

ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY



e-Workshop 2020 – October 27-29

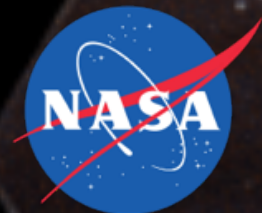
TELLING THE STORY OF LIFE IN THE COSMOS

THE LUVOIR OBSERVATORY CONCEPTS

AKI ROBERGE

NASA GODDARD SPACE FLIGHT CENTER

5TH NUVA WORKSHOP
OCT. 29, 2020



WHAT IS LUVOIR ?



Large UV / Optical / Infrared Surveyor (LUVOIR)

Space telescope concept with broad science capabilities

Exoplanets, Solar System, Astrophysics

Far-UV to near-IR bandpass

Two architectures: 15-m (LUVOIR-A) and 8-m (LUVOIR-B) telescopes

Serviceable and upgradable

Community-driven operations

"Space Observatory for the 21st Century"

Ability to answer questions of the 2030s and beyond

A composite image showing the blue and white swirling clouds of Earth in the upper left and the heavily cratered, brownish-grey surface of the Moon in the lower right, both set against the black background of space.

EXOTIC WORLDS

THE SEARCH
FOR LIFE

A close-up image of the planet Jupiter, showing its characteristic brown and white swirling cloud patterns and a prominent white oval storm feature near the top center.

OUR DYNAMIC
SOLAR SYSTEM

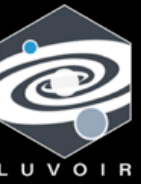
A deep-space image of a spiral galaxy, likely the Pinwheel Galaxy, showing its bright central core and intricate, glowing blue and white spiral arms against a dark background.

COSMIC ORIGINS
&
THE ULTRA-FAINT
UNIVERSE



LUV O I R

DESIGNING A WELL-POSED SEARCH FOR LIFE EXPERIMENT



Finding Earth-like planets and life would be a momentous achievement

2008

Worlds Beyond: A Strategy for the Detection and Characterization of Exoplanets
Report of the ExoPlanet Task Force
Astronomy and Astrophysics Advisory Committee

2010

New Worlds,
New Horizons

2013

Enduring Quests
Daring Visions
A Thirty-Year Roadmap for NASA Astrophysics

2018

CONSENSUS STUDY REPORT

Need *space-based direct spectroscopy* to do it for exoplanets around Sun-like stars

Washington, D.C.
May 22, 2008

AAAC Exoplanet
Task Force



NAS Astro2010 Decadal

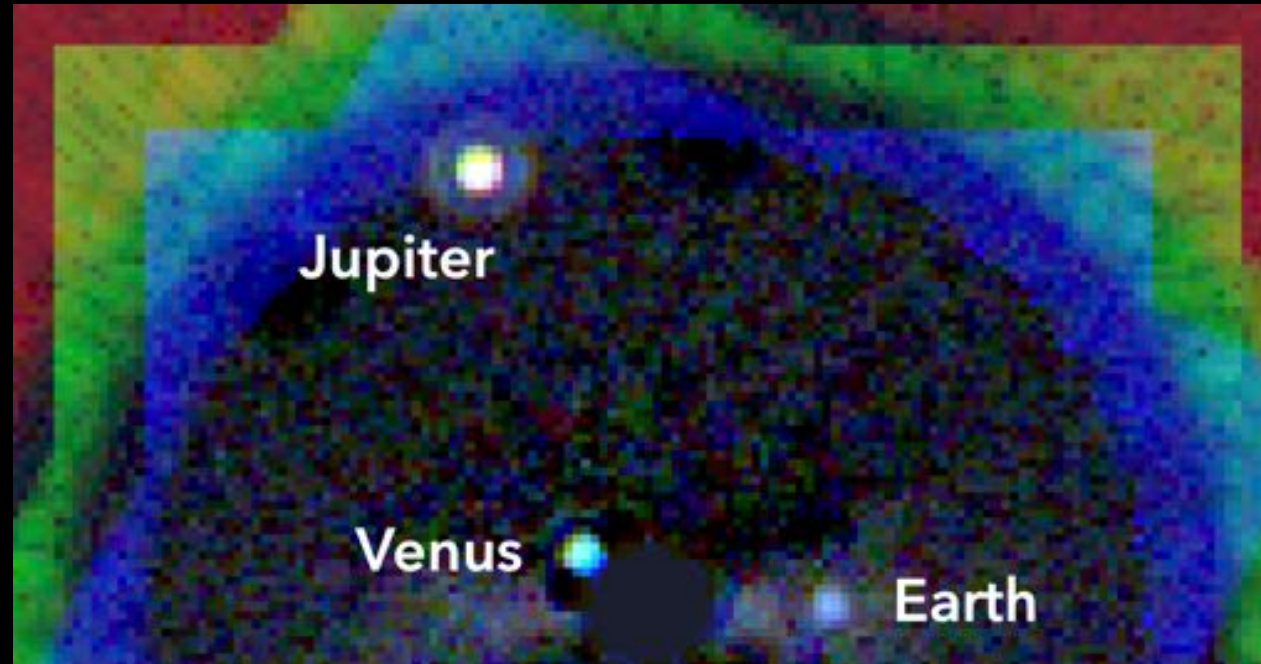
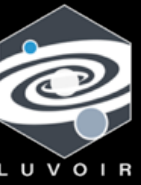


NASA Astro Roadmap

EXOPLANET
SCIENCE
STRATEGY

NAS Consensus Study

THE HABITABLE PLANET SURVEY OBSERVATIONS



High-contrast direct imaging of *hundreds of stars* with LUVOIR ECLIPS.

Colors, orbits, & partial spectra for every habitable planet candidate

Simulated high-contrast image of the Solar System
at 12.5 pc with ECLIPS on LUVOIR-A

HOW MANY CANDIDATES DO WE NEED?

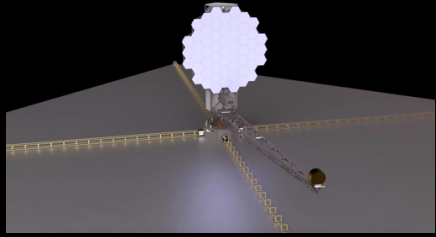
Are habitable planets common or rare?

Want order of magnitude increase in knowledge

Requirement : Measure frequency of habitable planets for values $>10\%$

Ensures scientifically valuable null result

HOW MANY CANDIDATES FOR $>10\%$ FREQUENCY?



