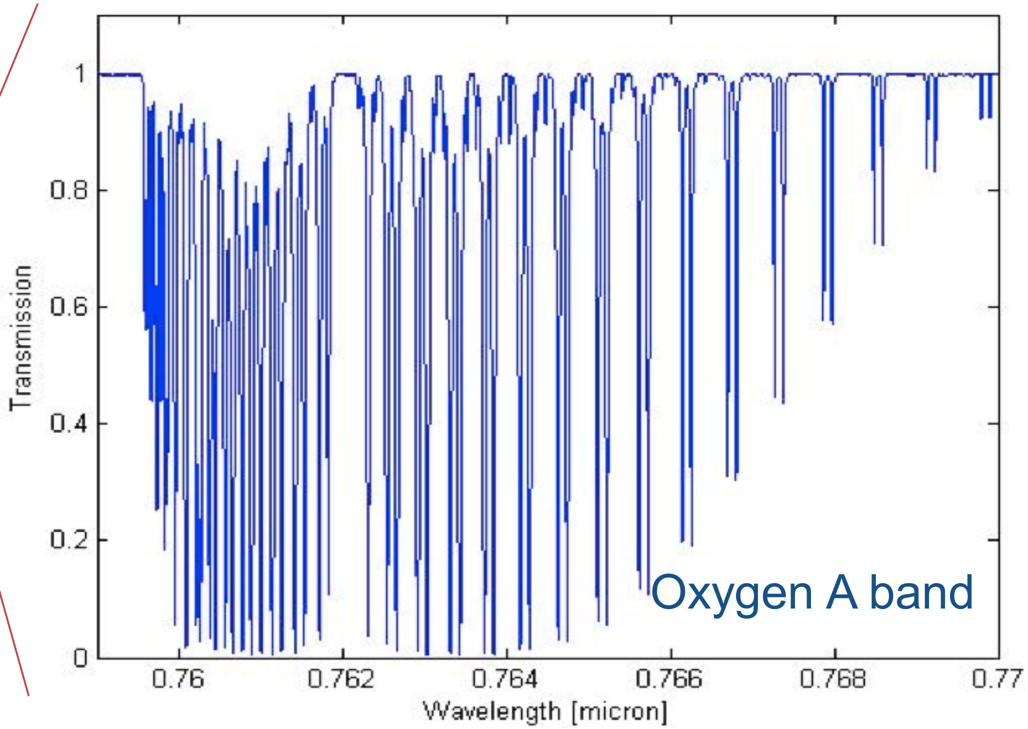
Simulating E-ELT observations of beta Pic b

Crossfield et al. 2014, Nature
Snellen et al. 2014, Nature

HCI/HRS
Detection of Oxygen on Rocky Planets



- High-contrast imaging (contrast ~10^{-4}) with high-resolution spectroscopy
- Differentiate between Planet light and stellar background (>10^{4} , e.g. Lockwood et al. 2014)
- **10^{-8} detection capability**



