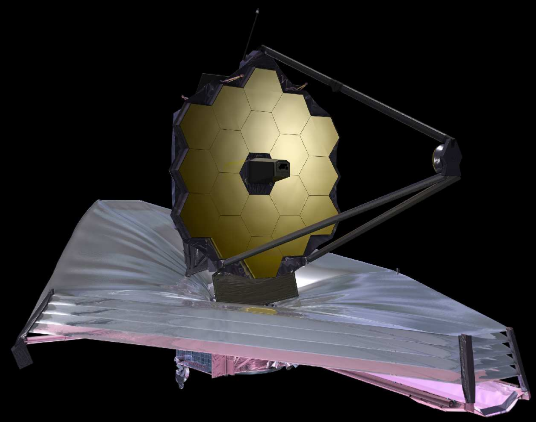
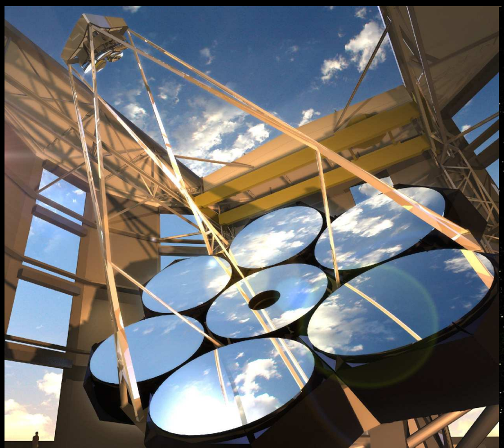
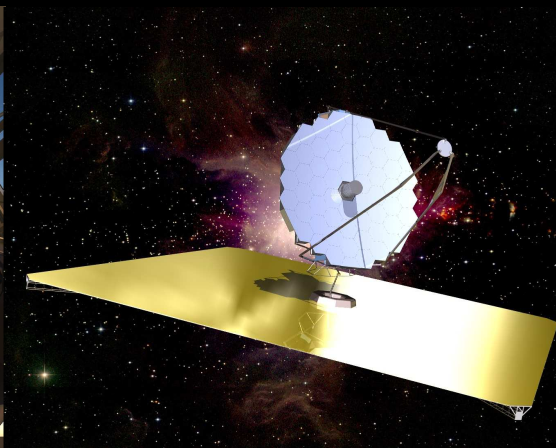
Big Telescope Projects in SESE — Past, Present, & Future

Rogier Windhorst (ASU) — on behalf of SESE faculty





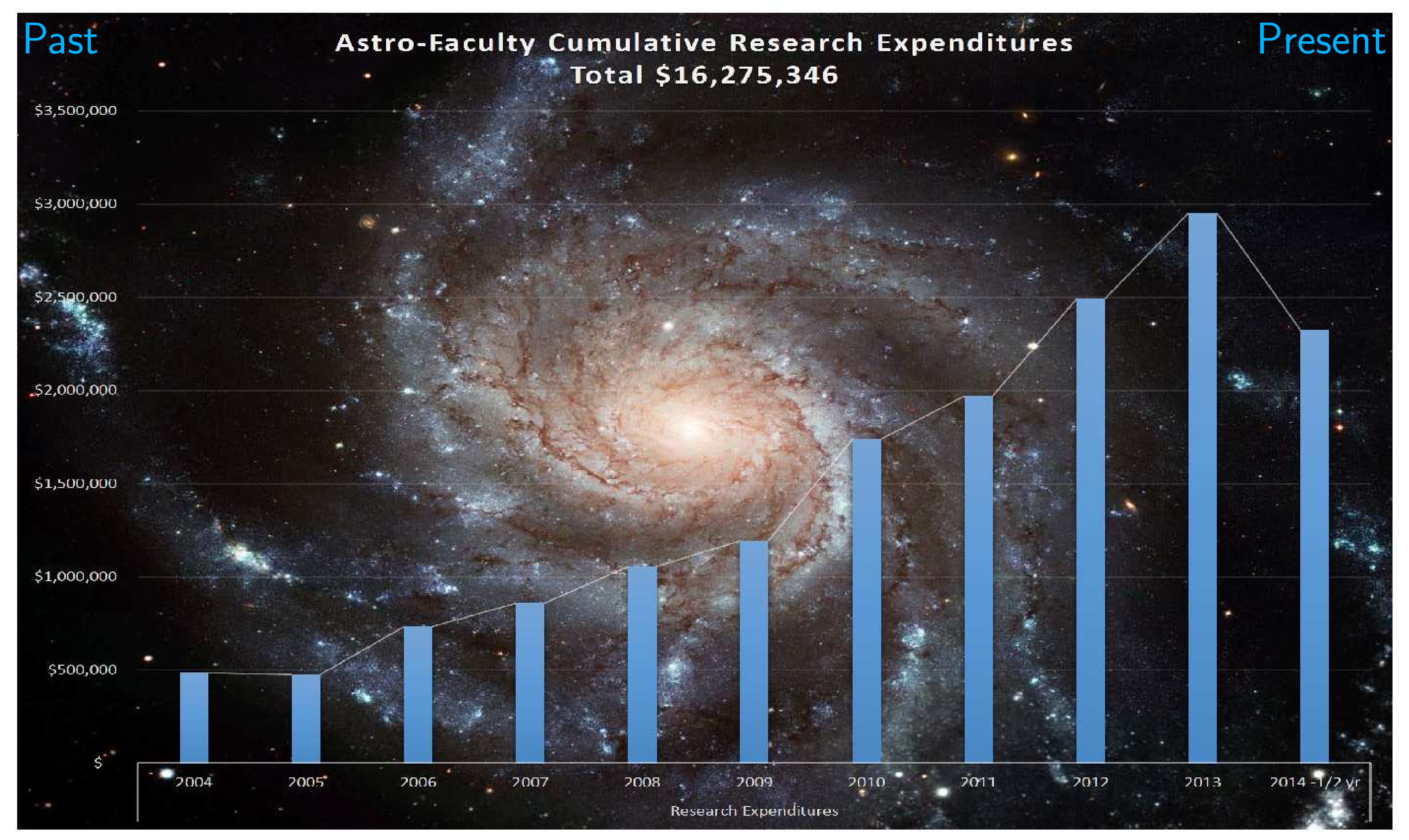


1973∼2018$^+$; 1996∼2029; 2000∼2050$^+$ 2020∼2050$^+$?

Talk at the SESE Retreat, Th/Fr Aug. 14–15, 2014, ASU, Tempe, AZ

(How) can SESE play in the big telescope league in the next 30 years?

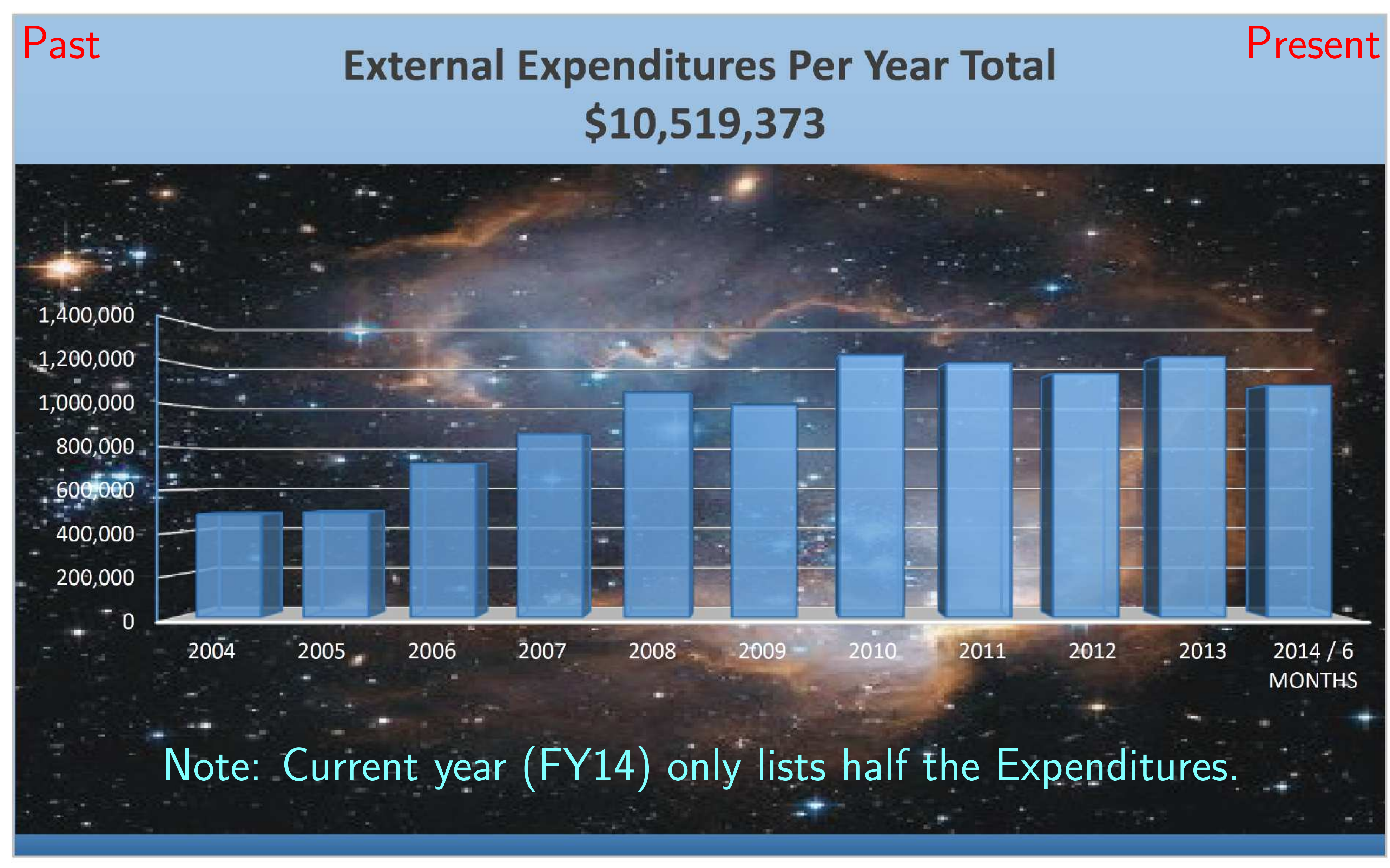
We need to think of large projects that will knock it out of the ball-park ...



• SESE astro faculty grants increased steadily since SESE started in 2006.

• True, even when corrected for growth in astro faculty since 2006 (next pg).

Return-on-investment ROI=Σ(expend/startup)$\simeq 2.6\times$ (range$\simeq$0.2–173[∞]).

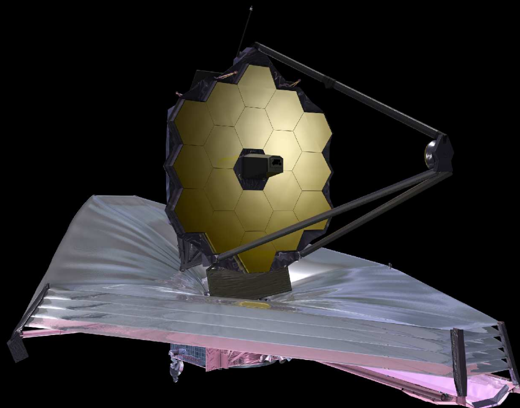


- Grants also increased for astro faculty at ASU before SESE started in 2006.

Return-on-investment ROI$=\Sigma$(expend/startup)$\simeq$16.5$\times$ (range$\simeq$5–173[∞]).

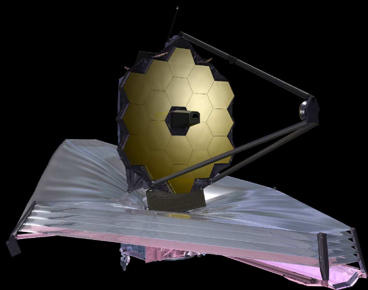
- Access to new facilities is key to move beyond any funding plateau.

