Interferometry Systems and Architecture

JPL

Searching for Planets and Life with Interferometry

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"Light, Waves and Interference"
Jet Propulsion Laboratory
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Overview

- Build - in theory - an astronomical interferometer
- Examine the real thing being built
- Planet detection
- Space-based interferometers
- Detection of life

Relative Scales

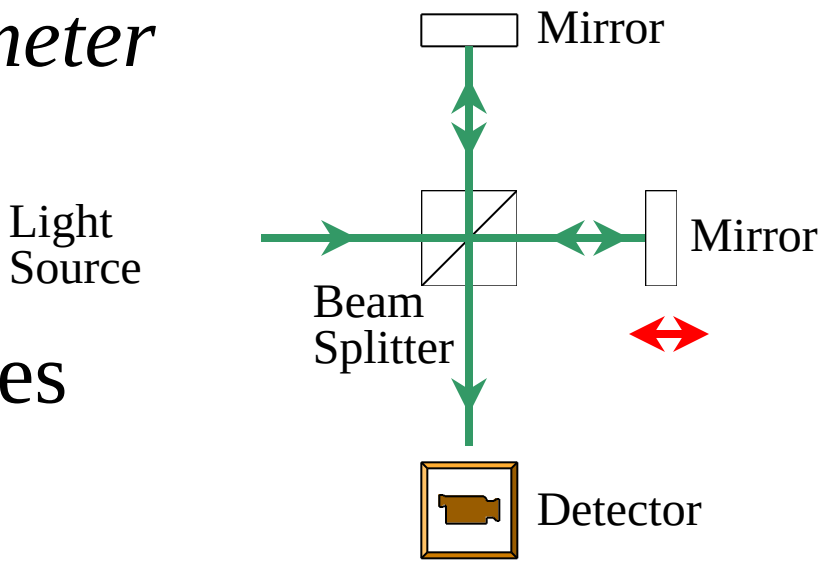
- A circle = 360 degrees
- 1 degree = 60 minutes of arc (arcminutes)
  - The moon: 1/2 a degree
- 1 arcminute = 60 seconds of arc (arcseconds)
  - Jupiter: 1/2 an arcminute
- 1 arcsecond = 1000 milliarcseconds (mas)
  - Stars: largest are 20-50 mas, typically 1 mas
  - 1 mas = Apparent size of an orange in NYC if you are in LA
- 1 mas = 1000 microarcseconds (μas)
  - 1 μas = 1/10 of the dot on the “i” in Sunkist on that orange

Building an Astronomical Interferometer

- Start with a traditional interferometer
- “Unwrap” it
- Add telescopes
- Add delay lines
- Put at a nice location
- Get a research grant

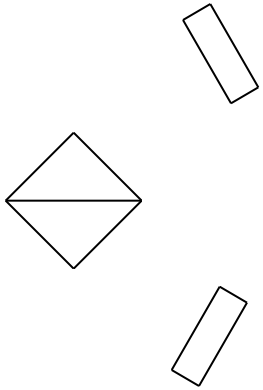
"Traditional" Interferometer

- *Michelson Interferometer*
- Beam splitter splits, recombines light
- Mirror motion changes arm pathlength
- Detector sees constructive and destructive interference



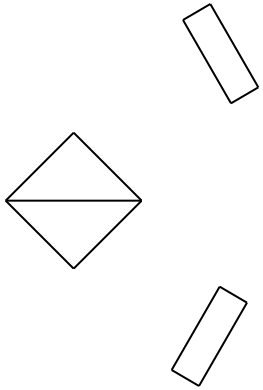
Unwrapping the “Traditional” Interferometer

Light Source (Star)



