BIG BANG TO BIOSIGNATURES: THE LUVOIR MISSION CONCEPT

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LUVOIR Workshop
Paris, France
January 11, 2017

What is LUVOIR ?

Crab Nebula with HST ACS/WFC
Credit: NASA / ESA

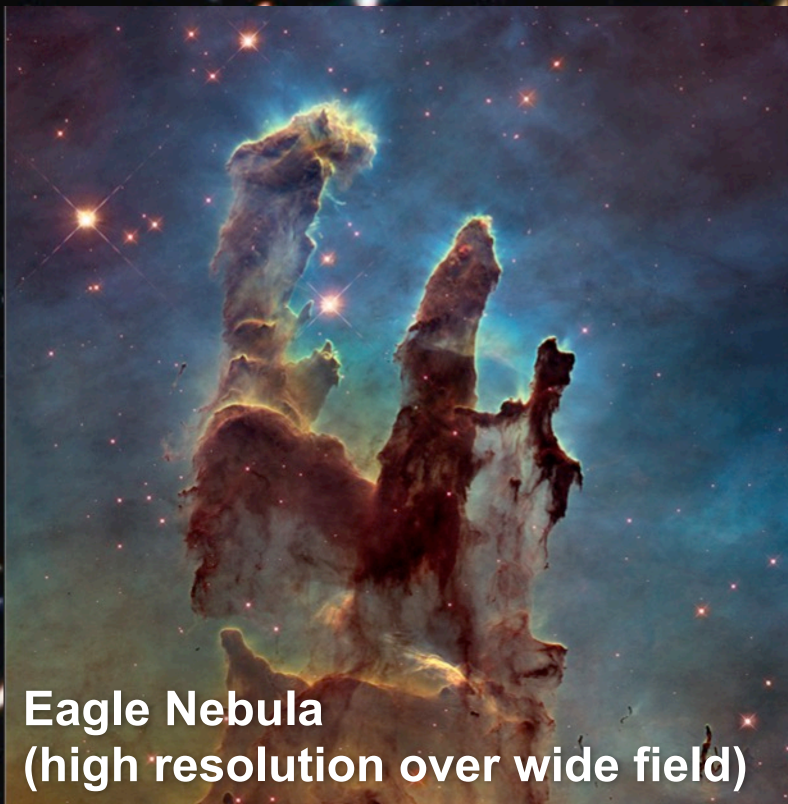
Large UV / Optical / Infrared Surveyor (LUVOIR)

A space telescope concept in tradition of Hubble

- Broad science capabilities
- Far-UV to Near-IR bandpass
- ~ 8 – 16 m aperture diameter
- Suite of imagers and spectrographs
- Serviceable and upgradable

"Space Observatory for the 21st Century"
Decades of science
Ability to answer questions we have not yet conceived

Imagine astronomy without Hubble …

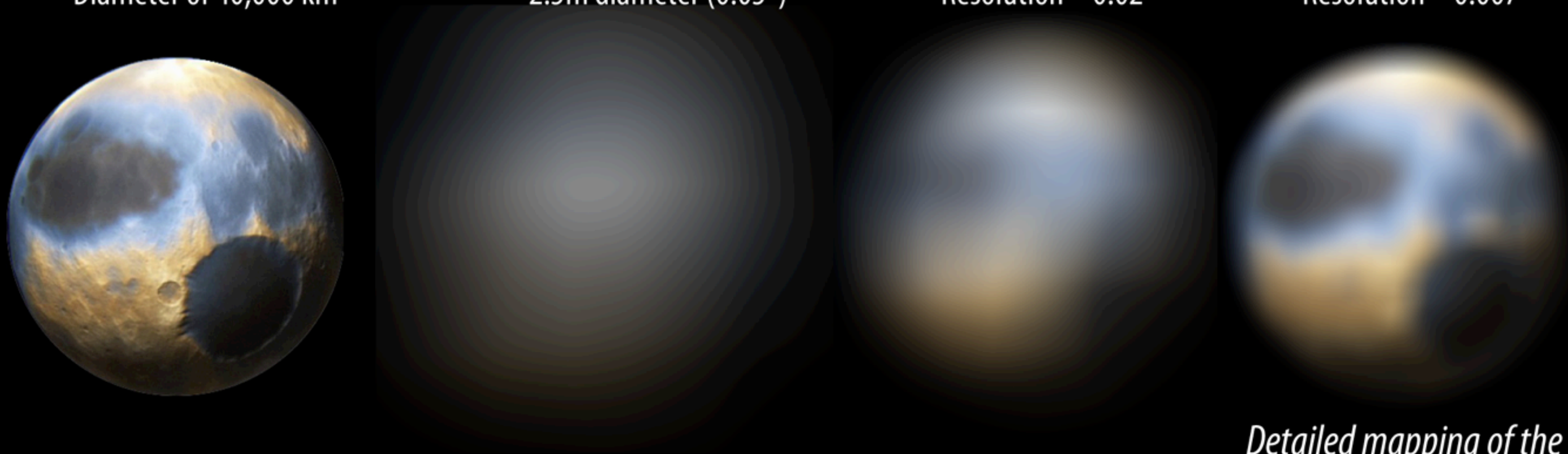

Eagle Nebula
(high resolution over wide field)

Hubble Ultra Deep Field
(ultra-deep imaging)


Jupiter’s aurora
(UV, global monitoring)

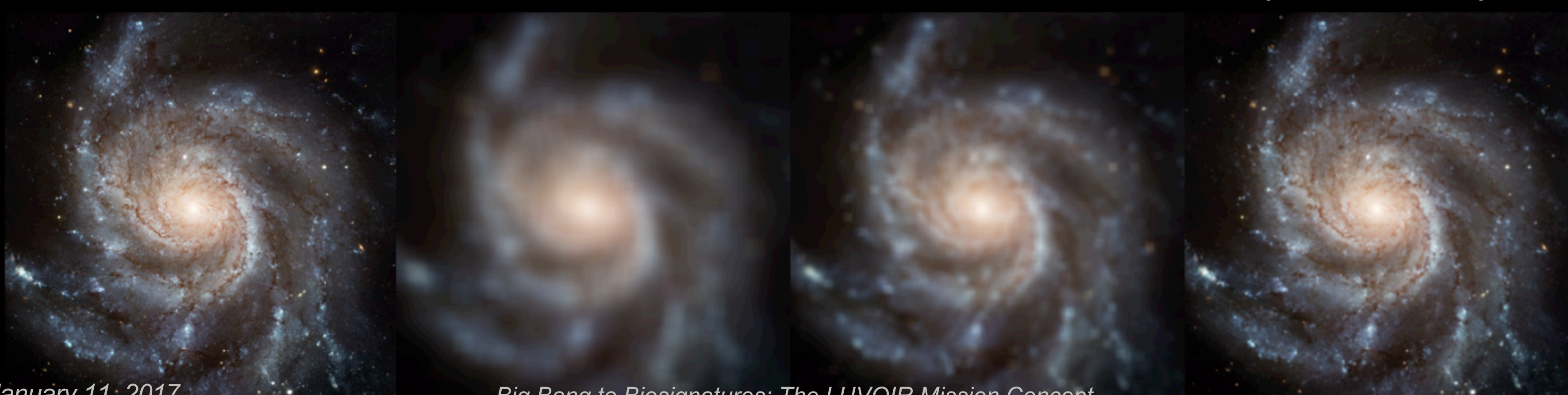
Imagine astronomy with LUVOIR …

Hypothetical planet "Nine"	Hubble Space Telescope (HST)	LUVOIR	LUVOIR
Located at ~1000 AU	Best optical resolution (2016)	6m diameter	18m diameter
Diameter of 40,000 km	2.5m diameter (0.05")	Resolution ~0.02"	Resolution ~0.007"

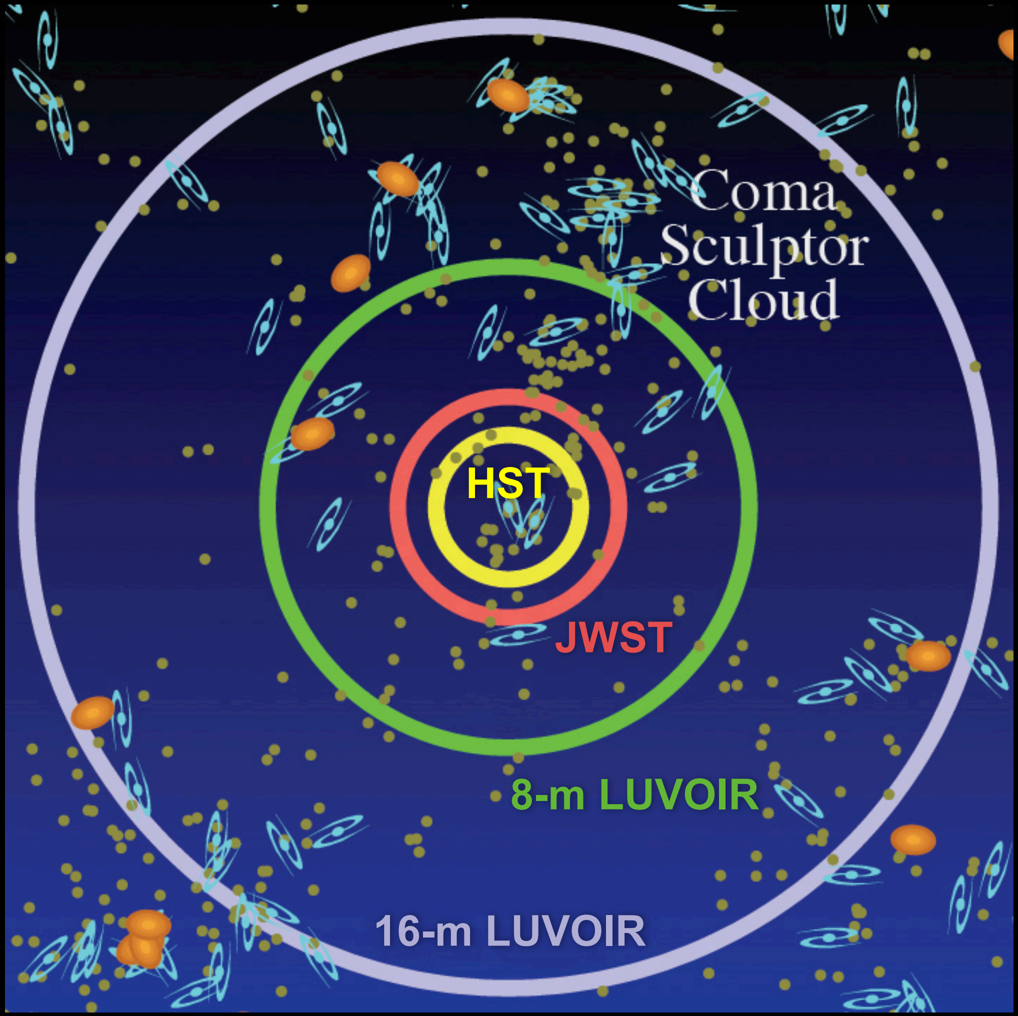


Clear Identification of local differences

Detailed mapping of the surface morphologies and composition anisotropies



How do galaxies assemble their stars?



