AIAA Space 2018 September 19, 2018

Priority Science Goals Enabled by In-Space Assembled Telescopes

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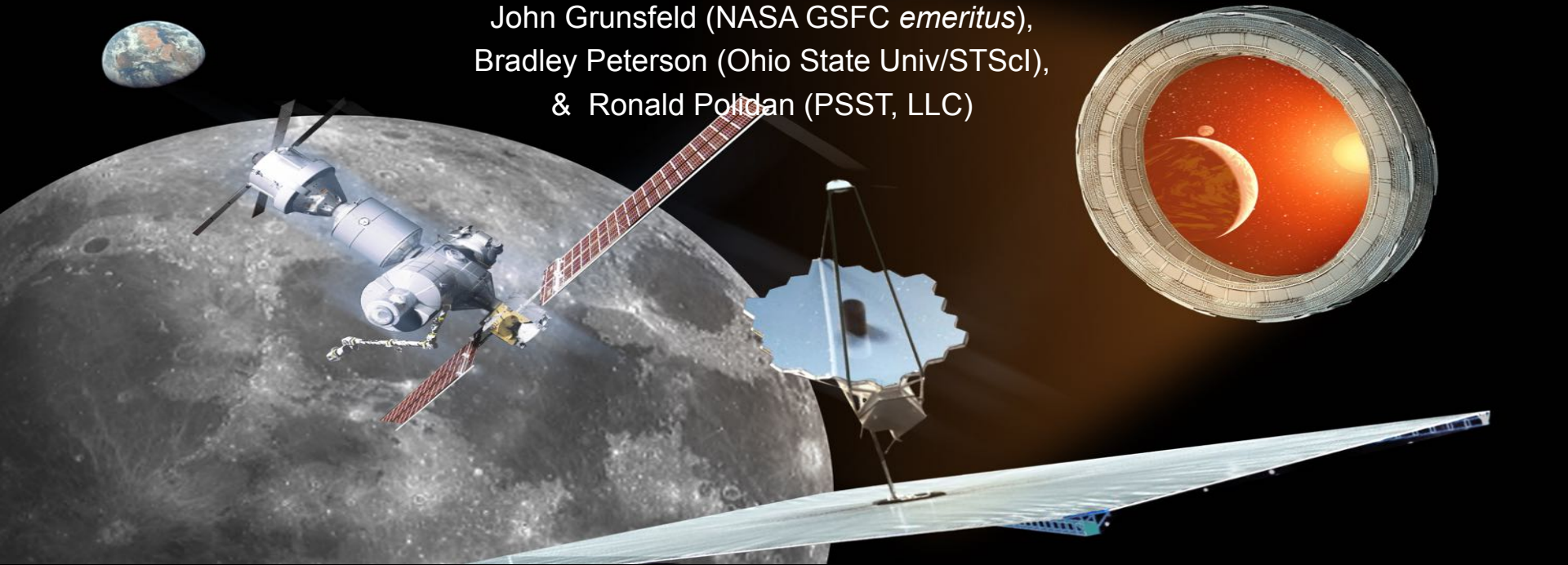
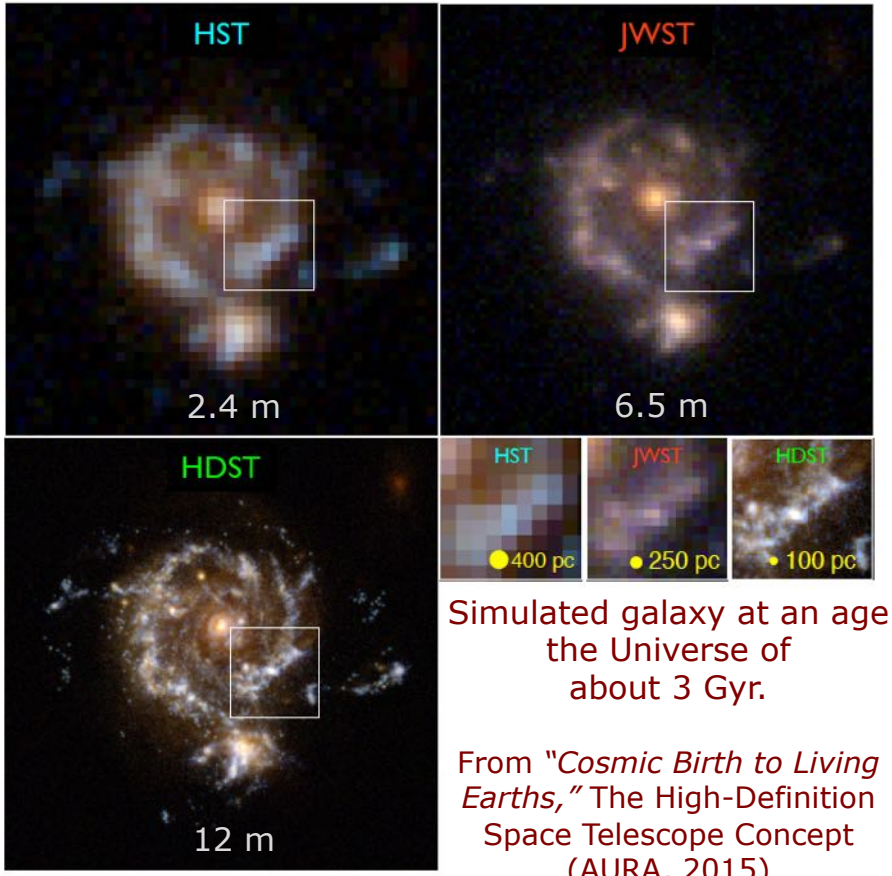


