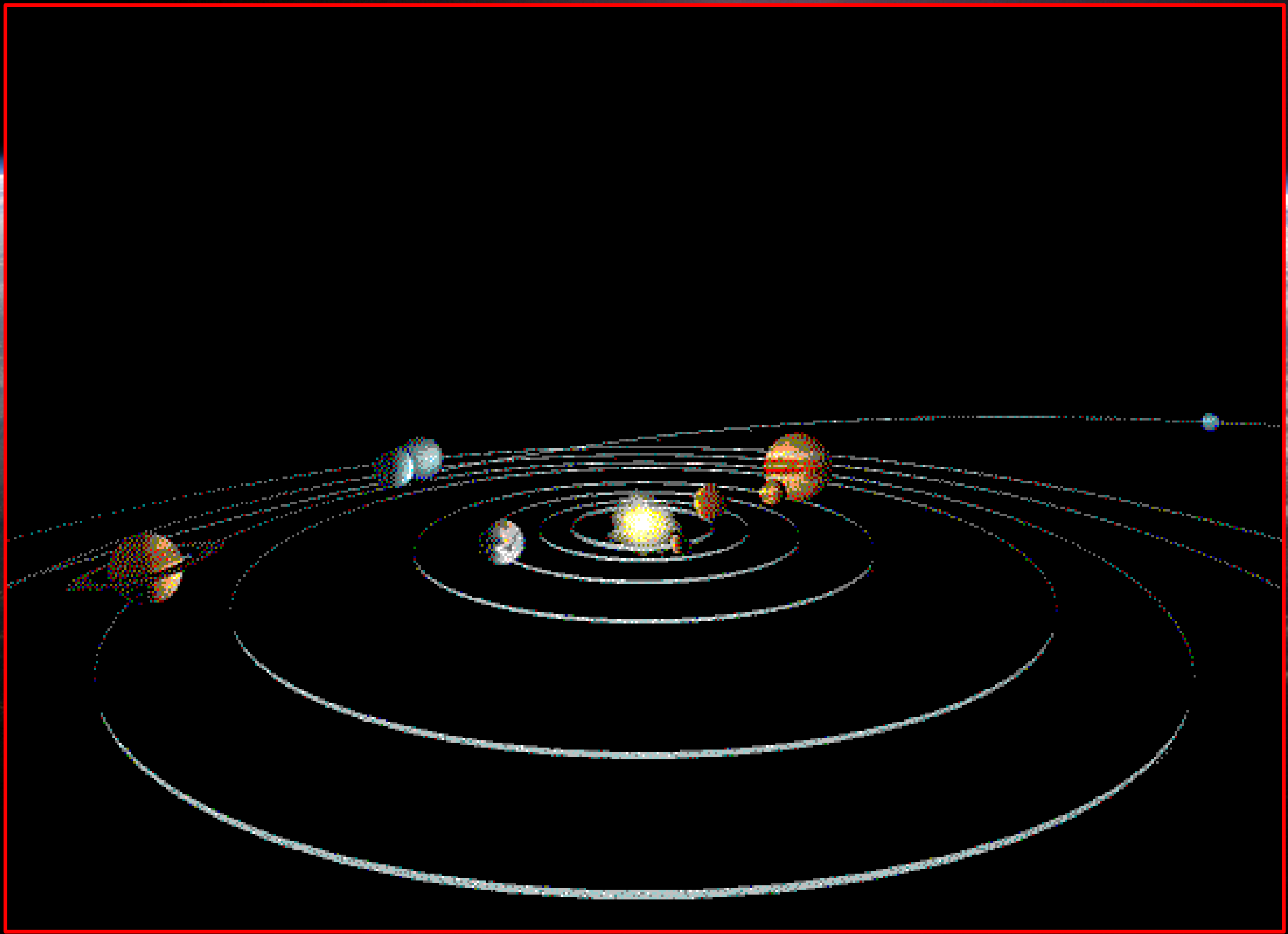
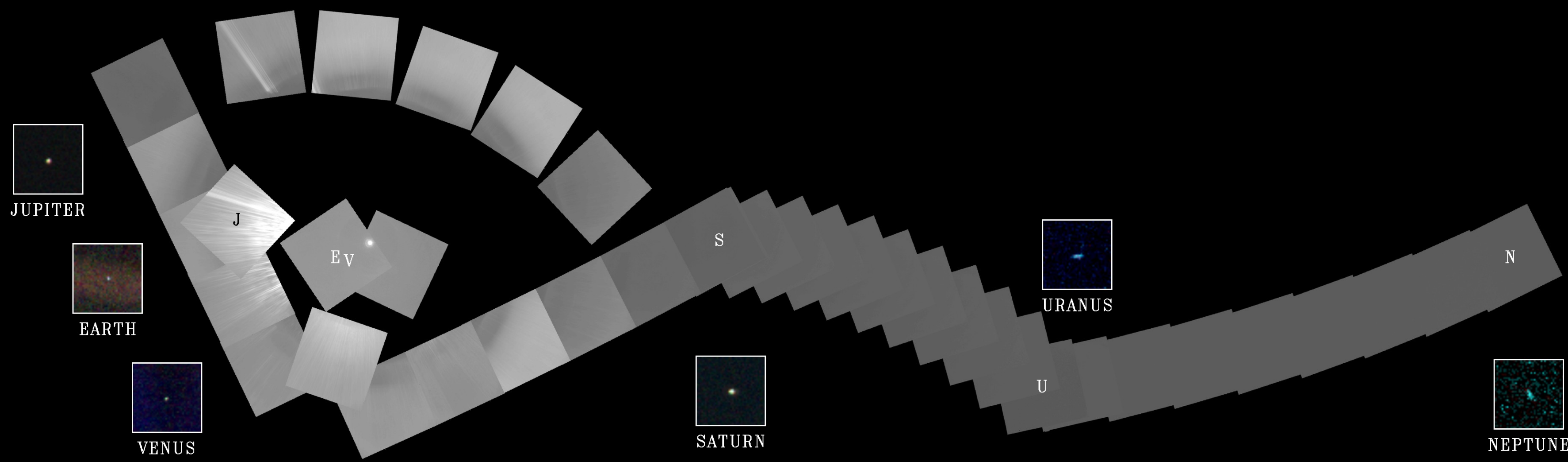
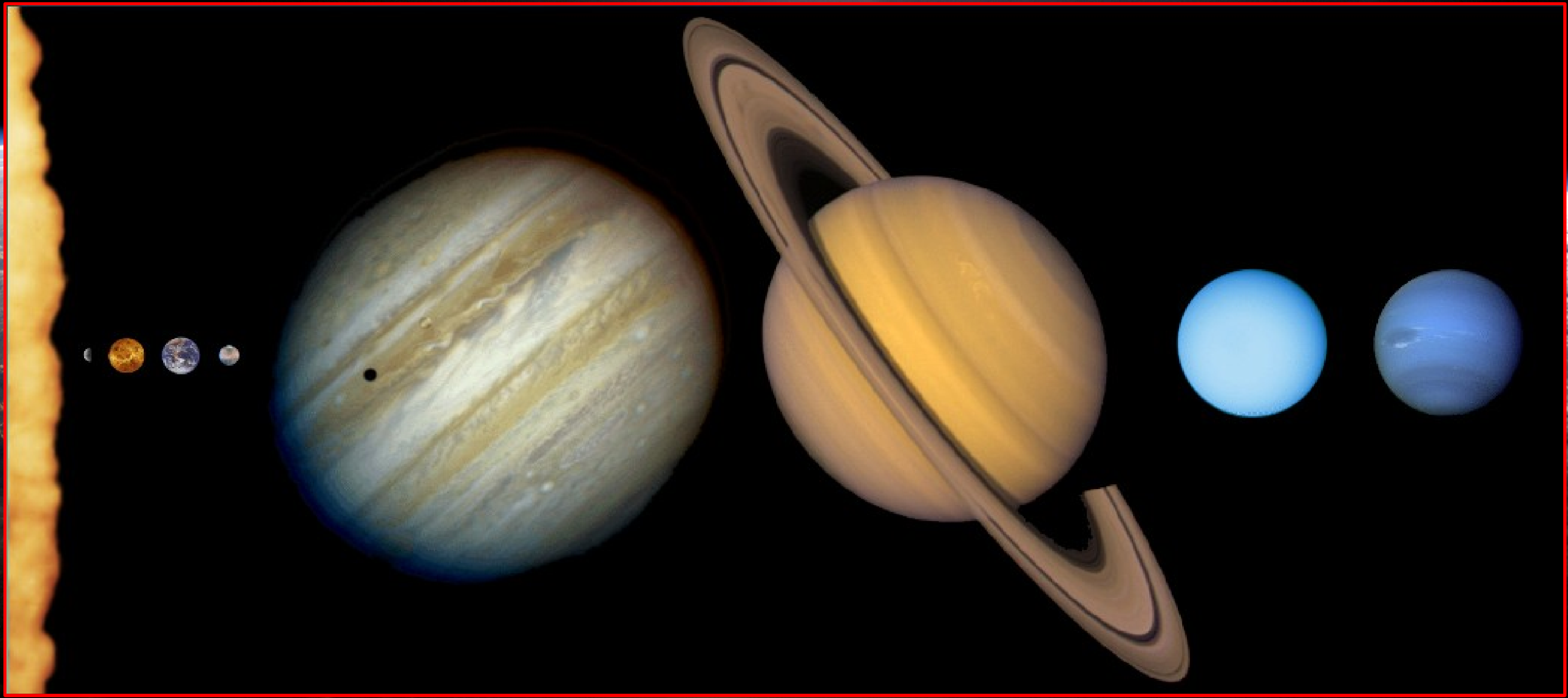
Naše Osončje