Map of Galaxies within 12 Mpc of Our Galaxy

Circles show distance out to which individual solar-type stars can be detected

Provides ages and star formation histories

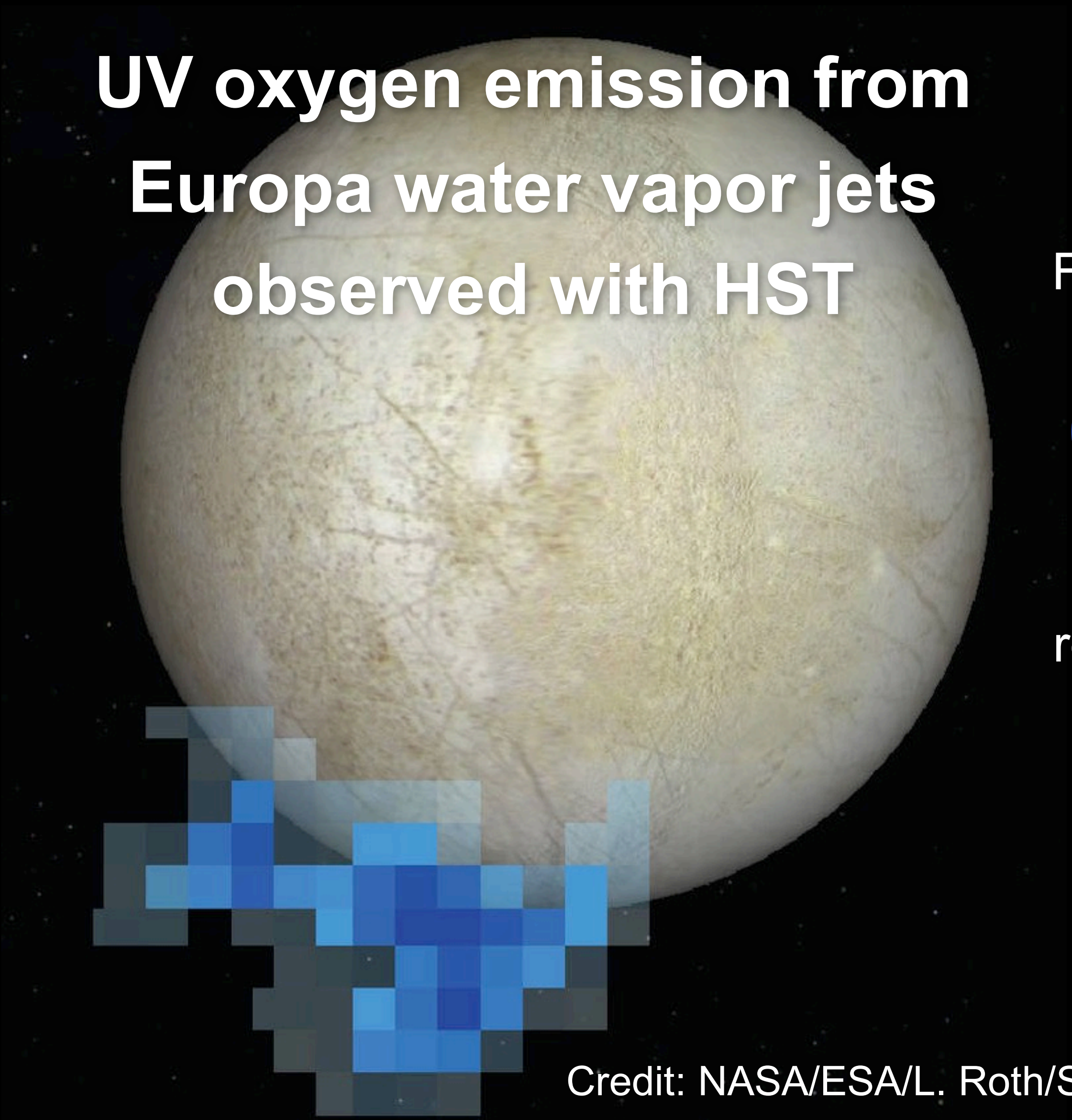
Need LUVOIR to reach the nearest giant elliptical galaxies

