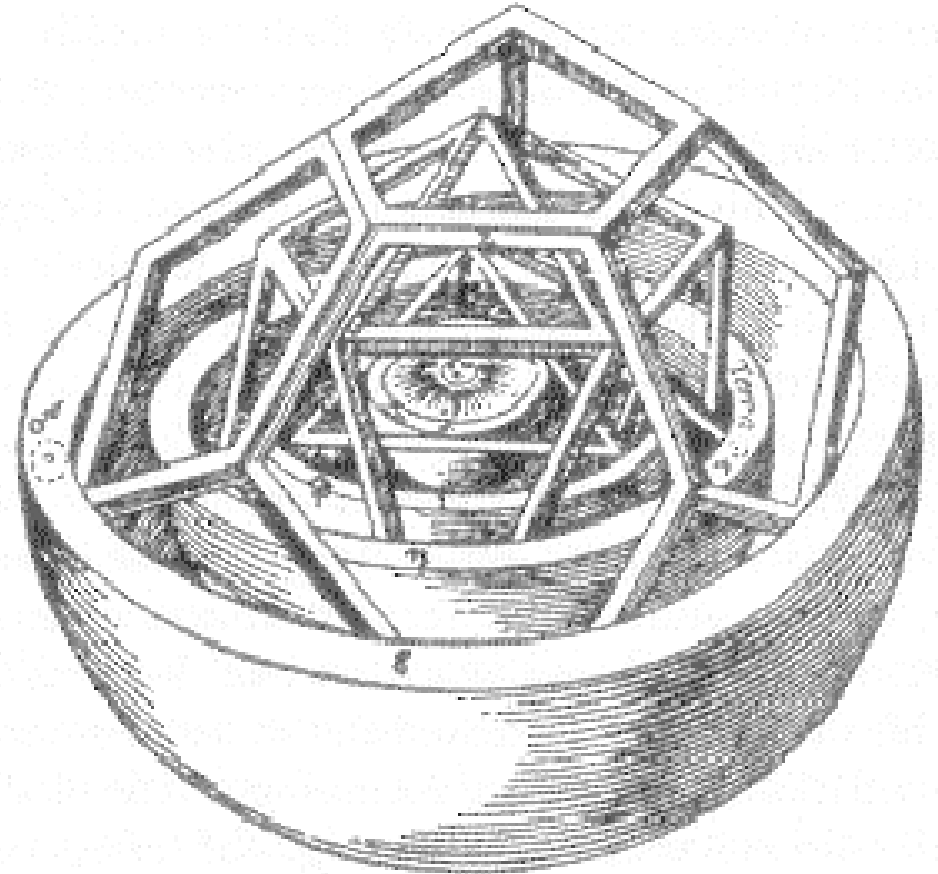
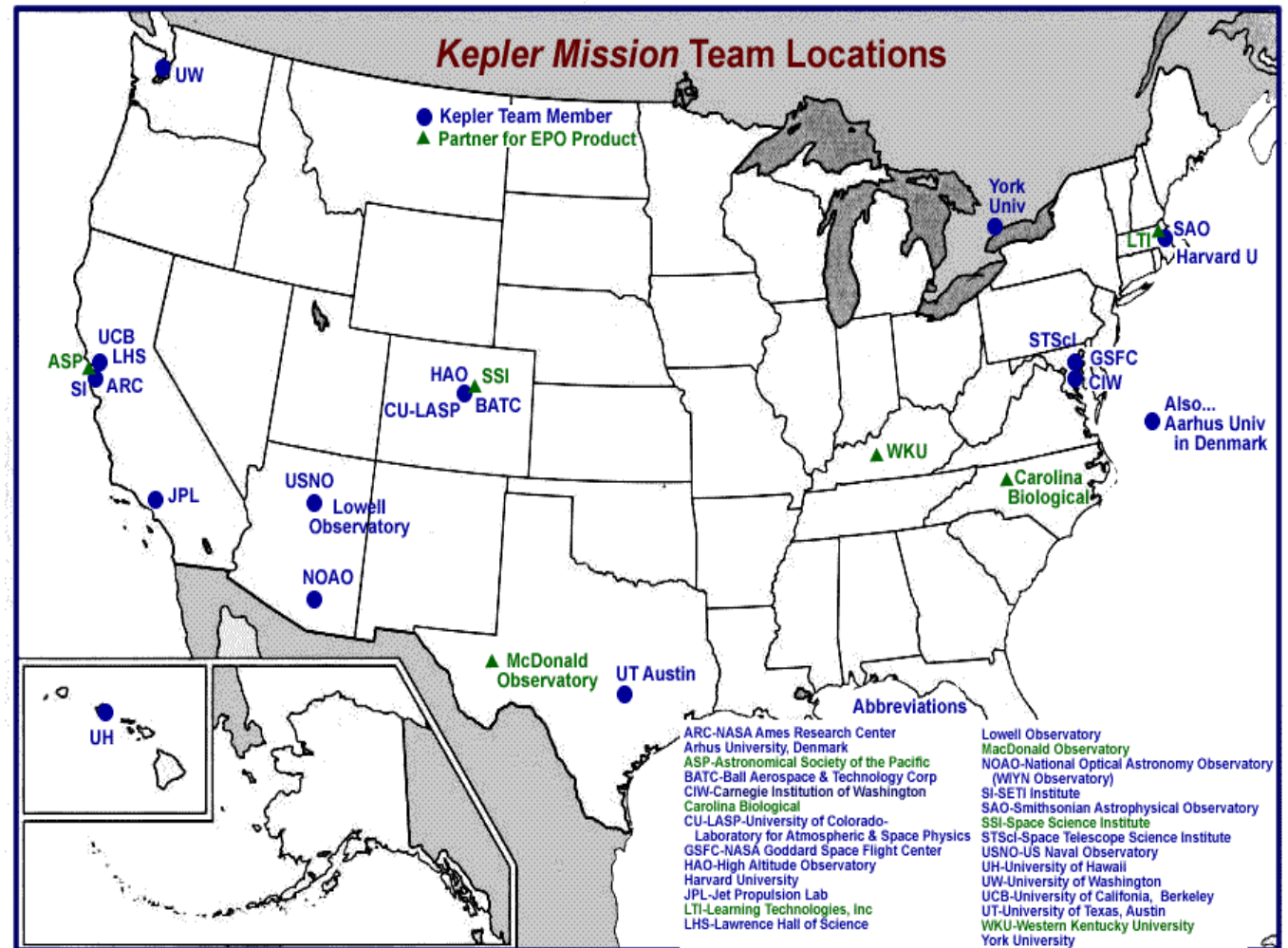