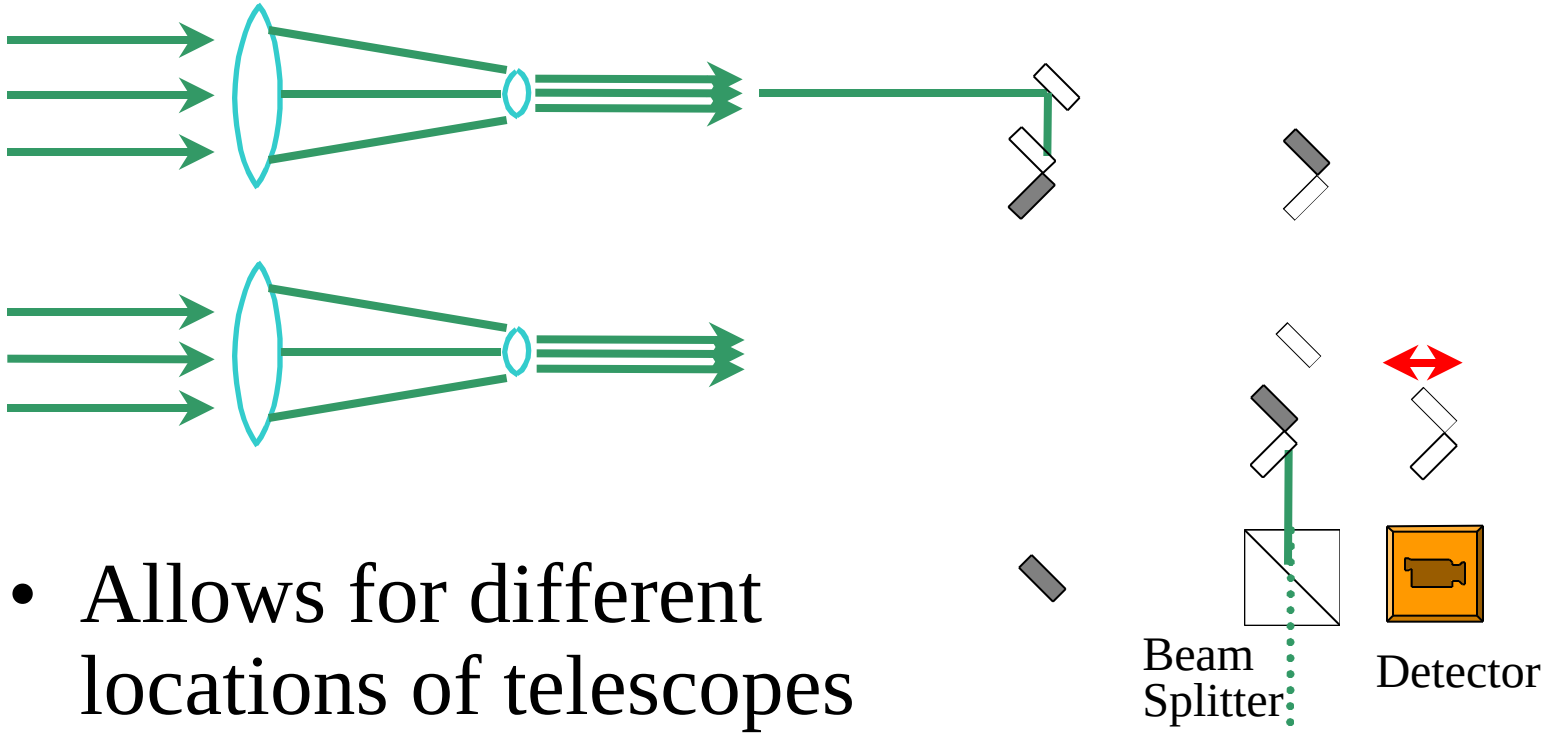
- Move light source to a great distance
- Use distance to split the light

Add Telescopes



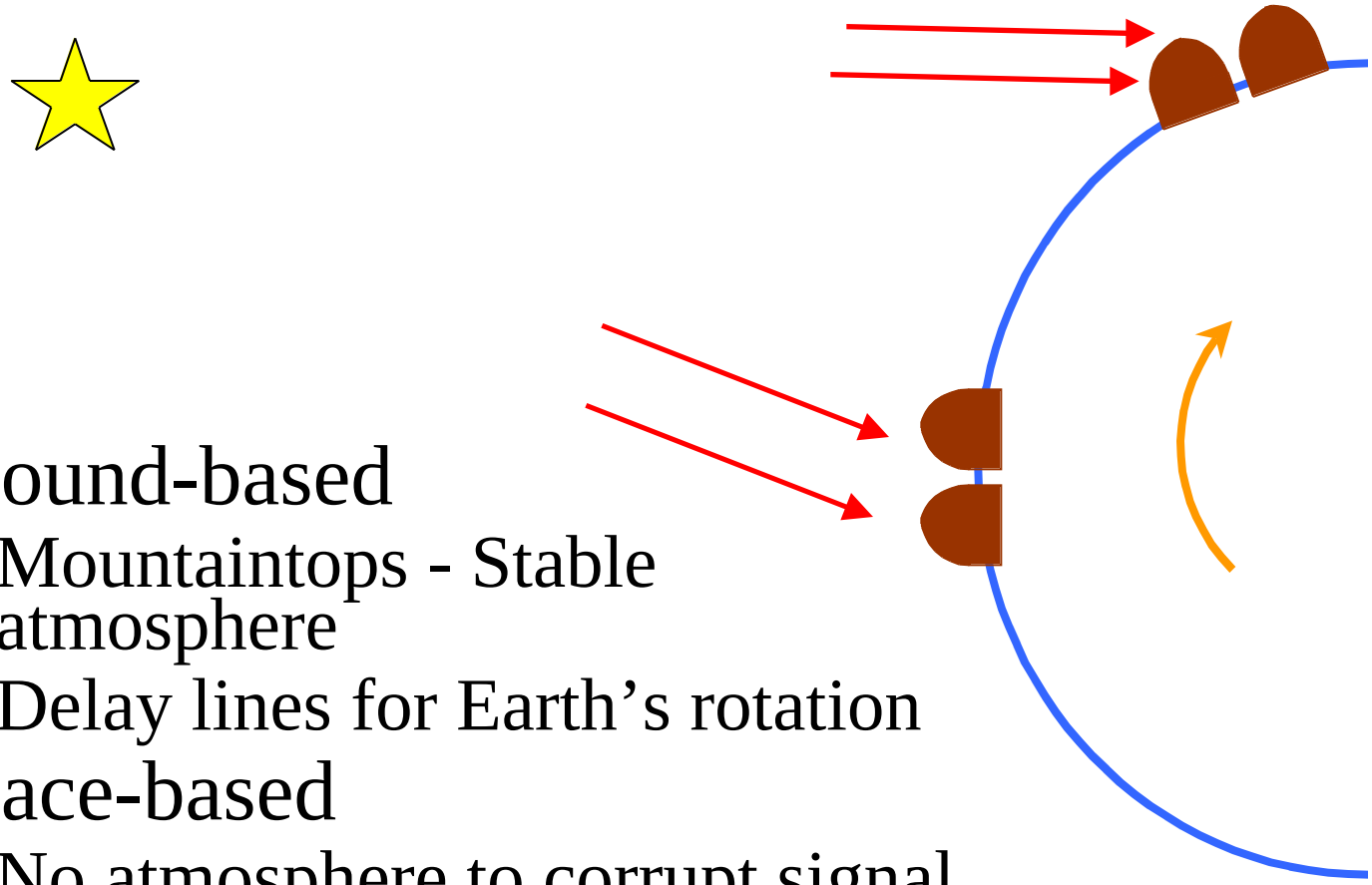
- Increased light collection equals increased sensitivity

