

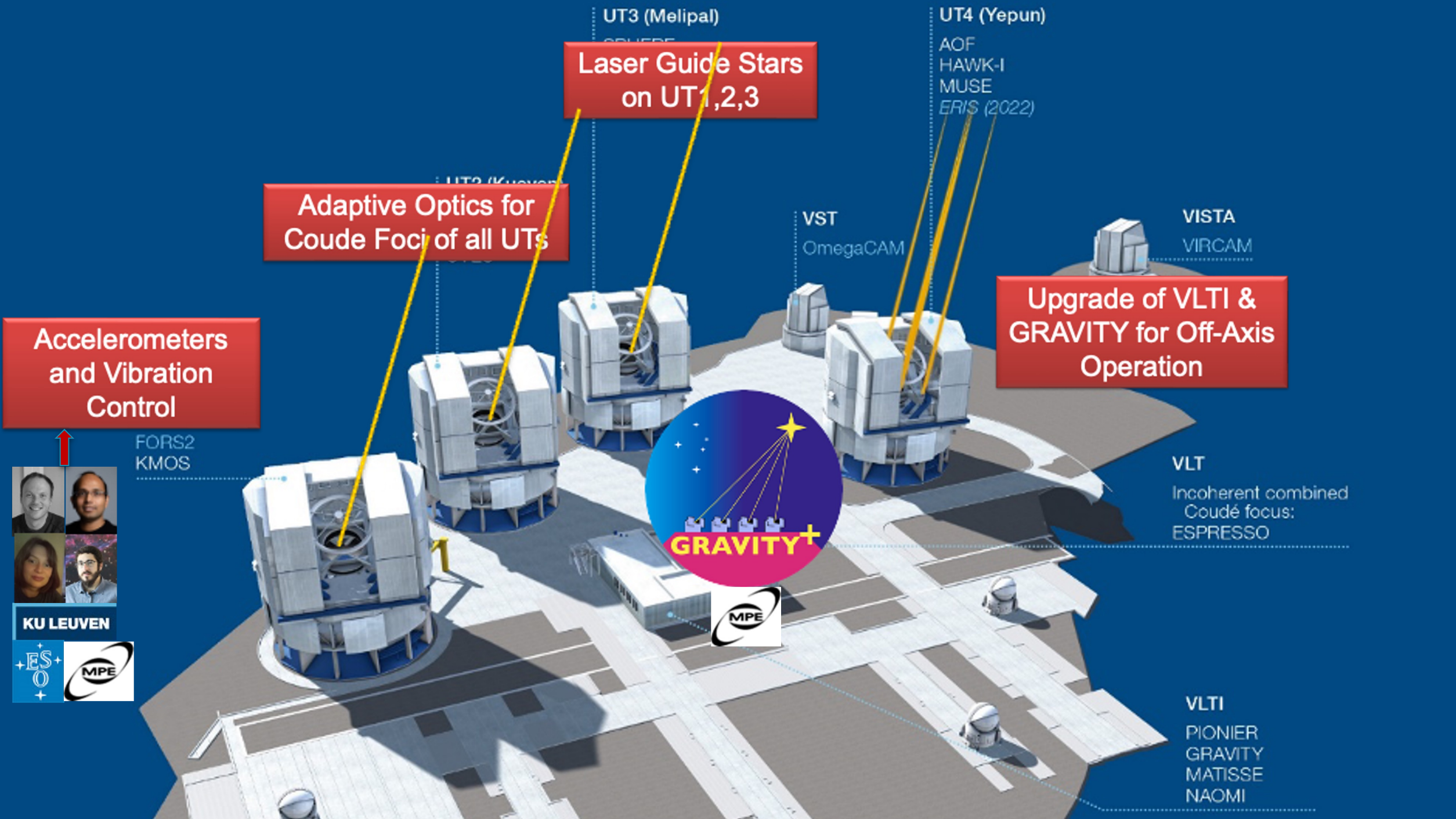


ASGARD

HEIMDALLR | Baldr | BIFROST | NOTT

Science with the VLTI: GRAVITY+ and Asgard

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Institute of Astronomy, KU Leuven



UT3 (Melipal)
**Laser Guide Stars
 on UT1,2,3**

UT2 (Kueyen)
**Adaptive Optics for
 Coude Foci of all UTs**

**Accelerometers
 and Vibration
 Control**

**Upgrade of VLTI &
 GRAVITY for Off-Axis
 Operation**



UT4 (Yepun)
 AOF
 HAWK-I
 MUSE
 ERIS (2022)

