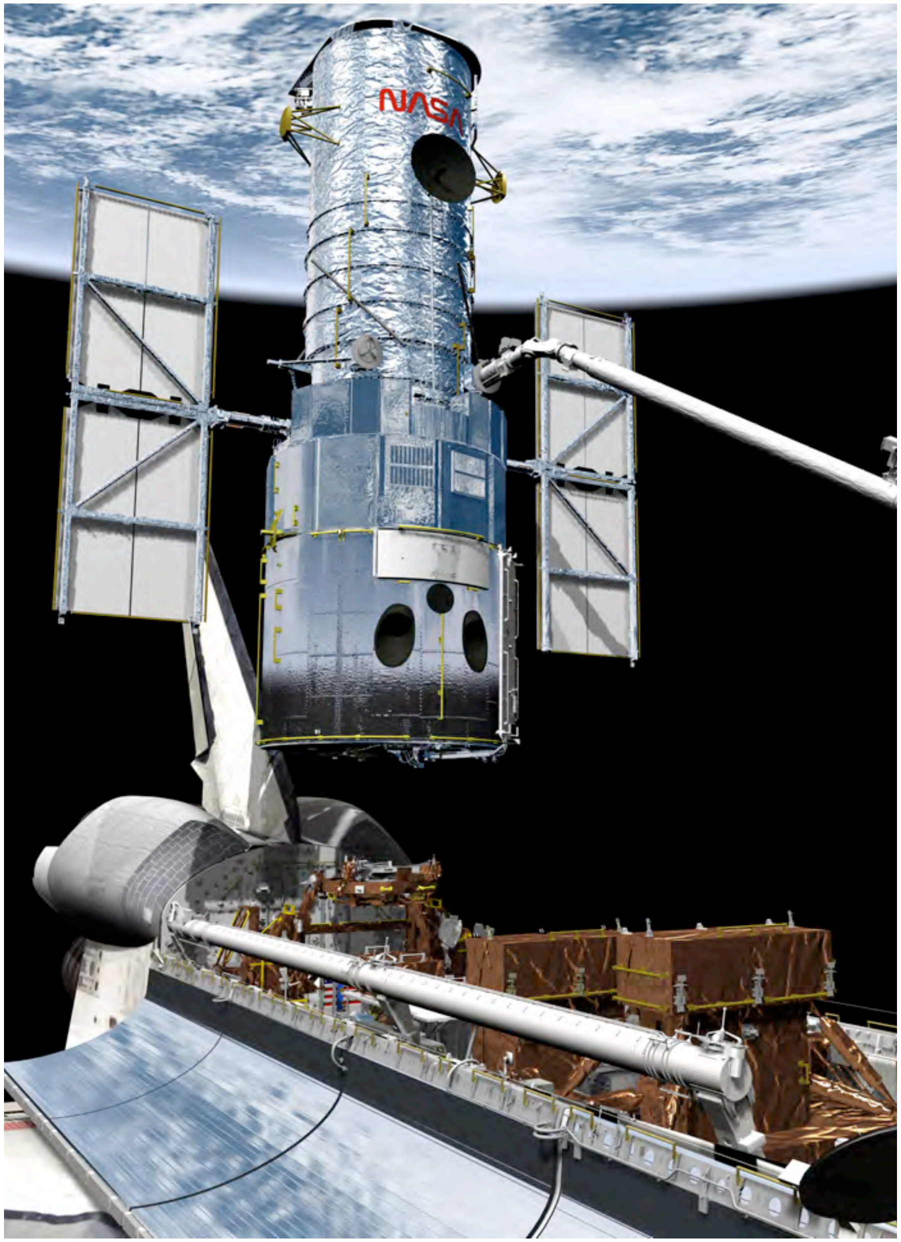
Goddard Space Flight Center

Hubble Space Telescope Program



HSTP/GSFC Project Science Report

Presentation to:

Space Telescope User's Committee

Jennifer Wiseman

November 1, 2010

Topics

- **HST Science (Wiseman):**
  - – Venice HST III mtg
    - HST and Exoplanets
  - – NASA Laboratory Astrophysics and HST
  - – HST Science Year in Review
- **HST Observatory Issues (Niedner):**
  - – COS FUV sensitivity degradation
  - – GSFC Detector Characterization Laboratory activities: ACS CTE and WFC3 issues

Science with the Hubble Space Telescope - III two decades and counting

- **In honour of Bob Fosbury**

Approximately 200 scientists participated in the Hubble Space Telescope – III conference in Venice, Italy October 11-14.

Palazzo Cavalli-Franchetti

Thousands of ACS/HRC grism spectra were projected at night.

A public exhibit of SM4 tools and Hubble artifacts was very well received with much larger than expected attendance.

Palazzo Loredan

John Grunsfeld guides
A tour of the exhibit

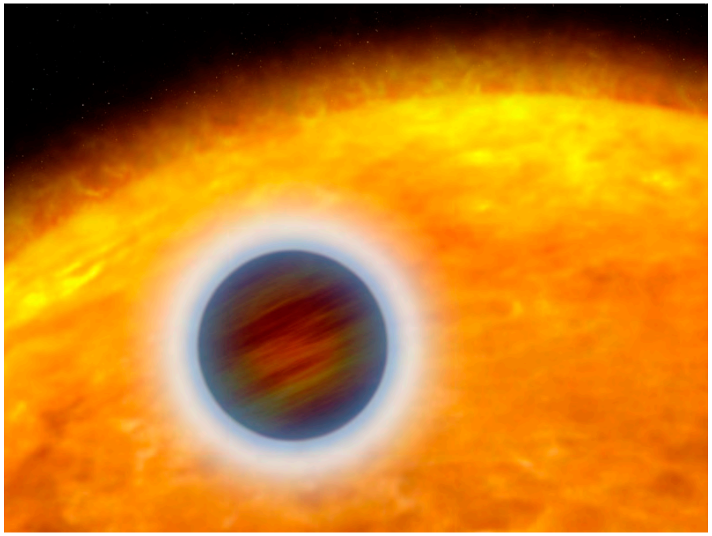
Thoughts on Exoplanets with HST

Not an original goal for HST, but HST has become a major contributor to exoplanet studies, via transit spectroscopy, astrometry, and imaging.

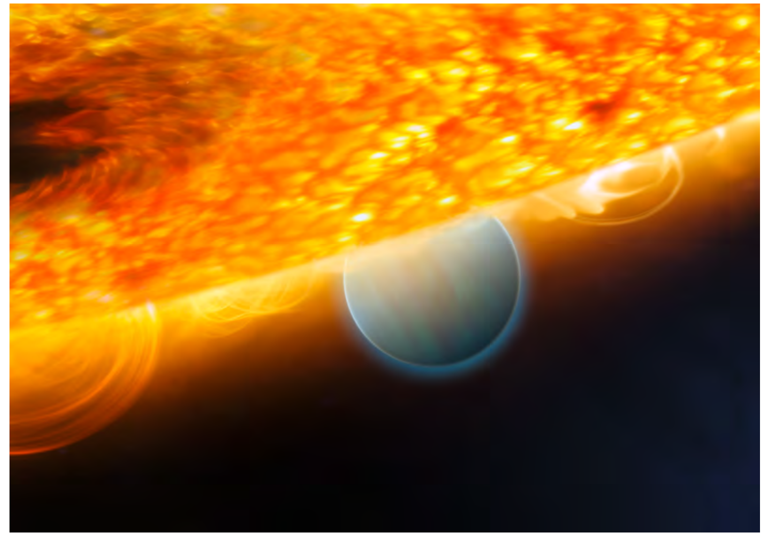
Moving beyond simply detection (most exoplanets detected by radial velocity motions of the associated star), Hubble (in concert with other facilities like Spitzer) is now being used for beginning *characterization* of exoplanets (generally gas giants).

Astro2010 recommended WFIRST as the next flagship mission, which would enable exoplanet statistics using microlensing, complementing Kepler's statistical study via distant transits. Neither allows followup spectroscopic study and characterization. JWST will allow IR studies of circumstellar disks and transit IR spectroscopy of mostly gas giants (and hopefully super-Earths). SO, in the meantime, important to maximize scientific use of unique HST capabilities for exoplanet characterization while we still can.

TRANSITING EXOPLANETS ("HOT JUPITERS")



PRIMARY ECLIPSE –
Spectroscopy/Photometry probe terminator region in absorption

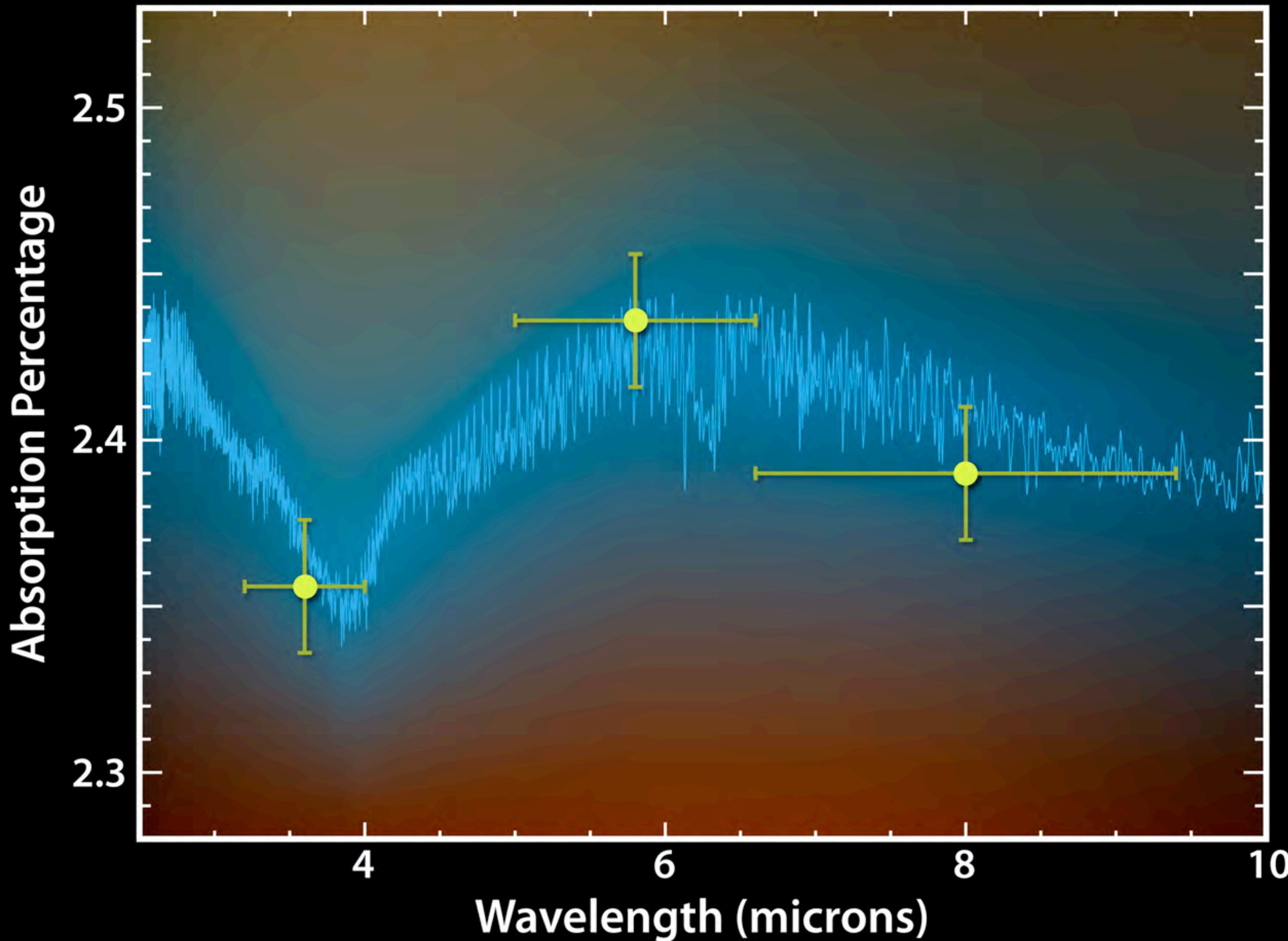


SECONDARY ECLIPSE –
Spectroscopy/Photometry probe dayside in emission/reflection

OBSERVATIONS WITH HUBBLE (NICMOS) AND SPITZER

- Enable identification of atmospheric molecular and atomic constituents
- Provide information about thermal profiles, dynamics of atmospheres
- At least four "hot Jupiters" observed to date
- Observed constituents include CH_4, H_2O, CO_2, CO

e.g. G. Tinelli, M. Swain, et al.



