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Panel Session III - Astronomical Search for Origins Program

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Astronomical Search for Origins Program

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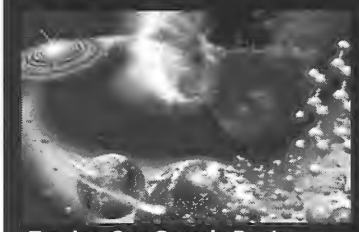
Origins Theme's Two Defining Questions

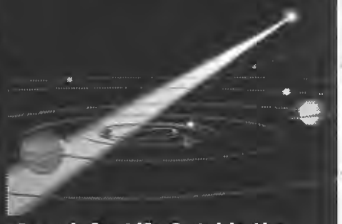
Where Did We Come From?



Tracing Our Cosmic Roots

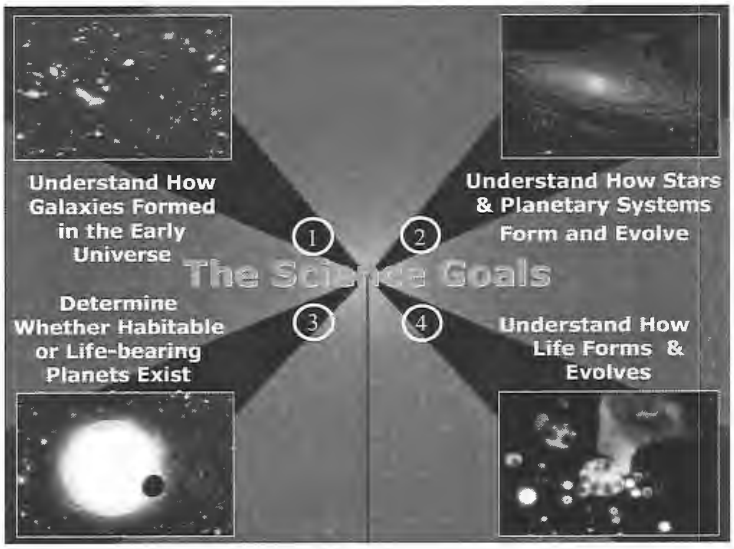
- Formation of galaxies, stars, heavy elements, planetary systems and ... life on the early Earth

Are We Alone?



Search for Life Outside the Solar system

- Remote detection of biological activities on planets beyond our solar system



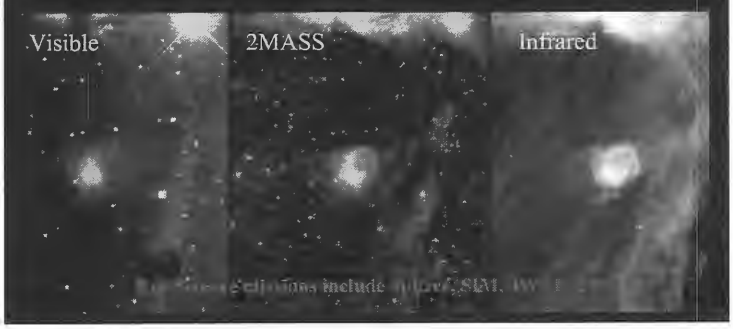
Understand How the Galaxies Formed in the Early Universe

- Determine the role of gravity in the emergence of galaxies
- Establish how the birth and aging of a galaxy influence the chemical composition that is available to stars, planets, and living organisms

- HST, COBE and WMAP gave us our first hints
- Spitzer and JWST will complete our understanding

Understand How Stars and Planetary Systems Form and Evolve

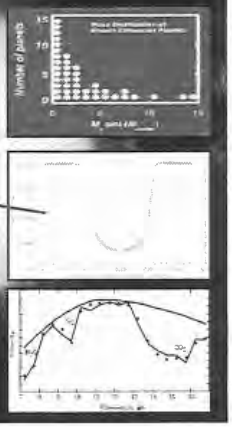
- Discover planetary systems forming around young stars
- Characterize the planets and planetary systems around stars



Key missions include JWST, SIM, IW

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

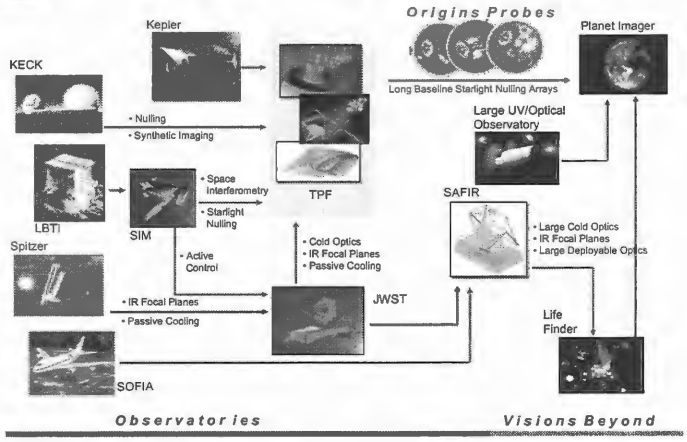


- Key Science missions include the Keck interferometer, SIM, and ultimately Terrestrial Planet Finder

