LUVOIR Study

Community co-chairs: Brad Peterson, Debra Fischer
Study scientist: Aki Roberge

8 Exoplanet STDT members
7 Cosmic origins STDT members
2 Solar system STDT members
2 Technology STDT members
9 Ex Officio International observers

Working groups: Exoplanets, Cosmic Origins, Solar System, Technology, Simulations, Communication
Two telescope architectures (~9-m and ~15m)
Five instrument design studies

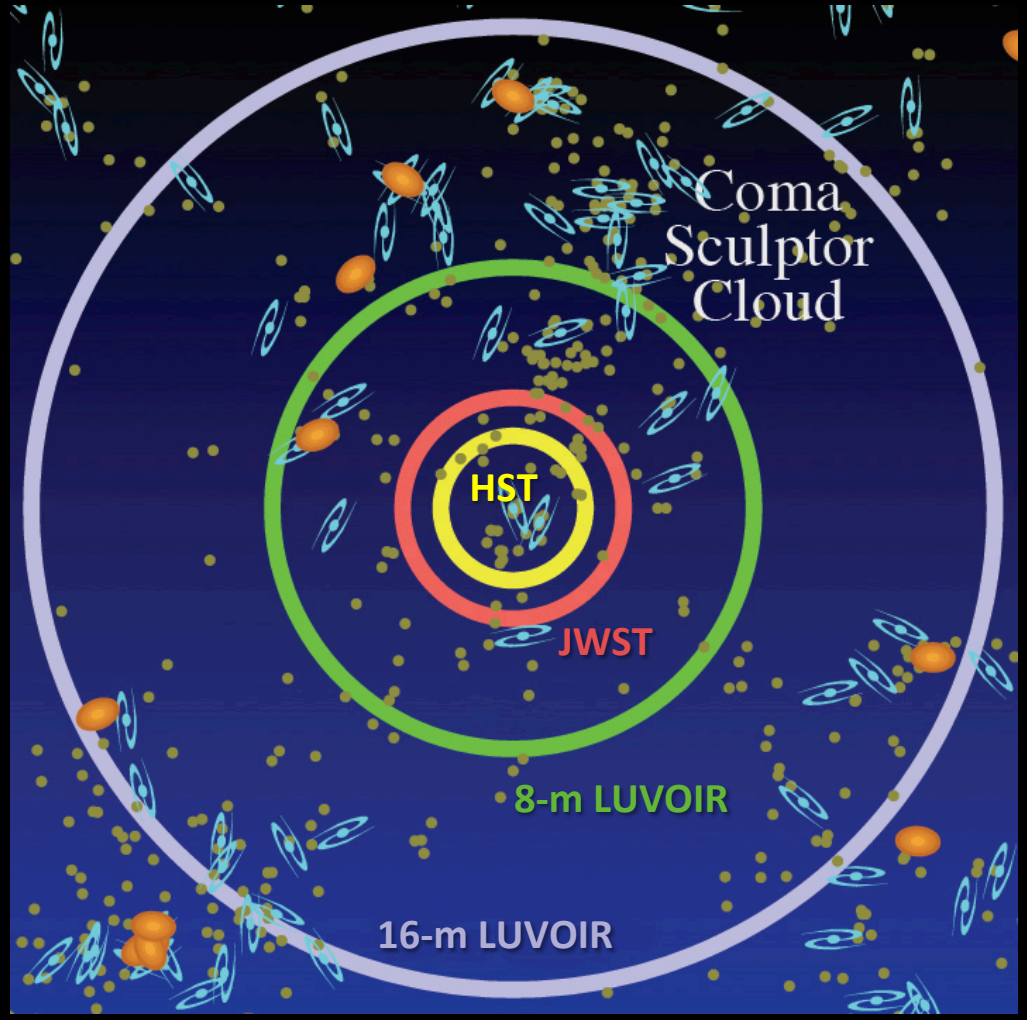
Weekly telecons, F2F meetings (3 per year), Joint leadership meetings with LUVOIR and HabEx
Several community presentations
Weekly science seminars (Harley Thronson, Ravi Kopparapu)
Now drafting the interim report at the WG level; integrate this in the Fall; submit in December 2017

What is LUVOIR ?

- 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

How do galaxies assemble their stars?