Naše Osončje: portret s sonde Voyager



Naše Osončje



Zgodovina odkrivanja našega Osončja

- do 1600: Zemlja, Sonce, Luna, Merkur, Venera, Mars, Jupiter, Saturn
- 17. stoletje: 9 Jupitrovih in Saturnovih lun
- 18. stoletje: Uran in 2 njegovi luni, 2 Saturnovi luni
- 19. stoletje: Neptun, še 8 večjih lun, asteroidi (464)
- 20. stoletje: Pluton, z vesoljskimi sondami in uporabo CCD kamer število odkritij malih objektov "eksplodira"
- 21. stoletje: Plutona ni več med planeti

Porazdelitev mase v našem Osončju

- Porazdelitev mase:
  - Sonce: 99.85%
  - planeti: 0.135%
  - kometi: 0.01% ?
  - sateliti: 0.00005%
  - medplanetna snov (prah in plin): 0.0000001% ?

Porazdelitev vrt. količine v našem Osončju

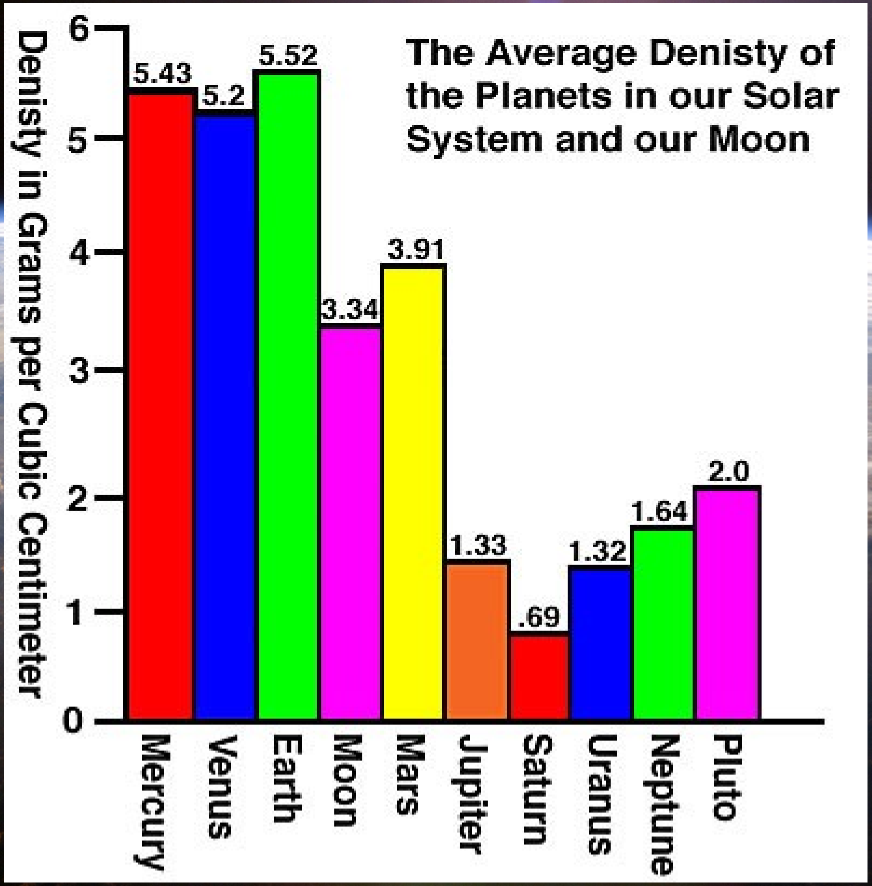
Planet	*Mass ($x10^{27}$ kg)*	*Period (years)*	*AM (gcm^2s^{-1})*
Mercury	0.33	0.24	$8.6x10^{45}$
Venus	4.87	0.61	$1.9x10^{47}$
Earth	5.97	1	$2.6x10^{47}$
Mars	0.64	1.88	$3.4x10^{47}$
Jupiter	1898.8	11.86	$1.9x10^{50}$
Saturn	568.41	9.5	$7.8x10^{49}$
Uranus	86.97	19.31	$1.7x10^{49}$
Neptune	102.85	30	$2x10^{49}$
Pluto	0.0129	39.91	$3.7x10^{45}$