Asteroseismology with Kepler



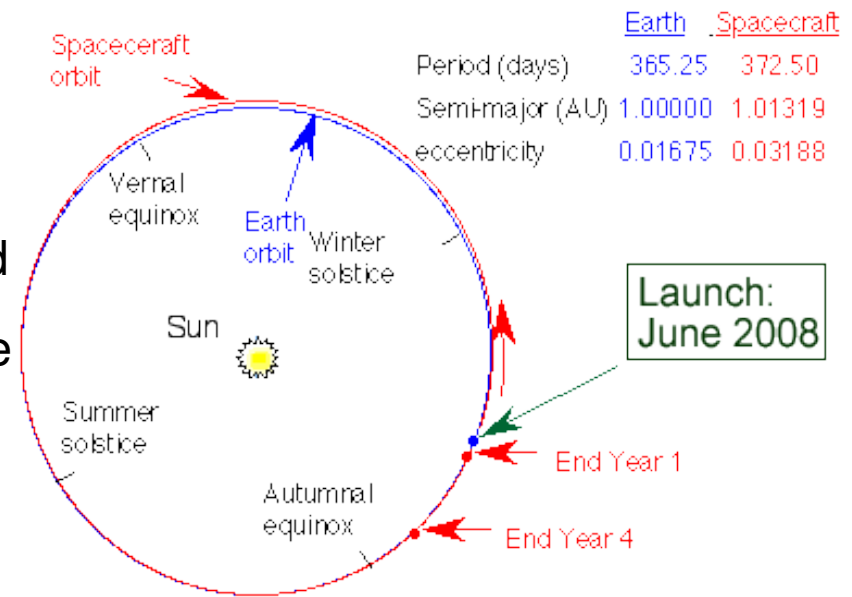
Kepler mission

- special purpose space mission in the NASA Headquarters Discovery Program designed for detection terrestrial planets
- launch: October 2008
- duration: 4-6 years
- Kepler team:
 - William Borucki (Principal Investigator, NASA Ames Research Center)
 - 14 Science Working Group Members and 15 co-investigators



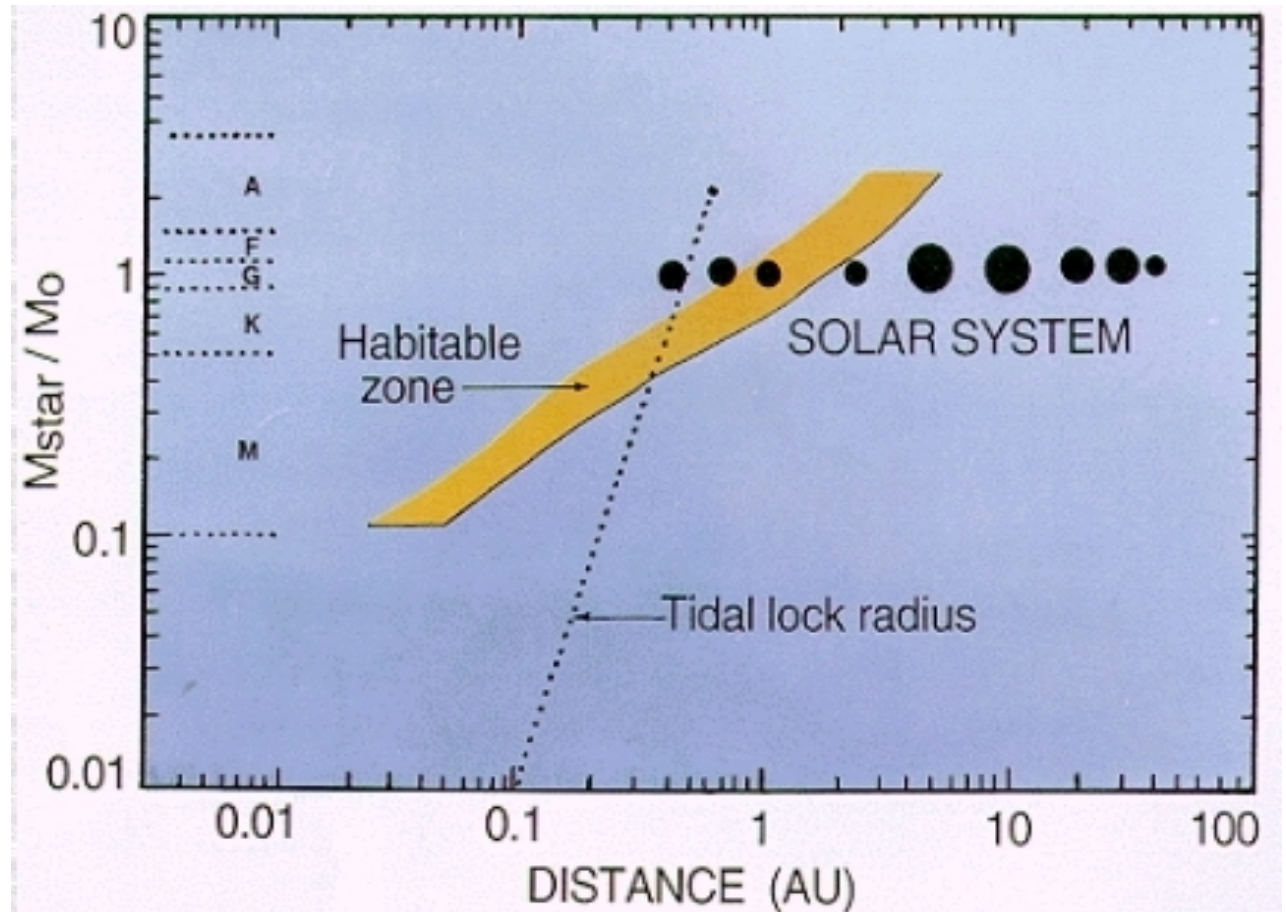
Kepler mission

- detection of Earth-size and larger planets with the method of photometric transits
- conditions of the success;
 - continuous viewing of the selected field
 - the field of view out of the ecliptic plane
 - sufficiently high star density
 - mission must last long enough to detect and confirm periodic nature of the transits
- duration of the mission is 4-6 years
 - enables four transits of all orbits up to one year
 - three transit detections of orbits up to one year