Add Delay Lines



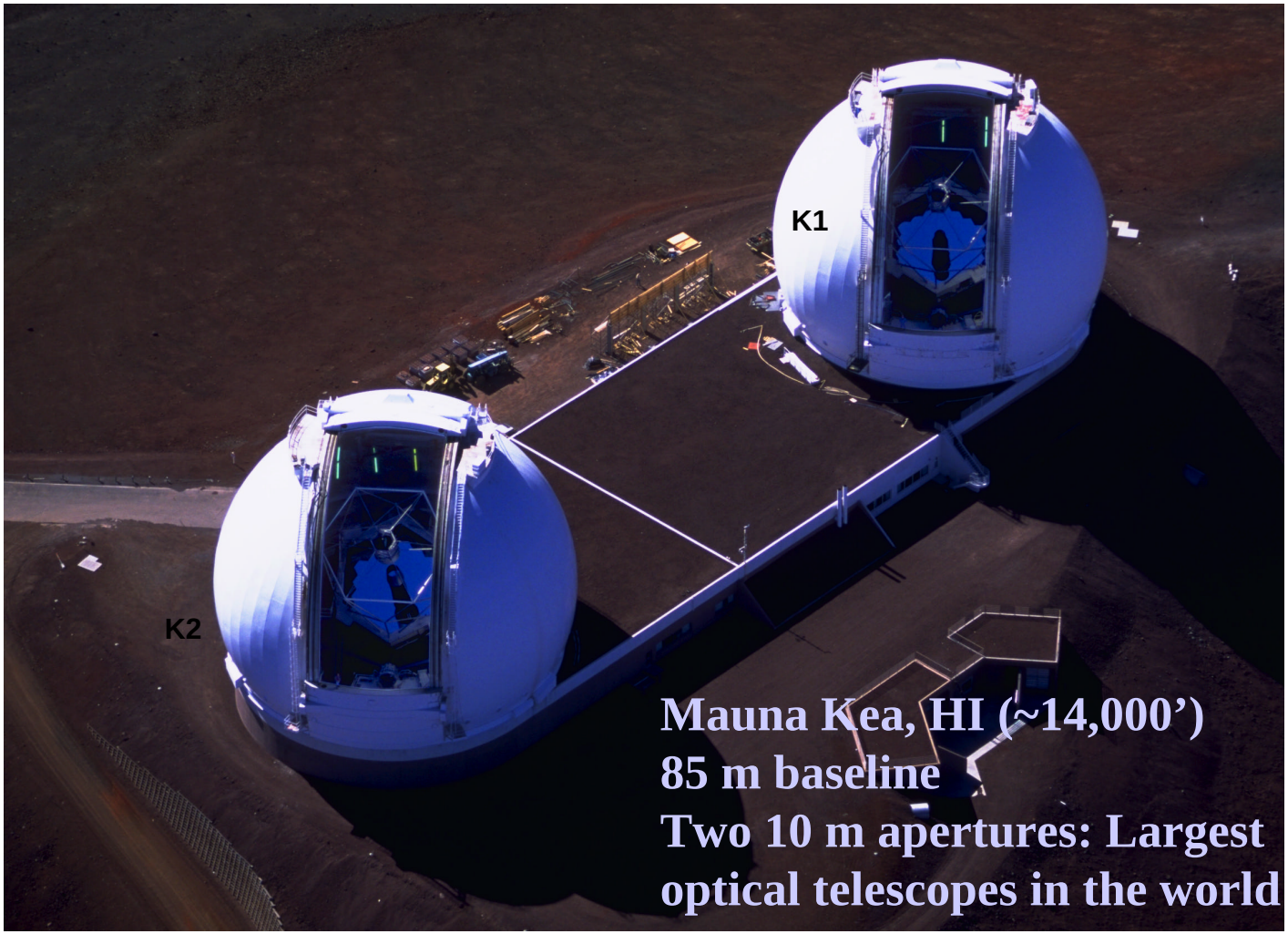
- Allows for different locations of telescopes

