

BIG BANG TO BIOSIGNATURES: THE LUVOIR MISSION CONCEPT

Aki Roberge (Study Scientist)

Brad Peterson & Debra Fischer (STDT chairs)

Julie Crooke (Study Manager)

Matt Bolcar (Chief Engineer)

Shawn Domagal-Goldman (Deputy Study Scientist)

Decadal Studies Pause & Learn #2

June 1, 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
- Hubble-like guest observer program

“Space Observatory for the 21st Century”

Ability to answer questions we have not yet conceived


SCIENCE PROGRESS




LUVOIR online science simulation tools

<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
- Science
- LUVOIR Flyer
- Technology
- Seminars
- Events
- Meet the Team
- Working Groups
- Documents
- Images & Videos
- Simulation Tools

On-Line Simulation Tools

This page links to performance simulation and visualization tools for the LUVOIR mission, a future ultraviolet / optical / near-infrared observatory concept.

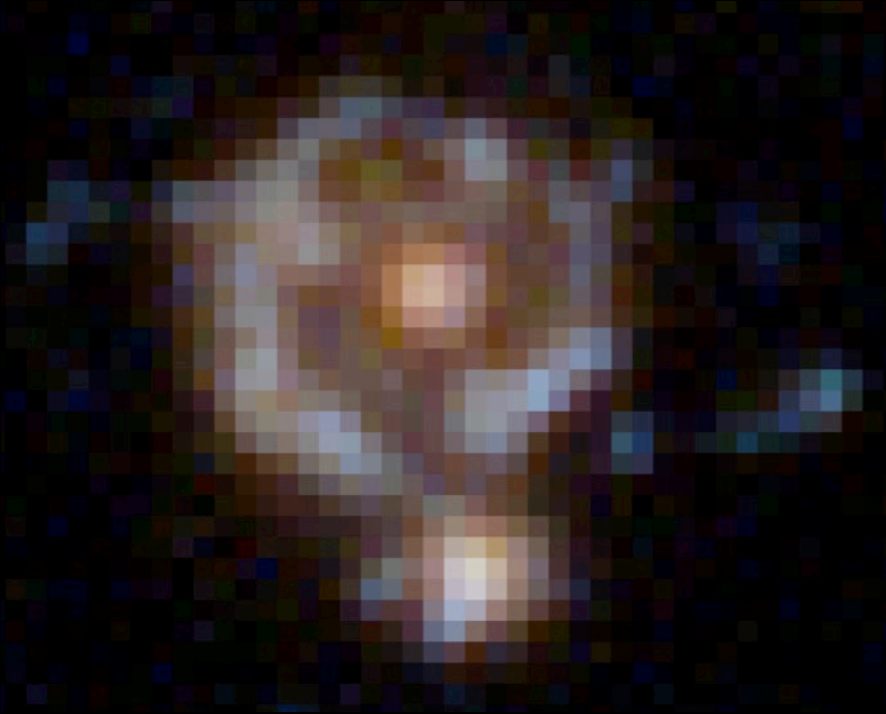
These widgets are experimental. If they are not working, email [Jason Tumlinson \(STScI\)](mailto:Jason.Tumlinson@stsci.edu). For the Planetary Spectrum Generator, email [Geronimo Villanueva \(GSFC\)](mailto:Geronimo.Villanueva@gsfc.nasa.gov).

HDI Photometric ETC Basic exposure time calculator for optical photometry in multi-band images.	Coronagraphic Spectra of Exoplanets Simulate optical/near-IR reflection spectra of various exoplanets with realistic noise.
LUMOS Spectroscopic ETC Simple exposure time calculator for UV spectroscopy.	Multiplanet Yield Tool 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 Advanced tool for simulating spectra of Solar System bodies (with LUVOIR and other telescopes).
High-Resolution Imaging Examples of astronomical objects viewed with different sized telescopes.	

Contacts

- [For Science](#)
- [For Press](#)
- [Twitter](#)
- [Facebook](#)