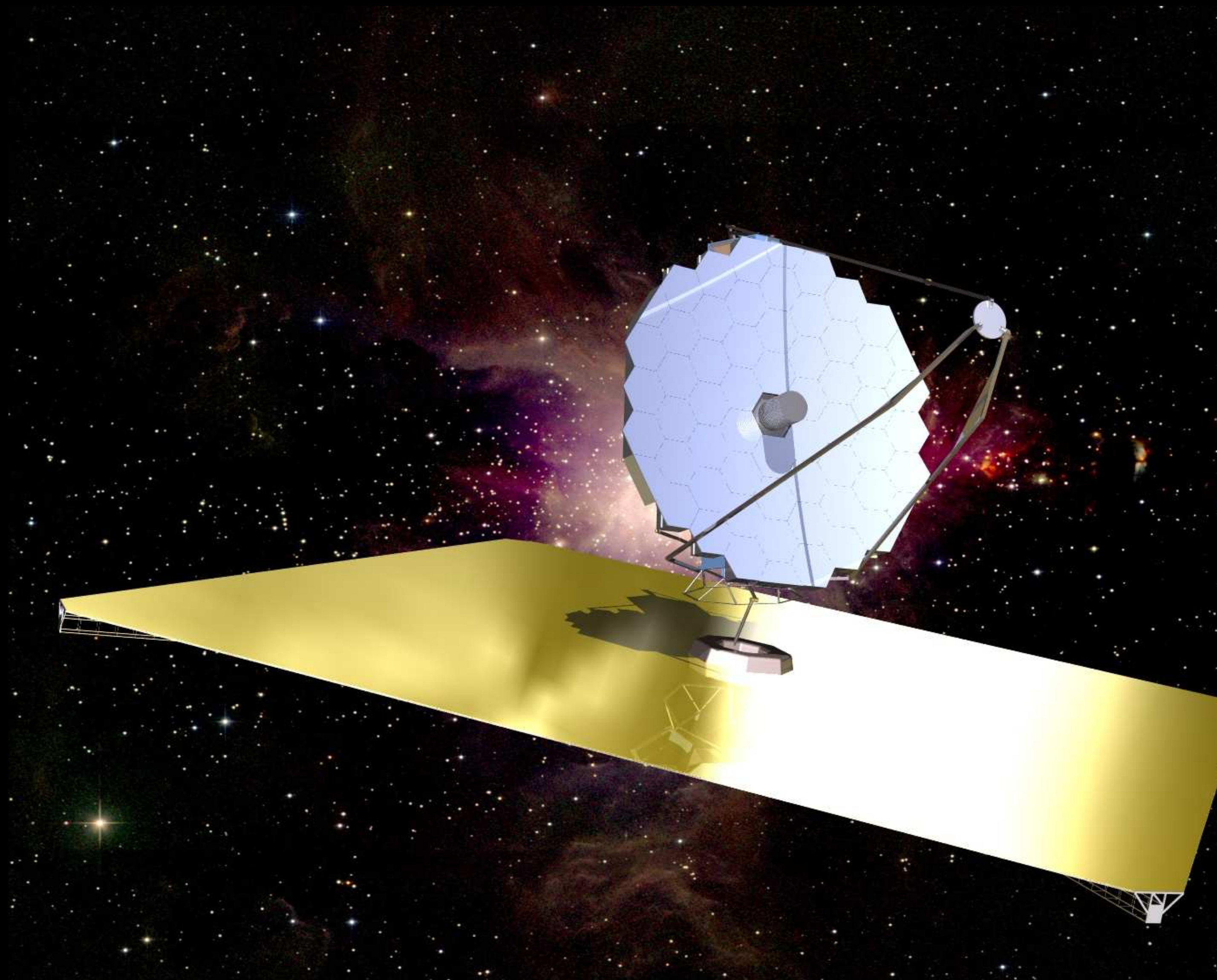
True relative size: Hubble, James Webb, & Giant Magellan Telescope



18 B\$ (1973∼2018); 9 B\$ (1996∼2029); ∼1 B\$ (2000∼2050$^+$).

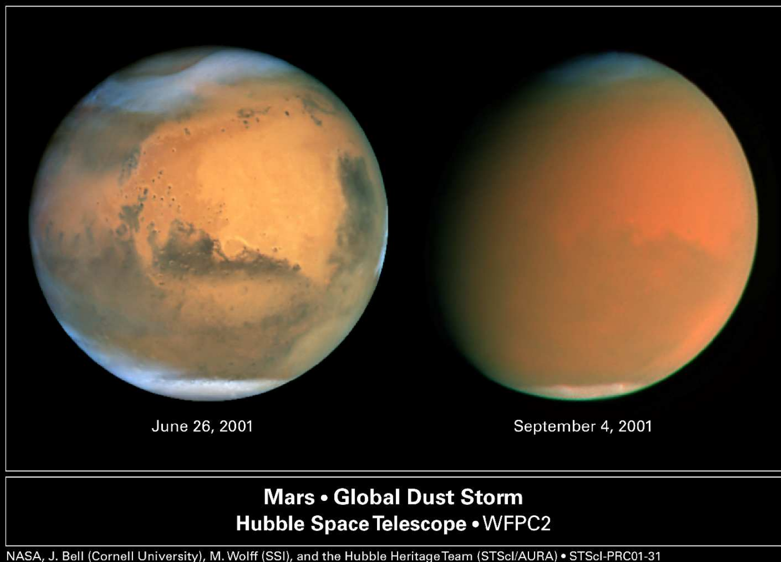
True relative size: Hubble, James Webb, and ATLAST ...

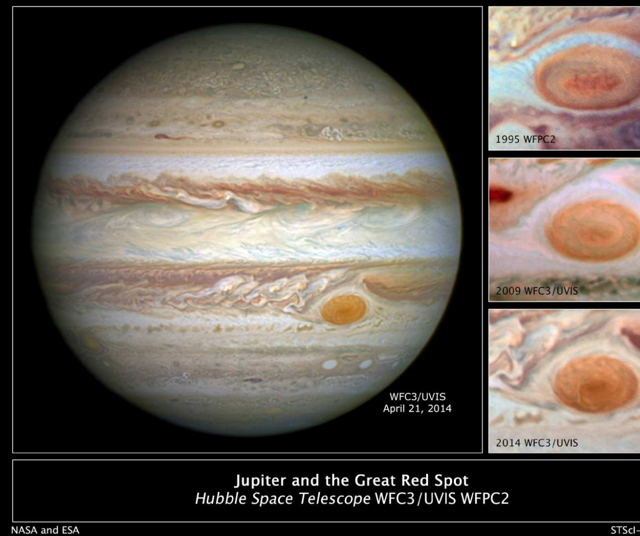


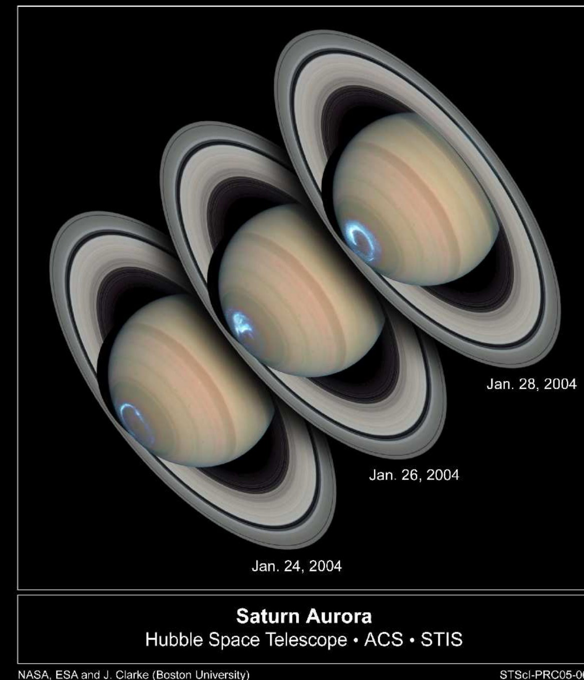


18 B$ (1973∼2018); 9 B$ (1996∼2029); 15–20 B$ (2020∼2050^{+}?).

Potential GMT+ATLAST synergy with SESE Solar System research:





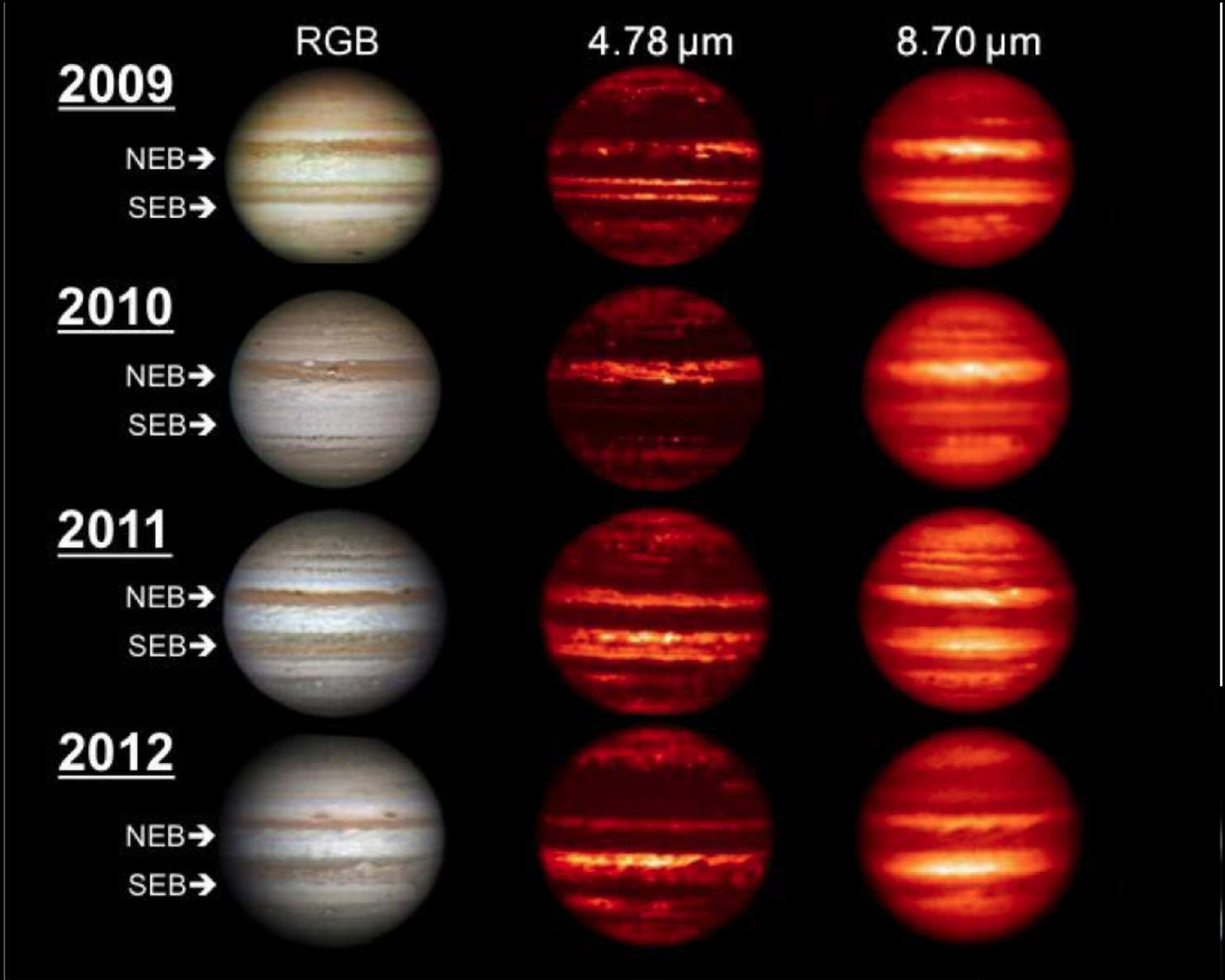


Left: Hubble maps Mars' global dust-storm in 2001, in support of Mars Global Surveyor.

Middle: Hubble sees Jupiter's Great Red Spot decline over two decades.

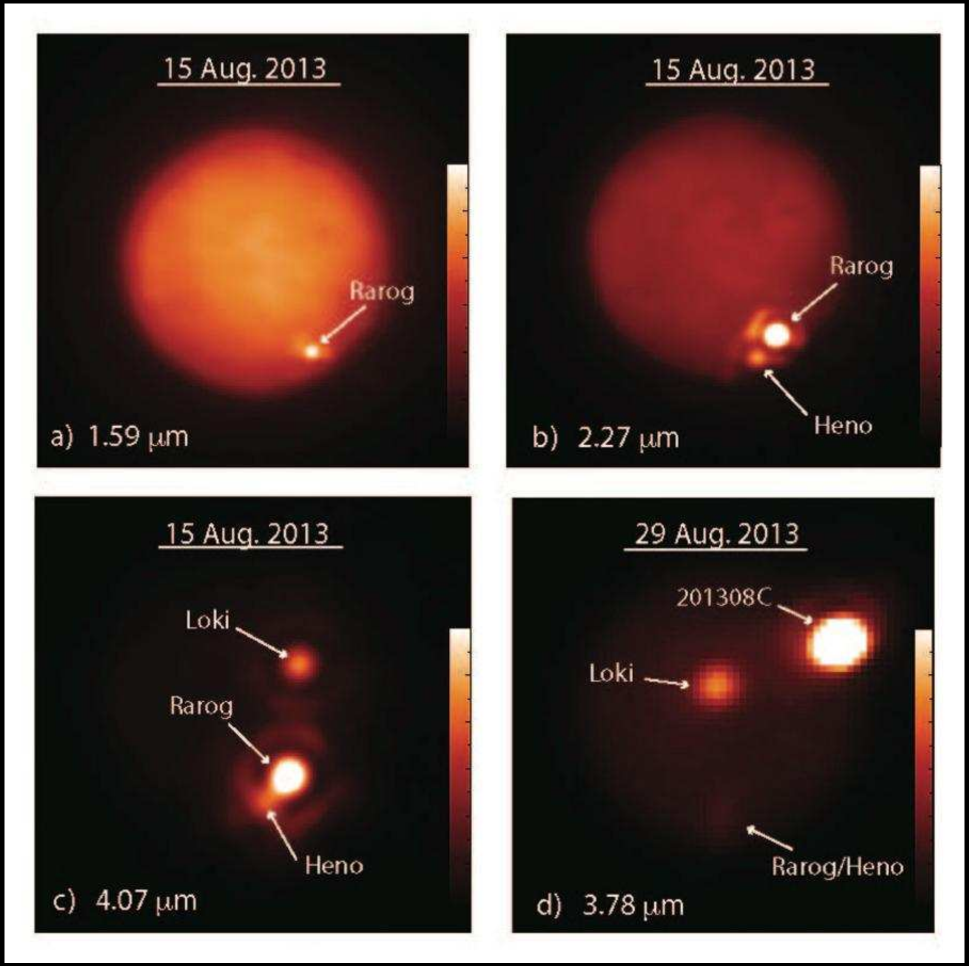
Right: Hubble sees Saturn's Aurora change, in support of Cassini Mission.