Location, Location, Location



- Ground-based
  - Mountaintops - Stable atmosphere
  - Delay lines for Earth's rotation
- Space-based
  - No atmosphere to corrupt signal

Keck I, Keck II - Winter 97



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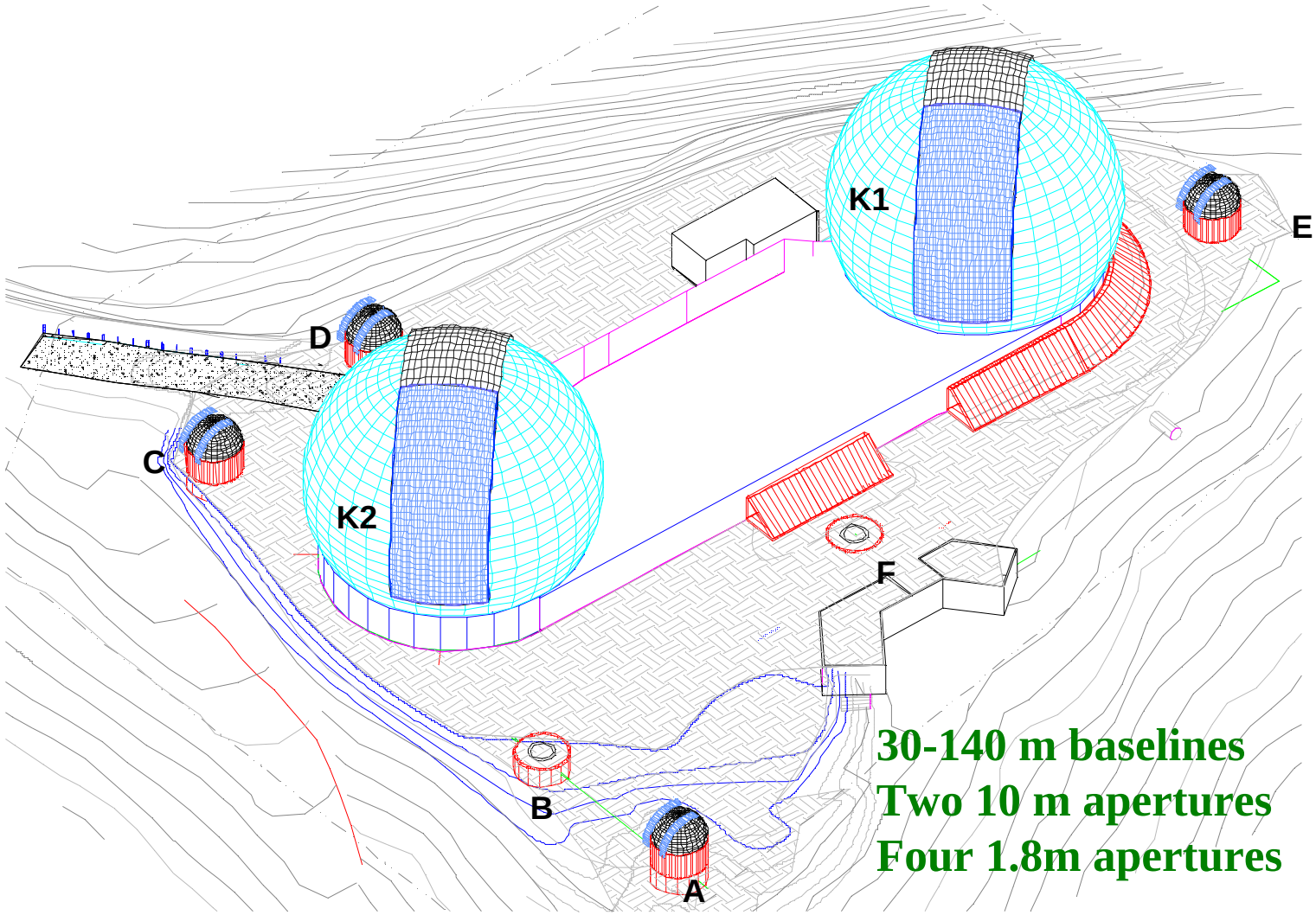
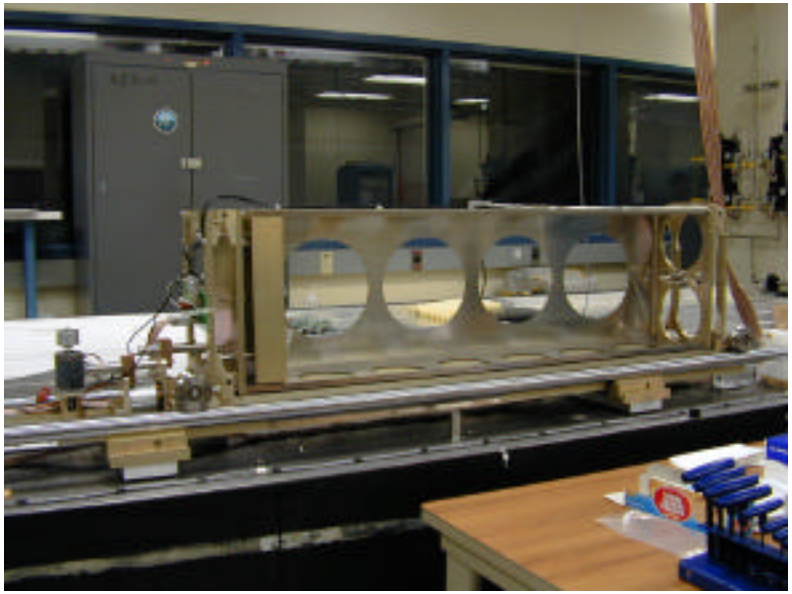
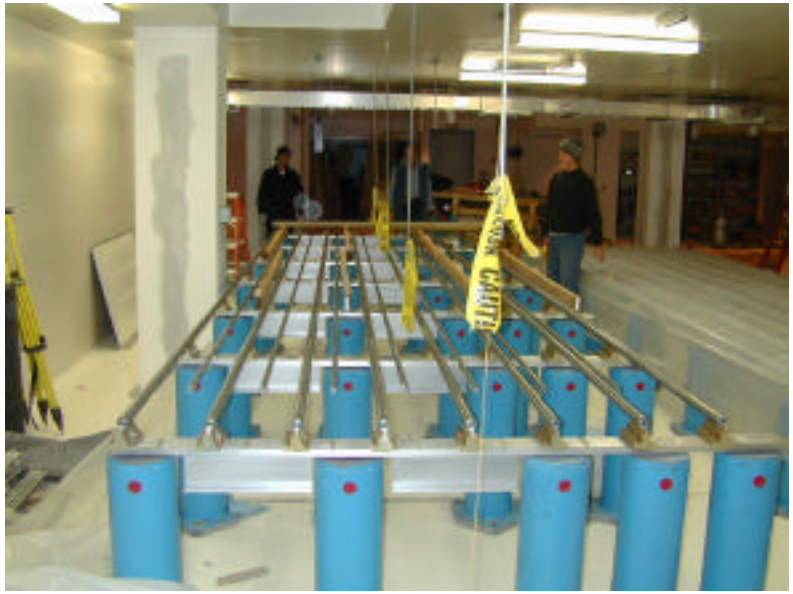
Keck Interferometer - Fall 2001