Imaging performance simulations



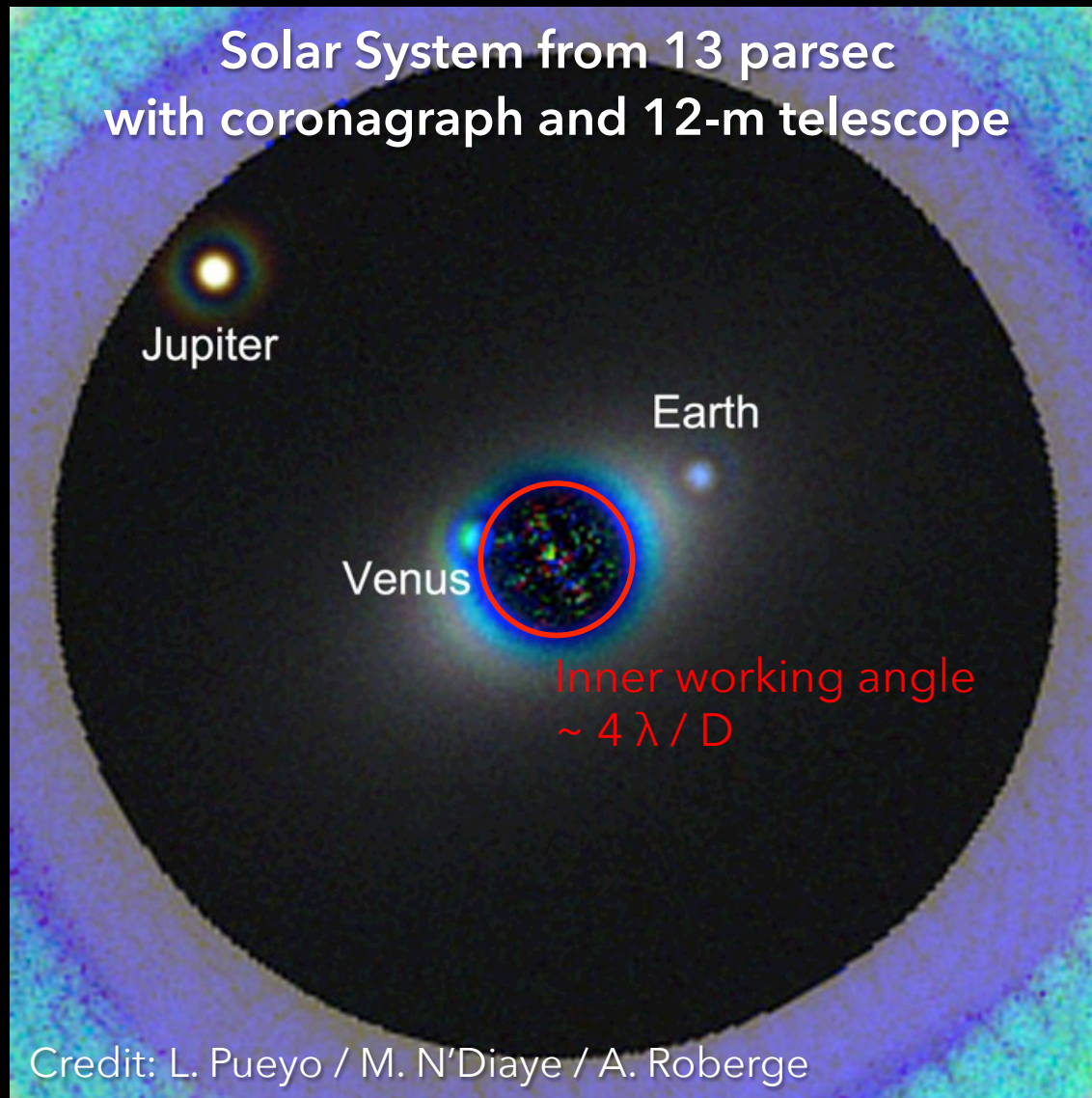
Galaxy at $z = 2$
with HST



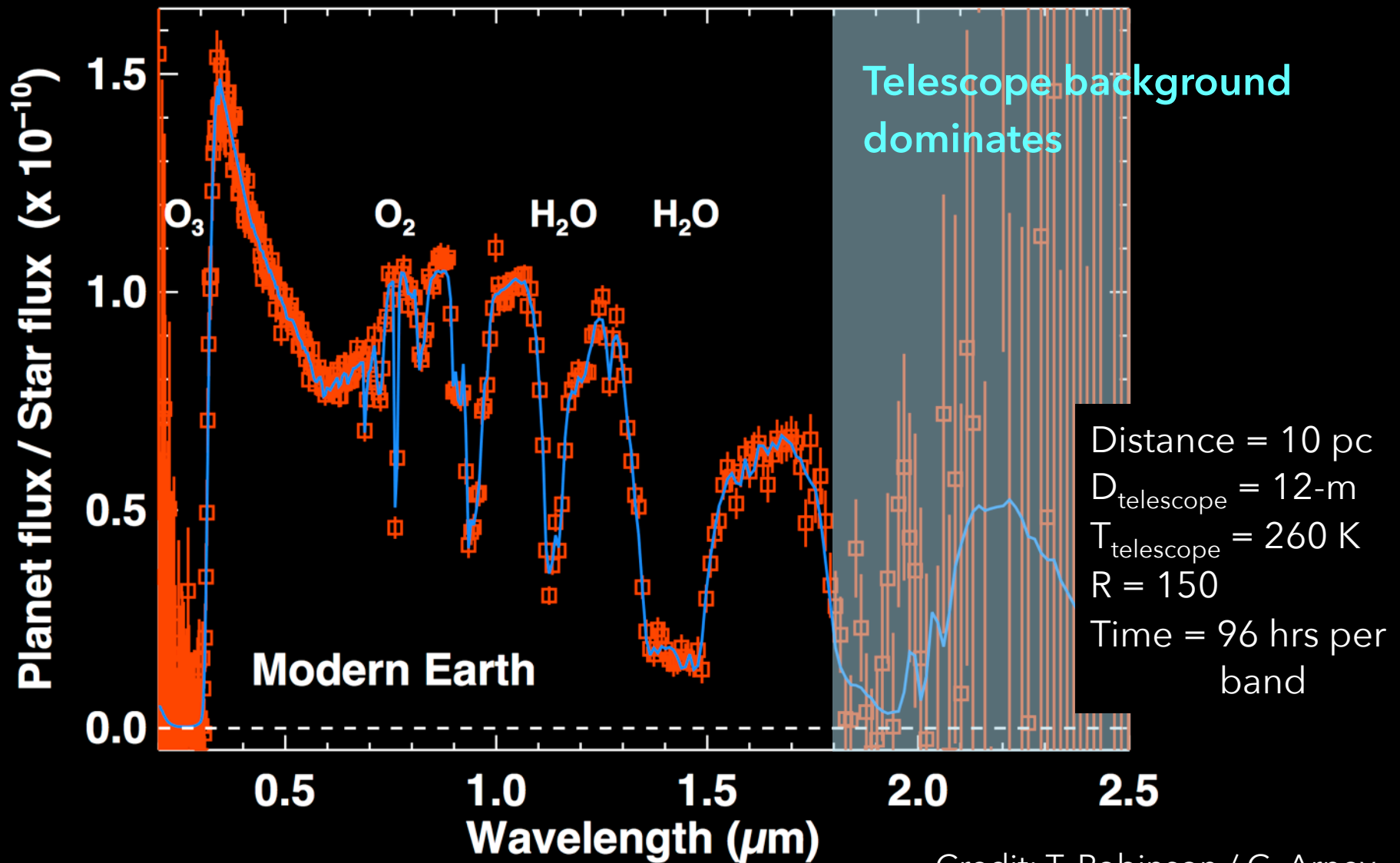
Galaxy at $z = 2$
with 12-m LUVOIR

Credit: G. Snyder / J. Tumlinson

Imaging Earth 2.0



Reality check ...

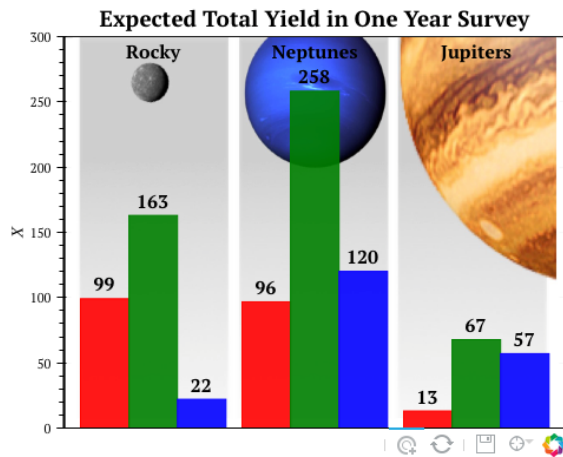


Credit: T. Robinson / G. Arney

Exoplanets imaged as function of aperture

LUVOIR: The Large UltraViolet Optical Infrared Surveyor