Motivation: Cosmic Revelations Increase Rapidly with Telescope Aperture (I)



Simulated galaxy at an age the Universe of about 3 Gyr.

From *"Cosmic Birth to Living Earths,"* The High-Definition Space Telescope Concept (AURA, 2015)

With spatial resolutions achievable by apertures in excess of ~10 meters, regions of active star formation in extremely distant galaxies can be separated from the older stellar populations.

The evolution over cosmic time of the star formation in galaxies can be studied in detail.

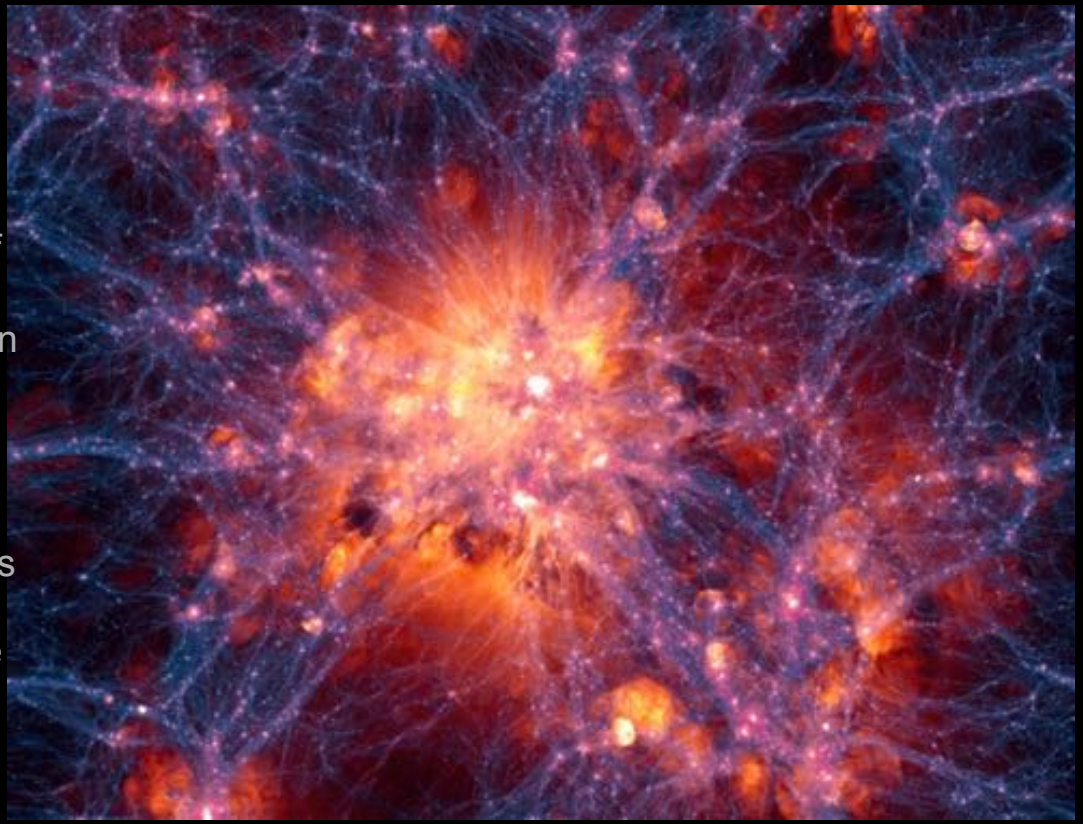
Moreover, the dynamic structure of very young galaxies, include the presence of dwarf and colliding companions can be revealed.