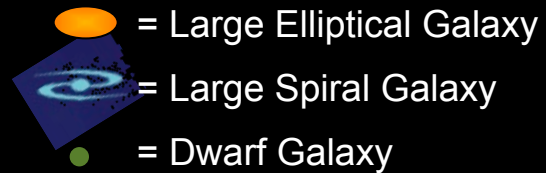


Map of Galaxies within 12 Mpc of Our Galaxy

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

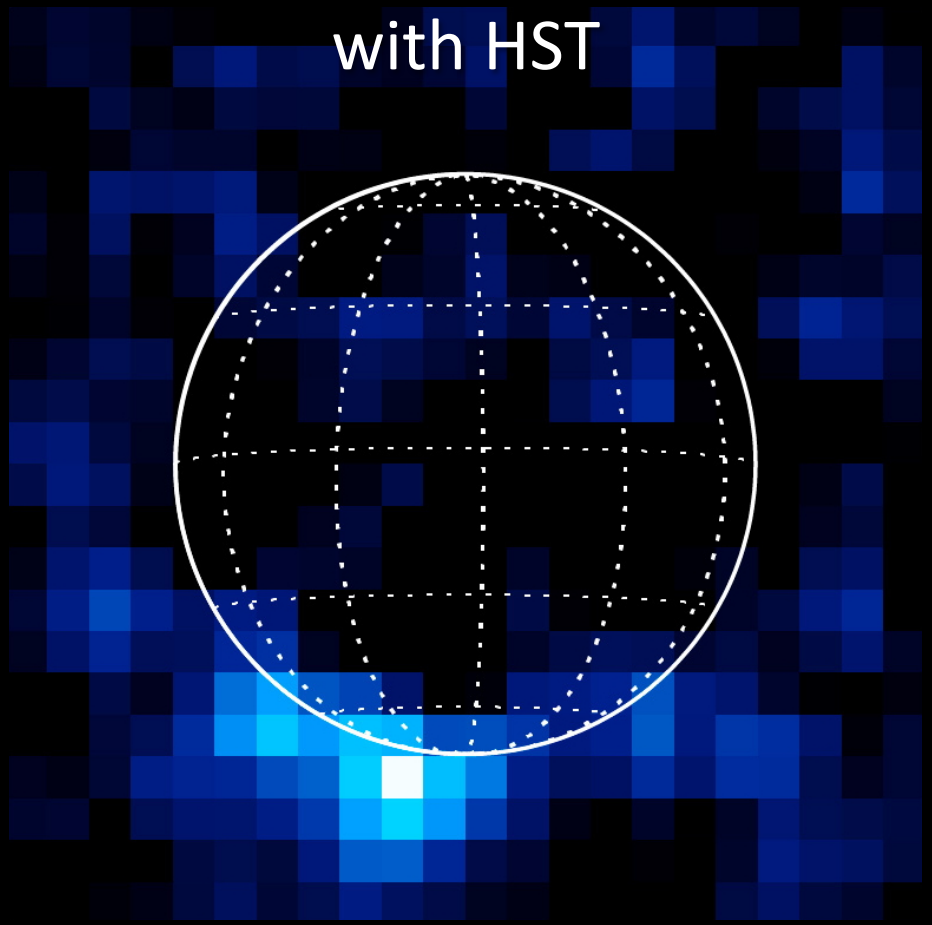
Provides ages and star formation histories

Need LUVOIR to reach the nearest giant elliptical galaxies out to 12 Mpc



Monitoring Solar System ocean moons

Europa jets observed with HST



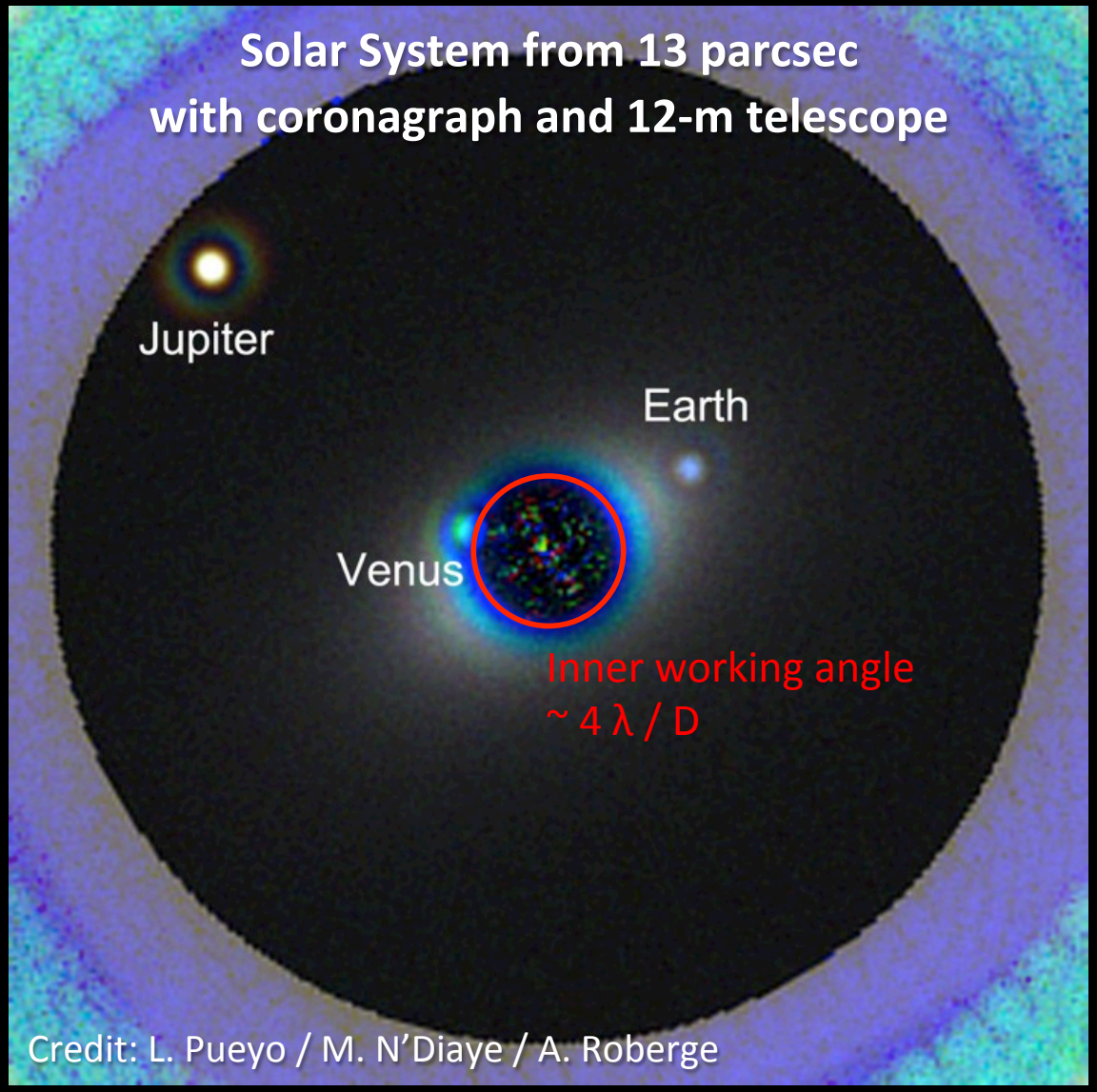
Roth et al. (2014)

