Future Opportunities for Exoplanet Science at Gemini

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AAS243 US NGO Splinter Session: The Present and Future of Exoplanet Science with the Gemini Observatory

Discovering Our Universe Together

Overview of Gemini Capabilities

(*as of late 2023…*)

	Gemini North	Gemini South
Optical:	• GMOS *(imaging, spectroscopy)* • `Alopeke *(speckle imaging)* • MAROON-X *(HR spectroscopy)* • GRACES *(HR spectroscopy)*	• GMOS *(imaging, spectroscopy)* • Zorro *(speckle imaging)*
NIR:	• GNIRS *(spectroscopy)* • NIFS *(IFU spectroscopy)*	• Flamingos-2 *(imaging, spectroscopy)* • GSAOI+GeMS *(AO imaging)* • IGRINS *(HR spectroscopy)*

Overview of Gemini Capabilities

(*2024 onwards…*)

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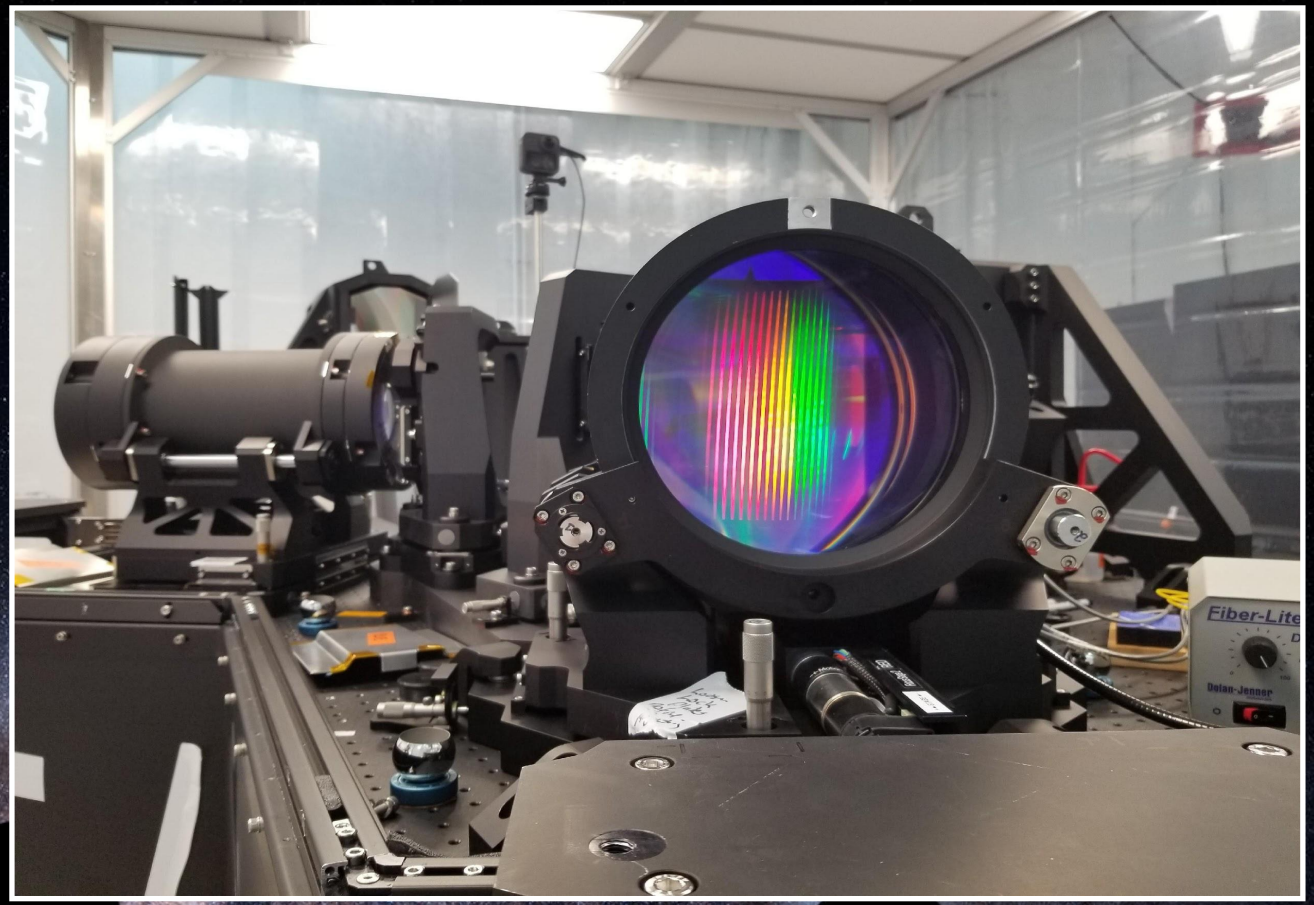
Optical:	• GMOS *(imaging, spectroscopy)* • `Alopeke *(speckle imaging)* • MAROON-X *(HR spectroscopy)* • ~~GRACES *(HR spectroscopy)*~~	• GMOS *(imaging, spectroscopy)* • Zorro *(speckle imaging)* • **GHOST *(HR spectroscopy)*** • SCORPIO *(imaging, spectroscopy)*
NIR:	• GNIRS *(spectroscopy)* • NIFS *(IFU spectroscopy)* • **IGRINS-2 *(HR spectroscopy)*** • GNAO+GIRMOS *(imaging, spectroscopy)*	• Flamingos-2 *(imaging, spectroscopy)* • GSAOI+GeMS *(AO imaging)* • ~~IGRINS *(HR spectroscopy)*~~ • **GPI 2.0 *(AO imaging polarimetry+IFU spectroscopy)***

NEW at Gemini South: The Gemini High-Resolution Optical SpecTrograph (GHOST)

Exploring the Universe, Sharing its Wonders!

What is GHOST?

- Fibre-fed, high-resolution optical (347-1060 nm) echelle spectrograph at Gemini South (*facility instrument*)
- Standard (>50k) and high resolution (>75k) modes
- Partnership between AAO and ANU (*Australia*), NRC (*Canada*) and Gemini