If your pictures aren't good enough, you aren't close enough.– Robert Capa

Motivation: Cosmic Revelations Increase Rapidly with Telescope Aperture (II)

Clusters of galaxies are strung out along dark matter webs like jewels in space, but many unanswered questions remain about the nature of the cosmos, including the nature of dark matter and how galaxy formation works on small size scales.

Future large-aperture observatories can investigate these questions by imaging fainter and smaller structures in the universe than ever before. Additionally, it will be able to map the distribution of dark matter in the nearby universe.



Theoretical model of the “cosmic” web from the LUVOIR science program.

Motivation: Cosmic Revelations Increase Rapidly with Telescope Aperture (III)

Active star-forming regions shine in the rose-red light of hydrogen emission along the arms of a spiral galaxy similar to the Milky Way.

A large-aperture space observatory will be able to investigate stellar populations and the role of energetic young stars and HII regions in galaxies at distances of tens of mega-parsecs. This allows a much wider range of galaxy types to be observed than is currently the case.

Spiral galaxy M83 from the Hubble Heritage program.

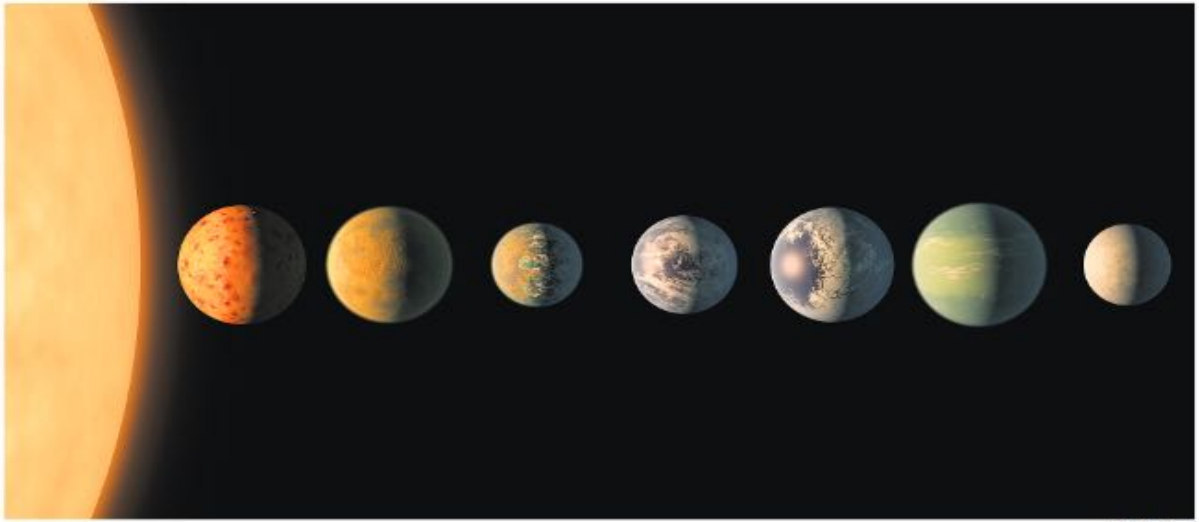
"All the News That's Fit to Print"

The New York Times

Late Edition
Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI ... No. 57,517

NEW YORK, THURSDAY, FEBRUARY 23, 2017 $2.50



JPL-CALTECH/NASA

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

Question of Transgender Rights Splits DeVos and Sessions

This article is by Jeremy W. Peters, Jo Becker and Julie Hirschfeld Davis.

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

In a joint letter, the top civil rights officials from the Justice Department and the Education Department rejected the Obama administration's position that nondiscrimination laws require schools to allow transgender students to use the bathrooms of their choice.