VST
 OmegaCAM

VISTA
 VIRCAM



FORS2
 KMOS

VLTI
 Incoherent combined
 Coude focus:
 ESPRESSO

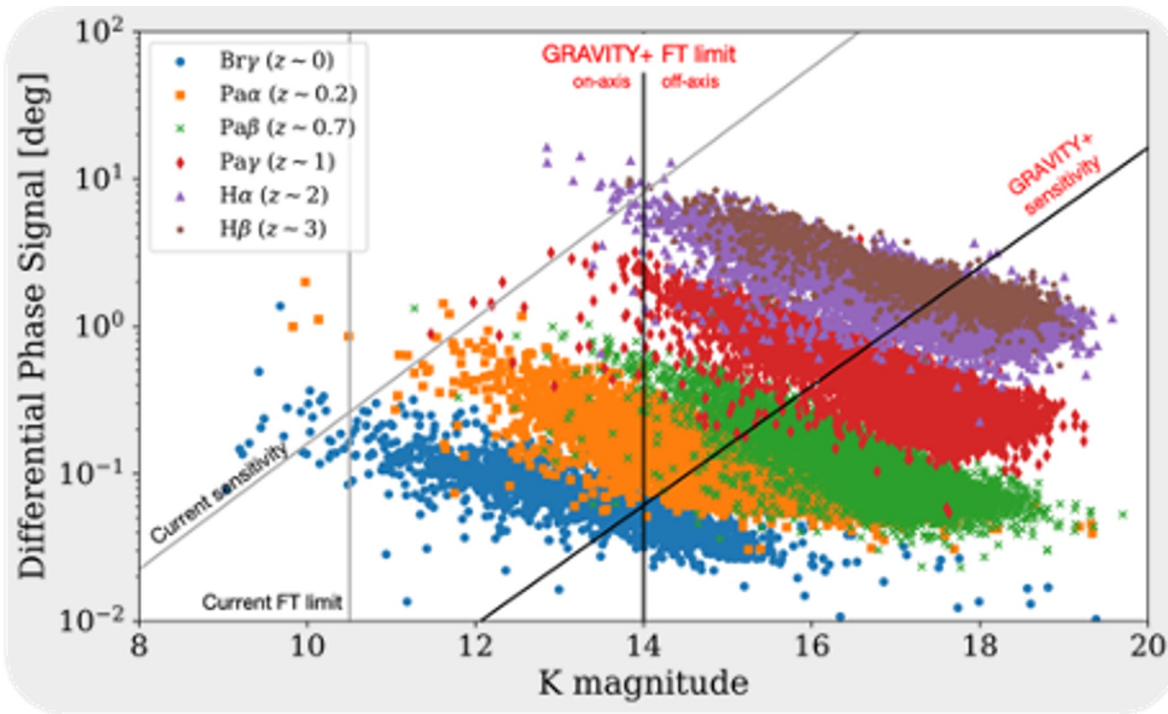


VLTI
 PIONIER
 GRAVITY
 MATISSE
 NAOMI

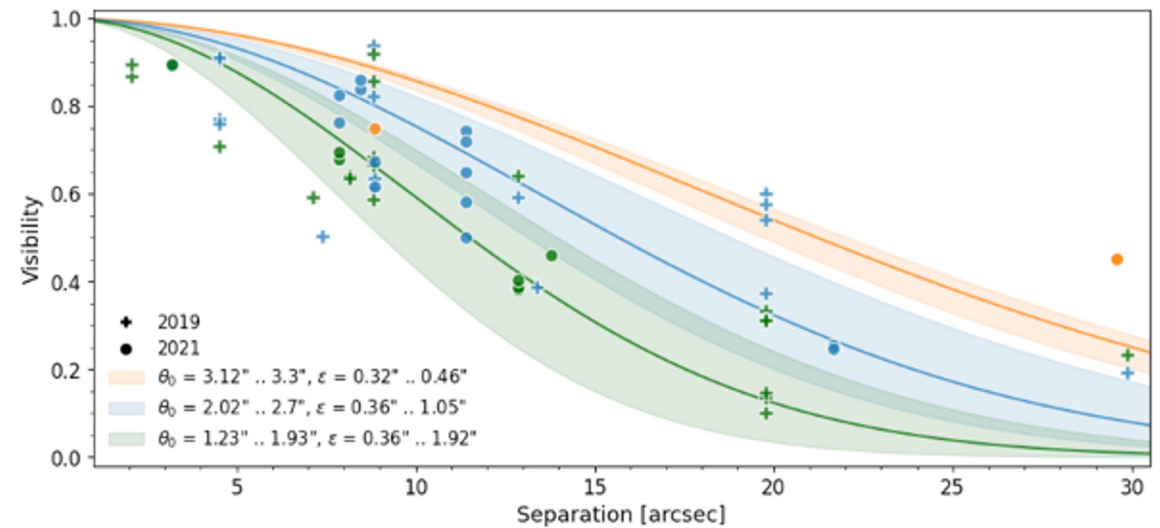


GRAVITY+ key science case

Black holes at cosmic noon

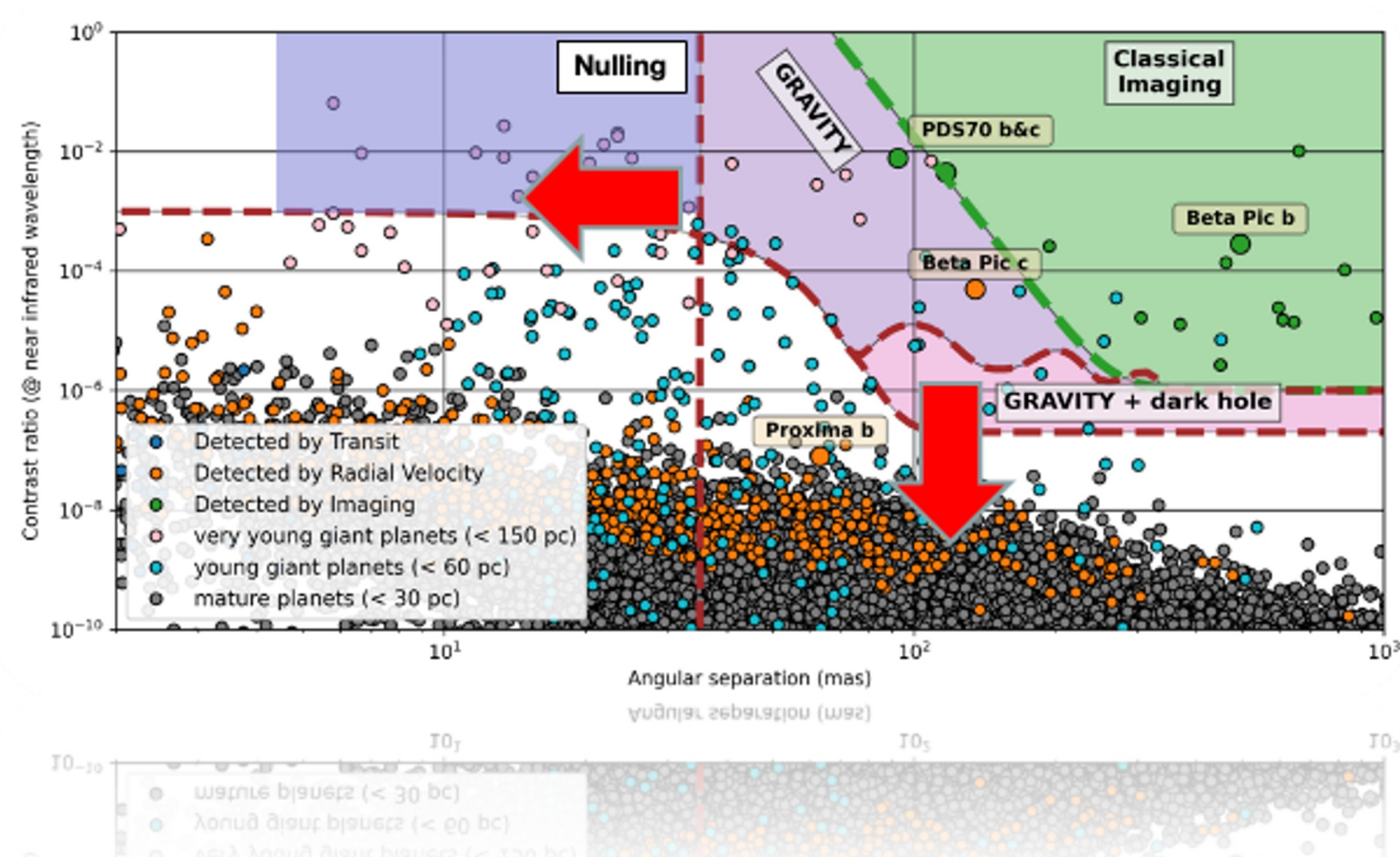


First light of GRAVITY wide (GRAVITY+ collaboration, 2022)