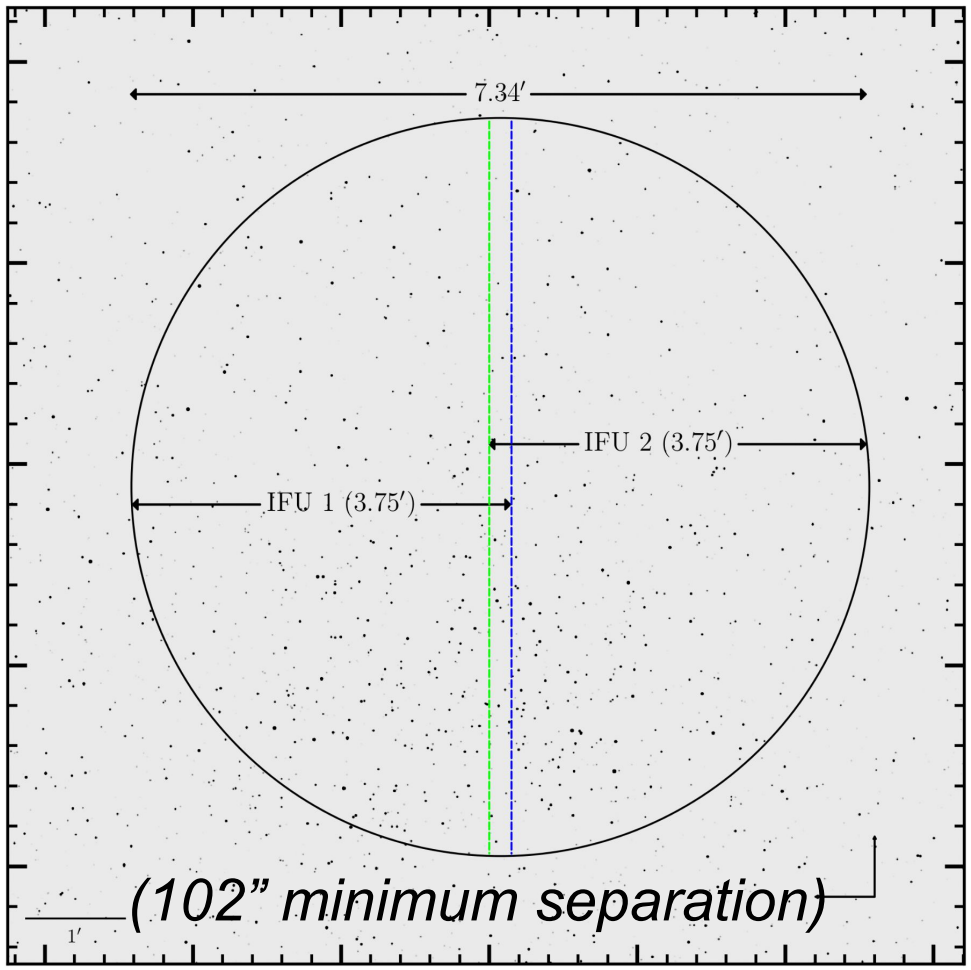


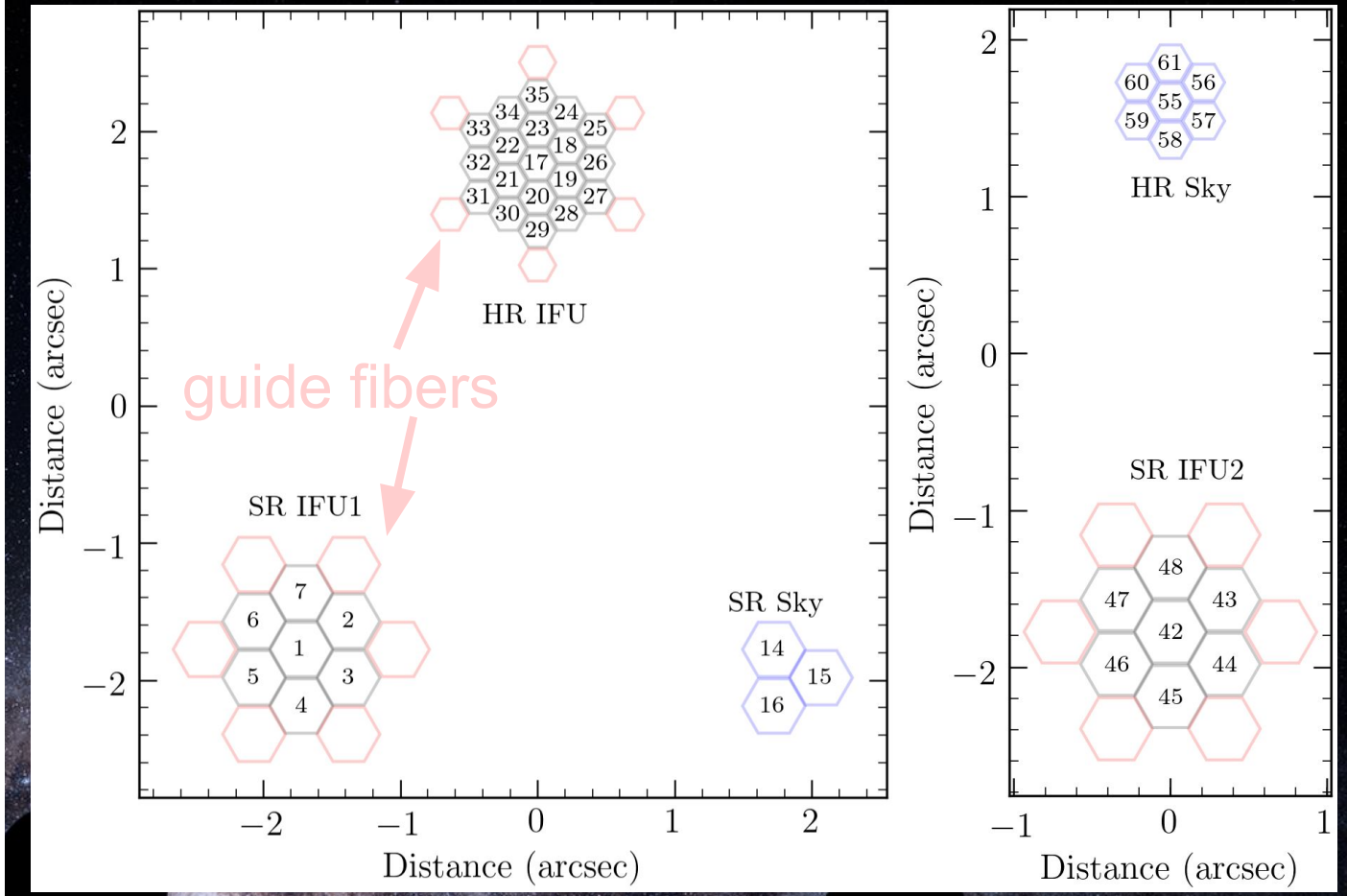
GHOST Modes

- Standard Resolution Mode
  - R ~ 56,000
  - Single target, *or*
  - dual targets over 7.34’ field (102” minimum separation)
  - Dedicated sky fiber
  - 10-15% throughput (blue/red)
- High Resolution Mode
  - R ~ 76,000
  - Single target *only*
  - Dedicated sky fiber
  - 7-9% throughput (blue/red)