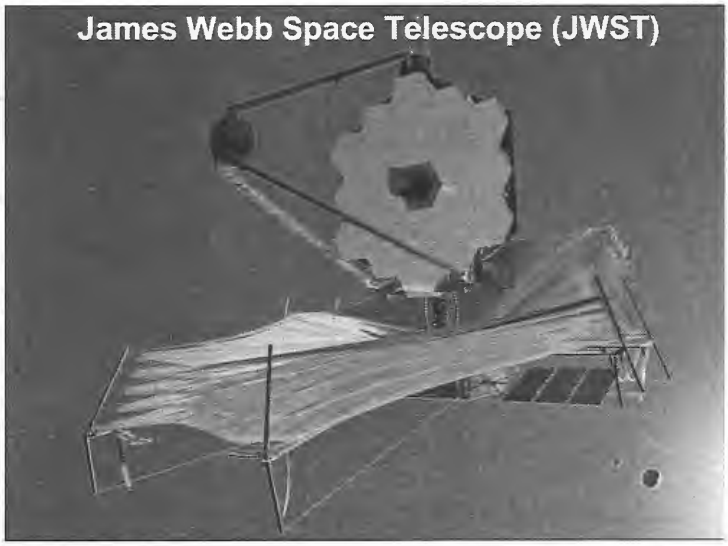
Understand How Life Forms & Evolves

- Determine the principles governing the organization of matter into living systems
- Determine limits of life in environments analogous to conditions on other worlds
- Astrobiology roadmap to identify next steps

Origins Program Missions



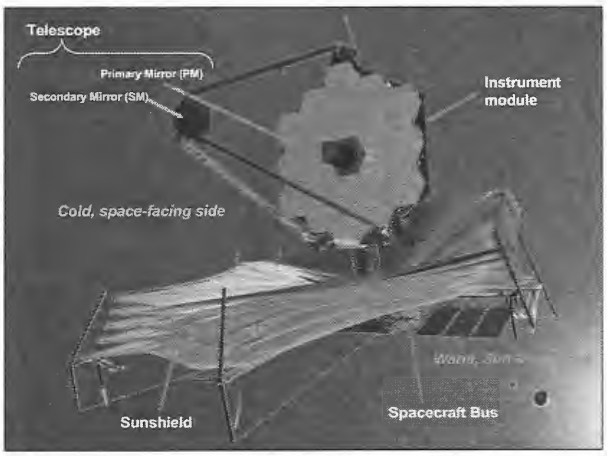
James Webb Space Telescope (JWST)



JWST Overview

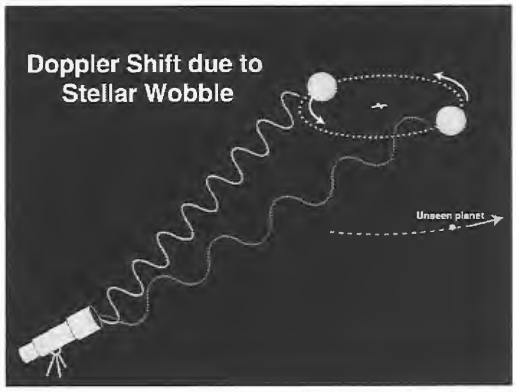
- **Mission** (Part of NASA's *Astronomical Search for Origins* theme)
  - Detect light from the first objects in the universe
  - Study of the birth and evolution of galaxies
  - Understand star and planet formation
- **Description**
  - Sensitive (large and cold) infrared (0.6-28μm) space observatory
  - Orbit at Sun-Earth Lagrange Point 2 (L2 – about 1.5 million km from Earth)
  - Launch in 2011
  - 5 year lifetime (10 year goal)
  - ~$3B total value:
    - ~$2.5B U.S. (~$1.9B development + ~$0.6B ops) + ~$0.4B equivalent value from ESA + ~$0.1B equivalent value from CSA [nearest $0.1B]
- **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)