0.4% AM

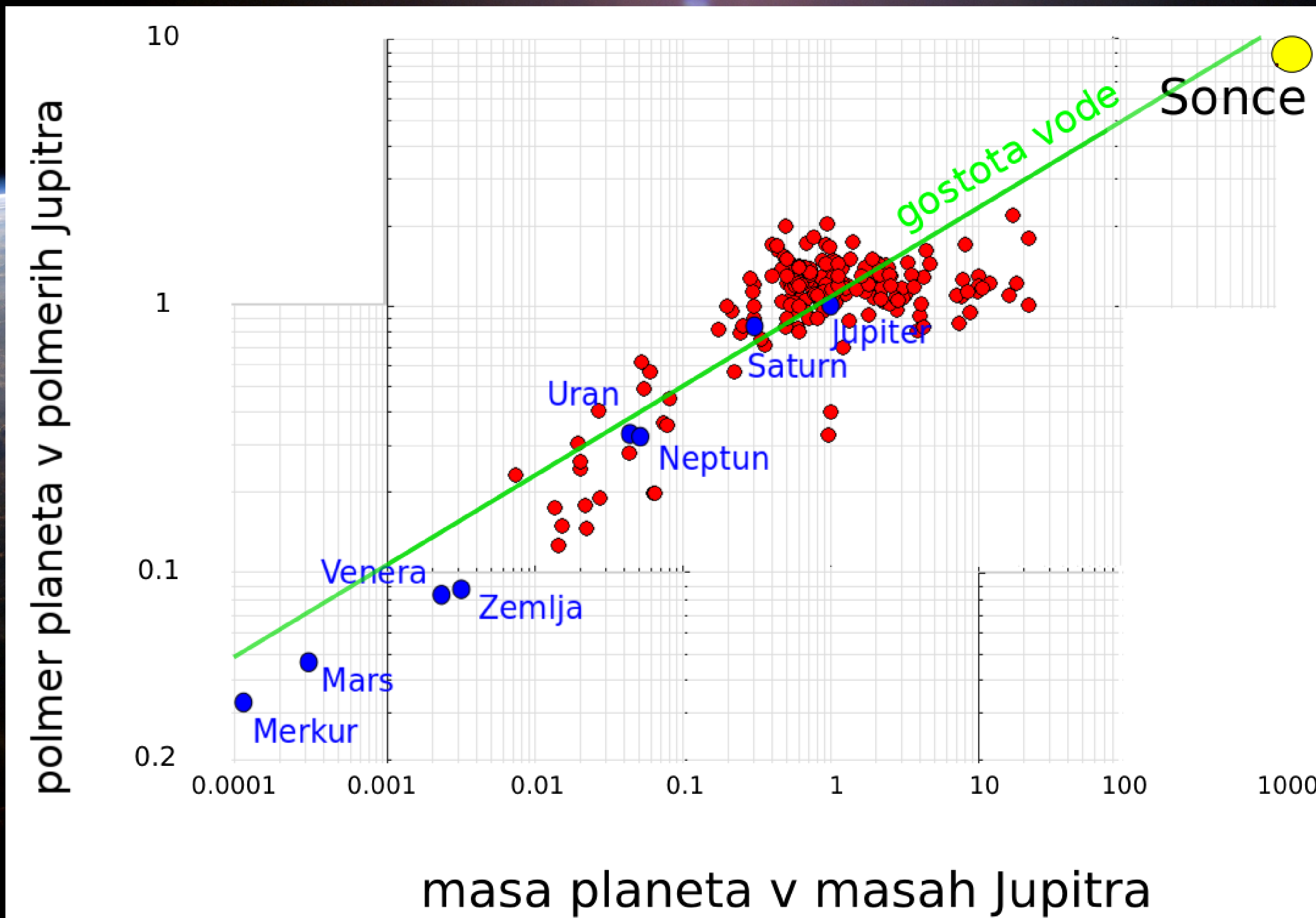
99.2% AM

=>Sonce ima le 0.4% vrtilne količine Osončja.

Gostota planetov



Masa in polmer planetov



Planeti okoli drugih zvezd: zgodovina

- Prvi planet odkrit zunaj Osončja odkrit leta 1991 (pulzar s planeti), prvi planeti okoli normalne zvezde (51 Peg) pa leta 1995.
- Kasneje se je potrdilo še eno zgodnejše odkritje:

letters to nature

Nature **339**, 38 - 40 (04 May 1989); doi:10.1038/339038a0

The unseen companion of HD114762: a probable brown dwarf

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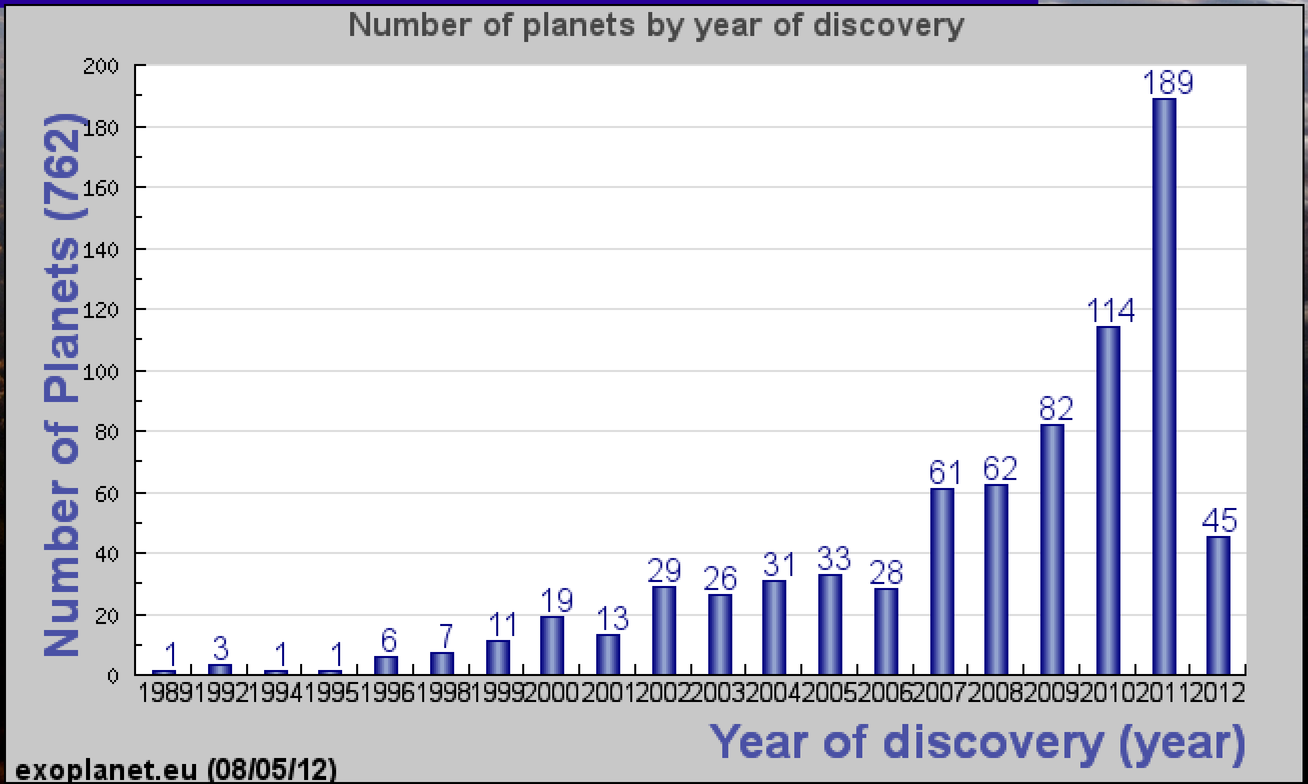
[†]School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Science, Tel Aviv University, Tel Aviv 69978, Israel
[‡]Observatoire de Geneve, Chemin des Maillettes 51, Ch-1290 Sauverny, Switzerland

