LOGAN PEARCE

MAGAO-X: CURRENT STATUS AND SCIENCE RESULTS PAST, PRESENT, AND FUTURE

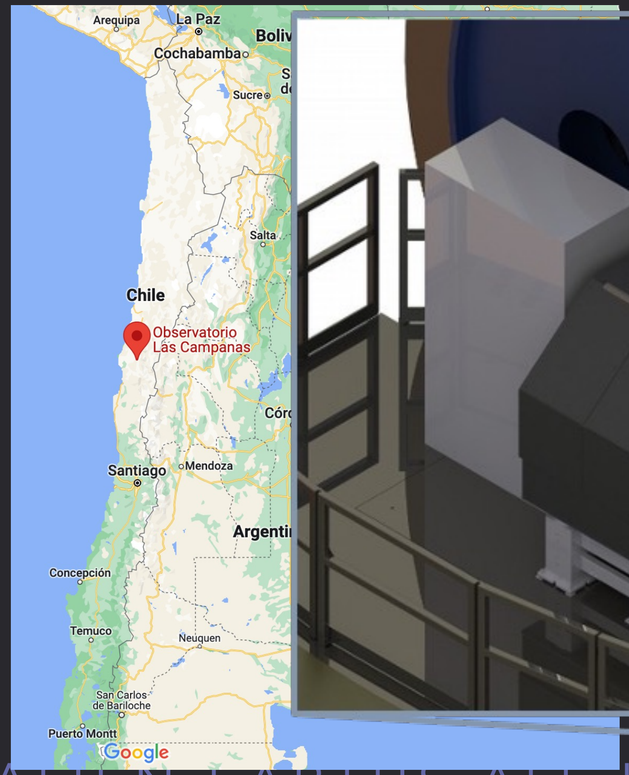
ALIEN EARTHS ALL-HANDS MEETING
BODY LEVEL TWO
BODY LEVEL THREE

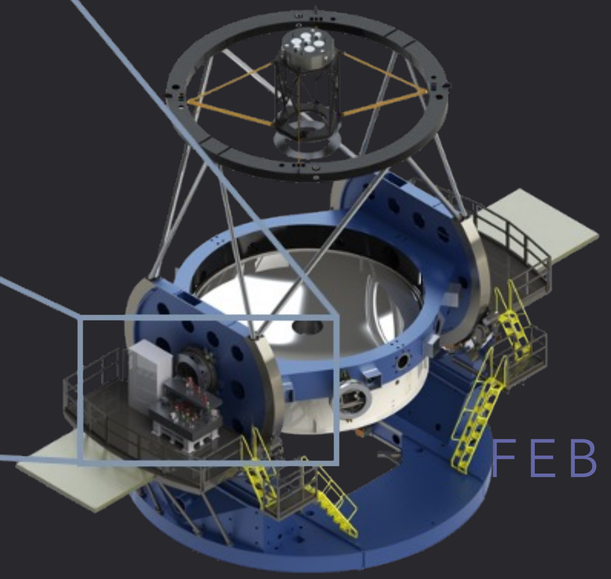
FEB 1-3, 2023

MagAO-X

"Extreme" adaptive optics instrument on the Magellan Clay Telescope, Las Campanas Observatory

- 6.5m telescope
- Magellan Consortium: Carnegie, Arizona, Harvard, Michigan, MIT
- MagAO-X sits on Nasmyth platform

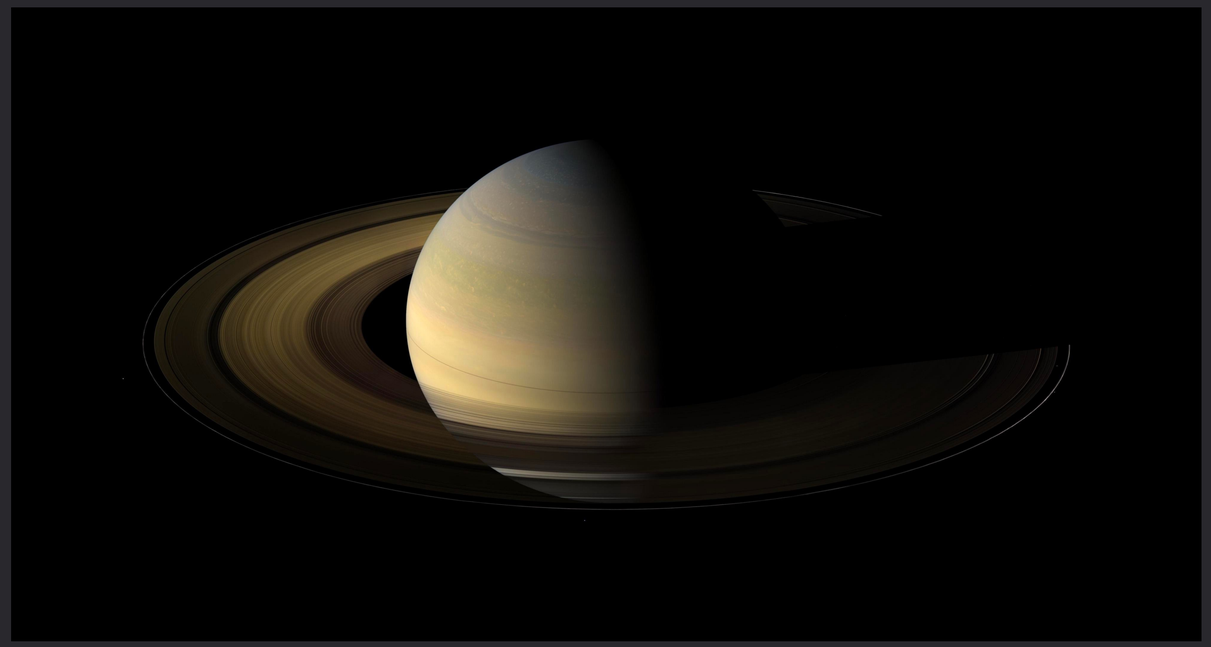




MagAO-X

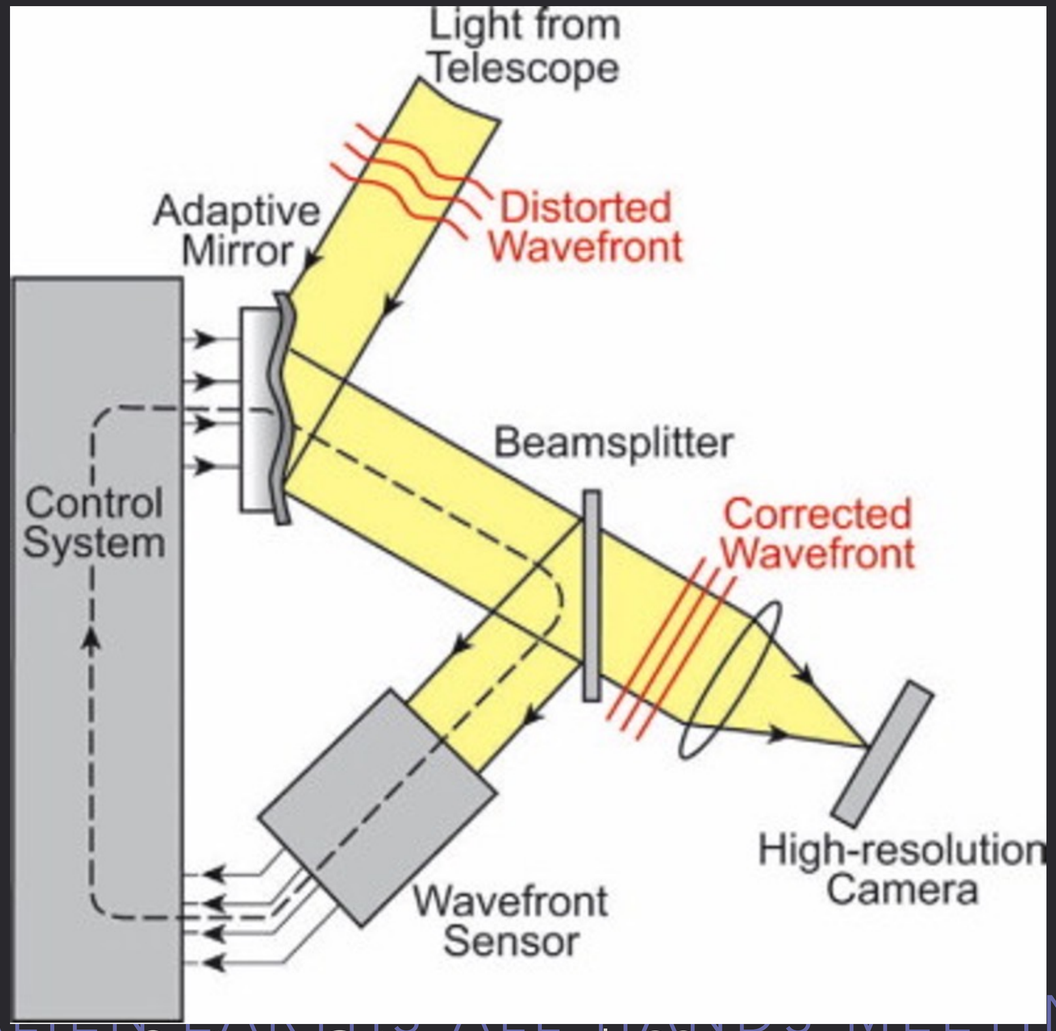
Ultimate Science goal: Image nearby exoplanets in reflected light