That directive, they said, was improperly and arbitrarily devised, "without due regard for the primary role of the states and lo-

Circling a Star Not Far Away, 7 Shots at Life

By KENNETH CHANG

Uber's Culture Of Gutsiness Under Review

By MIKE ISAAC

Migrants Hide, Fearing Capture on 'Any Corner'

By VIVIAN YEE

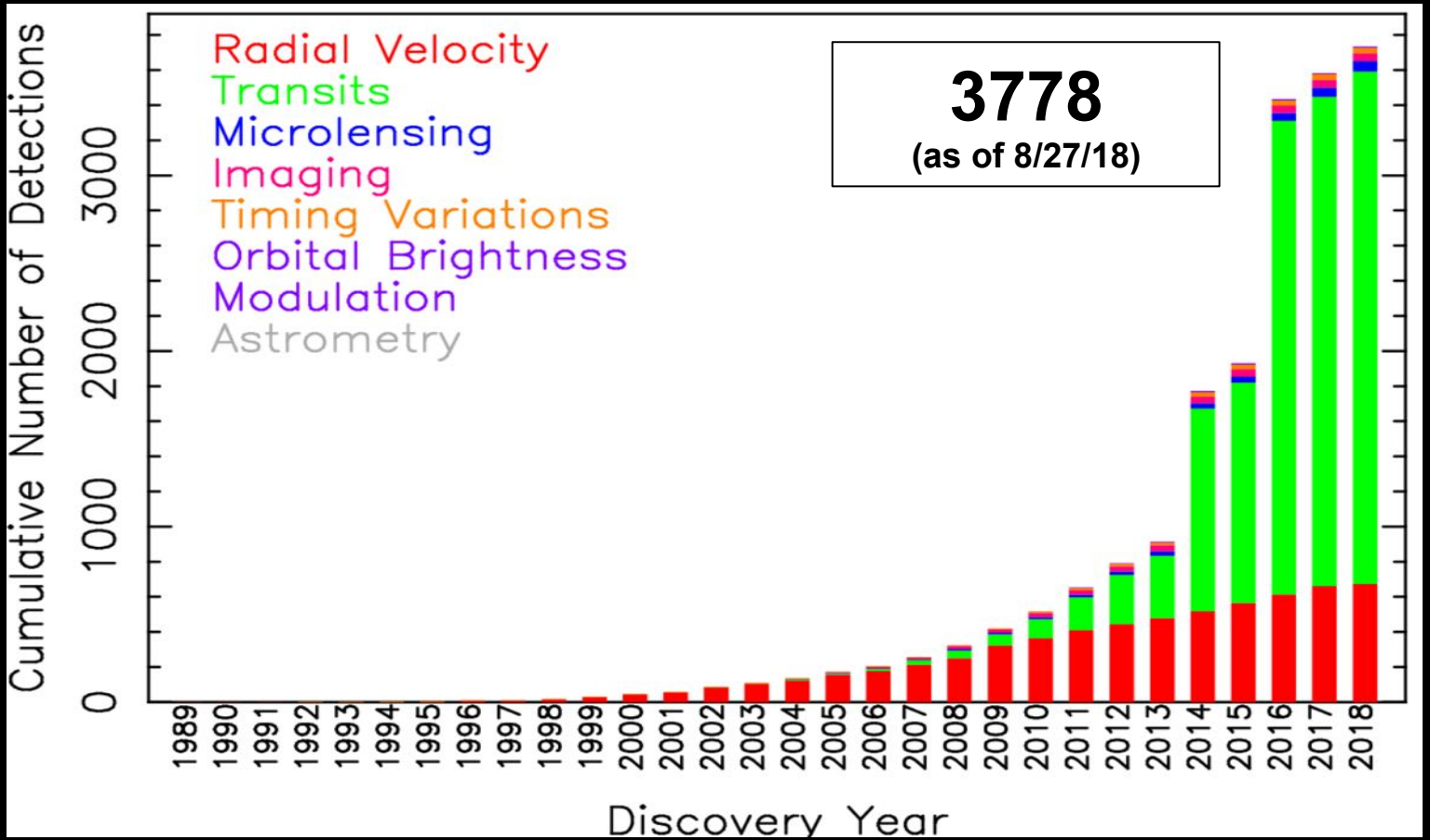
No going to church, no going to the store. No doctor's appointments for some, no school for others. No driving, period — not

IMMIGRATION A police department worries a crackdown will harm work to fight gangs. PAGE A14