BROWN dwarfs are substellar objects with too little mass to ignite hydrogen in their cores. Despite considerable effort to detect brown dwarfs astrometrically[1–4], photometrically[4–9], and spectroscopi-cally[10–12], only a few good candidates have been discovered. Here we present spectroscopic evidence for a probable brown-dwarf companion to the solar-type star HD114762. This star undergoes periodic variations in radial velocity which we attribute to orbital motion resulting from the presence of an unseen companion. The rather short period of 84 days places the companion in an orbit similar to that of Mercury around the Sun, whereas the rather low velocity amplitude of about 0.6 km s^{-1} implies that the mass of the companion may be as low as 0.011 solar masses, or 11 Jupiter masses. This leads to the suggestion that the companion is probably a brown dwarf, and may even be a giant planet. However, because the inclination of the orbit to the line of sight is unknown, the mass of the companion may be considerably larger than this lower limit.

Trenutno stanje

12. maja 2012 poznanih ~630 zvezd s planeti

- 762 planetov
- ~100 večplanetnih sistemov



Definition of a Planet

2003: IAU members try to Agree…

- A planet is any object in orbit around the Sun with a diameter greater than 2000 km.
- A planet is any object in orbit around the Sun whose shape is stable due to its own gravity.
- A planet is any object in orbit around the Sun that is dominant in its neighborhood.

…but they end up having to call a General Assembly (2006)

The IAU therefore resolves that planets and other bodies in our Solar System, except satellites, be defined into three distinct categories in the following way:

(1) A "planet" is a celestial body that: (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

(2) A "dwarf planet" is a celestial body that: (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

(3) All other objects except satellites orbiting the Sun shall be referred to collectively as "Small Solar System Bodies".

⇒ **Exoplanets are not planets!!**

ExoPlanet/Brown Dwarf

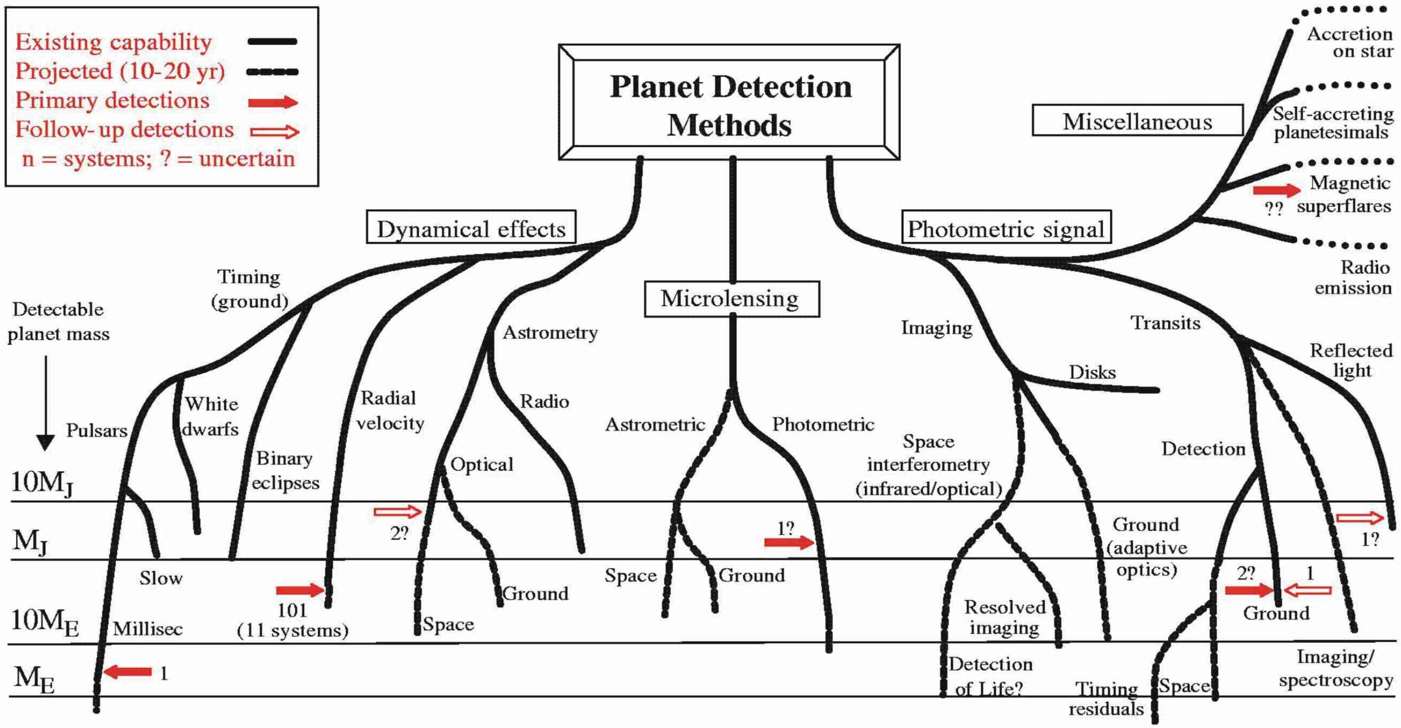
2003: IAU Working Group on Exoplanets:

- ✓ Objects with true masses below the limiting mass for thermonuclear fusion of deuterium (currently calculated to be 13 Jupiter masses for objects of solar metallicity) that orbit stars or stellar remnants are "planets" (no matter how they formed). The minimum mass/size required for an extrasolar object to be considered a planet should be the same as that used in our Solar System.
- ✓ Substellar objects with true masses above the limiting mass for thermonuclear fusion of deuterium are "brown dwarfs", no matter how they formed nor where they are located.
- ✓ Free-floating objects in young star clusters with masses below the limiting mass for thermonuclear fusion of deuterium are not "planets", but are "sub-brown dwarfs" (or whatever name is most appropriate).

THE BIG PICTURE IS STILL QUITE UNCLEAR!

Planet Detection Methods

Michael Perryman: Rep. Prog. Phys, 2000, 63, 1209 (updated Aug 2002)



Načini odkrivanja

Pri poskusu direktnega opazovanja planeta nas močno slepi svetloba z zvezde.