- Necessary to directly image & characterize evolved systems, small planets
- Very hard!
- 1e-7 contrast needed to image Proxima Centauri b
- Need to work very close to star where stellar irradiation sets brightness



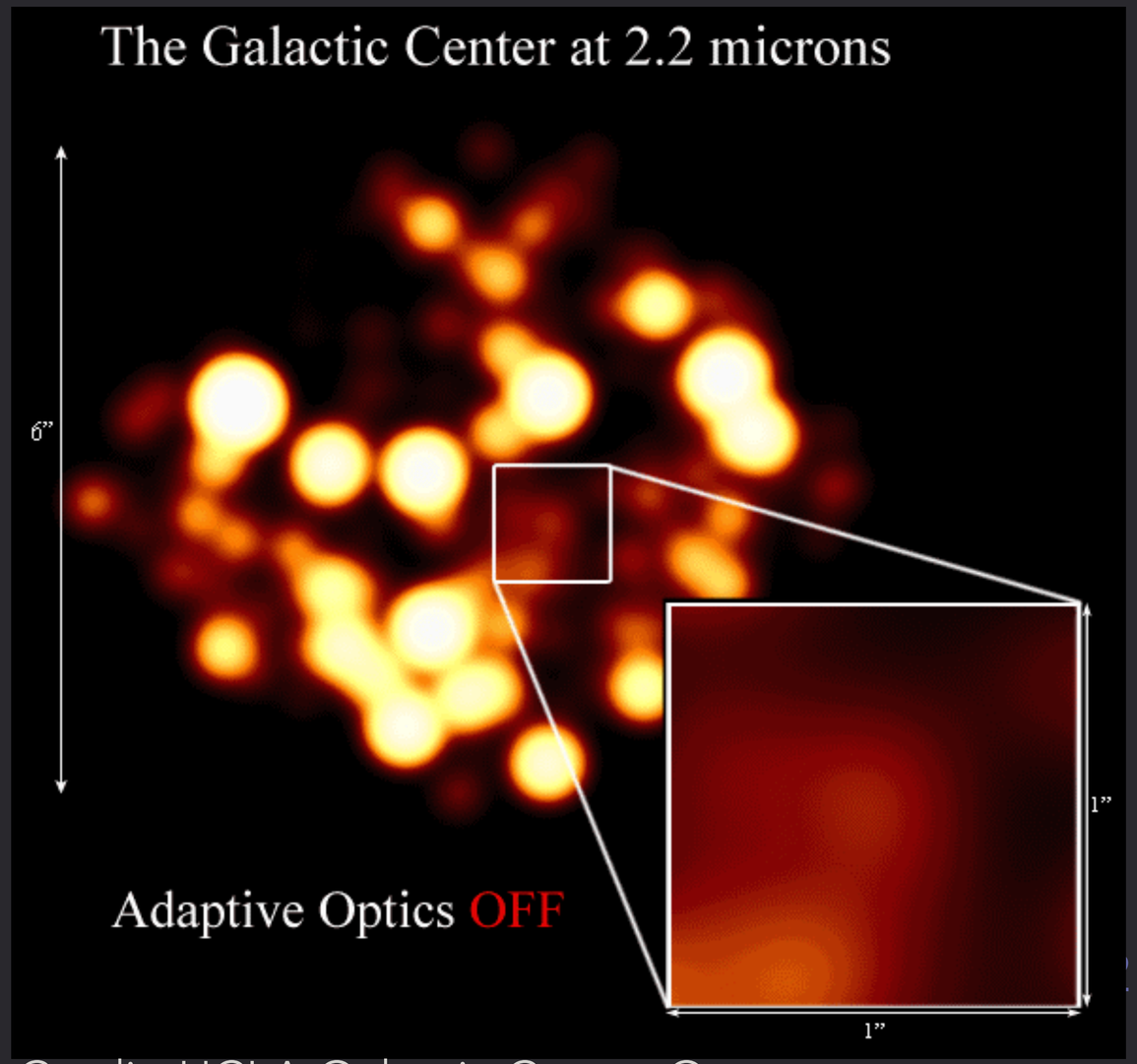
Source: NASA/JPL

TERMINOLOGY BREAK: ADAPTIVE OPTICS



Suárez-Gómez et al. 2017

Diffraction limited imaging from the ground



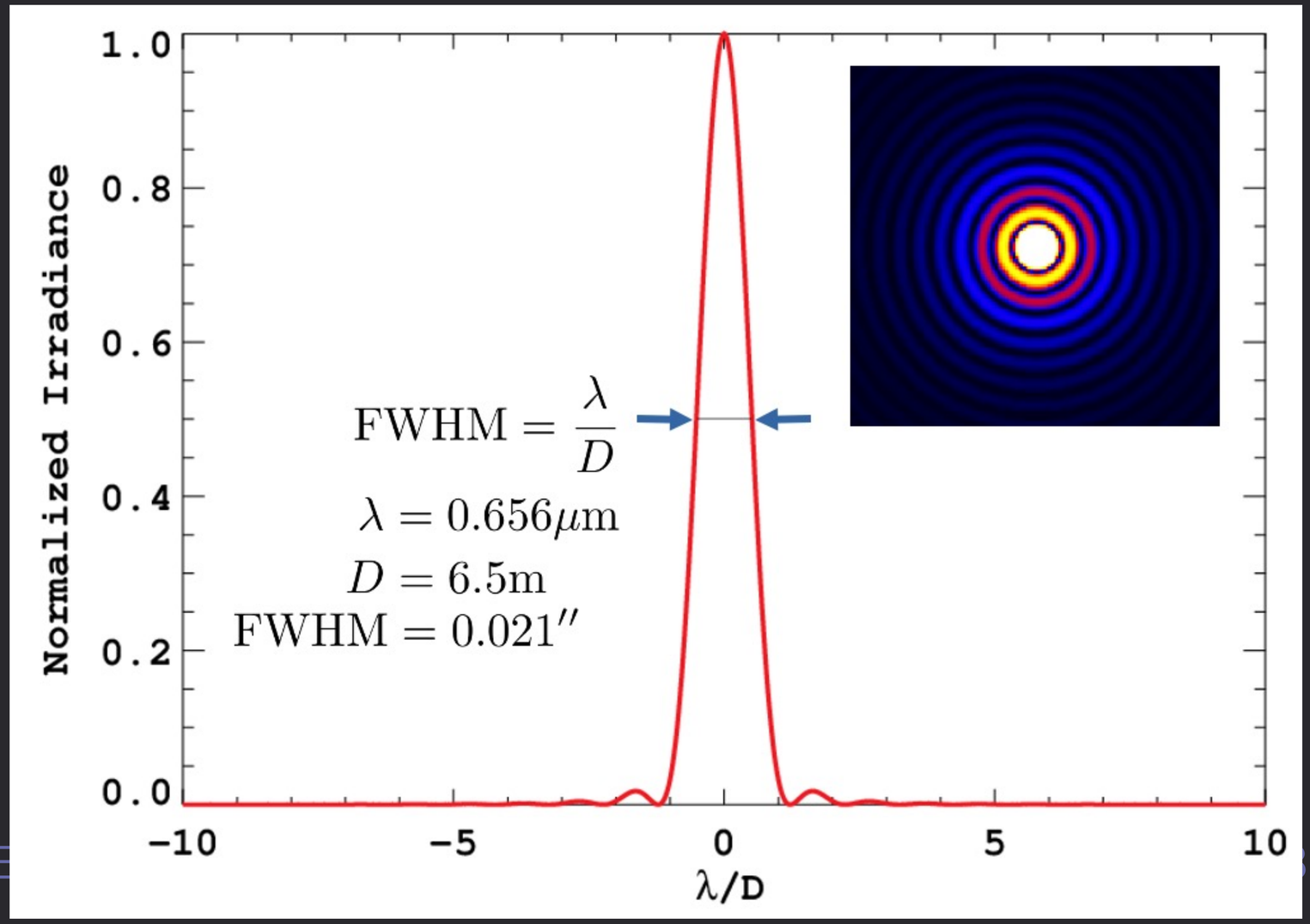
Credit: UCLA Galactic Center Group

TERMINOLOGY BREAK: λ/D

Point Spread Function: Fourier transform of telescope pupil

λ/D: Fundamental length scale in diffraction limited imaging