Europa jets observed with 15-m LUVOIR

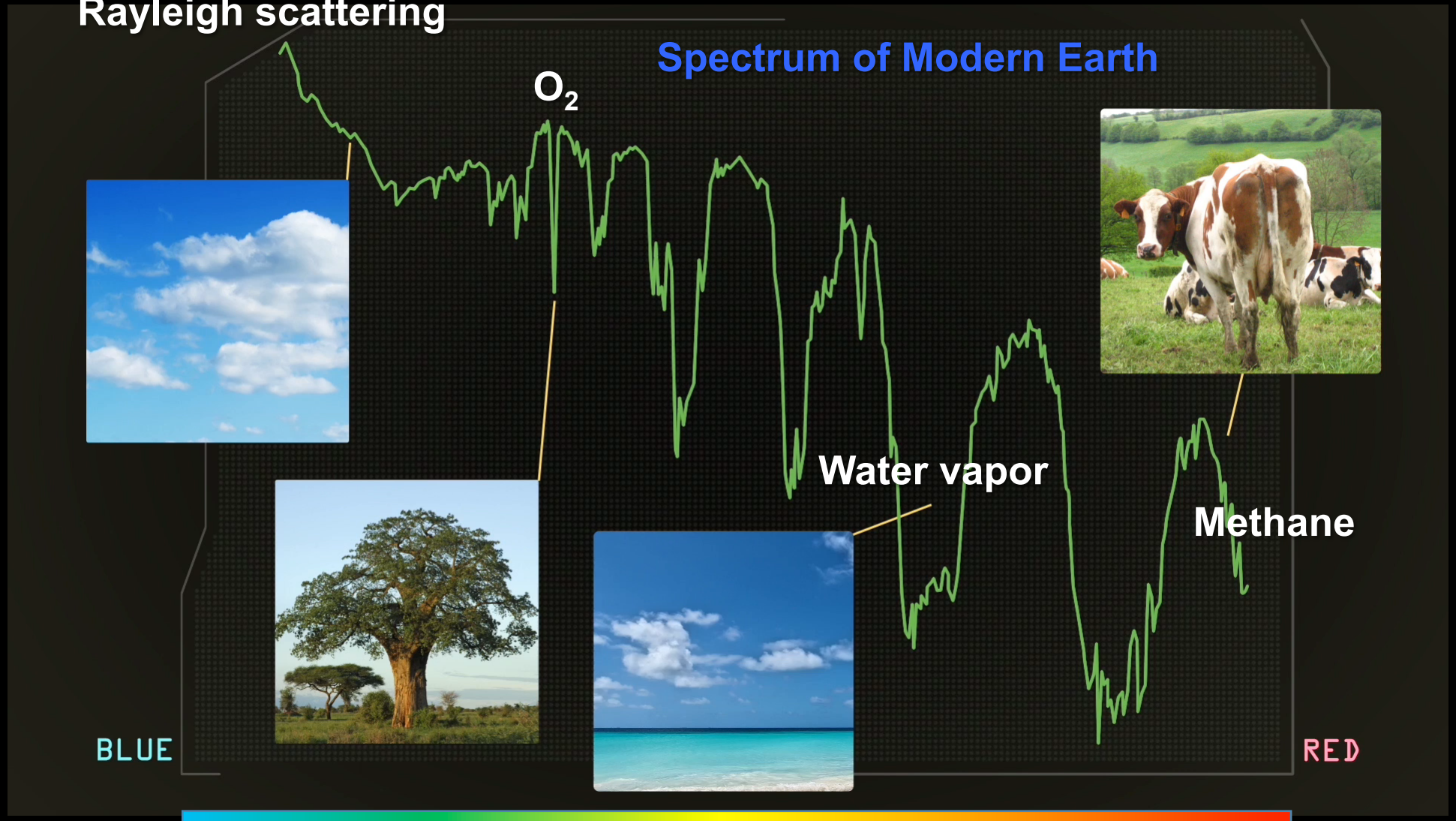
UV hydrogen emission

Credit: G. Ballester (LPL)