New EP Science Capabilities: Wanted

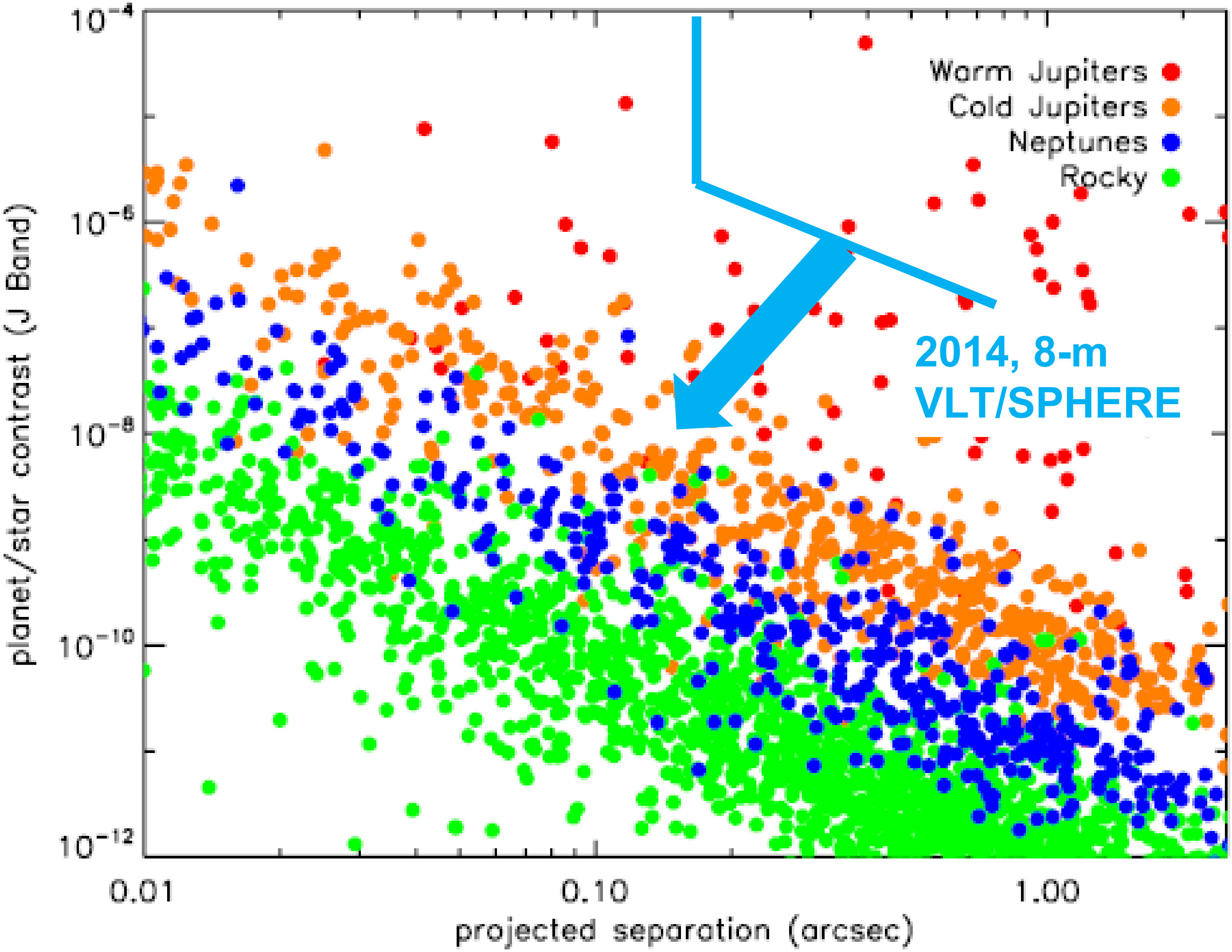
- High-contrast: ~10^{-8} at 0.2″, 10^{-6} – 10^{-7} at 50 mas
  - Planets in reflected light: GJ 876b, Pollux b, Proxima b…
  - Many more nearby Giant Planets expected from Gaia (2 AU @ 20 pc are 0.1″)
  - Other SPHERE science cases benefit as well: EP discovery programs, debris disks, …

- High-contrast and high-resolution spectroscopy
  - Rotational periods
  - Surface Gravity
  - Modeling of atmospheric structure
  - Exo-Weather

- High-contra
  - Detectior follow up)
  - Complem for modeling of chemical composition