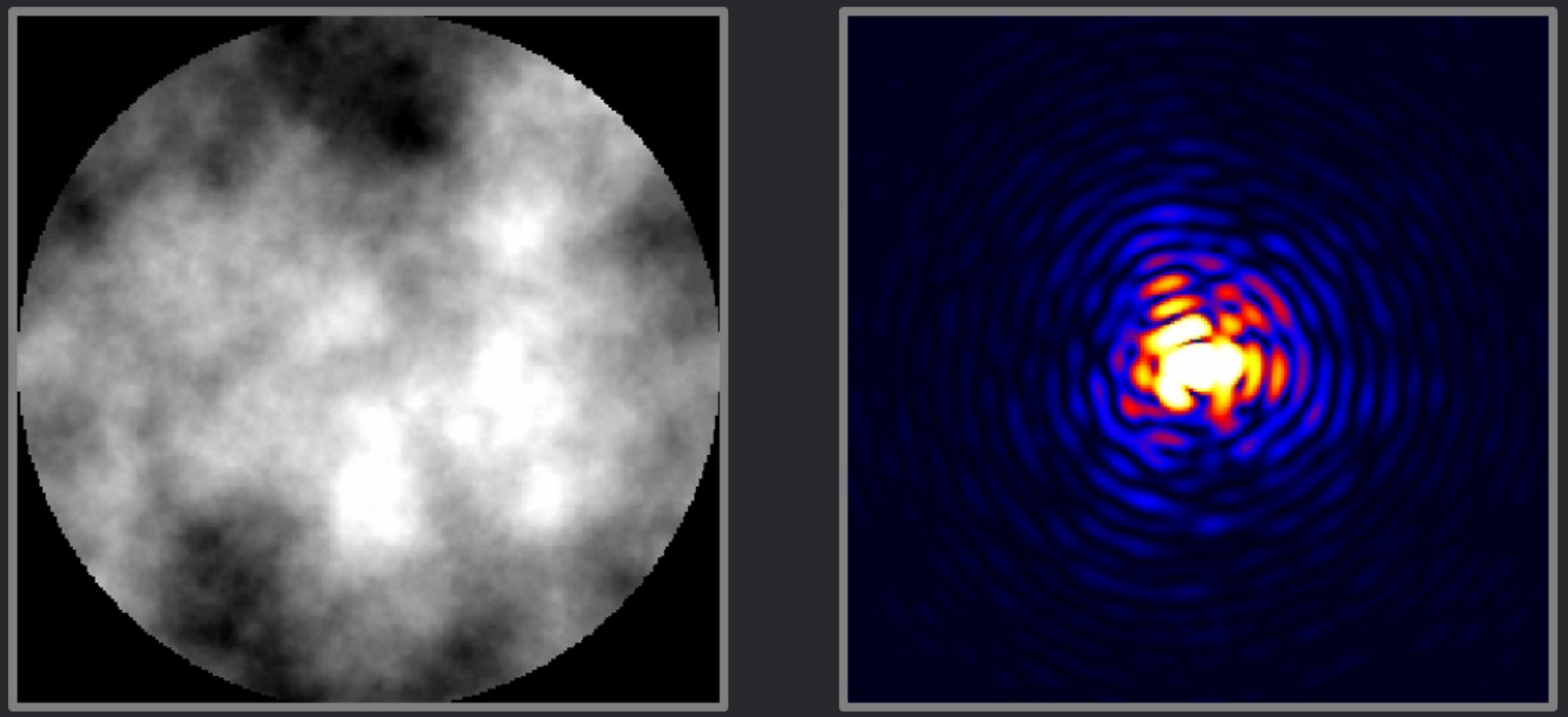
Inner Working Angle (IWA): How close in can we detect faint things?



ALIEN EARTHS ALL-HANDS ME
BODY LEVEL TWO
BODY LEVEL THREE

TERMINOLOGY BREAK: SPECKLES

- Atmosphere patterns, less-than-perfect optics, etc. produce speckles - a copy of the PSF
- Affects signal to noise, and creates signals that can be confused for astrophysical



Atmosphere → PSF

SPECKLES ARE THE MAJOR OBSTACLE TO WORKING AT ~3 λ/D

TERMINOLOGY BREAK: CORONAGRAPH

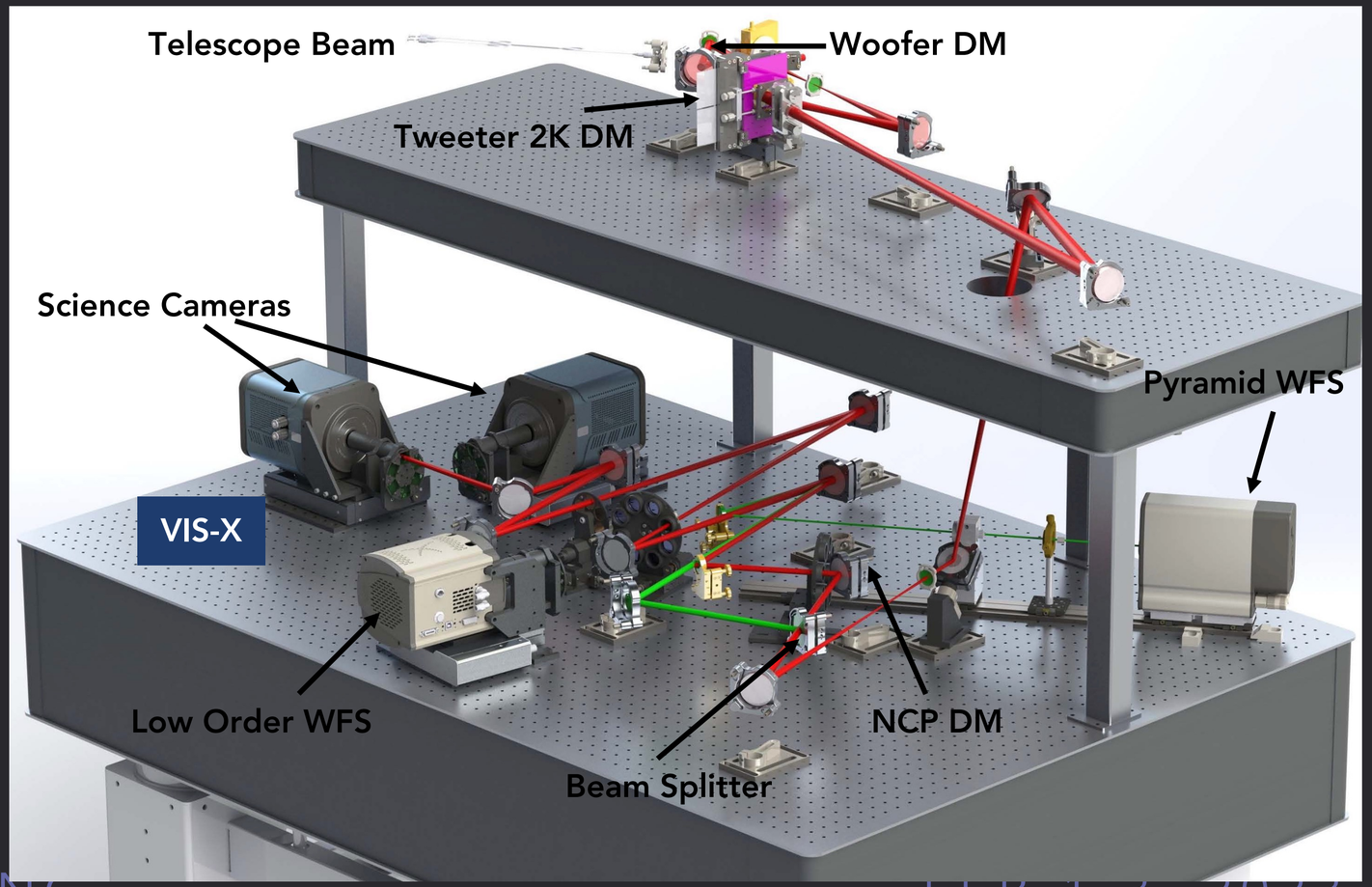
Just like in a total eclipse ("corona"graph)

