Apr 27th, 8:00 AM

Panel Session III - Astronomical Search for Origins Program

Eric P. Smith

*Origins Theme Scientist, James Webb Space Telescope Program Scientist*

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Astronomical Search for Origins Program

Eric P. Smith
Origins Theme Scientist,
James Webb Space Telescope Program Scientist

Understand How the Galaxies Formed in the Early Universe
- Determine the role of gravity in the emergence of galaxies
- Establish how the formation and evolution of a galaxy influence the chemical composition that is available to stars, planets, and living organisms

Understand How Stars and Planetary Systems Form and Evolve
- Discover planetary systems forming around young stars
- Characterize the planets and planetary systems around stars

Determine Whether Habitable or Life-bearing Planets Exist around Nearby Stars
- Determine how common habitable worlds are in the Universe
- Establish how to recognize the signatures of life on other worlds

Key Science missions include the Keck interferometer, SIM, and ultimately Terrestrial Planet Finder
Origins Program Missions

- KECK
- Origins Probes
- Long Baseline Starlight Nulling Arrays
- Starlight Nulling
- Large UV/Optical Observatories
- Adaptive Optics
- Infrared Detection
- Space Interferometry
- Large Deployable Optics
- IR Focal Planes
- Passive Cooling

Observatories

Visions Beyond

James Webb Space Telescope (JWST)

- Mission (Part of NASA's Astronomical Search for Origins theme)
  - Detect light from the first objects in the universe
  - Study of the birth and evolution of galaxies
  - Understand star and planet formation
- Description
  - Sensitive (large and cold) infrared (0.6-28µm) space observatory
  - Orbit at Sun-Earth Lagrange Point 2 (L2 ~ about 1.5 million km from Earth)
  - Launch in 2011
  - 5 year lifetime (10 year goal)
- Status
  - Preliminary Design (Formulation/Phase B)

JWST Overview

- Organization
  - Project Lead: NASA's Goddard Space Flight Center
  - International collaboration w/ European and Canadian Space Agencies (ESA & CSA)
  - Prime Contractor: Northrop Grumman Space Technology
  - Other mission hardware & software: University of Arizona, JPL, STScI
- Status
  - Preliminary Design (Formulation/Phase B)

JWST Observatory

- Telescope
- Secondary Mirror
- Primary Mirror
- Instrument module
- Sunshield
- Spacecraft Bus

JWST Animation

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Transits Reveal Planet

- Transits of a planet orbiting HD 209458 determine properties of another Solar System
  - Previously known from radial velocity
  - Inclination = 87.1°
  - Mass = 0.63 M$_{\text{Jup}}$
  - Radius = 1.27 - 1.6 R$_{\text{Jup}}$
  - Density = 0.27 - 0.38 g/cc
  - Spectroscopy of transit signal can probe planet's atmosphere

Origins Program Missions

- Use transit photometry to detect Earth-size planets
  - Wide field-of-view 0.95-meter (3-foot) diameter telescope
  - Monitor 100,000 stars (every 15 minutes) for 4 years
  - Enough precision (20 ppm) to detect transits of Earth-size planets
  - Launches 2007

The Kepler Mission

Expected Number of Planetary Discoveries if most Stars have Planets
Origins Program Missions

KECK
- Nulling
- Synthetic Imaging

LBTI
- Space Interferometry
- Nulling

Spitzer
- Real Time Nulling
- IR FOcal Planes

SOFIA
- Large Cool Optics
- IR FOcal Planes
- Large Deployable Optics

JWST
- Large Deployable Optics

Sun's wobble seen from 33 light-years away

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Terrestrial Planet Finder (TPF)

“Like finding a firefly next to a searchlight on a foggy night”

- Detecting light from planets beyond solar system is hard:
  - Parent star is 10⁵ to 10⁶ times brighter
  - Planet within 1 AU of its parent star
- The science goal of TPF: identify terrestrial planets in the habitable zones of ~100-200 nearby stars and to examine the brightest detected planets for signs of life itself

The Habitable Zone* for Various Types of Stars

*The Habitable Zone is the range of distances from a star at which water can remain liquid on the surface of an orbiting planet

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Simulated TPF Spectrum of an Earth-like Planet

Atmospheric Composition of an Early Earth-like World Harboring Life?

Main Constituents
CO₂, N₂, H₂O

Secondary Constituents
CO, H₂, H₂S, CH₄

Trace Constituents
Organo-sulfur compounds, hydrocarbons, other reduced gases

How do Origins Missions Align with the Vision?

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Why Fly a TPF Coronagraph and an Interferometer?

- Respond to president's vision - "...conduct advanced telescope searches for Earth-like planets and habitable environments around other stars."
- The technology appears to be maturing for both
- Fly sooner -- A small to moderate sized coronograph in ~2014
  - Starlight suppression technology must be fully demonstrated first (by 2006)
  - Enter phase A in 2007
- More capable, later --- Formation flying interferometer done jointly with ESA later towards end of decade
  - Continue technology development during coronagraph formulation and implementation
  - Collaboration with ESA on SMART3 (~2011)
  - Enter Phase A in ~2011
- Most compelling science --- Data from both wavelength regions provide robust assessment of habitability and biomarkers
- Doing both within ORIGINS line requires no near term augmentation

Changes to Missions in response to the Vision

- JWST: project considering white paper study by astrobiologists outlining observatory capabilities for optimal astrobiology science return
- TPF: Split TPF program into two components, coronographic and interferometric observatories and accelerate development on coronographic option.

Origins Science in the New Vision

Implement a sustained and affordable human and robotic program to explore the solar system and beyond

Conduct advanced telescope searches for Earth-like planets and habitable environments around other stars

What are the properties of giants orbiting other stars? New evolutions of terrestrial planets?
What are their properties and which of them might be habitable?
Is there life on planets outside the solar system?

Origins Investigations
1. Study the properties of giant extra-solar planets using the combined light of planet and parent star.
2. Detect giant planets by direct imaging and study their properties.
3. Investigate which nearby stars host terrestrial planets that might be suitable for life.
4. Study the composition of atmospheres of terrestrial planets orbiting nearby stars.
5. Determine optimal biomarkers for life in the habitable zone.
6. Search for evidence of life on habitable planets orbiting other stars.

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ORIGINS Program Status:

- Well Aligned with New NASA Vision
  - ORIGINS program already investigating planetary systems today
  - Existing programs adopting the vision
- 2003 was an important year for ORIGINS
  - Both SIM and JWST passed into Phase B and are meeting technology and schedule milestones
- Long Term issues
  - Develop technology program for the large telescopes of a decade from now