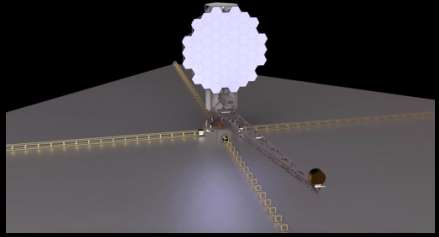
LUVOIR-B
8-m



28 candidates

Measure frequency of Earth-like planets if $>10\%$

WHAT IF EARTH IS EVEN MORE RARE?

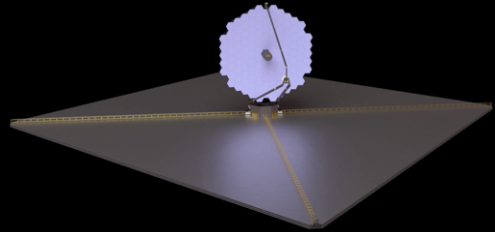


LUVOIR-B
8-m



28 candidates

Measure frequency of Earth-like planets if $>10\%$



LUVOIR-A
15-m

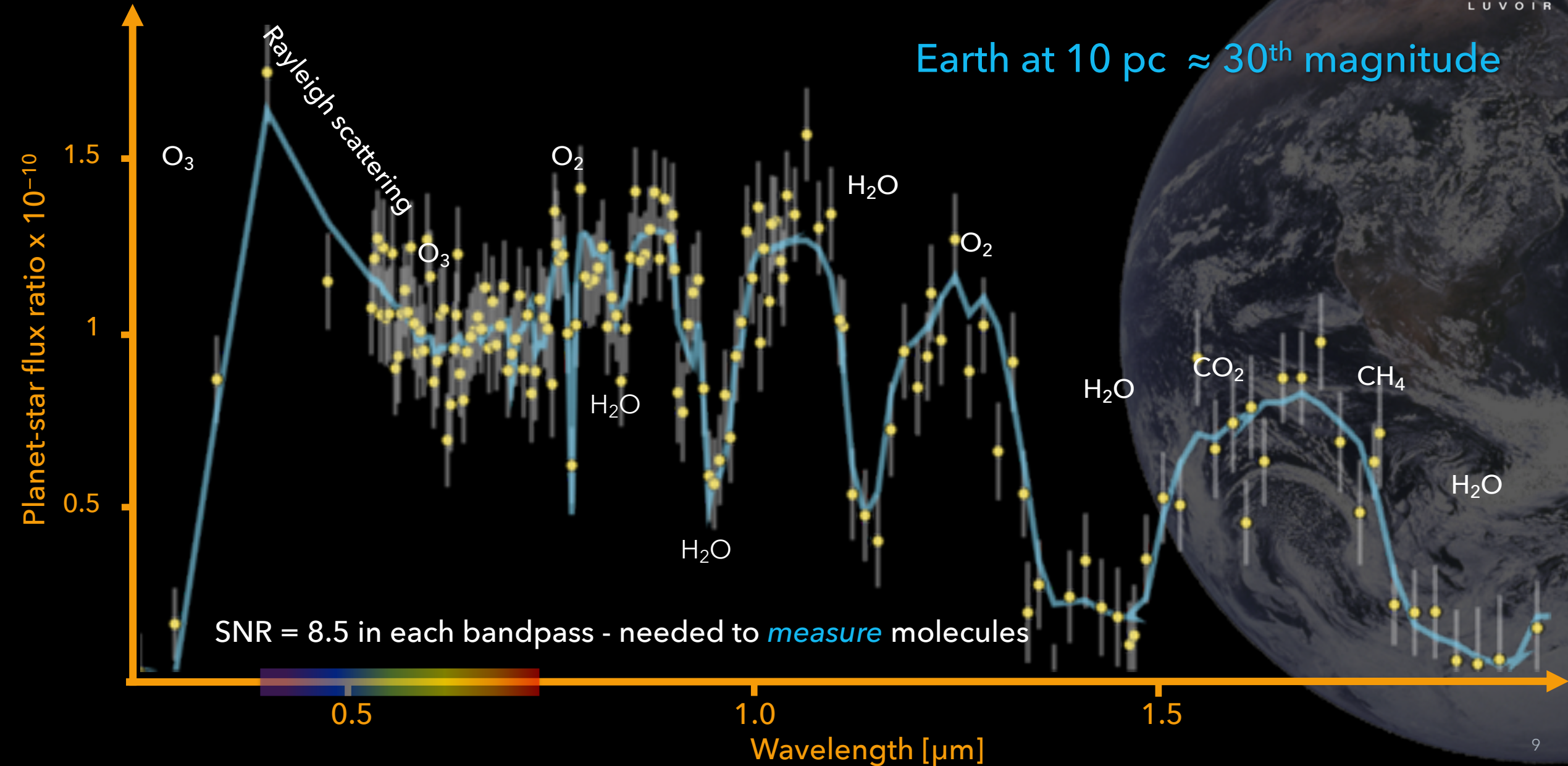


54 candidates

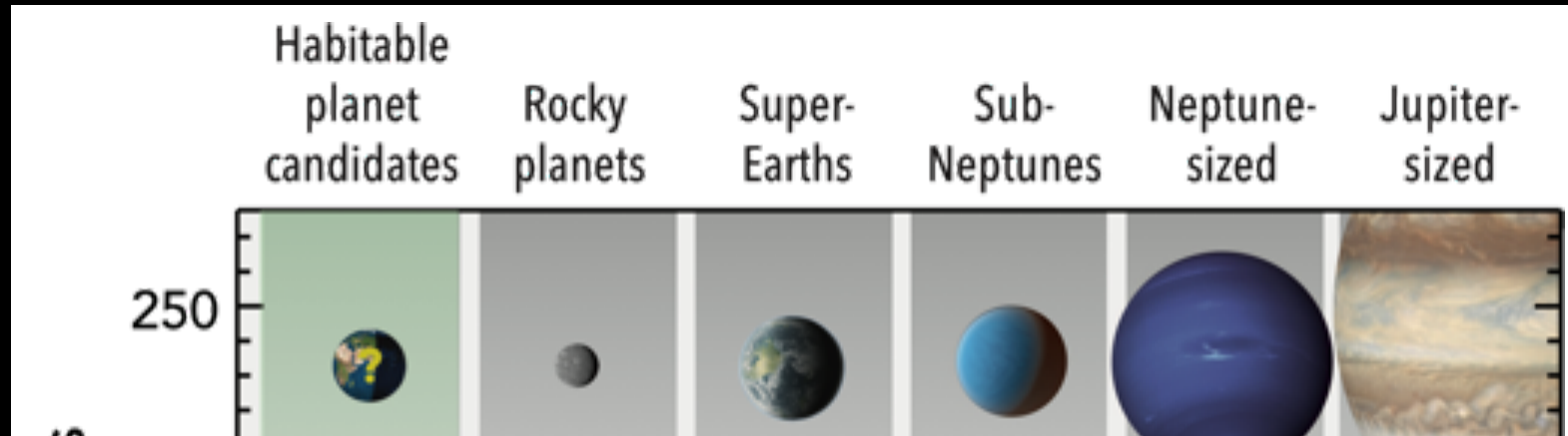
Measure frequency of Earth-like planets if $>5\%$

WHAT WOULD AN INHABITED EXOPLANET LOOK LIKE?

