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
Exotic Worlds

The Search for Life

Our Dynamic Solar System

Cosmic Origins & The Ultra-Faint Universe
DESIGNING A WELL-POSED SEARCH FOR LIFE EXPERIMENT

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

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

AAAC Exoplanet Task Force

NAS Astro2010 Decadal

NASA Astro Roadmap

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?

28 candidates

Measure frequency of Earth-like planets if >10%
What if Earth is even more rare?

- **LUVOIR-B**
  - 8-m
  - Measure frequency of Earth-like planets if >10%
  - 28 candidates

- **LUVOIR-A**
  - 15-m
  - Measure frequency of Earth-like planets if >5%
  - 54 candidates
WHAT WOULD AN INHABITED EXOPLANET LOOK LIKE?

Earth at 10 pc ≈ 30th magnitude

SNR = 8.5 in each bandpass - needed to measure molecules
DOZENS OF HABITABLE CANDIDATES, HUNDREDS OF PLANETS

For every exoEarth candidate, LUVOIR will observe $>10x$ 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
Exotic Worlds

The Search for Life

Our Dynamic Solar System

Cosmic Origins & the Ultra-Faint Universe
IMAGINE SOLAR SYSTEM SCIENCE WITH LUVOIR …

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

Roth et al. (2014)

Credit: G. Ballester (LPL)
Exotic Worlds

The Search for Life

Our Dynamic Solar System

Cosmic Origins & The Ultra-Faint Universe
**SEEKING THE BUILDING BLOCKS OF GALAXIES**

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

- **LUVOIR-B (8 m)**
  - Dwarf galaxy
  - $z = 2$ galaxy, $10^6$ solar masses ($m_{AB} \sim 25.5$)

- **LUVOIR-A (15 m)**
  - Ultra-faint dwarf galaxy
  - $z = 2$ galaxy, $10^6$ solar masses ($m_{AB} \sim 30$)
**The Baryon Cycle and the Essential Ultraviolet**

<table>
<thead>
<tr>
<th>Time [Gyr]</th>
<th>Redshift</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

90% of all stars formed and the cosmic star-formation rate peaked

**Representative WAVELENGTHS:**
- 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

<table>
<thead>
<tr>
<th>Time [Gyr]</th>
<th>0</th>
<th>0.1</th>
<th>0.5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redshift</td>
<td>14</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

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.
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.

With access to 1000-3000 Å, LUVOIR can map all phases of diffuse galactic gas over >80% of cosmic time.
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

## LUVOIR-A and LUVOIR-B in Starship

<table>
<thead>
<tr>
<th></th>
<th>LUVOIR-A</th>
<th>LUVOIR-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA SLS Block 1</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>NASA SLS Block 1B</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>NASA SLS Block 2</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Blue Origin New Glenn</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>SpaceX Starship</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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 $\mu$m to 2.0 $\mu$m

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

Tech development via Roman Space Telescope coronagraph instrument
THE LUVOR 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
**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
POLLUX - A EUROPEAN CONTRIBUTION TO THE LUVOIR MISSION STUDY

UV spectropolarimeter (100 - 400 nm)
Circular + linear polarization
High resolution point-source spectroscopy (R ~ 120,000)

- Star-exoplanet interactions
- Fundamental physics & cosmology
- ISM and CGM
- Stellar magnetic fields
- AGN
- Solar System
http://luvoirtelescope.org

Follow LUVOIR on twitter
@luvoirtelescope