+ precision radial velocity mode in the future

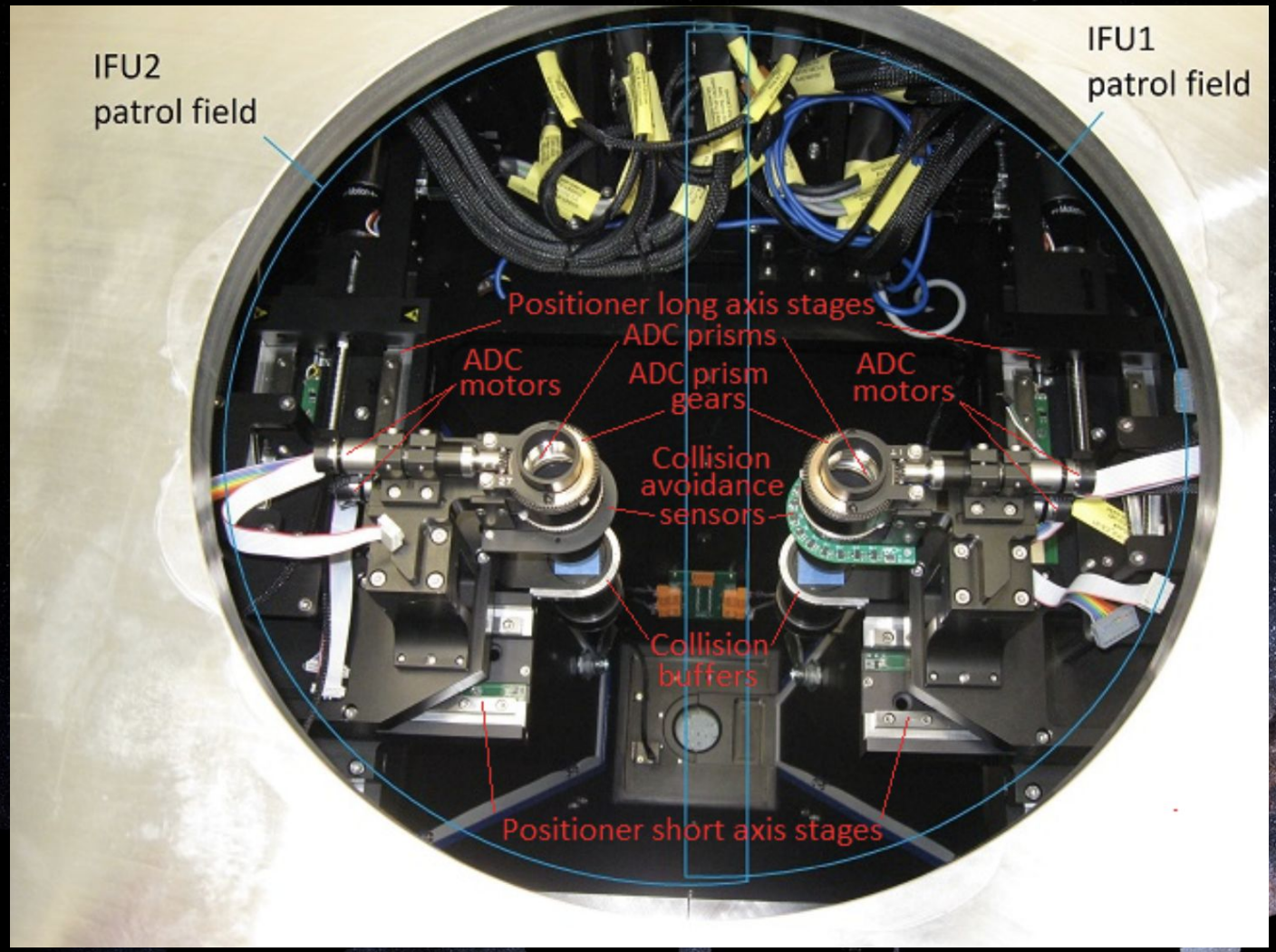
GHOST Design





(Kalari et al. in prep.)

GHOST Design



GHOST Capabilities

Mode	Standard resolution	High Resolution
Spectral coverage	347–1060 nm (simultaneous)	347–1060 nm (simultaneous)
Spectral resolution	56 000	76 000
Binning modes	2,4,8 (spatial); 2, 4 (spectral)	2,4,8 (spatial); 2, 4 (spectral)
Radial velocity precision	600 m s^{-1}	10 m s^{-1}
Multiplexing	Two targets (minimum separation 102″)	Single target
Field of view	7.34′ (overlap of two IFU's 16″)	7.34′
IFU aperture	0.94 $arcsec^2$	0.92 $arcsec^2$
Sky aperture	0.4 $arcsec^2$	0.34 $arcsec^2$
Microlens configuration	7 microlenses in each object IFU 3 microlenses in sky IFU	19 microlenses in object IFU 7 microlenses in sky IFU
Calibration source	None	Internal ThXe lamp
Limiting magnitude[1]	$V \sim 20.8$ mag	$V \sim 19.6$ mag

NOTE—[1] Defined at the magnitude at which a SNR of 5 is achieved in 1 hr under clear skies, and median site seeing.

(Kalari et al. in prep.)

Future Upgrades to GHOST

- Precision Radial Velocity (PRV) mode
  - Internal Thorium Xenon lamp in HR mode for wavelength calibration
  - Allows for tracking of wavelength drift + wavelength calibration
  - Fiber agitator available to reduce modal noise
  - *GHOST is not in a pressure-controlled environment*, but early testing indicates expected RV precision < 10 m/s, goal 1 m/s
  - **Commissioning of PRV mode ongoing in 2024**
- Spectropolarimetry may be possible in the future

Science Case: High-Res Mode

High-resolution dayside spectroscopy of the ultra-hot Jupiter WASP-189b

PI: Emily Deibert (Gemini South, Chile)

- high resolution (R~76,000), single object time-series observations of WASP-189b (ultra-hot Jupiter) covering orbital phases from 0.58 - 0.63
- Fe detected in the dayside (Yan+20), many species in transit (Prinoth+22,23)

Parameter [unit]	Value	Reference
T_0 [BJD]	2456706.4566 ± 0.0023	[1]
Period [days]	2.7240308 ± 0.0000028	[1]
R_p $[R_J]$	$1.600^{+0.017}_{-0.016}$	[2]
M_p $[M_J]$	$1.99^{+0.16}_{-0.14}$	[3]
$T_{\rm eq}$ [K]	> 2600	[3]

NOTE—[1] Ivshina & Winn (2022), [2] Deline et al. (2022), [3] Lendl et al. (2020), [4] Yan et al. (2020)