MEXICO The secretary of state pays a visit as a time of rising

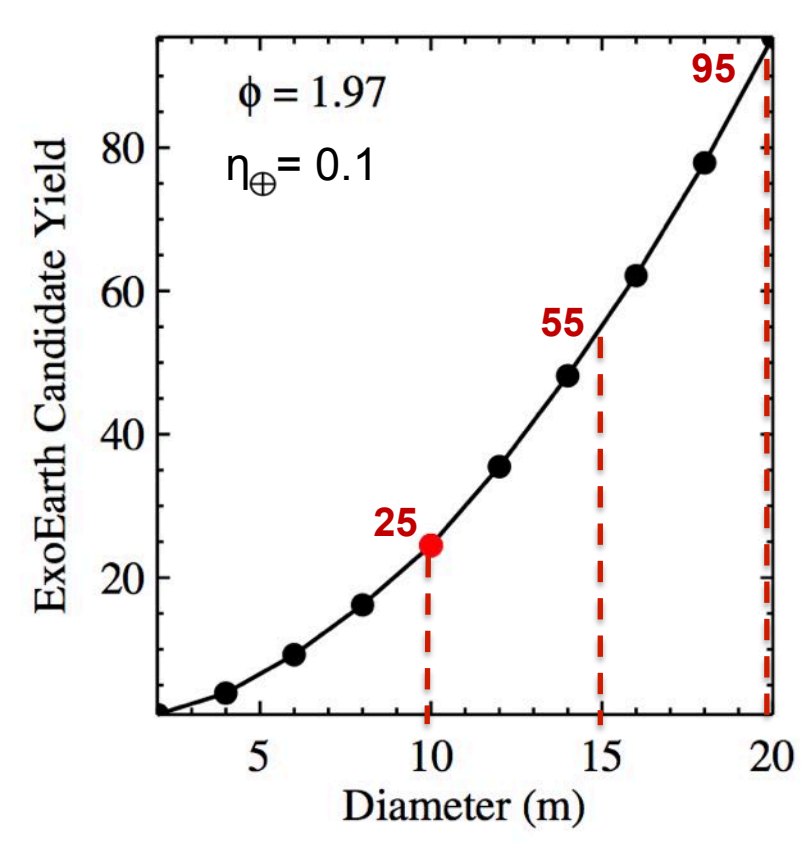
duras.

If deportation has always been a threat on paper for the 11 million people living in the country illegally, it rarely imperiled those who did not commit serious crimes. But with the Trump ad-



exoplanetarchive.ipac.caltech.edu

Cosmic Revelations Increase Rapidly with Telescope Aperture: exo-Earths



Number of candidate exo-Earths increases approximately as D^2 for a fixed integration time.

Increasing sample size will increase likelihood of discovery of an exo-Earth . . .or else put credible limits on their existence.

With ~100 candidates, if η_{Earth} = 0.1, one exo-Earth should be detected with a confidence of 95%.

In addition, a large aperture will reduce the integration time to obtain diagnostic spectra.

Calculated number of candidate exoEarths in the solar neighborhood, assuming the fraction of stars orbited by an Earth-like planet is 0.1 (Stark *et alia*, ApJ, *808*, 2015).