ERIS approved

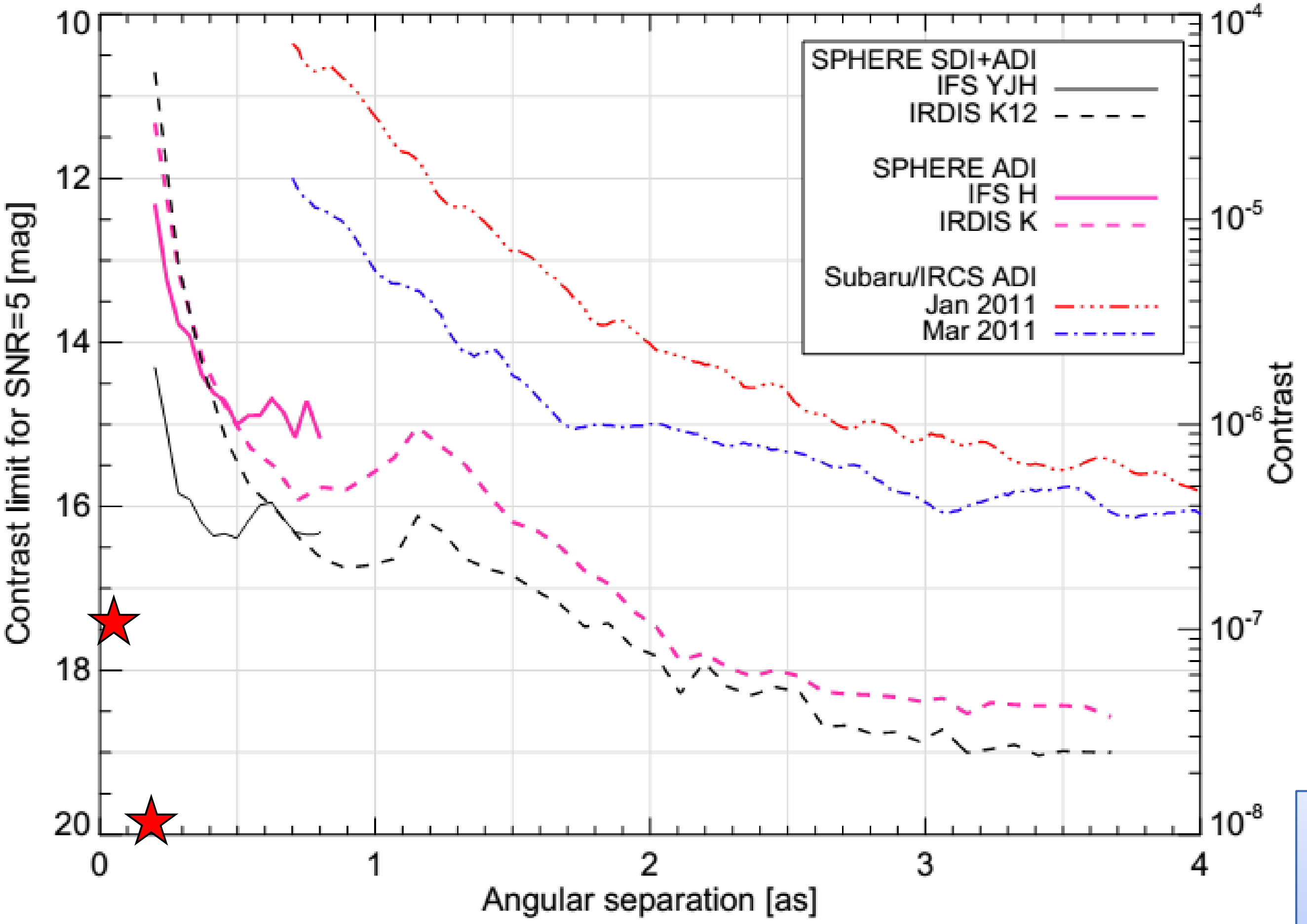
High-Contrast at Small Angles



2014, 8-m VLT/SPHERE

Bonavita et al. 2012

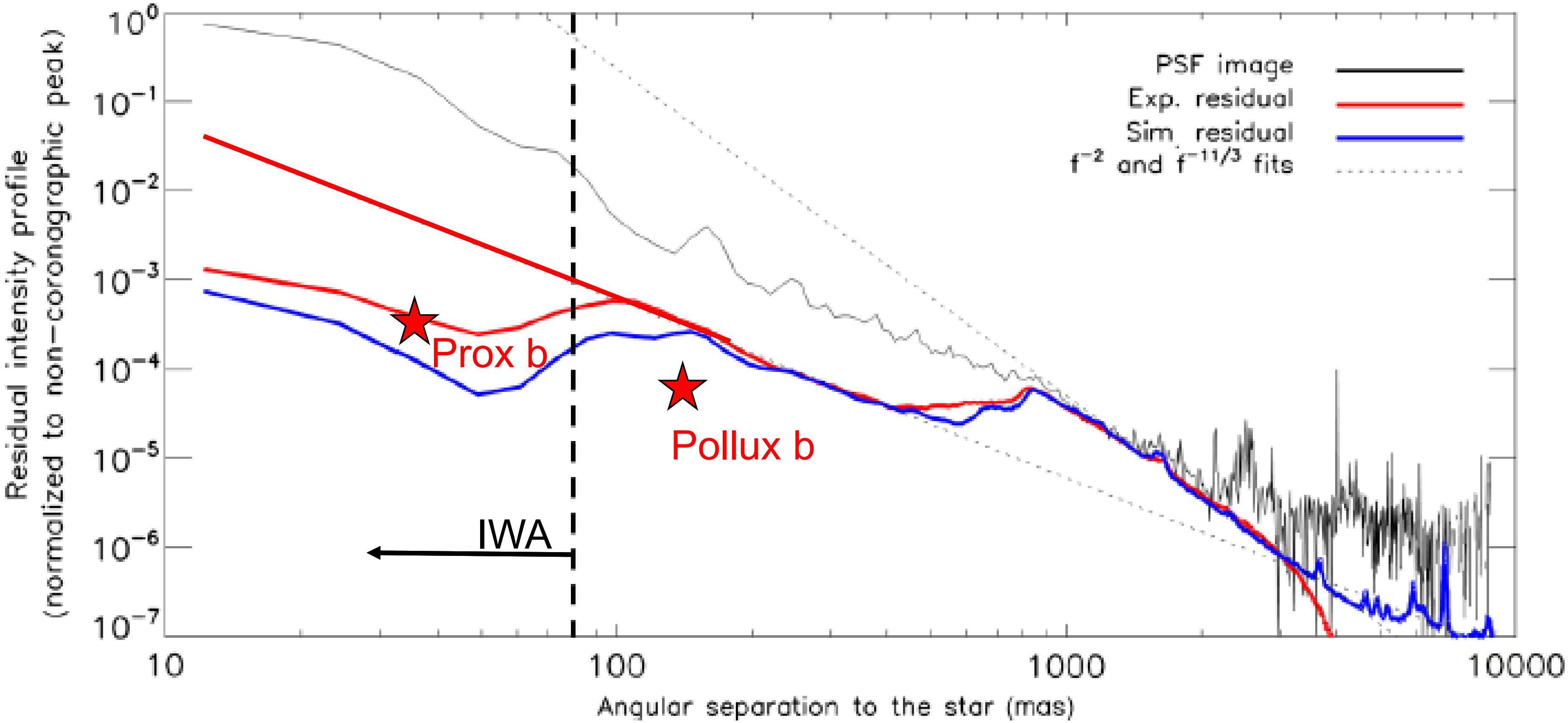
SPHERE imaging contrast perf



Sirius A with SPHERE, Vigan et al. 2015

Want ~50x deeper contrast, smaller IWA

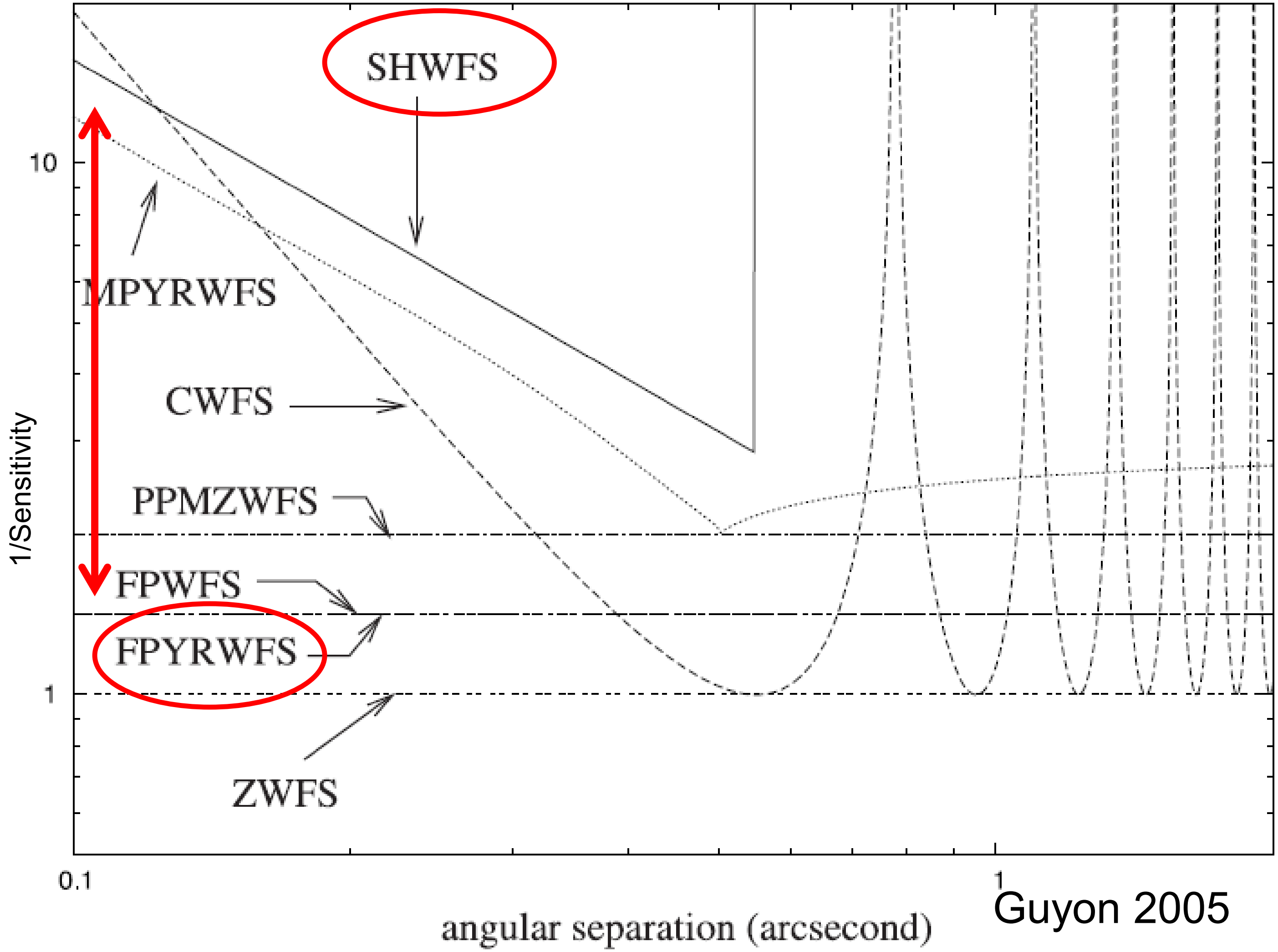
