Kepler

A Search for Habitable Planets

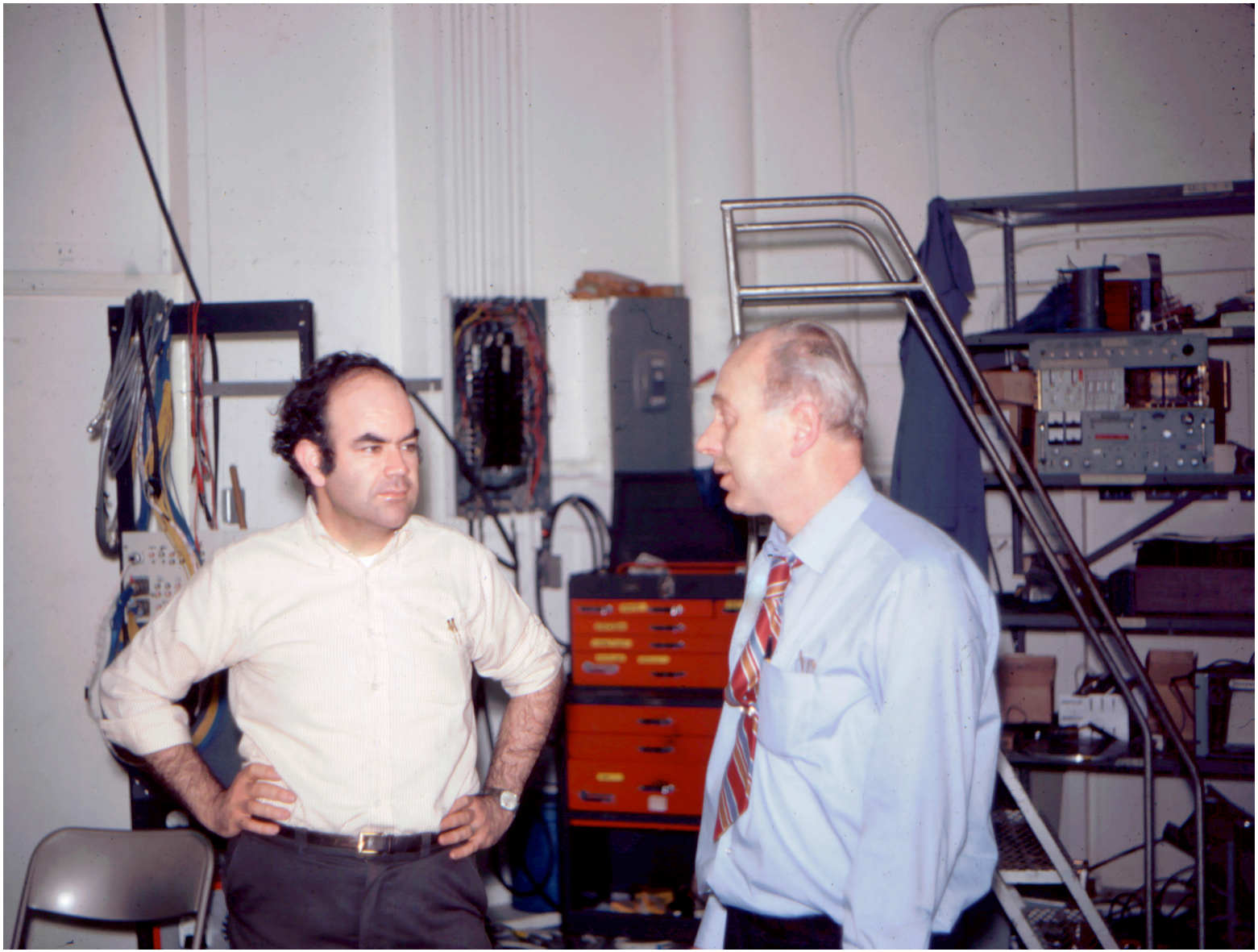
Kepler Mission:
Overview, Commissioning & Prospectus