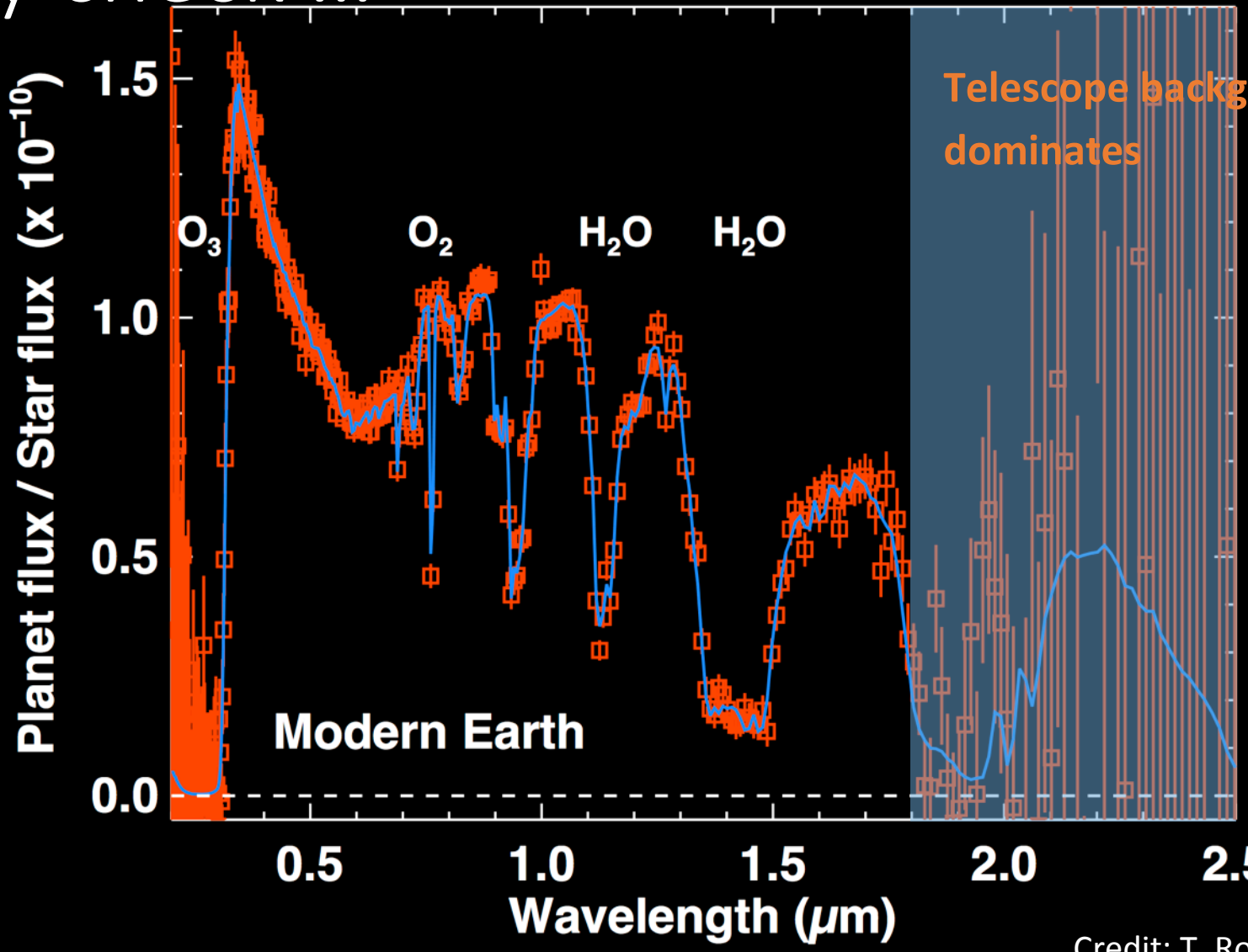
Imaging Earth 2.0



The search for life – biosignatures



Reality check …



Distance = 10 pc

$D_{telescope}$ = 12-m

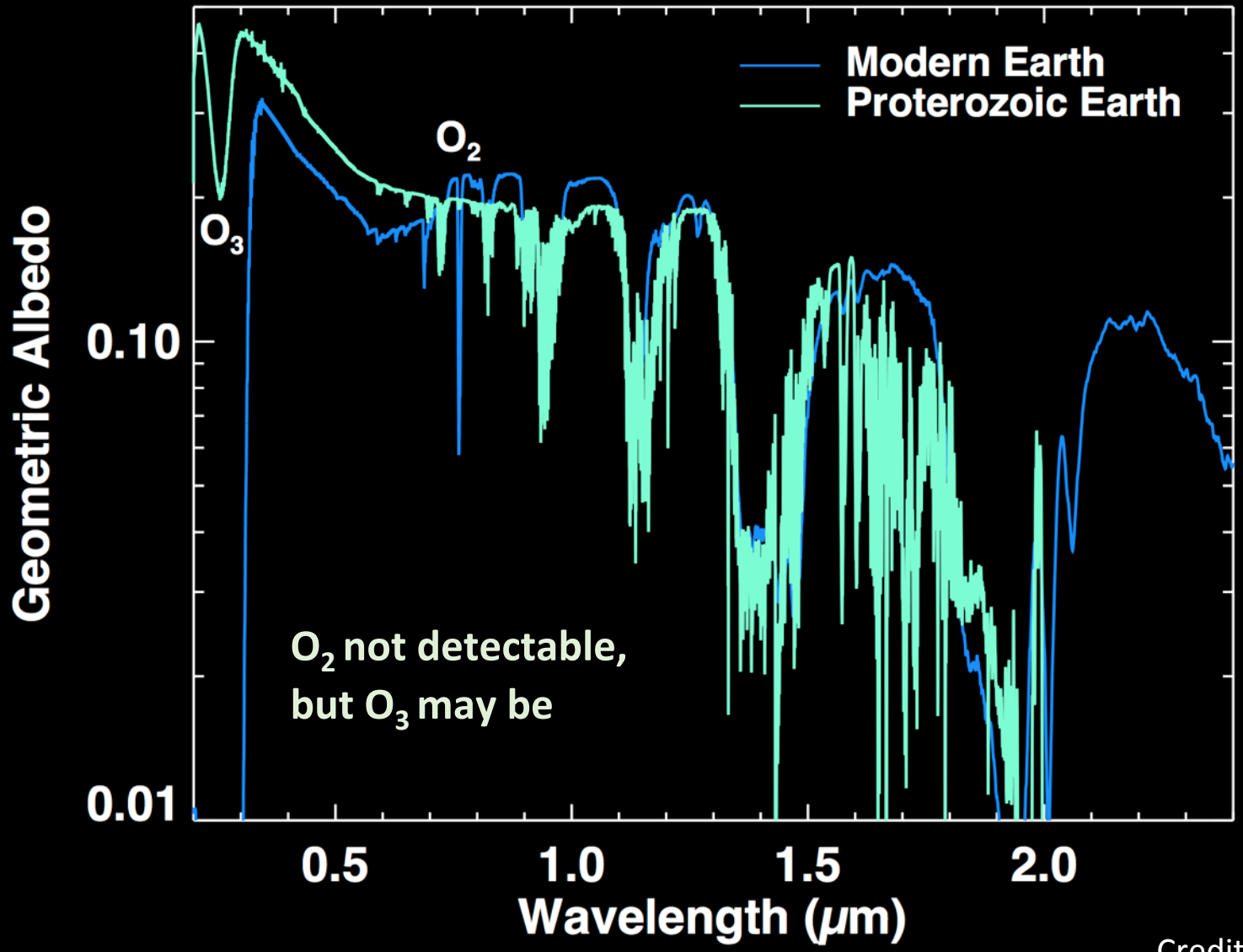
