



BIG BANG TO BIOSIGNATURES: THE LUVOIR MISSION CONCEPT

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NASA Goddard Space Flight Center

LUVOIR Workshop

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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

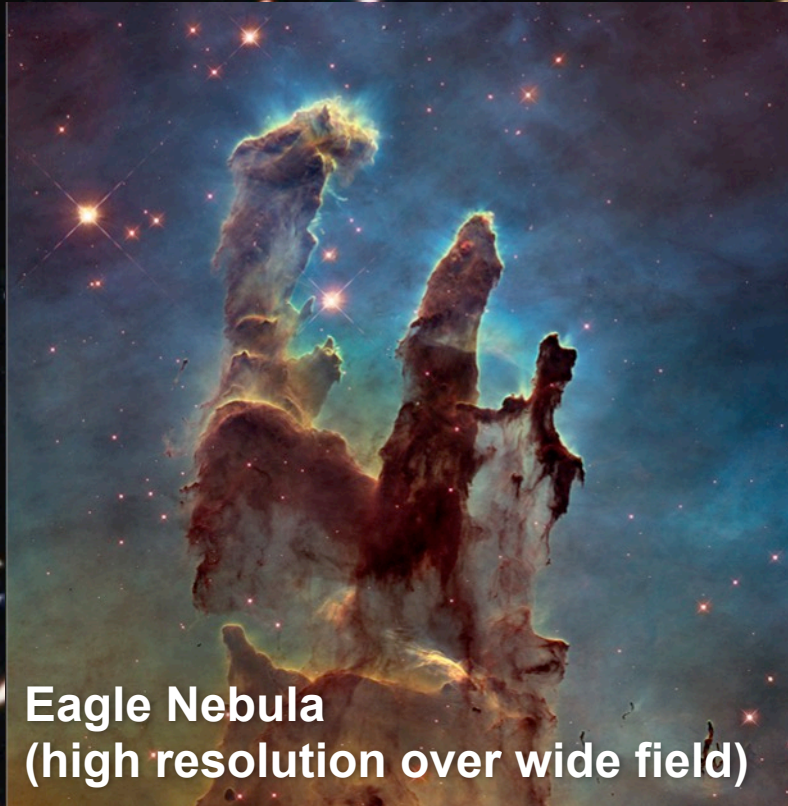
- Broad science capabilities
- Far-UV to Near-IR bandpass
- ~ 8 – 16 m aperture diameter
- Suite of imagers and spectrographs
- Serviceable and upgradable

“Space Observatory for the 21st Century”

Decades of science

Ability to answer questions we have not yet conceived

Imagine astronomy without Hubble ...



Hubble Ultra Deep Field
(ultra-deep imaging)



Imagine astronomy with LUVOIR ...

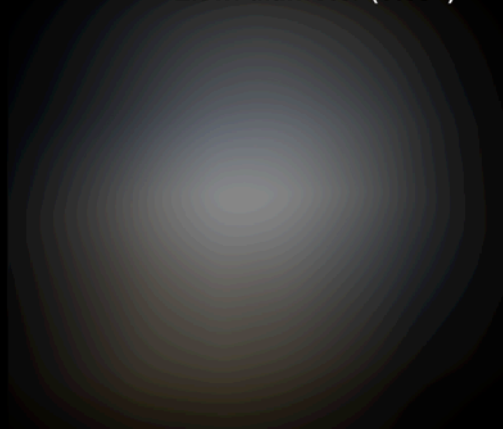
Hypothetical planet "Nine"

Located at ~ 1000 AU
Diameter of 40,000 km



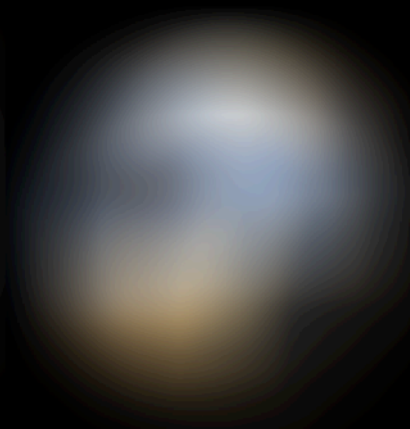
Hubble Space Telescope (HST)

Best optical resolution (2016)
2.5m diameter (0.05")