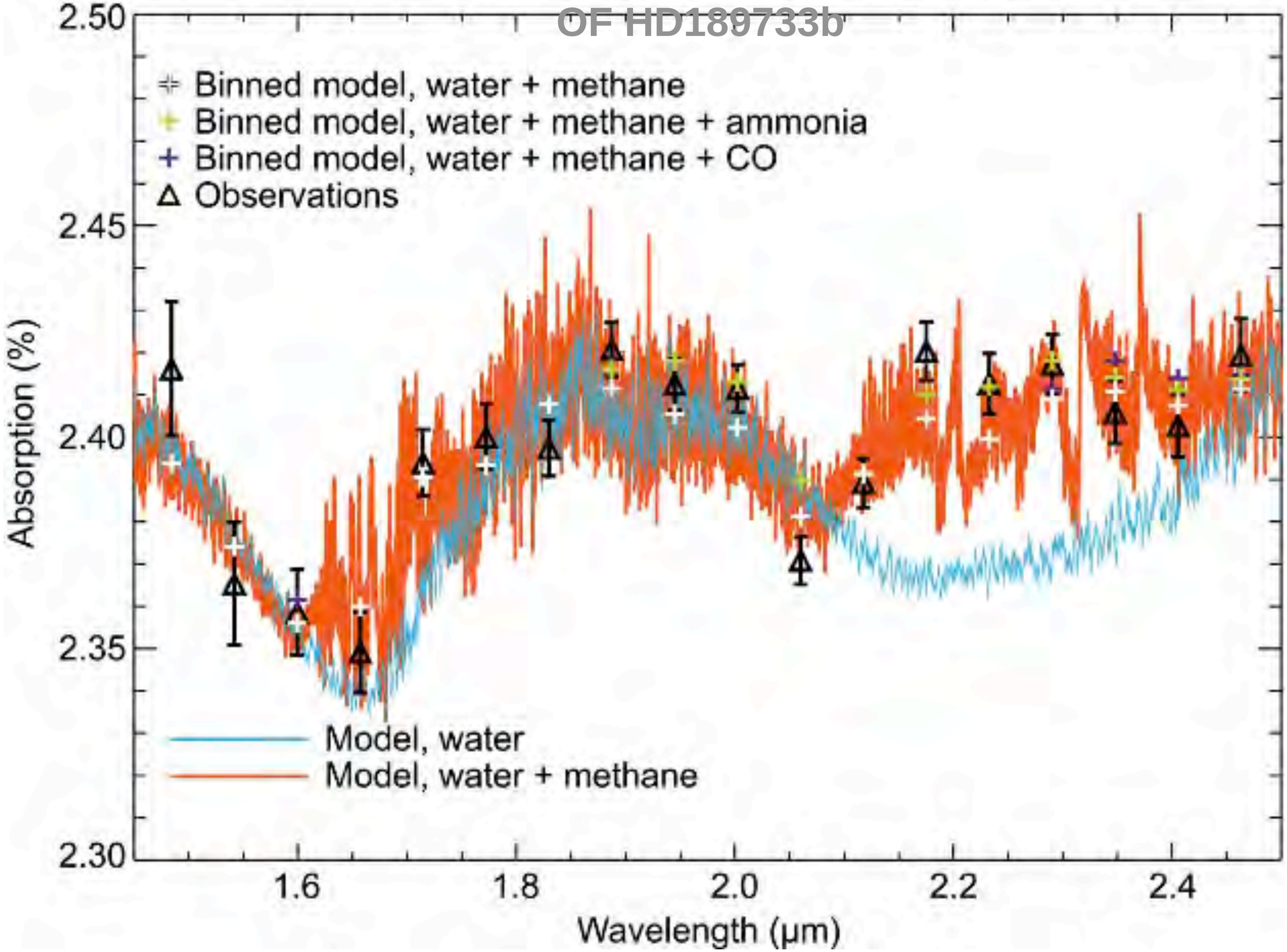
Water Signatures in Exoplanet HD189733b

Spitzer Space Telescope • IRAC

NASA / JPL-Caltech / G. Tinetti (Institute d'Astrophysique de Paris)