Symposium Honoring Giovanni Fazio
27-28 May 2009

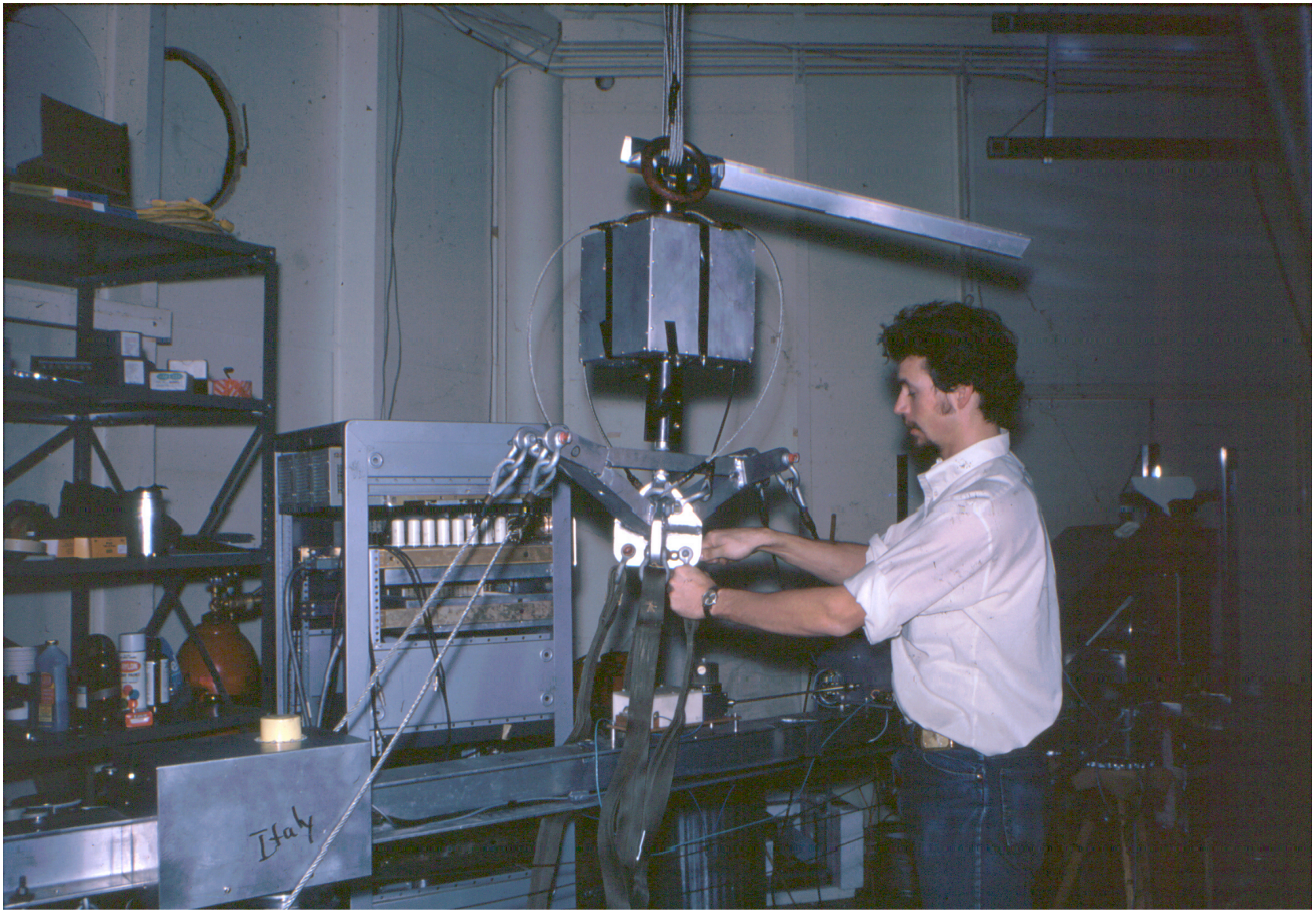
David Koch
Kepler Deputy Principal Investigator