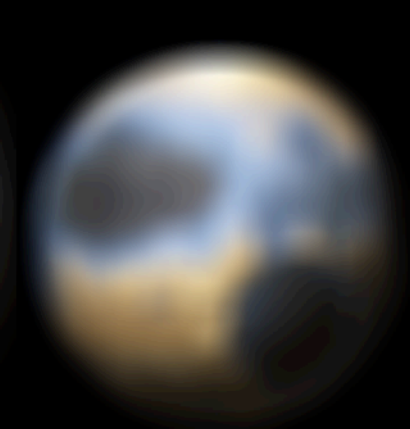
LUVOIR

6m diameter
Resolution $\sim 0.02''$



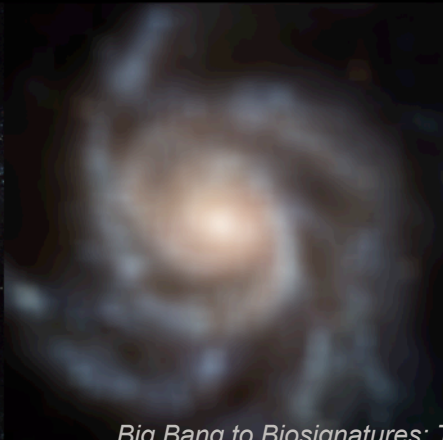
LUVOIR

18m diameter
Resolution $\sim 0.007''$

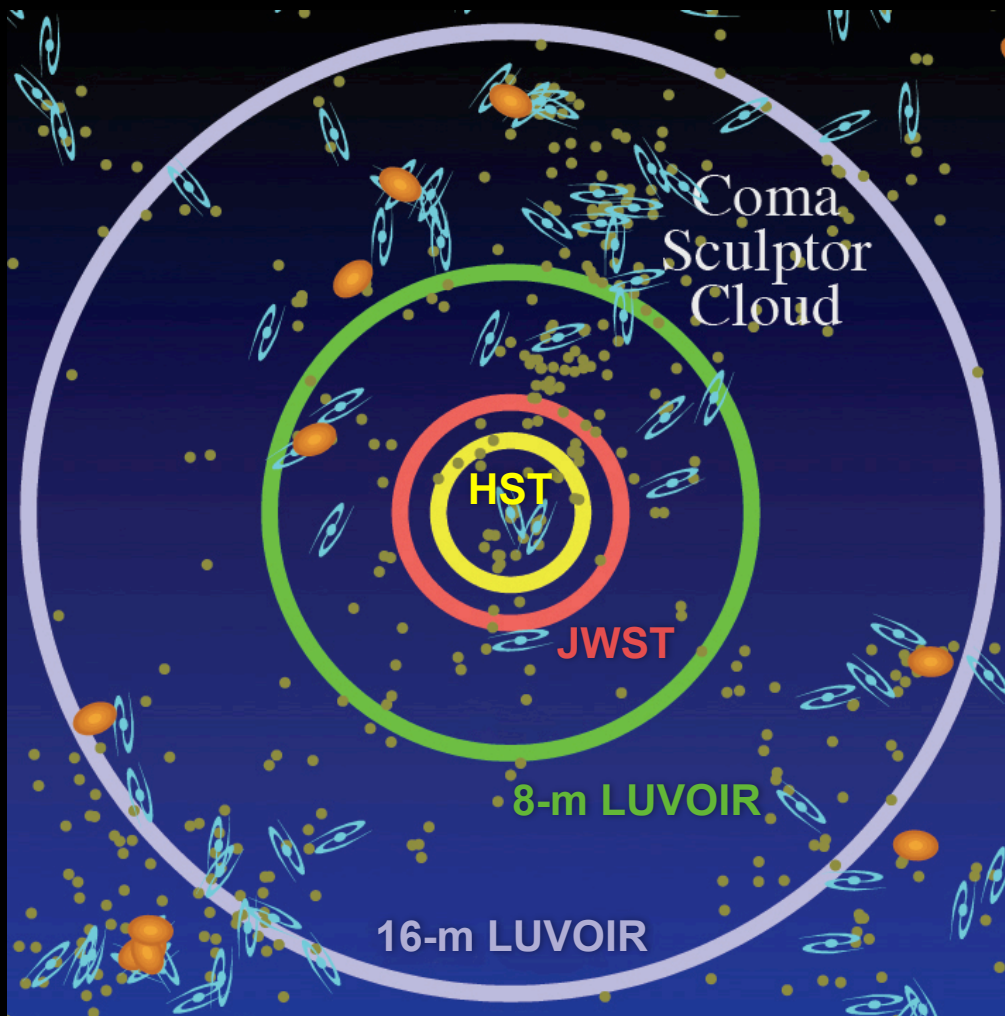


*Clear Identification of
local differences*

*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

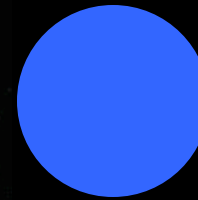
Need LUVOIR to reach the nearest giant elliptical galaxies