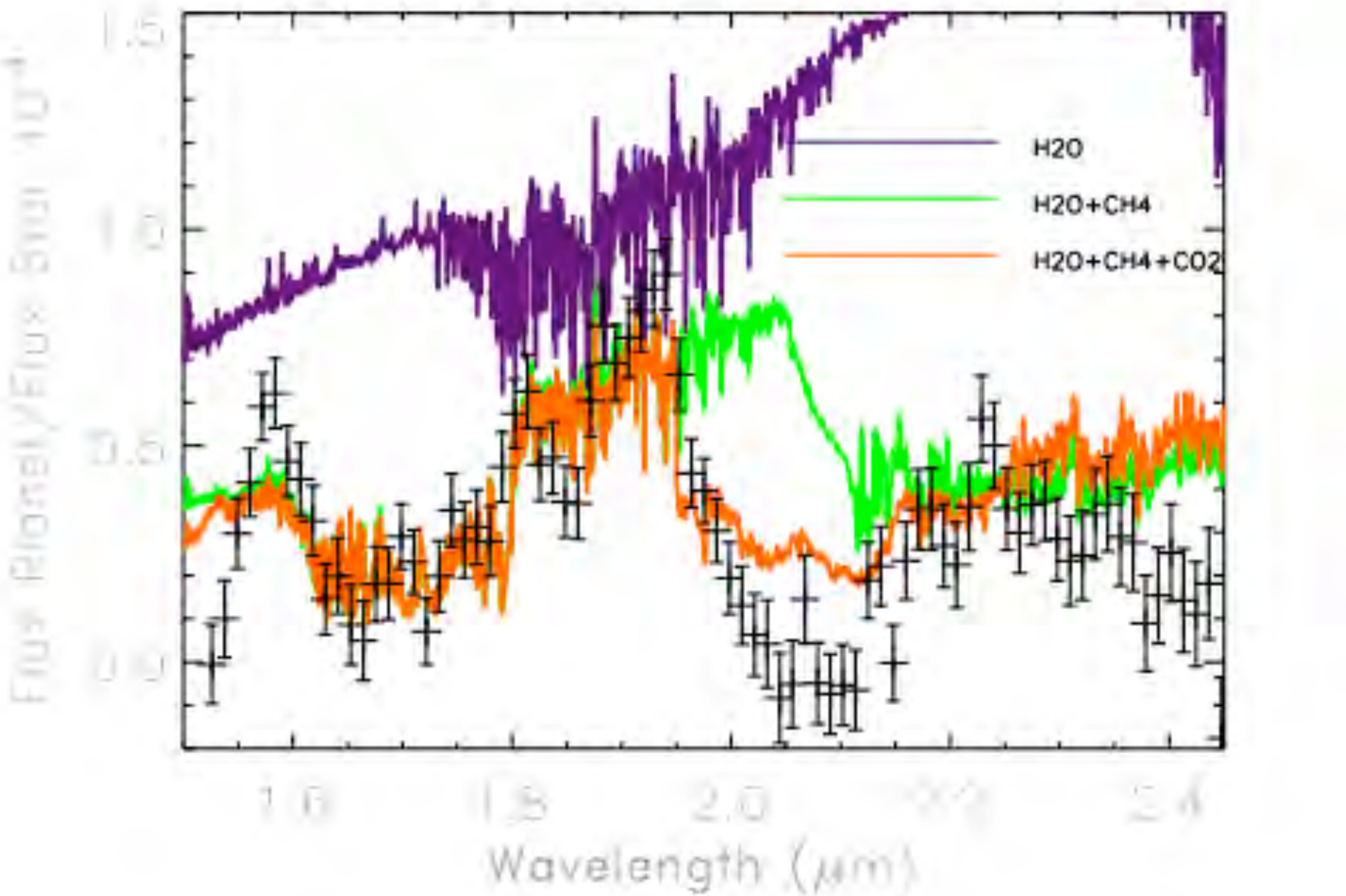
ssc2007-12a

HUBBLE/NICMOS PRIMARY ECLIPSE SPECTROSCOPY OF HD189733b

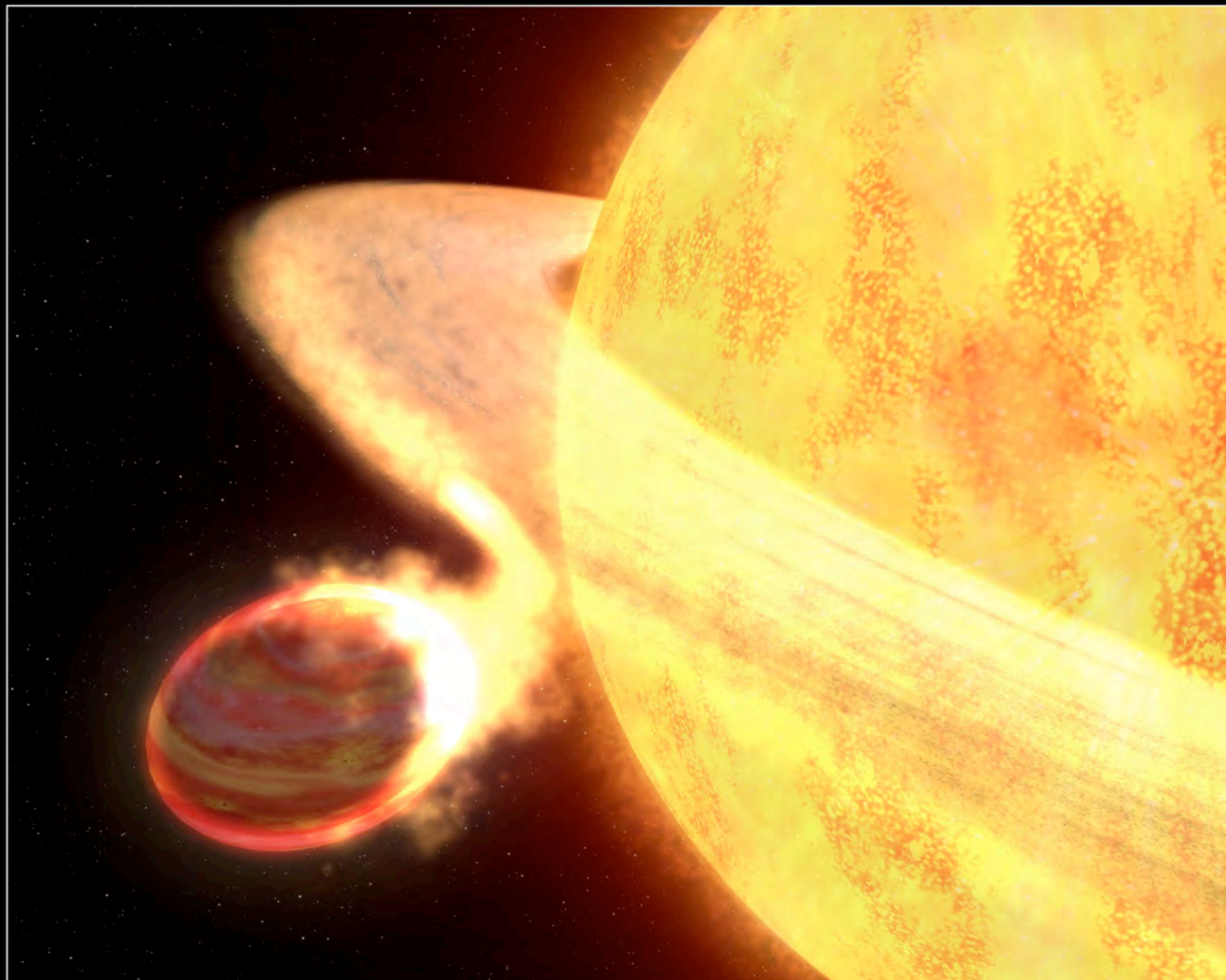


M. Swain, G. Vasisht, G. Tinetti 2008, *Nature*, **452**, pp. 329-331

HUBBLE/NICMOS SECONDARY ECLIPSE SPECTROSCOPY OF HD209458b

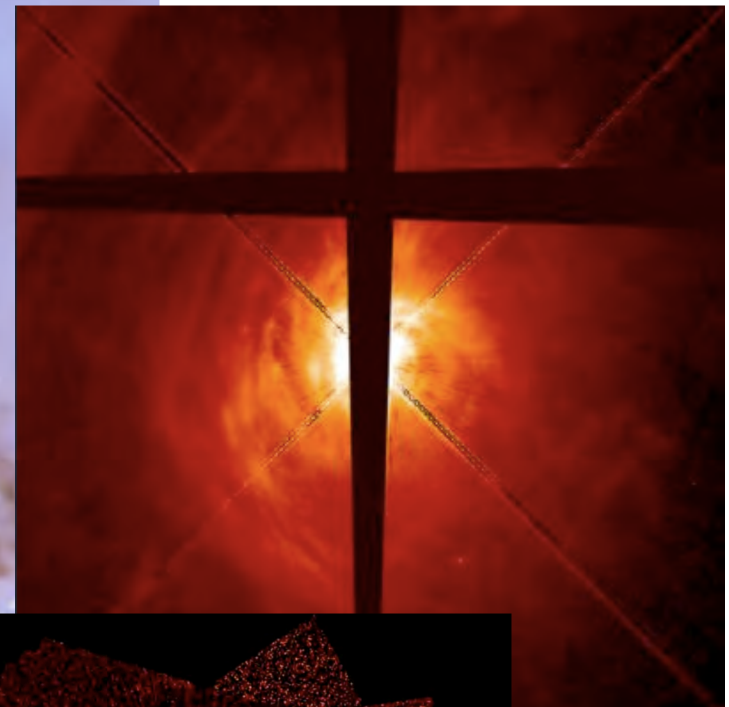


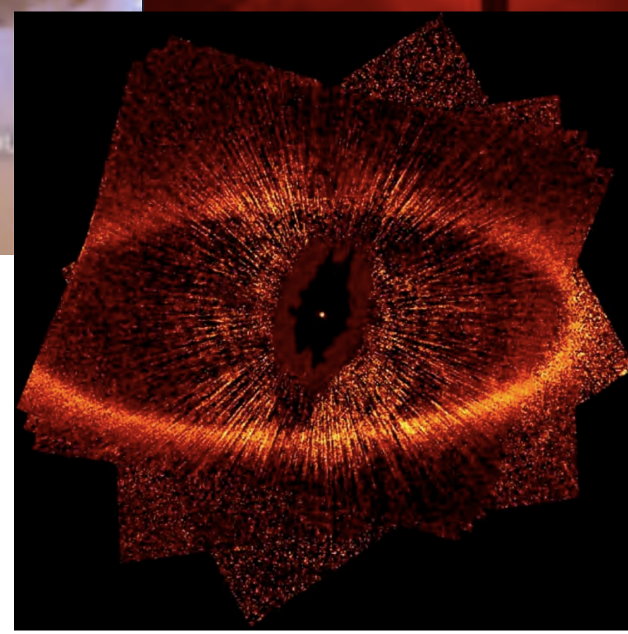
M.R. Swain, *et al.* 2009, ApJ, **704**, pp 1616-1621



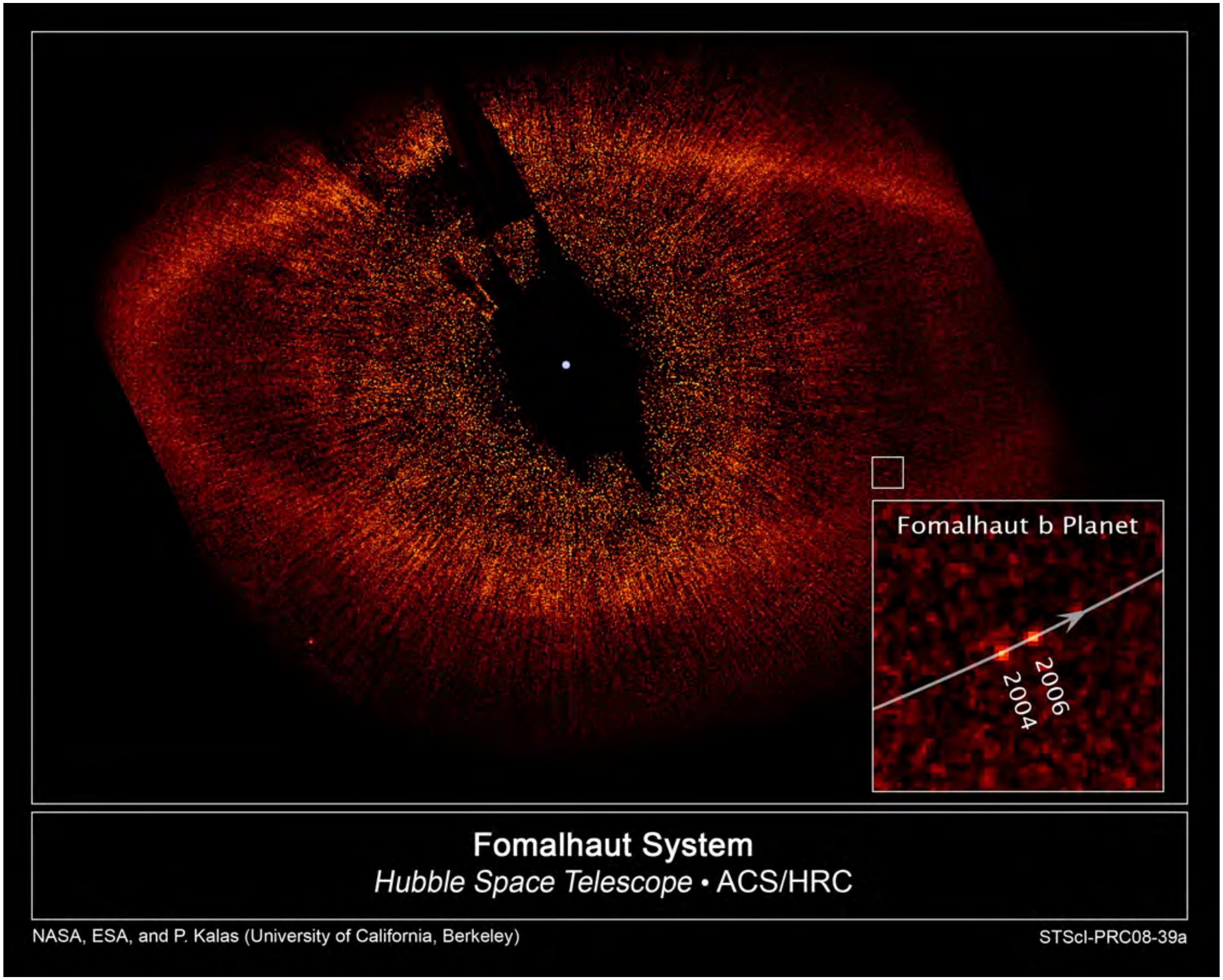
Artist's View of Extrasolar Planet WASP-12b