30-140 m baselines
Two 10 m apertures
Four 1.8m apertures

Delay Lines in Action





- Lab prototypes operational
- Construction at the Mauna Kea summit

What's the Big Deal?

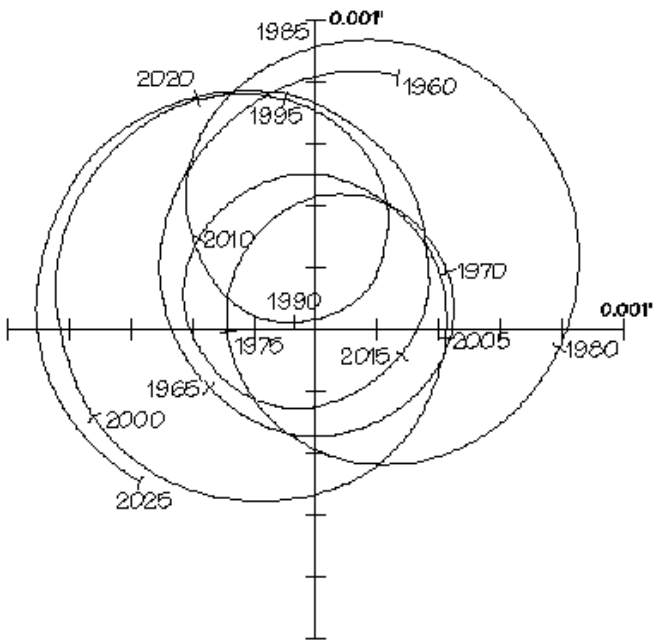
- High resolution imaging
  - Fields of 100x100 mas, Pixels of 2 mas
  - Comparison:
    - HST 35x35 arcsec fields, 46 mas pixels
    - Ground-based: 34x34 arcmin fields, 1 arcsec pixels
    - Ground-based AO: 20x20 arcsec fields, 40 mas pixels
- Even higher resolution angular measures
  - 20 μas measm'ts