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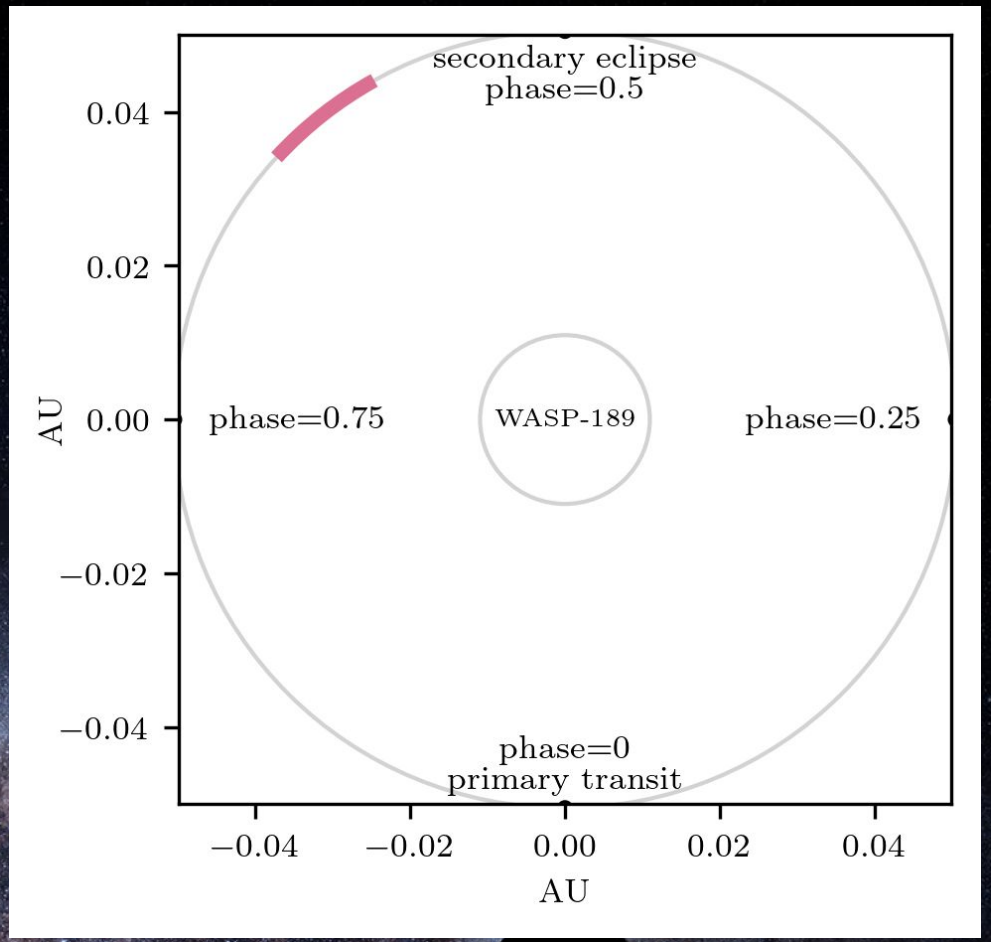
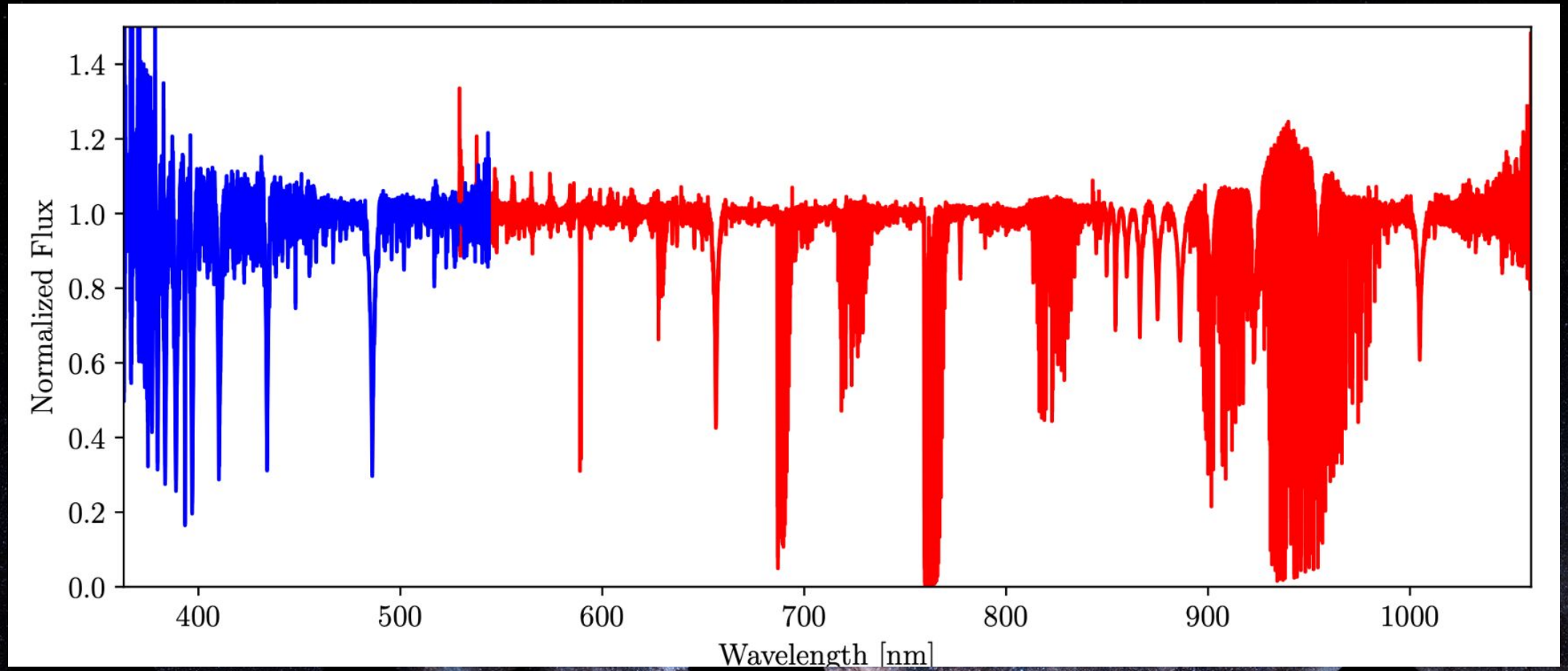
Date (UT)	Num. Exposures	Exposure Time (s)	Orbital Phase Coverage	Airmass Variation
13 May 2023	162	45	0.58 – 0.63	1.12 – 1.53