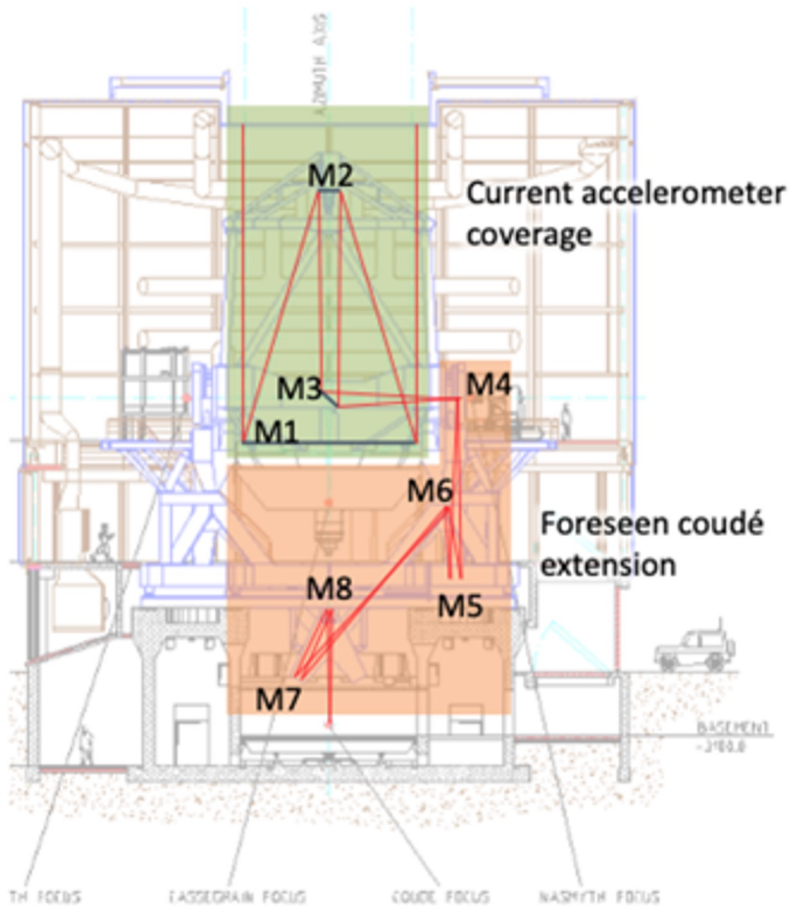
GRAVITY+ key science case

Exoplanet atmospheres (see exoGRAVITY results)

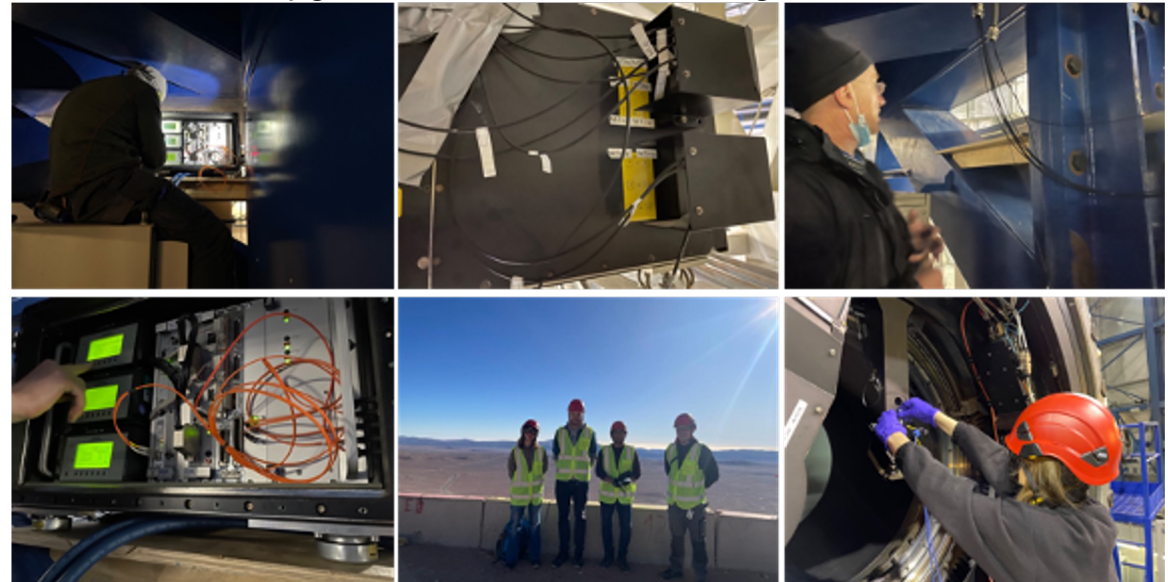


GRAVITY+ key science case

KU Leuven participation: vibration control



Upgraded UT1 and UT2 in August 2022



Biogili et al. (2022), Courtney-Barrer et al. (2022)