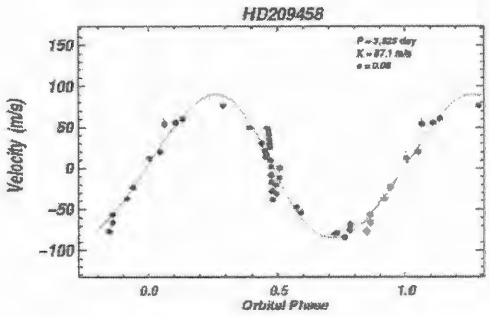
JWST Observatory



JWST Animation

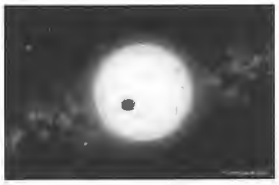
Radial Velocity Planet Detection

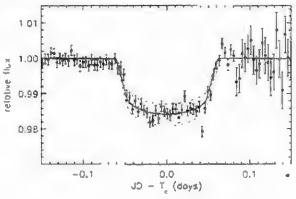




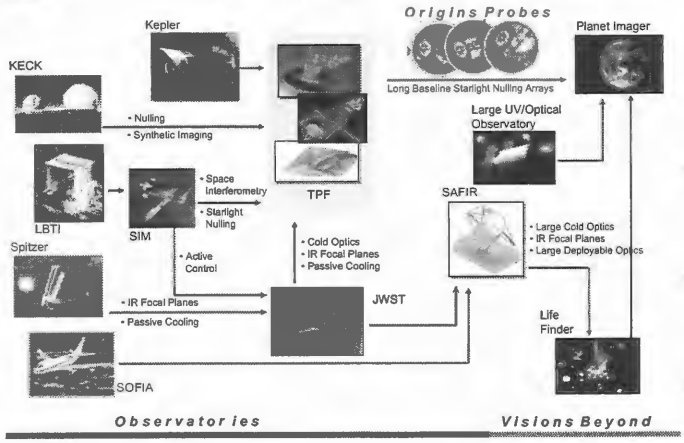
Transits Reveal Planet

- 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_{jup}
  - Radius =1.27-1.6 R_{jup}
  - Density= 0.27-0.38 g/cc <Saturn
- Spectroscopy of transit signal can probe planet's atmosphere





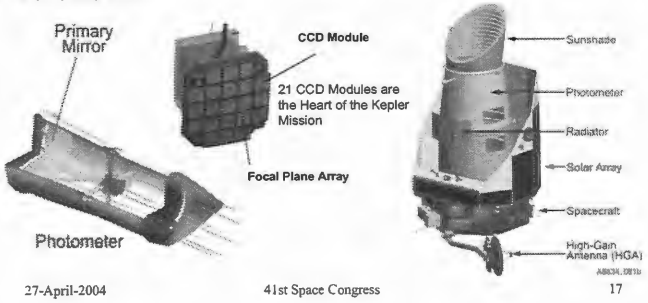
Origins Program Missions



The *Kepler* Mission

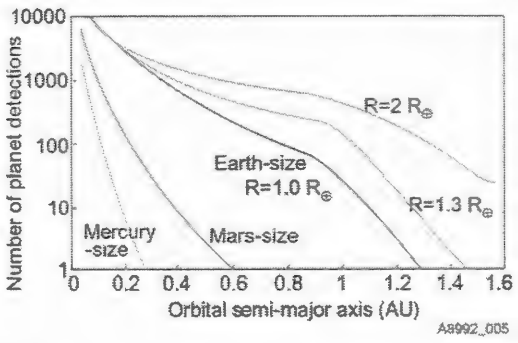
Use transit photometry to detect Earth-size planets

- 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

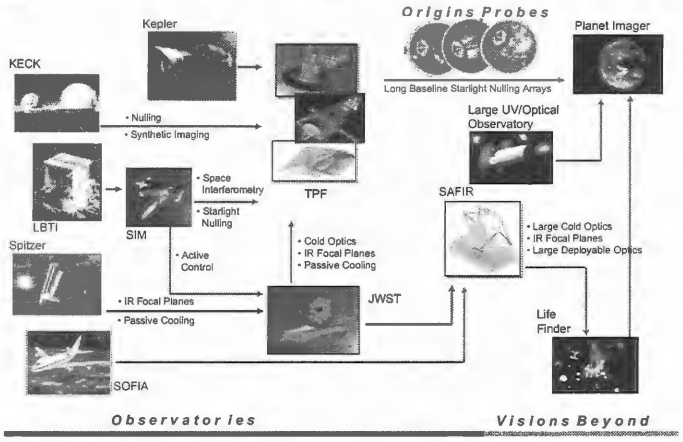


The *Kepler* Mission

Expected Number of Planetary Discoveries if most Stars have Planets



Origins Program Missions



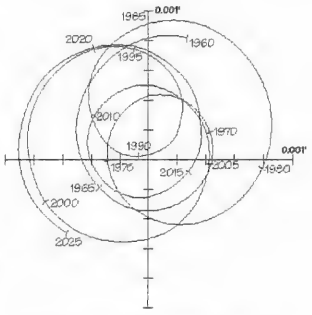
Space Interferometers: SIM

Space Interferometer Mission (SIM):