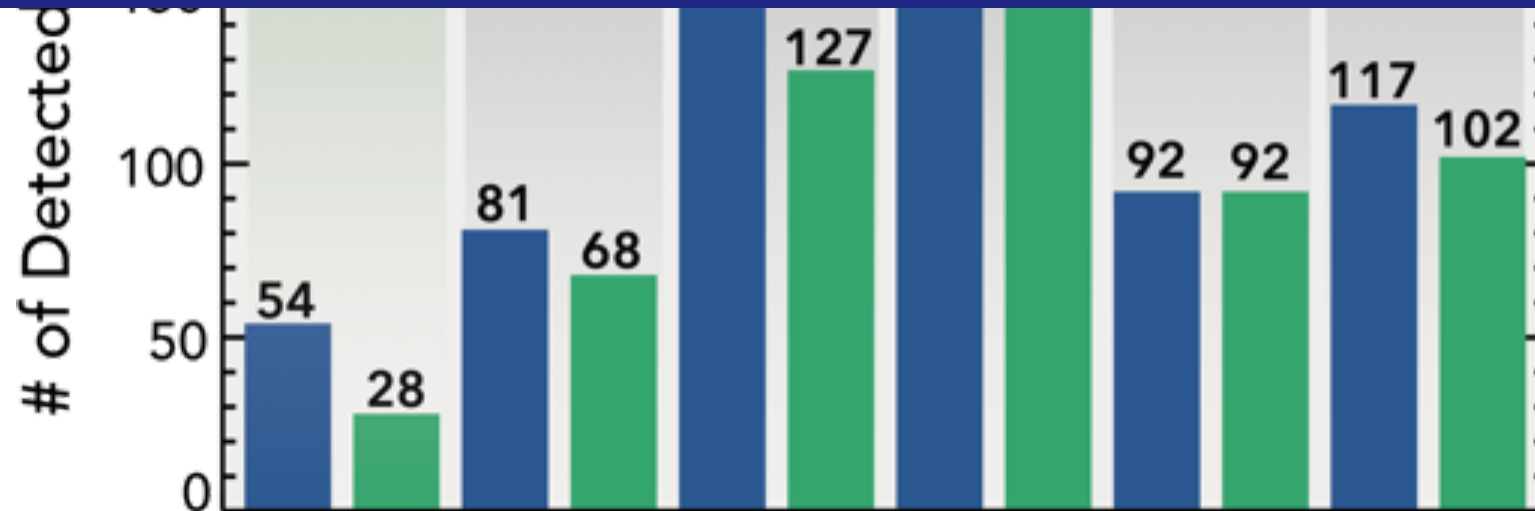
Earth at 10 pc $\approx 30^{\text{th}}$ magnitude



DOZENS OF HABITABLE CANDIDATES, HUNDREDS OF PLANETS



For every exoEarth candidate, LUVOIR will observe $>10\times$ as many exotic exoplanets