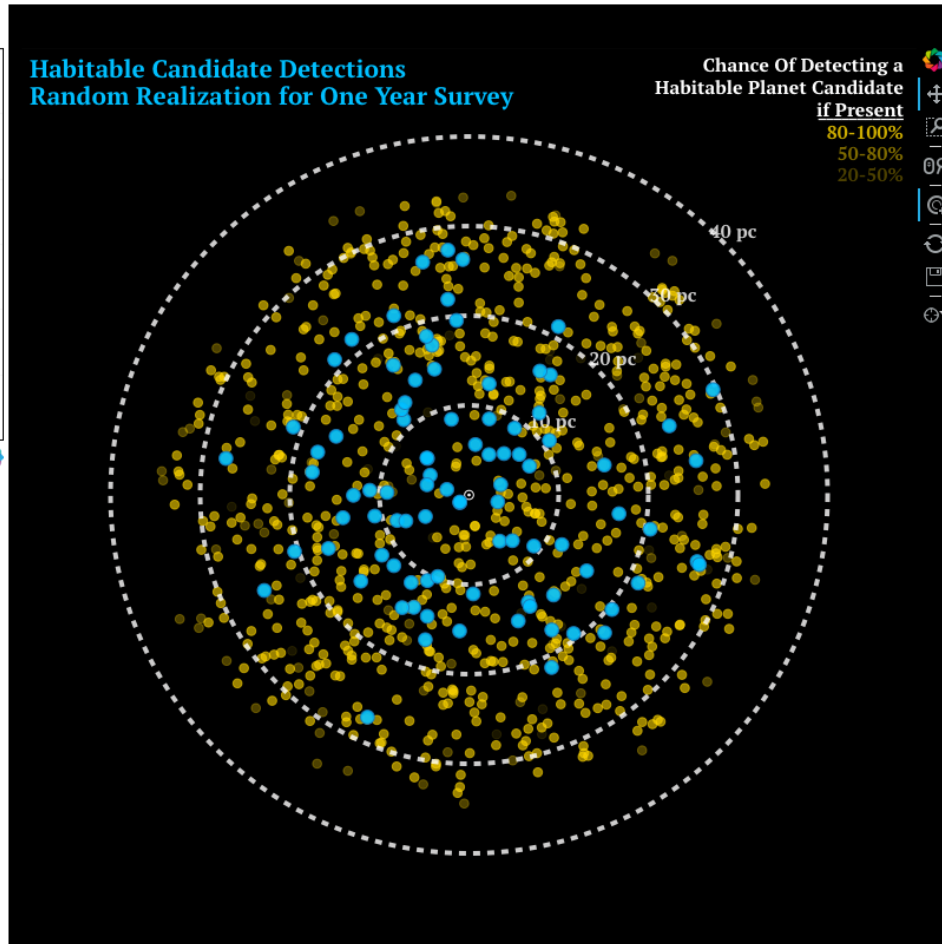
Multiplanet Yields



Habitable Candidate Detections Random Realization for One Year Survey

Chance Of Detecting a
Habitable Planet Candidate
if Present

- 80-100%
- 50-80%
- 20-50%



Controls

[Info](#)

[Planets](#)

Aperture (meters): 16

Log (Contrast): -10

Regenerate the Sample of Detected Candidates

Kopparapu, Stark, et al., in prep.