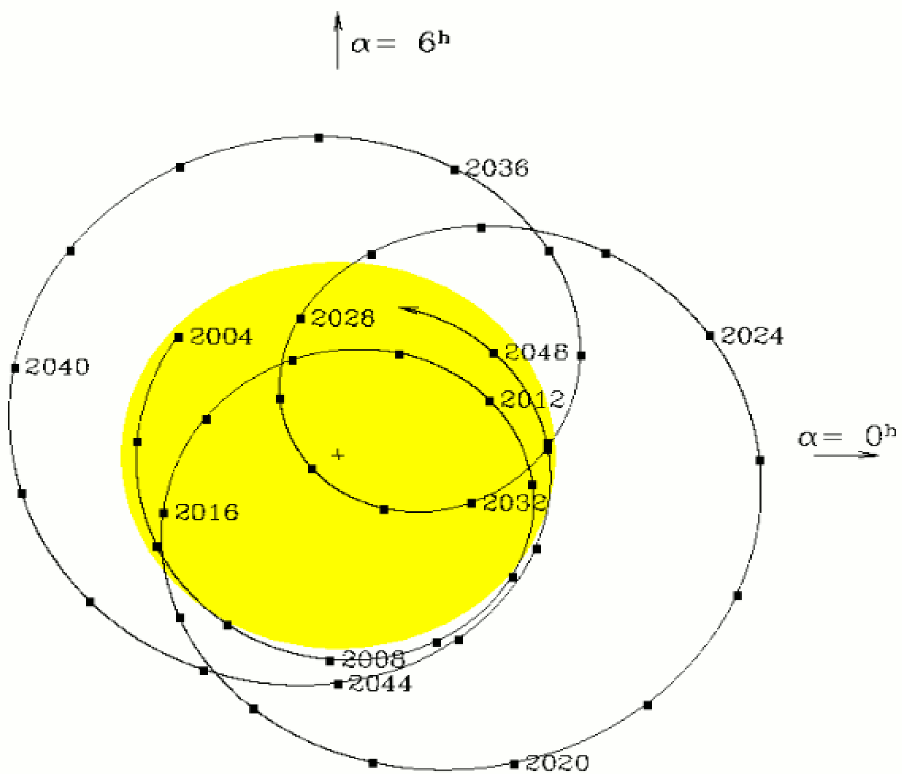
Zvezde se gibljejo skozi prostor. Sonce z 220 km/s obkroži središče Galaksije v 200 milijonih let. Torej v nekaj letih zelo majhen del obhoda. Let zvezde skozi prostor je v ravni črti.

Izjema: dvojna zvezda ali zvezda s planeti. V obeh primerih zvezda kroži okoli skupnega težišča.

Načini odkrivanja: astrometrija

$$r_{\odot} = r_{\text{planet}}\,(m_{\text{planet}}/M_{\odot})$$

Pentljasta krivulja označuje položaj težišča Osončja glede na položaj središča Sonca (znak +). Rumeni krog je velikost Sonca. Pike na krivulji označujejo položaj težišča ob začetku vsakega koledarskega leta.



Načini odkrivanja: astrometrija

$$r_{\star} = r_{planet} \left(m_{planet} / M_{\star} \right)$$

$$v_{planet} = 2 \pi \, r_{planet} / P$$

$$v_{planet}^{2} / r_{planet} = G \, M_{\star} \; / \; r_{planet}^{2}$$

$$r_{\star} = (2\pi)^{-2/3} \, G^{1/3} \, m_{planet} \, (M_{\star})^{-2/3} \, P^{2/3}$$

Če je za planet z maso Jupitra, ki kroži okoli zvezde z maso Sonca, perioda 2 leti, je $r_{\star}$ enak 0.32 polmera Sonca.

Načini odkrivanja: astrometrija

$$r_{\odot} = (2\pi)^{-2/3} G^{1/3} m_{planet} (M_{\odot})^{-2/3} P^{2/3}$$

0,32 polmera Sonca vidimo na razdalji
1,3 pc pod kotom 1,2 mas = 5,7 mm na razdalji 1000 km;
100 pc pod kotom 15 μas = 0,07 mm na razdalji 1000 km.

Astrometry's Blunders

PROPOSAL FOR A PROJECT OF HIGH-PRECISION STELLAR RADIAL VELOCITY WORK

By Otto Struve

With the completion of the great radial-velocity programmes of the major observatories, the impression seems to have gained ground that the measurement of Doppler displacements in stellar spectra is less important at the present time than it was prior to the completion of R. E. Wilson's new radial-velocity catalogue.

I believe that this impression is incorrect, and I should like to support my contention by presenting a proposal for the solution of a characteristic astrophysical problem.

One of the burning questions of astronomy deals with the frequency of planet-like bodies in the galaxy which belong to stars other than the Sun. K. A. Strand's[1] discovery of a planet-like companion in the system of 61 Cygni, which was recently confirmed by A. N. Deitch[2] at Poulkovo, and similar results announced for other stars by P. Van de Kamp[3] and D. Reuyl and E. Holmberg[4] have stimulated interest in this problem. I have suggested elsewhere that the absence of rapid axial rotation in all normal solar-type stars (the only rapidly-rotating G and K stars are either W Ursae Majoris binaries or T Tauri nebular variables,[5] or they possess peculiar spectra[6]) suggests that these stars have somehow converted their angular momentum of axial rotation into angular momentum of orbital motions of planets. Hence, there may be many objects of planet-like character in the galaxy.

But how should we proceed to detect them? The method of direct photography used by Strand is, of course, excellent for nearby binary systems, but it is quite limited in scope. There seems to be at present no way to discover objects of the mass and size of Jupiter; nor is there much hope that we could discover objects ten times as large in mass as Jupiter, if they are at distances of one or more astronomical units from their parent stars.

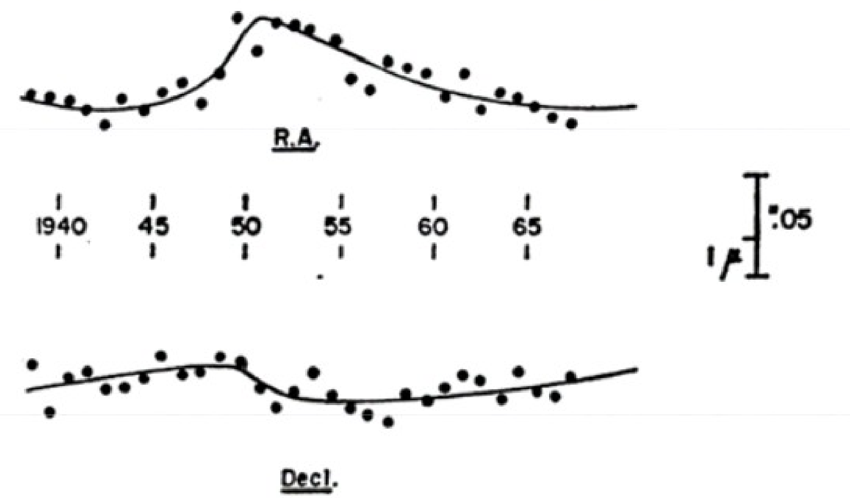


FIG. 1. Barnard's star: Yearly means, averaging 100 plates and weight 68; time–displacement curves for $P=25$ yr, $e=0.75$, $T=1950$.