Keck Interferometer Key Science

- Detection of planets through astrometry
- High-resolution imaging
- Detection of dust shells about stars

Planet Detection Through Astrometry

- Primary science: Astrometric detection of planets down to Neptune mass from their reflex motion

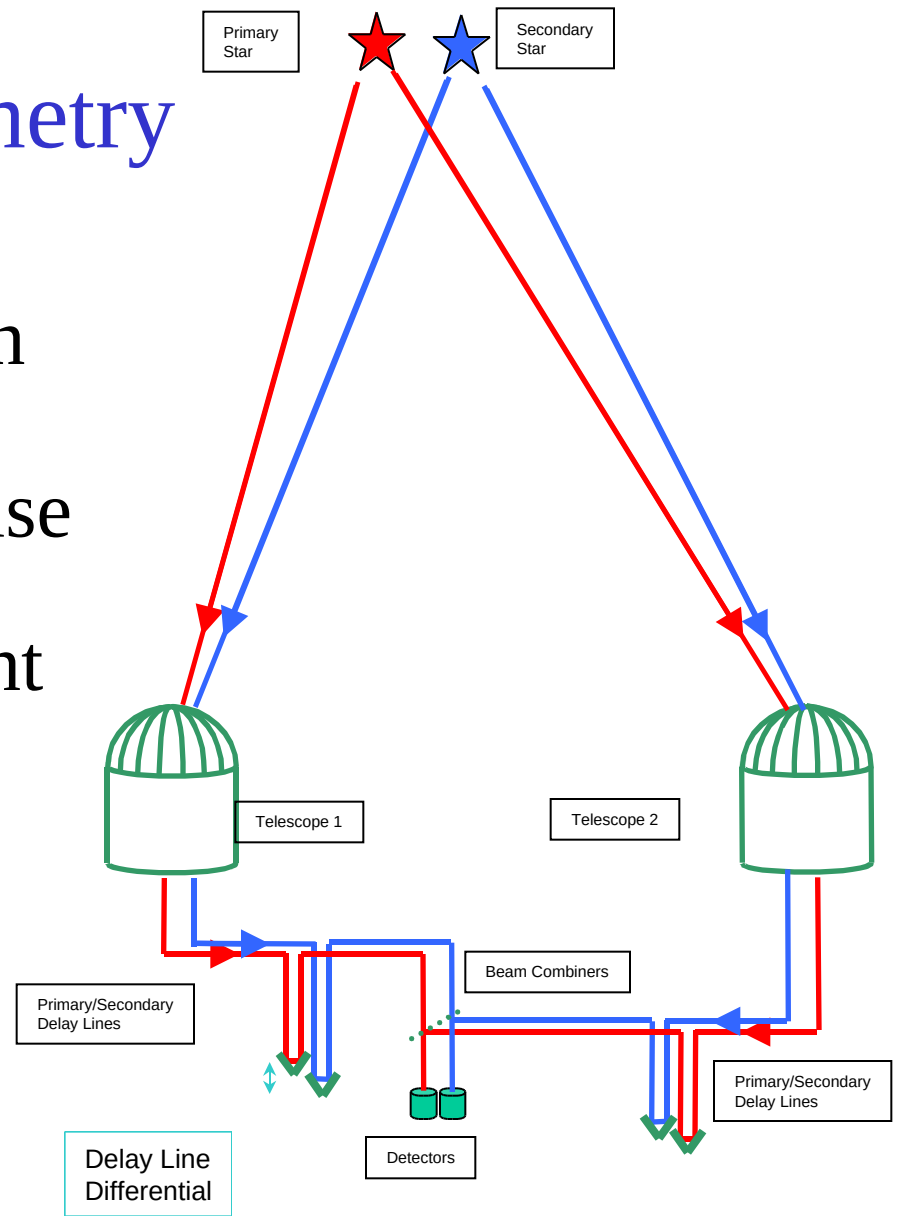


Apparent motion of the Sun due to the gravitational influence of the planets

Interferometry Systems and Architecture

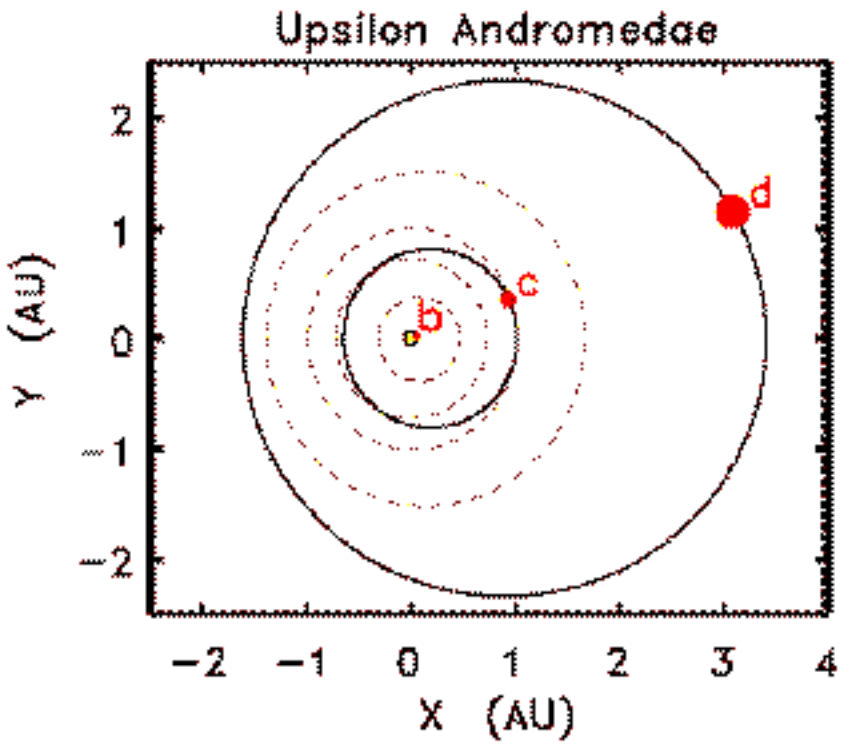
Dual Star Astrometry

- Two interferometers on top of each other
- Can convert precise measures of internal instrument geometry to precision angular measures on the sky