NASA, ESA, and G. Bacon (STScI) ▪ STScI-PRC10-15



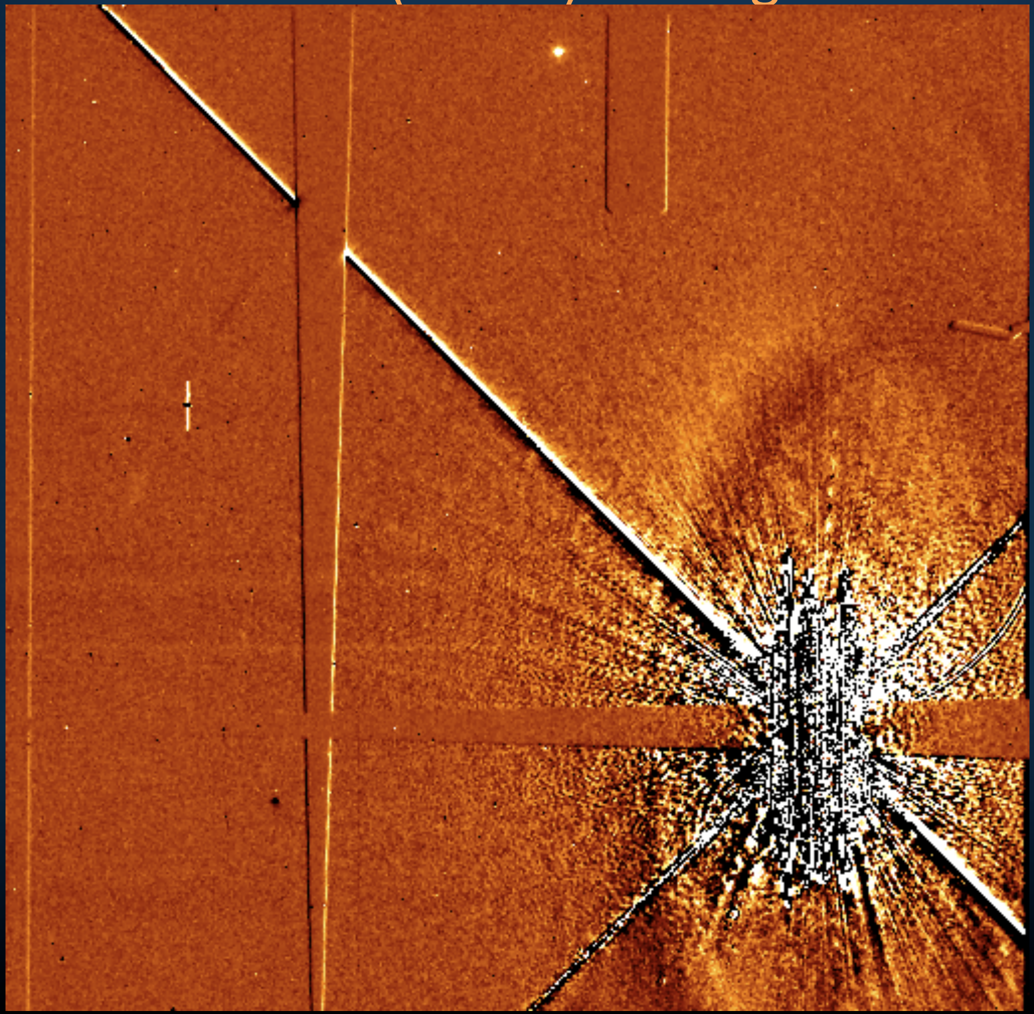


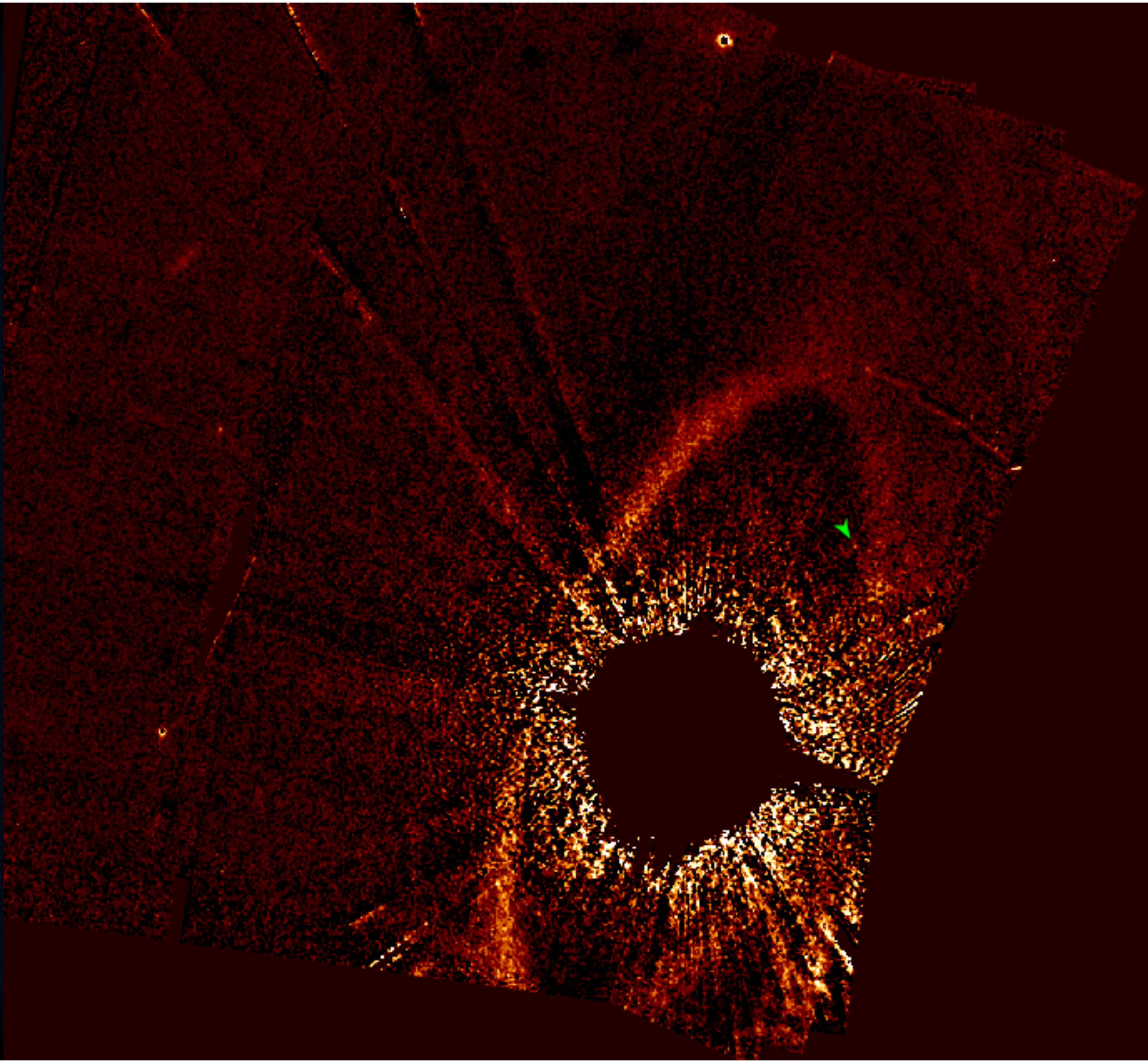
Planetary System Formation



Fomalhaut b Planet
2004
2006
Fomalhaut System
Hubble Space Telescope • ACS/HRC
NASA, ESA, and P. Kalas (University of California, Berkeley)
STScI-PRC08-39a

New observations – *Preliminary Results*
STIS coronagraphy: Fomalhaut
Sep. 13, 2010 Kalas et al.
4 orbits (4 rolls) - Wedge B2.5