PSF contrast perf



Sauvage et al. 2016

Want ~10x deeper contrast at small IWA

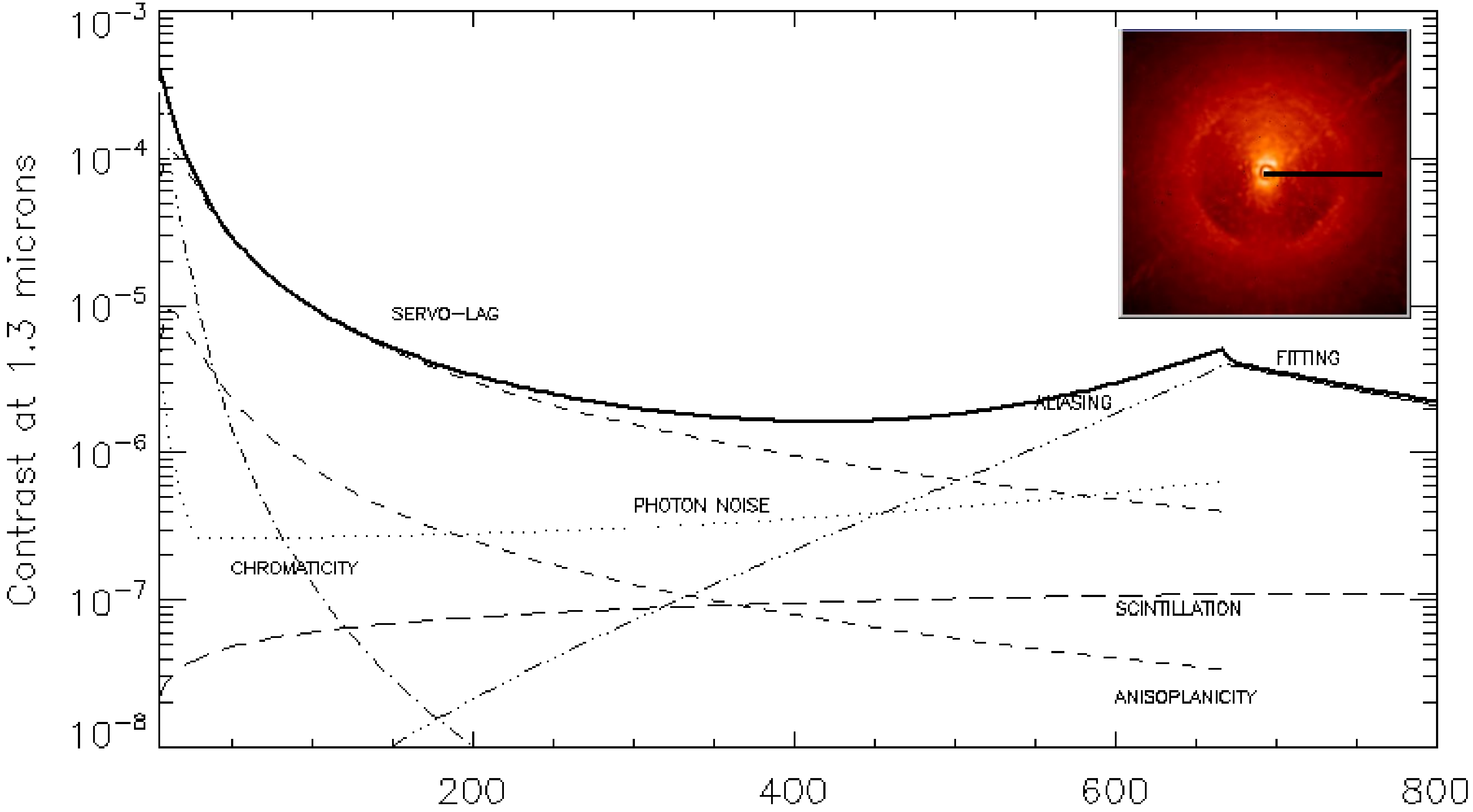
XAO, smaller IWA



Guyon 2005

Want Pyramid WFS

XAO error budget: Need for speed

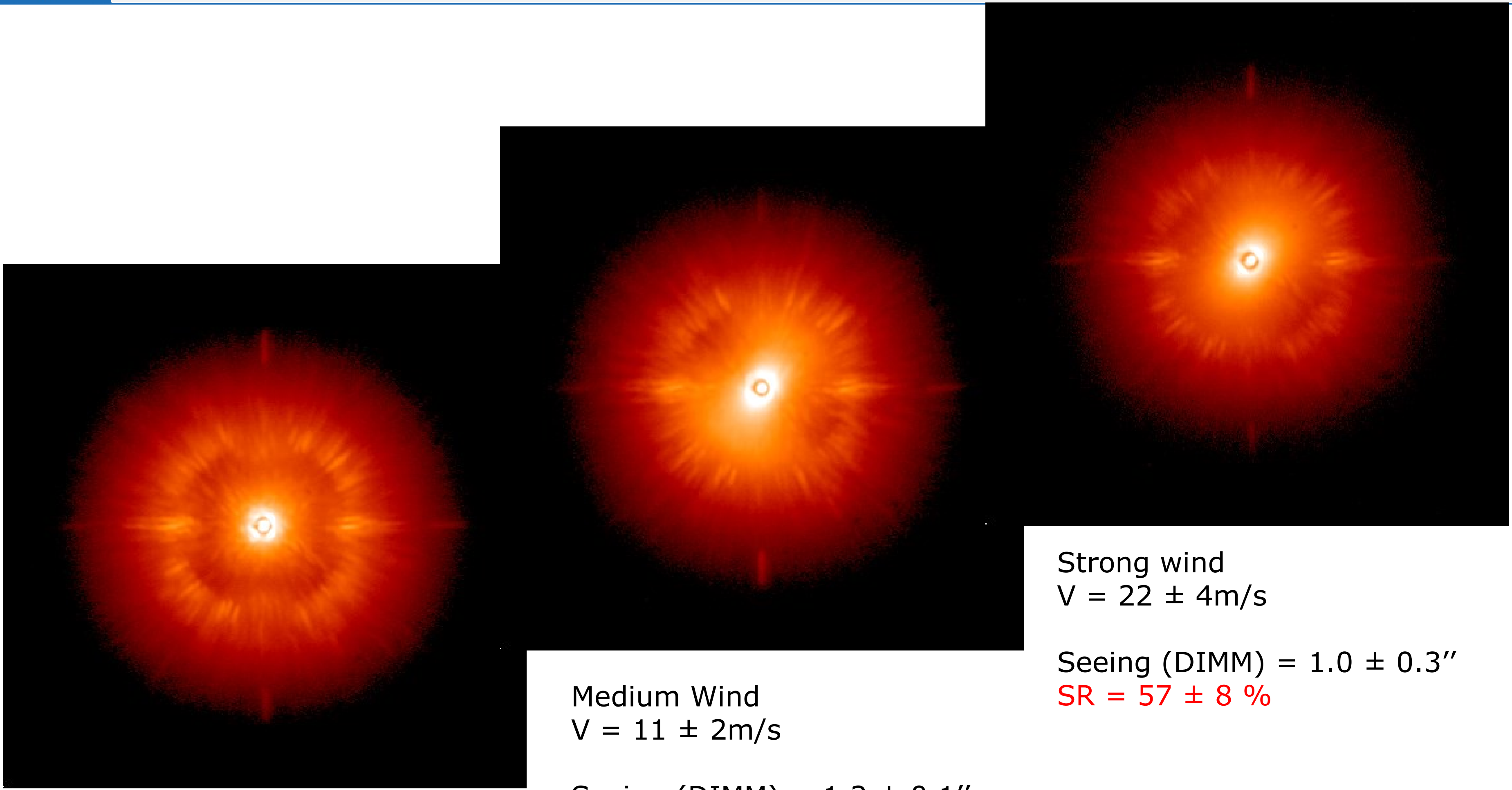


Want ultra-fast AO

$I_{halo} \sim (t_0 * f_{3db})^{-5/3}$ -> $4f_{3db}$ for $0.1 I_{halo}$