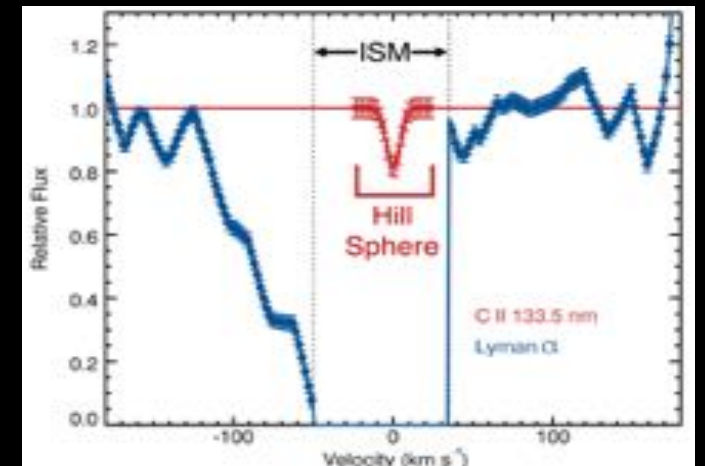
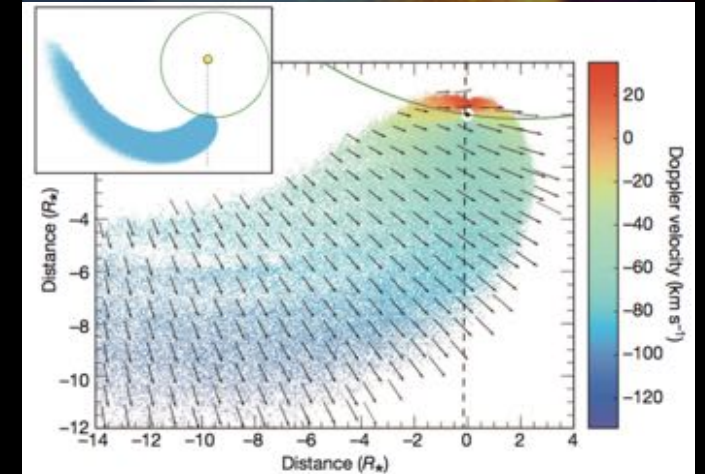
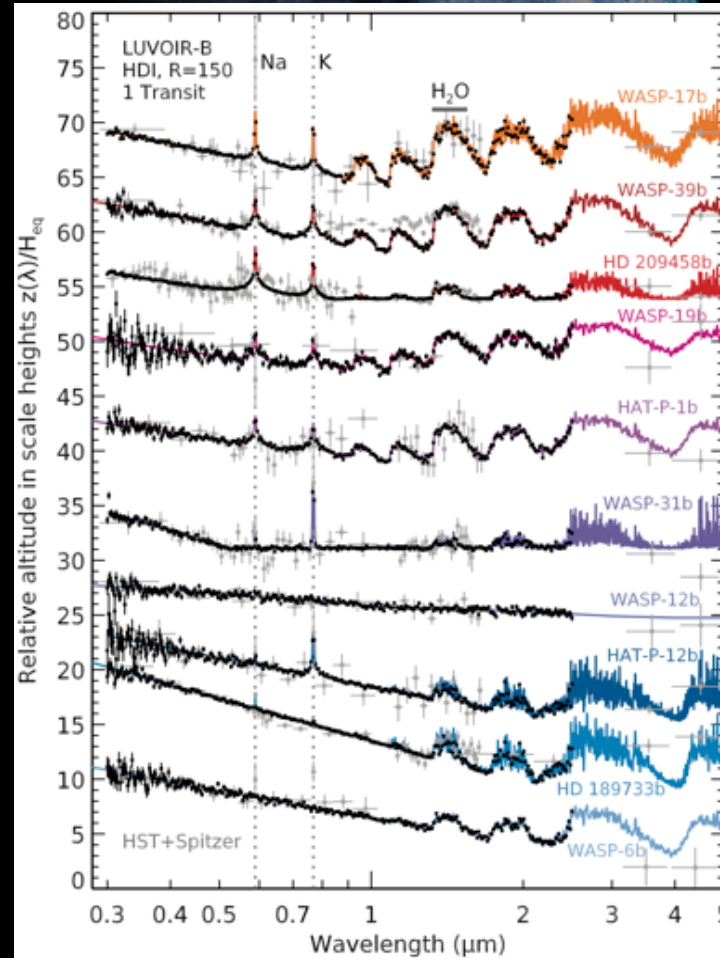
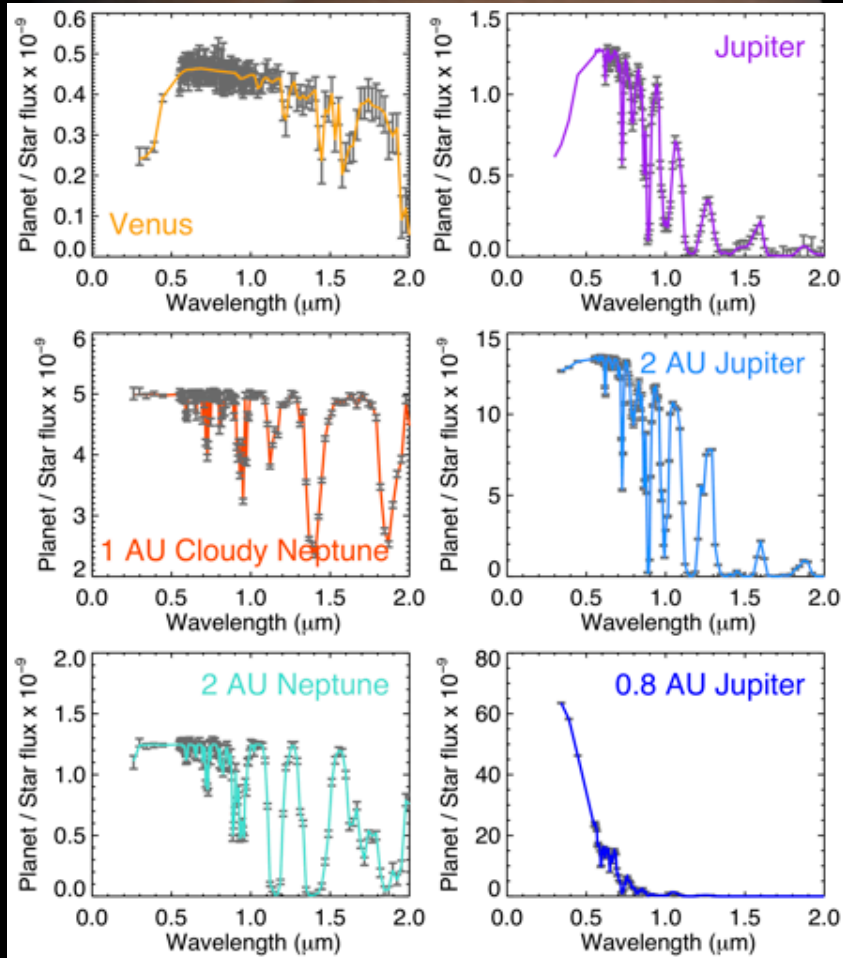


COMPARATIVE EXOPLANETOLOGY

Cold to warm planets
NUV / optical / NIR direct spectroscopy

Warm to hot planets
Optical / NIR transit spectroscopy

Atmospheric escape
FUV transit spectroscopy



A composite image showing the blue and white swirling clouds of Earth in the upper left and the heavily cratered, brownish-grey surface of the Moon in the lower right, both set against the black background of space.

EXOTIC WORLDS

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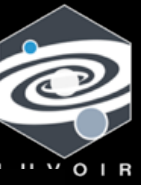
OUR DYNAMIC
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A deep-space image of a spiral galaxy, likely the Pinwheel Galaxy, showing its bright central core and glowing blue and white spiral arms against a dark background with distant stars.

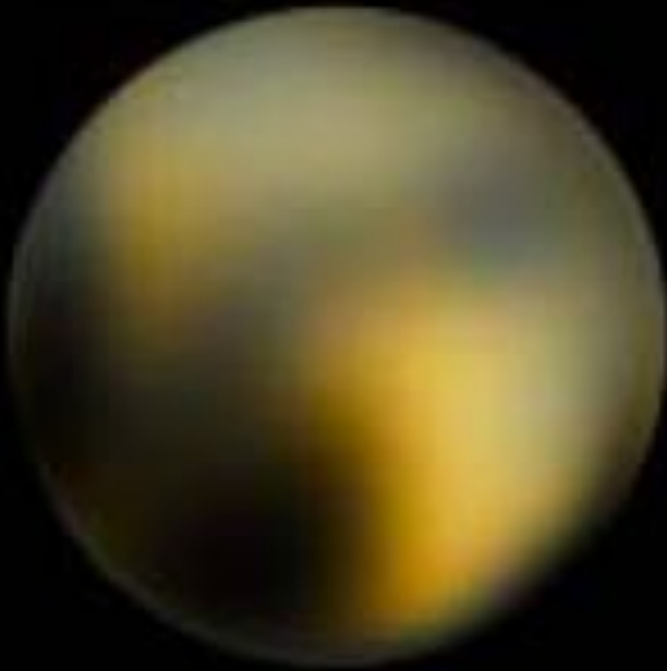
COSMIC ORIGINS
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IMAGINE SOLAR SYSTEM SCIENCE WITH LUVOIR ...