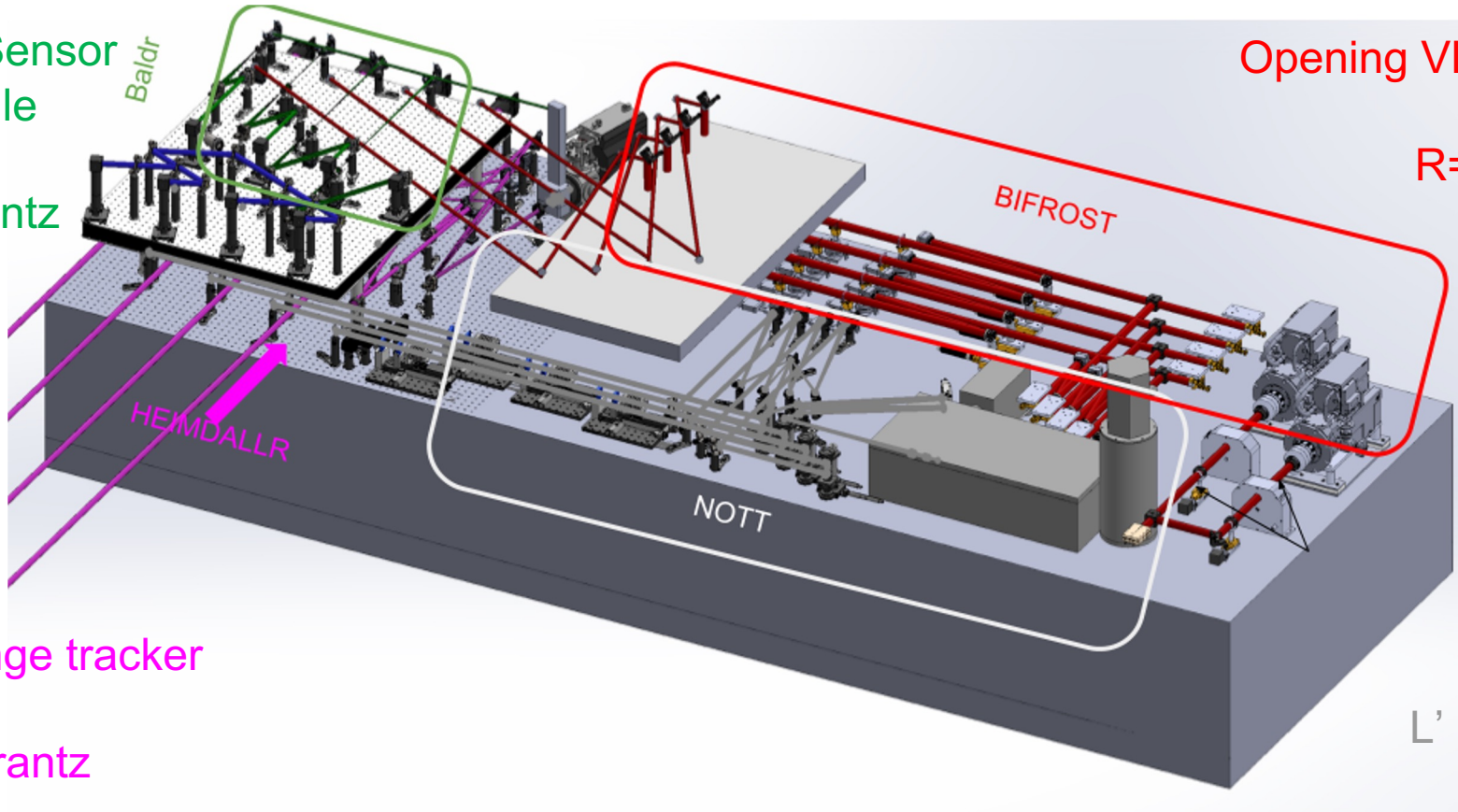
=> Vibrations on M4 to M7 comparable to M1-M3



Asgard: a proposed visitor instrument

BALDR

Zernike Wavefront Sensor
Fiber-injection module
H band
PI: Mike Ireland, Frantz Martinache



erc **BIFROST**
Opening VLT's short wavelengths
YJH bands
R=50, 1000, 5000, 25000
PI: Stefan Kraus

HEIMDALLR

High-sensitivity fringe tracker
Dual K band
PI: Mike Ireland, Frantz Martinache

erc **NOTT(/Hi-5)**
High-contrast nuller
L' band (3.5 4.0 microns)
R=20, 400, 2000
PI: Denis Defrère

VLT Visitor 2 optical table (former AMBER table)



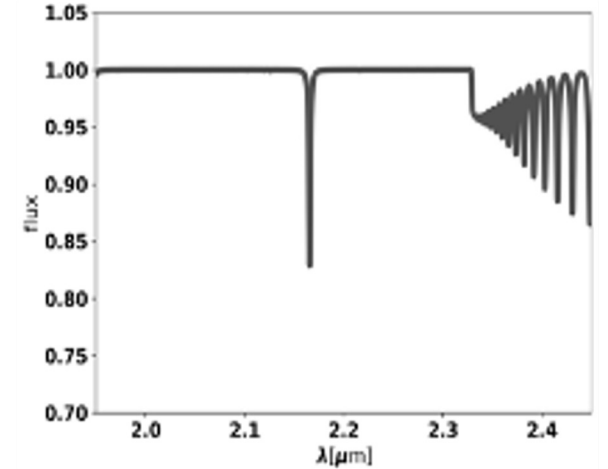
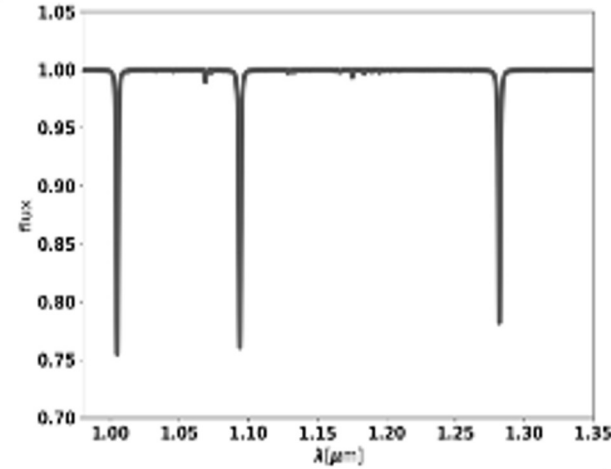
BIFROST key science case