-  = 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



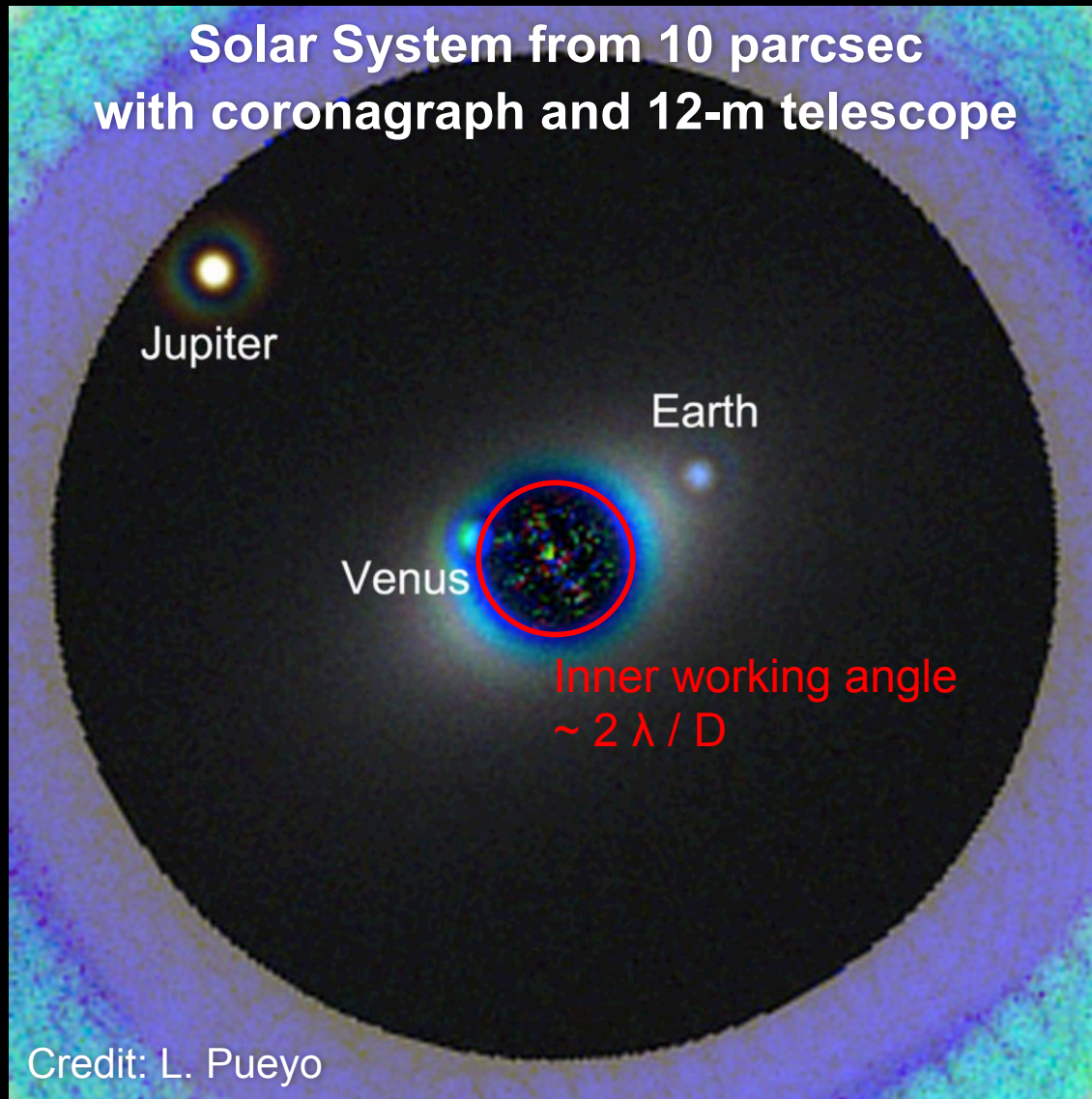
LUVUOIR
resolution
9-m



16-m

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

Imaging Earth 2.0



The search for life : biosignatures

Spectrum of Modern Earth

Rayleigh scattering



BLUE

0.5 μm

RED

2.4 μm

The search for life : biosignatures