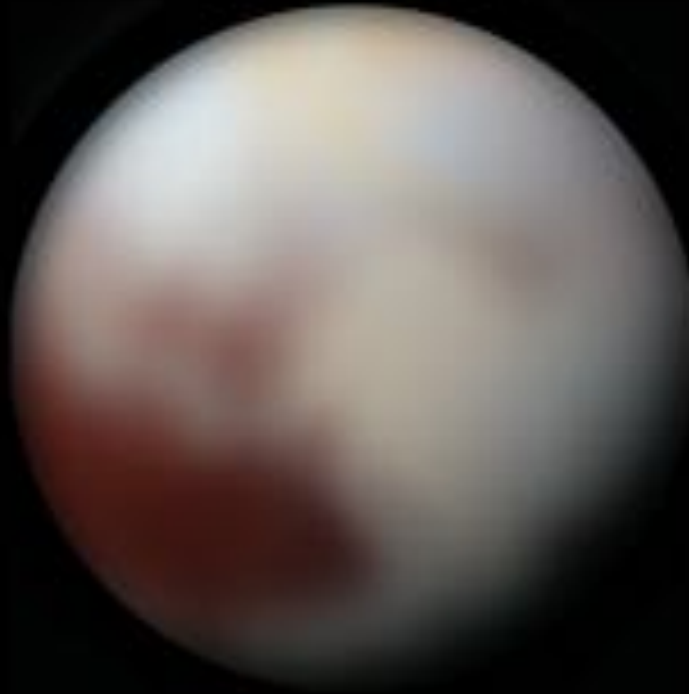


PLUTO

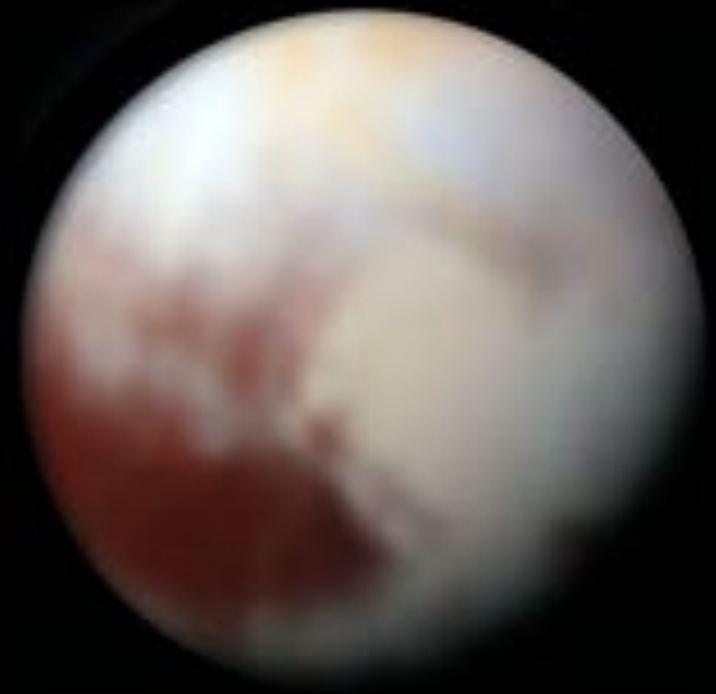


HST (2.4 m)

Buie et al. 2010



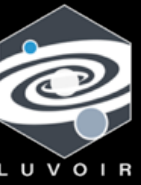
LUVOIR-B (8 m)



LUVOIR-A (15 m)

Credit: NASA / New Horizons / M. Postman (STScI)

IMAGINE SOLAR SYSTEM SCIENCE WITH LUVOIR ...



Far-UV hydrogen emission from Europa plumes

HST



LUVOIR-B



LUVOIR-A



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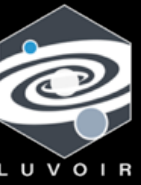
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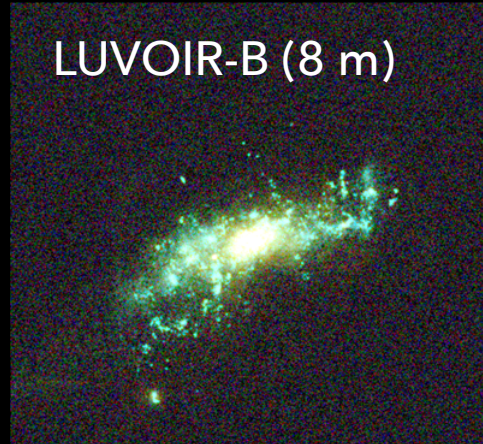


SEEKING THE BUILDING BLOCKS OF GALAXIES

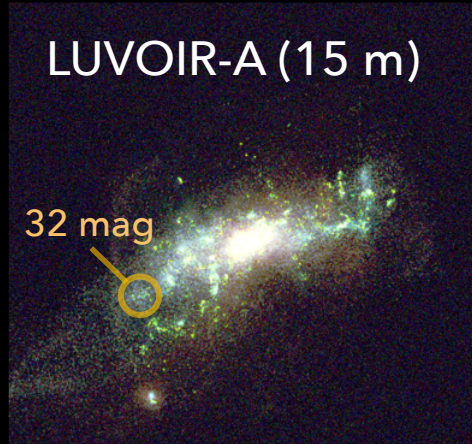


Dwarf galaxy

LUVOIR-B (8 m)

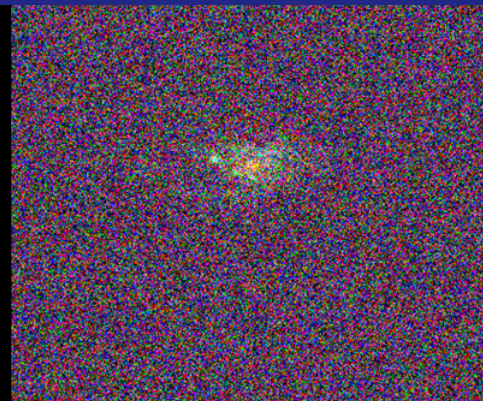


LUVOIR-A (15 m)

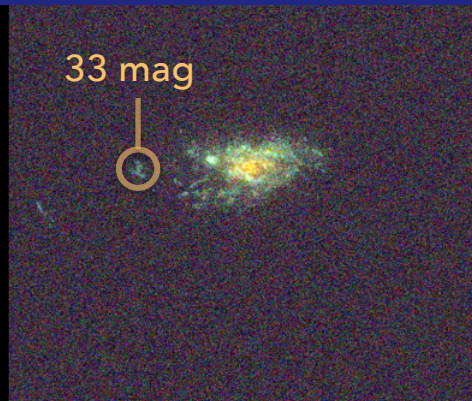


LUVOIR's *Deep Fields* – done in parallel with deep exoplanet observations – will reach the smallest mass scale of galaxy formation