Transit Exoplanet Survey Satellite

Launched April 18, 2018

Credit: NASA

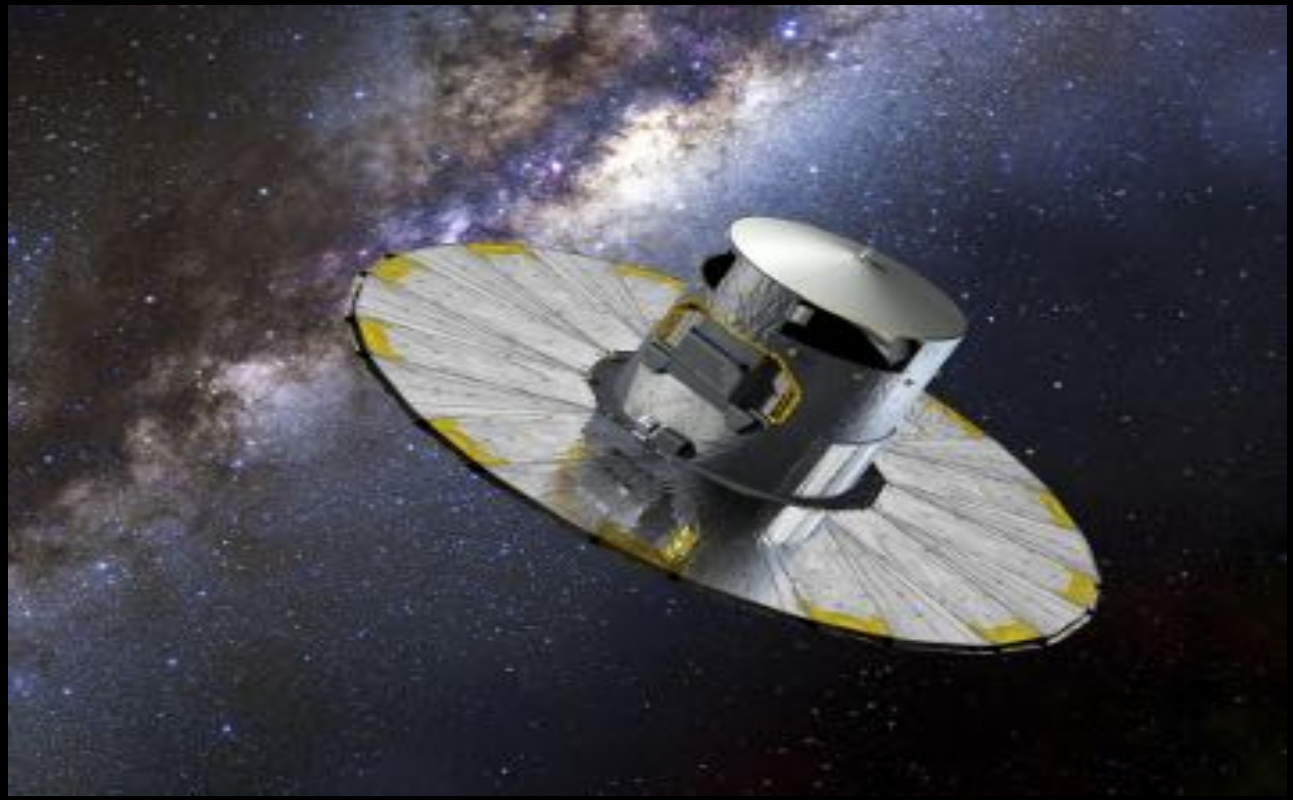
Wide Field InfraRed Survey Telescope (WFIRST)

Planned launch approximately mid-2020s

Photo: NASA

Gaia

Astrometric Discovery of Exoplanets (Launched December 2013)



Credit: ESA

We now know that in our Galaxy…

Planets are common
(> 1 per star)