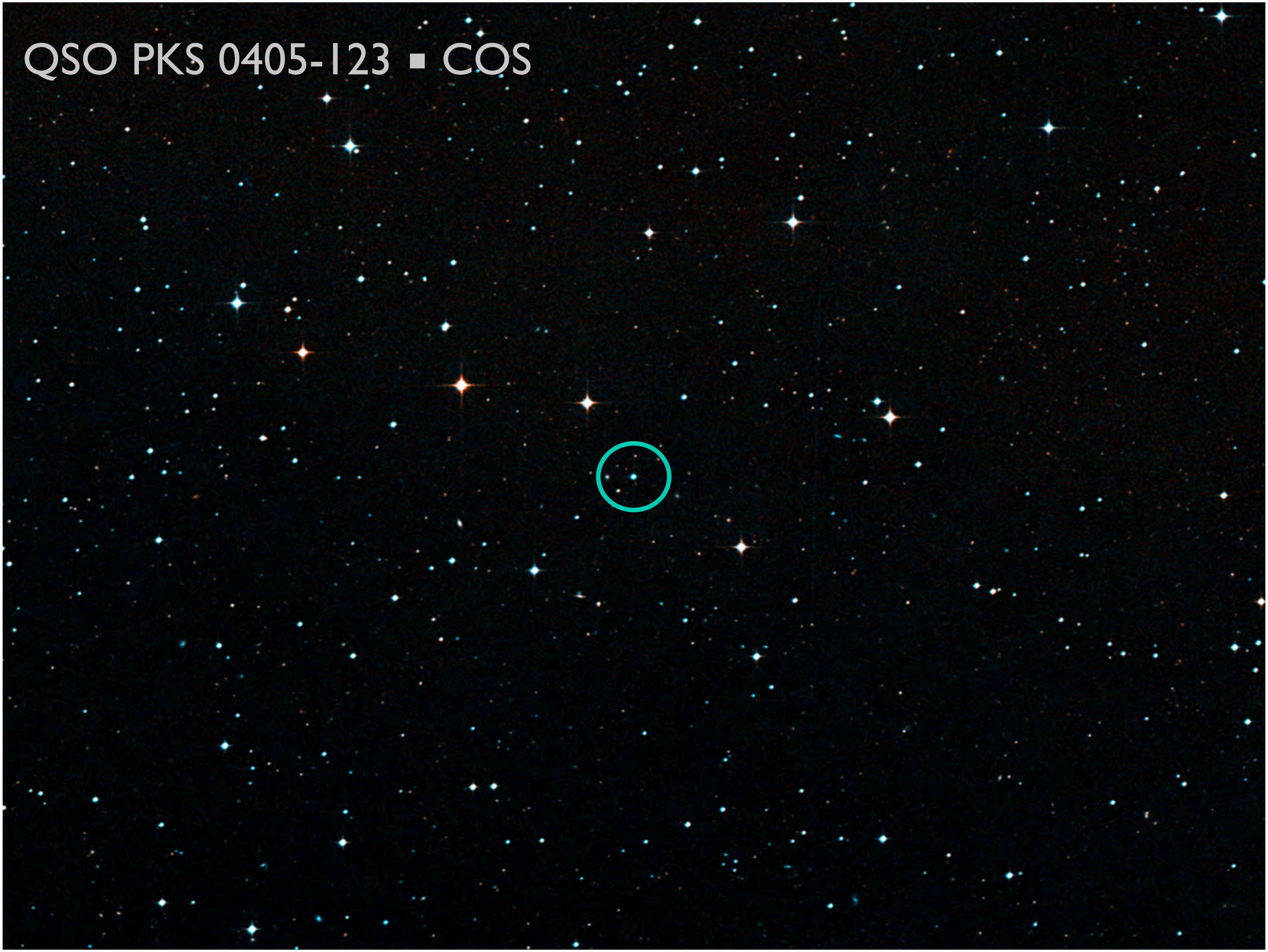


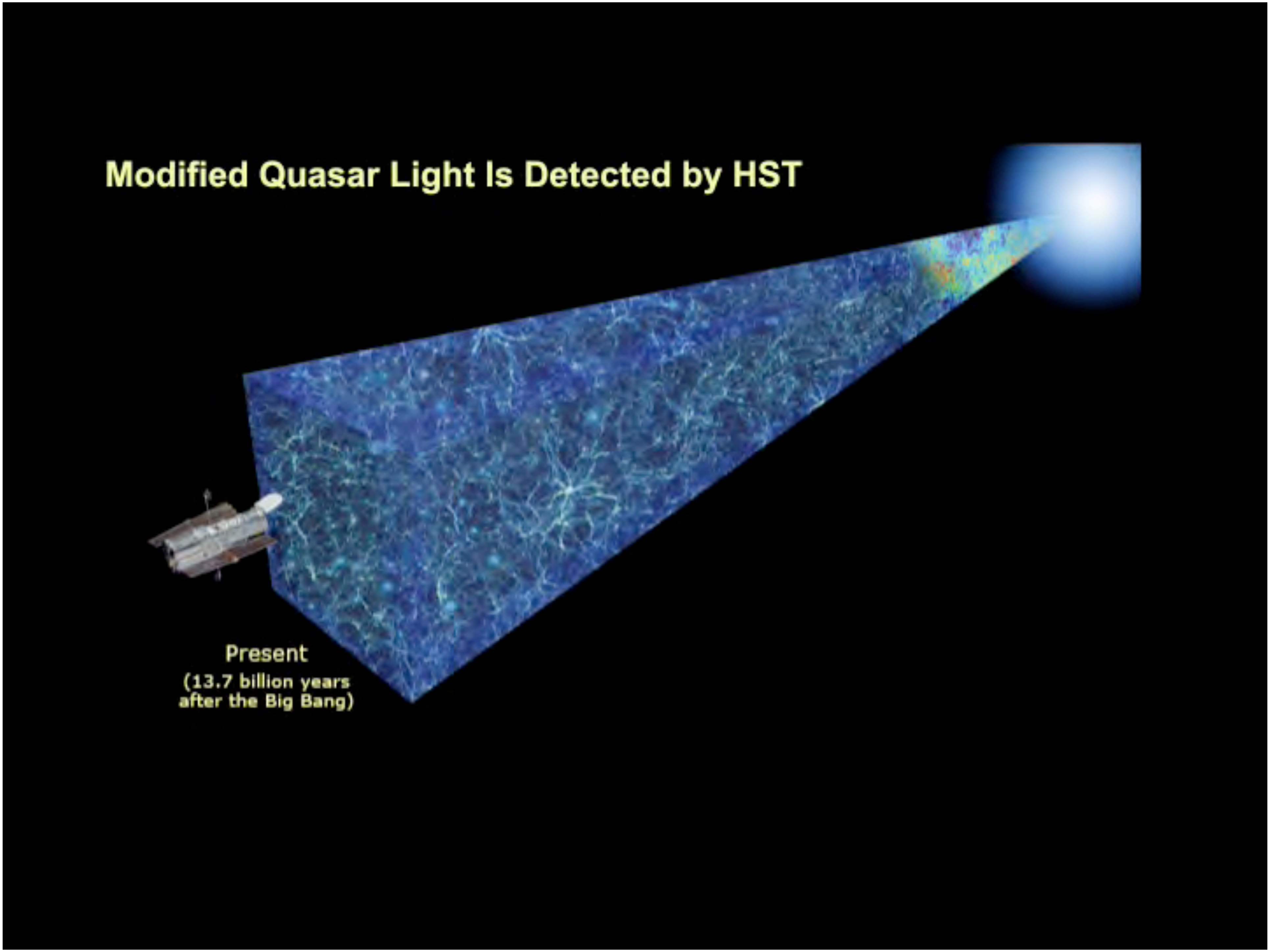


Thoughts on Exoplanets with HST, continued…

- Maximize use HST's *unique* spectral capabilities for studying exoplanet atmospheres via transit spectroscopy
  - UV (COS, STIS) (e.g. tidal stripping of atmospheres; outer atmosphere component identification)
  - NICMOS? (Reaches beyond the WFC3 1.7 micron limit) (atmospheric components like Methane)
- Image circumstellar disks and exoplanets with STIS (e.g. Fomalhaut-B)
- Many sources left to study: primary, secondary transits, imaging of disks (and associated exoplanets!)
  - Pursue JWST / HST potential to study super-Earths around M dwarf stars

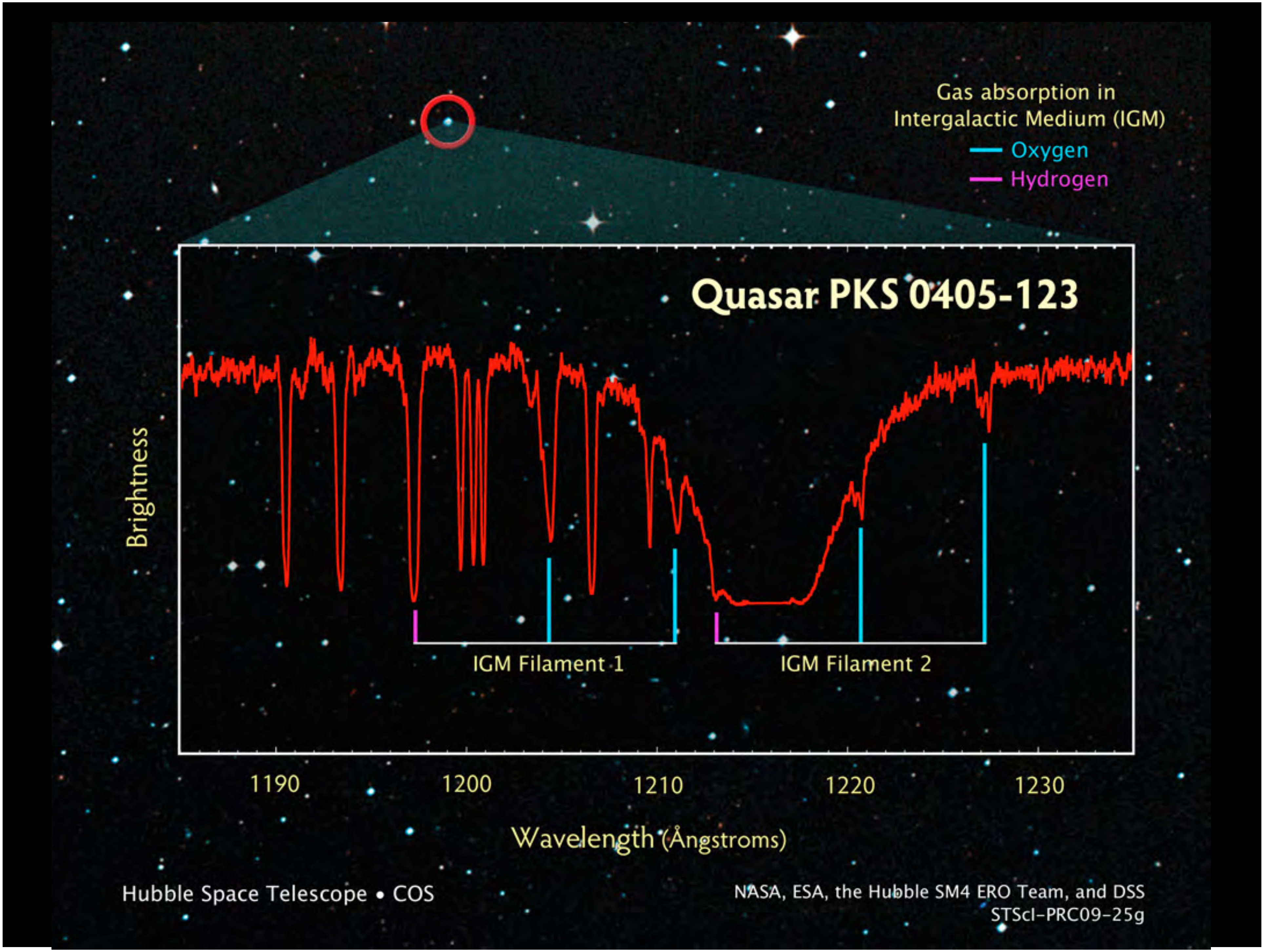
Thoughts on Laboratory Astrophysics with HST

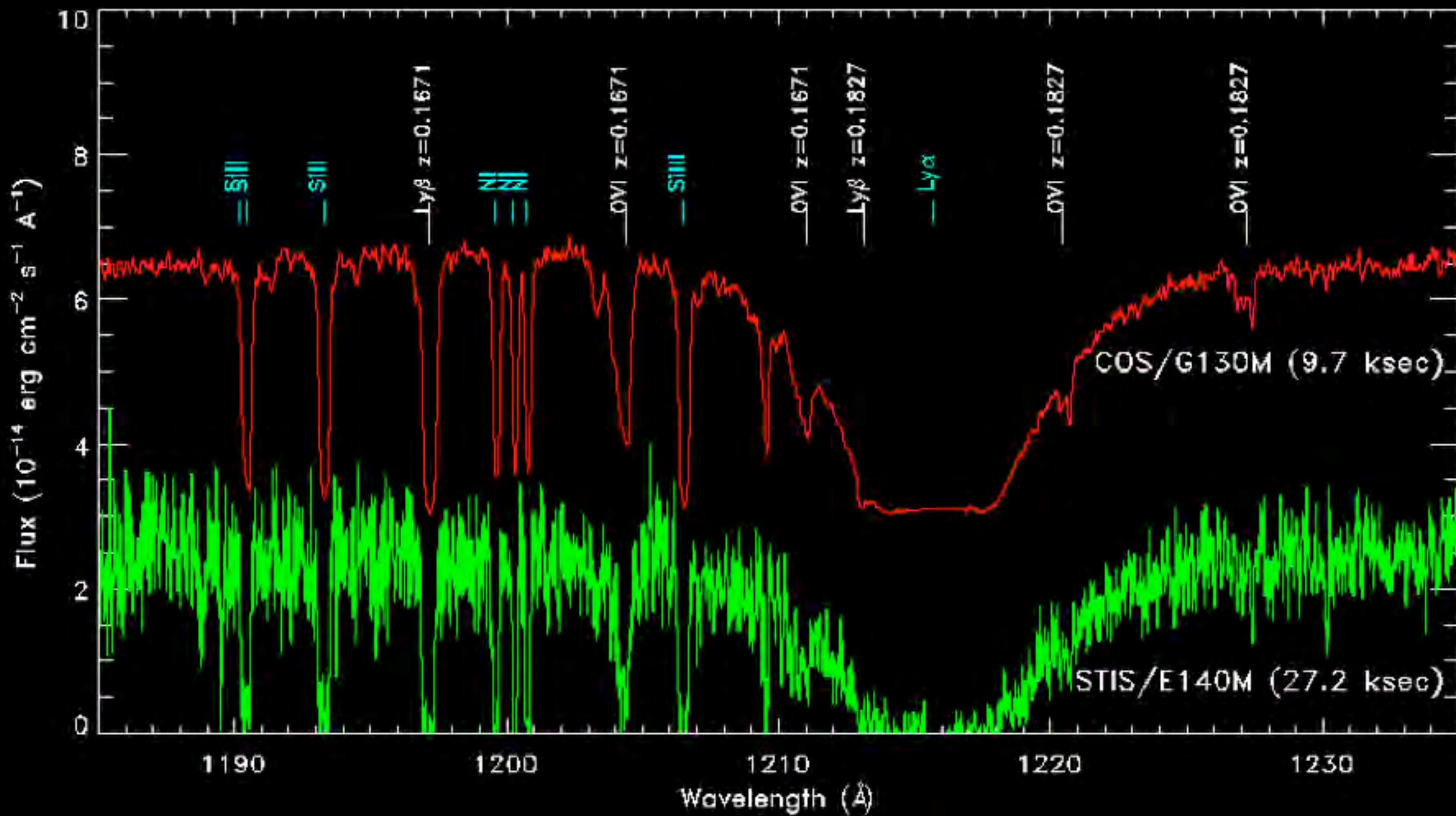

QSO PKS 0405-123 ▪ COS


Modified Quasar Light Is Detected by HST
Present
(13.7 billion years
after the Big Bang)