Discovered Planets

- 20 stars now known with planets
  - Discovered via a radial velocity technique
- First discovery of planetary *system* recently announced

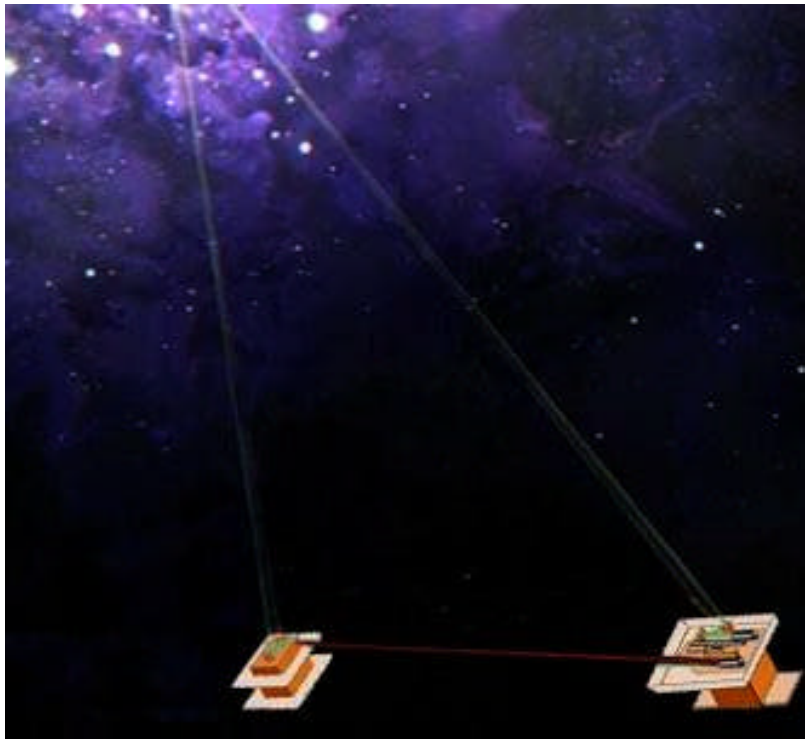


Moving to Higher Ground

- Space-based missions
  - Space Technology 3 (ST 3)
  - Space Interferometer Mission (SIM)
  - Terrestrial Planet Finder (TPF)
- Large gains in sensitivity, resolution
  - Factors of 10 to 100 - or more - in both

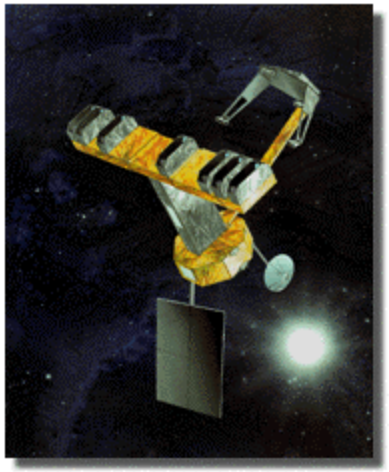
Space Technology 3

- Separated spacecraft interferometer
  - Formation flying
  - First multiple craft mission for NASA
- Technology validation mission