Solar System imaging



Pluto with HST

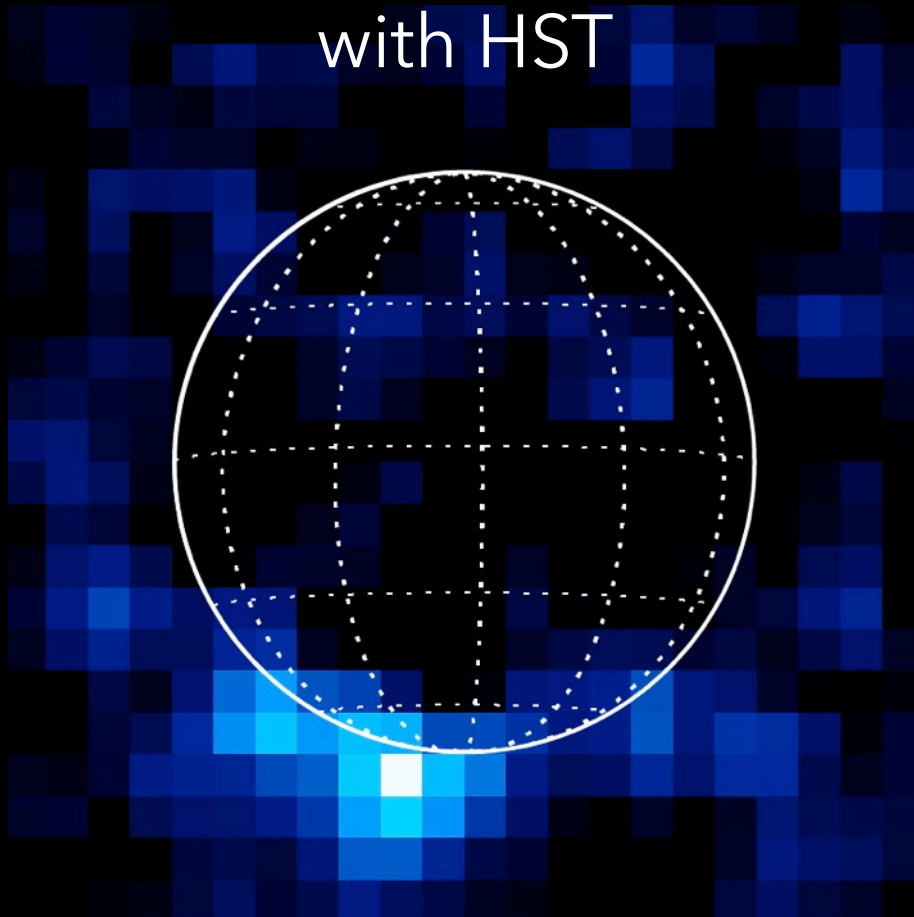


Pluto with 15-m LUVOIR

Credit: W. Harris

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)

Late-breaking ...



**Jupiter from JUNO at ~ 15 km/pixel resolution
Comparable to LUVOIR 15-m (~ 20 km)**

Science progress summary

Science goals and needed observations defined

Instrument performance characteristics described

1st draft of Interim Report outline complete

Writing has begun

Continues ↓

Table of Contents

1 EXECUTIVE SUMMARY.....	4
2 INTRODUCTION.....	4
3 IS THERE LIFE ELSEWHERE? HABITABLE EXOPLANETS AND SOLAR SYSTEM OCEAN WORLDS	4
3.1 STATE OF THE FIELD IN THE 2030S [KARL STAPELFELDT, COURTNEY DRESSING]	4
3.2 WHICH WORLDS ARE HABITABLE?	4
3.2.1 What does habitable mean? [Ty Robinson, Vikki Meadows].....	4
3.2.2 Conventional habitable environments [Ty Robinson, Vikki Meadows].....	4
3.2.3 Ocean / icy worlds of the Solar System [Britney Schmidt].....	4
3.2.4 Alternative habitable environments [Nick Cowan, Vikki Meadows].....	4
3.2.5 Gross atmospheric composition [Mark Marley].....	4
3.2.6 Searching for habitable exoplanet candidates [Chris Stark].....	4
3.3 HOW TO DETECT LIFE? ATMOSPHERIC BIOSIGNATURES.....	4
3.3.1 The inhabited Earth through time [Vikki Meadows?, Giada Arney?].....	4
3.3.2 False positives and false negatives for life [Shawn D-G?].....	4
3.3.3 The strategy for biosignature confirmation [Shawn D-G?].....	4
3.4 SYNERGIES DURING THE LUVUOIR ERA	4
4 ARE WE UNUSUAL? PLANETARY SYSTEMS AND COMPARATIVE PLANETOLOGY	4
4.1 STATE OF THE FIELD IN THE 2030S [DEBRA FISCHER, BRITNEY SCHMIDT, JACOB BEAN, NICK COWAN] 4	
4.2 PLANETARY SYSTEM ARCHITECTURES [BEKKI DAWSON]	5
4.2.1 Solar System comets, asteroids, and KBOs.....	5
4.2.2 Debris disks and planetesimal belts.....	5
4.2.3 Distant exoplanets and Solar System ice giants	5
4.2.4 System dynamics.....	5
4.2.5 Exoplanet masses and radii	5
4.2.6 Solar system planetary rings and moons [Britney Schmidt]	5
4.2.7 Multi-star systems	5
4.3 COMPARATIVE ATMOSPHERES	5
4.3.1 Diversity and composition [Mark Marley, Britney Schmidt].....	5
4.3.2 Photochemistry and hazes [Mark Marley, Giada Arney].....	5