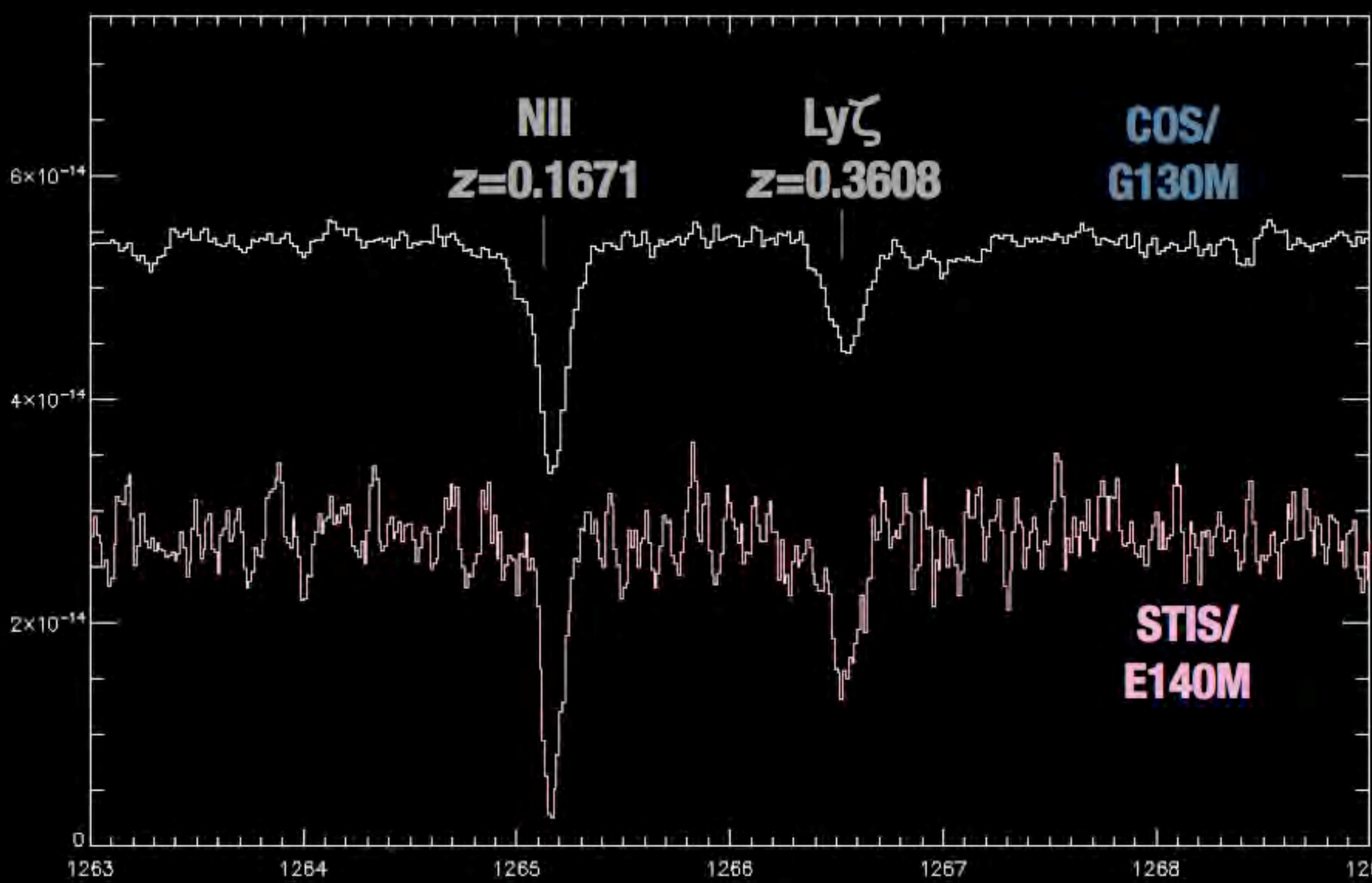
PKS 0405-12 Overview

- Well-studied, bright QSO, z=0.573
- Rich in IGM Lyα/metal ion lines
- Observed by every generation of HST far-UV spectrograph: FOS, GHRS, STIS, and now COS, as well as HUT, FUSE
  - FUSE: 150 ksec → **S/N=5-10** per 20 km s^{-1} resel
  - STIS/E140M: 27 ksec → **S/N≈12** per 7 km s^{-1} resel
  - COS: 17 ksec (7 orbits) → **S/N≈50** per 15 km s^{-1} resel


Gas absorption in Intergalactic Medium (IGM)
Oxygen
Hydrogen
Quasar PKS 0405-123
Brightness
IGM Filament 1
IGM Filament 2
1190
1200
1210
1220
1230
Wavelength (Ångstroms)
Hubble Space Telescope • COS
NASA, ESA, the Hubble SM4 ERO Team, and DSS
STScI-PRC09-25g



Courtesy Charles Danforth and the COS Science Team



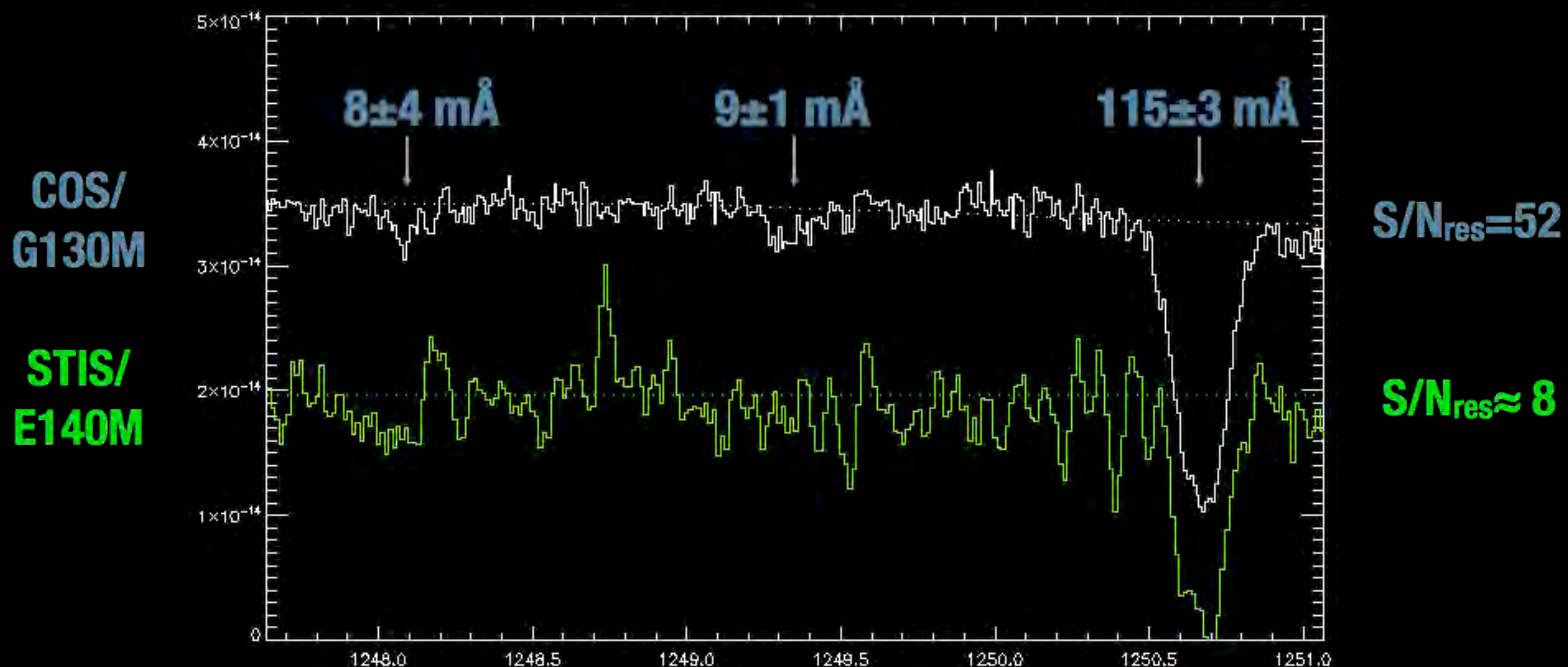
Courtesy Charles Danforth and the COS Science Team

PKS 0405-12: Weak Lines

- Can we see the weak features?

$$W_{\min} \approx \frac{(SL)\ \lambda}{R\ (S/N)}$$

$$W_{\min} \approx \frac{(4\sigma)\ 1300\text{Å}}{(2 \times 10^4)\ (50)} = 5\,\text{mÅ}$$



Courtesy Charles Danforth and the COS Science Team

An Illustrative Problem, requiring more laboratory astrophysics study

- Significant fraction of FUV lines cannot be identified with current line lists

- Either lines are missing or *f*-values are highly inaccurate

- Problem seen in stellar spectra covering a wide range in effective temperature

- Likely due to transitions to highly-excited levels, especially in iron-group ions

The Astronomical Journal, 117:1454–1470, 1999 March

VERY HIGH RESOLUTION ULTRAVIOLET SPECTROSCOPY OF A CHEMICALLY PECULIAR STAR: RESULTS OF THE χ LUPI PATHFINDER PROJECT

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Received 1998 September 28; accepted 1998 November 20

TABLE 6

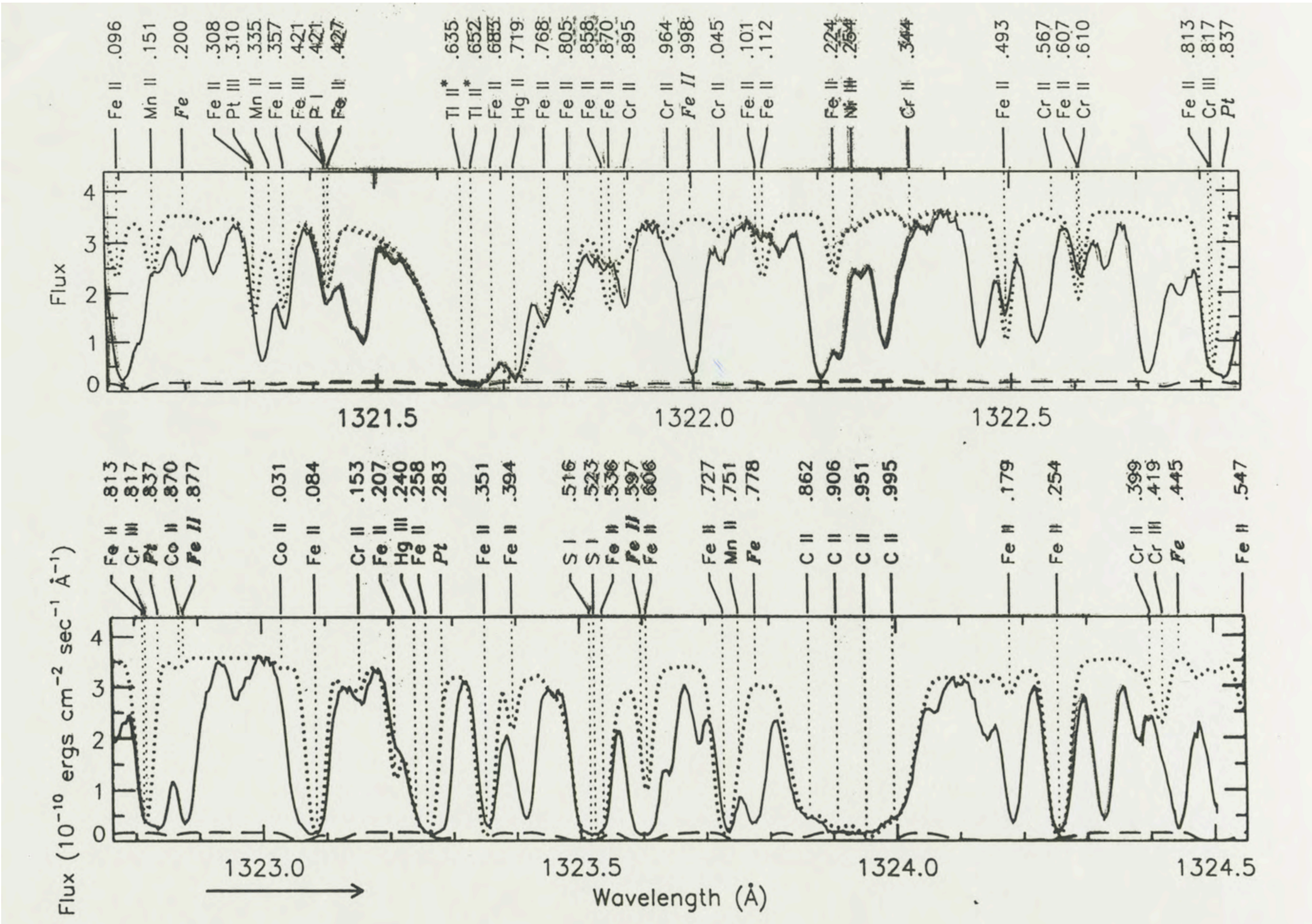
Statistics of Line Identifications versus Wavelength

λ Range (Å)	⟨δλ⟩[a] (Å)	⟨Number of Lines⟩[b]	Firm ID[c]	Probable ID[d]	Total Unidentified[e]	Stronger Unidentified[f]
2334–2688...... ⟨29, 34, 36⟩[g]	14	105	57%	36%	7%	3%
1904–2160...... ⟨17, 18, 24⟩	11	112	44%	36%	20%	7%
1644–1873...... ⟨13, 14, 16⟩	10	112	36%	42%	22%	13%
1317–1543...... ⟨3, 9, 11⟩	8	133	30%	31%	39%	28%

[a] Average width of observed intervals.
[b] Average number of spectral features counted per interval.
[c] Observed feature closely matched by spectrum synthesis.
[d] Discrepancies between spectrum synthesis and observations probably reflect uncertainties of atomic data or issues with abundances as discussed in the text. Unmodeled features plausibly identified by wavelength from laboratory spectra.
[e] Substantial line opacity missing in spectrum synthesis; no plausible identification.
[f] Subset of unidentified features that are moderately strong and (in most cases) well resolved.
[g] Statistics are averages for three intervals denoted by their figure numbers in Paper II.