Spectrum of Modern Earth

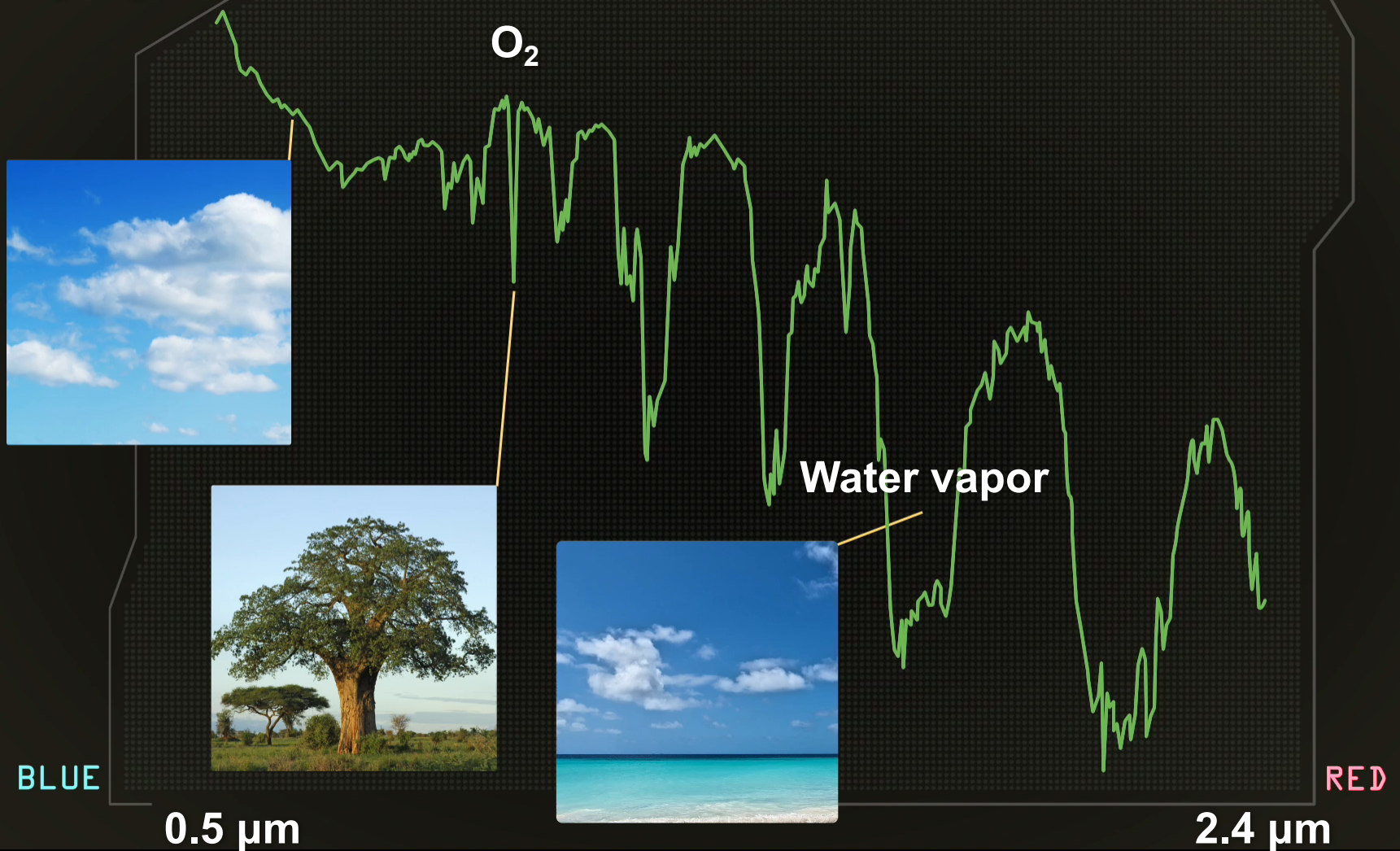
Rayleigh scattering



The search for life : biosignatures

Spectrum of Modern Earth

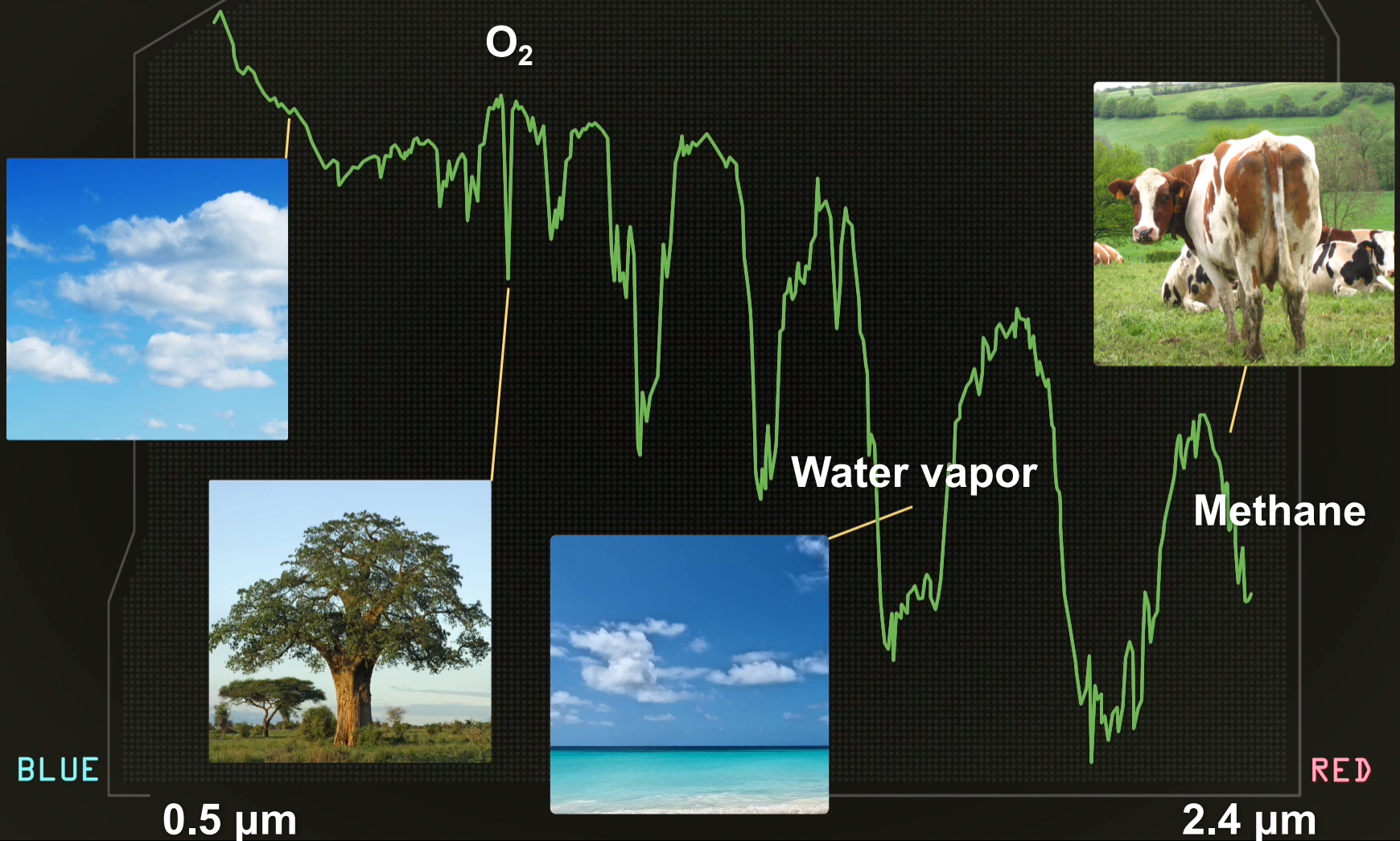
Rayleigh scattering



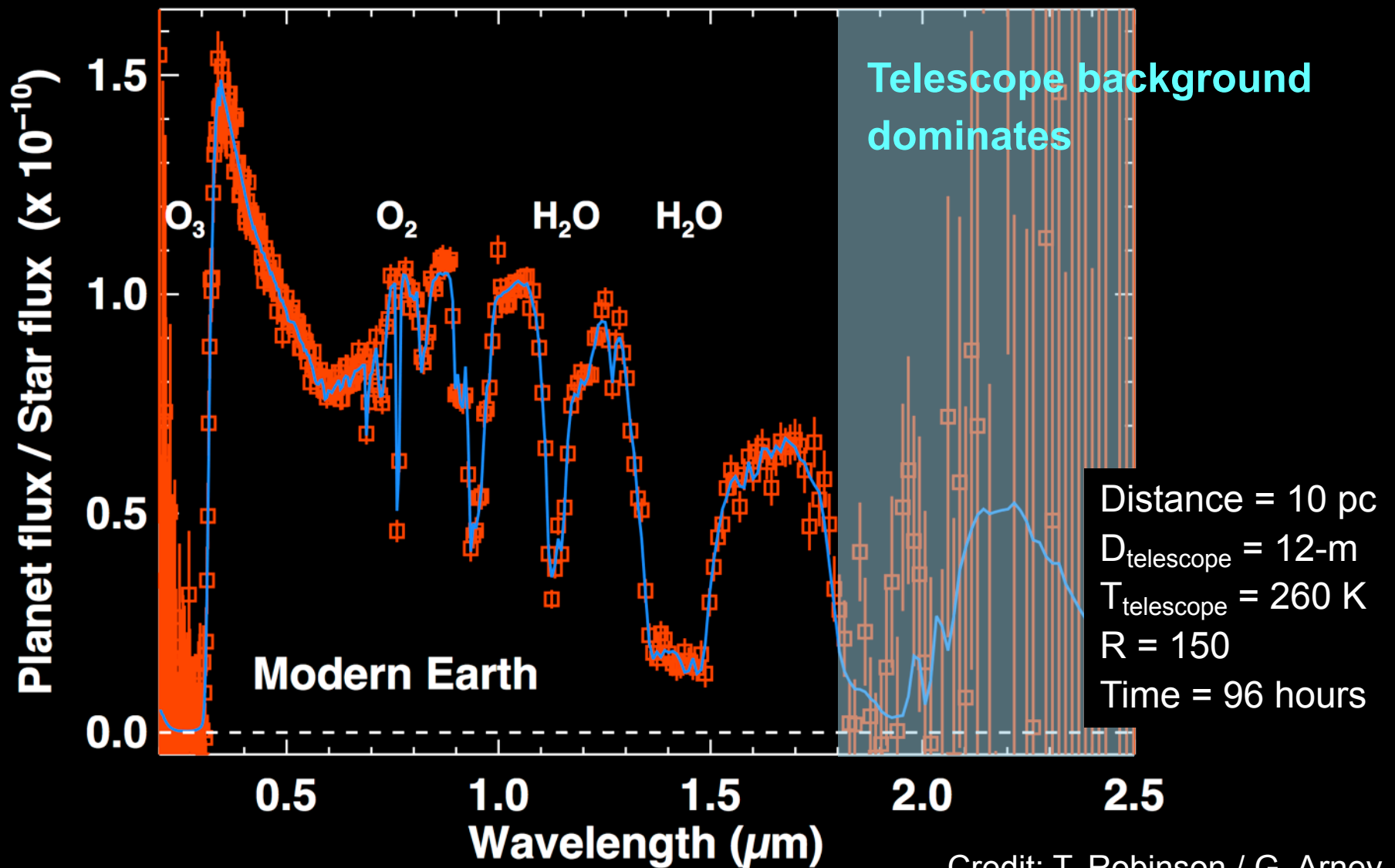
The search for life : biosignatures

Spectrum of Modern Earth

Rayleigh scattering

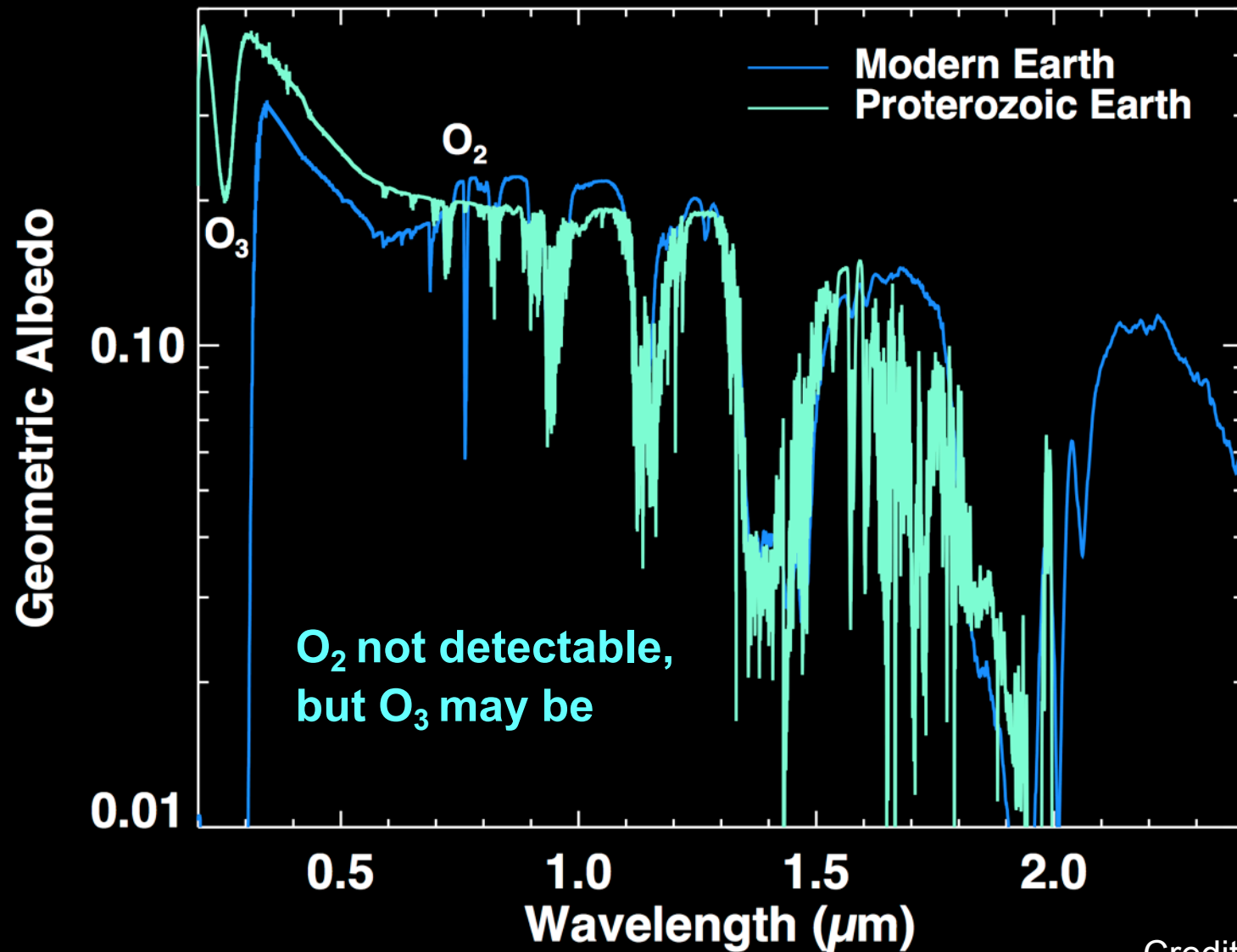