- Use astrometry to find planets orbiting nearby stars
  - From Jupiter's to a few Earth masses
- Carry out general astrometric program
- Demonstrate scientific operation of space interferometry
- Demonstrate TPF technologies and interferomeetric techniques
- Launch 2009
- 5+ year operation

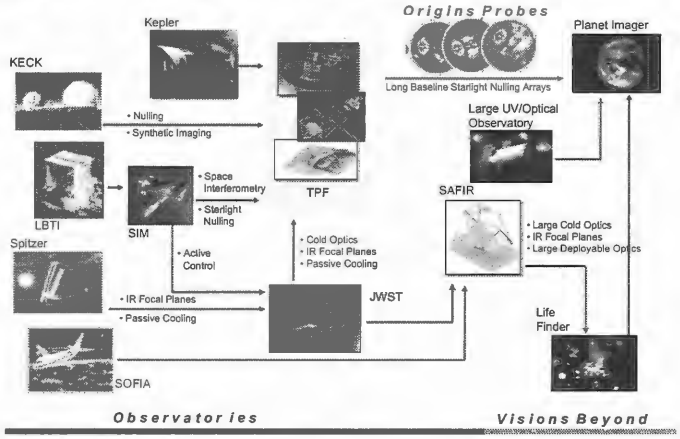
Astrometric Search for Planets

- Measure star's positional wobble
  - Complements radial velocity
  - Most sensitive to massive planets far from their stars
- **Space Interferometry Mission** will be able to detect tiny, tiny stellar wobble due to Earth-mass planets around nearby stars
  - Measures positions of stars with precision equivalent to the size of an ***amoeba in California as seen from Washington, DC!!***



Sun's wobble seen from 33 light-years away

Origins Program Missions

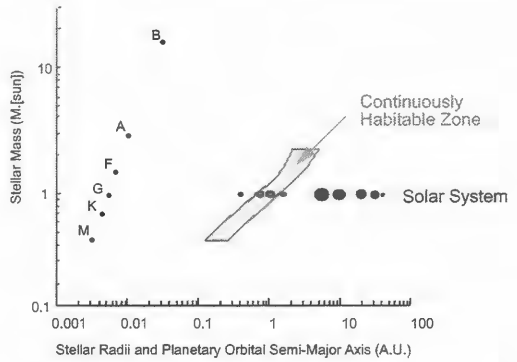


Terrestrial Planet Finder (TPF)

"Like finding a firefly next to a searchlight on a foggy night"

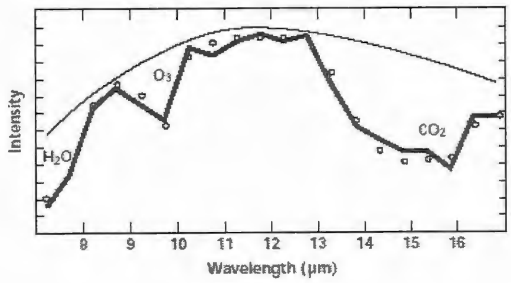
- Detecting light from planets beyond solar system is hard:
  - Parent star is 10^6 to 10^9 times brighter
  - Planet within 1 AU of its parent star
- The science goal of TPF : identify terrestrial planets in the habitable zones of ~100-200 nearby stars and to examine the brightest detected planets for 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

Simulated TPF Spectrum of an Earth-like Planet



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

Main Constituents

CO_2, N_2, H_2O

Secondary Constituents

CO, H_2, H_2S, CH_4

Trace Constituents

Organo-sulfur compounds, hydrocarbons, other reduced gases

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?
How common are terrestrial planets?
What are their properties and which of them might be habitable?
Is there life on planets outside the solar system?

Origins Investigations

11. Study the properties of giant extrasolar planets using the combined light of planet and parent star.
12. Detect giant planets by direct imaging, and study their properties
13. Investigate which nearby stars host terrestrial planets that might be suitable for life
14. Study the composition of atmospheres of terrestrial planets orbiting nearby stars
15. Determine optimal biosignatures for life on other worlds
16. Search for evidence of life on habitable planets orbiting other stars

How do Origins Missions Align with the Vision?

Mission	Status	Investigations
HST	Operational	11,23
Keck Interf.	ΦC/D	11,12
LBTI	ΦC/D	11,12
Kepler	ΦB, 2007 launch	11,13
SIM	ΦB, 2009 launch	11,13,14
JWST	ΦB, 2011 launch	11,12
TPF	~ 2014 launch	11,12,13,14,15,16

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.

Why Fly a TPF Coronagraph and an Interferometer?

- Respond to presidents 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

ORIGINS Program Status

- Well Aligned with New NASA Vision
  - ORIGINS program already investigating planetary systems today
  - Existing programs adapting to 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