- GMT & ATLAST will monitor global weather of solar system planets on many decades' timescales at $\gtrsim 10\times$ Hubble's resolution!



GMT, ATLAST will study Jupiter's weather at $\gtrsim 10\times$ Hubble's resolution.

Long orbital periods require data on many-decade time-scales (slide courtesy of Dr. J. Norwood).



GMT, ATLAST will study volcanic eruptions on solar system moons on decade's time-scales at $\gtrsim$3–10$\times$ Keck's resolution.

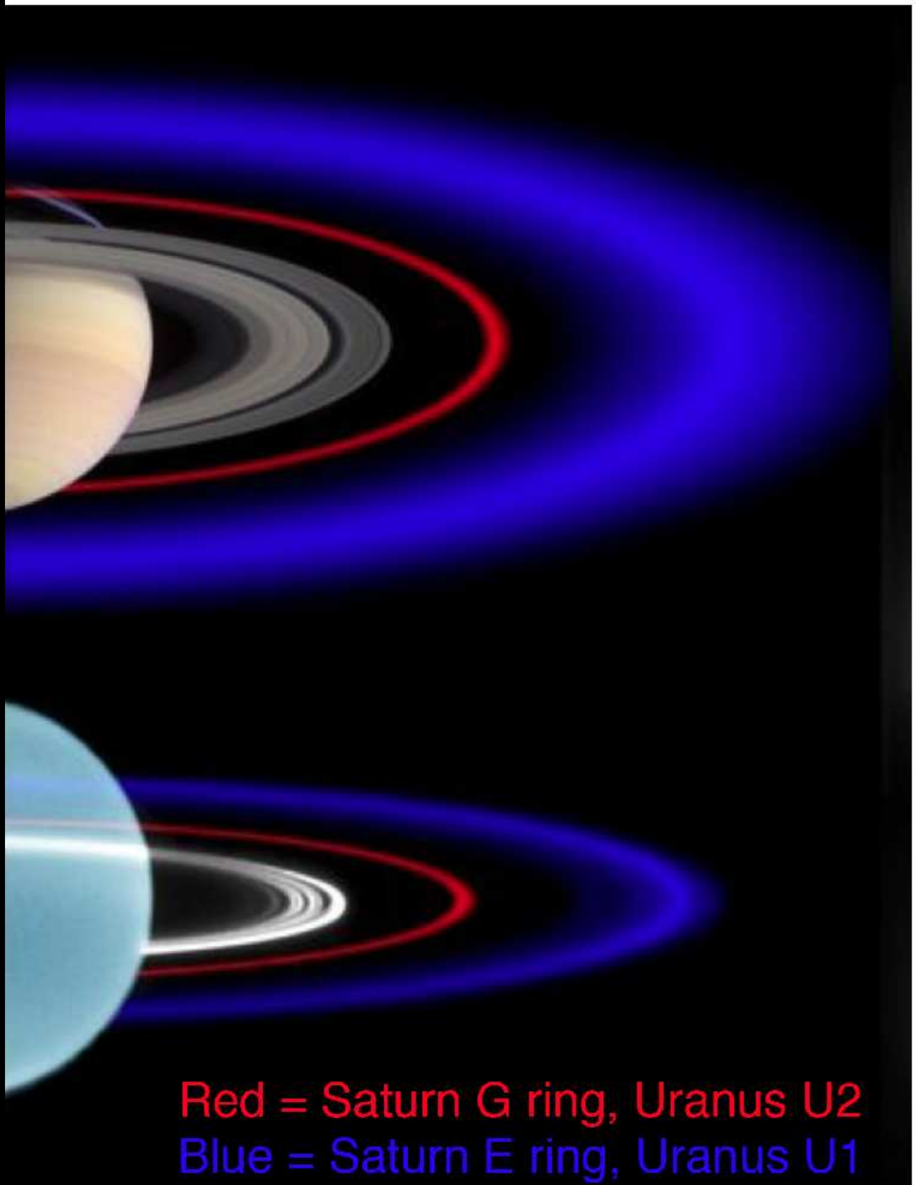
[LEFT]: April 1997 Galileo probe image of Jupiter's Moon Io.

[RIGHT]: Keck images of Aug. 2013 outbursts of Io's craters Rarog et al..

(slides courtesy of NASA and Dr. I. de Pater).

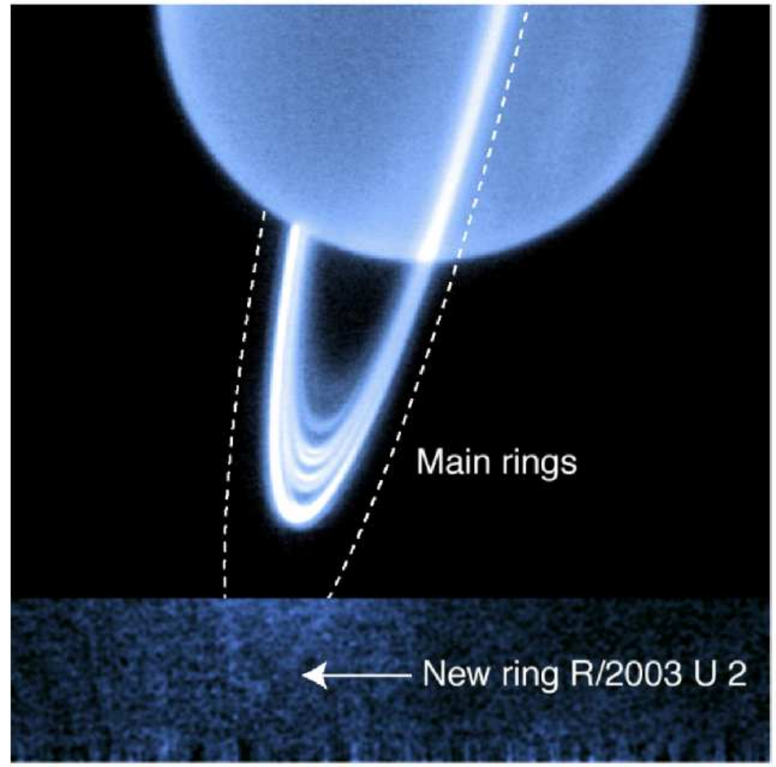
rings of uranus

de Pater et al. 2006



new rings discovered in 2005 with Hubble

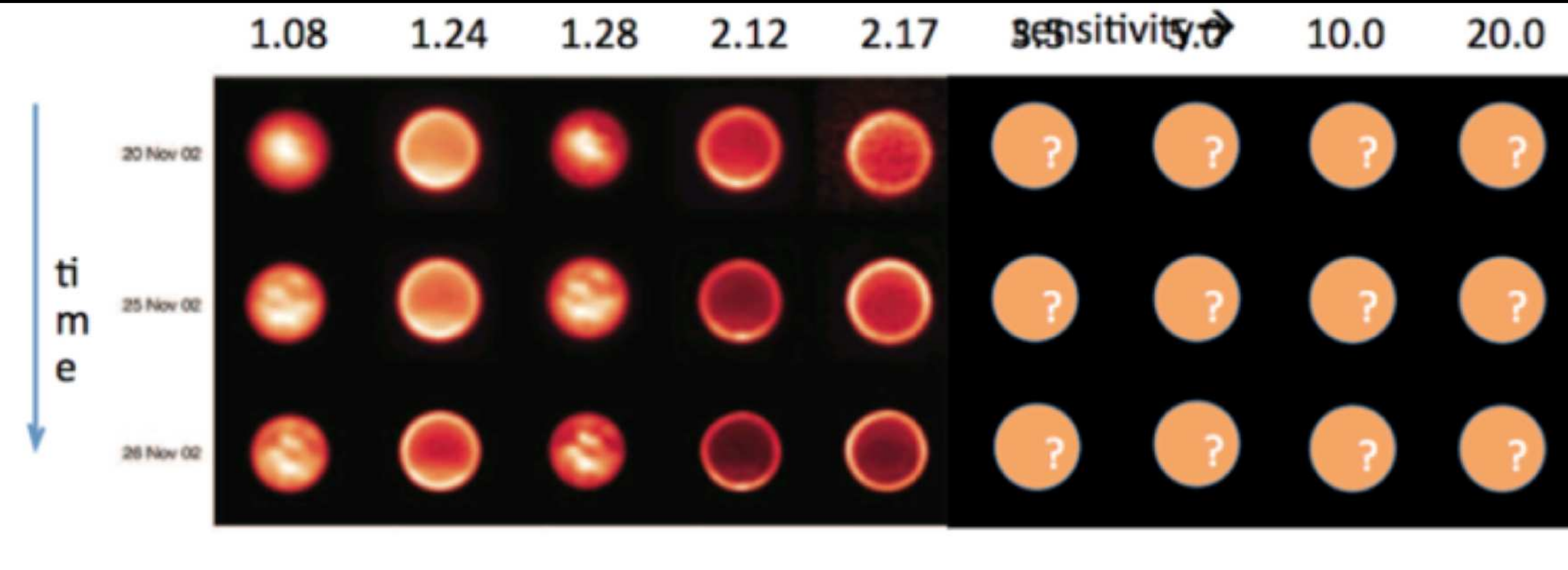
ring colors determined in 2006 with Keck



de Pater et al. 2006

GMT, ATLAST will study ring systems at $\gtrsim 10\times$ Hubble's resolution.

(slide courtesy of Dr. H. Hammel, I. de Pater et al.).

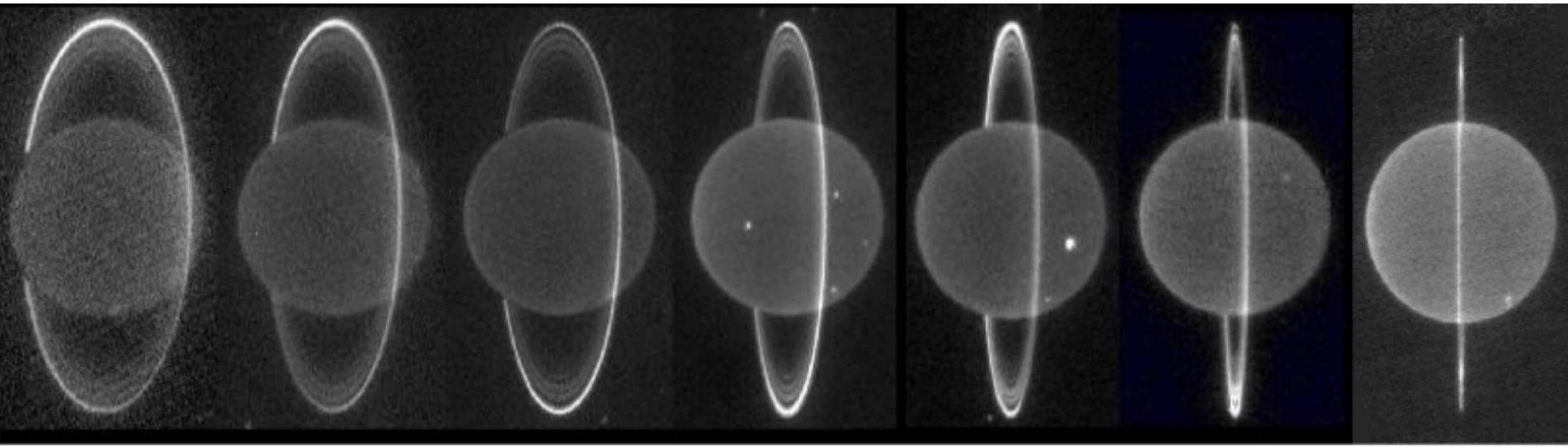


GMT, ATLAST will study Titan's Nitrogen-Methane atmosphere weather at $\gtrsim 10\times$ Hubble's resolution (at near–mid-IR wavelengths — for GMT in accessible atmospheric windows).