= Large Elliptical Galaxy

= Large Spiral Galaxy

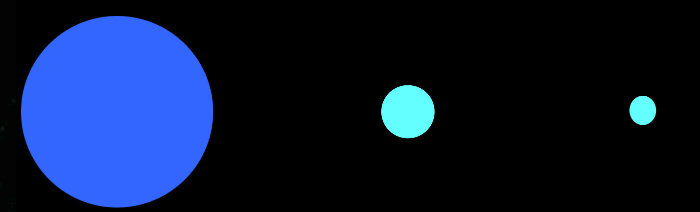
= Dwarf Galaxy

Monitoring Solar System ocean moons



UV oxygen emission from Europa water vapor jets observed with HST

For illustration …

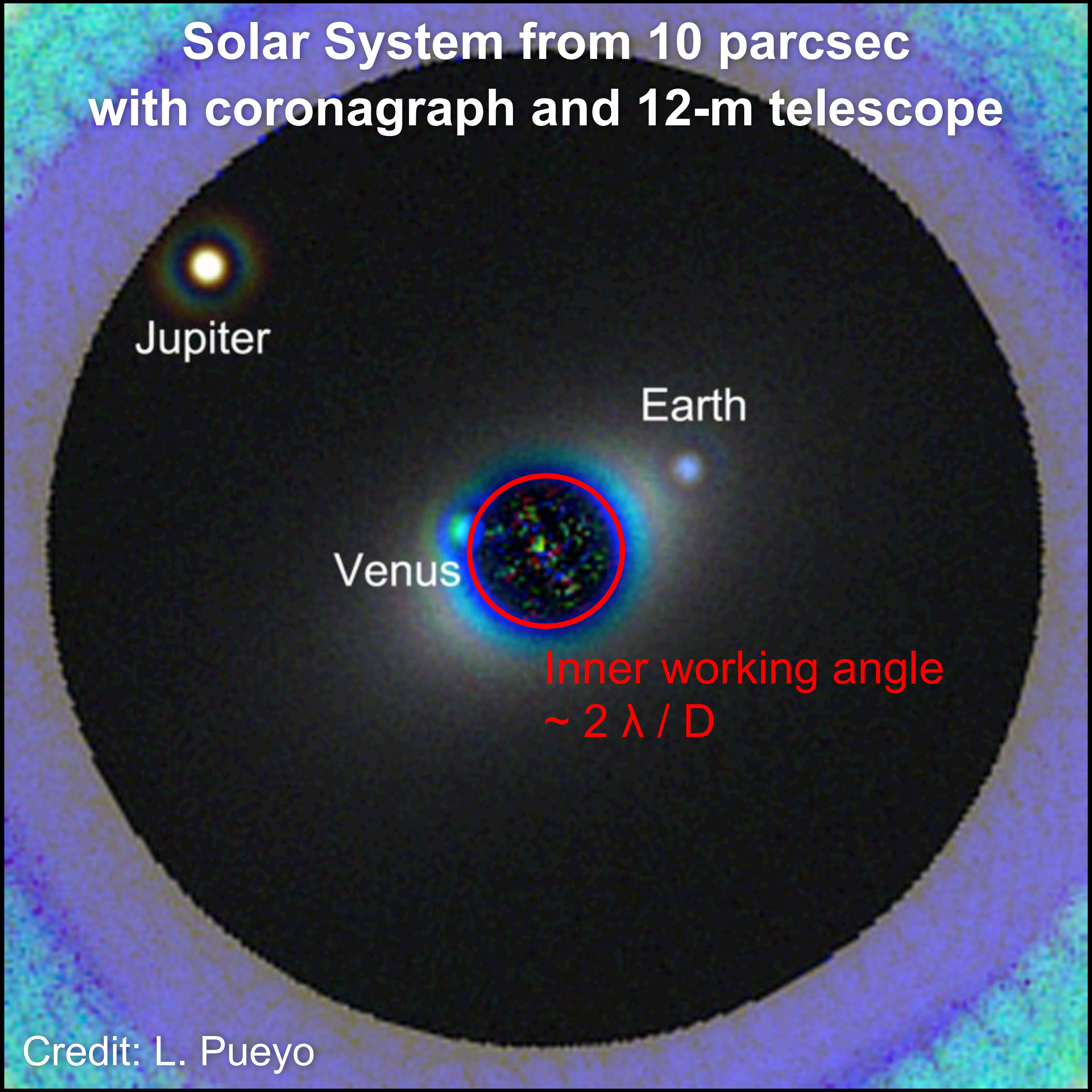


HST resolution 2.4-m

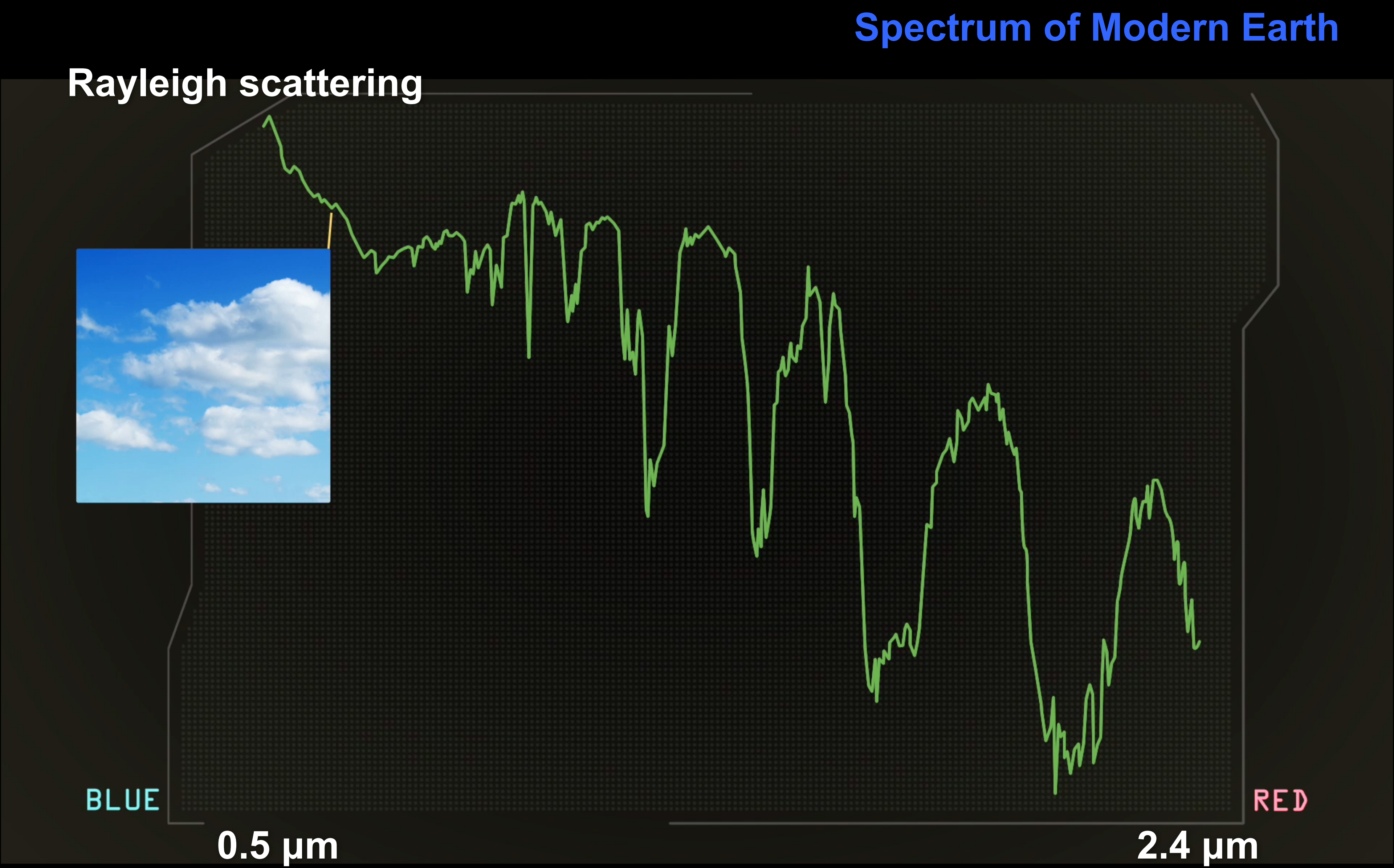
LUVOIR resolution 9-m 16-m

Credit: NASA/ESA/L. Roth/SWRI/University of Cologne

Imaging Earth 2.0

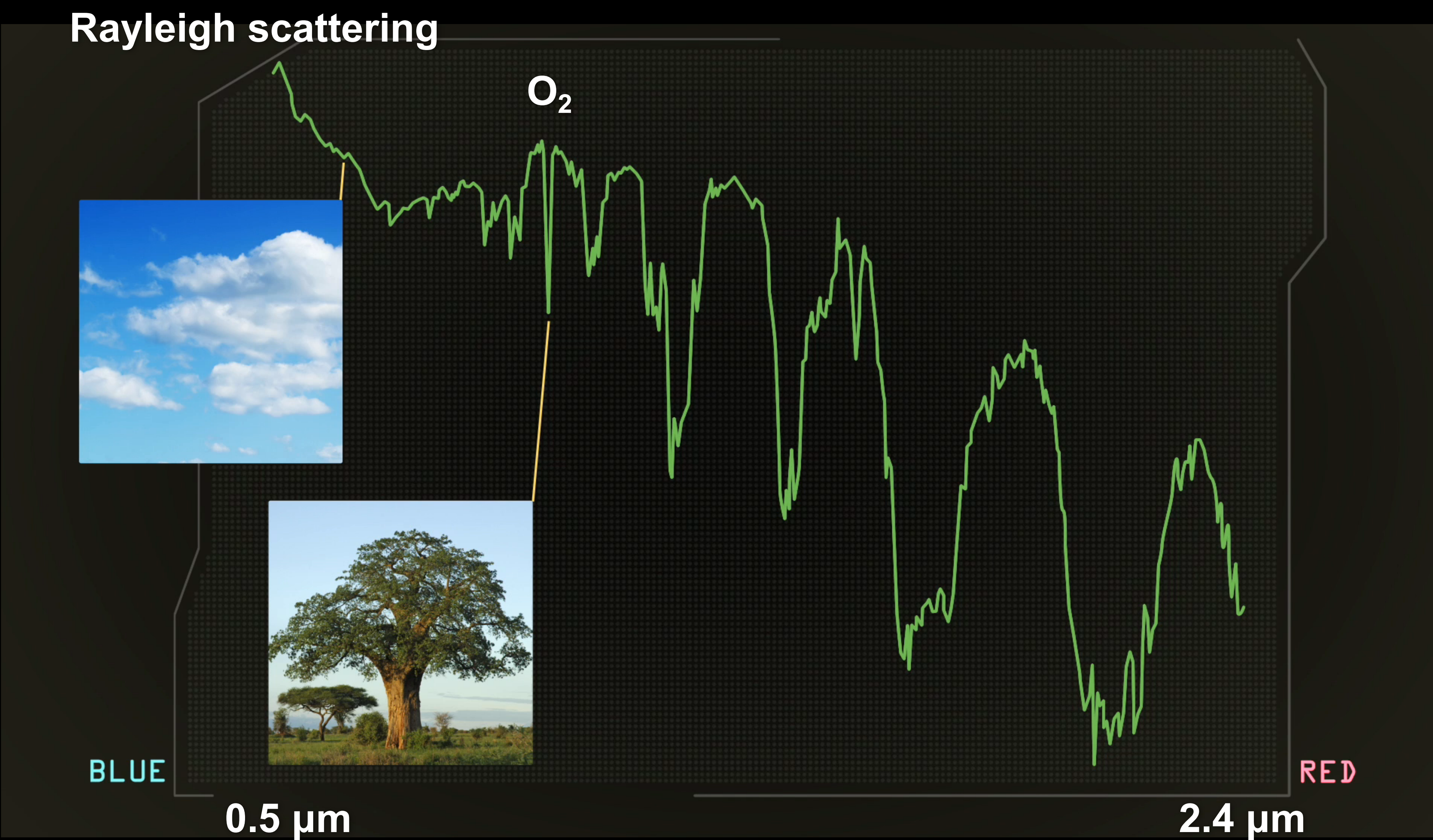


The search for life : biosignatures