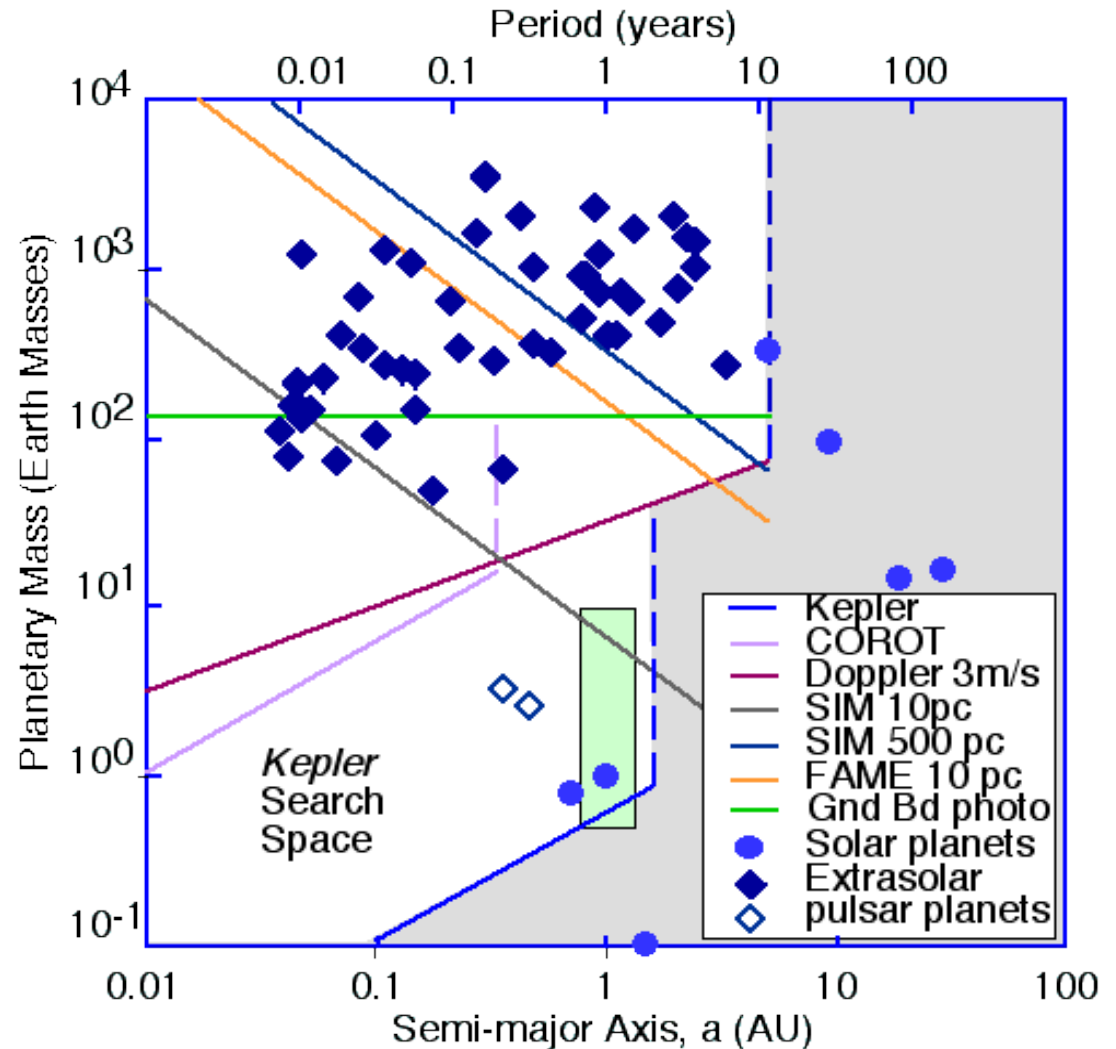
Kepler science

- determination of the frequency of Earth-size and larger planets in or near the habitable zone
- distribution of orbital major semi-axis, albedo, size, mass and density of planets
- identification of additional members of each discovered planetary system with the use of additional techniques
- determination of the properties of stars that harbour planetary systems



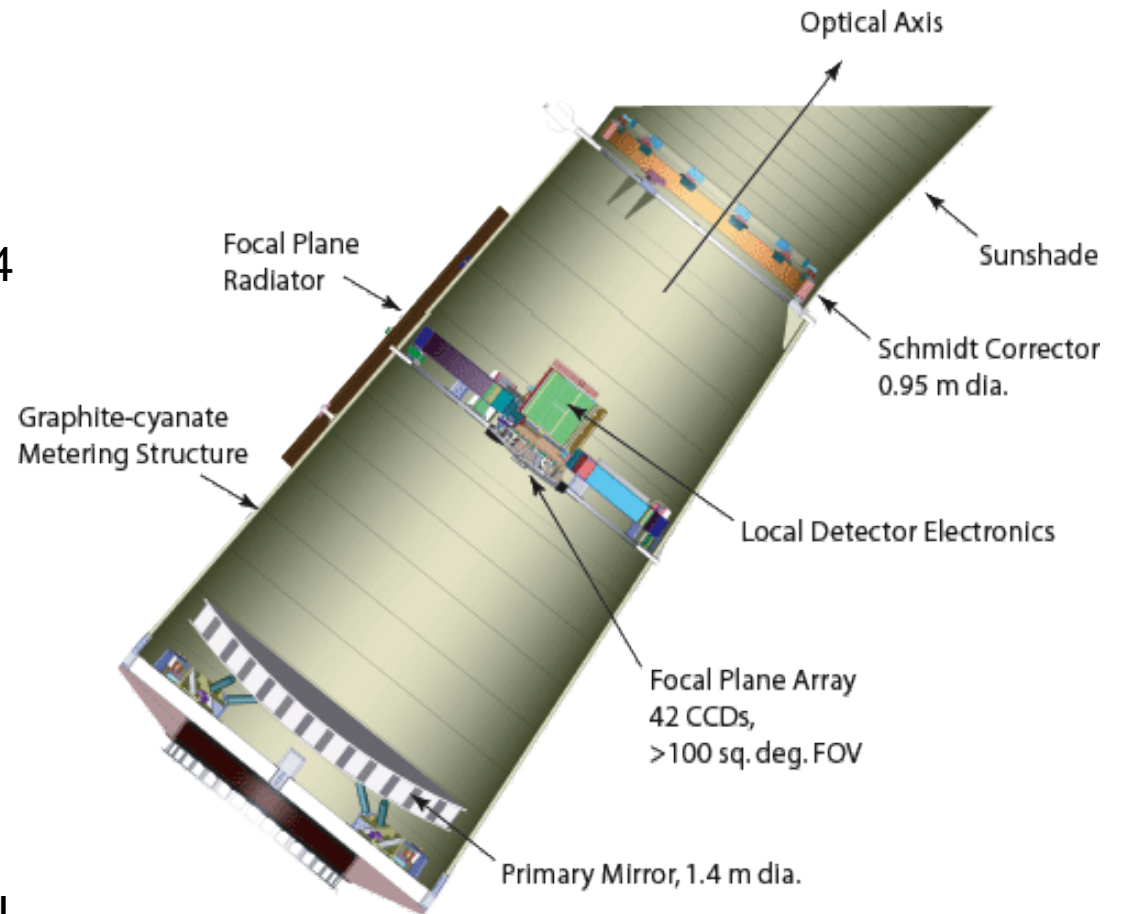
Kepler observations

- spectral bandpass: 400-850 nm
- precision: 20 ppm
- continuous and simultaneous observations of 100 000 main sequence A-K stars
- nominal magnitude limits: $V = 9-15$ mag
- temporal resolution: 1 or 30 minutes
- monitoring all stars brighter than $V = 11.5$ mag for p -mode oscillations (1-3 months, cadence: 1 minute)