Interferometry in Spectral Lines

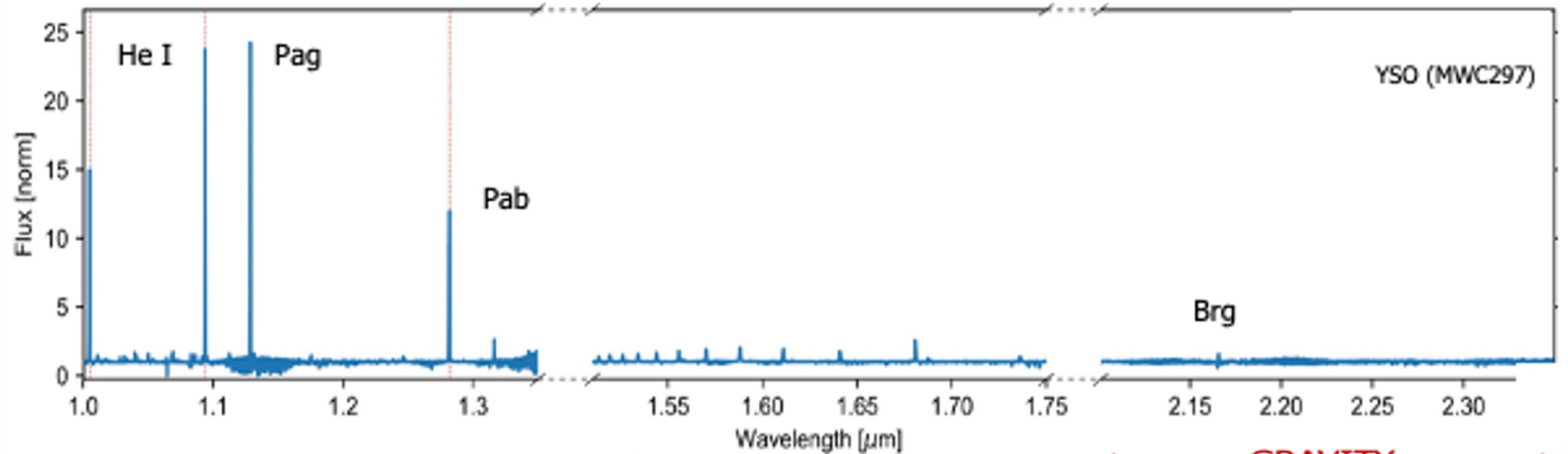
High spectral resolution
($R=1000, 6000, 25000$):
→ **Velocity-resolved studies at extreme angular resolution**