(slide courtesy of Dr. J. Lunine).

equinox = ring plane crossing
of Uranus in 2007

de Pater et al. 2007

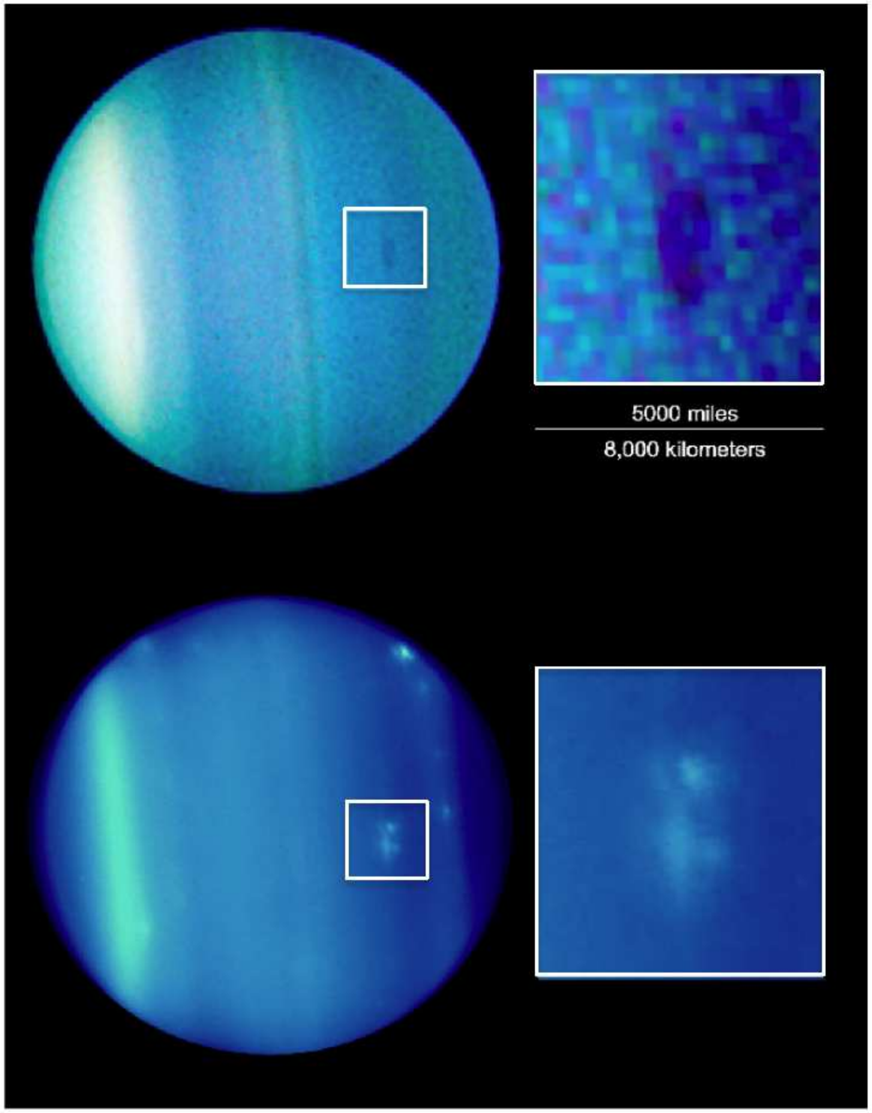


2001 2002 2003 2004 2005 2006 2007

GMT, ATLAST multi-decade weather monitoring especially powerful for outer planets. (slide courtesy of Dr. H. Hammel).

[Uranus went from “Summer” in 1986 (Voyager) to “Fall” in 2007].

dynamic atmosphere of uranus



Hammel et al. 2009

Uranus in 2006

Upper: Hubble spies Great Dark Spot on Uranus

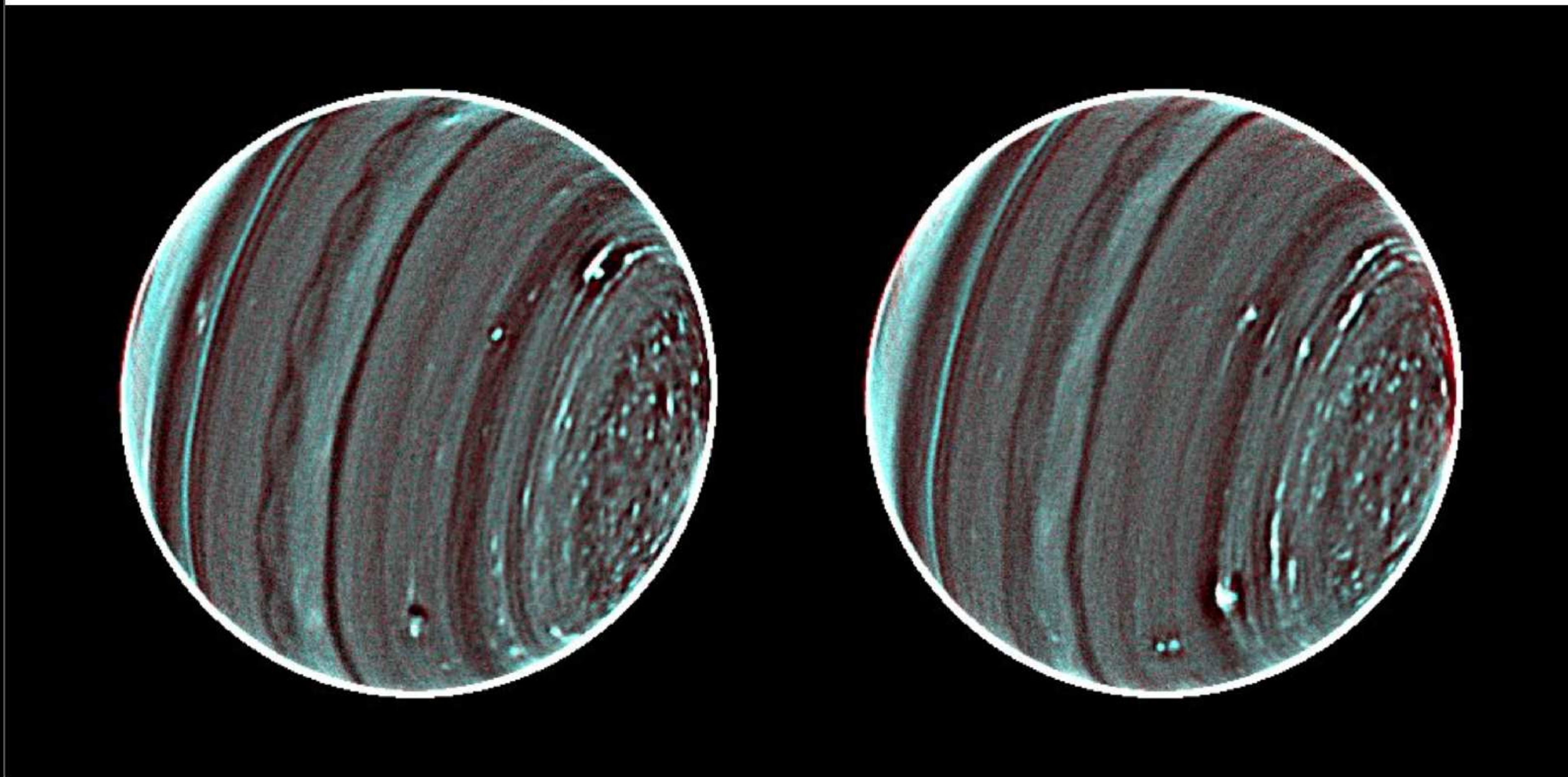
Lower: Keck images its Bright Companions

Voyager view of Neptune (rotated 90°) showing 1989 Great Dark Spot
(this GDS had disappeared by 1994)

GMT, ATLAST will study Uranus' weather at $\gtrsim 10\times$ Hubble's resolution.

(slide courtesy of Dr. H. Hammel et al.).

2012: Keck
best images of Uranus **EVER**

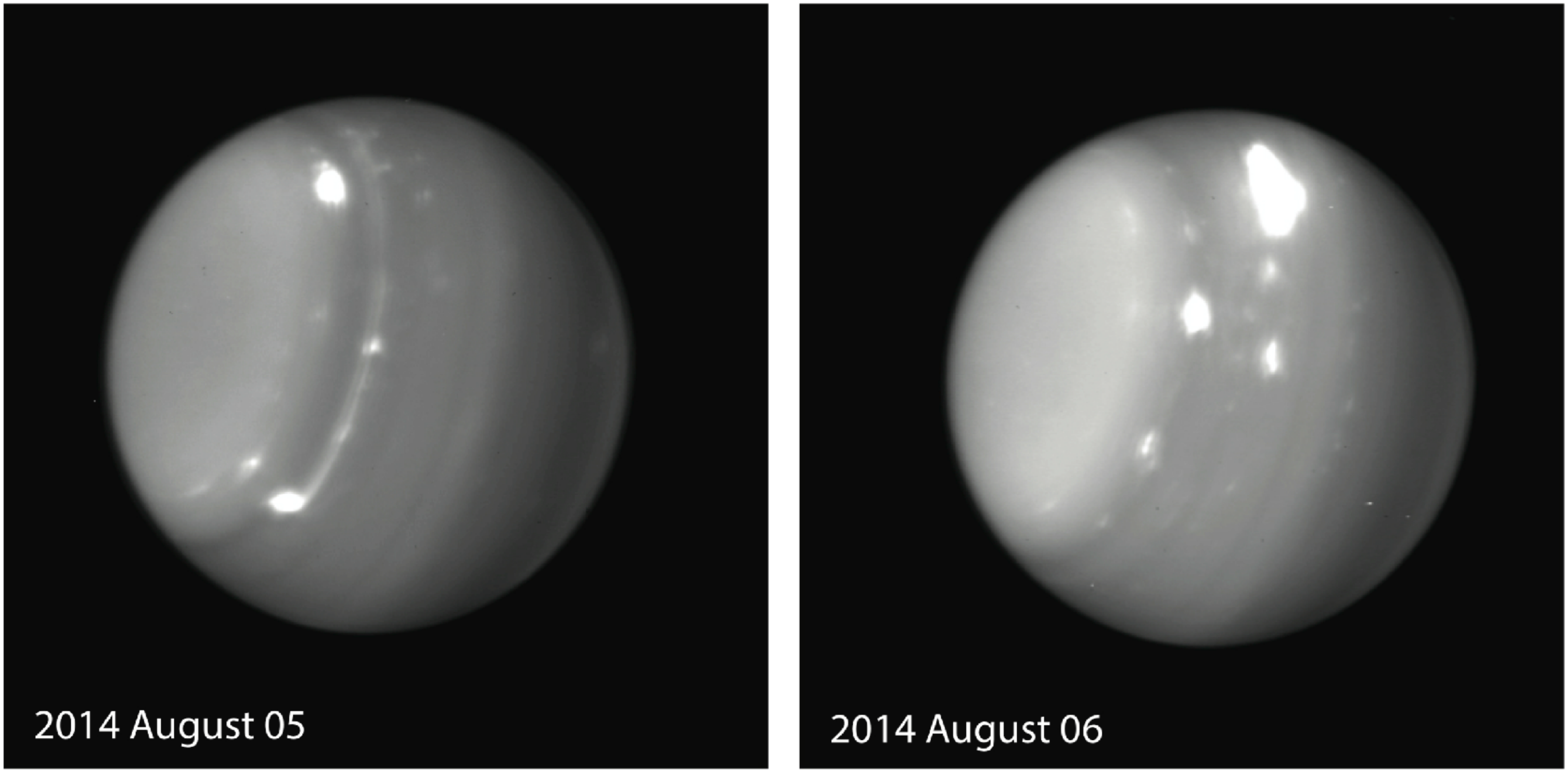


Larry Sromovsky, Pat Fry, Heidi Hammel, Imke de Pater
Keck Observatory, H band (1.6 microns), July 2012

GMT, ATLAST will study Uranus' weather at $\gtrsim$3–10$\times$ Keck's resolution.

(slide courtesy of Dr. H. Hammel et al.).