Ames Research Center Ball JPL LASP LHS SAO SETI Institute STScI

Giovanni and Ken Greisen, Palestine,TX 1971



Dave Koch working on pointing system built by Dave Hearn and Giovanni, Palestine,TX 1971



Giovanni and Val Puopolo, Palestine,TX 1971

First Flight of Gas Cherenkov Telescope Palestine,TX 1971

Gas Cherenkov Gamma Ray Telescope Palestine,TX 1972

Gas Cherenkov Telescope Palestine,TX 1972

Brian McBreen and Murray Campbell, Control Room, 1972

Control Room at the end of the Rainbow, Palestine,TX

Motivation for Kepler

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- Want to answer the question:

  What is the frequency of habitable planets in the extended solar-neighborhood?

- First, need to define "habitable"

  1. Planet's temperature needs to be such that liquid water can exist on the surface of the planet
  2. Planet's surface gravity needs to be in a range to allow for a life sustaining atmosphere

The Starting Point for Kepler

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What size planet?

To hold onto a life sustaining atmosphere
=> 0.5 to 10 $M_{\oplus}$ ~ 0.8 to 10 $R_{\oplus}$ => measurement precision

What kind of planetary orbit?

Continuous HZ => ~1 yr for solar like => how long to look

What type of star?

Luminosity class: main sequence == dwarfs

Spectral type:

- Time for planet to evolve => later than A
- Relatively stable => earlier than M

Binaries:

- Don't ignore, could have planet around both or each

Other characteristics: Age (>1 Gyr), metallicity

EXTRA-SOLAR PLANET DETECTIONS

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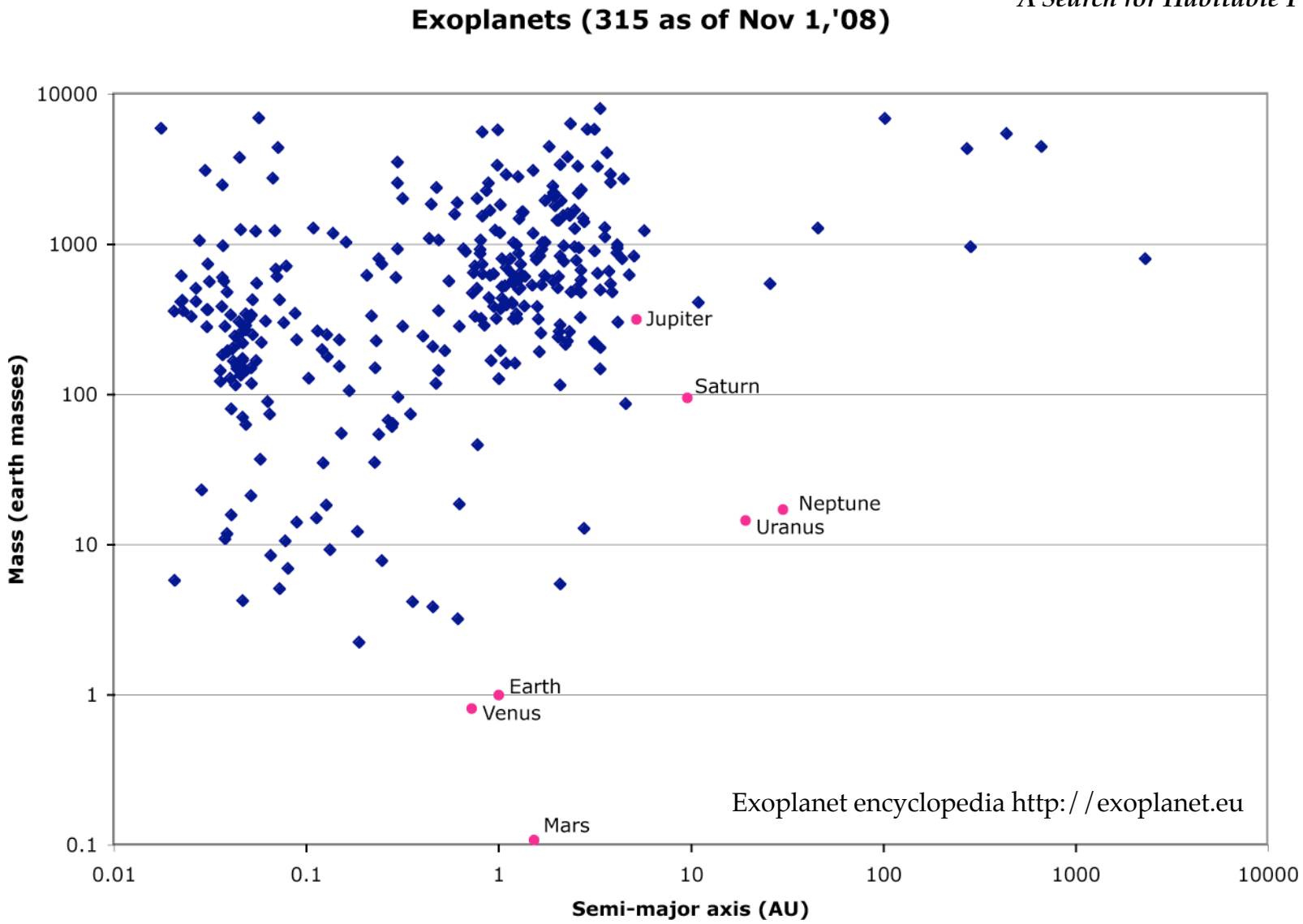