* The earliest, well-known planet search episode was a long-term effort by van de Kamp to detect planets around the Barnard star

* It was only in the 1970s that Gatewood and Eichhorn have shown, that van de Kamp's "detections" were the results of instrumental errors

mas-Astrometry: Not Enough!

TABLE 1
PARALLAX, PROPER MOTION, AND ASTROMETRIC SIGNATURES INDUCED BY PLANETS OF VARIOUS MASSES AND ORBITAL RADII

Source	α
Jupiter at 1 AU (μas)	100
Jupiter at 5 AU (μas)	500
Jupiter at 0.05 AU (μas)	5
Neptune at 1 AU (μas)	6
Earth at 1 AU (μas)	0.33
Parallax (μas)	1×10^5
Proper motion (μas yr^{-1})	5×10^5

NOTE.—A 1 $M_\odot$ star at 10 pc is assumed.

Sozzetti 2005

Gaia: Design Considerations

- Astrometry (V < 20):
  - completeness to 20 mag (on-board detection) ⇒ 10^9 stars
  - accuracy: 10–25 μarcsec at 15 mag (Hipparcos: 1 milliarcsec at 9 mag)
  - scanning satellite, two viewing directions
    ⇒ global accuracy, with optimal use of observing time
  - principle: global astrometric reduction (as for Hipparcos)

- Photometry (V < 20):
  - astrophysical diagnostics (low-dispersion photometry) + chromaticity
    ⇒ ΔT_{eff} ~ 200 K, log g, [Fe/H] to 0.2 dex, extinction

- Radial velocity (V < 17):
  - application:
    - third component of space motion, perspective acceleration
    - dynamics, population studies, binaries
    - spectra for V < 14: chemistry, rotation
  - principle: slitless spectroscopy in Ca triplet (847–874 nm) at R = 11,500

Gaia: Complete, Faint, Accurate

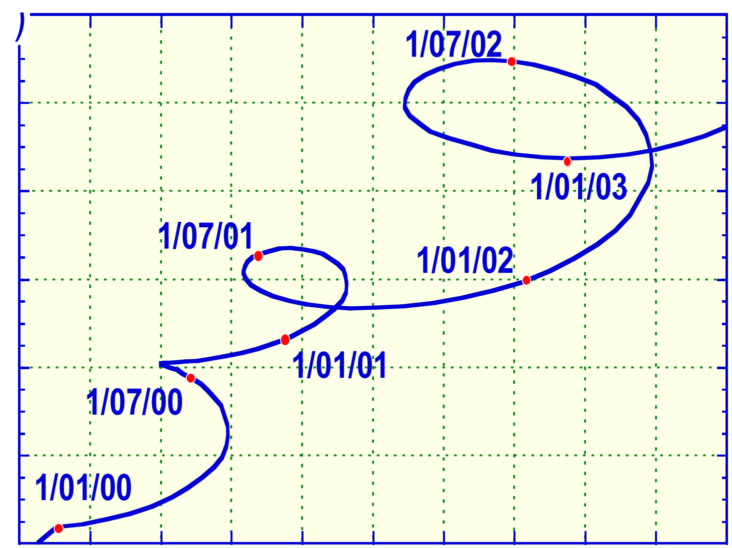
	Hipparcos	**Gaia**
Magnitude limit	12 mag	20 mag
Completeness	7.3 – 9.0 mag	20 mag
Bright limit	0 mag	6 mag
Number of objects	120,000	26 million to V = 15
		250 million to V = 18
		1000 million to V = 20
Effective distance	1 kpc	50 kpc
Quasars	1 (3C 273)	500,000
Galaxies	None	1,000,000
Accuracy	1 milliarcsec	7 μarcsec at V = 10
		10 – 25 μarcsec at V = 15
		300 μarcsec at V = 20
Photometry	2-colour (B and V)	Low-res. spectra to V = 20
Radial velocity	None	15 km s^{-1} to V = 17
Observing	Pre-selected	Complete and unbiased

Exo-Planets: Expected Discoveries

- Astrometric survey:
  - monitoring of ~150,000 FGK stars to ~200 pc
  - detection limits: ~1M_J and P < 10 years
  - complete census of all stellar types, P ~ 2–9 years
  - masses, rather than lower limits (m sin i)
  - multiple systems measurable, giving relative inclinations

- Results expected:
  - ~2000 exo-planets (single systems)
  - ~300 multi-planet systems
  - displacement for 47 UMa = 360 μas
  - orbits for ~1000 systems
  - masses down to 10 M_{Earth} to 10 pc