imaging $\lambda/B < 0.5$ mas
photocenter $< 1 \mu\text{as}$

Photospheric absorption lines



Emission lines

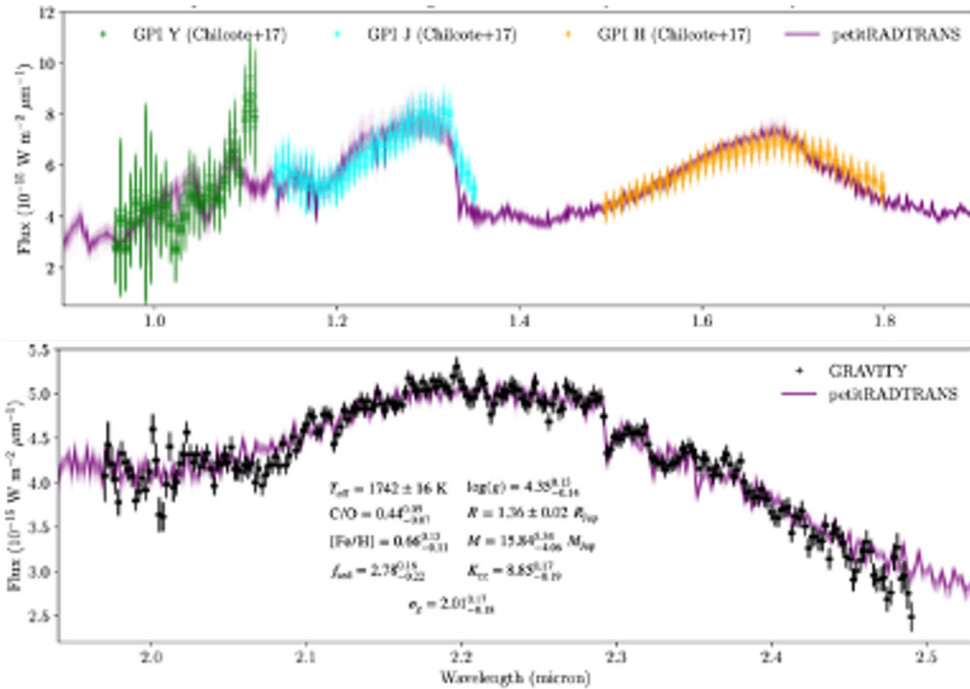


BIFROST

GRAVITY

BIFROST key science case

Exoplanet spectroscopy and formation

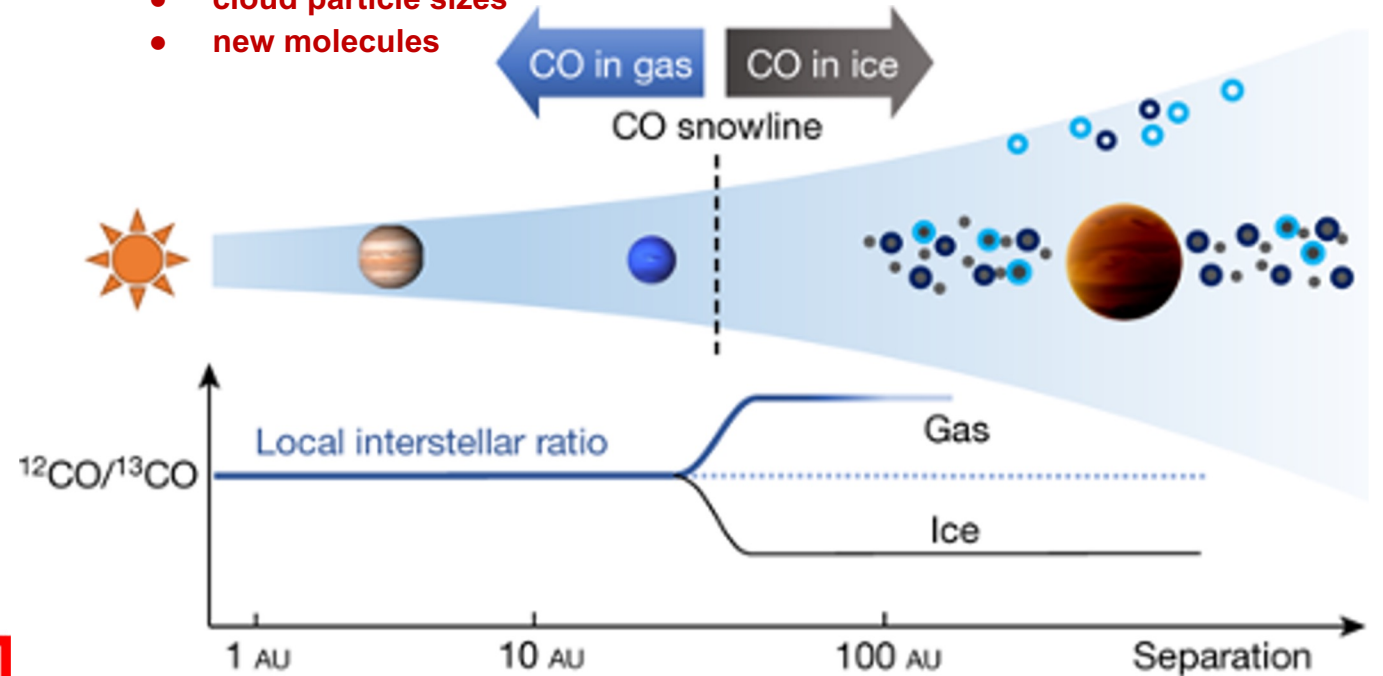


Chilcote+ 2017; Zhang+ 2021

Fit performed	T (K)	$\log(g/g_0)$	Metallicity [Fe/H]	C/O ratio	Mass (M_{Jup})
GRAVITY data only	1847 ± 55	$3.3^{+0.54}_{-0.42}$	$-0.53^{+0.28}_{-0.34}$	$0.35^{+0.07}_{-0.09}$	$1.4^{+3.94}_{-0.87}$
GRAVITY + GPI YJH band data	1742 ± 10	$4.34^{+0.08}_{-0.09}$	$0.68^{+0.11}_{-0.08}$	$0.43^{+0.04}_{-0.03}$	$15.43^{+2.91}_{-2.79}$

BIFROST wavelength range (1-1.7 μm) complements GRAVITY+:

- surface gravity
- cloud particle sizes
- new molecules

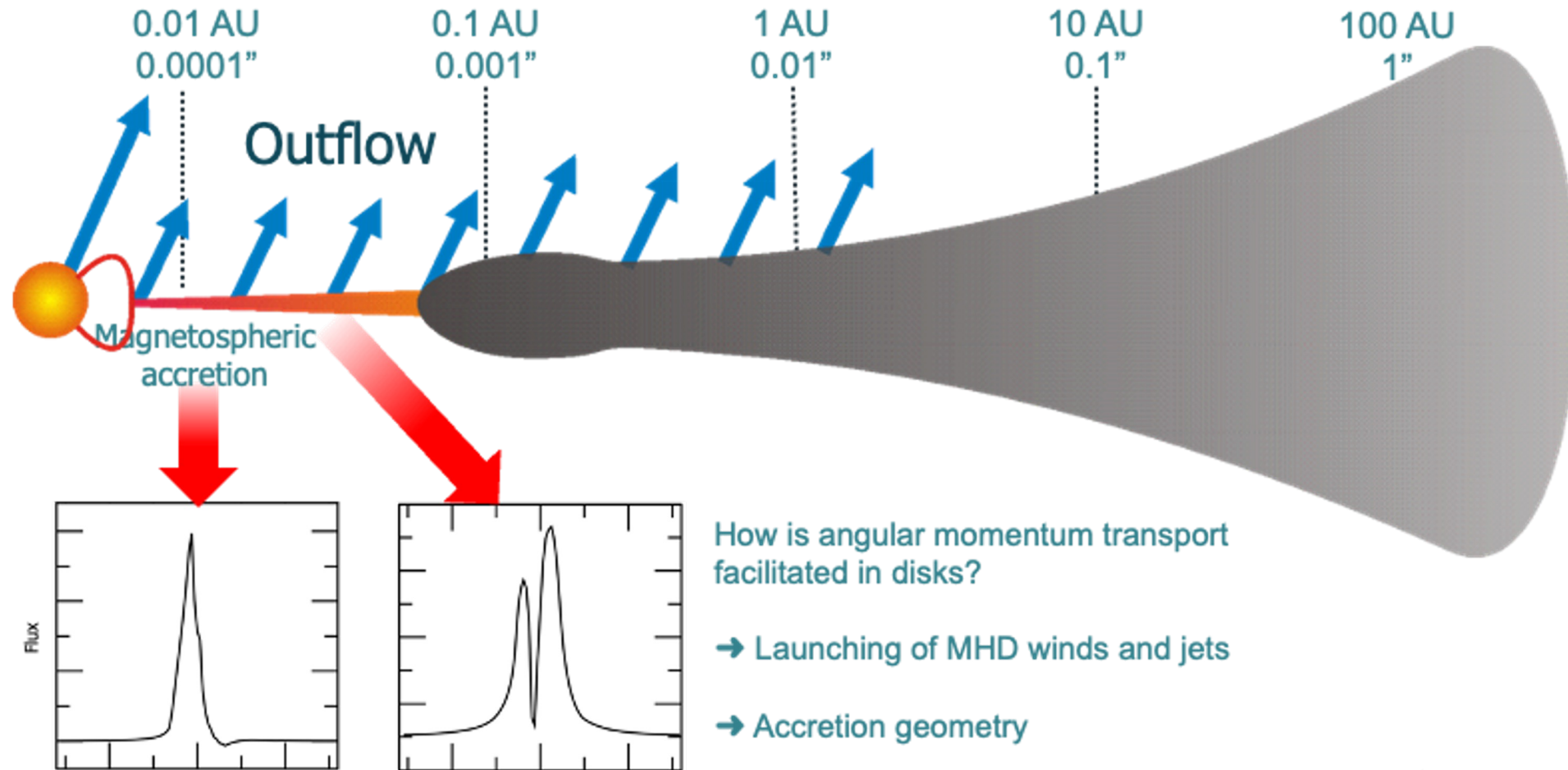


→ Formation location from volatile abundances / isotopologues (C/O , $^{12}\text{CO}/^{13}\text{CO}$, ...)



BIFROST key science case

Mass accretion and rejection

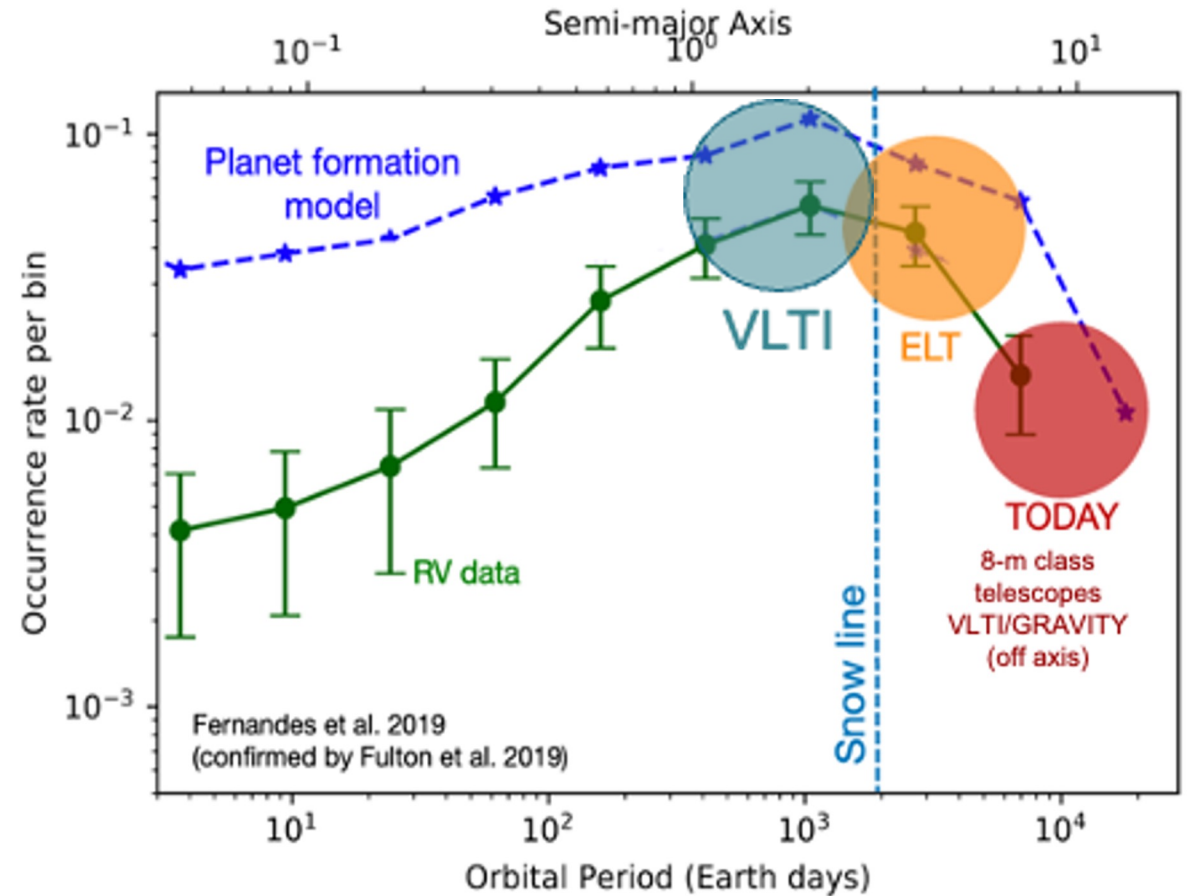
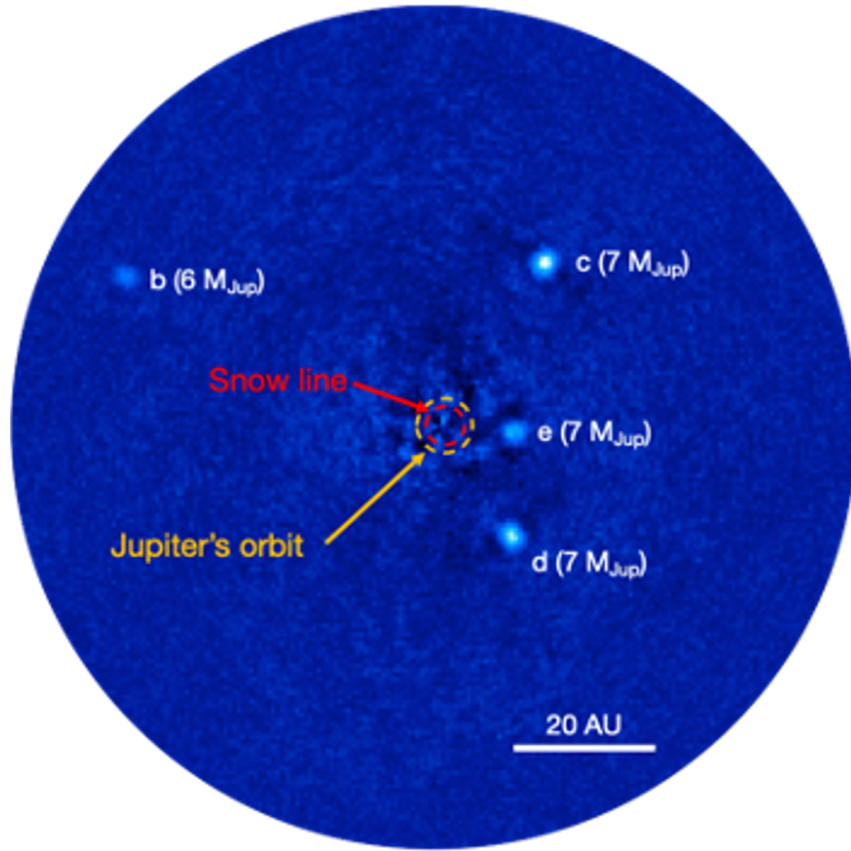