Uranus a few days ago (Aug 2014)

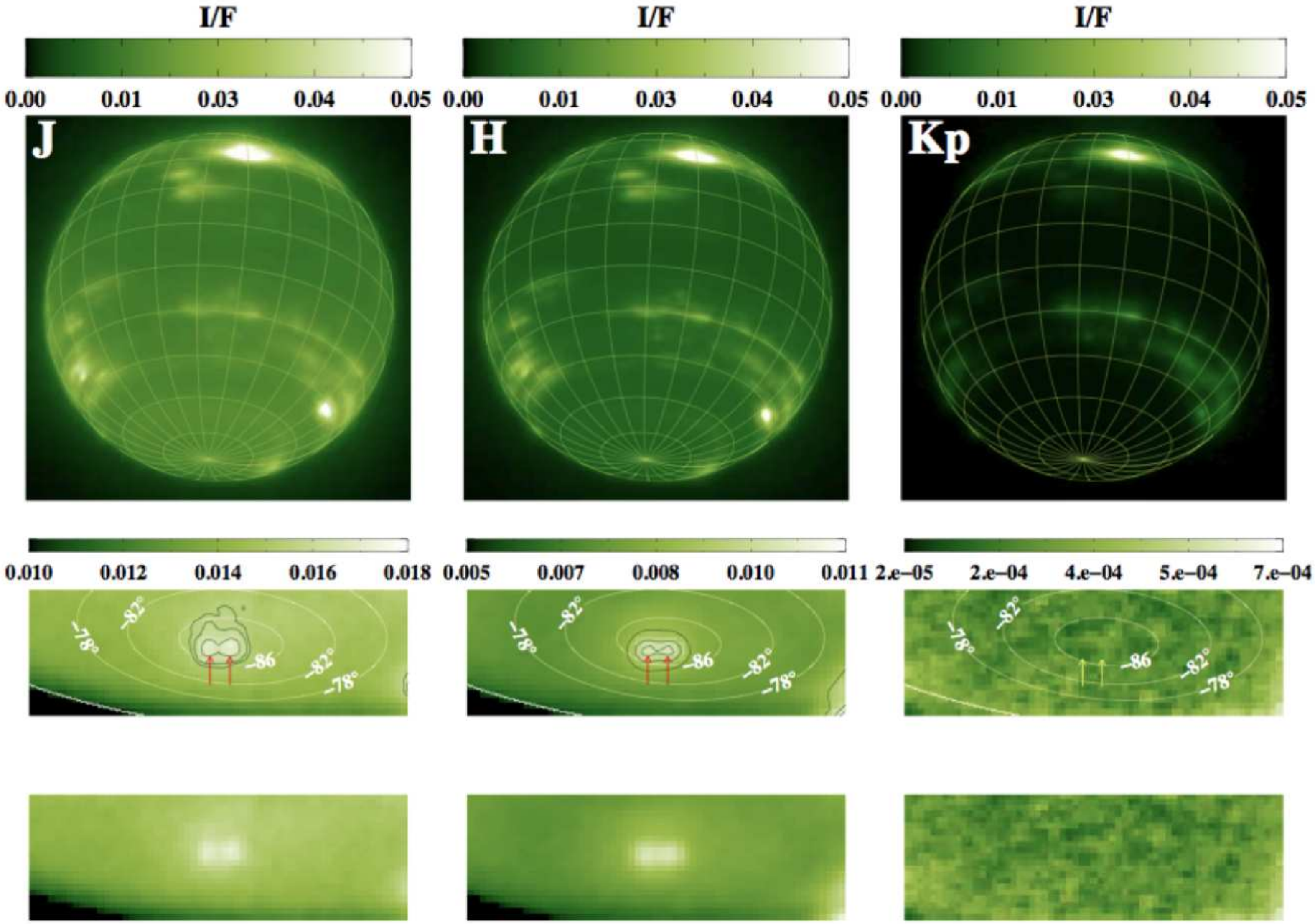


Credit: I. de Pater (UC Berkeley) and Keck

GMT, ATLAST will study Uranus' weather at $\gtrsim$3–10$\times$ Keck's resolution.

(slide courtesy of Dr. I. de Pater & H. Hammel et al.).

Keck: atmospheric detail on Neptune



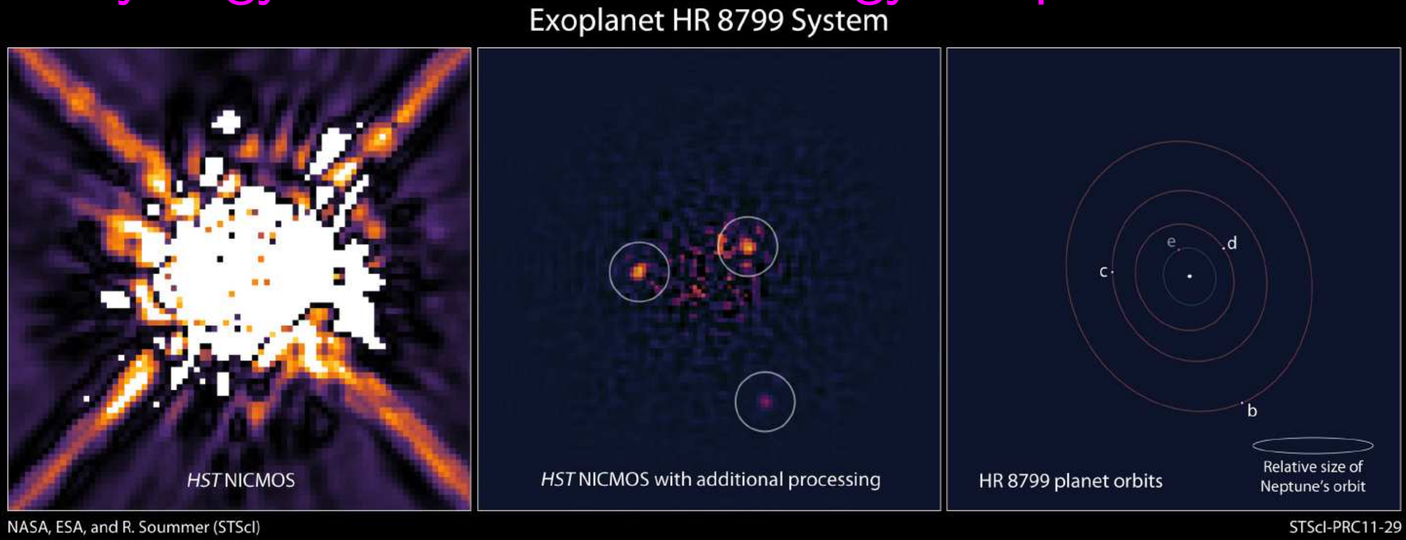
Seeing Double at Neptune's South Pole

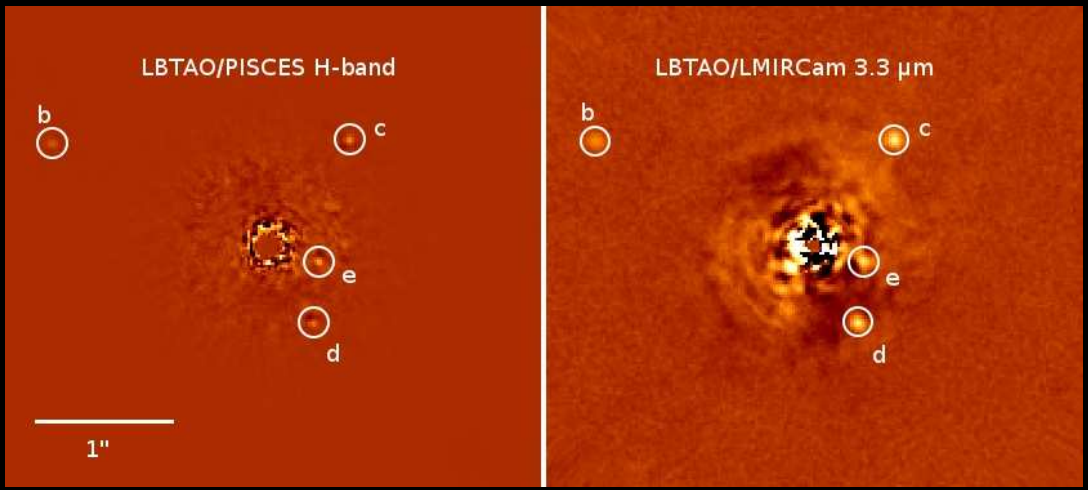
Luszcz-Cook, de Pater, Adamkovics, and Hammel (2010), Icarus 208, 938

GMT, ATLAST will study Neptune's weather at $\gtrsim$3–10$\times$ Keck's resolution.

(slide courtesy of Dr. H. Hammel et al.).

GMT+ATLAST synergy with SESE astrobiology, exoplanets, element production

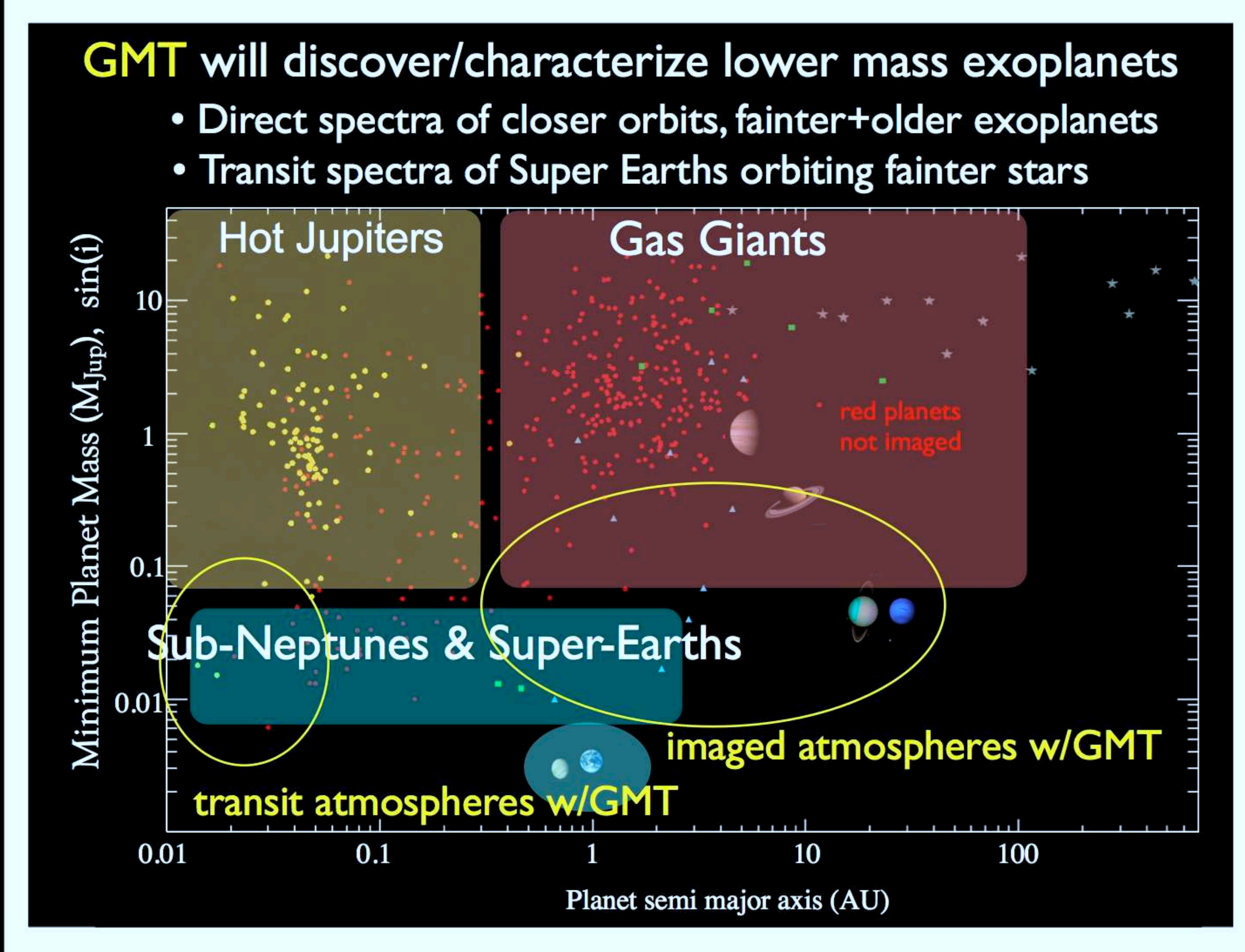




Top: Hubble NICMOS near-IR imaging of exoplanet system around the (very carefully subtracted!) star HR 8799.