Block on-axis light (star), off axis light (planet) passes through

Credit: SOHO/LASCO, ESA & NASA

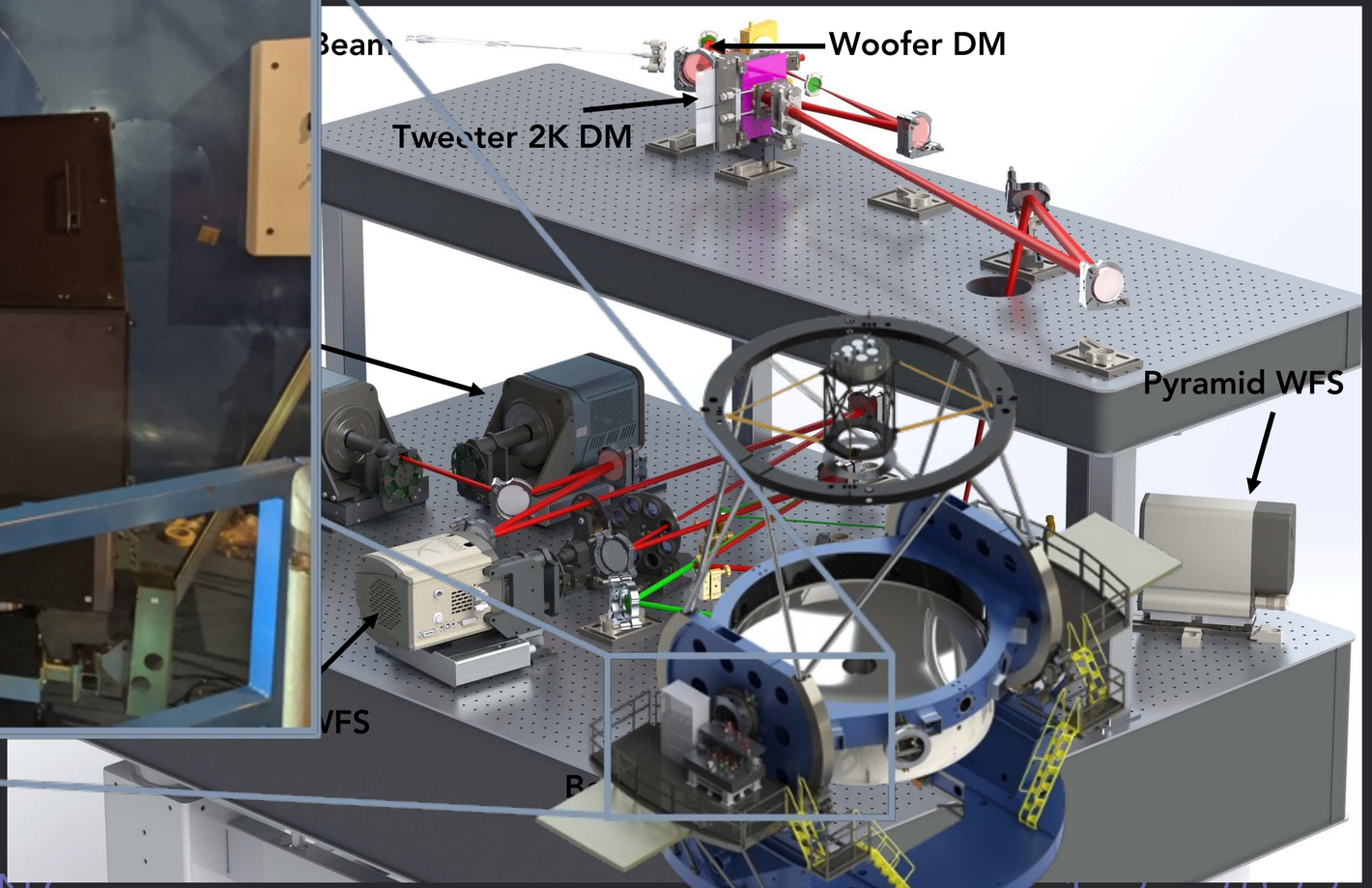
MagAO-X

- 3 deformable mirrors, including “woofer”, 2000 actuator “tweeter”, and non-common path correction DM
- 2 science cameras
- Broadband photometry in g’, r’, i’, z’, Narrowband H-alpha, Methane
- VIS-X IFU



MagAO-X

- 3
- 2
- L
- B
- V



ALIEN EARTHS ALL-HANDS MEETING
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MagAO-X

Schedule:

- First light fall 2019
- Upgrades, lab experiments 2020-2021
- Returned to telescope April 2022, Nov/Dec 2022
- Returning in Feb/March 2023
- Upgrades/lab time rest of 2023