Note: Masses are only lower limits except for transit cases and typically about 2x greater than shown

Kepler is the Next Step

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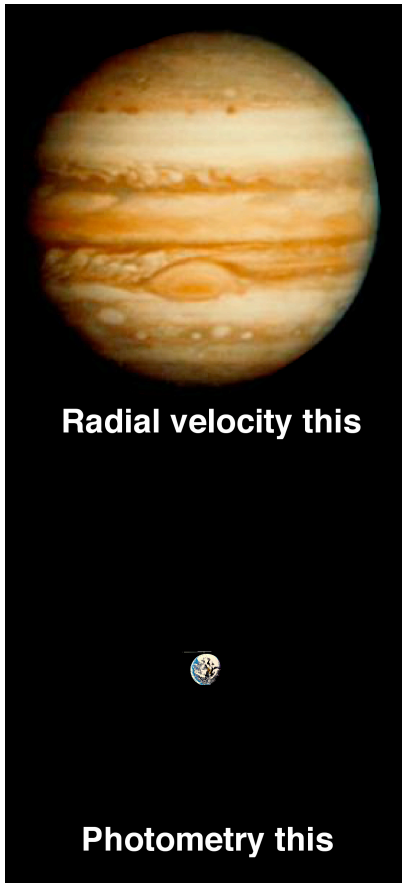
- **Radial velocity** (Doppler spectroscopy) method has been the MOST PRODUCTIVE but it is unable to detect Earth-size planets, and especially not in the HZ. Limited to few m/sec.
- Earth-like planets are about 300 times less massive and about 100 times smaller in area than Jupiter
- **Ground-based** transit photometry is limited to about sub-Jupiter due to terrestrial atmospheric turbulence



- The ***Kepler Mission*** uses photometry from space to measure transits and detect Earth-size planets
- ***Kepler Mission*** is optimized for finding:
  Habitable planets (0.5 to 10 $M_{\oplus}$)
  in the HZ (near 1 AU) of solar-like stars