Interim report schedule (in reverse order)

Action	Date / Duration	Comments
Deliver interim report to HQ	Early Dec 2017	
Revise whole report and finalize	Month of Nov	Make it pretty
Reviews	Month of Oct	Senior advisors, Aerospace Corp, GSFC red team
Deliver complete “reviewer’s draft”	Oct 1, 2017	
STDT review of whole report	Mid Sept	At STDT meeting #6
Finalize complete “reviewer’s draft”	Month of Sept	Make it complete and uniform
Individual writing assignments due	Mid Aug	
Assess report progress	July 31 – Aug 2	At STDT meeting #5 (joint w/ HabEx)
Writing !	3.5 months	
Finalize report outline	Late April	Start at STDT meeting #4

TECHNICAL PROGRESS



LUVOIR architectures overview

Architecture A

Integrated Design Center runs Jan 2017 – July 2017

- 15-m telescope
 - First Instrument Design Lab (IDL) run complete Jan 2017
- Four instruments
 1. Coronagraph A
 2. LUMOS A
 3. High-Definition Imager
 4. POLLUX

LUVOIR architectures overview

Architecture B

Integrated Design Center runs Sept 2017 – July 2018

- ~ 9-m telescope
 - First Instrument Design Lab (IDL) run in Sept 2017
- Three instruments
 1. Coronagraph B
 2. LUMOS B
 3. ONIRS

The LUVOIR instruments

Observational challenge

Faint planets next to bright stars

Solution

Optical / Near-IR Coronagraph

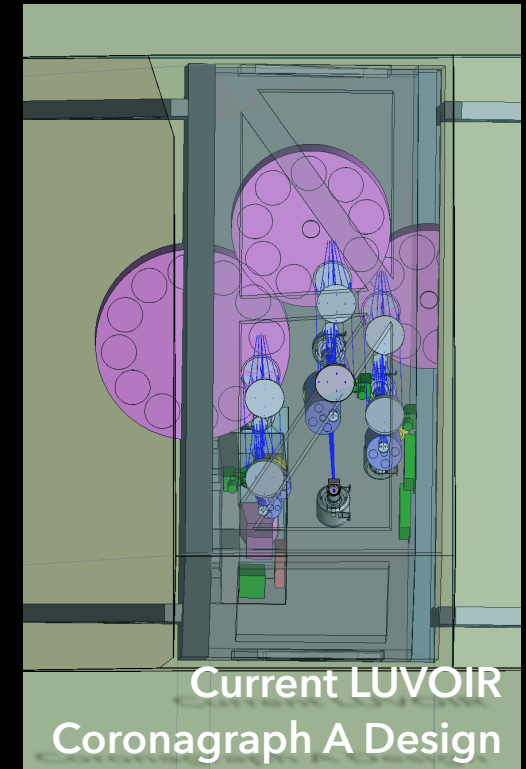
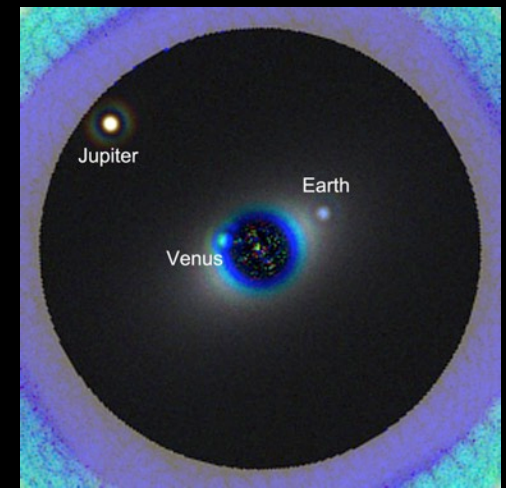
Contrast $< 10^{-10}$ to observe exoEarths

Multi-resolution spectroscopy

Bandpass: $0.2 \mu\text{m}$ to $2.5 \mu\text{m}$

Tech development via WFIRST
coronagraph

First IDL run complete (March 2017)



The LUVOIR instruments

Observational challenge

No UV through Earth's atmosphere

Solution

LUMOS

Multi-object spectroscopy ($R = 500 - 45,000$)

Bandpass: 100 nm to 400 nm

UV imaging

Major upgrade of HST STIS



HST STIS UV instrument

First IDL run complete (May 2017)