Reality check ...



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

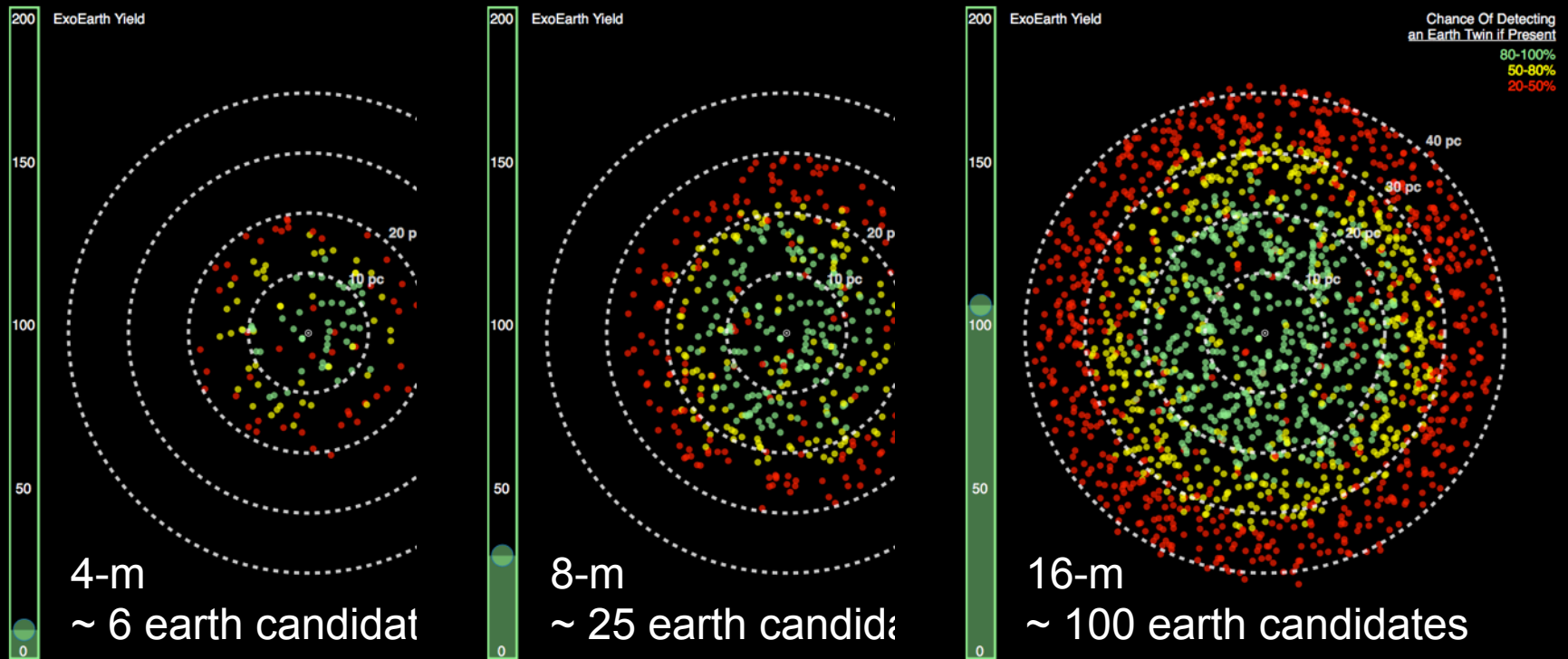
- 0.2 – 2.4 μm contains absorption bands of O_2 , O_3 , O_4 , H_2O , CO , CO_2 , CH_4

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 $\text{IWA} \sim \lambda / D$, observing hab. zone planets at longer wavelengths demands larger telescope aperture