Ultra-faint
dwarf galaxy

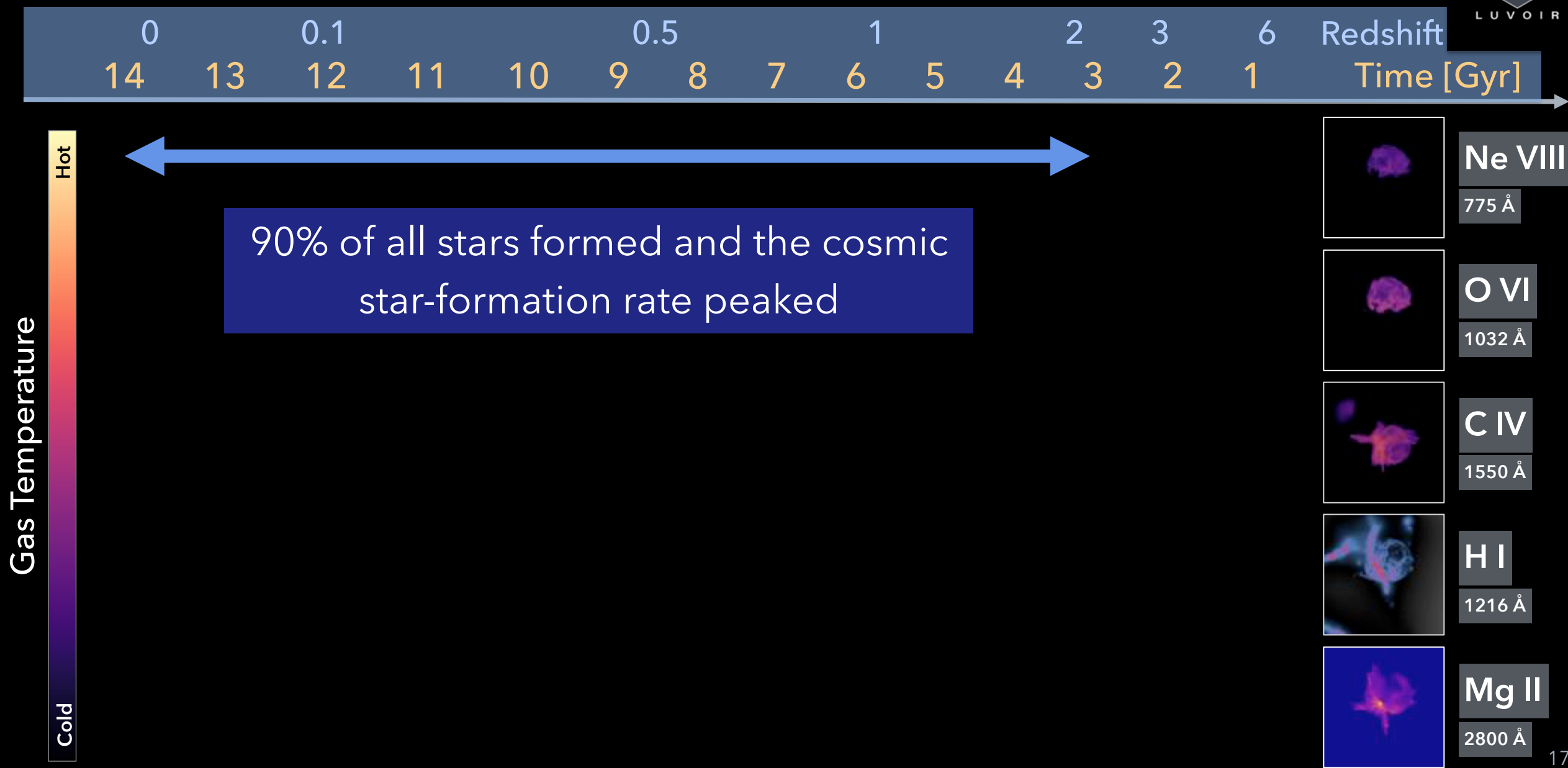


33 mag



$z = 2$ galaxy, 10^6 solar masses ($m_{AB} \sim 30$)

THE BARYON CYCLE AND THE ESSENTIAL ULTRAVIOLET



THE BARYON CYCLE AND THE ESSENTIAL ULTRAVIOLET



With ground-based OIR we can probe the cold gas down almost to $z = 0$, but lack access to the warm/hot gas over most of cosmic time