The LUVOIR instruments

Observational challenge

Imaging wide fields at high resolution

Solution

High-Definition Imager

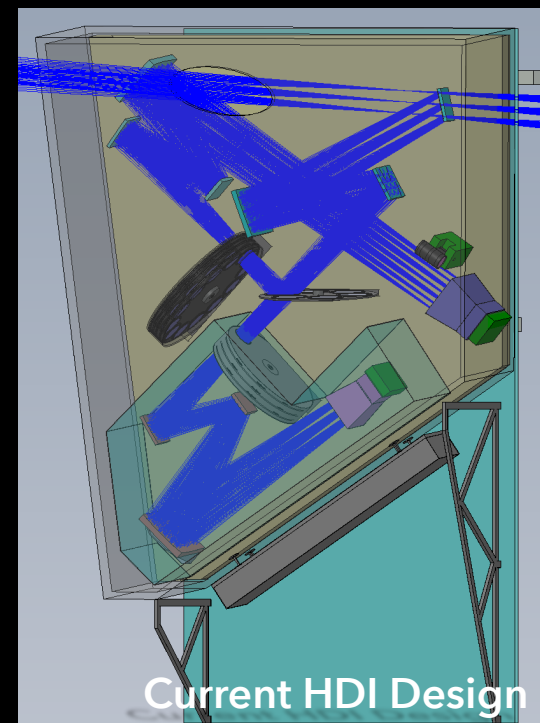
2 x 3 arcmin field-of-view

Bandpass: 0.2 μm to 2.5 μm

High precision astrometry capability
(measure planet masses, etc.)

Major upgrade of HST WFC3

First IDL run complete (Feb 2017)



The LUVOIR instruments

Observational challenge

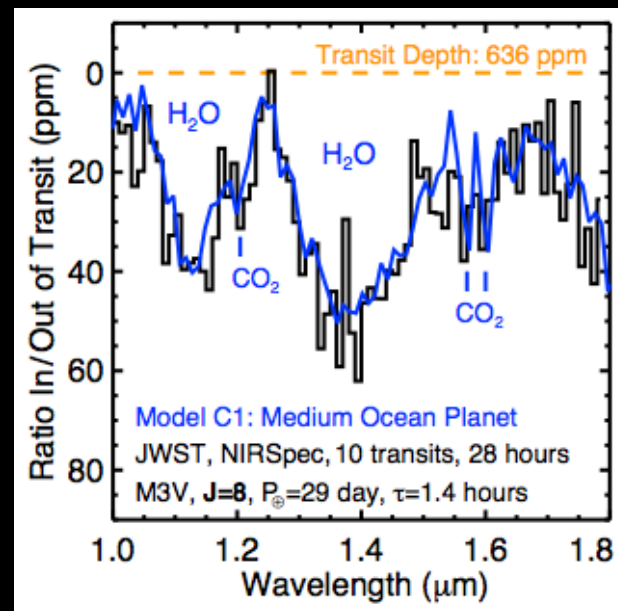
Measuring warm molecules present in Earth's atmosphere

Solution

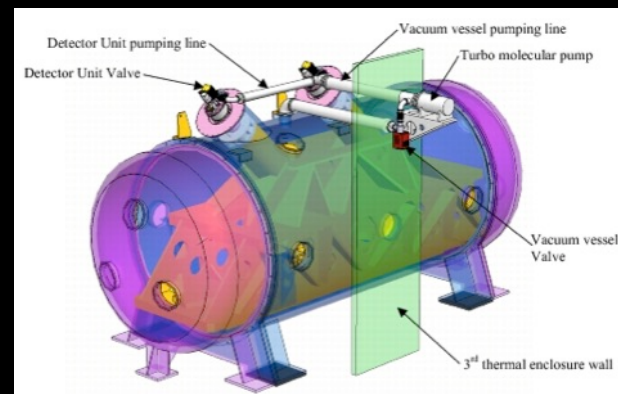
Optical / Near-IR Spectrograph

Multiple resolutions up to $R \sim 10^5$
High photometric precision (transits)
Possibly high precision RV capability
Ground-based analogs in develop.

First IDL run in Spring 2018



Credit: Natasha Batalha



ESPRESSO spectrograph
for VLT (Credit: ESO)

POLLUX: a European contribution to the LUVOIR mission study

- ▶ POLLUX is a concept for a UV spectro-polarimeter with high resolution point-source capability ($R \sim 10^5$)
- ▶ Complementary to the LUMOS instrument
- ▶ To be defined & designed by a consortium of 10 European institutions, with leadership/support from CNES
- ▶ The conceptual study conducted by CNES could serve as a support for a future ESA contribution

Preliminary Architecture A visualization



LUVOIR Architecture A (15-m)

Credit: A. Jones (GSFC)

Technology gap list (team version)

Technology	TRL	Criticality
Ultra-stable Opto-mechanical Systems	2	Enabling
Closed-loop Segment Phasing	4	
Vibration Isolation	4	
Wavefront Sensing & Control	3	
Thermal Sensing & Control	4	
Mirror Segments	5	
High-contrast Segmented Aperture Coronagraphs	4	Enabling
Coronagraph Architecture	4	
Deformable Mirrors	4	
Post-processing	3	
Ultra-Low Noise Large Format NIR Detectors:	3	Enabling
Ultra-Low Noise Large Format VIS Detectors:	4	Enabling
Ultra-Low Noise Large Format UV Detectors:	4	Enhancing
Mirror Coatings	3	Enabling

BROADER INVOLVEMENT:
COMMUNITY, OTHER STUDIES,
INDUSTRY, INTERNATIONAL

The image is a composite of two celestial scenes. On the right side, there is a large, detailed view of the Earth, showing the Western Hemisphere with North and South America visible. The Earth is illuminated from the left, creating a bright horizon and a dark shadowed side. On the left side, there is a vast, colorful spiral galaxy, likely the Whirlpool Galaxy (M51), with its characteristic blue and red hues. The text is overlaid in the upper left quadrant in a light blue, sans-serif font.