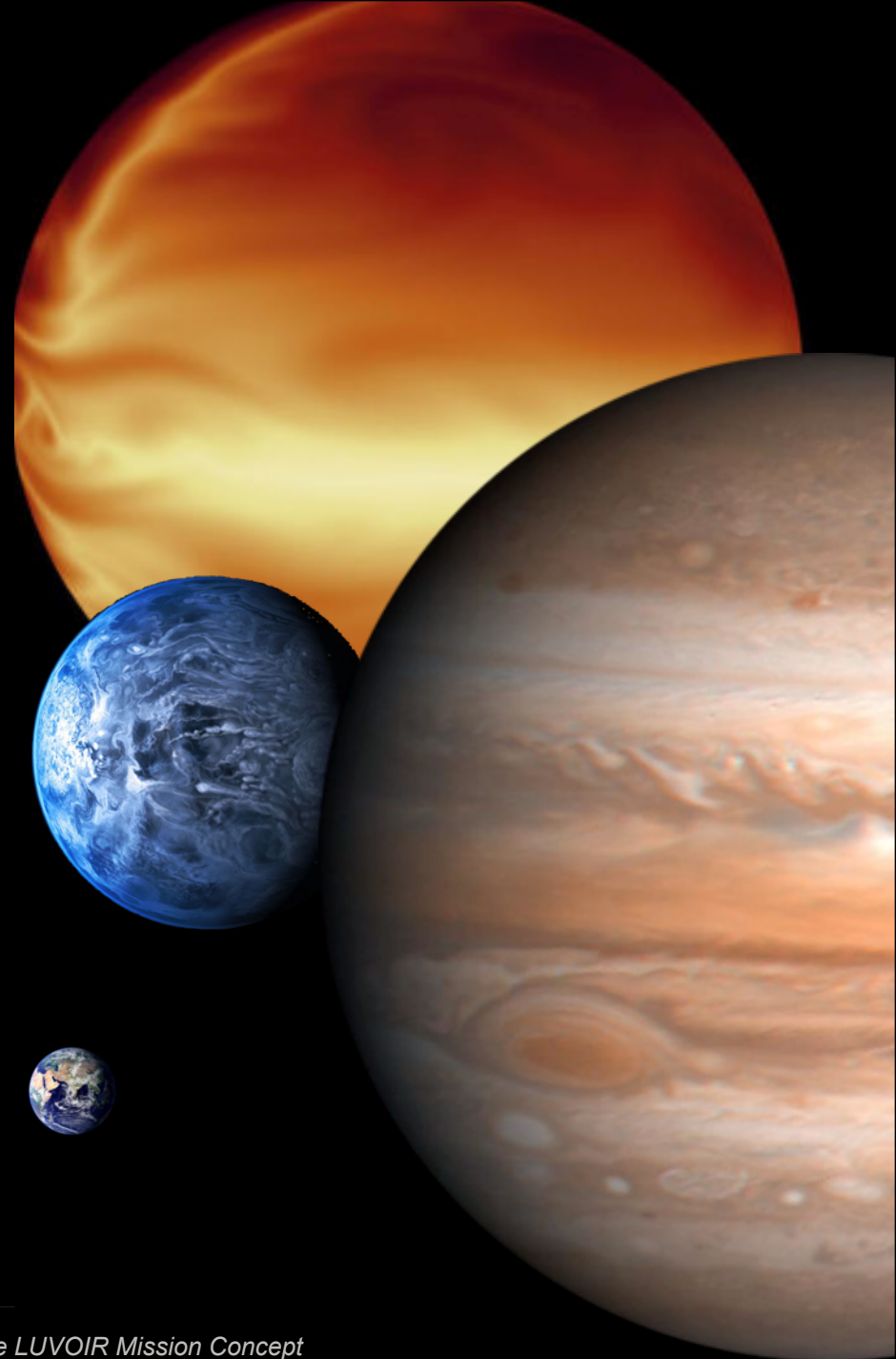
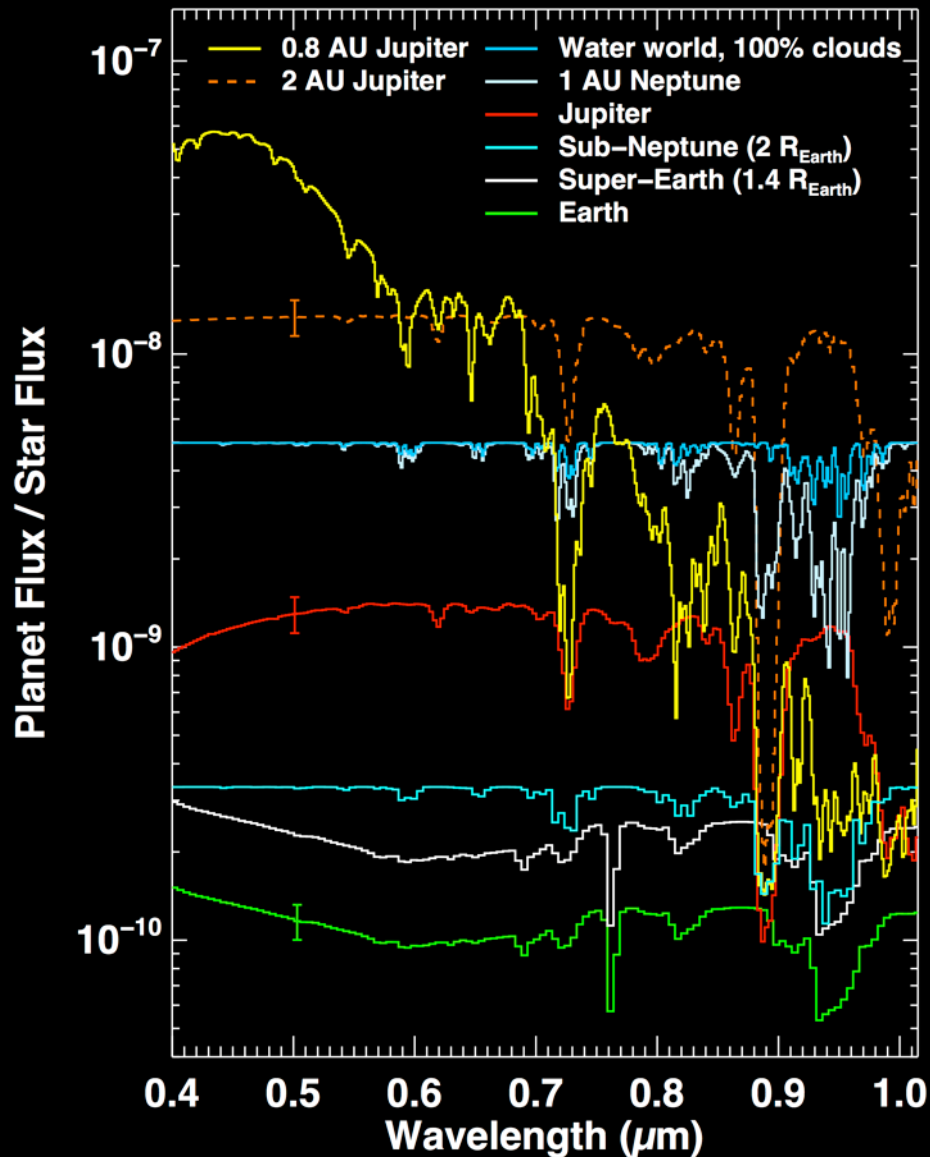
ExoEarth candidates as function of aperture