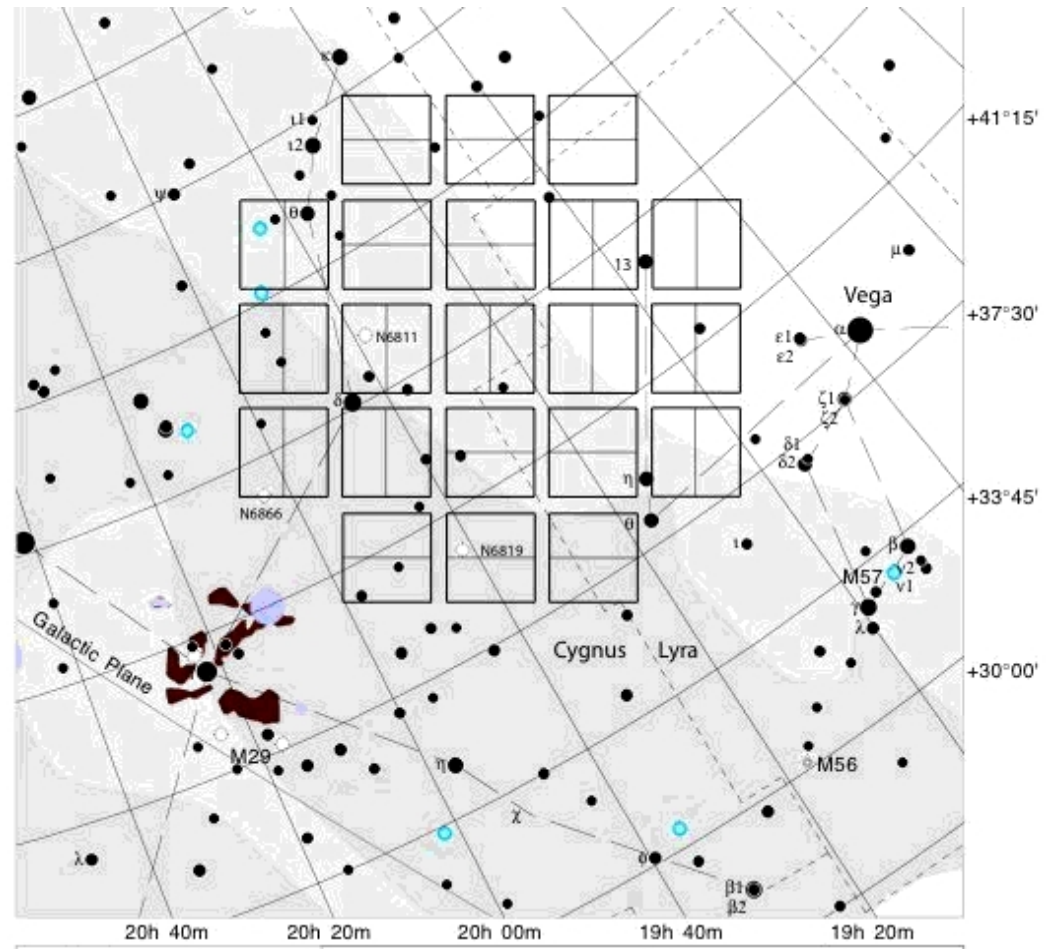
Kepler instrument

- Schmidt telescope with 0.95m aperture and 105 deg² field of view (12 deg diameter)
- 42 CCDs 50x25 mm and 2200x1024 pixels each
- information will be recorded only from pixels that contain stars brighter than $V = 15$ mag
- images will be defocused to 10 arc sec to improve the photometric precision
- sensitivity high enough to detect a transit of Earth-like planet on a 1 AU orbit at a G2, $m_V = 12$ mag star with in 6.5 hours of integration



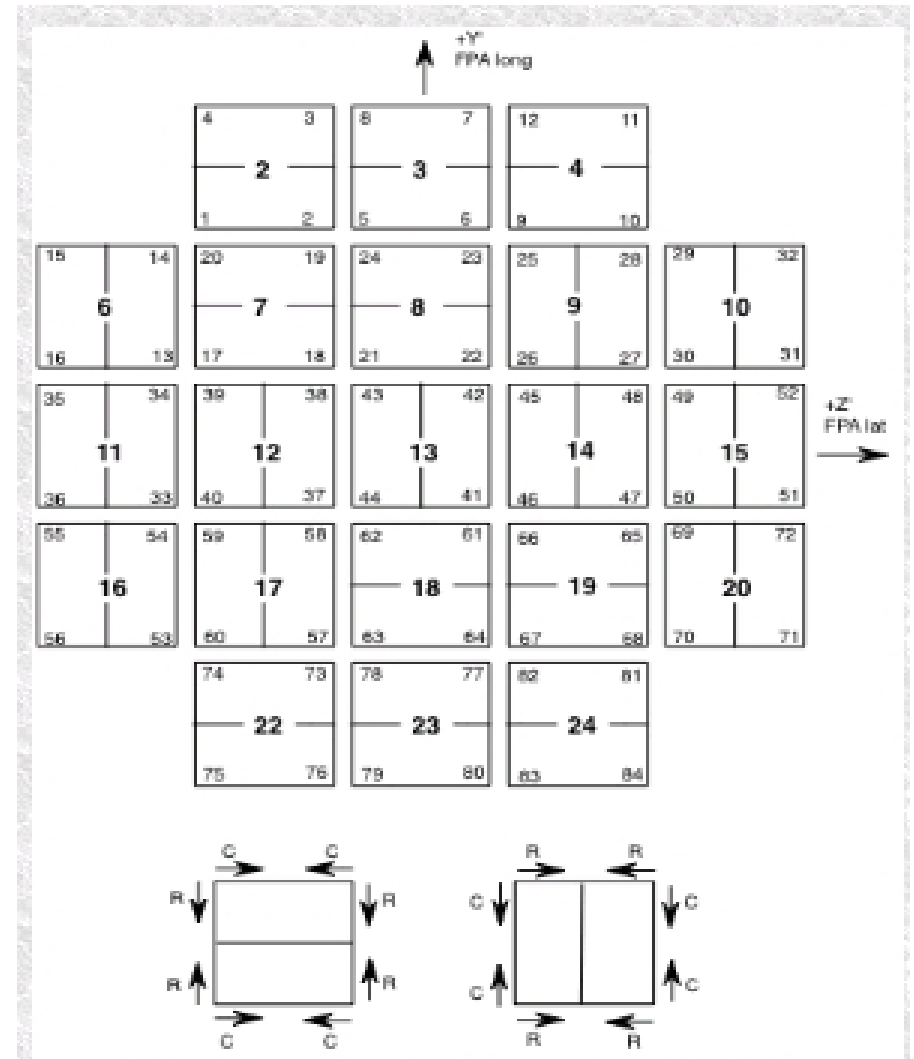
Kepler field of view

- centred at galactic coordinates $l = 76.5$ deg, $b = +13.3$ deg
- far enough from the ecliptic plane so as not to be obscured by the Sun at any time of the year
- eliminates any confusion resulting from occultations by asteroids and Kuiper-belt objects
- comet objects in the Oort cloud subtend too small an angular size and move too rapidly to be a problem
- one star, ϑ Cyg, brighter than 5 mag; 13 others, brighter than 6 mag
- four open clusters: NGC 6791, 6811, 6819 and 6866