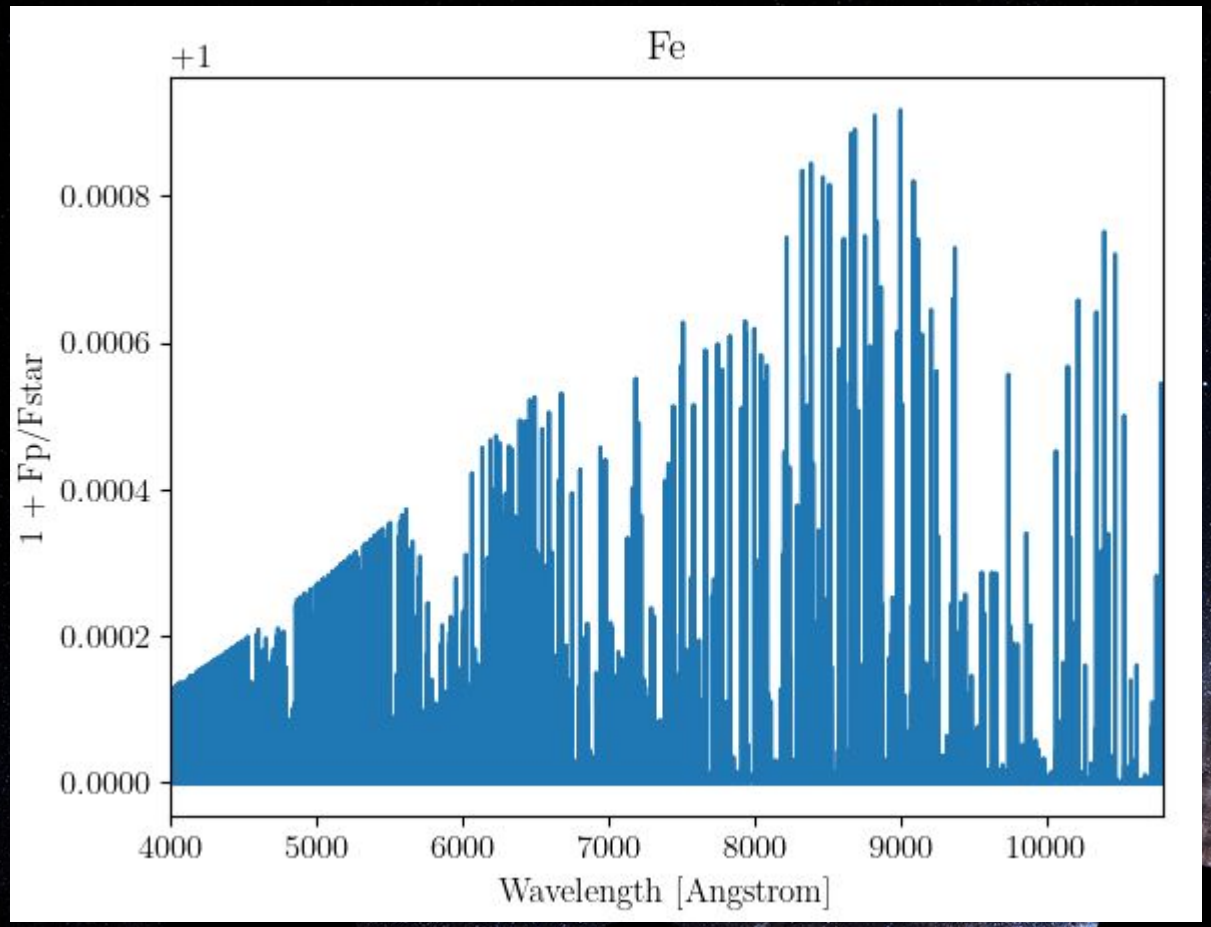


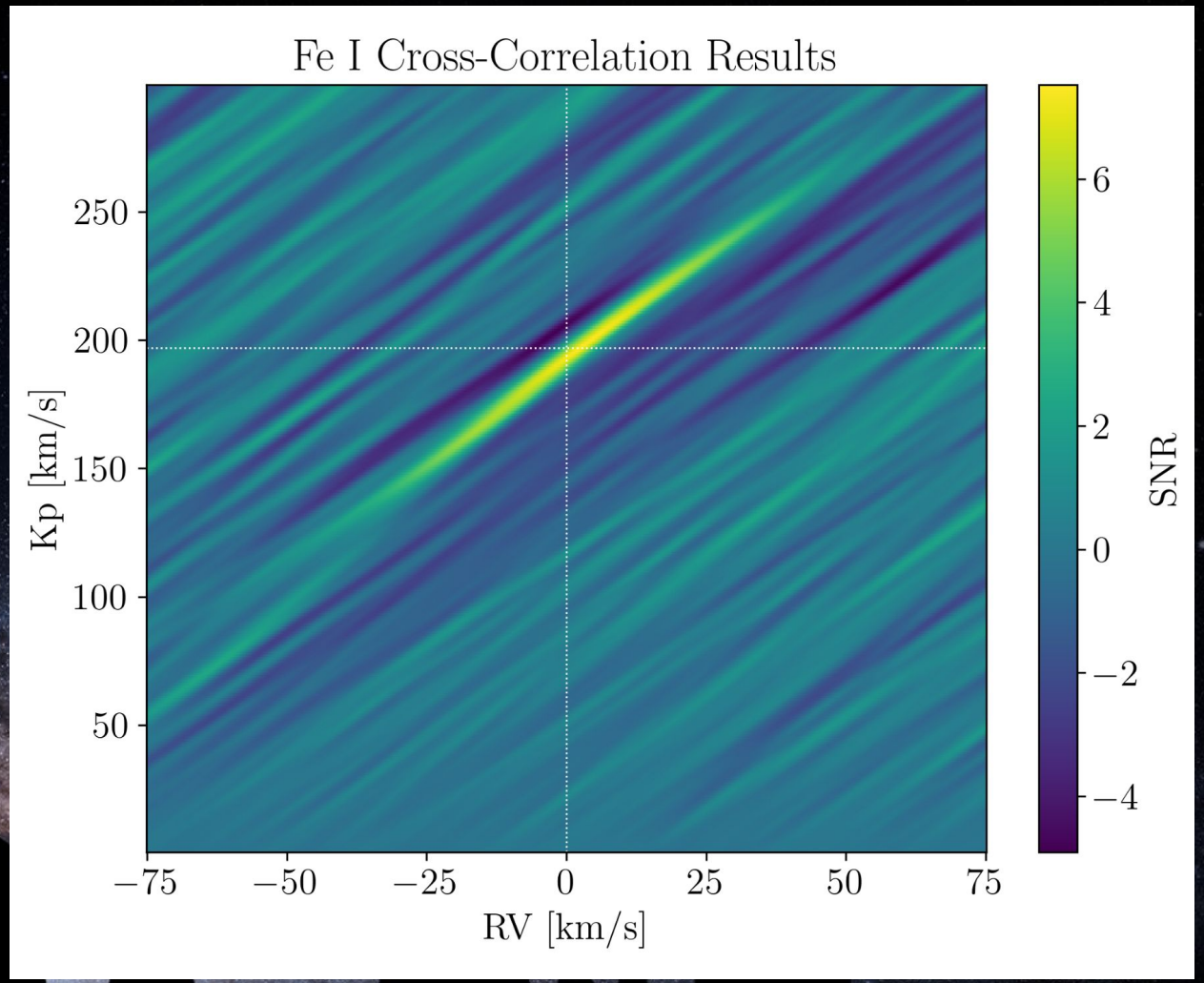
Science Case: High-Res Mode



Normalized WASP-189 spectrum, reduced with GHOSTDR/DRAGONS software V1.0.0

Science Case: High-Res Mode

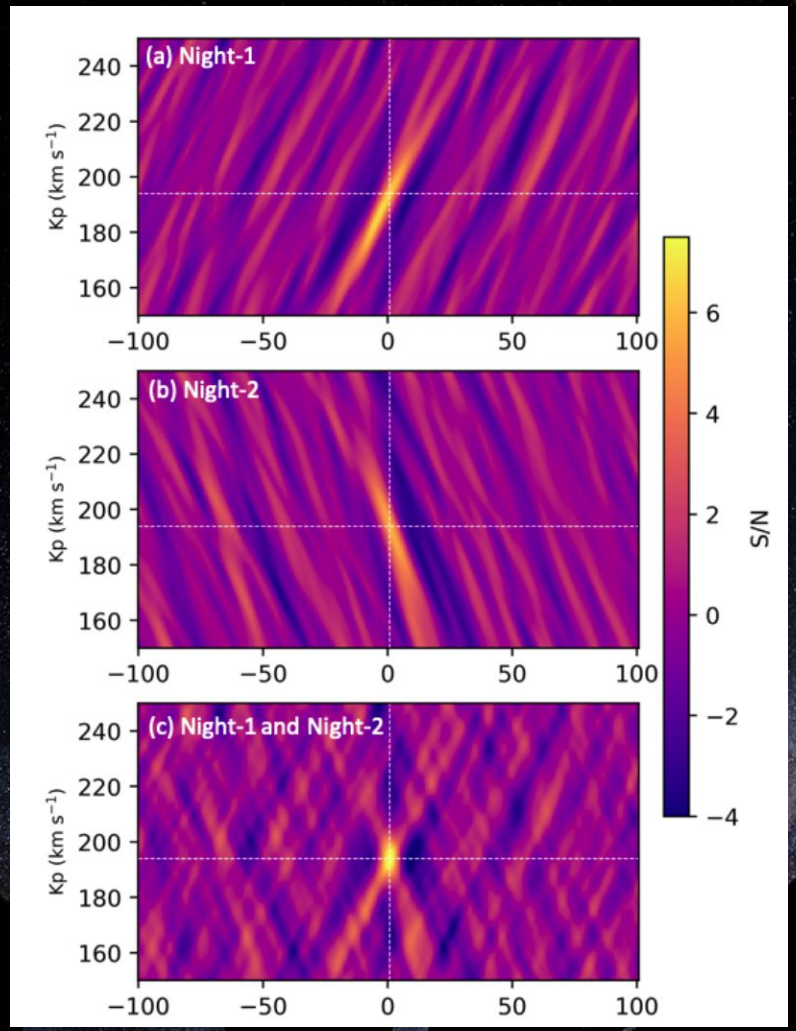