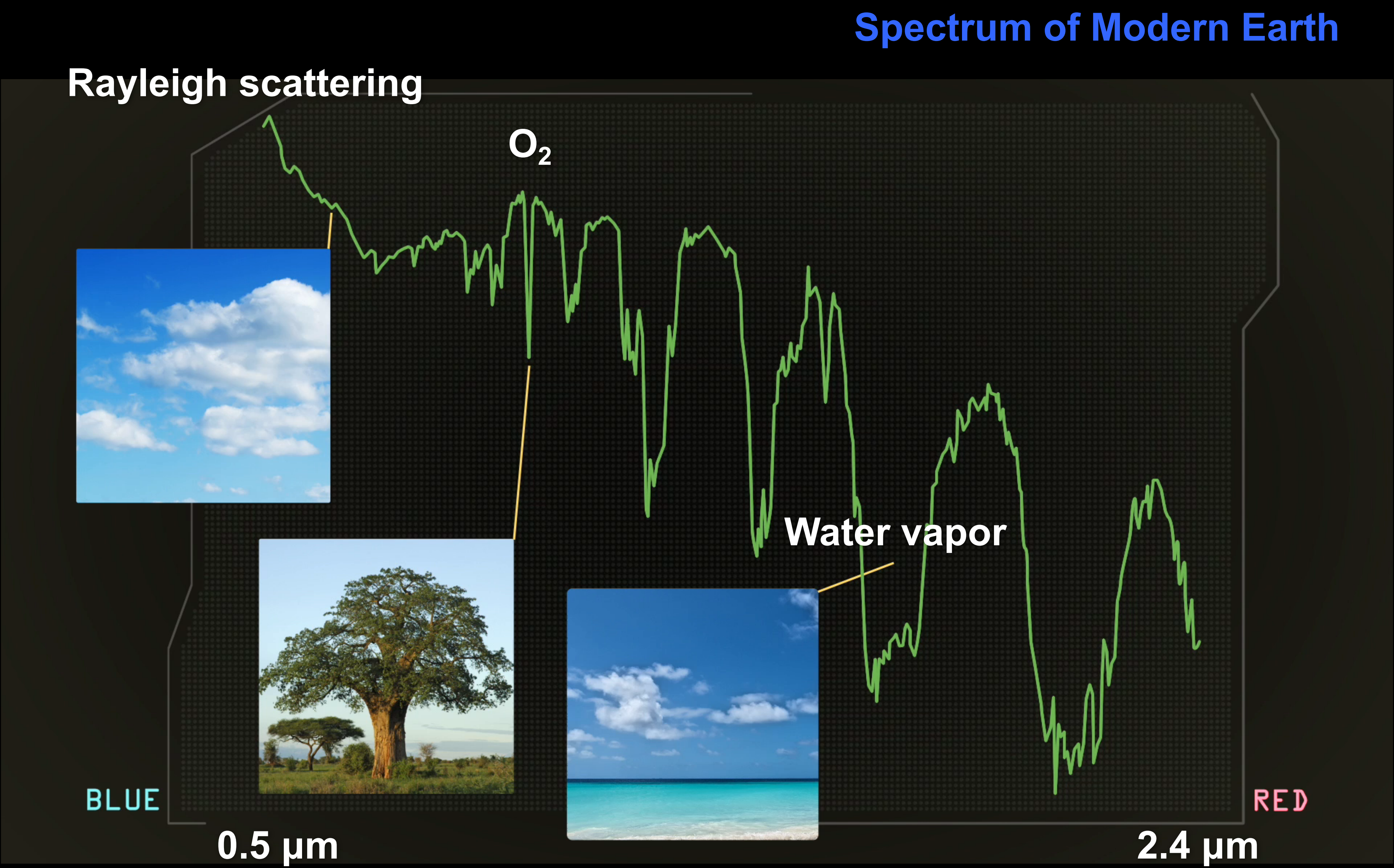


The search for life : biosignatures

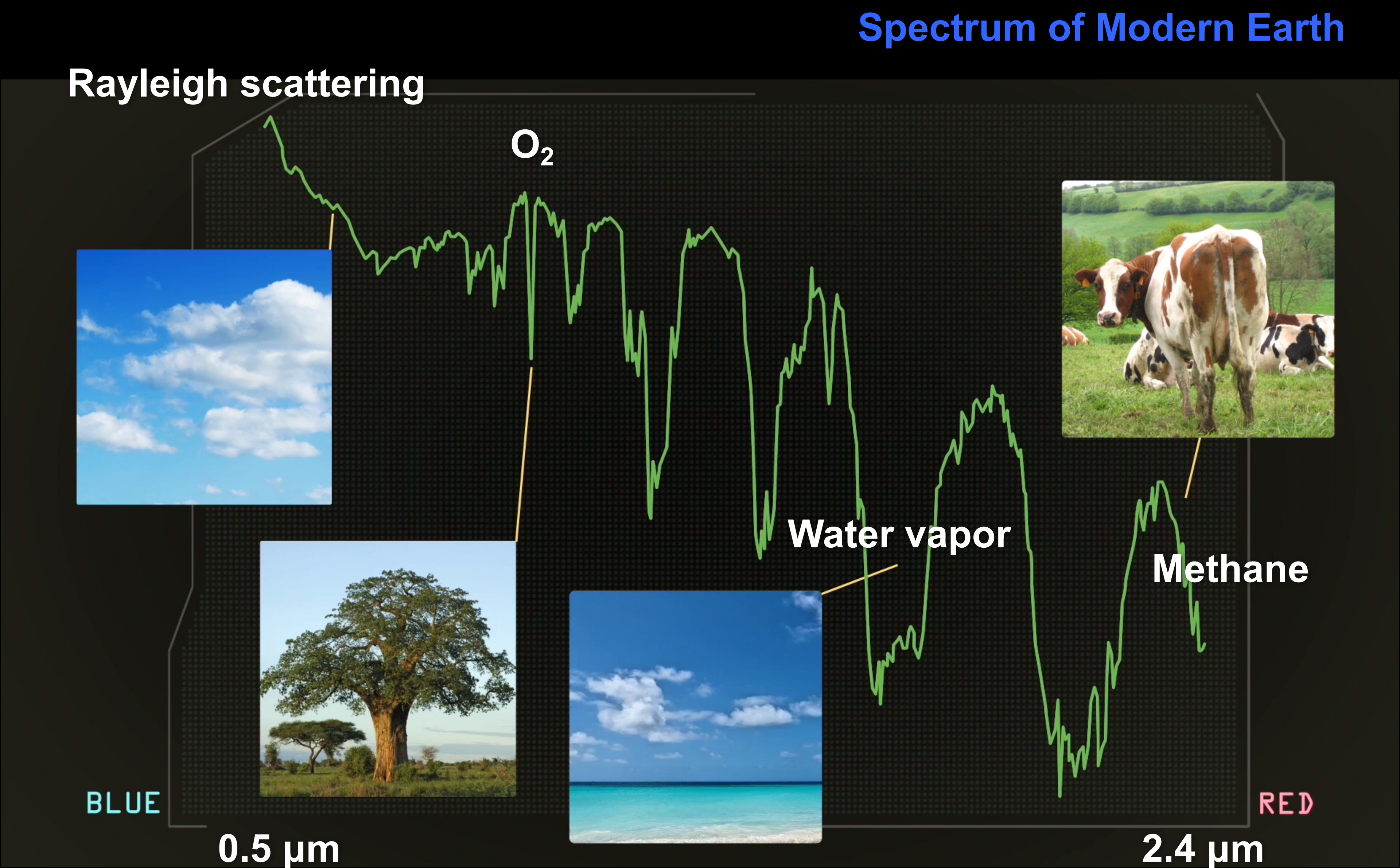
Spectrum of Modern Earth



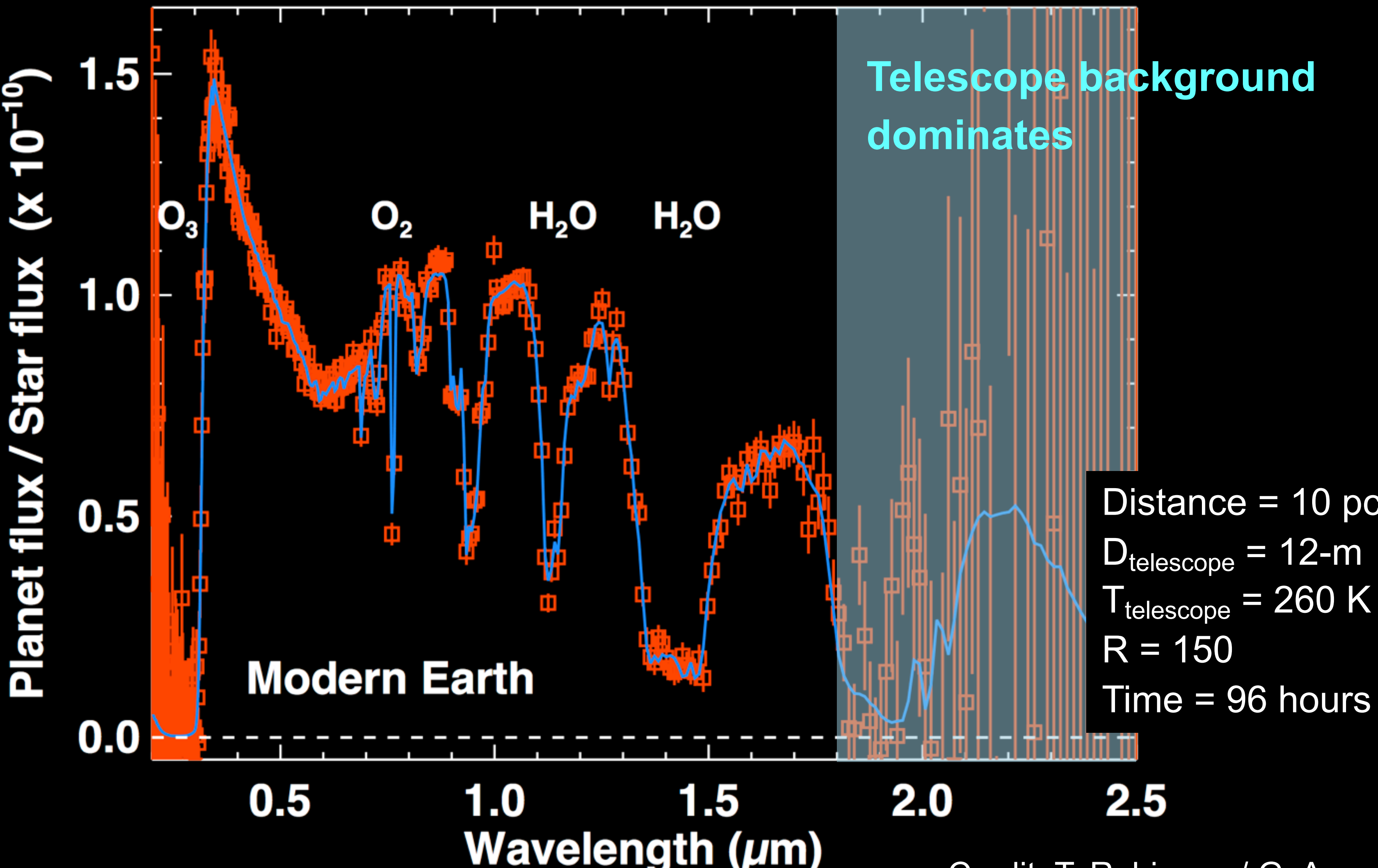
The search for life : biosignatures



The search for life : biosignatures

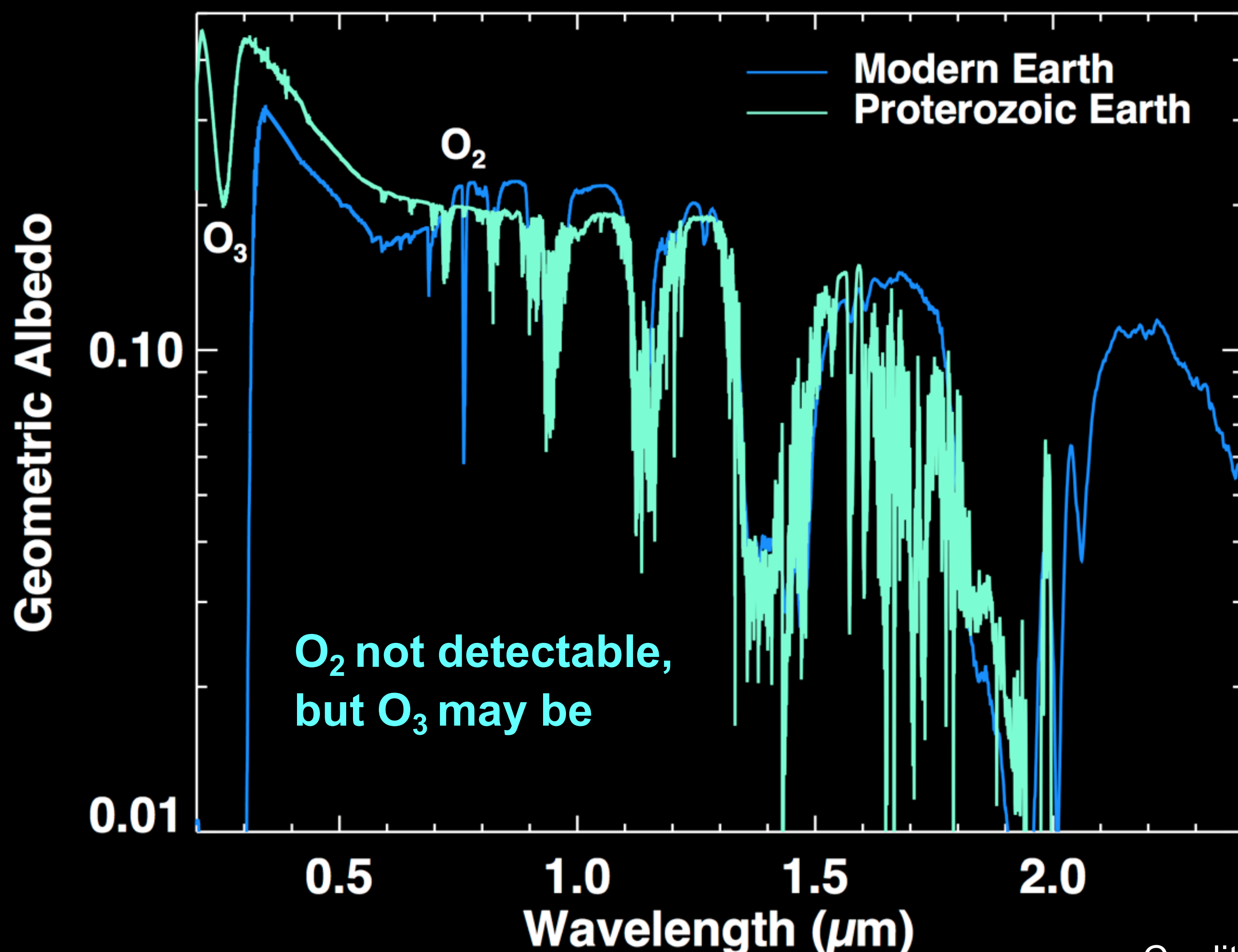


Reality check …



Credit: T. Robinson / G. Arney

Detecting biosignatures over Earth’s history



Credit: G. Arney

Confirming biosignatures

Access to many molecules is essential for understanding state of atmosphere