Mission patch genius:
Joseph Long

2022B

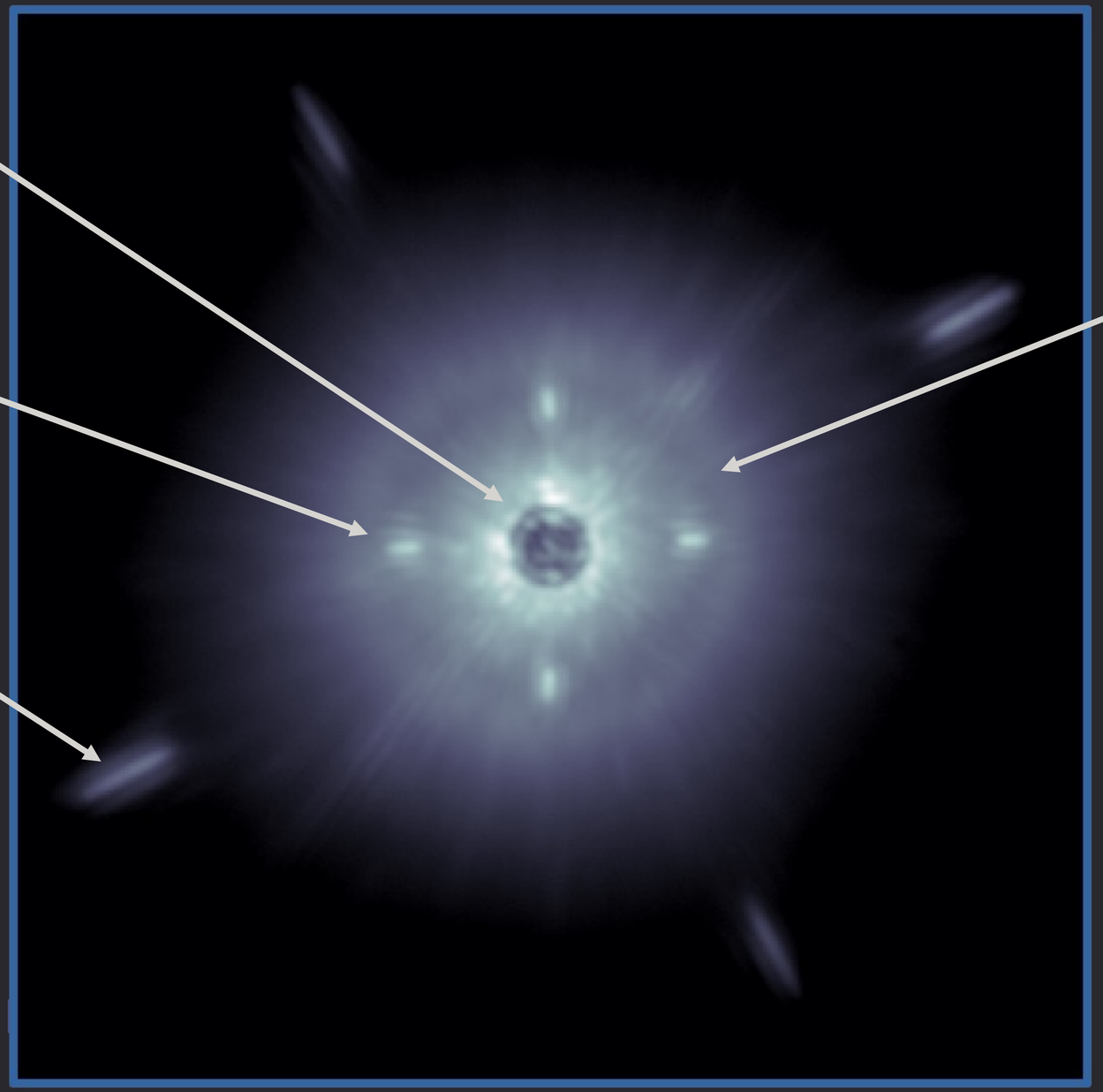
1376 modes controlled at 2 kHz

22 λ/D dark hole

Coronagraph

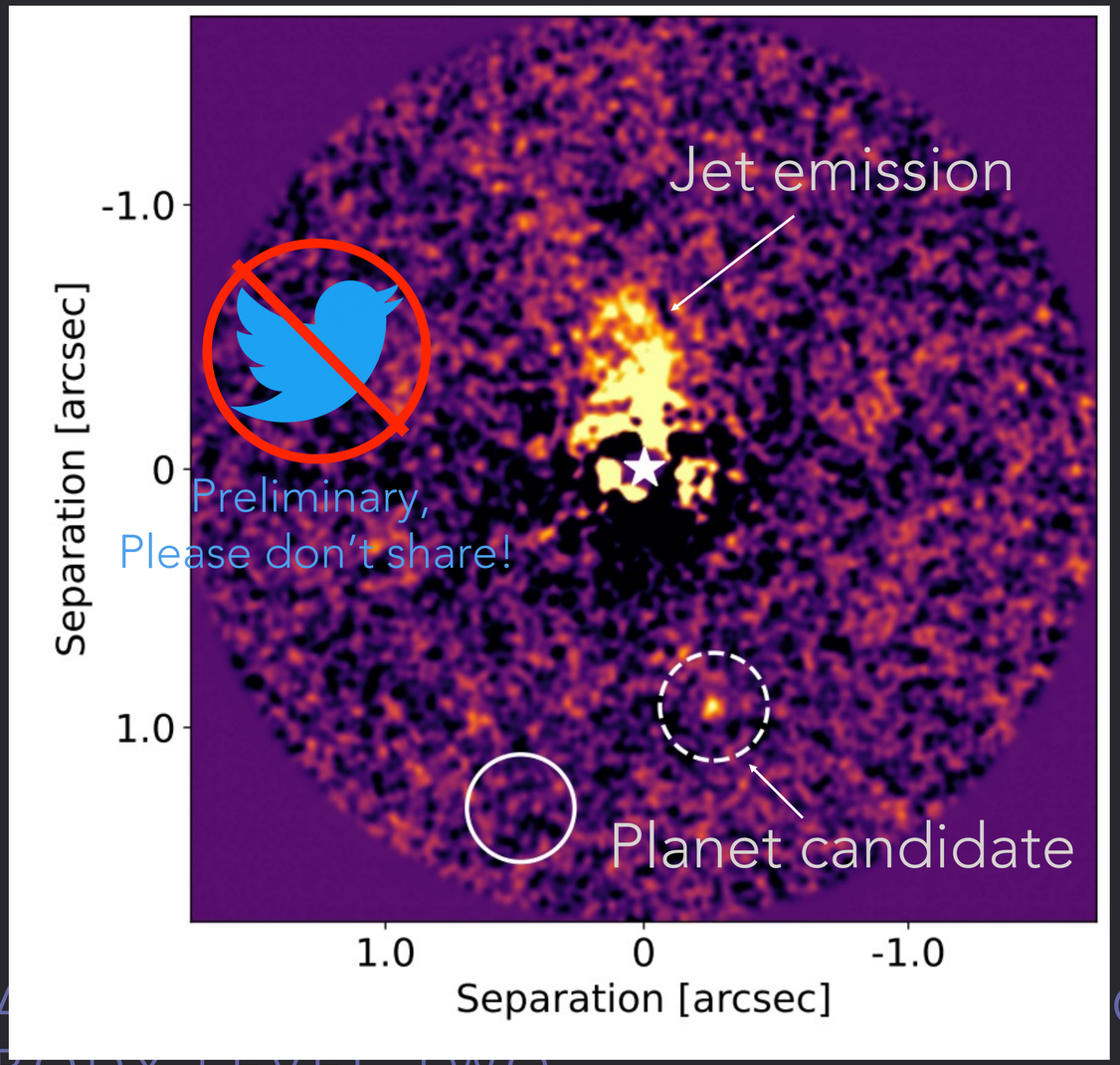
Calibration speckles

Speckles from DM



“Dark hole” AO control radius

FIRST SCIENCE RESULTS!



A new accreting protoplanet and jet emission detected in H alpha

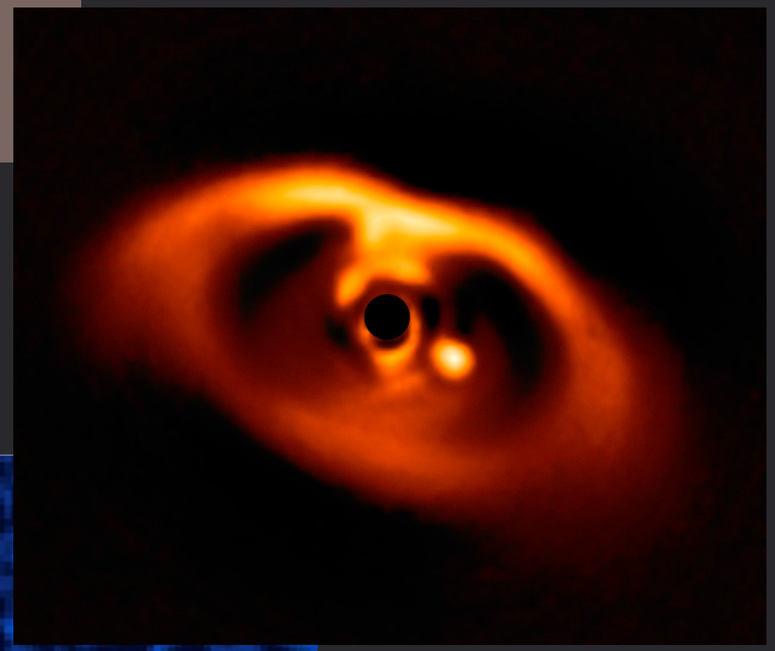
PI: Gabriele Cugno, U. Michigan

Keep an eye out for this paper!

ONGOING SURVEYS: MAXPROTOPLANETS

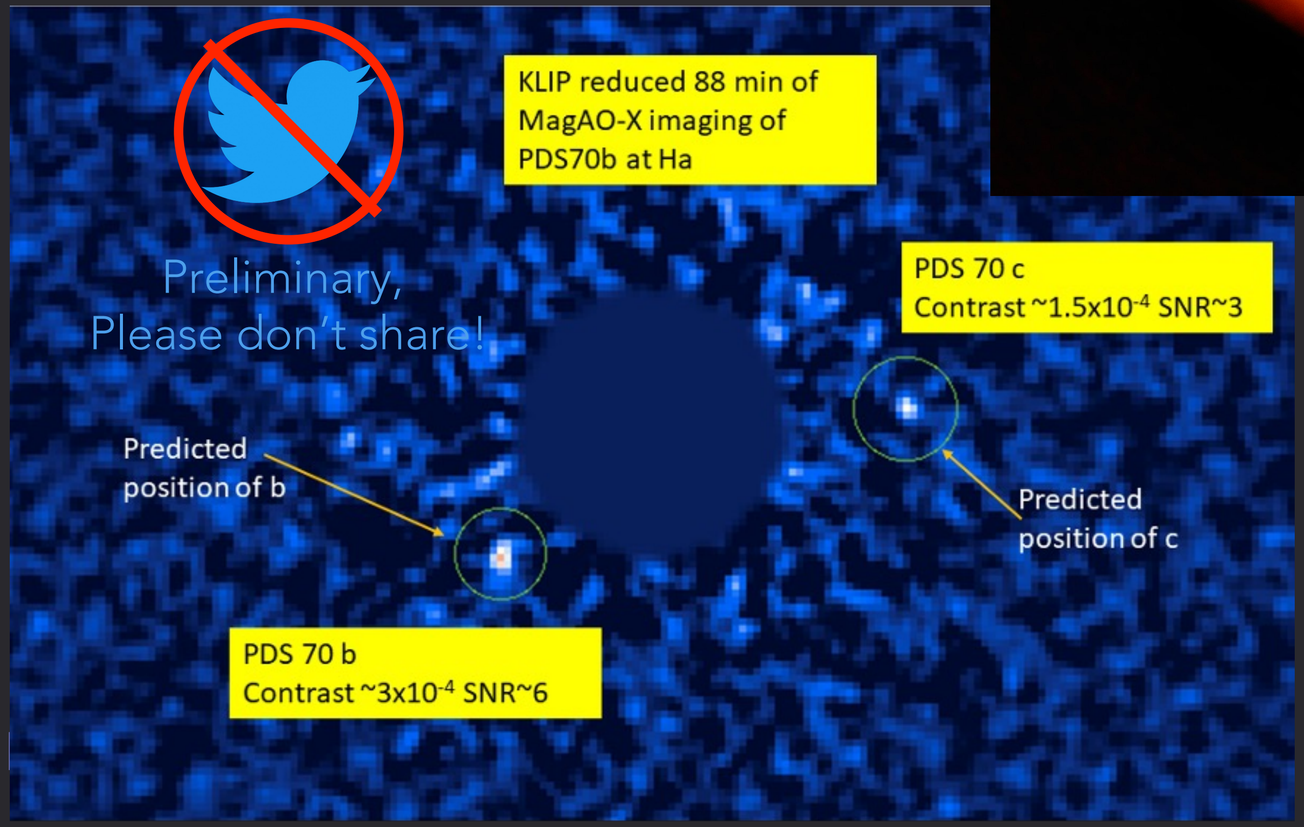
- Image accreting planets in disk gaps in Halpha
- PI: Laird Close

PDS 70 ALMA Continuum



Source: ESO/ A. Muller et al.