Kepler MISSION CONCEPT

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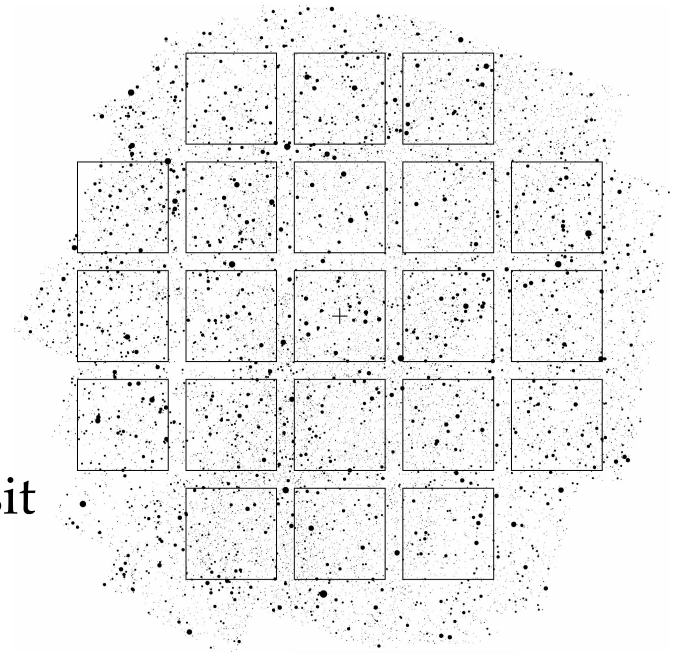
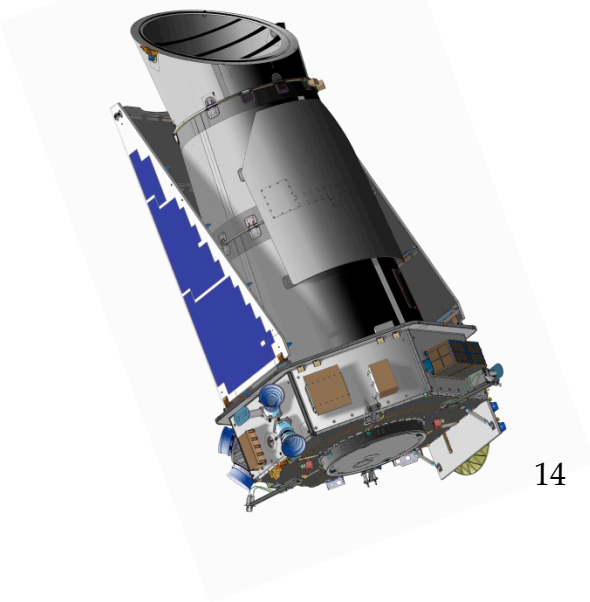
Mission design requirements were:

- Continuously and simultaneously monitor 100,000 main-sequence stars since alignment probability in HZ ~0.5%
- Have a photometric precision with noise < 20 ppm in 6.5 hours V = 12 solar-like star => 4σ detection for a single Earth-size transit
- Continuous viewing for ≥ 3.5 year



Design concept resulted in:

A one-meter Schmidt telescope with >100 deg^2 FOV using an array of 42 CCDs placed into a heliocentric orbit