Kepler Guest Observers program

- open for proposals of observations of objects of any nature that are in the Kepler field of view
- up to 3 025 targets at any time
- time resolution 30 minutes for 3000 targets and 1, for 25, at any given time
- targets may be as faint as $V = 18$ mag, or slightly brighter than $V = 9$ mag
- observations will be continued for 3 months but may be continued for the entire life-time of the mission
- data from objects that are not at the Kepler list will not be telemetered to the ground and archived



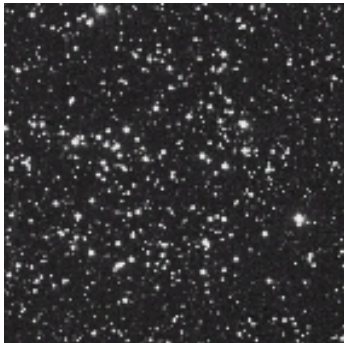
Kepler asteroseismic program

- Prof. Joergen Christensen-Dalsgaard from the Institute of Physics and Astronomy, University of Aarhus, Denmark
 - University of Aarhus (Denmark): Prof. Hans Kjeldsen, Dr. Torben Arentoft, Dr. Michael Bazot
- collaborators
 - University of Wrocław (Poland): Dr. Joanna Molenda-Żakowicz
 - Catania Astrophysical Observatory (Italy): Dr. Antonio Frasca and Dr. Alfio Bonanno
 - Harvard-Smithsonian Center for Astrophysics (US): Prof. David Latham
 - Slovak Academy of Sciences (Slovakia): Dr. Martin Vaňko

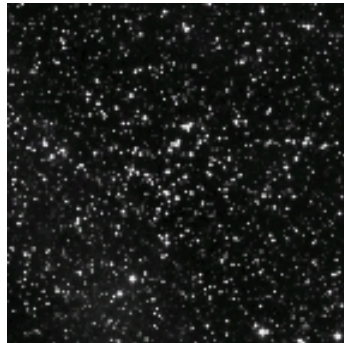


Kepler asteroseismic program - targets

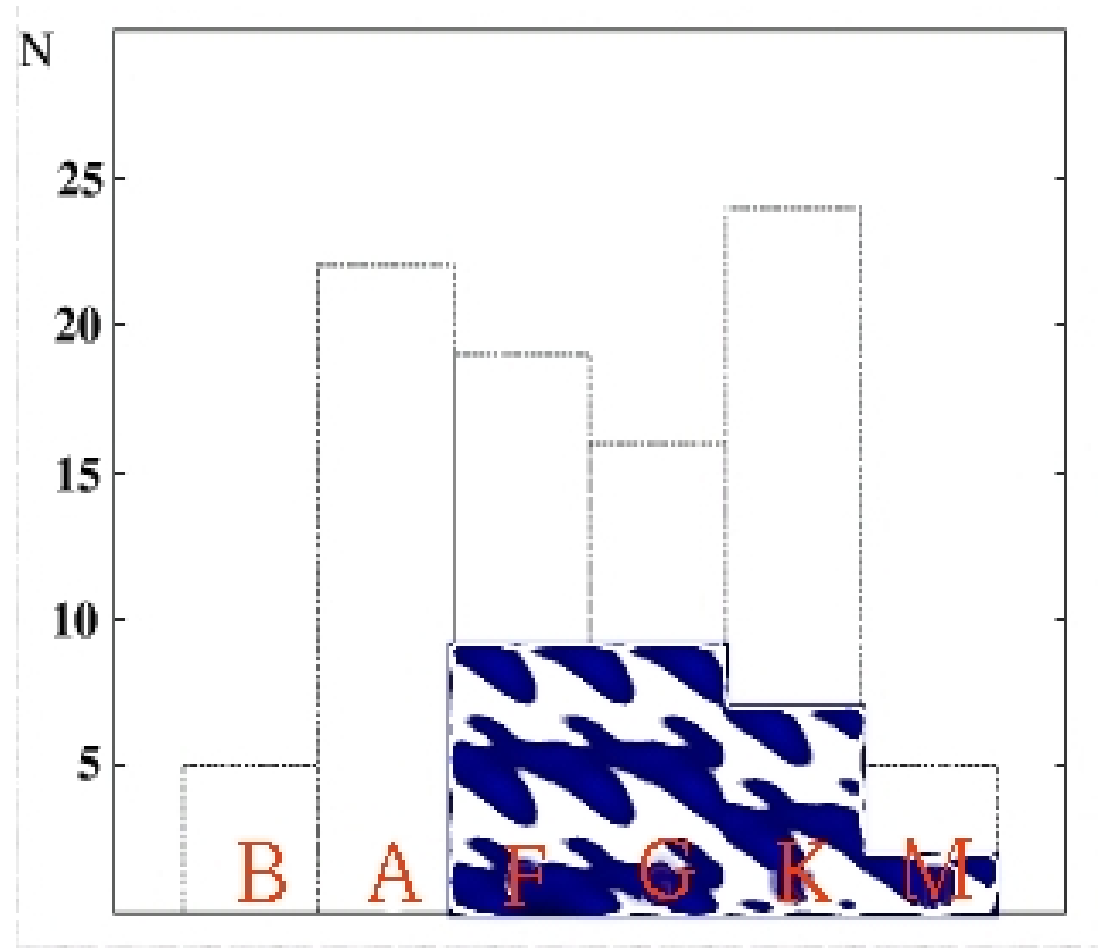
- 104 Hipparcos stars
 - 30 with precise parallaxes, $\sigma_{\pi}/\pi < 0.175$ (*Kepler primary targets*)
 - 74 other Hipparcos stars (*Kepler secondary targets*)
- two open clusters:
 - NGC 6811
 - NGC 6866