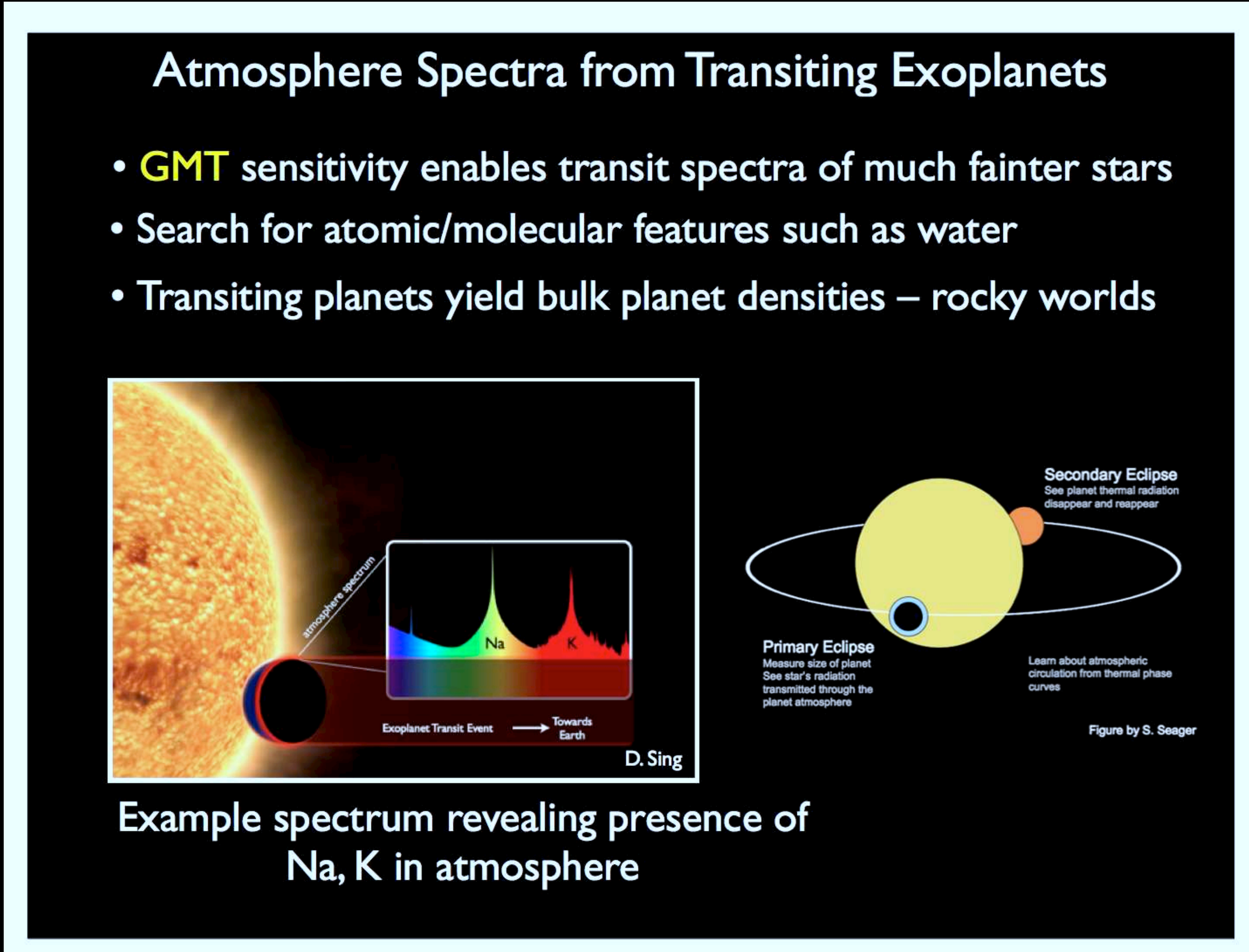
Bottom: AZ Large Binocular Telescope (LBT) Adaptive Optics imaging of HR 8799: Direct imaging of exoplanets & orbits around nearby star!

- GMT & ATLAST will find planets much closer in for more distant stars!

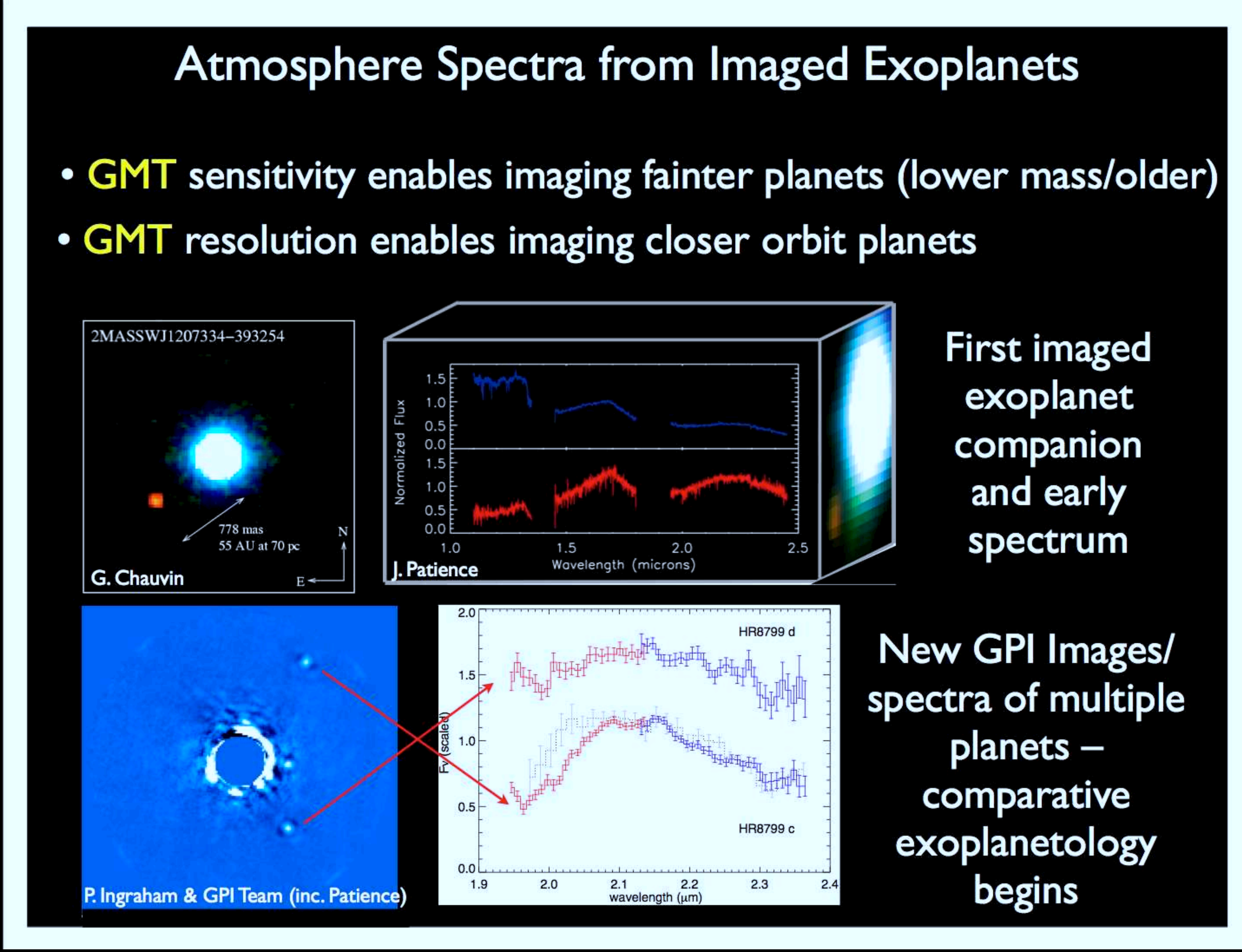


GMT, ATLAST will characterize the parameter space of Super-Earths.

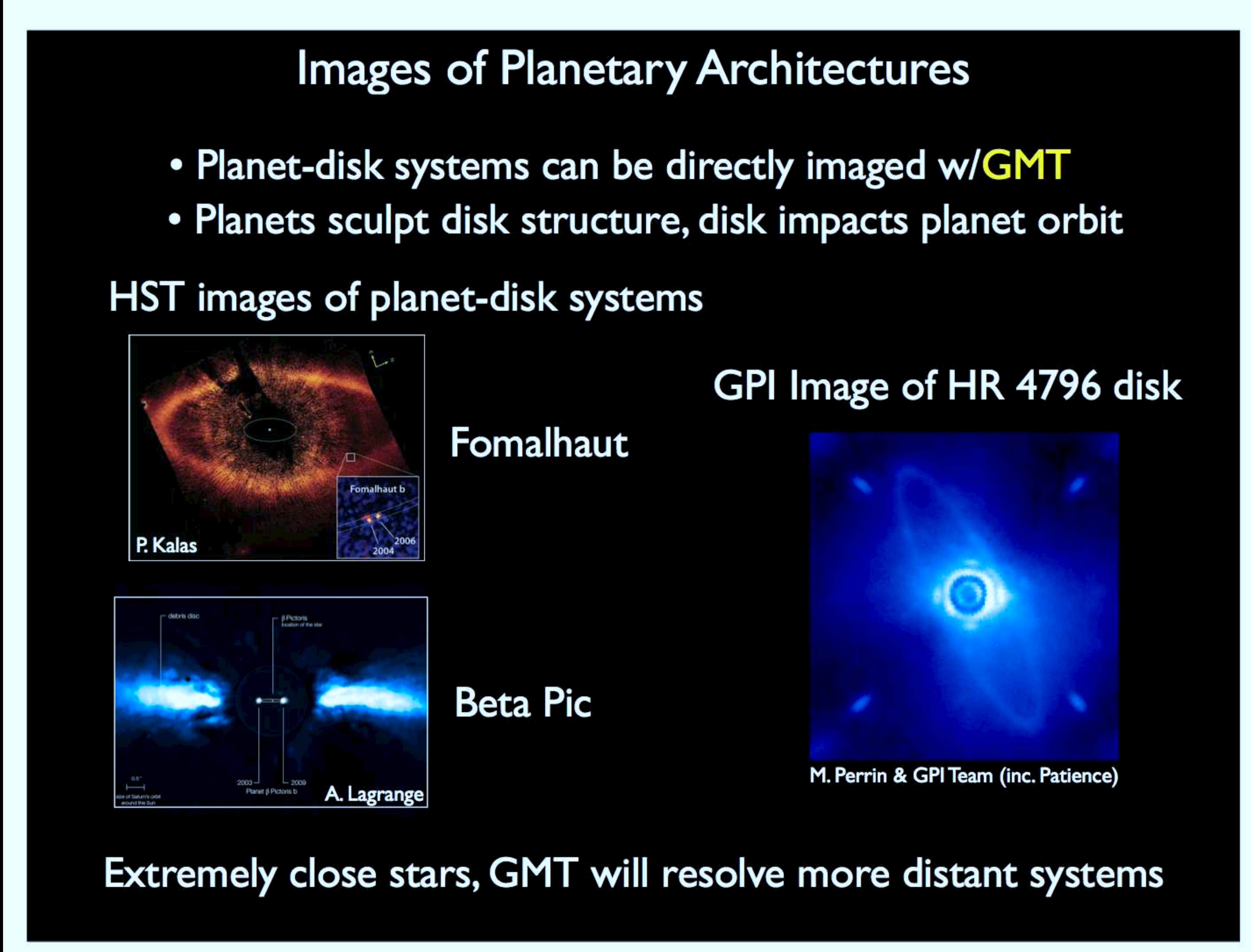
(slide courtesy of Dr. J. Patience; ASU).



GMT, ATLAST will find chemical building blocks of life in Exoplanet atmospheres. (slide courtesy of Dr. J. Patience; ASU).



GMT, ATLAST will characterize the atmospheres of (Super-) Earth-like Exoplanets. (slide courtesy of Dr. J. Patience; ASU).

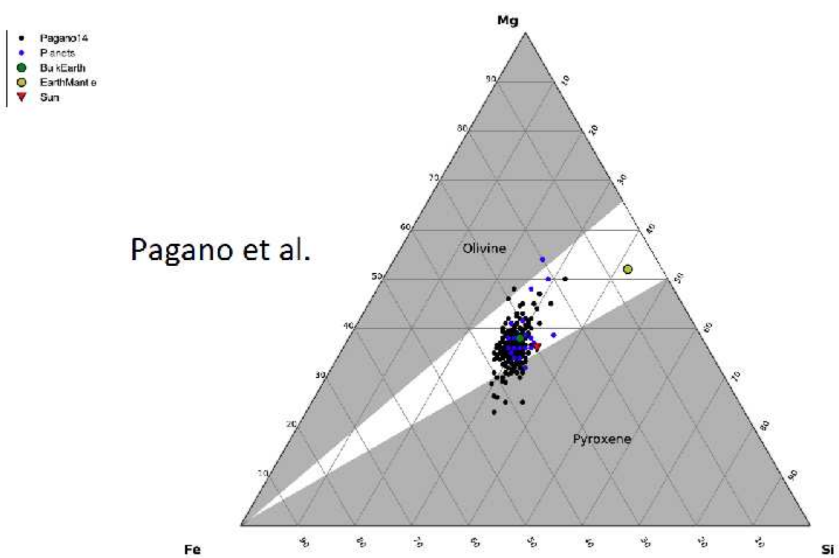


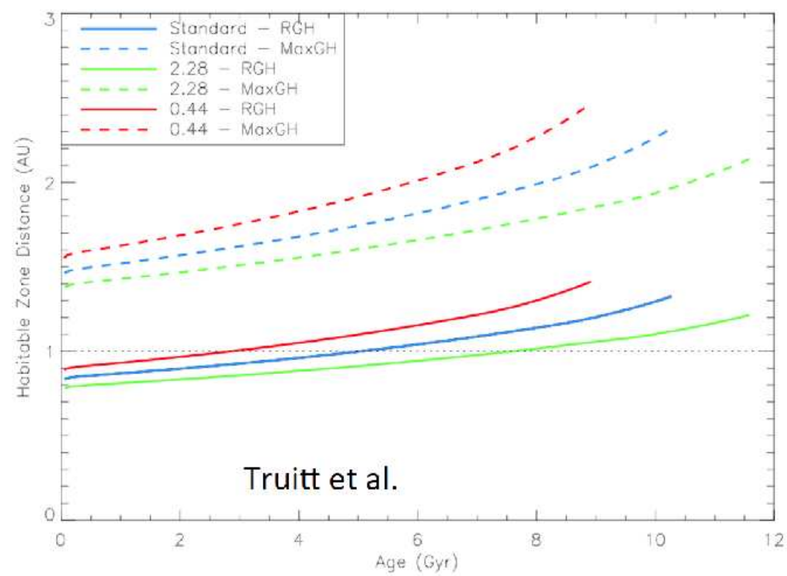
GMT, ATLAST will characterize planetary debris disks before they form planets. (slide courtesy of Dr. J. Patience; ASU).