Unidentified Lines and/or Inaccurate *f*-values in the FUV

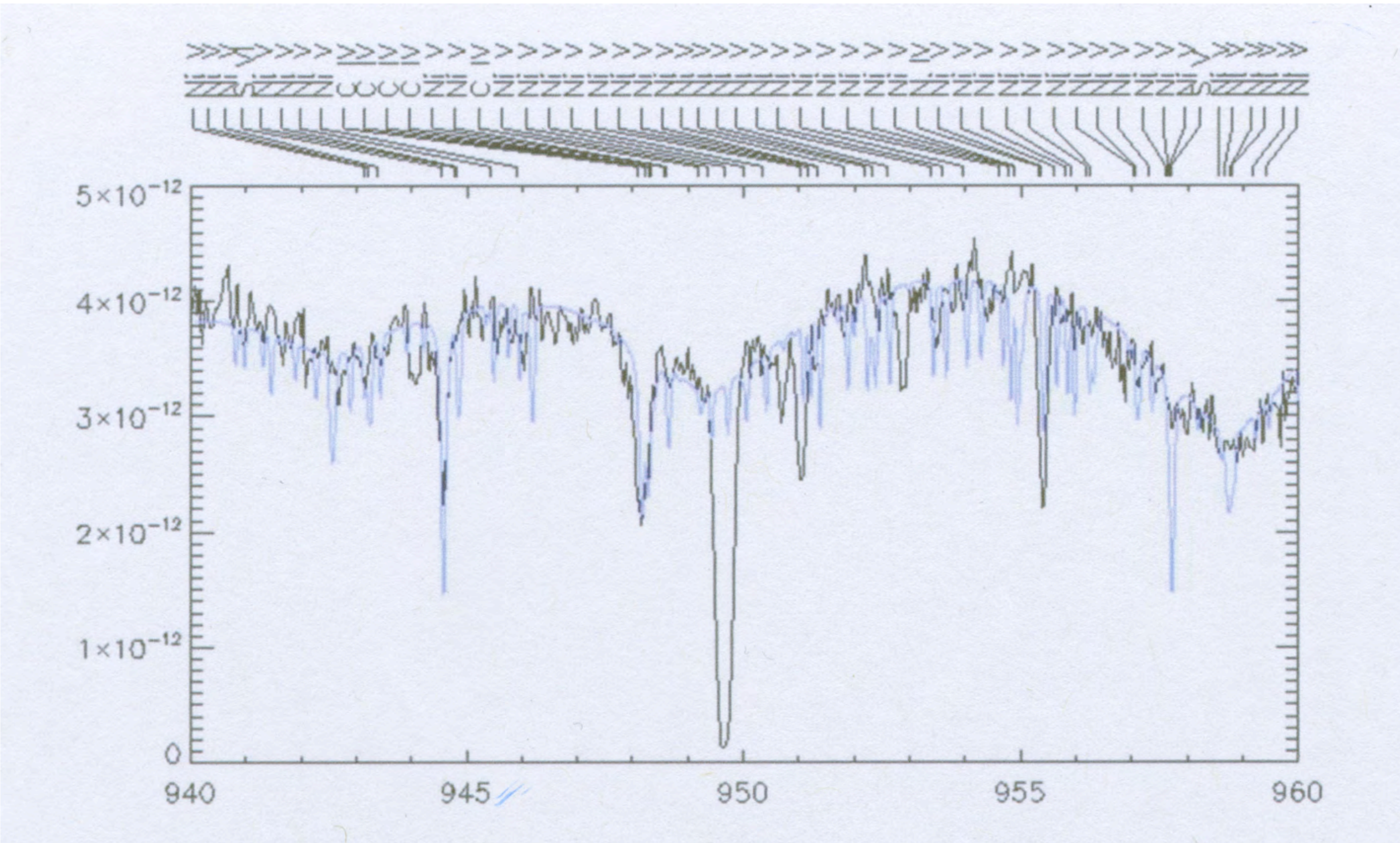
chi Lupi, B9.5p, Teff=10,650 K (Leckrone, et al. 1999)



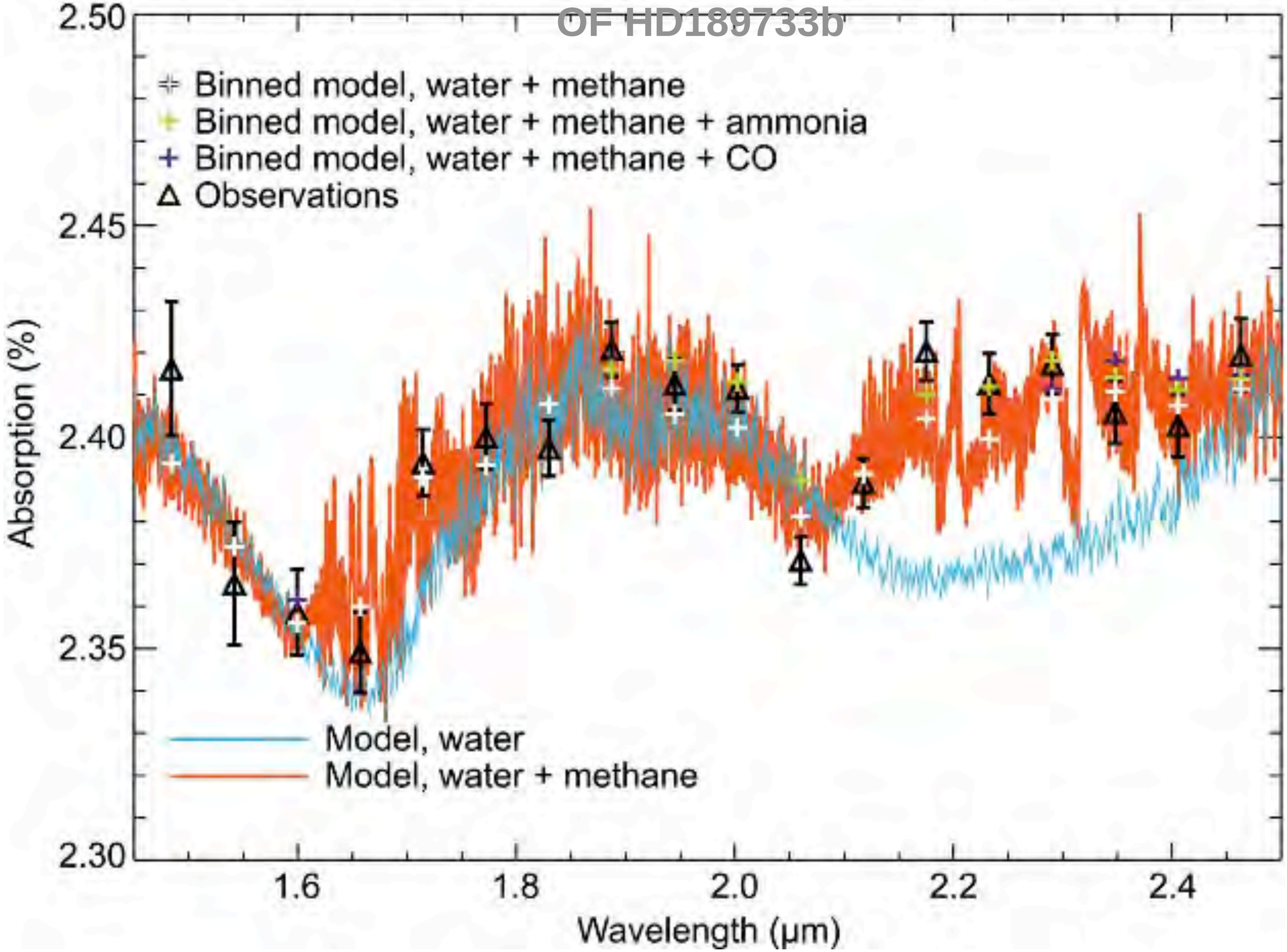
Unidentified Lines and/or Inaccurate *f*-values in the FUV

White Dwarf REJ0503-289, Teff = 70,000 K; FUSE observation

Barstow, et al. (includes “Kentucky” line database – www.pa.uky.edu/peter/atomic/)