PDS 70 MagAO-X Halpha



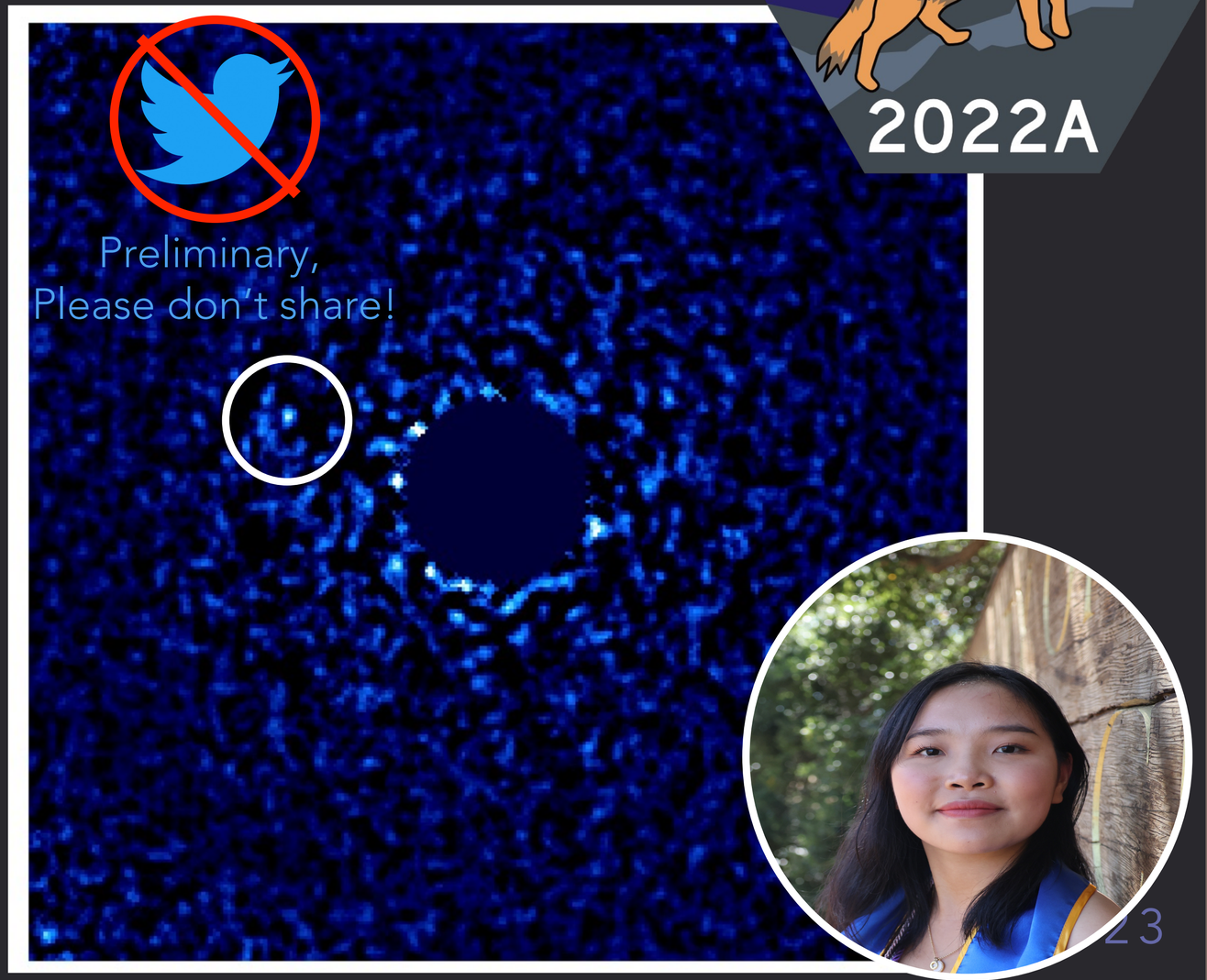
Close et al., in prep

FIRST SCIENCE RESULTS!

MaxProtoPlanetS discovery of a new accreting protoplanet candidate embedded in a disk

Led by graduate student Jialin Li

Keep an eye out for this paper!



ONGOING SURVEYS: MAGAO-X SIRIUS-LIKE SYSTEMS SURVEY

- White Dwarfs are excellent (the only!) probes of exoplanetary non-volatile material composition through pollution of photospheres.
- WD pollution has shown exoplanetary material is compositionally similar to inner Solar System
- PI: Logan Pearce

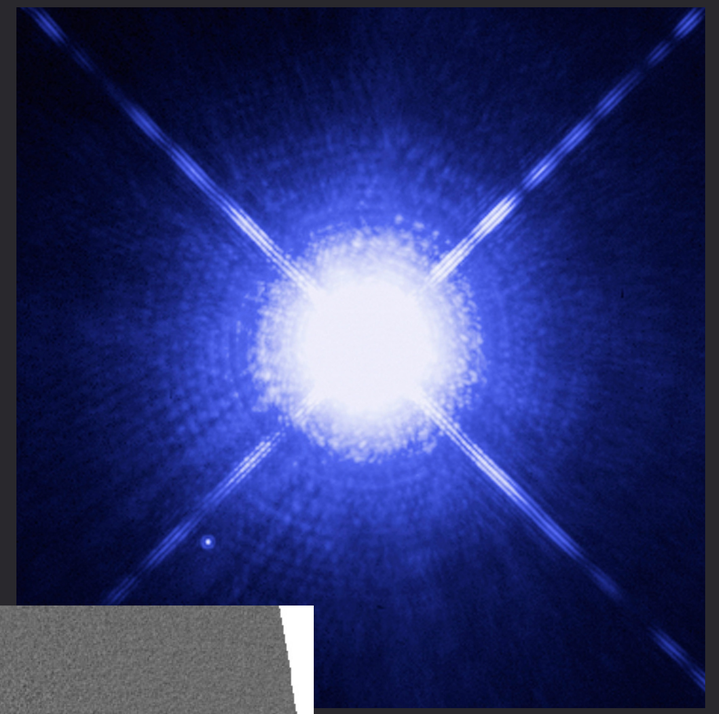
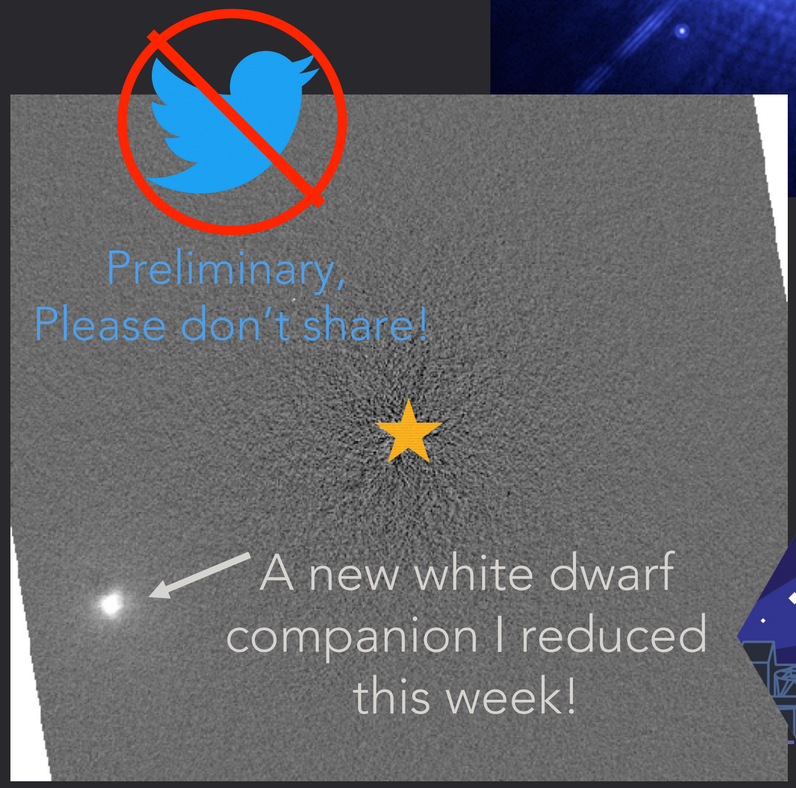


Image Credit: NASA, ESA, H. Bond (STScI), M. Barstow (University of Leicester)