NGC 6811

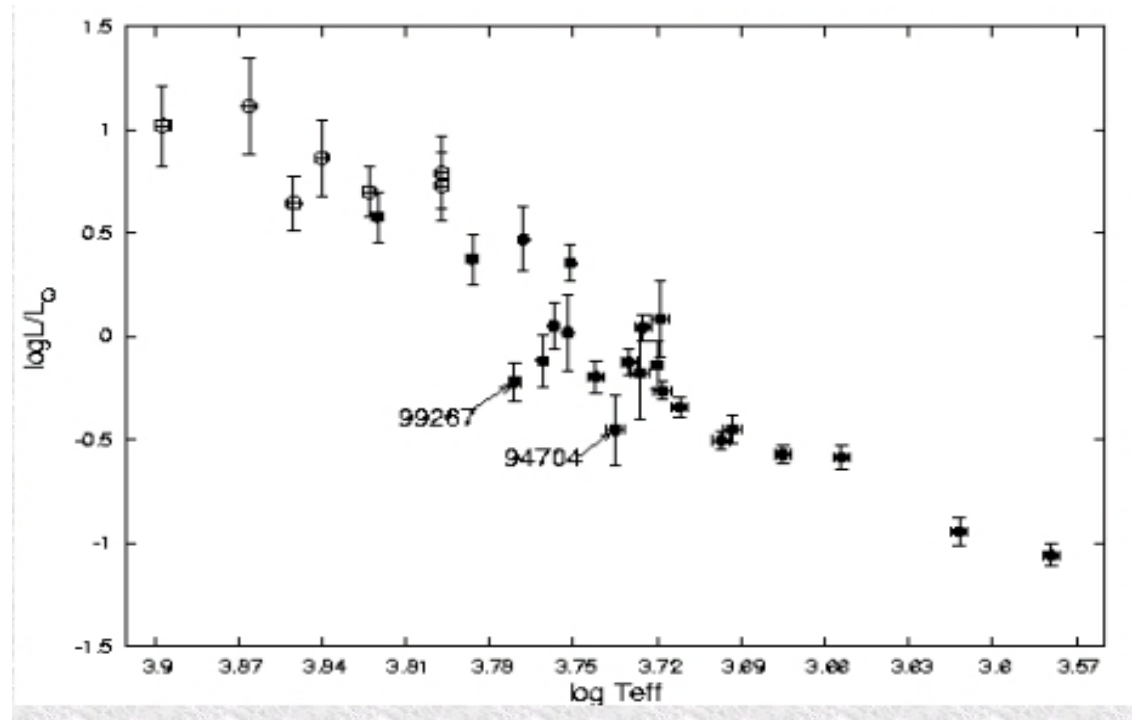


NGC 6866



Kepler asteroseismic program - targets

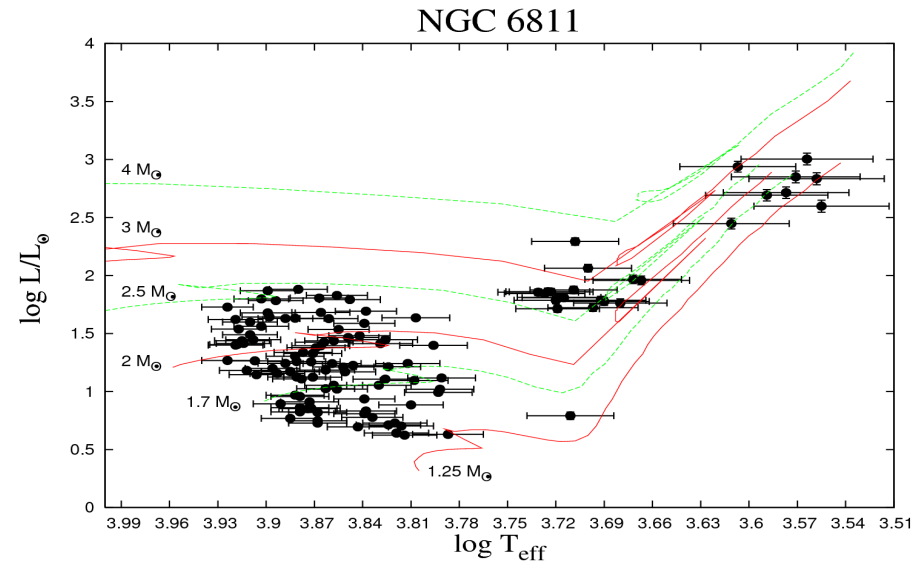
- 30% are high proper motion stars (60% of the primary targets and several secondary targets)
- there are two subdwarfs
- all have JHK photometry from 2MASS Catalogue, some also Strömngren photometry so that their effective temperatures can be computed
- 30 have precise parallaxes so that their luminosities can be computed
- only few have MK spectral classification or other astrophysical parameters determined



Kepler asteroseismic program - targets

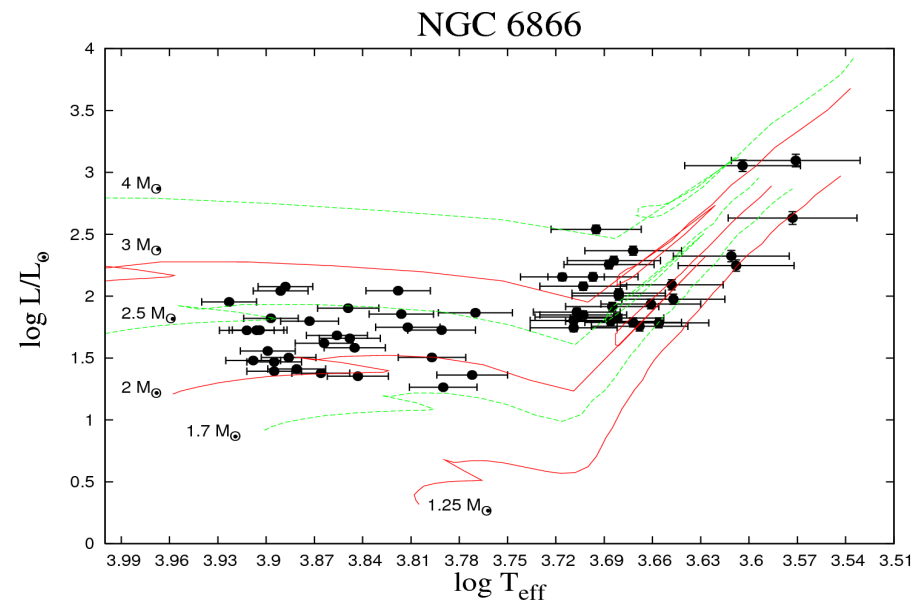
- NGC 6811

- distance: 1215 pc
- reddening: 0.160 mag
- log age: 8.799
- 6 SB systems
- ~50 red giants (members?)