Gas Temperature

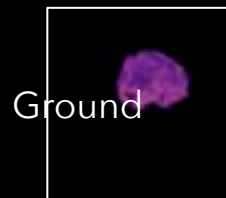
Hot

Cold



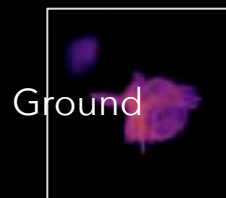
Ne VIII

775 Å



O VI

1032 Å



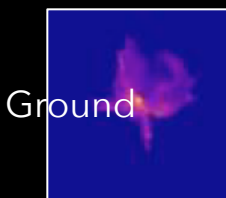
C IV

1550 Å



H I

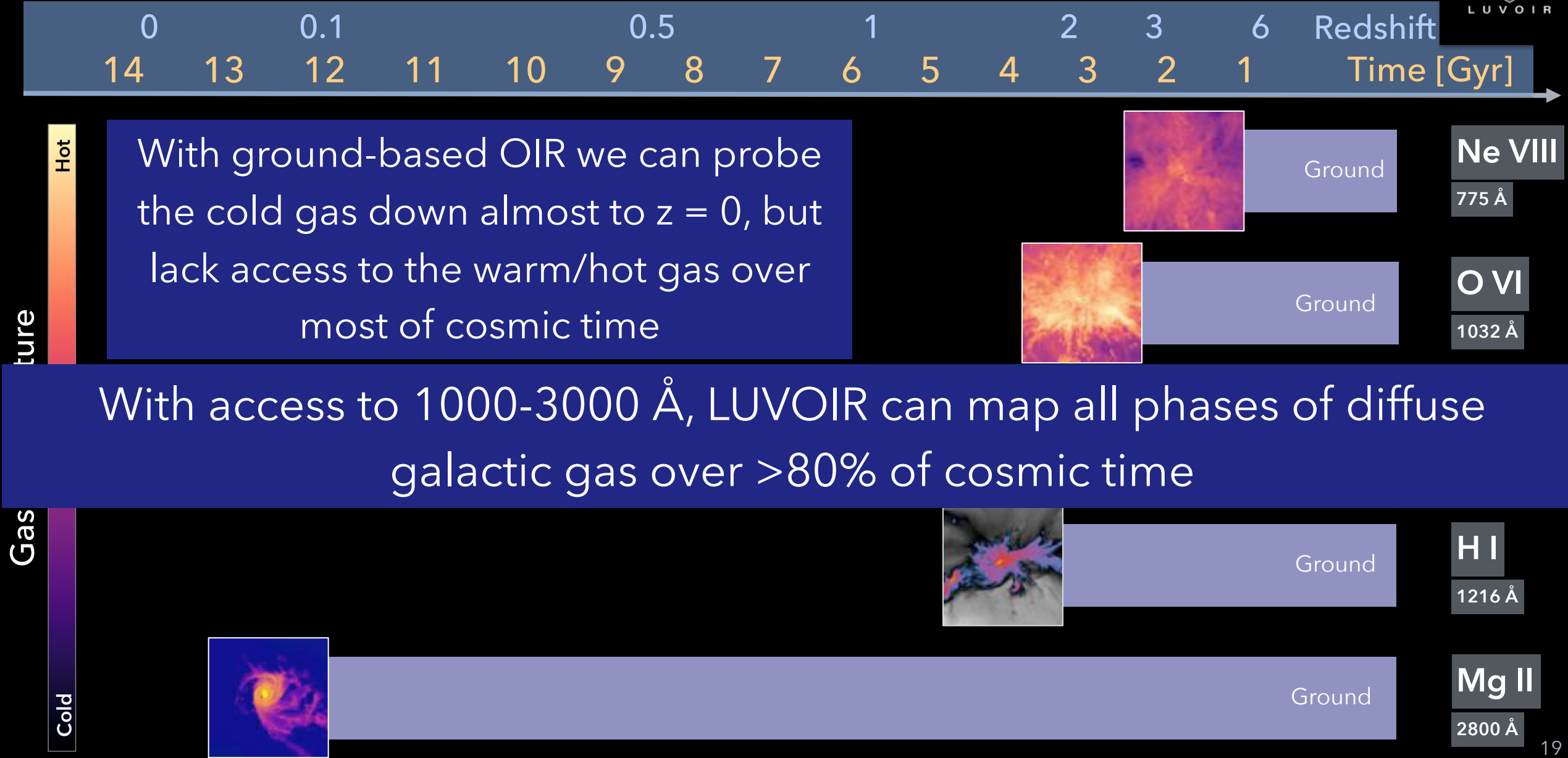
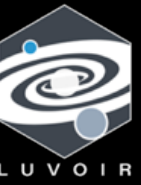
1216 Å



Mg II

2800 Å

THE BARYON CYCLE AND THE ESSENTIAL ULTRAVIOLET



LUVOIR-A

15-m, on-axis telescope

120 segments, 1.223-m flat-to-flat

155 m² collecting area

Four instrument bays

ECLIPS

LUMOS

HDI

POLLUX



LUVOIR-B

8-m, off-axis telescope

55 segments, 0.955-m flat-to-flat

43.4 m² collecting area

Three instrument bays

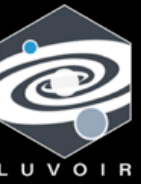
ECLIPS

LUMOS

HDI



LAUNCH VEHICLE OPTIONS

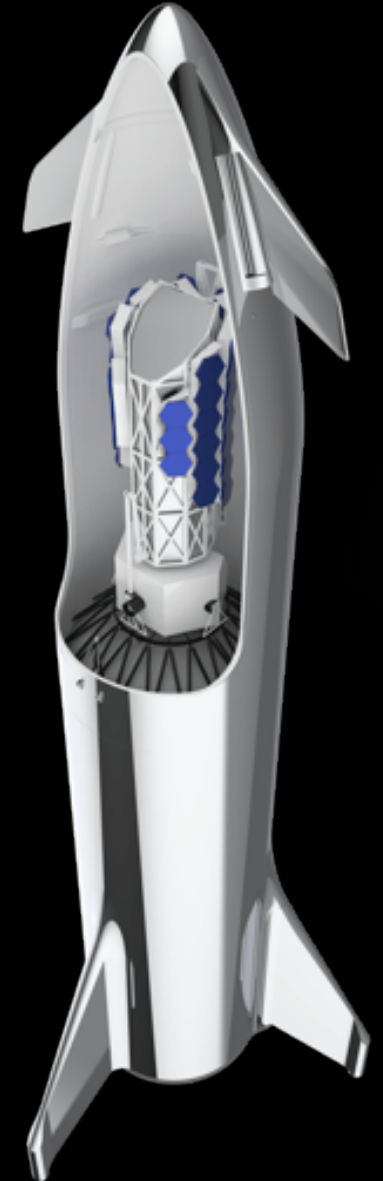


	LUV OIR-A	LUV OIR-B
NASA SLS Block 1	No	Yes
NASA SLS Block 1B	Yes	Yes
NASA SLS Block 2	Yes	Yes
Blue Origin New Glenn	No	Yes
SpaceX Starship	Yes	Yes

LUV OIR-A
in SLS Block 2



LUV OIR-B
in Starship
(courtesy of
SpaceX)



THE LUVOIR INSTRUMENTS

Observational challenge

Faint planets next to bright stars

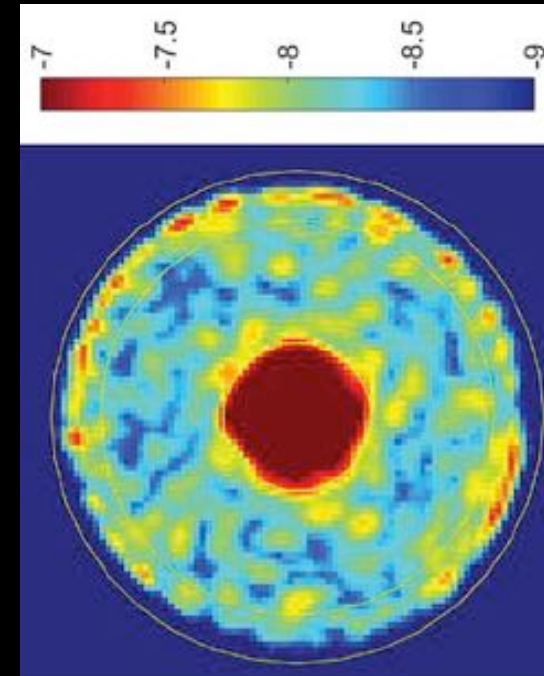
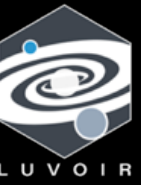
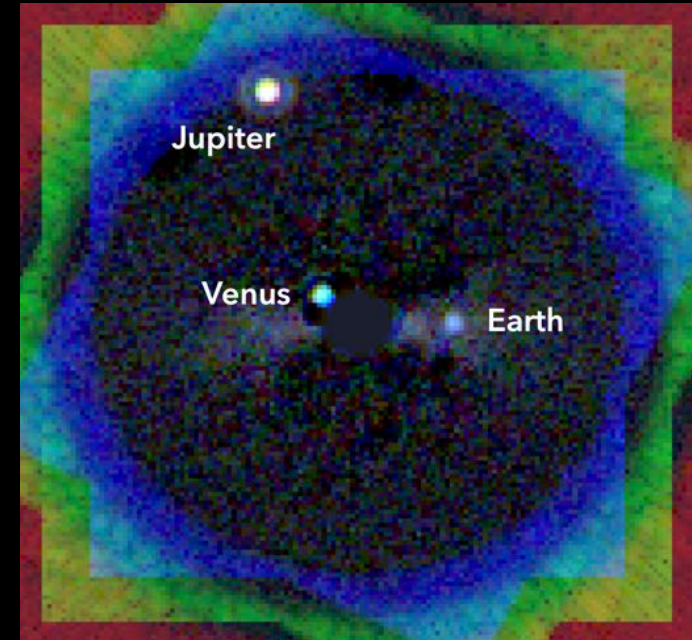
Extreme Coronagraph for Living Planetary Systems (ECLIPS)