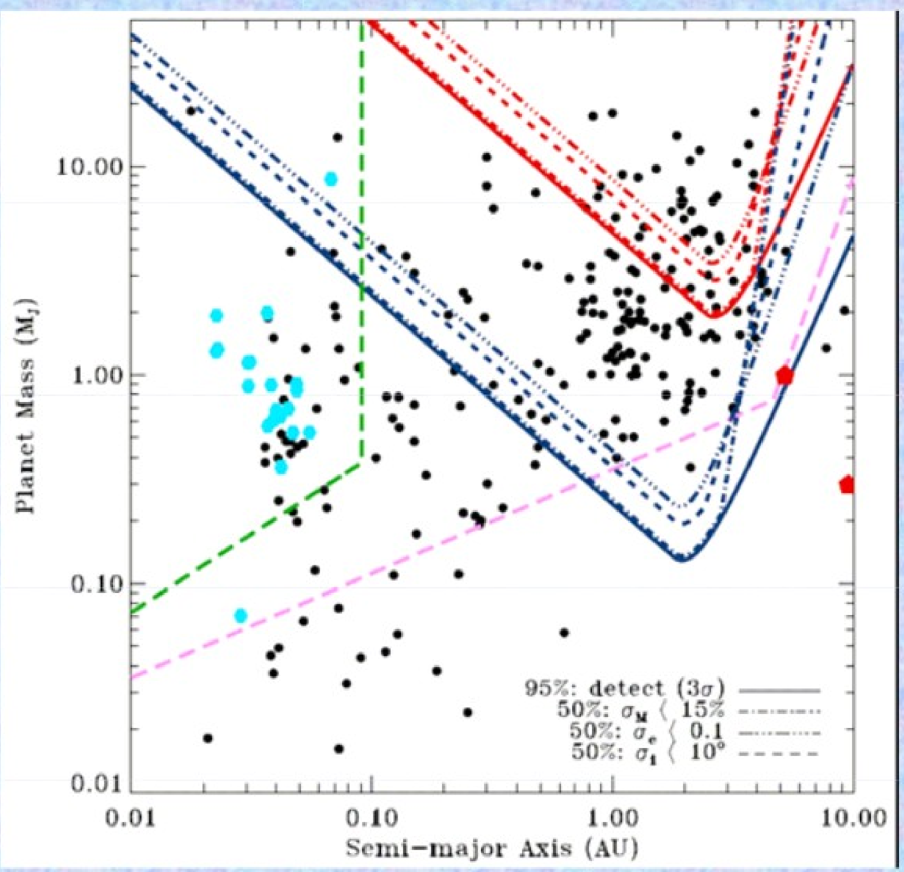
- Photometric transits: ~5000



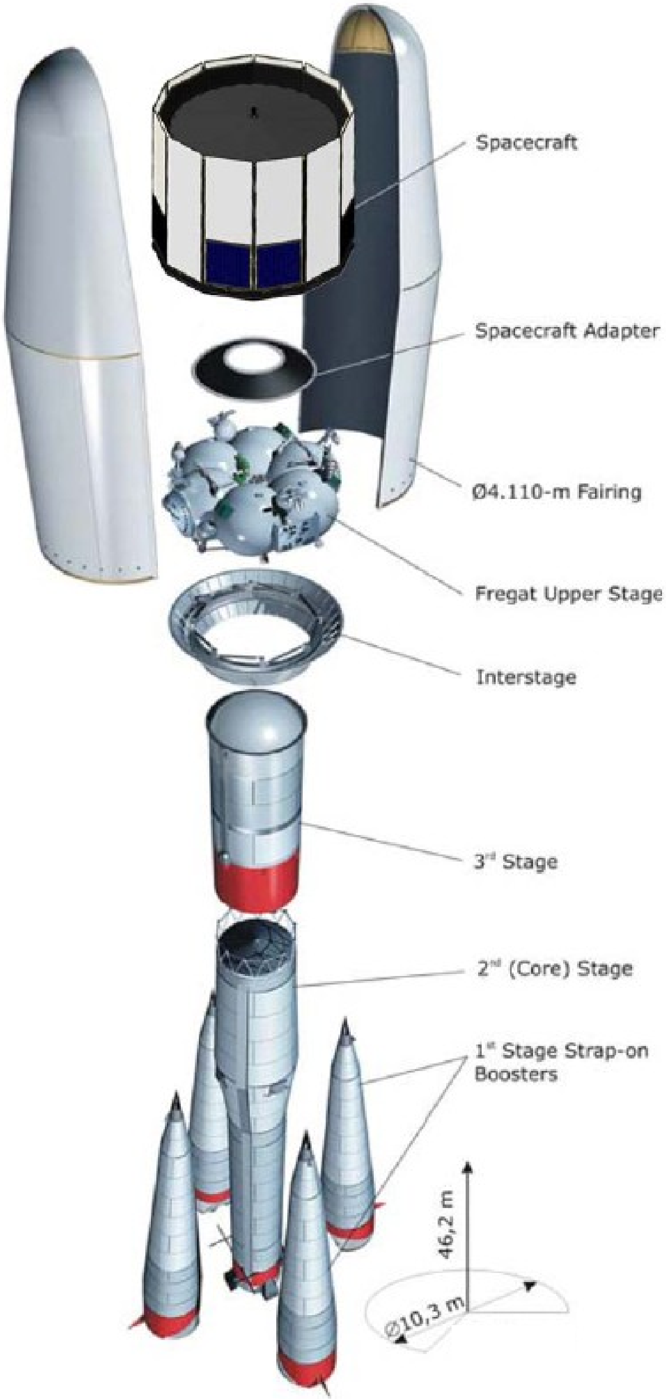
Gaia Discovery Space (1)

1) Massive planets (>2-3 M_J) at 2<a<4 AU are detectable out to ~200 pc around solar analogs
2) Saturn-mass planets with 1<a<4 AU are measurable around nearby (<25 pc) M dwarfs