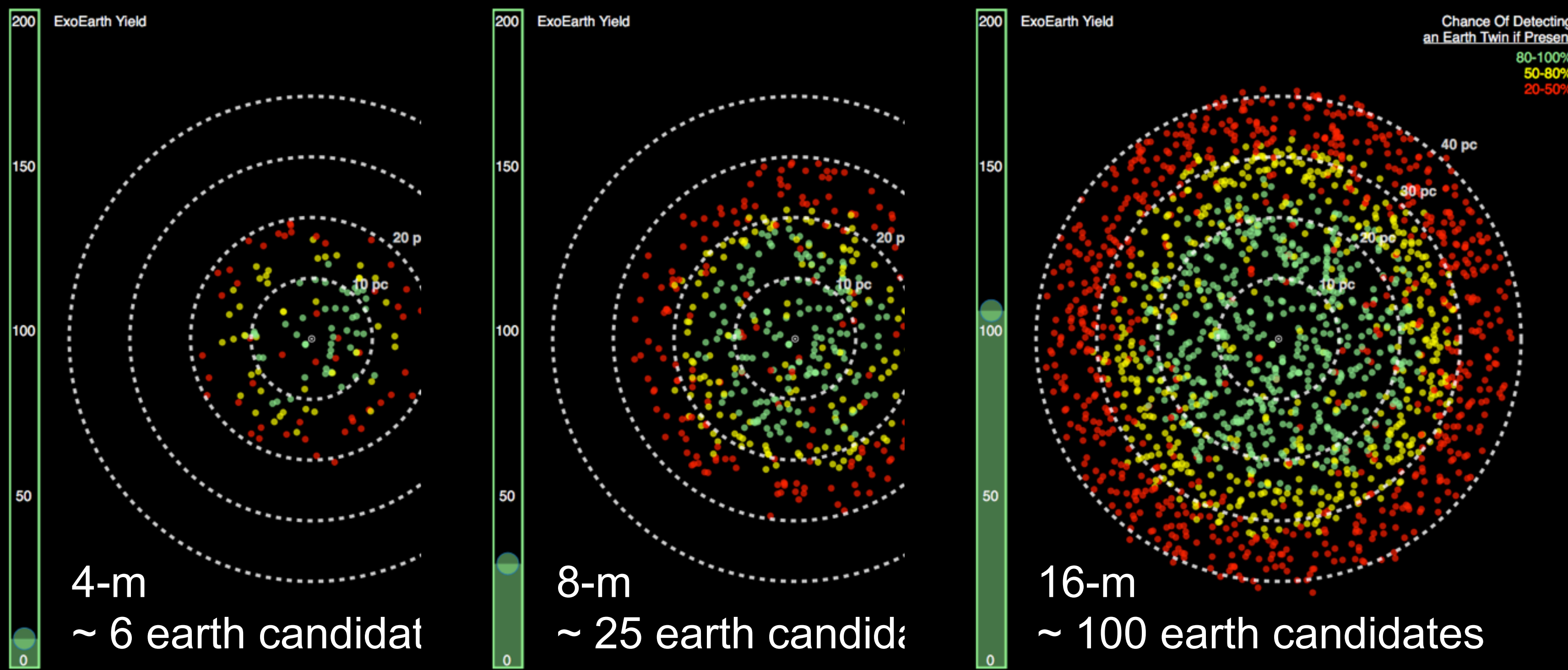
- 0.2 – 2.4 μm contains absorption bands of O_2, O_3, O_4, H_2O, CO, CO_2, CH_4

Access to multiple bands of same molecule aids abundance measurement

Broad spectral bandpass and UV spectrum of star can likely rule out false positive oxygen biosignatures

Since IWA ~ λ / D, observing hab. zone planets at longer wavelengths demands larger telescope aperture

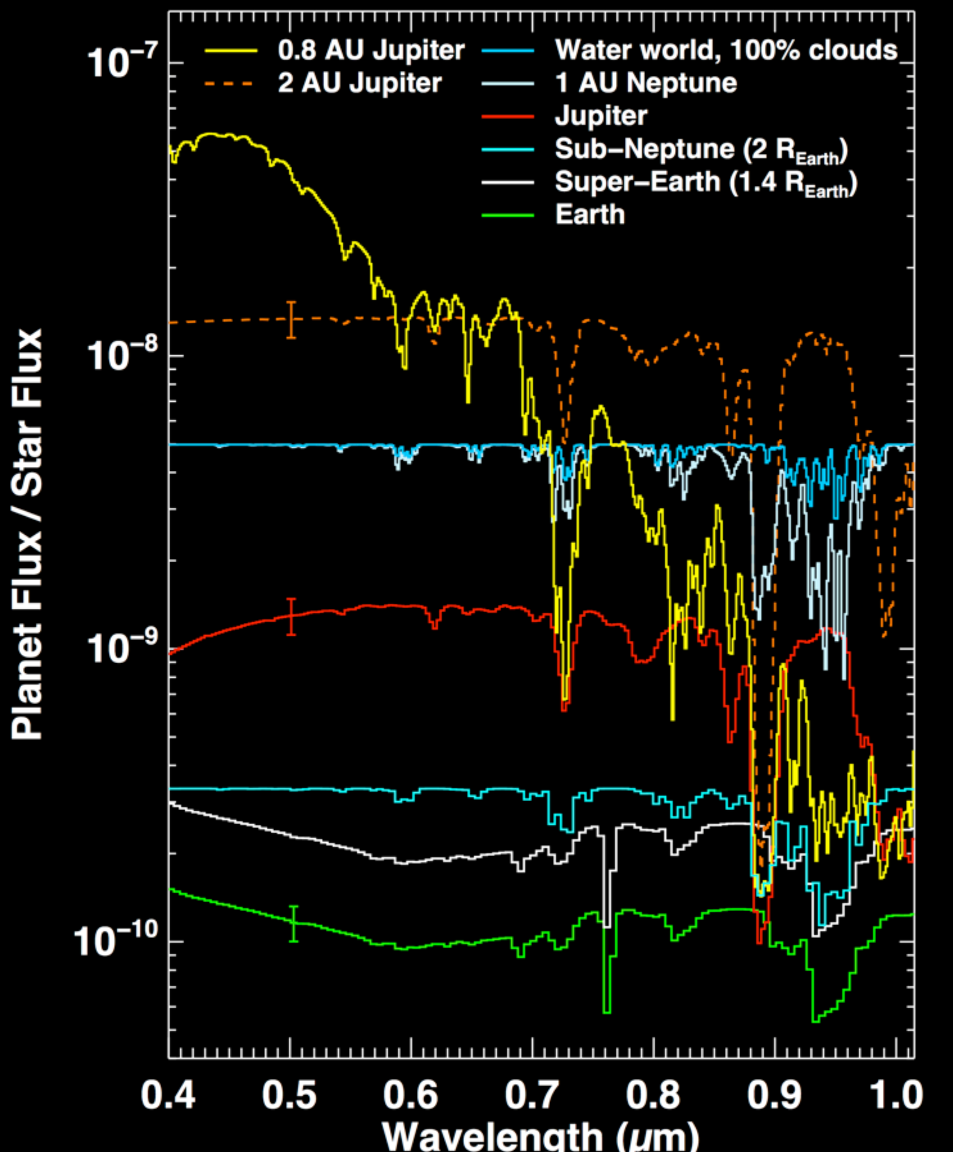
ExoEarth candidates as function of aperture