Kurosawa+ 2006



NOTT key science case

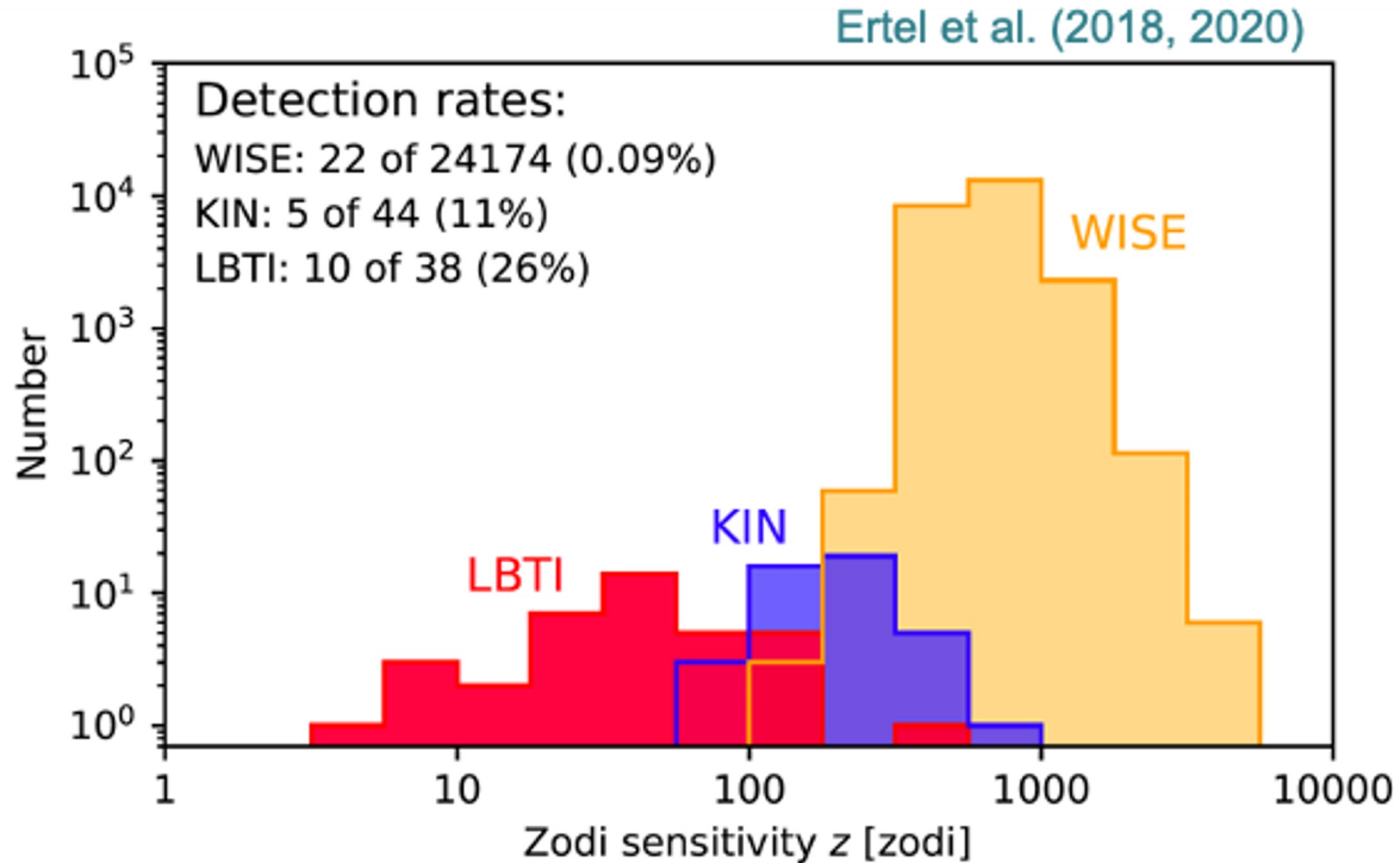
Exoplanet imaging within the snow line





NOTT key science case

Exozodiacal disks



- Measuring the faint end of the exozodi luminosity function (complementary with LBTI in northern hemisphere)
- L band = missing link in current exozodiacal disk models



Summary

- GRAVITY+: ongoing upgrade of GRAVITY and VLTI infrastructure (2025)
 - Better sensitivity and fringe tracking performance
 - Key science cases:
 - Black holes at the cosmic noon
 - Exoplanet atmospheres and planet formation
 - Many more
- Asgard: proposed VLTI visitor instrument to extend its scientific capabilities
 - BIFROST: YJ-band spectro imager
 - NOTT: L-band high-contrast nuller
 - HEIMDALLR: high-sensitivity fringe tracker
 - Key science cases
 - Exoplanet atmosphere and planet formation
 - Exozodiacal disks