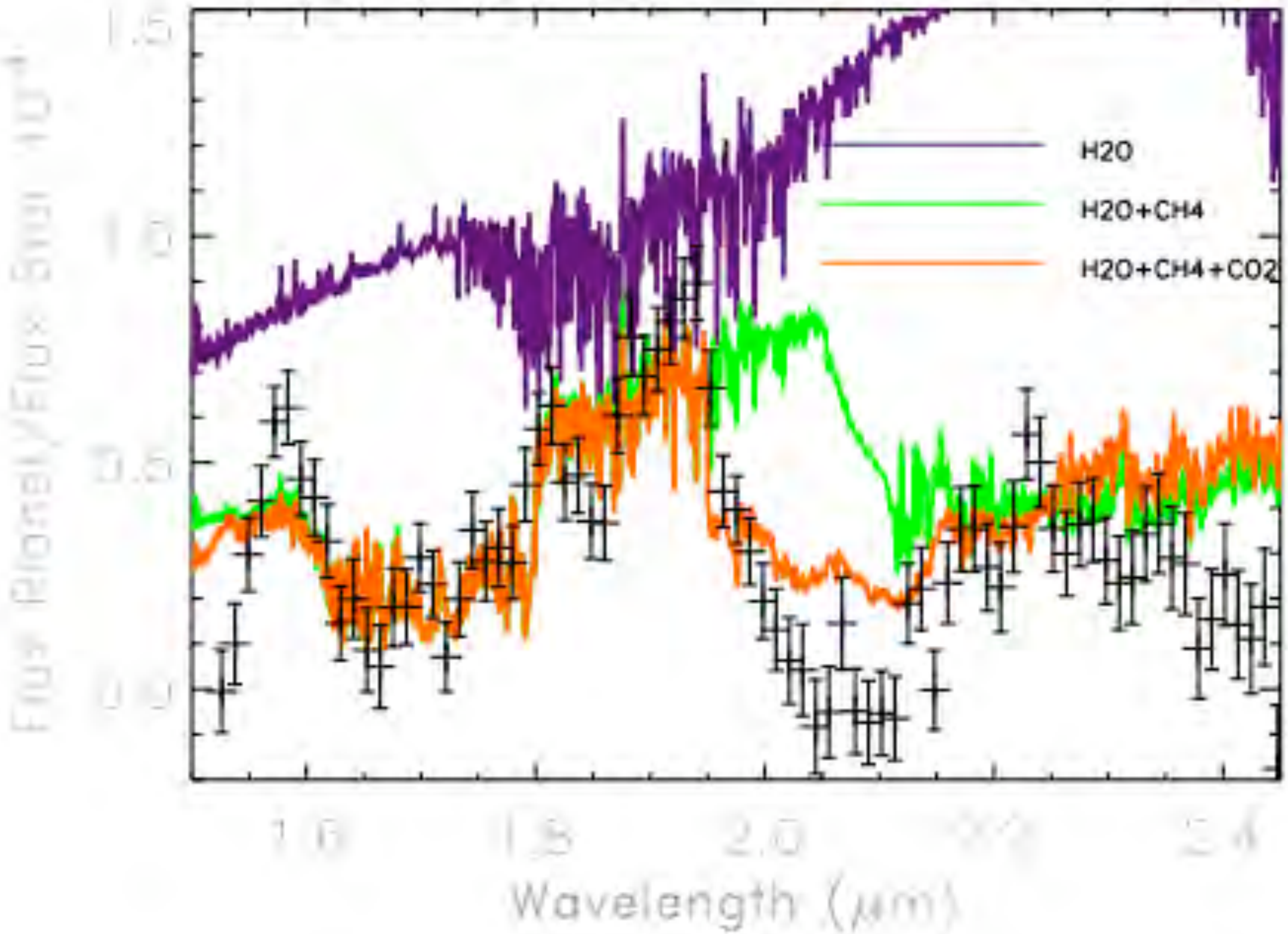


HUBBLE/NICMOS PRIMARY ECLIPSE SPECTROSCOPY OF HD189733b

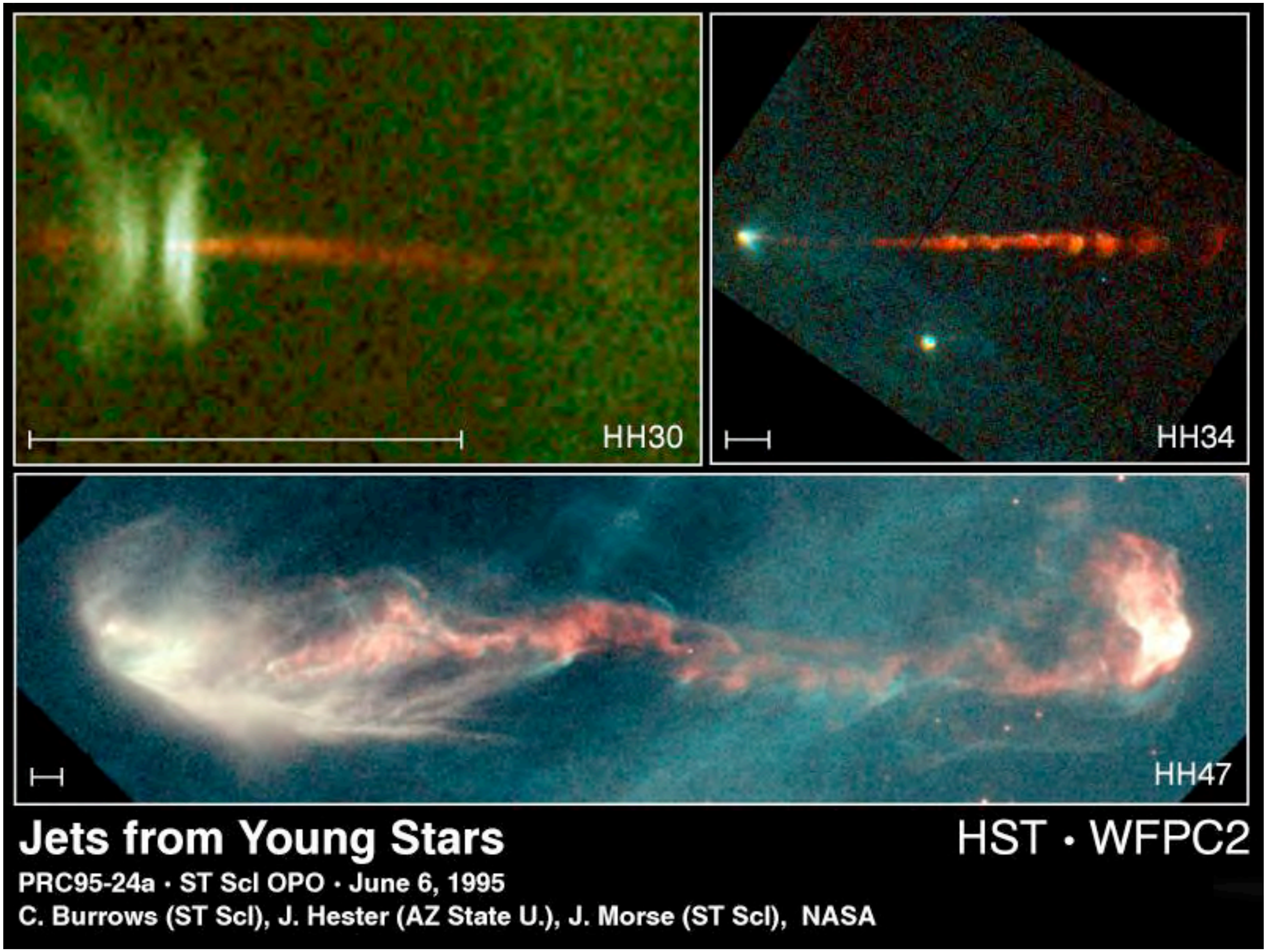


M. Swain, G. Vasisht, G. Tinetti 2008, *Nature*, **452**, pp. 329-331

HUBBLE/NICMOS SECONDARY ECLIPSE SPECTROSCOPY OF HD209458b



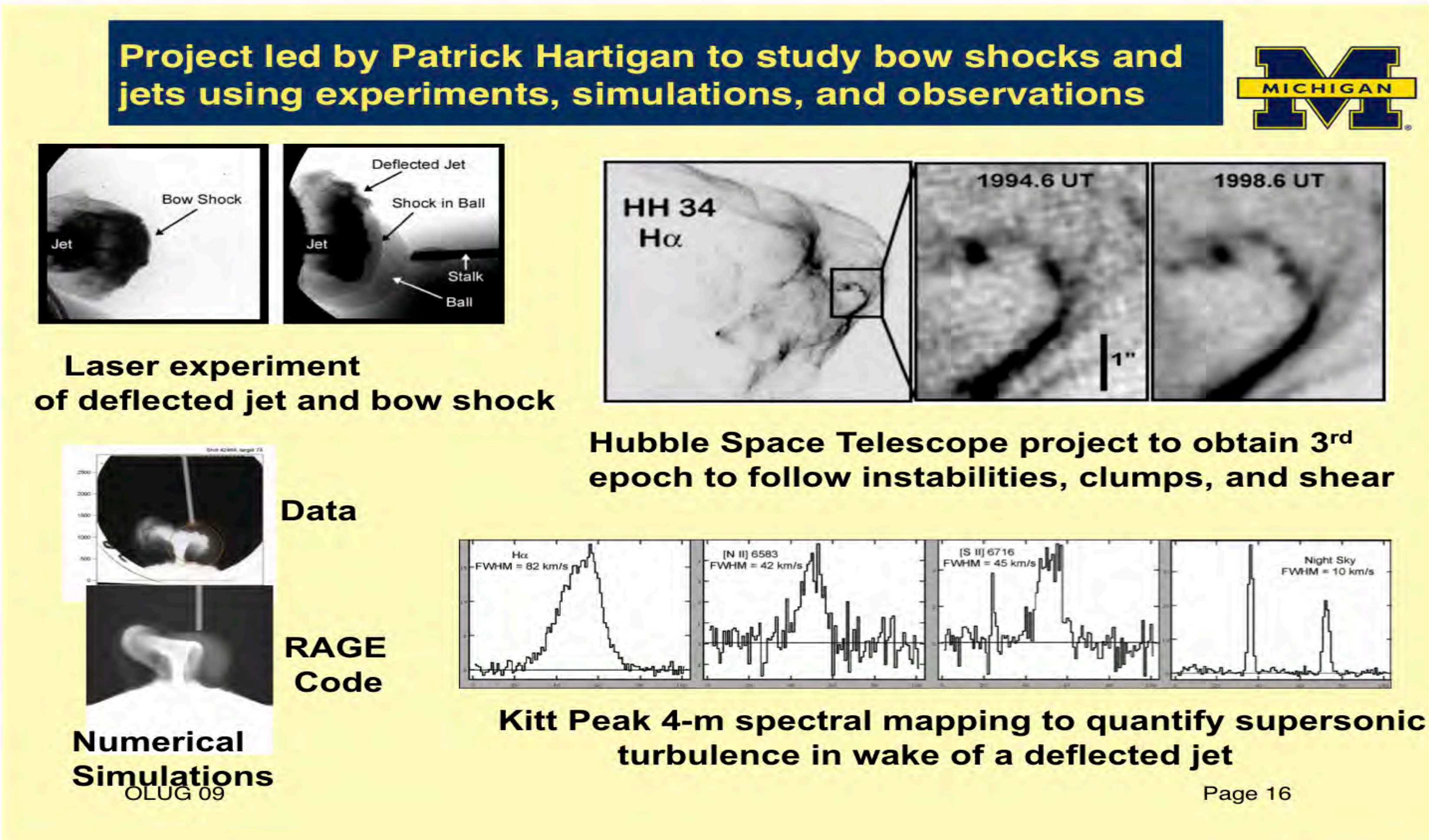
M.R. Swain, *et al.* 2009, ApJ, **704**, pp 1616-1621


HH30
HH34
HH47
Jets from Young Stars
HST • WFPC2
PRC95-24a • ST ScI OPO • June 6, 1995
C. Burrows (ST ScI), J. Hester (AZ State U.), J. Morse (ST ScI), NASA

Modeling and simulating jets

(Hartigan et al., Rice Univ.,

from Lab Astro presentation of R. Paul Drake, Univ. Michigan)



HST and Laboratory Astrophysics

- Spectroscopy with HST is particularly powerful since SM4, with STIS restored and the new Cosmic Origins Spectrograph
- Spectroscopy and related laboratory astrophysics are supporting studies of diverse sources including stellar atmospheres, supernova remnants, the IGM and Cosmic Web, astrophysical jets, and exoplanets
- Of particular need for laboratory astrophysics studies are the higher level atomic/ionic transition lines (identifications and f-values) for study of, e.g., stellar/ white dwarf atmospheres. Also needed are better models for exoplanet atmosphere transit spectra, such as in the infrared.
- With no more planned astronaut servicing, and no new space flagship UV-optical mission in development (though technology development is recommended), it is important to maximize the scientific return of HST (and its archive) in its remaining years, including relevant laboratory astrophysics
- NASA’s Laboratory Astrophysics Workshop discussion recommendation: Encourage continued or increased support for relevant laboratory astrophysics as components of GO/AR programs as well as through NASA’s APRA program


National Aeronautics and Space Administration
NASA
Hubble 2009
Science Year in Review
www.nasa.gov

Inside

Messier 101 is a face-on spiral galaxy about 22 million light-years away in the constellation Ursa Major (the Big Dipper). It is in many ways similar to, but larger than, our own Milky Way Galaxy.