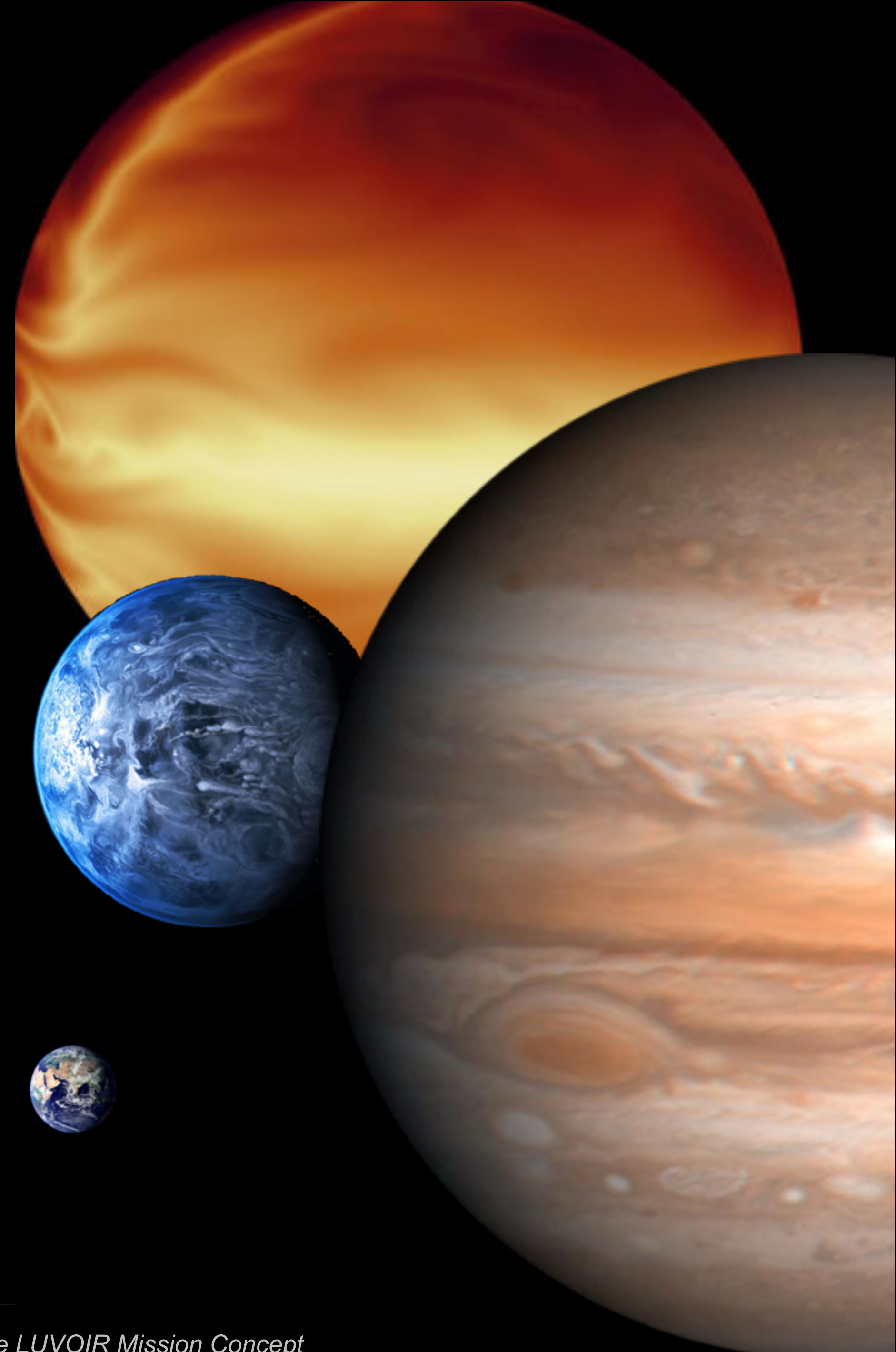


Stark et al. (2014)

If frequency of habitable conditions is 10%,
need 30 candidates to guarantee seeing one true exoEarth
(at 95% confidence)

The exoplanet zoo





The LUVOIR instruments

Observational challenge

Faint planets next to bright stars

Solution

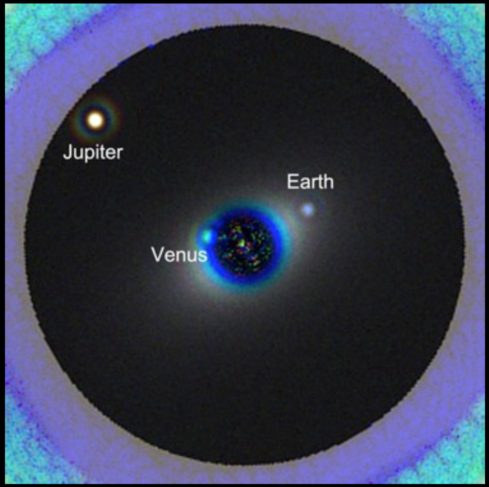
Optical / Near-IR Coronagraph

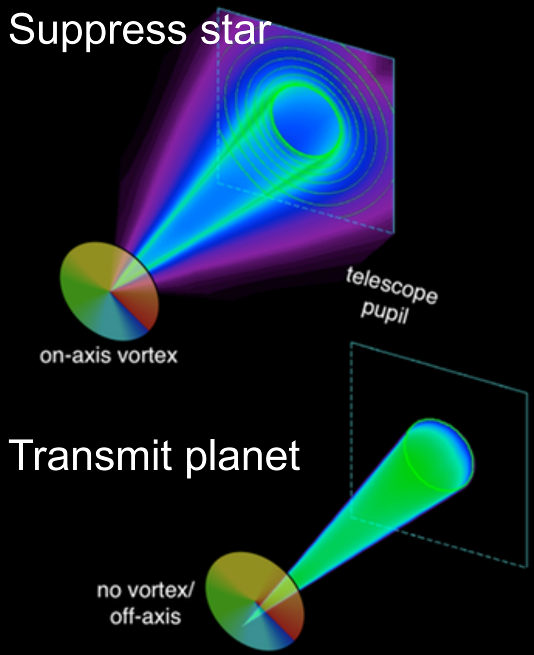
Contrast < 10^{-10} to observe exoEarths

Low resolution spectroscopy (R > 150)

Bandpass: 0.2 μm to 2.4 μm

Tech development via WFIRST coronagraph





Vector vortex coronagraph (Credit: D. Mawet)