STDT voting members



Debra Fischer
(Yale)



Brad Peterson
(Ohio State / STScl)



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
(STScl)



Laurent Pueyo
(STScl)



David Redding
(JPL)



Jane Rigby
(NASA GSFC)



Aki Roberge
(NASA GSFC)



David Schiminovich
(Columbia)



Britney Schmidt
(Georgia Tech)



Karl Stapelfeldt
(JPL)



Jason Tumlinson
(STScl)

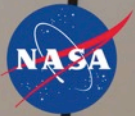
Face-to-face meetings

5th meeting July 31 – Aug 2, 2017 at Caltech

Observers welcome at all LUVOIR meetings & weekly 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

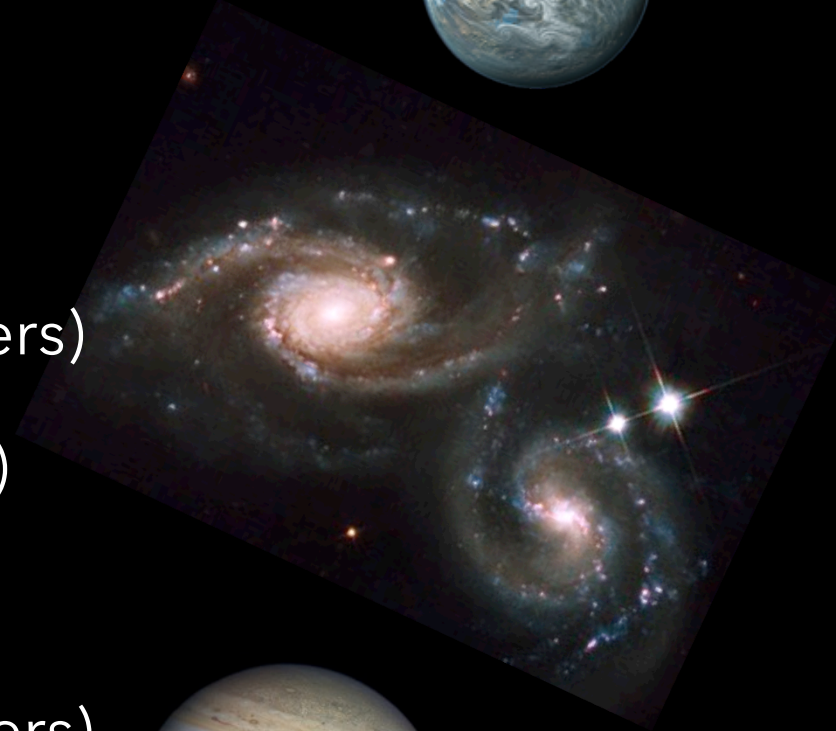
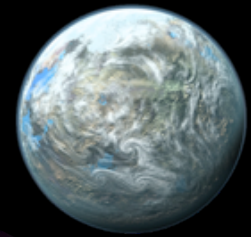
Community involvement

Six Working Groups

- Exoplanets (21 members)
- Cosmic Origins (26 members)
- Solar System (10 members)
- Simulations (9 members)
- Communications (8 members)
- Technology (~ 65 members)

Five Instrument Teams

- Include both STDT and community participants



Community involvement

Activities at Jan 2017 AAS meeting

- Splinter meeting for hands-on work with simulation tools
- Tools demos at STScI booth in poster hall
- Three talks at NASA Hyperwall
- STDT presence at NASA booth

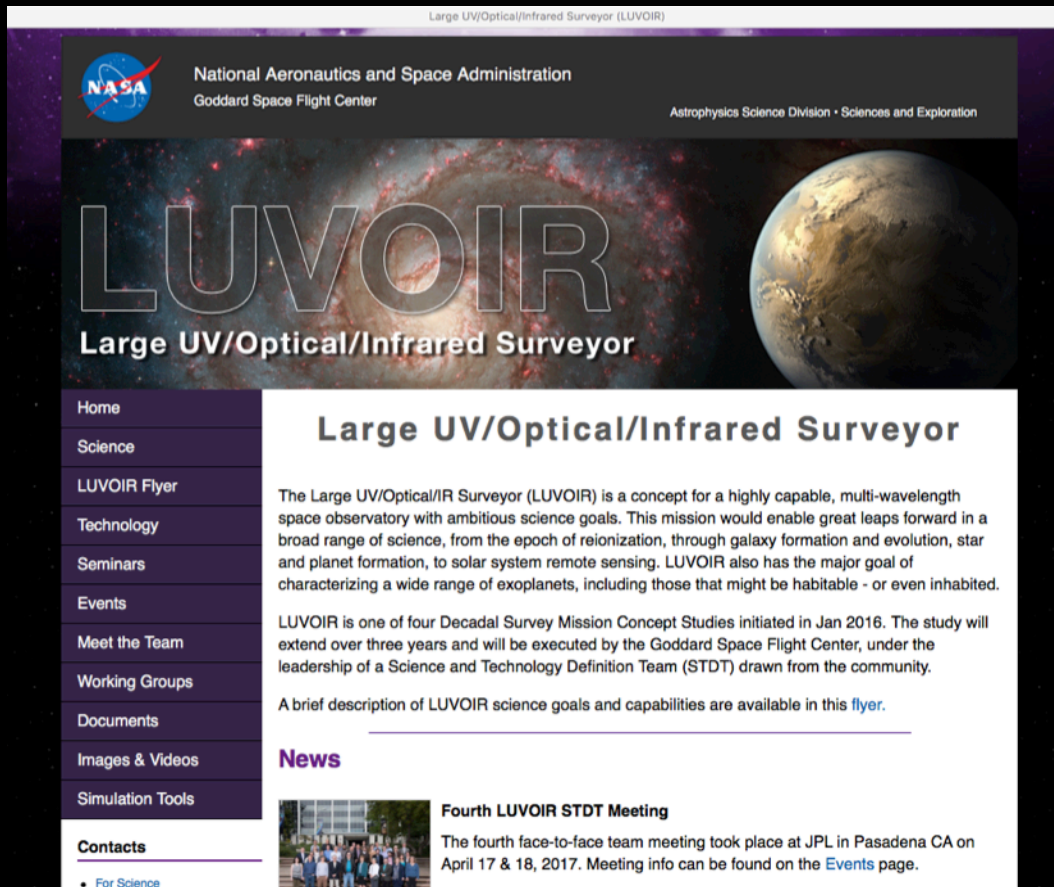
Splinter session at HST/JWST 5 conference in Venice (Mar 2017)