$T_{telescope}$ = 260 K

R = 150

Time = 96 hours

Credit: T. Robinson / G. Arney

Detecting biosignatures over Earth's history



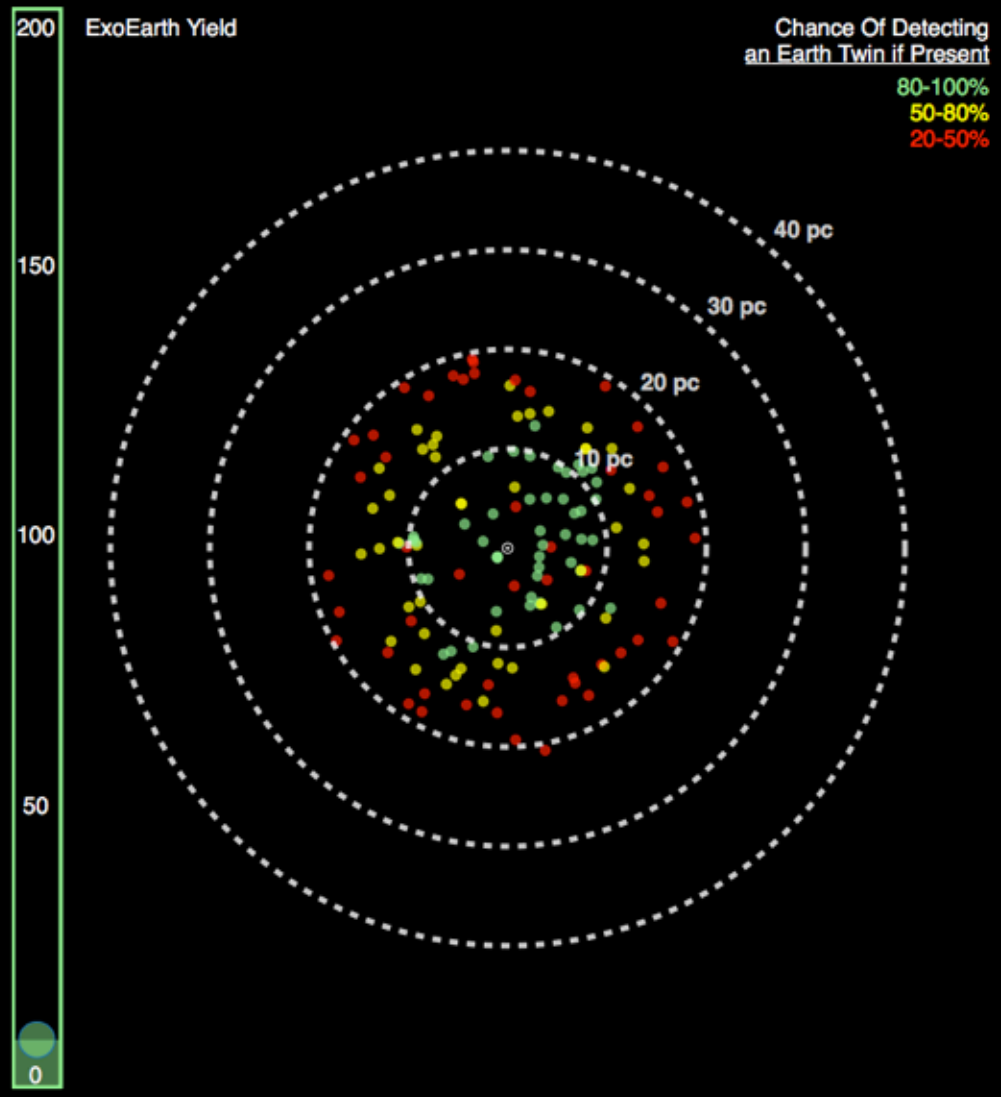
Credit: G. Arney

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