The LUVOIR instruments

Observational challenge

No UV through Earth's atmosphere

Solution

LUMOS

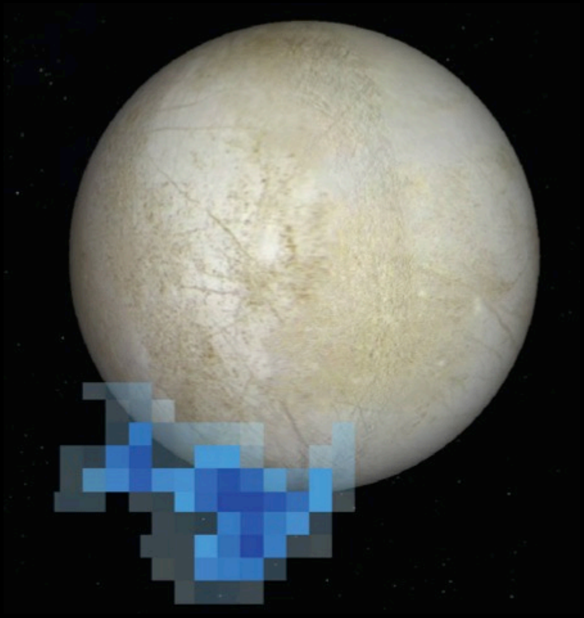
Far-UV to near-UV spectroscopy

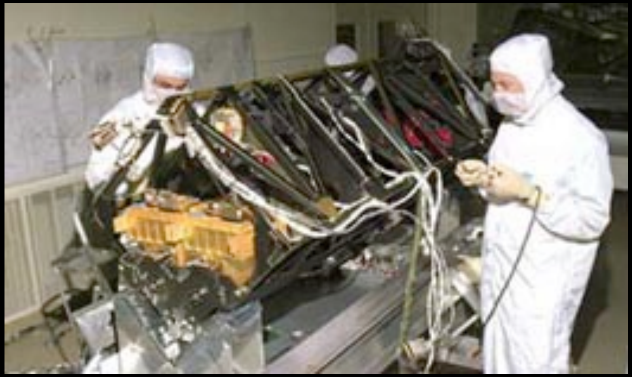
High resolution (R ~ 10^5) spectroscopy

Med. res. multi-object spectroscopy

Near-UV imaging

Major upgrade of HST STIS





HST STIS UV instrument

The LUVOIR instruments

Observational challenge

Imaging wide fields at high resolution

Solution

High-Definition Imager

4 – 6 arcmin field-of-view

Optical to near-IR bandpass

Possibly high precision astrometry to measure planet masses

Major upgrade of HST WFC3

HST Wide Field Camera 3

The LUVOIR instruments

Observational challenge

Measuring warm molecules present in Earth's atmosphere

Solution

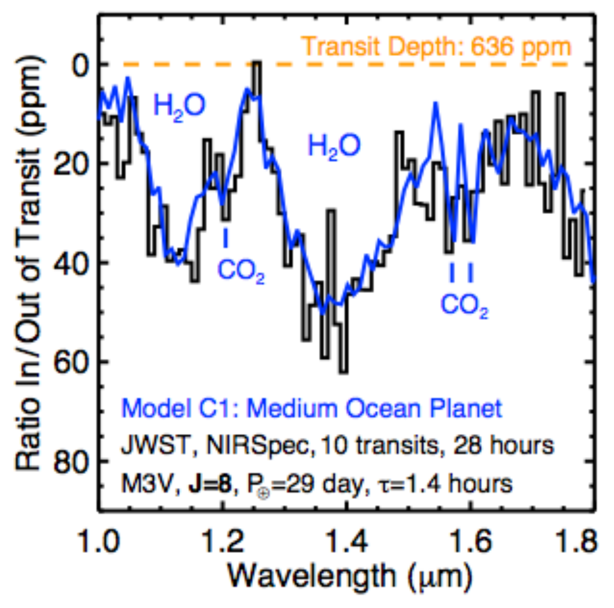
Optical / Near-IR Spectrograph

Multiple resolutions up to R ~ 10^5

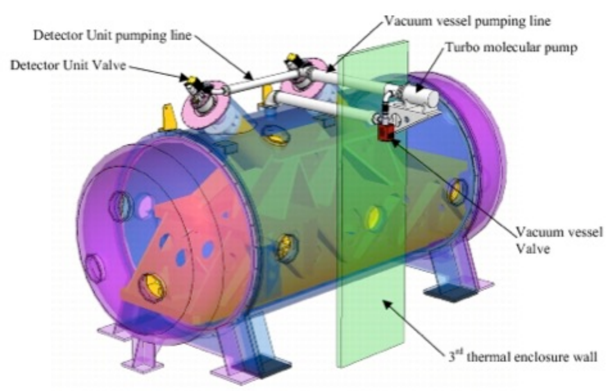
High photometric precision for transits

Possibly high precision RV to measure planet masses

Ground-based analogs in development



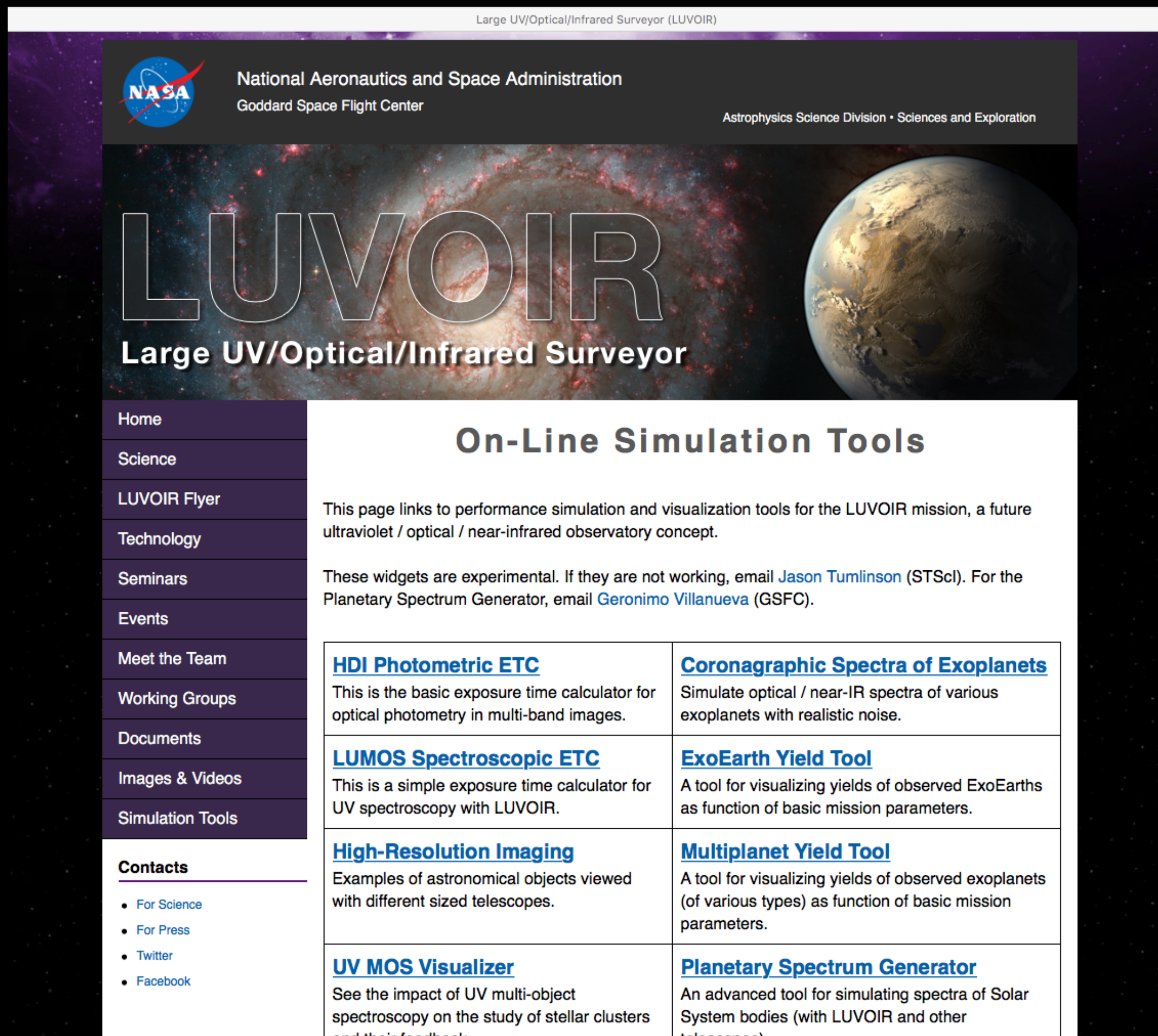
Credit: Natasha Batalha



ESPRESSO spectrograph for VLT (Credit: ESO)

LUVOIR online simulation tools in development

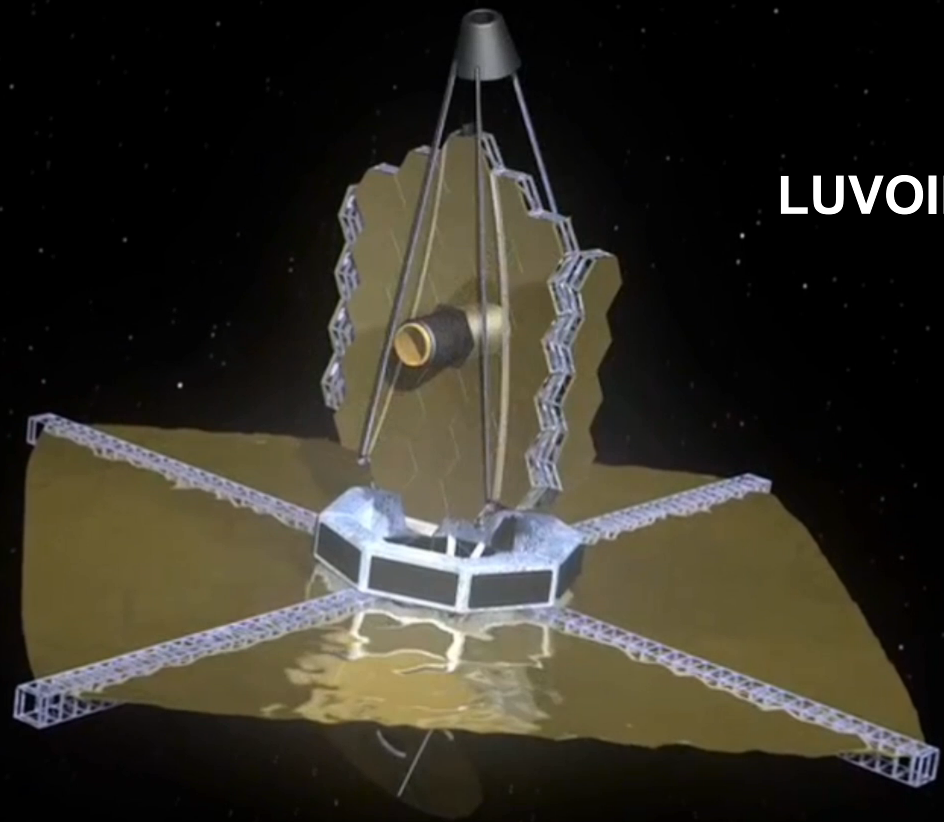
http://asd.gsfc.nasa.gov/luvoir/tools/



Technological challenges

Deployment of large segmented telescope

To be demonstrated by JWST



Technological challenges

Need heavy lift launch vehicle with large fairing

Suitable vehicles (SLS and commercial) in development

Compatibility of UV and coronagraphy

New lab work shows UV reflective mirrors are just fine for coronagraphy

Ultra-high contrast observations with a segmented telescope

Coronagraphs can be designed for segmented telescopes. Working hard to demonstrate needed system stability

Series of short, readable "LUVOIR Tech Notes" available at
http://asd.gsfc.nasa.gov/luvoir/tech/

How we're doing the study

Four large mission concept studies started in Jan 2016 to prepare for Astro2020 Decadal Survey

- LUVOIR
- Habitable Exoplanet Imaging Mission (HabEx)
- Origins Space Telescope (aka. Far-IR Surveyor)
- X-Ray Surveyor

Two LUVOIR mission architectures to be studied

- Aperture sizes chosen Nov 2016: ~ 16-m and ~ 9-m

Study office and engineering team at GSFC

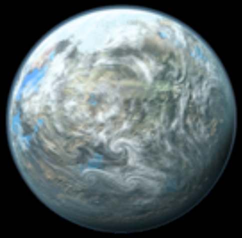
How we're doing the study

Science and Technology Definition Team

- 24 voting members from community
- 8 non-voting reps. of international space agencies

Six Community Working Groups

- Exoplanets
- Cosmic Origins
- Solar System
- Simulations
- Communications
- Technology



Four Instrument Teams

STDT voting members


Debra Fischer
(Yale)


Brad Peterson
(Ohio State / STScI)


Jacob Bean
(Chicago)


Daniela Calzetti
(U Mass)


Rebekah Dawson
(Penn State)


Courtney Dressing
(Caltech)


Lee Feinberg
(NASA GSFC)


Kevin France
(Colorado)


Olivier Guyon
(Arizona)