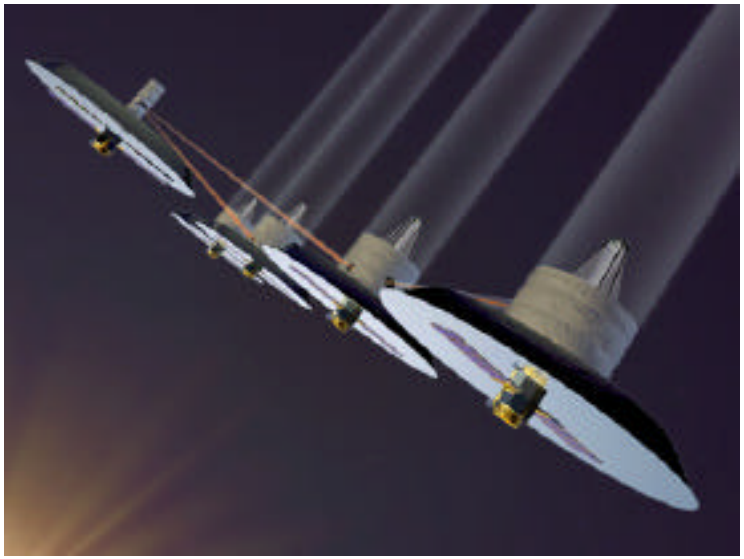
Space Interferometer Mission (SIM)

- Detection of nearby terrestrial planets
- 1-4 μas astrometry
  - Measure distance, dynamics of stars in our galaxy
  - Measure distances of nearby galaxies
  - Other uniquely inaccessible astrophysical questions



SIM Classic

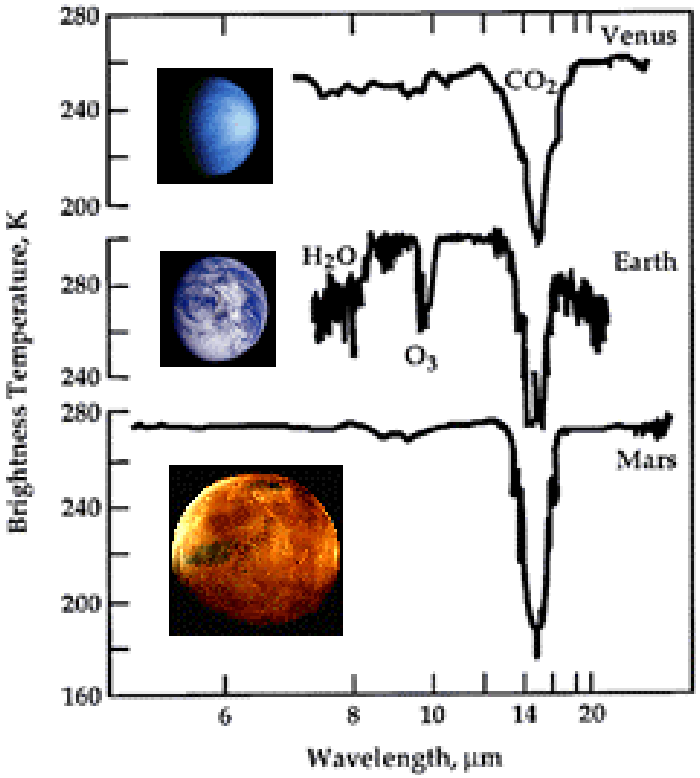
Terrestrial Planet Finder (TPF)



- TPF will find & characterize Earth-like planets
- Mission culminates with inspection of discovered planets for chemical signatures of life
- Combines technologies from SIM, ST3 and other space-based single-aperture telescopes

Chemical Signatures of Life

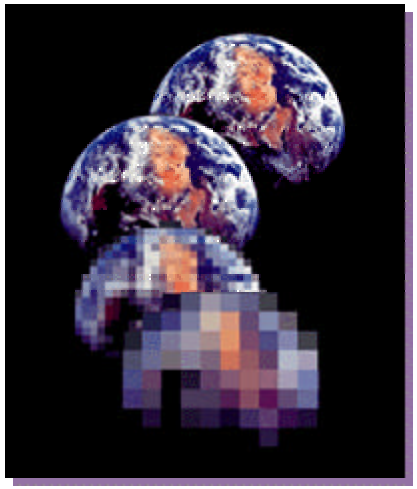
- Presence of life can alter the atmospheric chemistry
- Earth: abundances of water, ozone, methane affected by life



Further Down the Road?

- Terrestrial Planet Imager
  - Maps of Earth-like planets
  - 10x10 pixels: continents
  - 1k x 1k pixels: local weather
- This is *insanely* difficult

… and exactly the sort of challenge we excel at meeting



References

- Keck: keck.jpl.nasa.gov
- ST-3: spacetechnology3.jpl.nasa.gov
- SIM: sim.jpl.nasa.gov
- TPF: tpf.jpl.nasa.gov