Multi-planet Yield tool
Online simulation tools
– share with HabEx



Stark et al. (2014)

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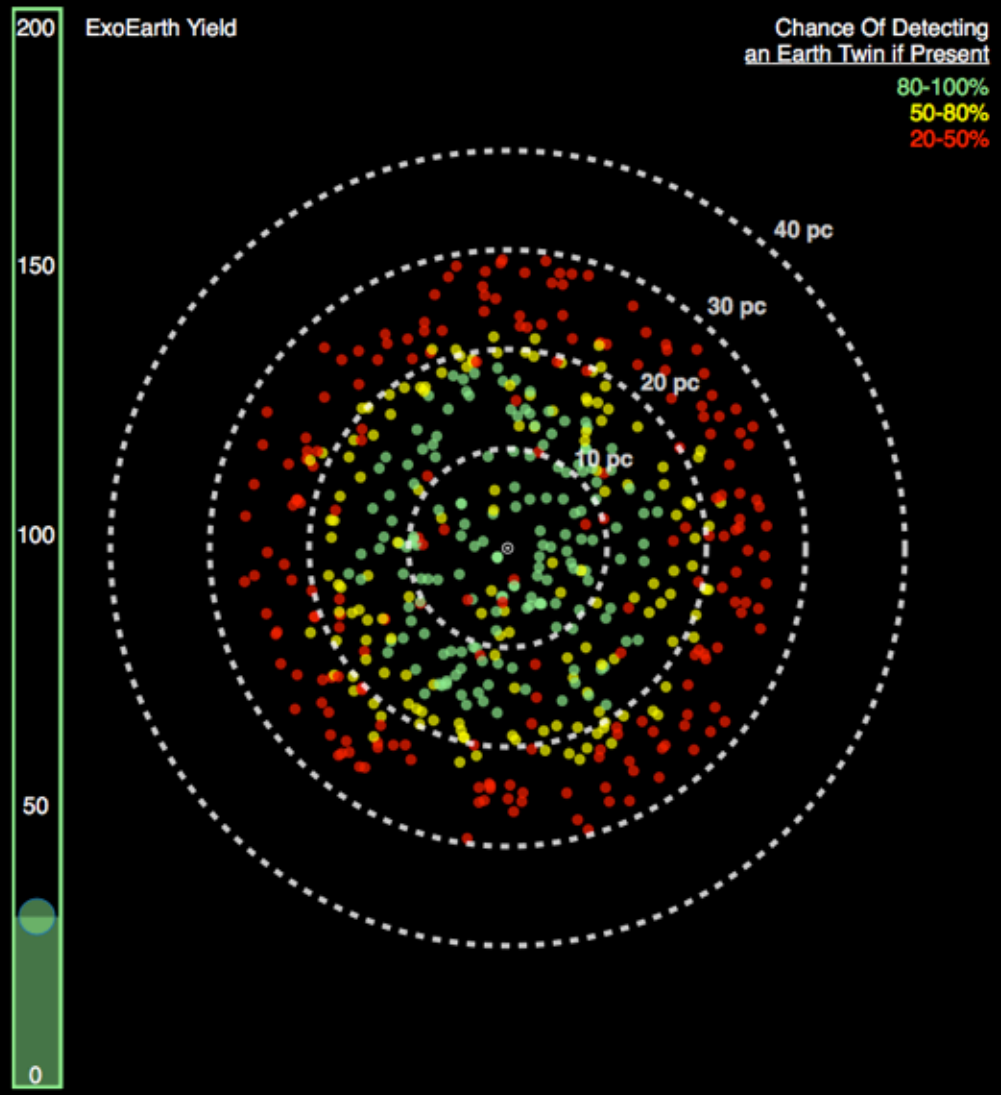