- NGC 6866

- distance: 1450 pc
- reddening: 0.169 mag
- 1 blue straggler
- 4 red giants



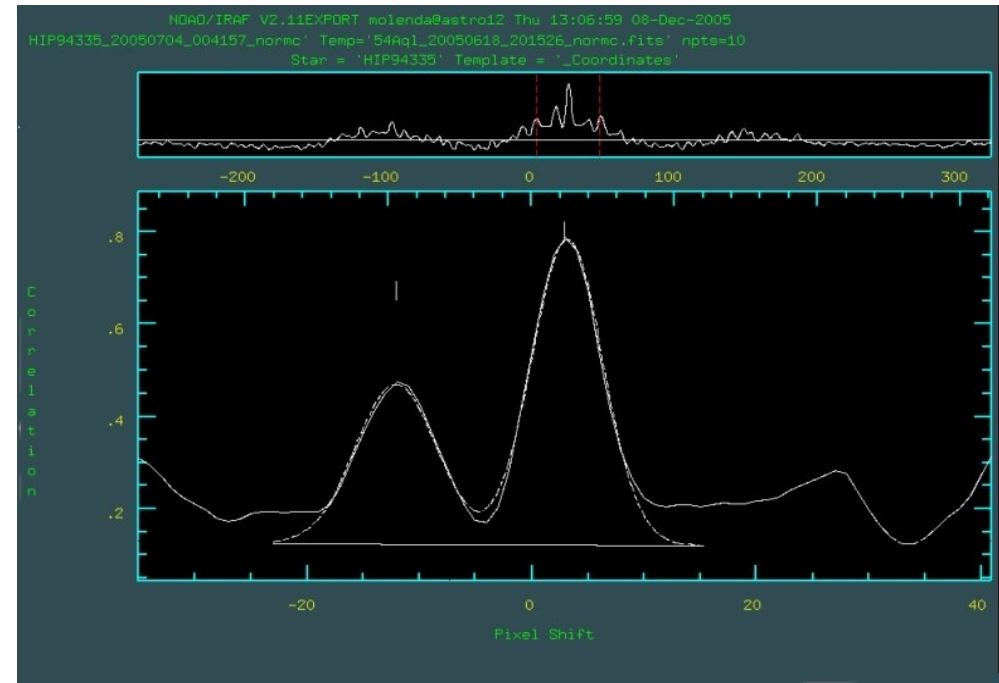
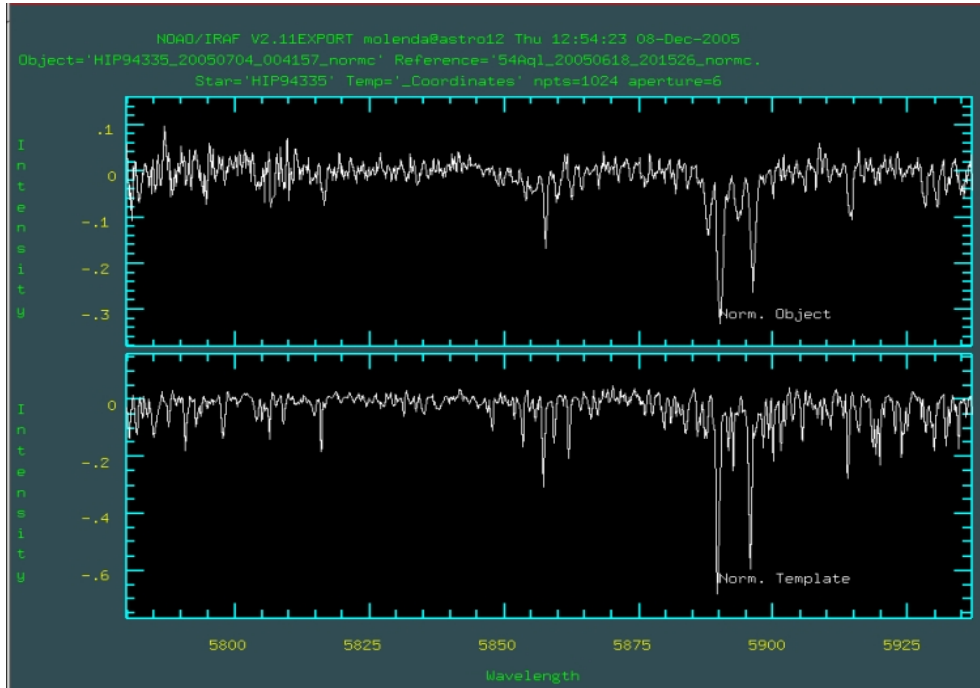
Kepler asteroseismic program

- Ground-based observations: spectroscopy
 - Harvard Smithsonian Astrophysical Observatory
 - MMT, Tillinghast reflector, Wyeth telescope
 - Catania Astrophysical Observatory at Fracastoro Mountain Station (Mt. Etna)
 - FRESCO spectrograph
- Ground-based observations: photometry
 - Catania Astrophysical Observatory
 - photoelectric and CCD observations (standard magnitudes of Kepler targets)
 - Stara Lesna Observatory
 - photoelectric and CCD observations (time series of open clusters)
 - Białków Astrophysical Observatory (Wrocław University)
 - CCD observations (time series of open clusters)