Full up Spacecraft

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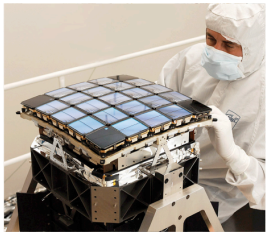
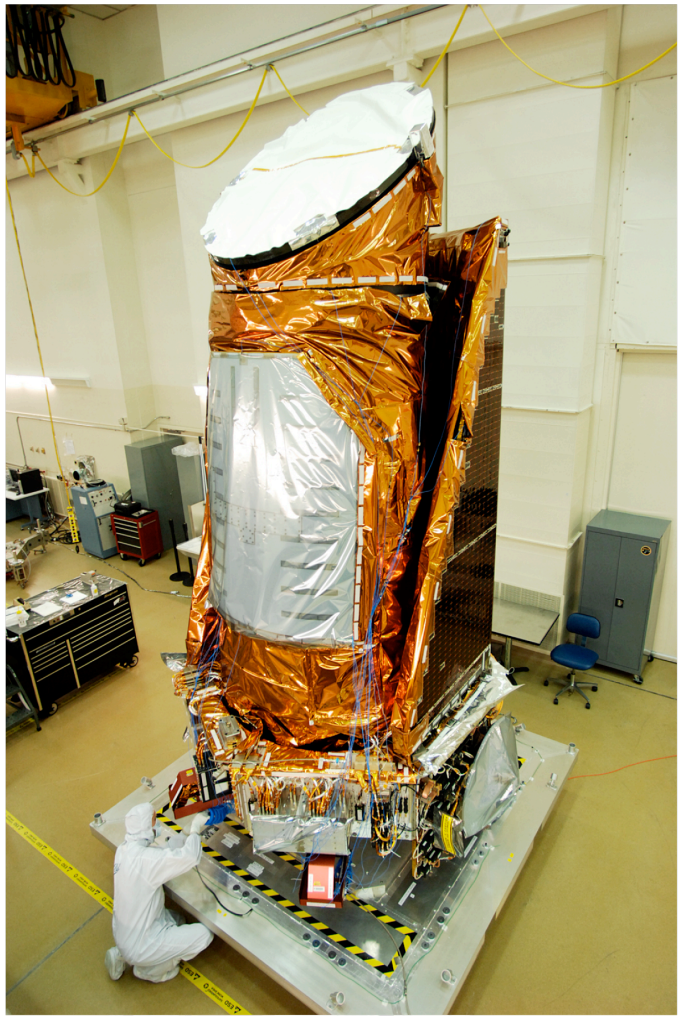
Schmidt Corrector 0.95 m dia.

Spider with Focal Plane
and Local Detector Electronics

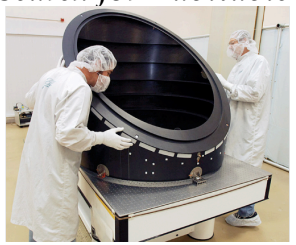


Focal Plane
95 Mega pixels, 42 CCDs

Primary Mirror
1.4 m dia., 85% lt. wt.



Fully assembled Kepler photometer
Mounted on the spacecraft



Sunshade

Upper Telescope Housing

Lower Telescope Housing

Spacecraft bus integration

Kepler Focal Plane

r Habitable Planets

The *Kepler* focal plane consists of 42 science CCD and 4 fine guidance CCD. Each science CCD is 2200 columns by 1024 rows, thinned, back-illuminated, anti-reflection coated, 4-phase devices manufactured by **e2v**. Each CCD has two outputs with the serial channel on the long edge. The pixels are 27 μm square, corresponding to 3.98 arcsec on the sky.