EPICS modeling, C. Verinaud

Temporal error on SPHERE



Small wind
V = 3 m/s ± 1 m/s

Seeing (DIMM) = 0.9 ± 0.03″
SR = 85 ± 1 %

Medium Wind
V = 11 ± 2m/s

Seeing (DIMM) = 1.2 ± 0.1″
SR = 68 ± 4 %

Strong wind
V = 22 ± 4m/s

Seeing (DIMM) = 1.0 ± 0.3″
SR = 57 ± 8 %

Slide of Jean-Luc

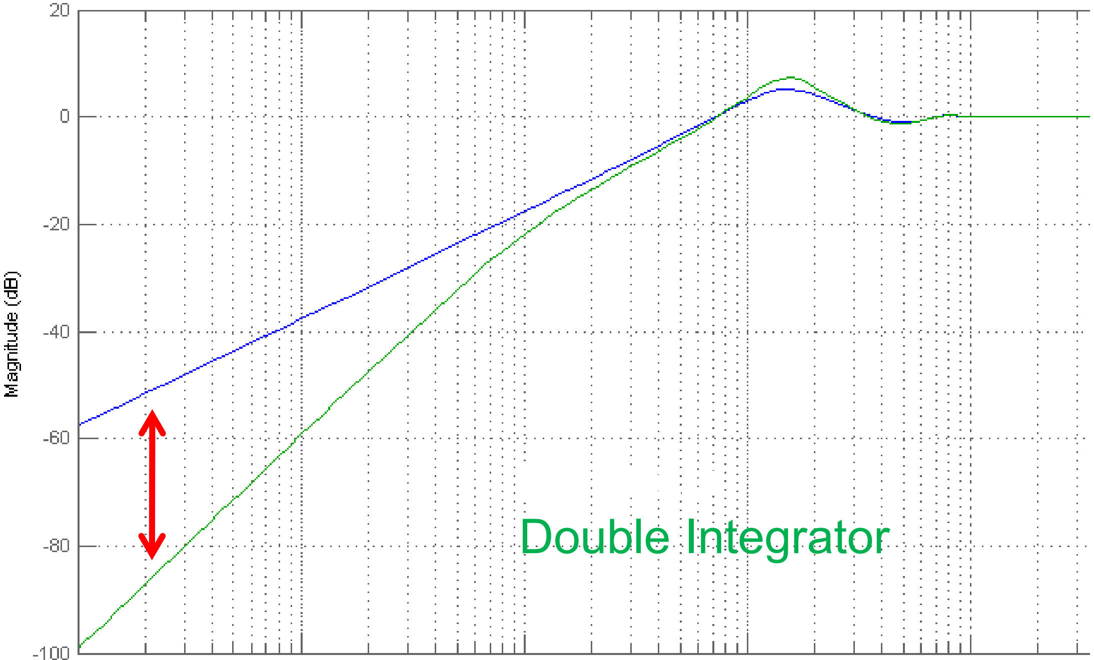
Residual XAO speckle life-time

Atmosphere $\xcancel{t_{\text{speckle}} = \tau_0?}$

$t \approx 0.6\, D/v_w \approx 0.5\text{s}$ (for $D = 8$ m, $v_w = 10$ m/s)

(Macintosh et al. 2005)

- 10^{-5} -> 10^{-7} requires 100^2 realizations of speckle pattern (~5 hours)
- holds for integrator control, DM always lagging behind the wave-front
- R&D: Reduce long-lived speckles through better LF rejection by AO



Want optimized temporal control

Conclusions

- Science goals demand to
  - Push IWA and contrast
  - Have high resolution spectrographs (HRS)
- HRS also helps to achieve high-contrast
- XAO must reduce stellar halo (main noise contrib)
  - WFS with high sensitivity at small spatial freq (e.g. PWS)
  - Ultra-fast AO to reduce dominating temporal error
  - Optimized temporal control to reduce atm speckle lifetime
  - For ELTs… deal with refractive index chromaticity of air
- SPHERE upgrade? PWS with binned CCD220 running at 3.7 kHz, mounted vertical in addition to SHS