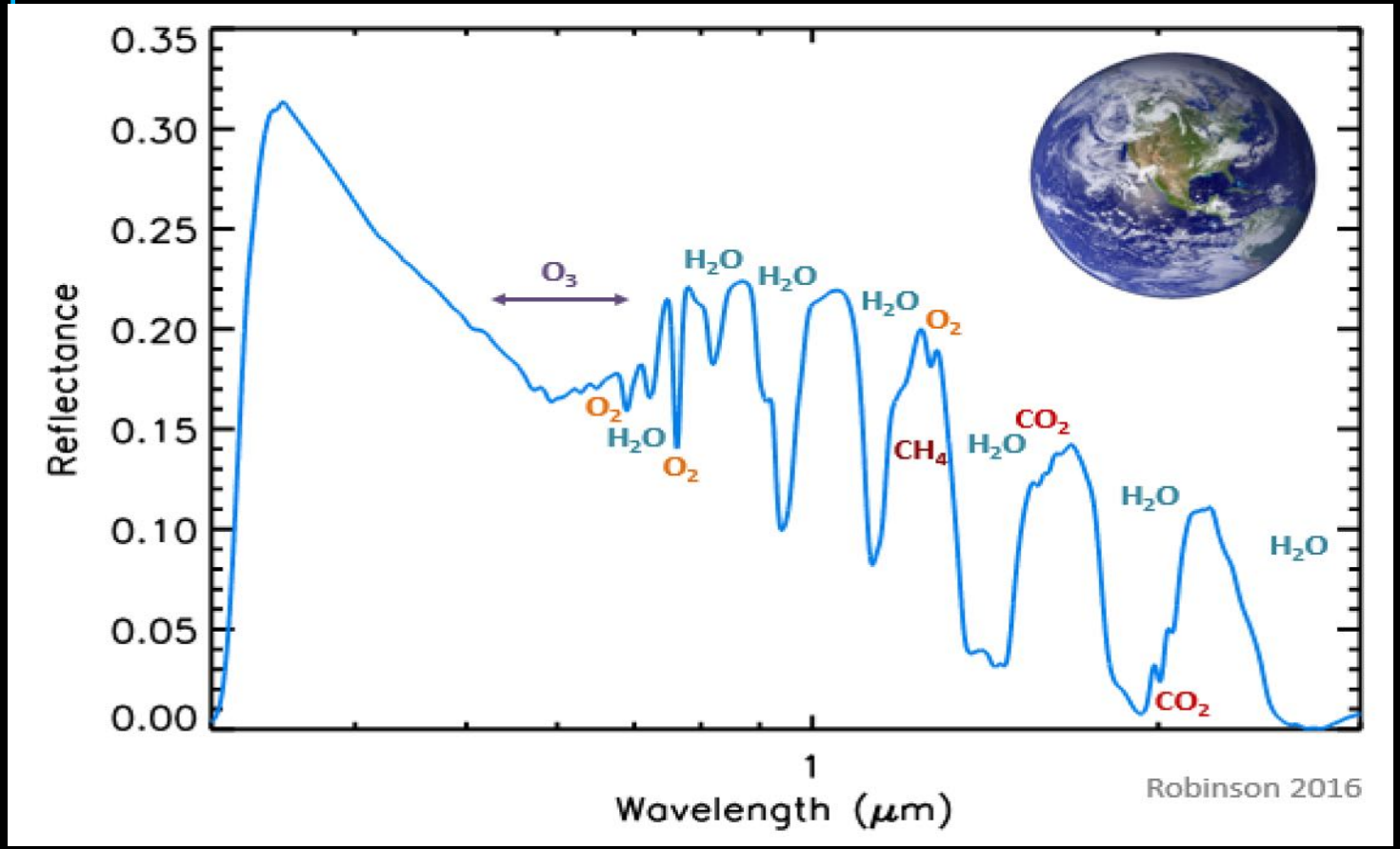
Planets with sizes
0.5-2 times Earth
are the most common