ALIEN EARTHS ALL-HANDS MEETING 2023
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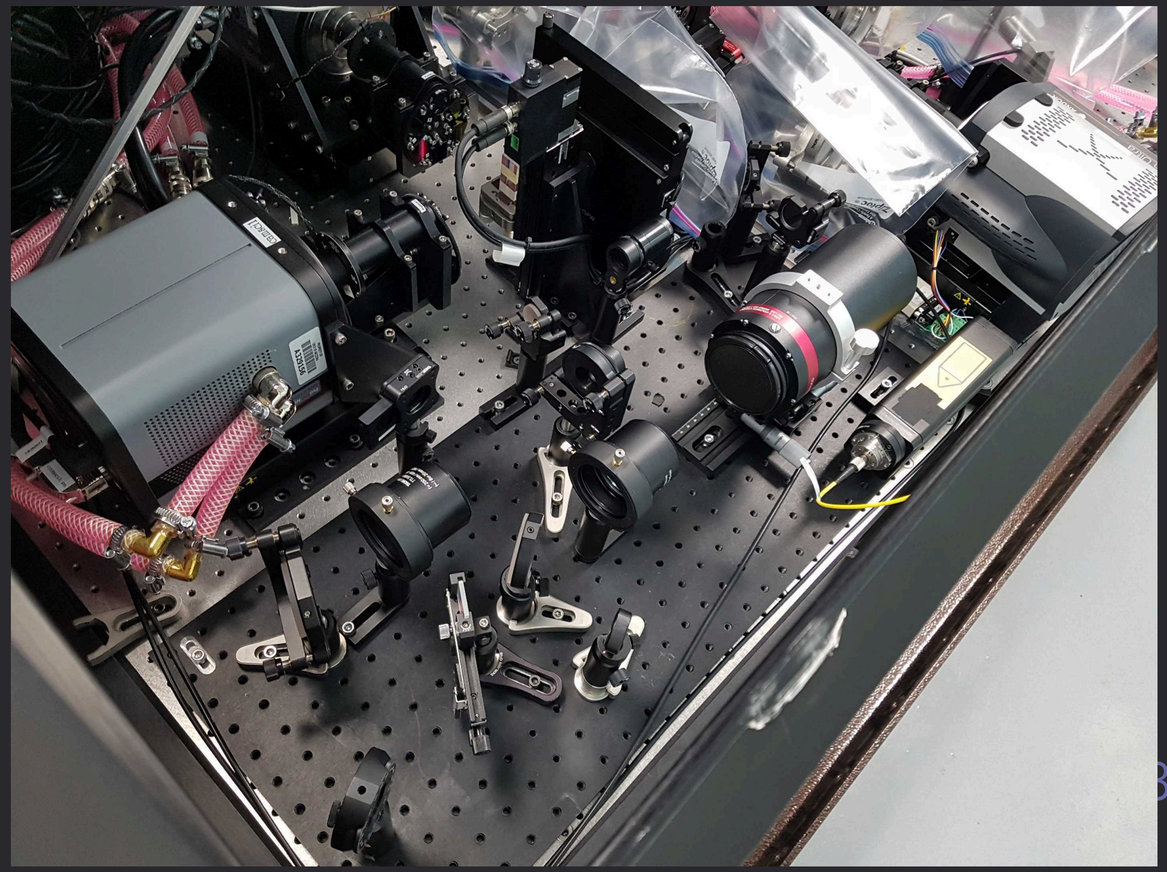
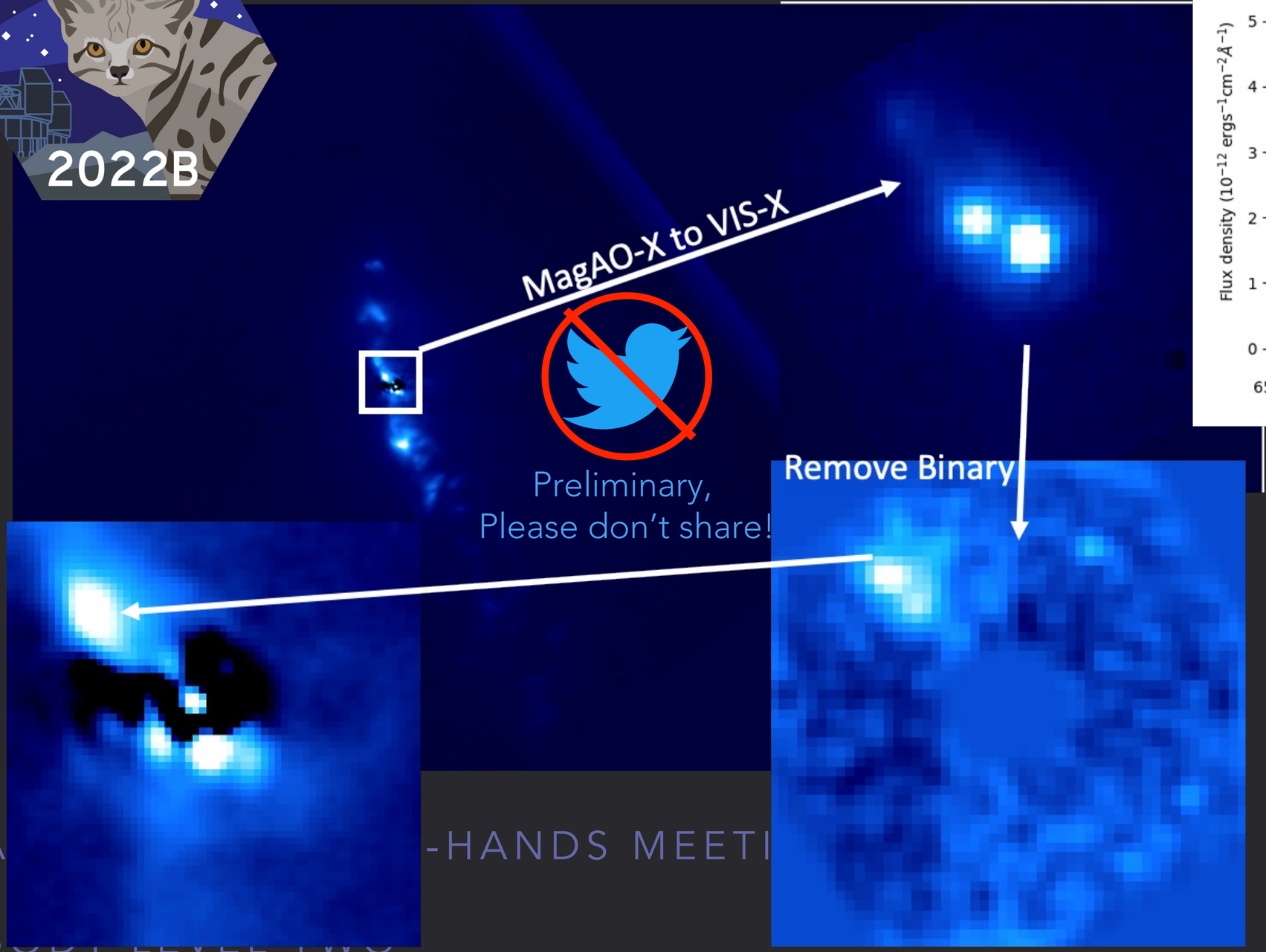
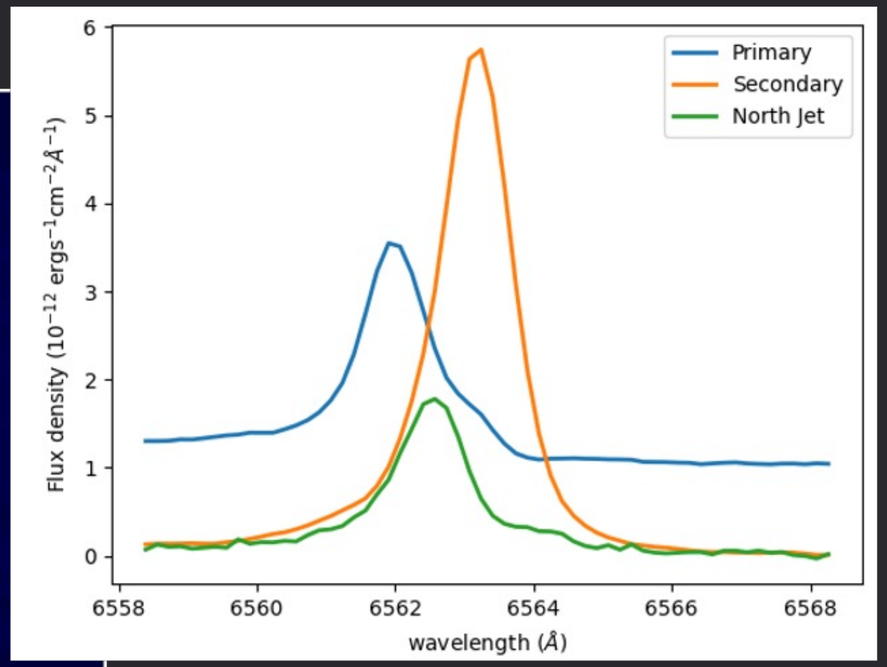
VIS-X

- Integral Field Unit Spectrograph on MagAO-X
- PI: Sebastiaan Haffert
- High resolution: R = 15,000
- Low resolution: R = 100



R Aqr: interacting binary with jet





H alpha emission from accretion and jet

TOWARDS PROXIMA B: PHASE II

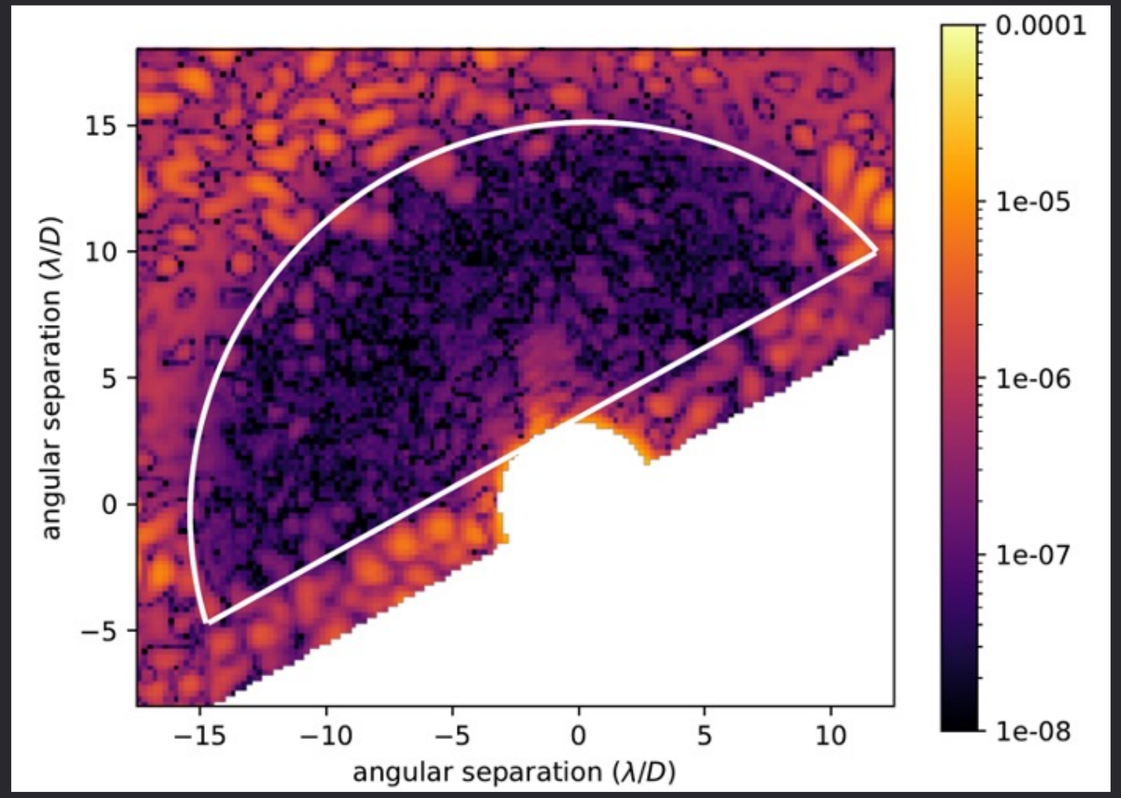
Coronagraph upgrades to deliver highest contrast at smallest inner working angle:

- Coronagraph Optimization (Sebastiaan Haffert)

- Phase Induced Amplitude Apodization (PIAA; Warren Foster)

TOWARDS PROXIMA B: PHASE II

5e-8 contrast dark hole created in the lab



Creating and maintaining “dark holes” on sky (Sebastiaan Haffert):

- Non-common path deformable mirror upgrade this summer
- Low-order wavefront sensor and linear dark field control (see Avalon McLeod’s talk at 2:10 today)

TOWARDS PROXIMA B: PHASE II

Science upgrades:

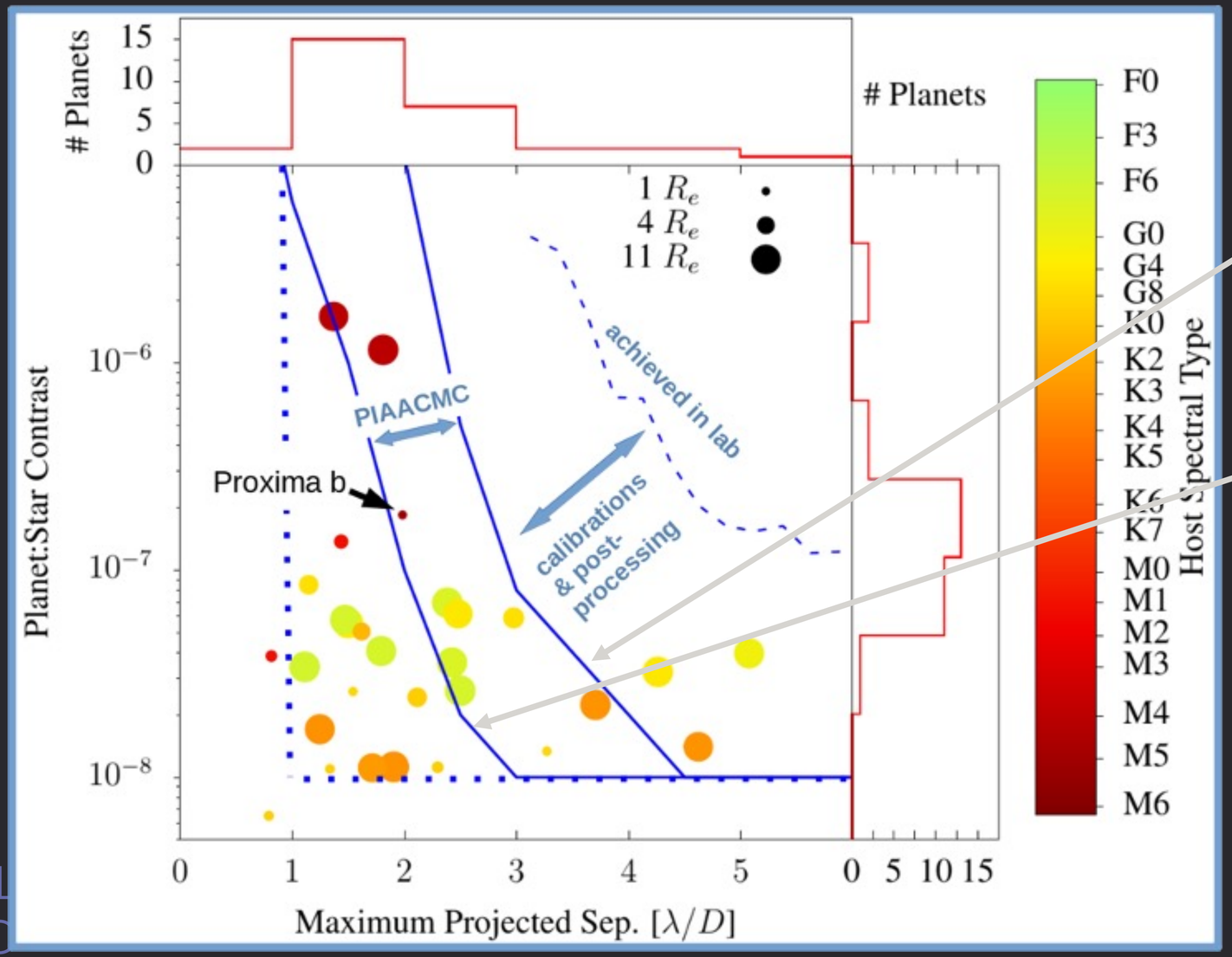
- MKID IFU upgrade (PI: Ben Mazin, UCSB)
- Planned integration of G-CLEF visible high dispersion IFU with MagAO-X

- Developing new post-processing technique using system telemetry to achieve high contrasts at close inner working angles (see Joseph Long's talk tomorrow afternoon)

AFTER PHASE II UPGRADES:

Direct reflected light imaging of a habitable zone terrestrial planet (Proxima b)

This will give us a broadband albedo measurement and begin to process of detailed characterization of the nearest terrestrial planet

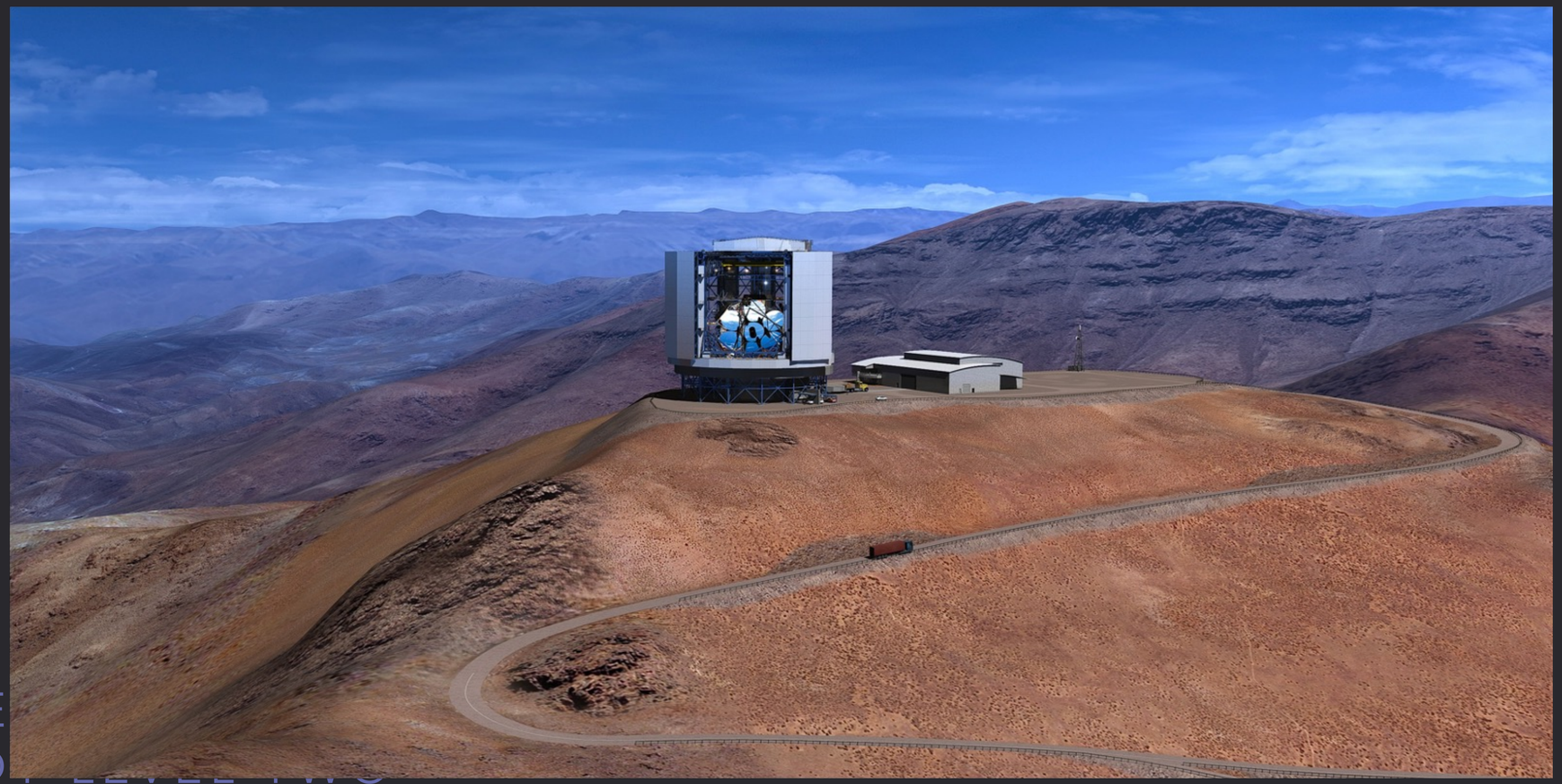


Post-processing improvements

Coronagraph upgrades

TOWARDS PROXIMA B: GMAGAO-X

- See Sebastiaan Haffert's talk at 1:30 today and Eden McEwen's talk at 4:20 today



SUMMARY

- Ground based reflected light direct imaging is a vital component of exoplanet characterization, complementing RV, transit, and space-based observations
- With Phase II upgrade and beyond, MagAO-X will be able to reach closest known planets in reflected light
- GMagAO-X will knock this out of the park