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

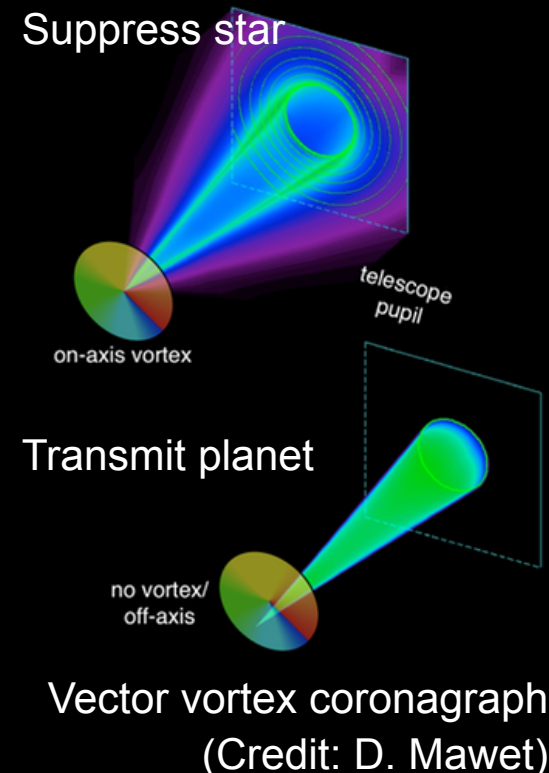
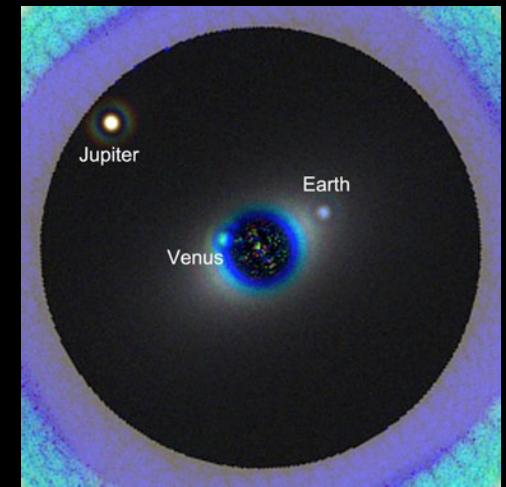
Optical / Near-IR Coronagraph

Contrast $< 10^{-10}$ to observe exoEarths

Low resolution spectroscopy ($R > 150$)

Bandpass: $0.2 \mu\text{m}$ to $2.4 \mu\text{m}$

Tech development via WFIRST
coronagraph



The LUVOIR instruments

Observational challenge

No UV through Earth's atmosphere

Solution

LUMOS

Far-UV to near-UV spectroscopy

High resolution ($R \sim 10^5$) 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

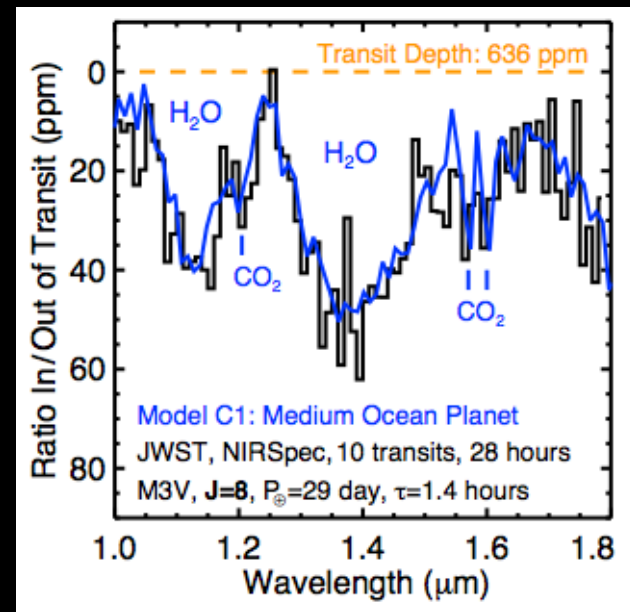
Optical / Near-IR Spectrograph

Multiple resolutions up to $R \sim 10^5$

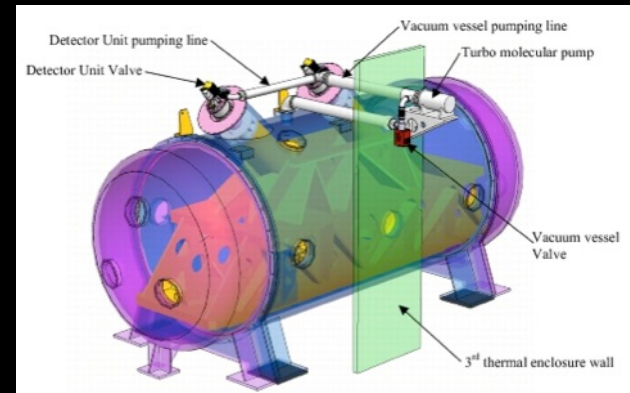
High photometric precision for transits

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/>

Large UV/Optical/Infrared Surveyor (LUVOIR)