Numerous talks at conferences and universities

Community involvement

LUVOIR webinars (~ monthly)

Public website: <http://asd.gsfc.nasa.gov/luvoir/>



The screenshot shows the homepage of the Large UV/Optical/Infrared Surveyor (LUVOIR) website. At the top, it features the NASA logo and the text "National Aeronautics and Space Administration" and "Goddard Space Flight Center". Below this is a large banner image of a galaxy and a planet, with the word "LUVOIR" in large, stylized letters. The banner also includes the text "Large UV/Optical/Infrared Surveyor".

On the left side, there is a navigation menu with the following items: Home, Science, LUVOIR Flyer, Technology, Seminars, Events, Meet the Team, Working Groups, Documents, Images & Videos, Simulation Tools, and Contacts.

The main content area is titled "Large UV/Optical/Infrared Surveyor" and contains the following text:

The Large UV/Optical/IR Surveyor (LUVOIR) is a concept for a highly capable, multi-wavelength space observatory with ambitious science goals. This mission would enable great leaps forward in a broad range of science, from the epoch of reionization, through galaxy formation and evolution, star and planet formation, to solar system remote sensing. 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 and capabilities are available in this [flyer](#).

News

Fourth LUVOIR STDT Meeting

The fourth face-to-face team meeting took place at JPL in Pasadena CA on April 17 & 18, 2017. Meeting info can be found on the [Events](#) page.

At the bottom left, there is a small image of a group of people standing together, and a link to "For Science".

Coordination with other studies

Three STDT members shared with HabEx STDT

Monthly LUVVOIR / HabEx leadership telecons

Joint STDT meetings with HabEx team

- First joint meeting Nov 10, 2016
- Second joint meeting Aug 2, 2017

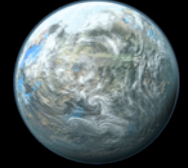
Some standard slides developed jointly with HabEx team
(one to follow)

LUVVOIR engineers helping HabEx with microshutters &
integral field spectrographs (supported by GSFC)

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

Coordination with other studies

LUVOIR representation on ExEP Standards Team

Telecon w/ LUVOIR, HabEx, & OST leadership (Feb 16, 2017)

Info on development of Cooperative Agreement Notices for industry involvement shared with OST & Lynx teams

Industry involvement

LUVOIR Cooperative Agreement Notice released (Dec 2016)

Two responses selected for 1-year, cost-shared studies (Mar 2017)

- Northrop Grumman, Ball Aerospace, & Harris Corp. consortium
- Lockheed Martin

Kick-off coordination meetings with both industry teams (Apr 2017)

International involvement

8 non-voting reps. of international space agencies on LUVUOIR STDT

- ESA, France, Canada, UK, Spain, Japan, Denmark, Germany

POLLUX European instrument study

- Participants from 10 European institutions
- Study funded and led by French Space Agency (CNES)

Kavli IAU Workshop July 2017 in Leiden

- "Global Coordination of Ground and Space Astrophysics: Future Space-Based Optical/UV/IR Telescopes"

LESSONS LEARNED & MOVING FORWARD



What's going well

STDT engagement

Effectiveness of face-to-face STDT meetings

Design progress

Communication with HQ program scientists

- Bi-weekly study office / HQ telecons

HQ reportage appropriate and not burdensome

Challenges

STDT travel logistics

- NRESS contractor unresponsive (getting worse)
- Becoming critical issue for STDT members
- How are the other teams handling their meeting logistics? Is there a better contractor?

Tough to design complex instruments in compressed IDL studies (1 week runs)

- Will rely on LUVDIR Engineering Team and Instrument Teams to adjust designs, fill gaps, perform analysis

Suggestions / requests (1 of 2)

One-size-fits-all approach to reports not favored

- Request flexibility in how each team designs their report(s)

Request for Decadal Studies table(s) in NASA booth area at Jan 2018 AAS

- Instead of having to stock / staff both COR and ExEP tables (like last time)

Suggestions / requests (2 of 2)

Solicit more team input on Program Office technology assessment

- So POs are up to date on current design approaches, which have been rapidly changing

What numbers to assume for launch vehicles with 5-m fairings?

- We'd like HQ to provide this, like they did for SLS