Walter Harris
(Arizona / LPL)


Mark Marley
(NASA Ames)


Leonidas Moustakas
(JPL)


John O'Meara
(St. Michael's)


Vikki Meadows
(Washington)


Ilaria Pascucci
(Arizona)


Marc Postman
(STScI)

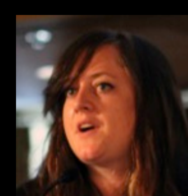

Laurent Pueyo
(STScI)


David Redding
(JPL)


Jane Rigby
(NASA GSFC)


Aki Roberge
(NASA GSFC)


David Schiminovich
(Columbia)


Britney Schmidt
(Georgia Tech)

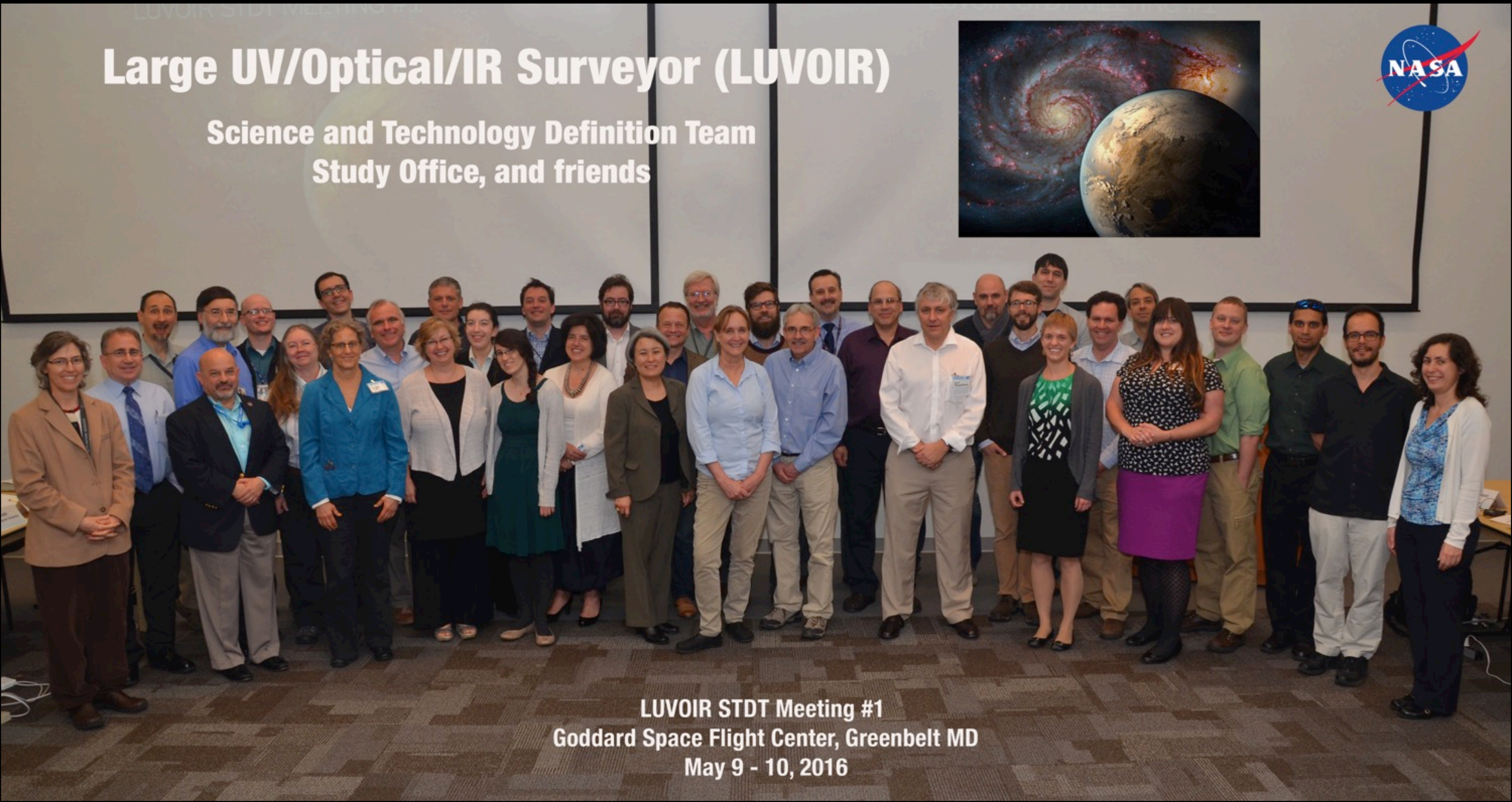

Karl Stapelfeldt
(JPL)


Jason Tumlinson
(STScI)

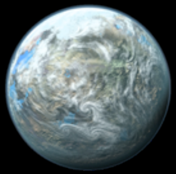
Face-to-face meetings

3rd meeting Nov 9 – 10, 2016 in New Haven CT, joint w/ HabEx team

Observers welcome at all LUVOIR meetings & telecons



Difference between LUVOIR and HabEx ?



Both LUVOIR and HabEx have two primary science goals

- Habitable exoplanets & biosignatures
- Broad range of general astrophysics

The two architectures will be driven by difference in focus

- For LUVOIR, both goals are on equal footing. LUVOIR will be a general purpose "great observatory", a successor to HST and JWST in the ~ 8 – 16 m class
- HabEx will be optimized for exoplanet imaging, but also enable a range of general astrophysics. It is a more focused mission in the ~ 4 – 8 m class

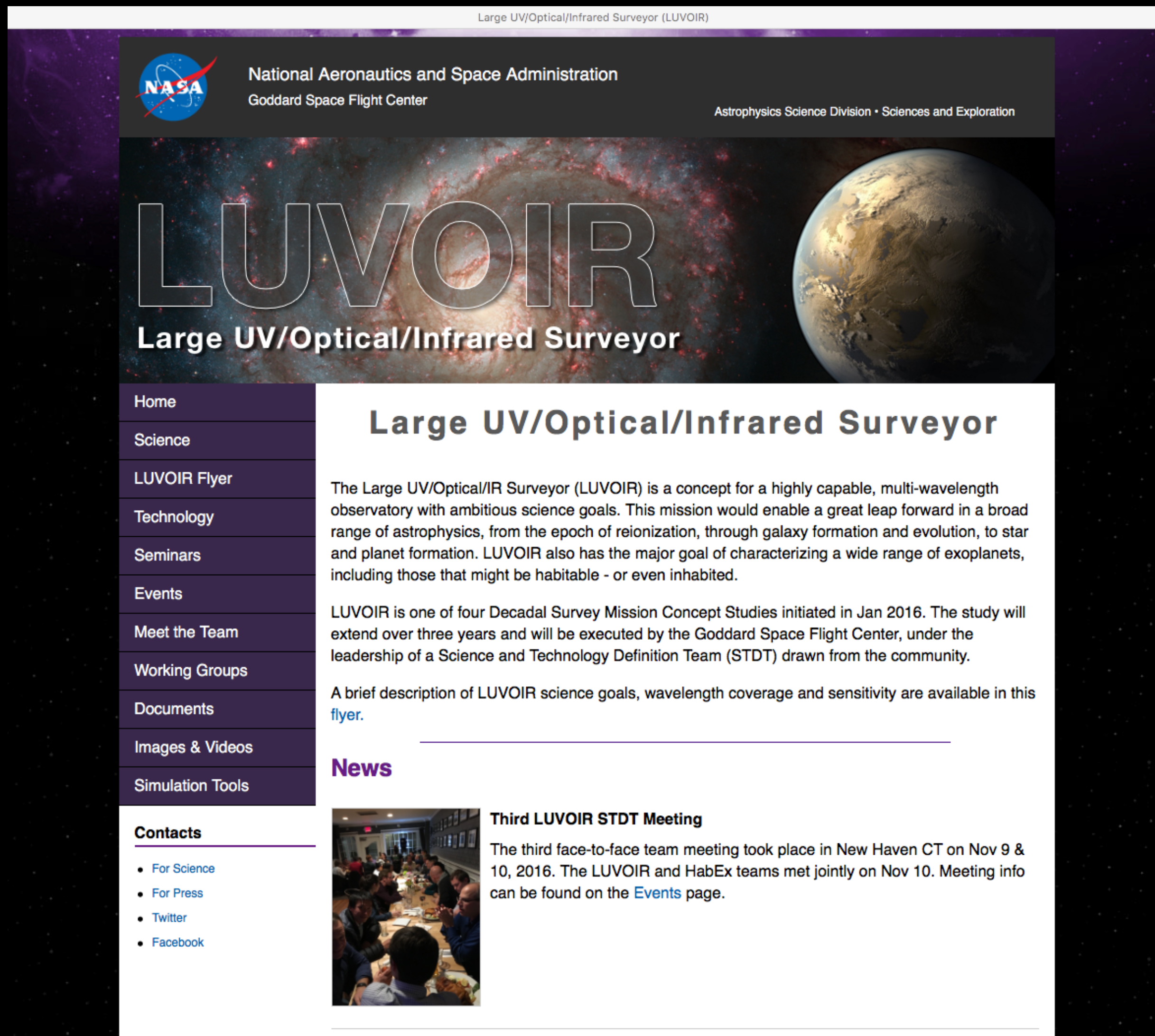
Similar exoplanet goals, differing in quantitative levels of ambition

- HabEx will *explore* the nearest stars to "search for" signs of habitability & biosignatures via direct detection of reflected light
- LUVOIR will *survey* more stars to "constrain the frequency" of habitability & biosignatures and produce a statistically meaningful sample of exoEarths

The two studies will provide a continuum of options for a range of futures

Get involved with LUVOIR

http://asd.gsfc.nasa.gov/luvoir/



Summary

LUVOIR has multiple primary science goals

① Habitable exoplanets & biosignatures

② Broad range of general astrophysics and Solar System observations

Challenge is to blend goals into single powerful mission

LUVOIR will provide a statistical study of Goal 1, factors of ~ 100 increased science grasp over Hubble for Goal 2

Wide range of capabilities to enable decades of future investigations and unexpected discoveries