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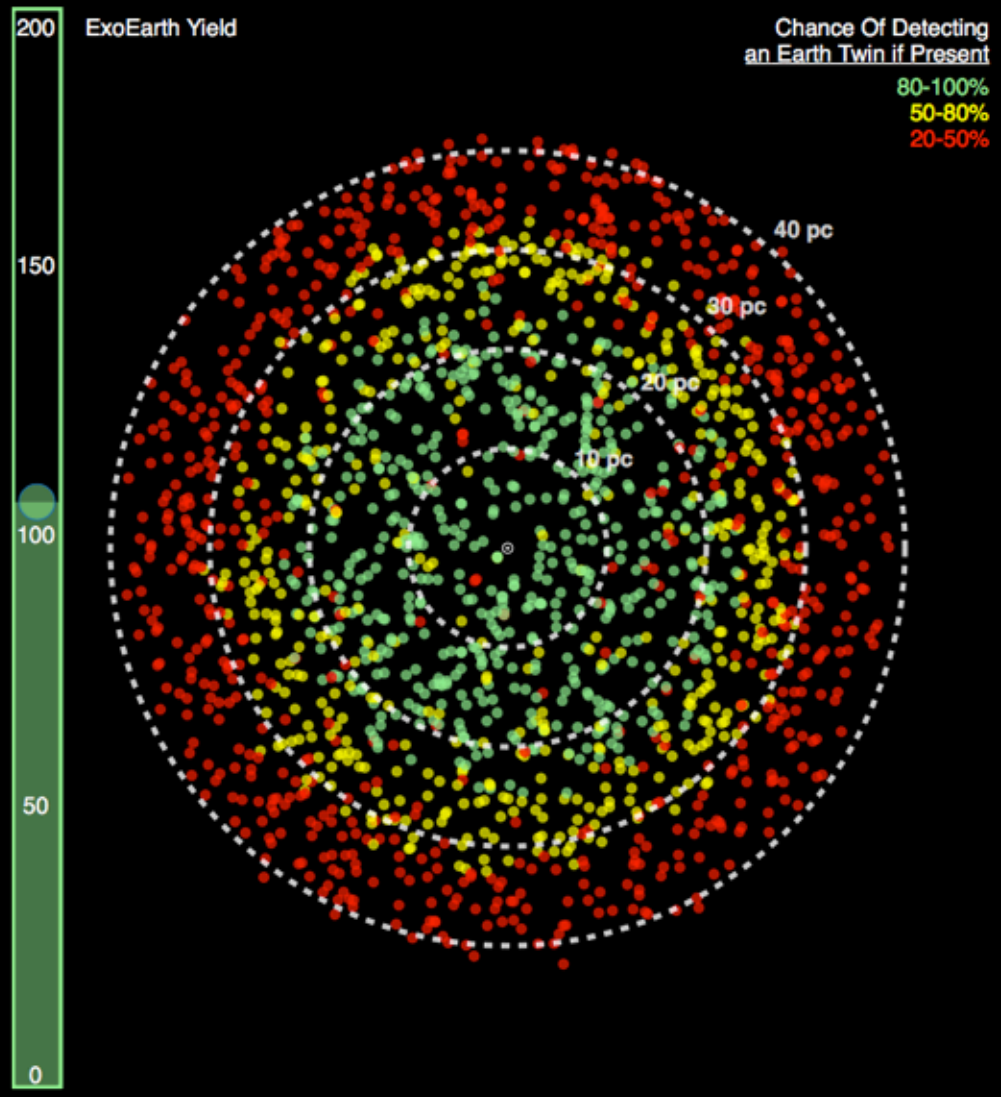

Stark et al. (2014)