 National Aeronautics and Space Administration
Goddard Space Flight Center

Astrophysics Science Division • Sciences and Exploration



LUVOIR

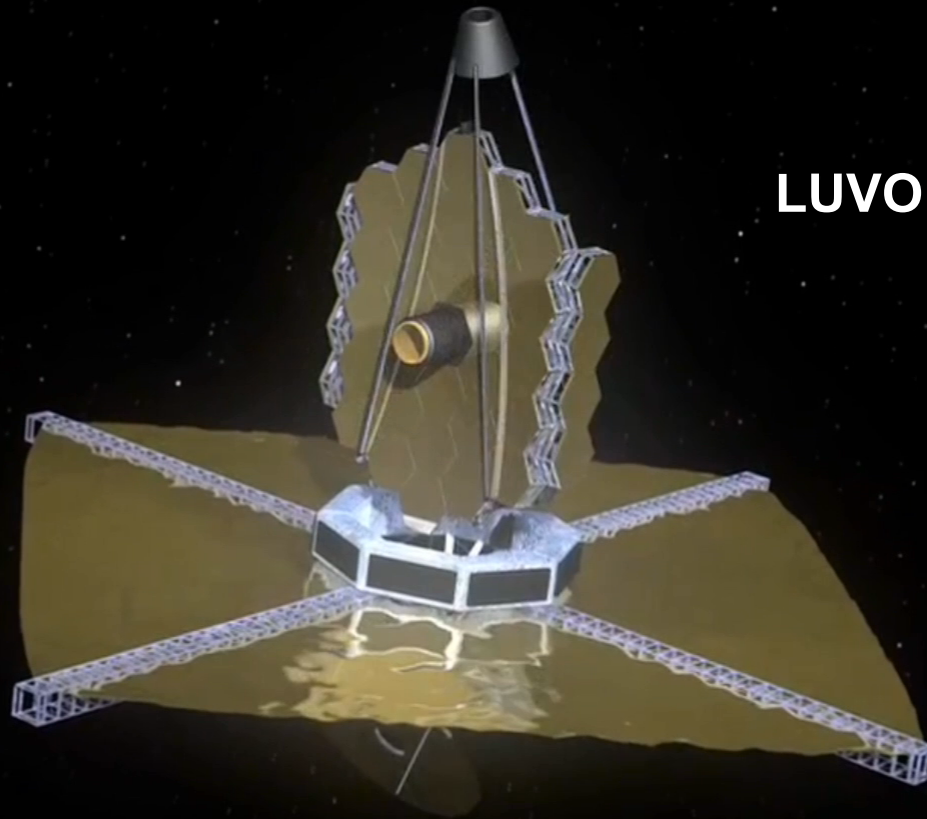
Large UV/Optical/Infrared Surveyor

Home	<h3>On-Line Simulation Tools</h3> <p>This page links to performance simulation and visualization tools for the LUVOIR mission, a future ultraviolet / optical / near-infrared observatory concept.</p> <p>These widgets are experimental. If they are not working, email Jason Tumlinson (STScI). For the Planetary Spectrum Generator, email Geronimo Villanueva (GSFC).</p> <table border="1"><tr><td>HDI Photometric ETC This is the basic exposure time calculator for optical photometry in multi-band images.</td><td>Coronagraphic Spectra of Exoplanets Simulate optical / near-IR spectra of various exoplanets with realistic noise.</td></tr><tr><td>LUMOS Spectroscopic ETC This is a simple exposure time calculator for UV spectroscopy with LUVOIR.</td><td>ExoEarth Yield Tool A tool for visualizing yields of observed ExoEarths as function of basic mission parameters.</td></tr><tr><td>High-Resolution Imaging Examples of astronomical objects viewed with different sized telescopes.</td><td>Multiplanet Yield Tool A tool for visualizing yields of observed exoplanets (of various types) as function of basic mission parameters.</td></tr><tr><td>UV MOS Visualizer See the impact of UV multi-object spectroscopy on the study of stellar clusters and their feedback.</td><td>Planetary Spectrum Generator An advanced tool for simulating spectra of Solar System bodies (with LUVOIR and other telescopes).</td></tr></table>	HDI Photometric ETC This is the basic exposure time calculator for optical photometry in multi-band images.	Coronagraphic Spectra of Exoplanets Simulate optical / near-IR spectra of various exoplanets with realistic noise.	LUMOS Spectroscopic ETC This is a simple exposure time calculator for UV spectroscopy with LUVOIR.	ExoEarth Yield Tool A tool for visualizing yields of observed ExoEarths as function of basic mission parameters.	High-Resolution Imaging Examples of astronomical objects viewed with different sized telescopes.	Multiplanet Yield Tool A tool for visualizing yields of observed exoplanets (of various types) as function of basic mission parameters.	UV MOS Visualizer See the impact of UV multi-object spectroscopy on the study of stellar clusters and their feedback.	Planetary Spectrum Generator An advanced tool for simulating spectra of Solar System bodies (with LUVOIR and other telescopes).
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Contacts <ul style="list-style-type: none">• For Science• For Press• Twitter• Facebook									

Technological challenges

Deployment of large segmented telescope

To be demonstrated by JWST



LUVOIR deployment

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

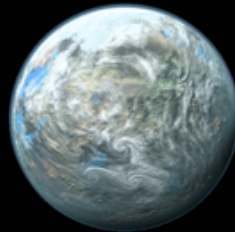
How we're doing the study

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)

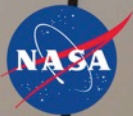
Face-to-face meetings

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

Observers welcome at all LUVOIR meetings & telecons

Large UV/Optical/IR Surveyor (LUVOIR)

Science and Technology Definition Team
Study Office, and friends

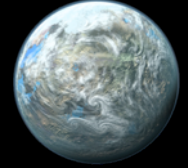


LUVOIR STDT Meeting #1
Goddard Space Flight Center, Greenbelt MD
May 9 - 10, 2016

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 $\sim 8 - 16$ 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 $\sim 4 - 8$ 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/>


Large UV/Optical/Infrared Surveyor (LUVOIR)

 National Aeronautics and Space Administration
Goddard Space Flight Center

Astrophysics Science Division • Sciences and Exploration

LUVOIR

Large UV/Optical/Infrared Surveyor



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- Simulation Tools

Large UV/Optical/Infrared Surveyor

The Large UV/Optical/IR Surveyor (LUVOIR) is a concept for a highly capable, multi-wavelength observatory with ambitious science goals. This mission would enable a great leap forward in a broad range of astrophysics, from the epoch of reionization, through galaxy formation and evolution, to star and planet formation. LUVOIR also has the major goal of characterizing a wide range of exoplanets, including those that might be habitable - or even inhabited.


LUVOIR is one of four Decadal Survey Mission Concept Studies initiated in Jan 2016. The study will extend over three years and will be executed by the Goddard Space Flight Center, under the leadership of a Science and Technology Definition Team (STDT) drawn from the community.

A brief description of LUVOIR science goals, wavelength coverage and sensitivity are available in this [flyer](#).

News

Third LUVOIR STDT Meeting

The third face-to-face team meeting took place in New Haven CT on Nov 9 & 10, 2016. The LUVOIR and HabEx teams met jointly on Nov 10. Meeting info can be found on the [Events](#) page.



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