Kepler Launch March 6, 2009 on Delta II

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OFF TO THE HUNT IN CYGNUS

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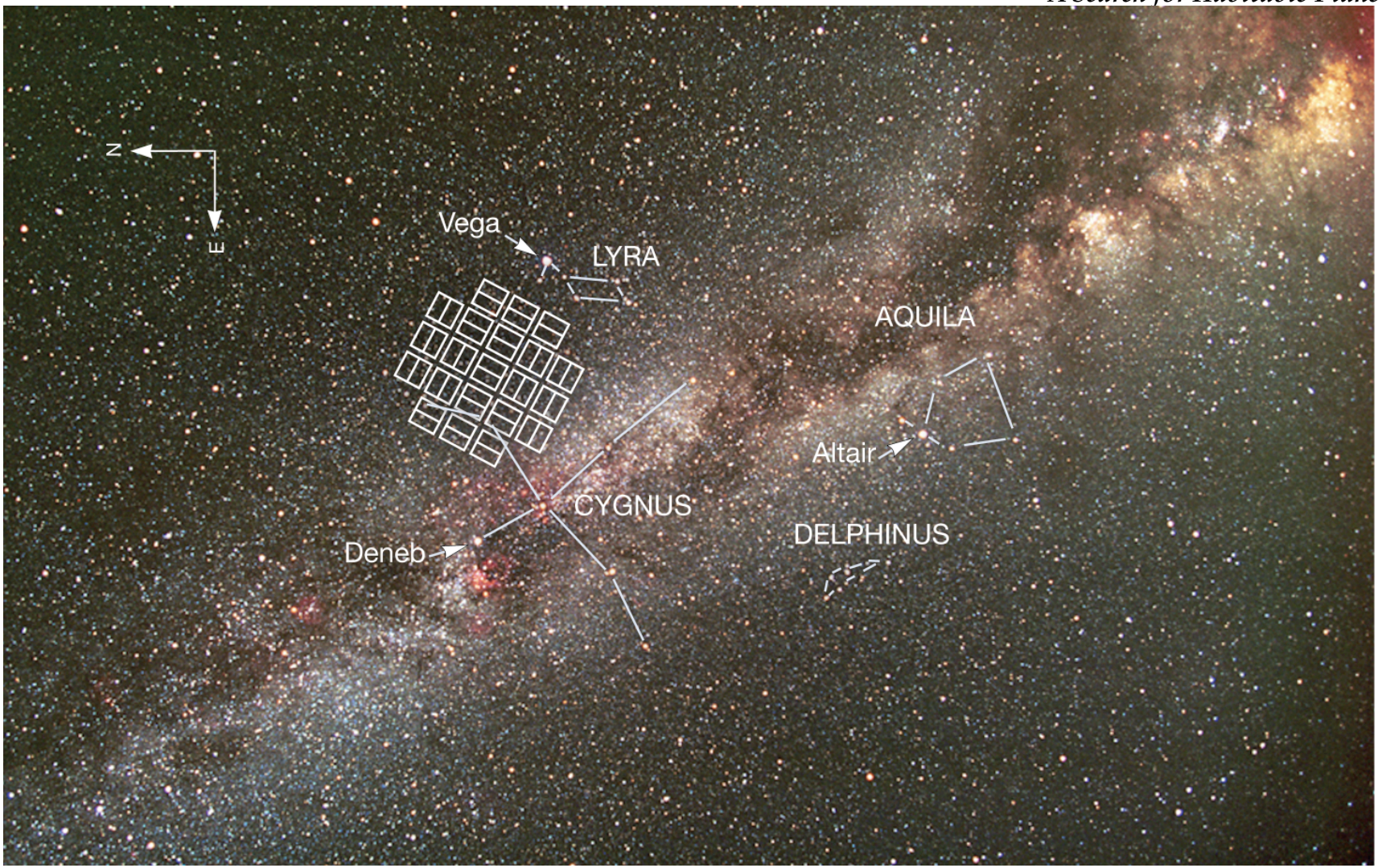
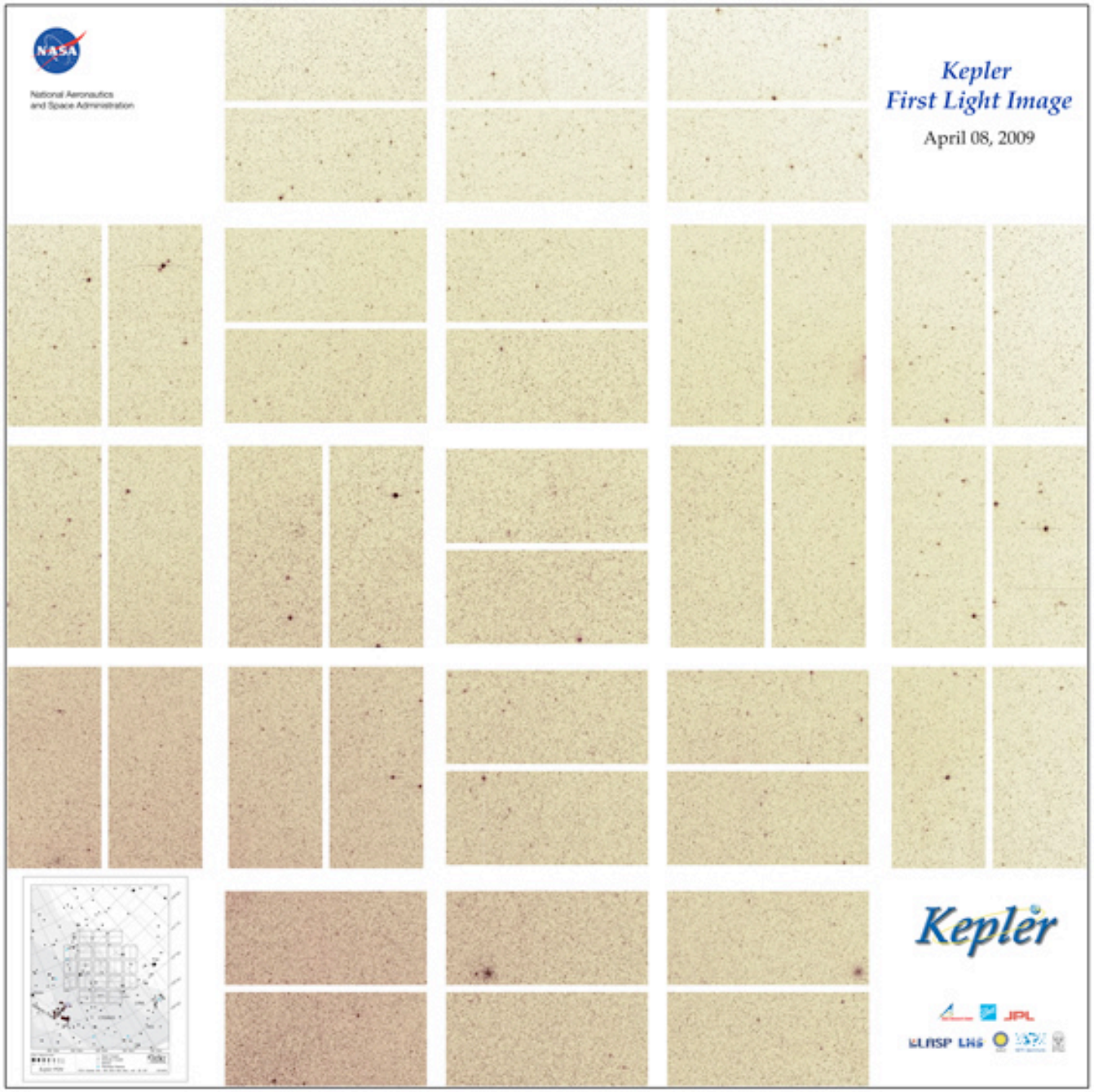