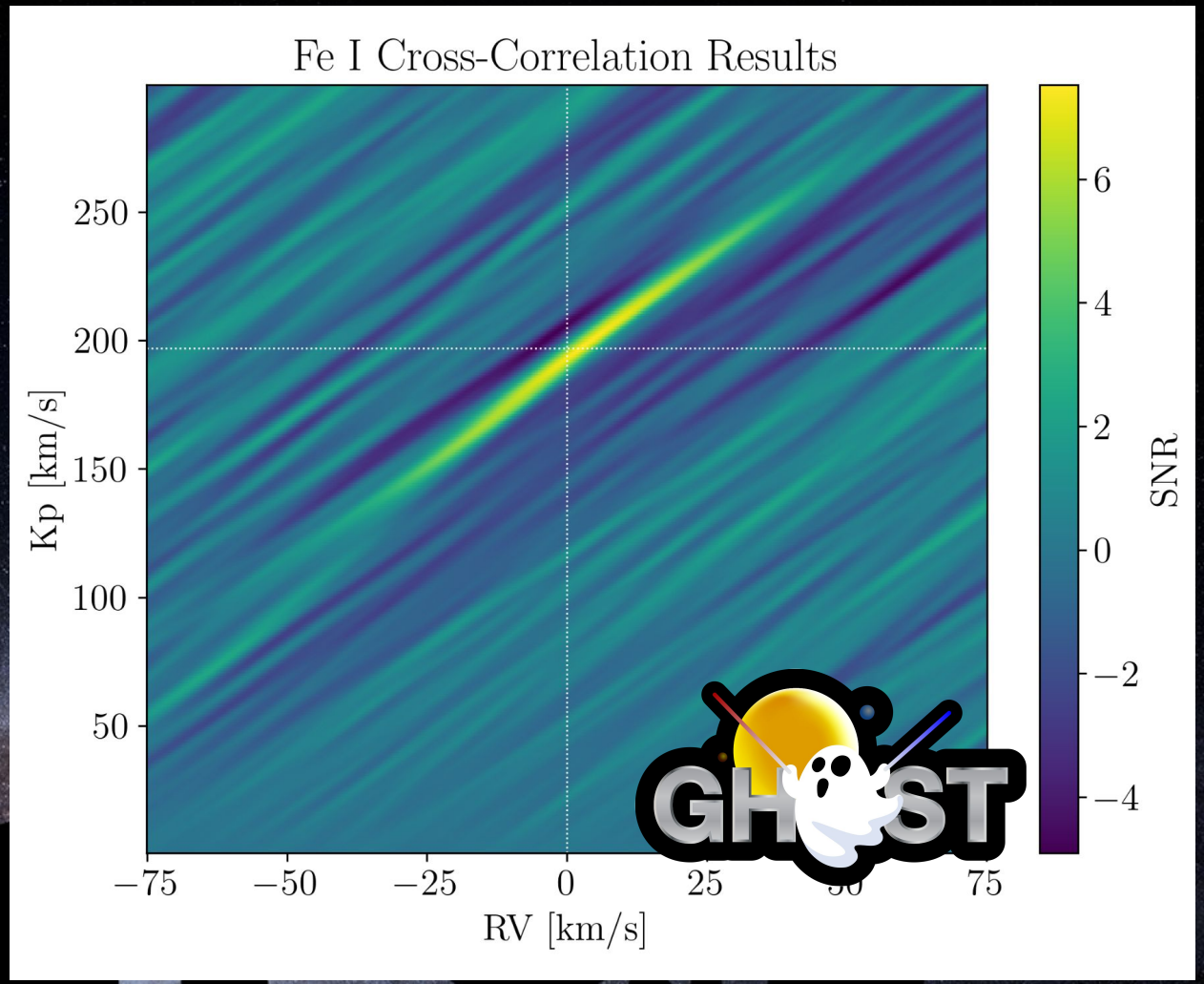


(Deibert et al. in prep.)

Science Case: High-Res Mode

HARPS; Yan et al. 2020

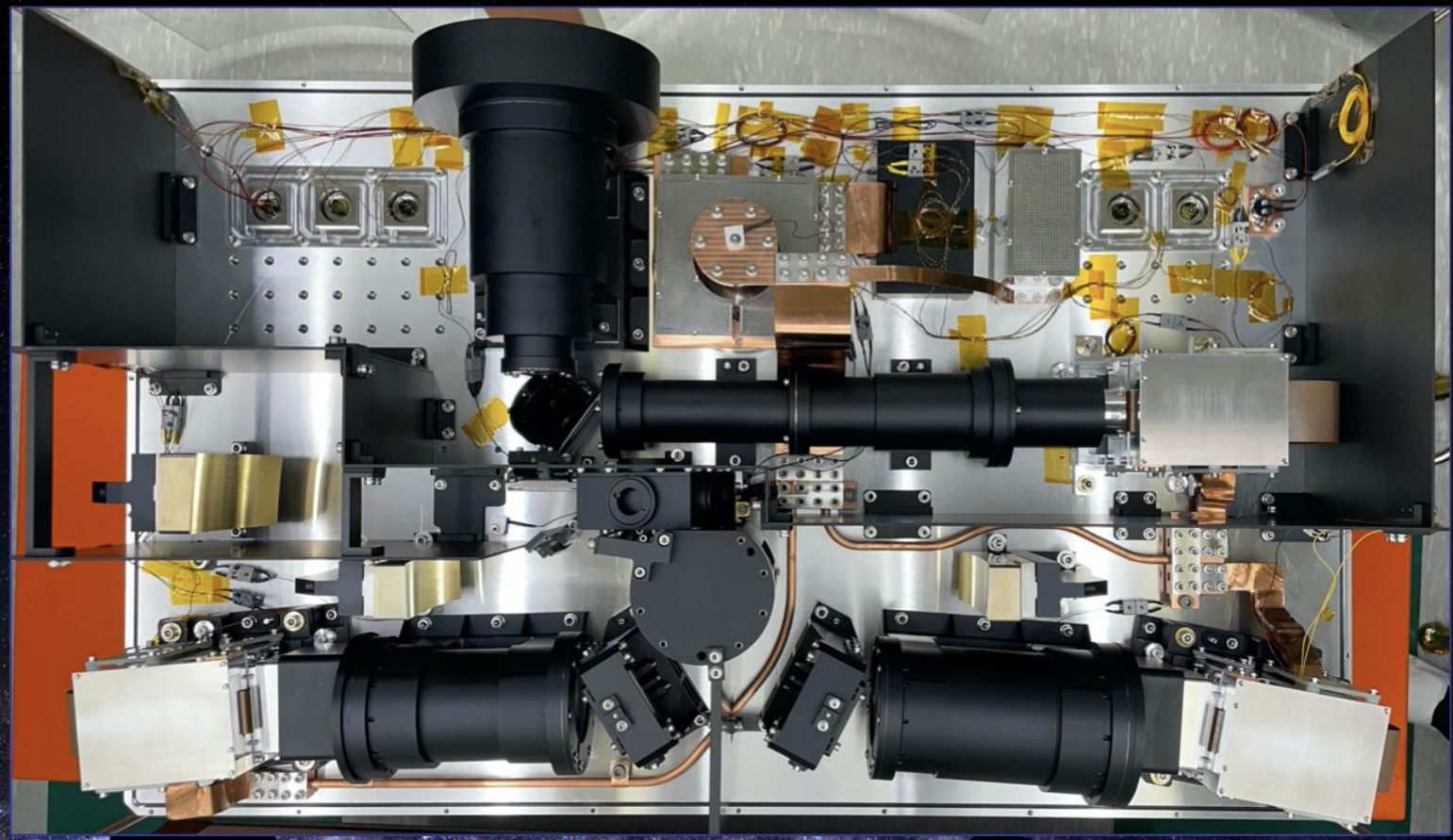





COMING VERY SOON to Gemini North: IGRINS-2
Exploring the Universe, Sharing its Wonders!