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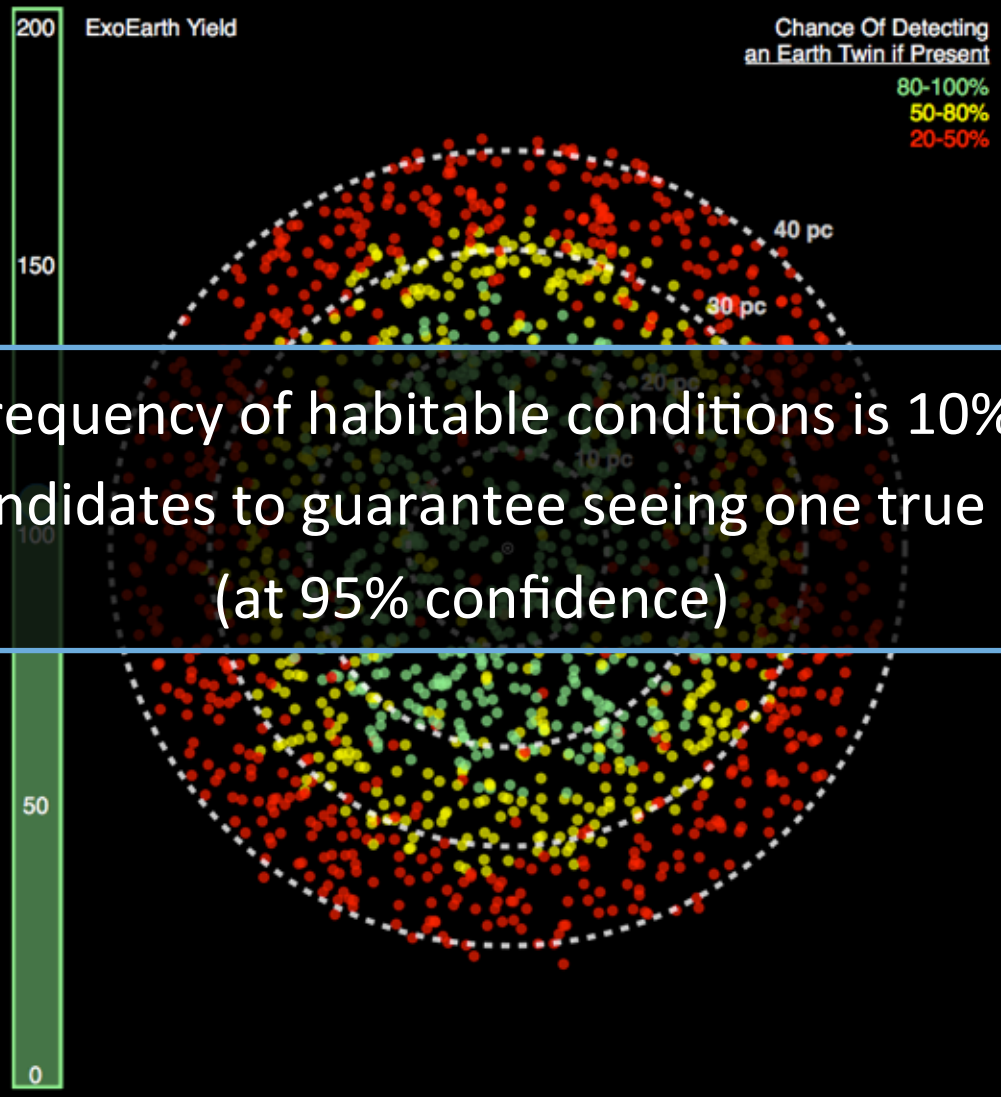


If frequency of habitable conditions is 10%,
need 30 candidates to guarantee seeing one true exoEarth
(at 95% confidence)

Stark et al. (2014)

The LUVOIR instruments

Telescope Architecture A, (IDL Jan 2017); ISIM (IDL June 2017)

Optical / Near-IR Coronagraph: contrast 10^{-10}, 0.2 to 2.4 um (IDL March 2017)

- coronographic spectra simulator

LUMOS: Far UV to near UV spectroscopy, med-res MOS, near UV imaging (IDL May 2017)

- LUMOS spectroscopic ETC, UV MOS visualizer

POLLUX: European study – complements LUMOS providing spectro-polarimetry

High-definition Imager: 2x3 arcmin FOV, OIR, precision astrometry for exoplanet masses (IDL Feb 2016)

- HDI ETC

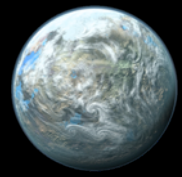
ONIRS: multiple resolutions up to 10^5, transmission spectroscopy, exoplanet masses?

Technology Area	Difficulty	Urgency
High-Contrast Segmented-Aperture Coronagraphy	CRITICAL	CRITICAL
Ultra-Stable Opto-mechanical Systems (includes Sensing, Control, Mirrors, and Structures)	CRITICAL	CRITICAL
Large Format, High Sensitivity, High-Dynamic Range UV Detectors	HIGH	HIGH
Vis/NIR Exoplanet Detectors	HIGH	MED
Starshade	HIGH	MED
Mirror Coatings	MED	MED
MIR (3–5 μm) Detectors	LOW	LOW

Tech notes:

Coronographs
Cold Temperature Telescope Considerations
Exoplanet Detectors
Launch Vehicle Considerations
Long Wavelength Performance
Polarization and Coronography
Starshades
UV Coatings and Shortwave cutoff
UV Detectors

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

What will LUVOIR & HabEx cost?

One of the major goals of these studies is to get accurate total mission cost estimates.

- Independent costing will happen twice: once before the interim reports (December 2017), and again before the final reports are submitted to the 2020 Astrophysics Decadal Survey (2019).

Both teams are planning to study two missions architectures, each with different apertures and capabilities. Providing a range of options covering a range of possible (unknown) futures.

It is the ultimate responsibility of the Decadal Survey to judge the optimal science-to-cost ratio.

Note that it is not straightforward to intuit the total cost of a space observatory by extrapolating based on a single parameter

- For example, the telescope is typically a small fraction of a mission's total cost.
- The cost of a telescope may or may not scale with aperture.

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