GMT and Astrobiology

Optical and IR echelle spectrographs:

- Stellar characterization – High precision elemental abundances including rarely observed S, K, P. Also much improved stellar luminosities, ages, and activity levels
- Basic input for models of stellar and habitable zone evolution
- Input for modeling of planet assembly and experimental/ theoretical study of exotic mineralogy



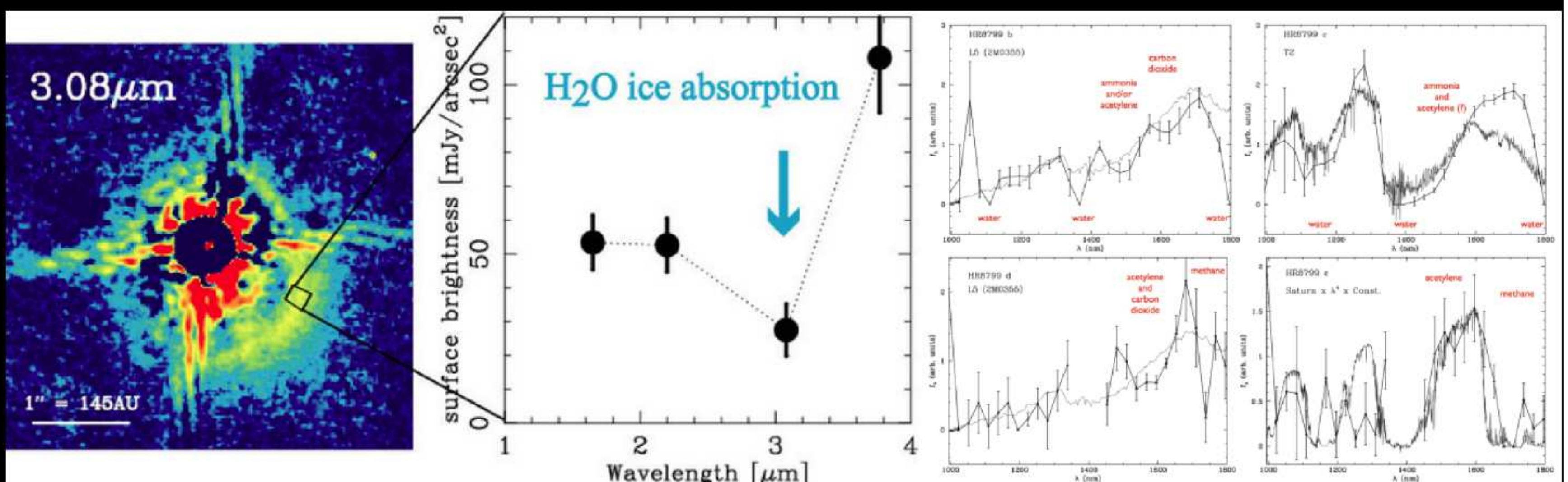


GMT, ATLAST will characterize chemical elements needed for (habitable) exoplanet formation. (slide courtesy of Dr. Timmes, Young, & Starrfield).

GMT and Astrobiology

IR echelle spectrograph and Near-IR Integral Field Unit:

- Spectroscopy of Jovian exoplanet atmospheres for conditions and composition
- Spatially resolved info on hot dust, molecular species, hot water vapor, and ice in protoplanetary and debris disks
- Constrain planet assembly, collision, and disk transport models, complement meteoritic studies on water transport in protosolar disk.



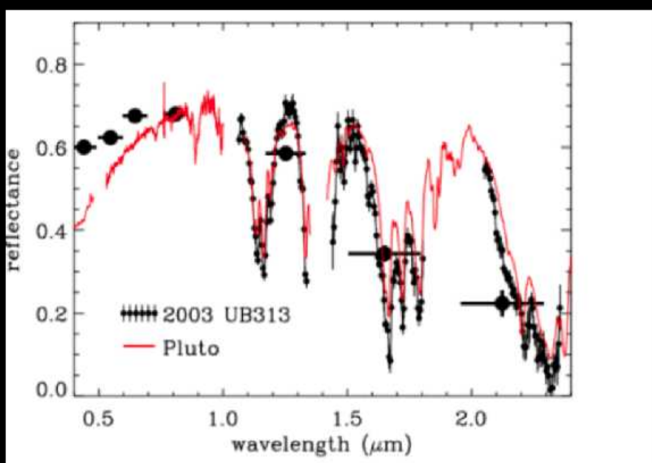
Honda et al. 2009 Oppenheimer eta l. 2013

GMT, ATLAST will measure atomic and molecular composition of exoplanets and (proto-)planetary disks. (slide courtesy of Dr. Timmes, Young, & Starrfield).

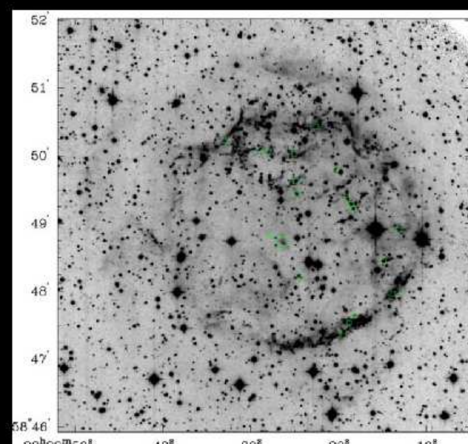
GMT and Astrobiology

Echelle spectrographs and Near-IR Integral Field Unit:

- Surface compositions of asteroids and icy bodies
- Mapping of “hidden” material and structure/composition in supernova remnants for nucleosynthesis simulations and measurements
- Abundance variations across galaxies, resolved stellar populations, and the local neighborhood



M. Brown



Eriksen et al. 2009

GMT, ATLAST will measure chemical composition of asteroids, Kuiper Belt Objects, and of star-forming regions in our own and other galaxies.

(slide courtesy of Dr. Timmes, Young, & Starrfield).

GMT - Transient Astrophysics

Transient phenomena - those with time-scales ranging from a few minutes to a few months - is a new frontier in astrophysical research.

They represent a vast, unexplored parameter space for testing fundamental physics in powerful cosmic explosions such as novae, gamma-ray bursts and supernovae.

Existing all-sky surveys are designed to document new transients, but a game-changing physical understanding of the nature of these events requires follow-up with large telescopes such as the GMT.

GMT, ATLAST provide most powerful, “always-ready” monitoring of the most explosive events in the universe. (slide courtesy of Dr. F. Timmes).

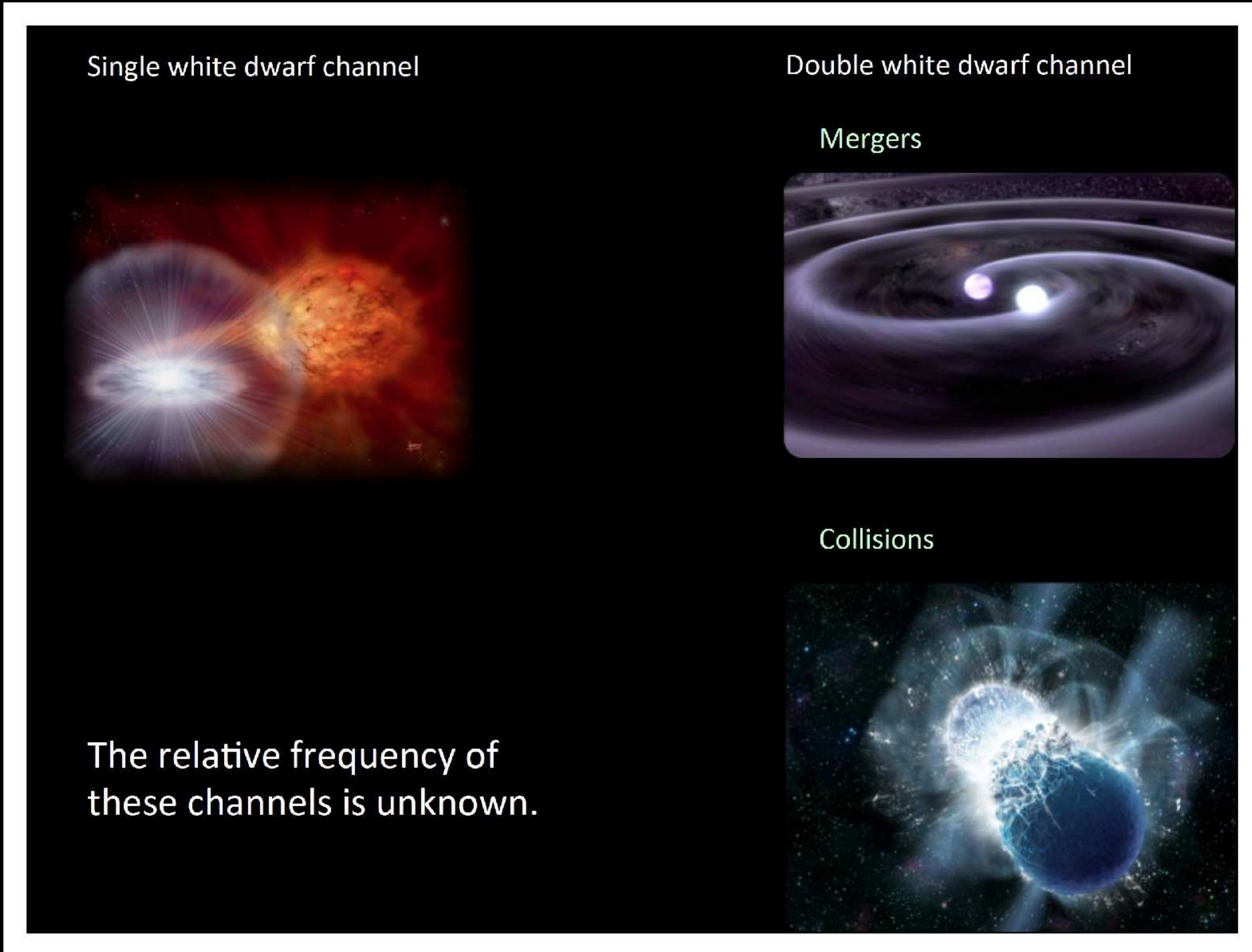
For example, the frontier for supernova research in the GMT era will be temporally well sampled, optical and NIR spectropolarimetry to address key questions regarding the nature of the progenitors and explosion mechanisms.

Answers to these questions bear significantly on the dark energy (Re: 2012 Nobel prize).