Contrast $\sim 10^{-10}$

Bandpass: $0.2\ \mu\text{m}$ to $2.0\ \mu\text{m}$

Imaging spectroscopy: Vis R=140, NIR R=70 & 200

Tech development via Roman Space Telescope coronagraph instrument



Roman
Hybrid Lyot
Coronagraph

THE LUVOIR INSTRUMENTS



Observational challenge

Very cold to very hot gases

LUVOIR UV Multi-Object Spectrograph (LUMOS)

Bandpass: 100 nm to 1000 nm

$R = 500 - 56,000$

Up to 840 simultaneous spectra

FUV imaging channel

Heritage from STIS, COS, & NIRSPEC



Europa plumes



HST STIS UV instrument

THE LUVOIR INSTRUMENTS

Observational challenge

Imaging the ultra-faint and very small at high resolution

High-Definition Imager (HDI)

2 x 3 arcmin field-of-view

Bandpass: 0.2 μm to 2.5 μm

Large suite of filters & grisms

Micro-arcsec astrometry capability

Heritage from HST WFC3 & Roman WFI



HST Wide Field Camera 3

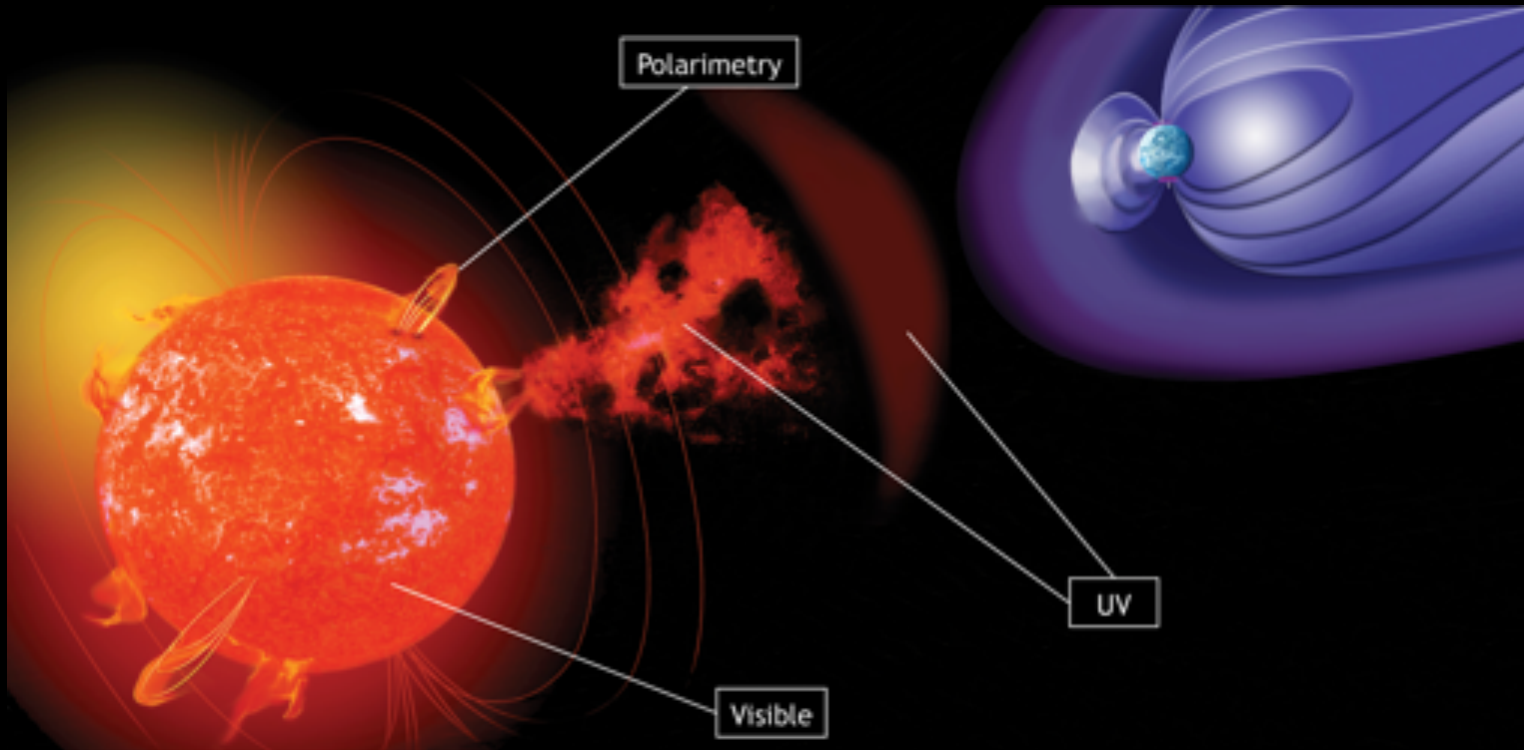
POLLUX – A EUROPEAN CONTRIBUTION TO THE LUVOIR

MISSION STUDY

UV spectropolarimeter (100 – 400 nm)

Circular + linear polarization

High resolution point-source spectroscopy ($R \sim 120,000$)



Star-exoplanet interactions

Fundamental physics & cosmology

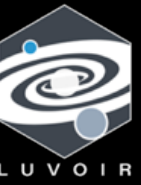
ISM and CGM

Stellar magnetic fields

AGN

Solar System

<http://luvoirtelescope.org>



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DESIGN

TOOLS

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TEAM

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LUVOIR

Space Telescope Concept for the 2030s