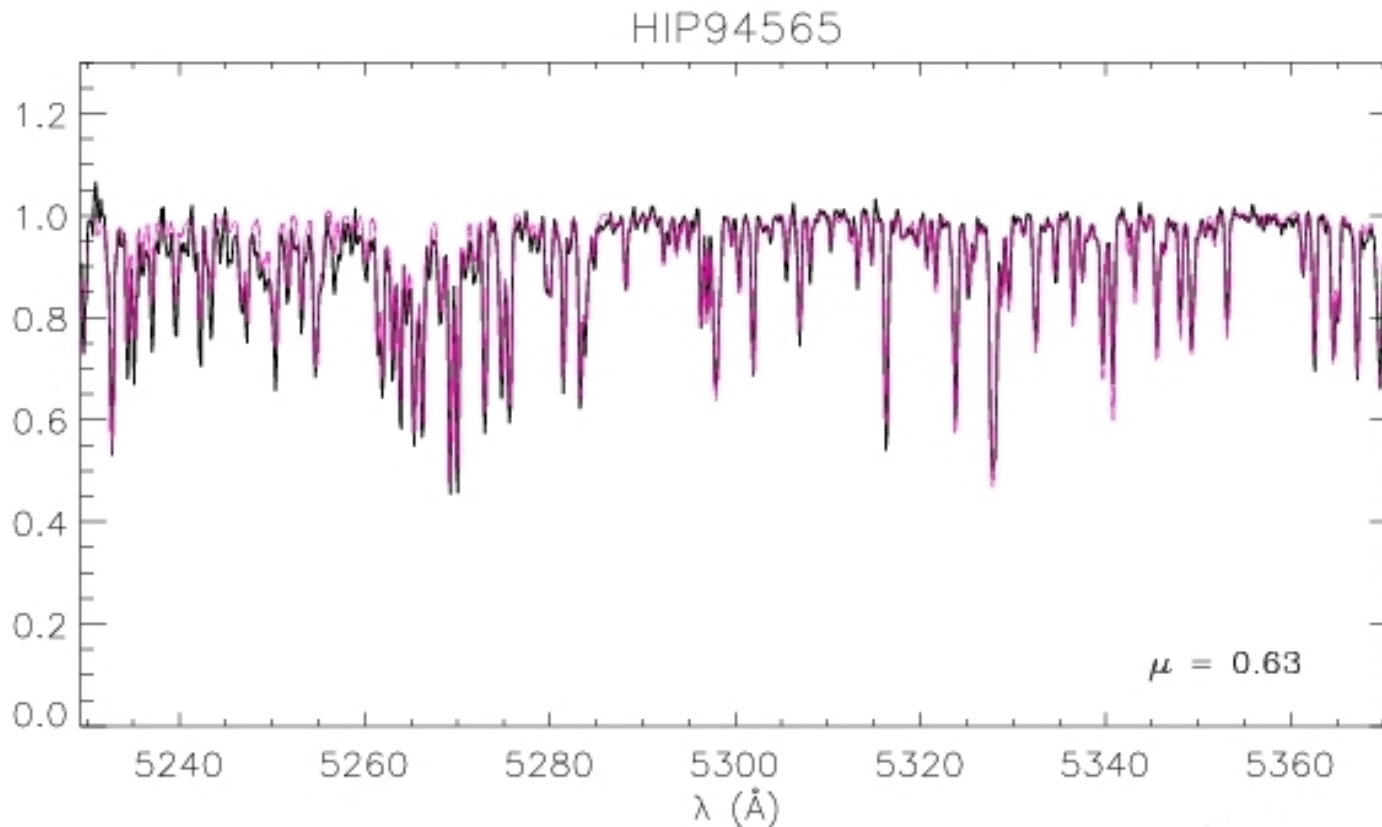
Kepler asteroseismic program

- radial velocity of primary targets
 - determined for all the primary targets
 - discovery of two SB stars
 - discovery of five stars variable in radial velocity



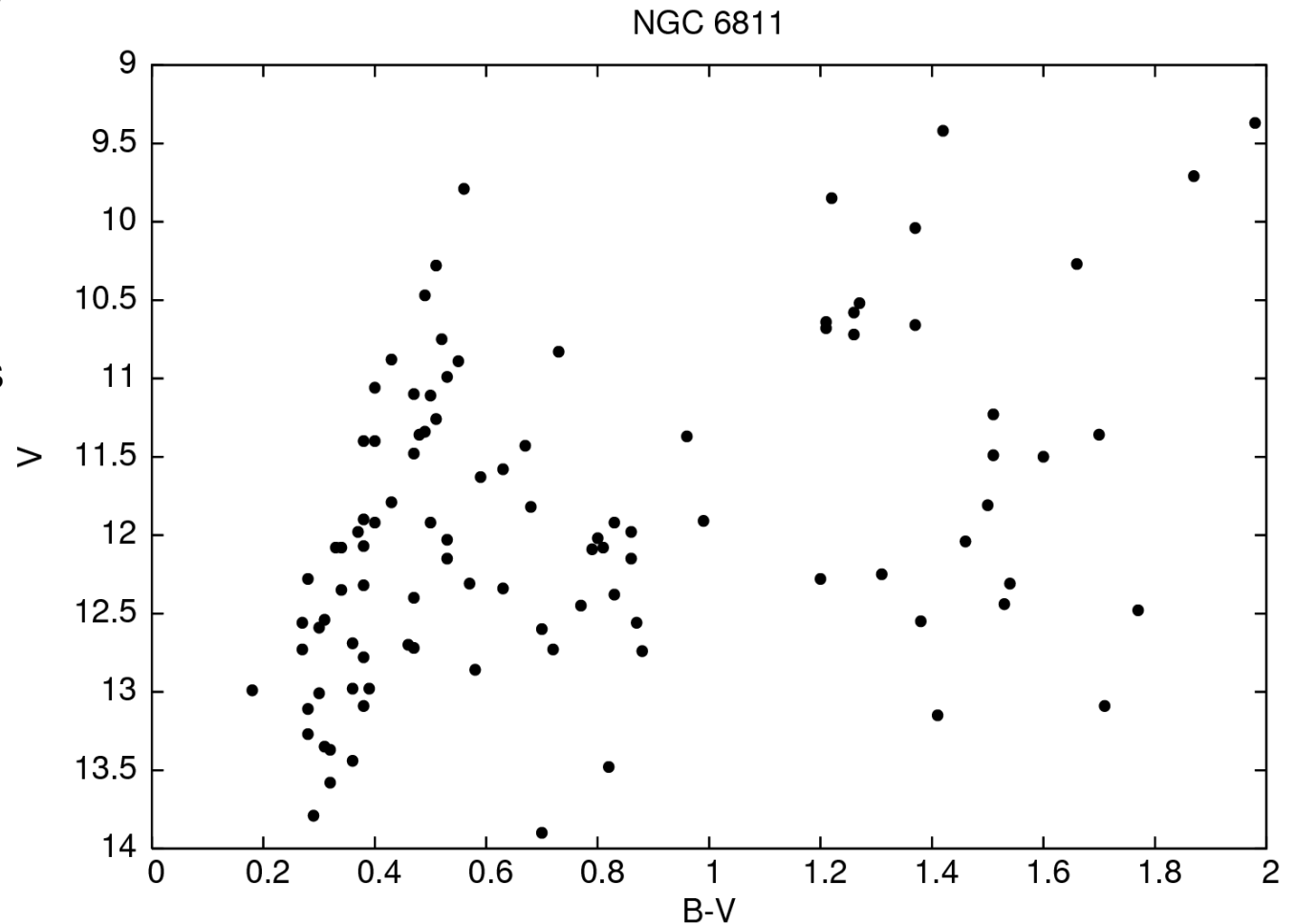
Kepler asteroseismic program

- rotational velocity of primary targets
 - determined with cross-correlation method for all the primary targets
 - template spectra: Serra la Nave and ELODIE library
- simultaneous determination of T_{eff} , $\log g$, $[\text{Fe}/\text{H}]$ and MK spectral type



Kepler asteroseismic program - photometry

- photoelectric UBV, uvby β standard magnitudes for all primary and secondary targets and open clusters (Serra la Nave, Italy)
- RI standard magnitudes for all primary and secondary targets and NGC 6811 and 6866 open clusters (Stara Lesna, Białków)
- CCD BVRI photometry of NGC 6811 and NGC 6866 open clusters – time series analysis (Stara Lesna, Białków)



Kepler asteroseismic program - future plans

- pulsational and evolutionary modelling of Kepler asteroseismic targets
- determination of astrophysical parameters of Kepler primary asteroseismic targets
- determination of astrophysical parameters of Kepler secondary asteroseismic targets
- study of binaries from the selected sample
- study of NGC 6811 and NGC 6866 open clusters
 - variability of stars from the fields of these clusters
 - probability of membership of the stars clusters
 - determination of astrophysical parameters of stars from the cluster