Earth-size planets in the
Habitable Zone are common

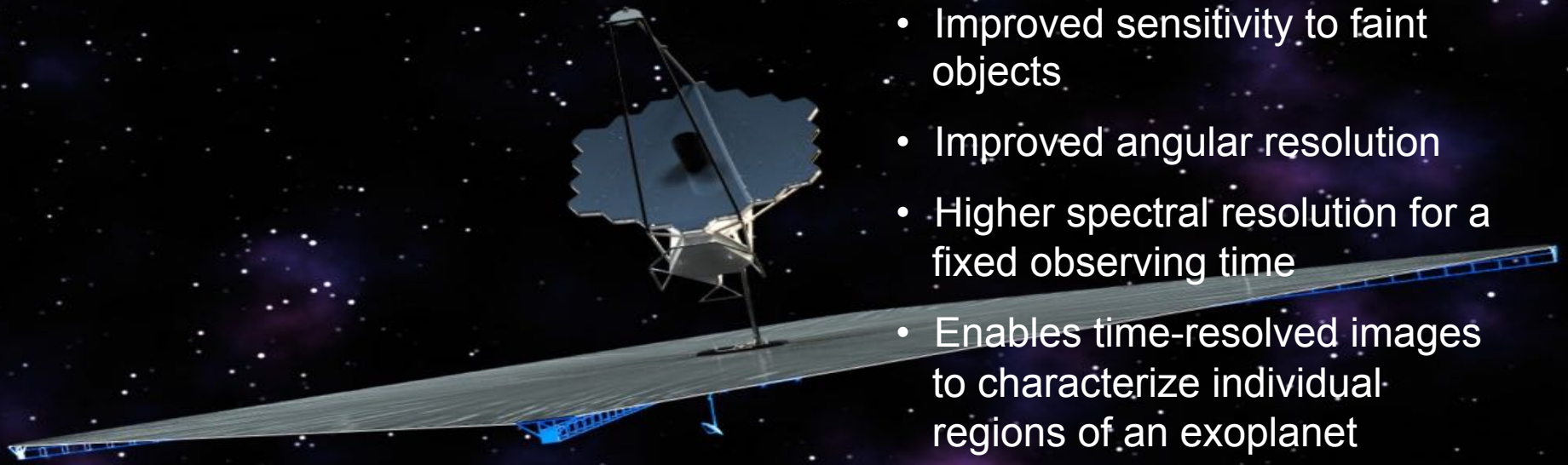
…we're ready for the search for life

Potential Biosignature Gases Requires Spectroscopy

Spectral Lines



In the Search for Life on Distant Planets
Bigger is Better



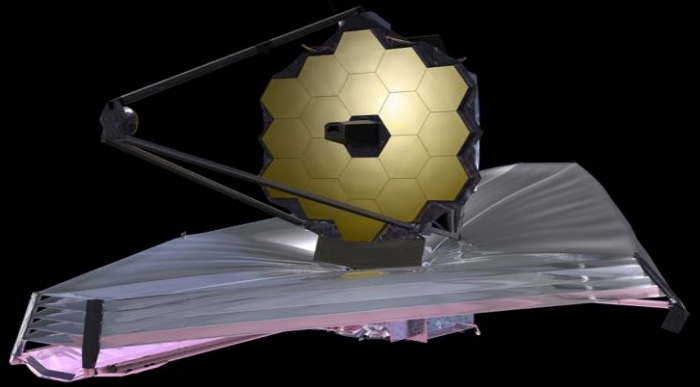
- Improved sensitivity to faint objects
- Improved angular resolution
- Higher spectral resolution for a fixed observing time
- Enables time-resolved images to characterize individual regions of an exoplanet
- Increased exoplanet yield

CREDIT: ATLAST Study Team (NASA) 2015

Telescope Size Currently Limited by Deployment Complexity, Fairing Size, and Lift Capacity

Ariane 5 (4.6 m fairing)

6.5 m JWST



SLS Block Ib Cargo (8.4 m fairing) < 9 m telescope
SLS Block 2 Cargo (8.4/10 m fairing) ~ 12 -- 15 m telescopes
?? – > 15 m telescopes

- 40 deployable structures
- 178 release mechanisms (all of which must work for the deployment to be successful)

Challenges in the not-so-distant future

- Science will require increasingly larger telescopes for which no existing or planned launch vehicles can deploy autonomously *a la* JWST.
  - SLS versions are not guaranteed

- Expensive telescopes and spacecrafts will continue to have relatively short lifetimes (~10–20 years) unless upgraded.
  - JWST's lifetime is expect to be 5-10 years and is not planned to be serviced
  - HST is entering its 29th year of operation and still providing exceptional science
  - Ground-based telescopes can have ~ 50+ year lifetimes

- Deployment designs are getting more complicated (i.e. costlier) and riskier

We need a new paradigm that provides the capability to build larger telescopes for less money and with less risk.

We need to begin developing the capabilities and technologies to service and assemble future generations of large space telescopes and spacecraft in-space robotically now.

A New Vision for Large Space Telescopes

1) **Assembled in space**

2) **Serviced in space to extend their utility by:**
   - replacing the instrument payloads with newer more advanced ones
   - upgrading spacecraft subsystems as they wear and age
   - refueling to extend their lifetimes,
   - repairing when needed, and
   - incrementally enlarging the apertures over time

Why Now?

- **Inform the 2020 National Academies' Decadal Survey, which is starting in a few months, and NASA's Science Mission Directorate that space servicing, upgrade, and assembly offers:**
  - potential science enabling capabilities: large science telescopes, extended lifetimes
  - cost reduction possibilities
  - risk reduction opportunities
  - synergies with other NASA directorates, commercial, DoD
- **Technology development time**
  - The process of identifying, developing, and maturing the technologies to enable servicing, repair, and assembly will take time
  - We need to begin creating a technology roadmap and implementing early development efforts in the very near future, for example using ISS as a testbed prior to its termination
- **Opportunity to coordinate early**
  - Early involvement with industry and NASA Gateway teams offers opportunities to influence studies before designs are "frozen in"

Introduction of Panels

Panel 1: Technology Capabilities, Challenges, and Opportunities

D. Akin (U Md), D. Arney (NASA LaRC),
S. Jefferies (NASA LaRC), & A. Tadros (SSL)

Panel 2: Programmatic and Policy Challenges and Opportunities

K. DiMarzo (MIS), E. Rodgers (NASA LaRC),
B. Sullivan (DARPA), & D. Tomek (NASA LaRC)

QUESTIONS?

Back-Up

New Ground-Based Extremely Large Telescopes

24 – 40 meters in diameter, approximately 2020s