The Kepler star field is a part of the extended solar neighborhood in the Cygnus-Lyra regions along the Orion arm.
It is located on one side of the summer triangle (Deneb-Vega-Altair)

First Light, April 8, 2009



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Unique *Kepler* Features

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1. 170,000 multi-channel photometer
2. Instrument precision of $\leq$10 ppm in 6.5 hrs
3. 95 mega-pixel focal plane
4. One of the largest Schmidt telescopes ever built
5. Largest FOV for this size aperture
   (covers an area equal to 6 Palomar plates)
6. Largest Schmidt telescope in space

Commissioning

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- Spacecraft checkout
- DSN checkout, X and Ka
- Lots of darks before dust cover ejection
- Calibrate Fine Guidance Sensors
- Determine Focal plane geometry
- Measure the pixel response function, PRF
- Calculate target and aperture definitions for 150k stars
- Test run of 10 days of science data
- Start Science Operations May 12

- Data look excellent, precision looks excellent, even for highly saturated stars (5^{th} to 16^{th} magnitude)
- Certainly we can detect planets as small as Earth
- Wealth of stellar information
  - Unique continuous, precise data base of >100,000 stars
  - Asteroseismology (m, r, age, inclination)
    - Changes in diameters of delta Scuti & B stars as they age
  - Gyrochronolgy (ages)
  - Activity cycles
- Propellant usage to date indicates >6 years life

JOHANNES KEPLER

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(By permission Sternwarte Kremsmünster)

Kepler should be smiling
IYA2009 is also the 400th anniversary for
Astronomia Nova

http://kepler.nasa.gov