What is IGRINS-2?

- High-resolution (R ~ 45,000), near-infrared (1.49-2.46 μm) spectrograph based on IGRINS at Gemini South
- *Facility-class* instrument at Gemini North
- Developed & built by the Korea Astronomy and Space Science Institute (KASI)
- **See Mike Line's talk for exoplanet science cases!**



IGRINS-2 Full Assembly, June 2023

IGRINS vs IGRINS-2

- Changes in optics, mechanics, and electronics (less relevant from user POV)

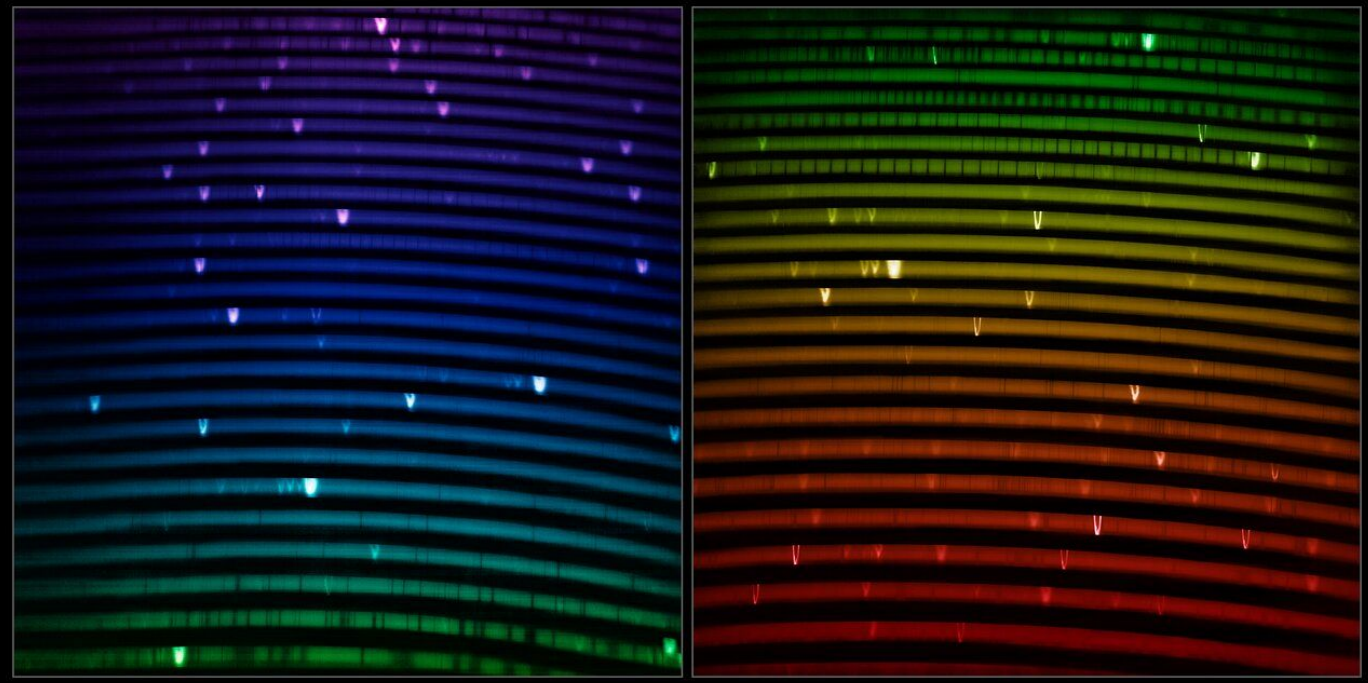
- **Fully integrated into Gemini systems!**
  - compatibility with seqexec (easier use for observer)
  - compatibility with OT, PIT, DRAGONS (easier use for PI)

IGRINS-2 Status & Timeline

- August 2023: Pre-shipment readiness review
- September 6, 2023: Arrival in Hilo Base Facility!
- September 26, 2023: Post-shipment readiness review
- **October 3-9, 2023: First light!**

IGRINS-2 Status & Timeline

- **January 3-9 2024 (now!): second on-sky test**
- Late April 2024: Final commissioning run
- Late July 2024: System Verification
- Late 2024B: Shared-Risk call for proposals (*pending!!*)