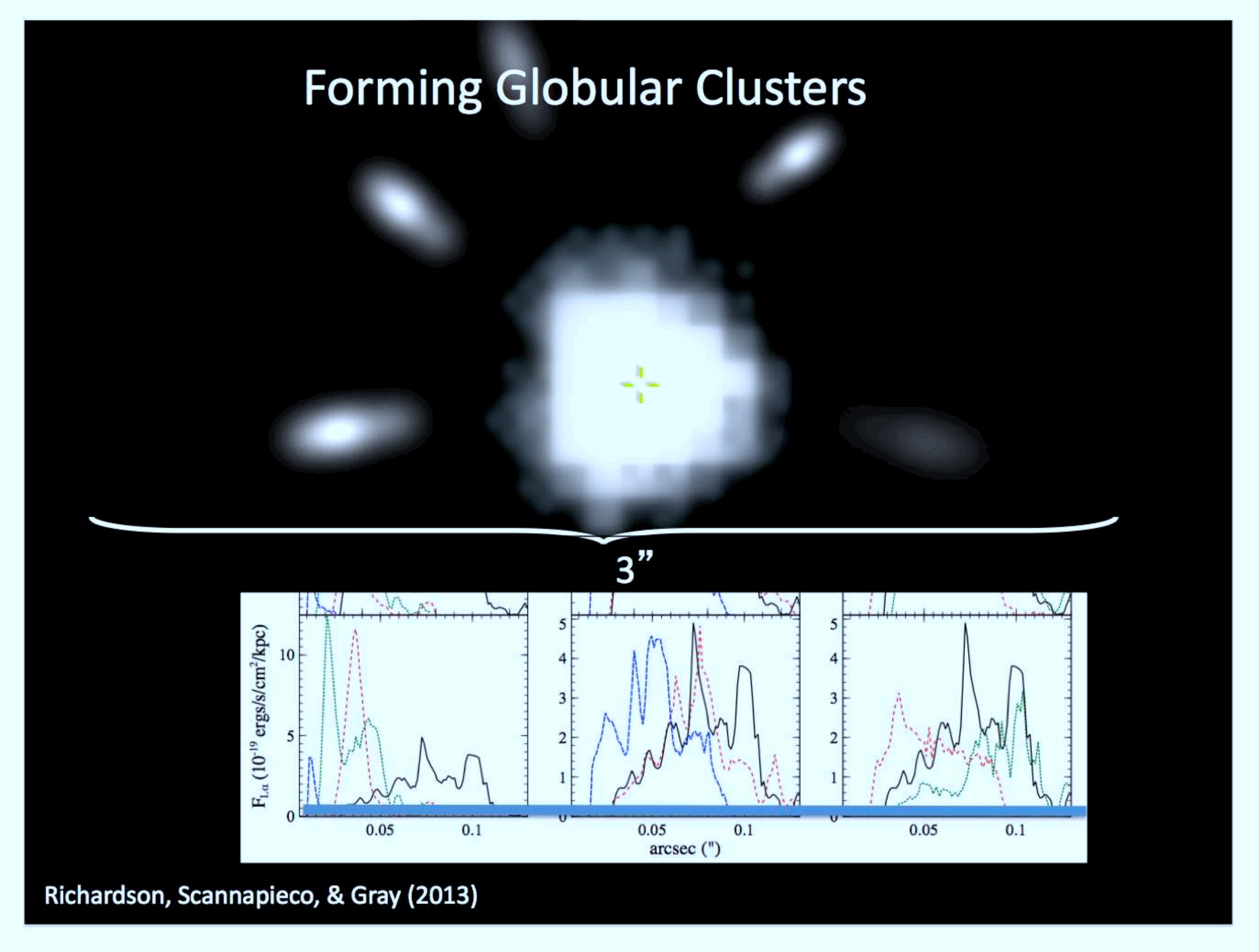
For instance, among the major outstanding issues in white dwarf supernova is proof that they arise in binary systems, and, if so, in single or double white dwarf systems, or some mix of the two.

GMT, ATLAST will elucidate whether the core of Dark Energy (Supernovae as “standard candles”; 2012 Nobel Prize) is observationally and theoretically correct. Powerful synergy with ASU supercomputer modeling.

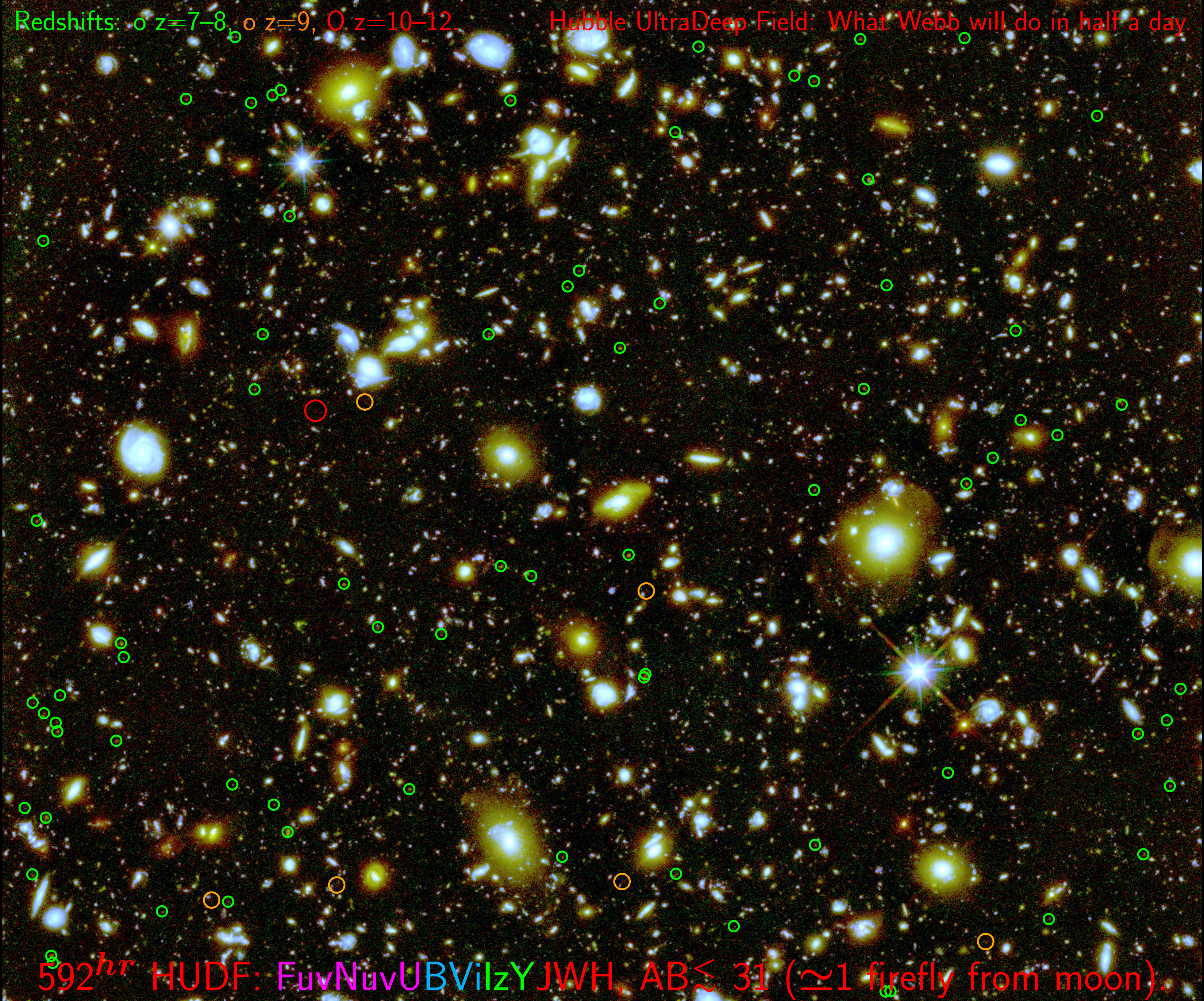
(slide courtesy of Dr. F. Timmes).

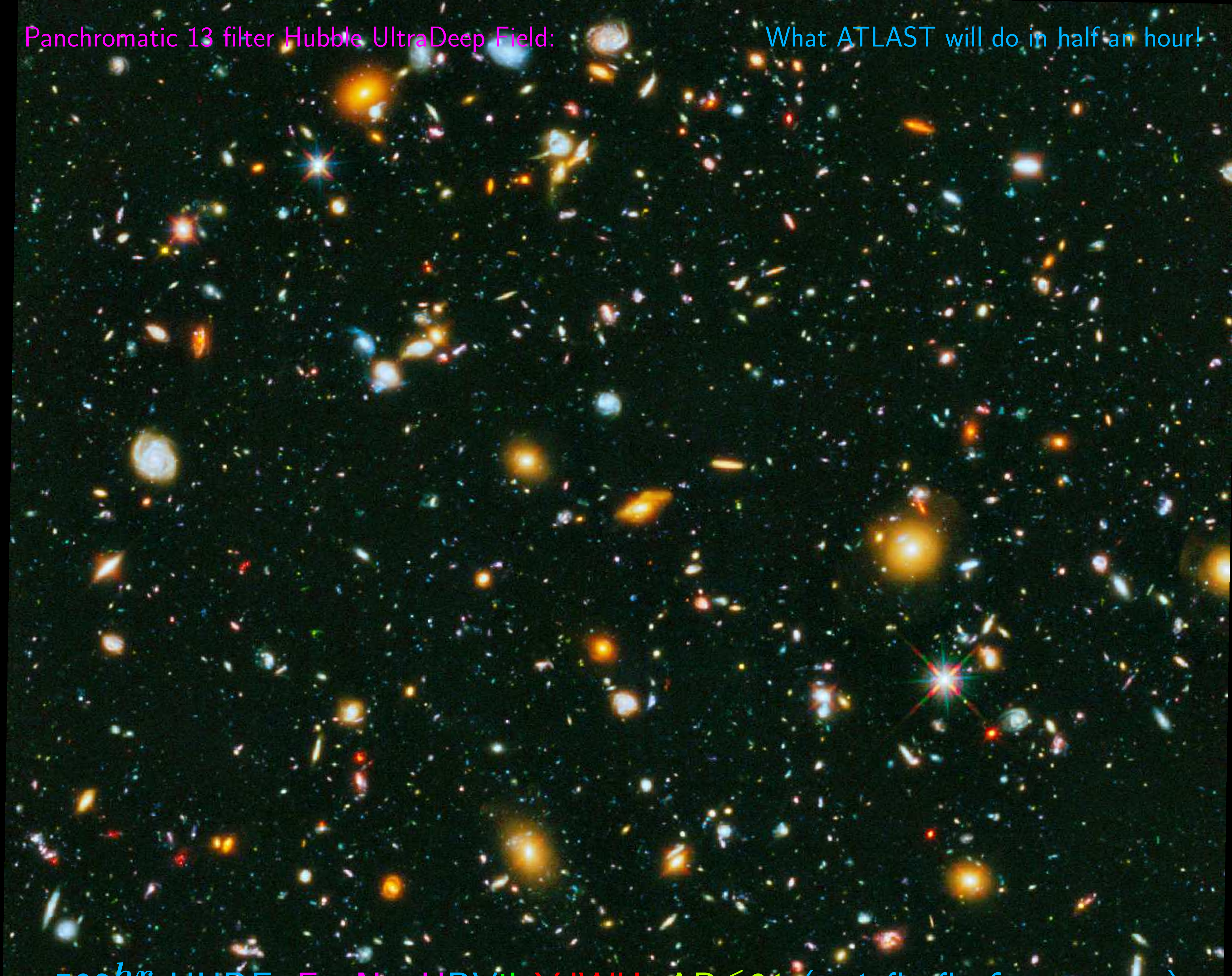


GMT, ATLAST will elucidate the nature of all types of exploding stars: *the* most energetic events in the Universe. (slide courtesy of Dr. F. Timmes).



GMT, ATLAST will measure the formation of the first stars in the (very small!) first globular clusters in the Universe. (slide courtesy of Dr. E. Scannapieco, M. Richardson).


Redshifts: o z=7–8, o z=9, O z=10–12.
Hubble UltraDeep Field: What Webb will do in half a day.
592^{hr} HUDF: FuvNuvUBViIzYJWH, AB$\lesssim$ 31 ($\simeq$1 firefly from moon).



592^{hr} HUDF: FuvNuvUBViIzYJWH, AB$\lesssim$31 ($\simeq$1 firefly from moon).

List of Future Grants and Large Projects

SMALL (0.1–1 M$):

- NSF AST, AAG, ATI (All SESE astro faculty).
- NASA Hubble, Herschel, Spitzer, Fermi, ADAP, ATP, Exoplanet, & EPO (all SESE astro faculty).
- DOE Low Energy Nuclear Physics (Krauss, Young).

MEDIUM (1–10 M$):

- NASA Hubble (and Webb) Treasury projects, such as Malhotra's 2006+2014; Windhorst JWST.
- NSF Physics Frontier Center (2013, 2016), such as Timmes' 2014!
- NSF Science & Technology Centers (2014).
- NSF Sustainable Research Computing Center (2015); NSF HPC Acquisition (every ∼3 years; Timmes).
- NSF NSPIRE; NSF AISL STEM learning — 2 M$ (400 k$/year; Bowman).
- NASA Astrobiology Institute (2017, 2020) Call 8 or 9 (Desch et al.).
- NASA Balloon program (5M$): BOBKAT CMB polarization (Mauskopf); *HiTiDe* outer planet monitoring (Scowen); GUSSTO sub-mm (Groppi).
- NASA APRA detector development: Groppi, Mauskopf, Scowen.

LARGE (10–100 M$):

- NSF MSIP (2013, 2016; 12 M$): Rhoads' MMT Widefield IR Imager; Bowman's HERA radio experiment.
- MIDEX (2017; 350 M$): Scowen's ORION and HORUS mission concepts.
- Widefield Imager+Coronagraph: GMT (2016; ∼50 M$) & ATLAST (2020's; ∼400 M$).

GOAL 1: Overall package to increase SESE astro expenditures to 10 M$/yr.

GOAL 2: ASU to partner in big telescope projects to enable major funding leaps forward.

Conclusion: To play in big league, ASU should consider joining big projects.

Each of GMT and ATLAST facility nearly fills the whole Yankee ballpark ...

- New paradigm: They are too large for an individual university to take on.
  - We suggest to SESE faculty to discuss options with ASU administration.