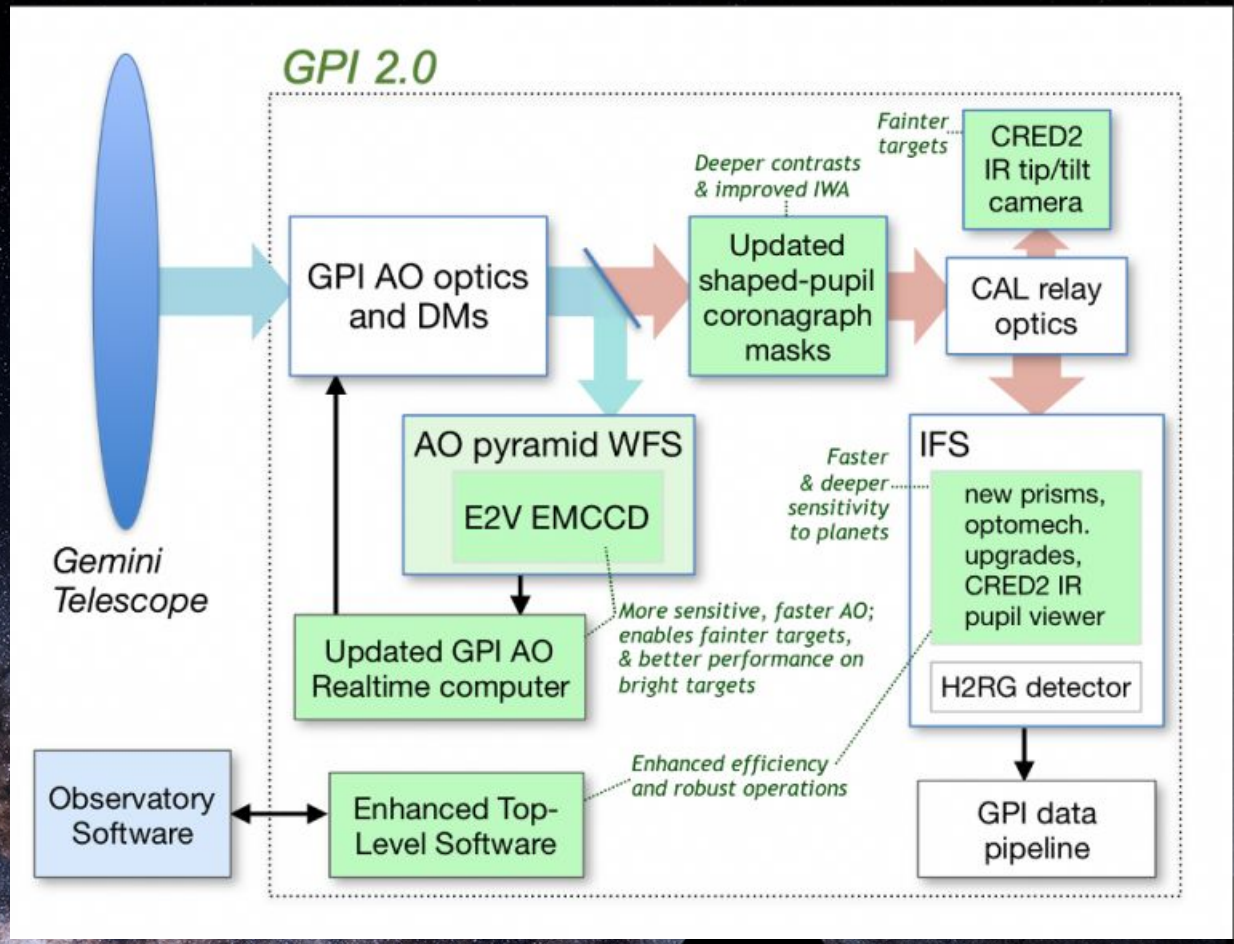


IGRINS-2 First Light (planetary nebula NGC 7027)


COMING SOON to Gemini North:
GPI 2.0
Exploring the Universe, Sharing its Wonders!

GPI 2.0 (Gemini North)

- Upgrade of GPI at GS
- Extreme AO imaging polarimeter and integral-field spectrometer
- **First light expected in early 2025**
- Work ongoing at the University of Notre Dame, the University of California San Diego, and the Herzberg Astronomy & Astrophysics Research Center (HAA) in Canada
- Direct imaging of exoplanets & disks
- **See Tom Esposito's talk for much more detail!**



(Chilcote et al. 2020)

GHOST: available now

IGRINS-2: expected 2024B

GPI 2.0: first light ~2025

MAROON-X: feasibility study for conversion to facility instrument ongoing

EXTRA SLIDES

Science Case: Dual Target Mode

Characterization of a solar-type star WASP-108 and its transiting hot Jupiter

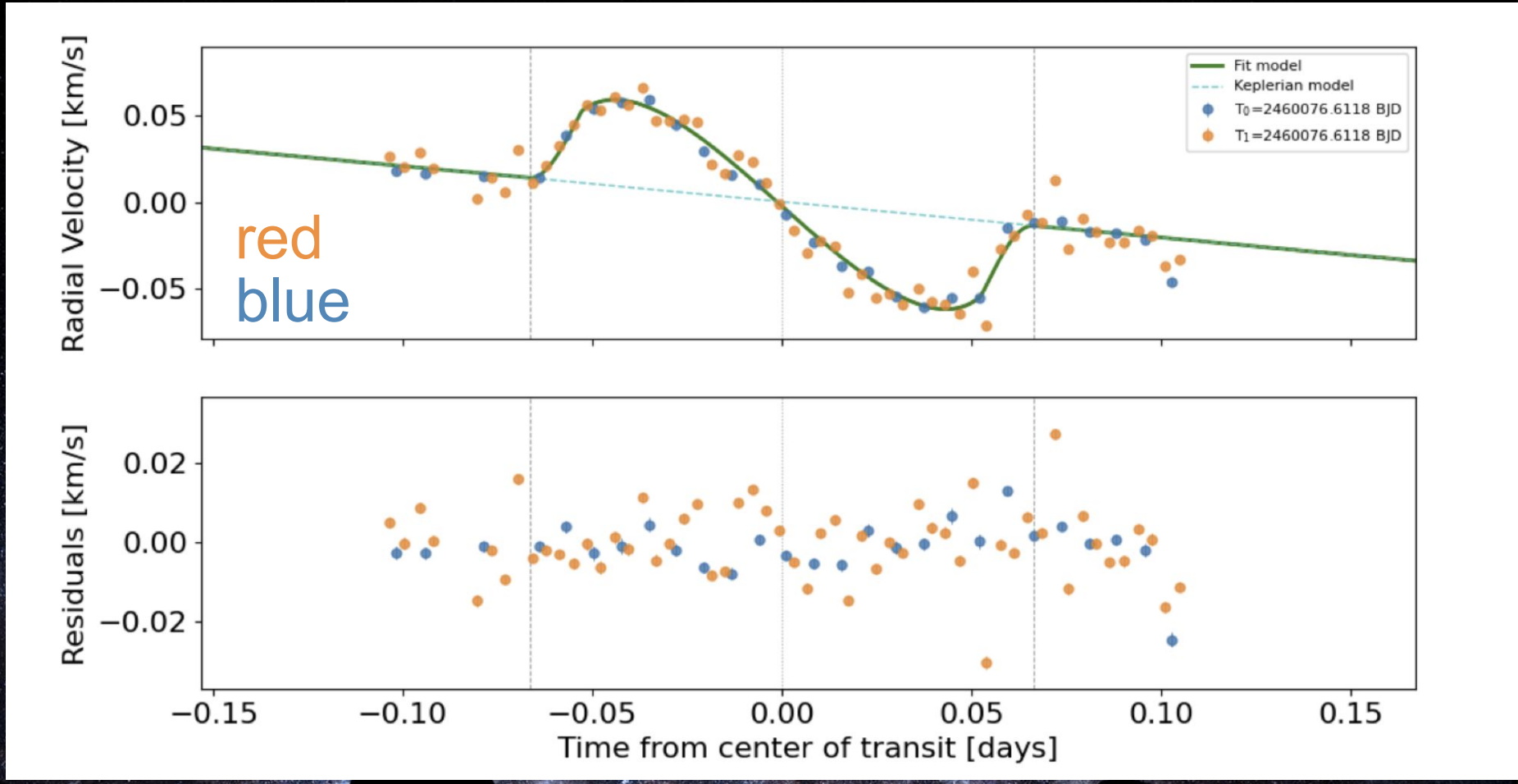
PI: Eder Martioli (Laboratório Nacional de Astrofísica, Brazil)

- standard resolution (R~56,000), dual-target time-series observations of WASP-108 (hot Jupiter host) and a reference star

1. Detect atmosphere via differential photometry
2. Detect Rossiter-McLaughlin (RM) effect and measure spin-orbit alignment
3. Measure stellar parameters and abundances

WASP-108b RM Effect

- **RM effect detected and modelled to determine the spin-orbit alignment; obliquity of λ=6.6°±1.1° (preliminary)**



Eder Martioli, Diego Lorenzo-Oliveira, Leandro de Almeida

Science Case: High-Res Mode

- models generated with petitRADTRANS (Molliere+19)
- T-p profile from Yan+20 best-fit to HARPS data (but we're working on retrieving the T-p profile from our GHOST data now)
- abundances from FastChem (Stock+18)