Critical assumption: σ_A ~ 15 μas

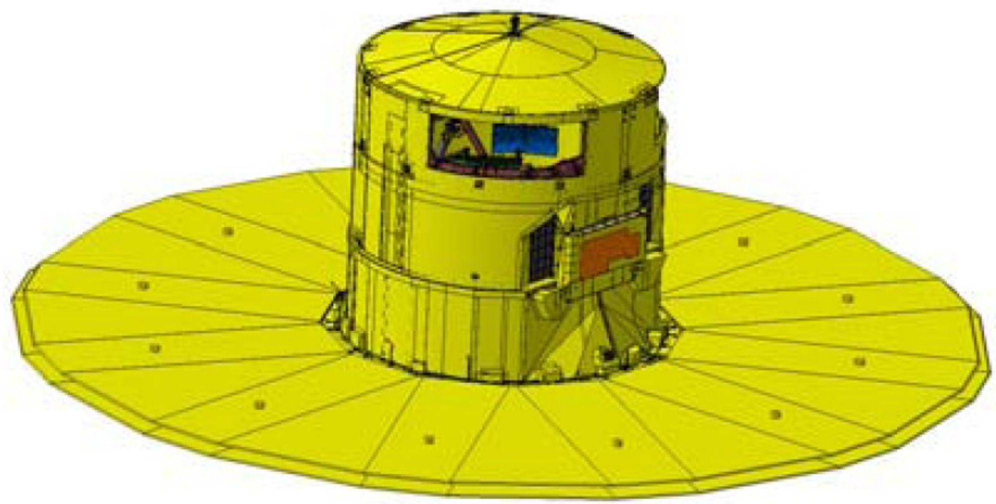


Casertano, Lattanzi, Sozzetti et al. 2008

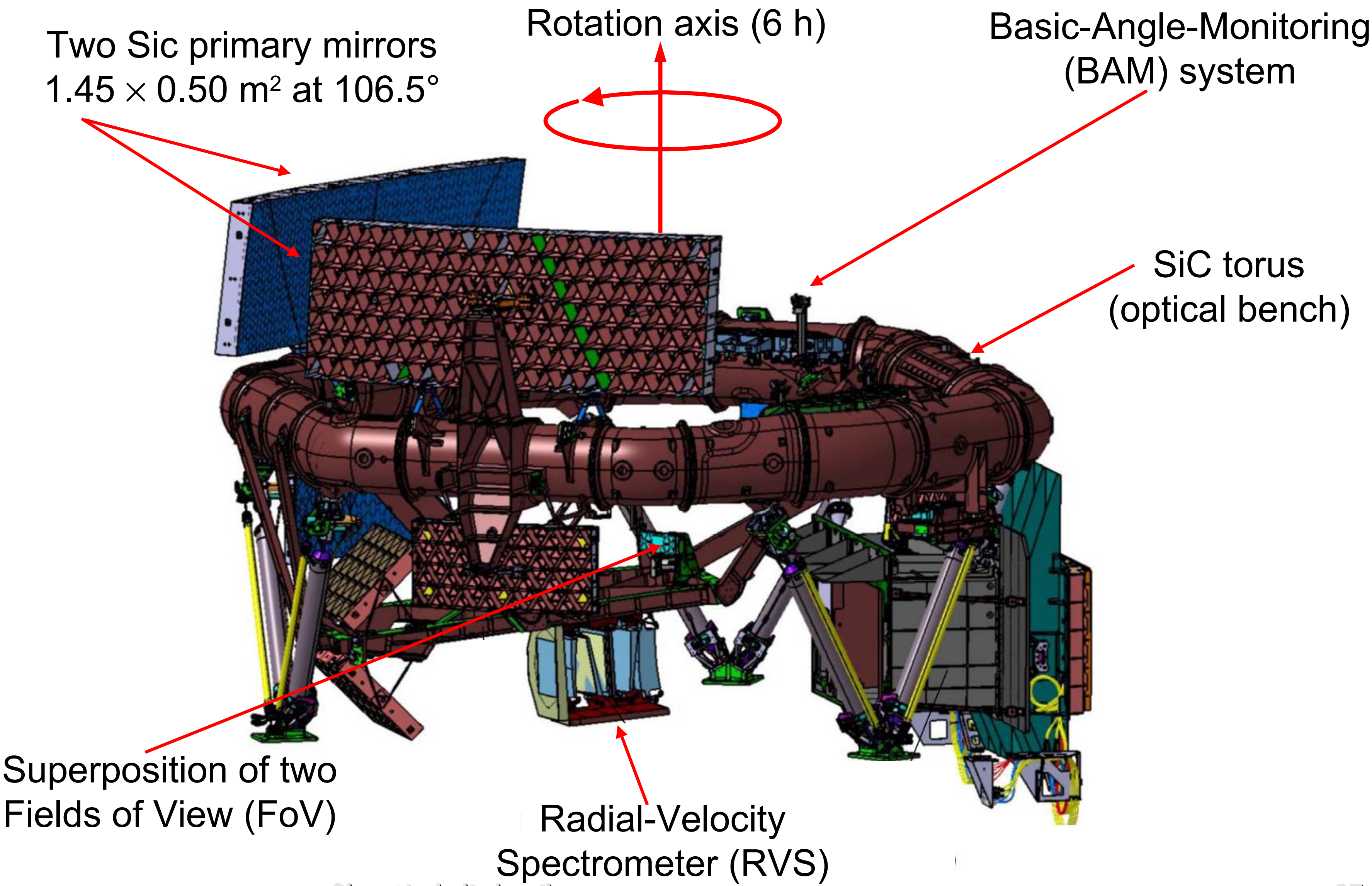


Satellite and System

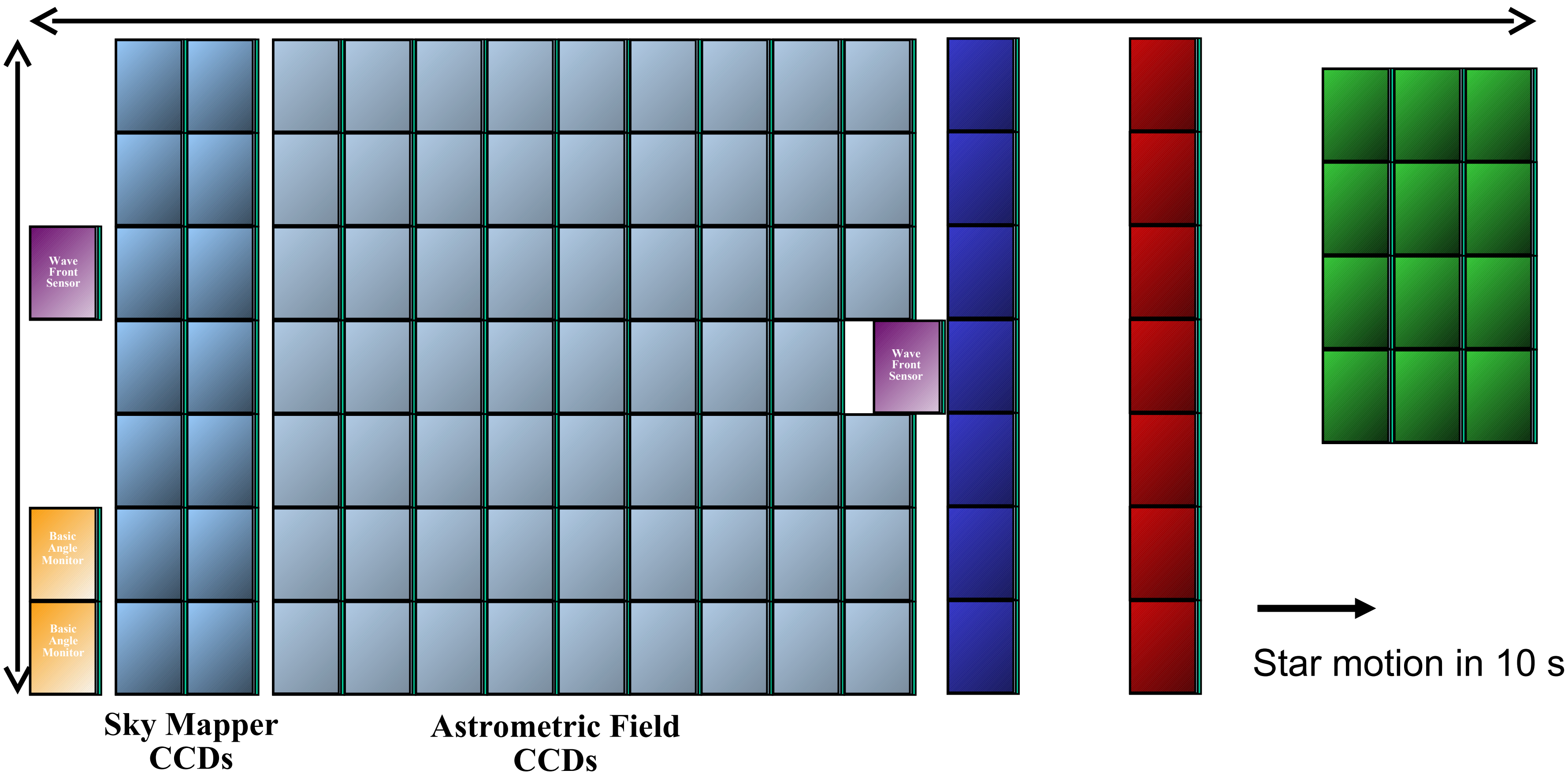
- ESA-only mission
- Launch: November 2012
- Launcher: Soyuz–Fregat from CSG
- Orbit: L2 Lissajous orbit
- Ground stations: Cebreros + New Norcia
- Lifetime: 5 years (1 year potential extension)
- Downlink rate: 4 – 8 Mbps



Payload and Telescope



Focal Plane



Total field:
- active area: 0.75 deg^2
- CCDs: 14 + 62 + 14 + 12 (+ 4)
- 4500 x 1966 pixels (TDI)
- pixel size = 10 µm x 30 µm
  = 59 mas x 177 mas

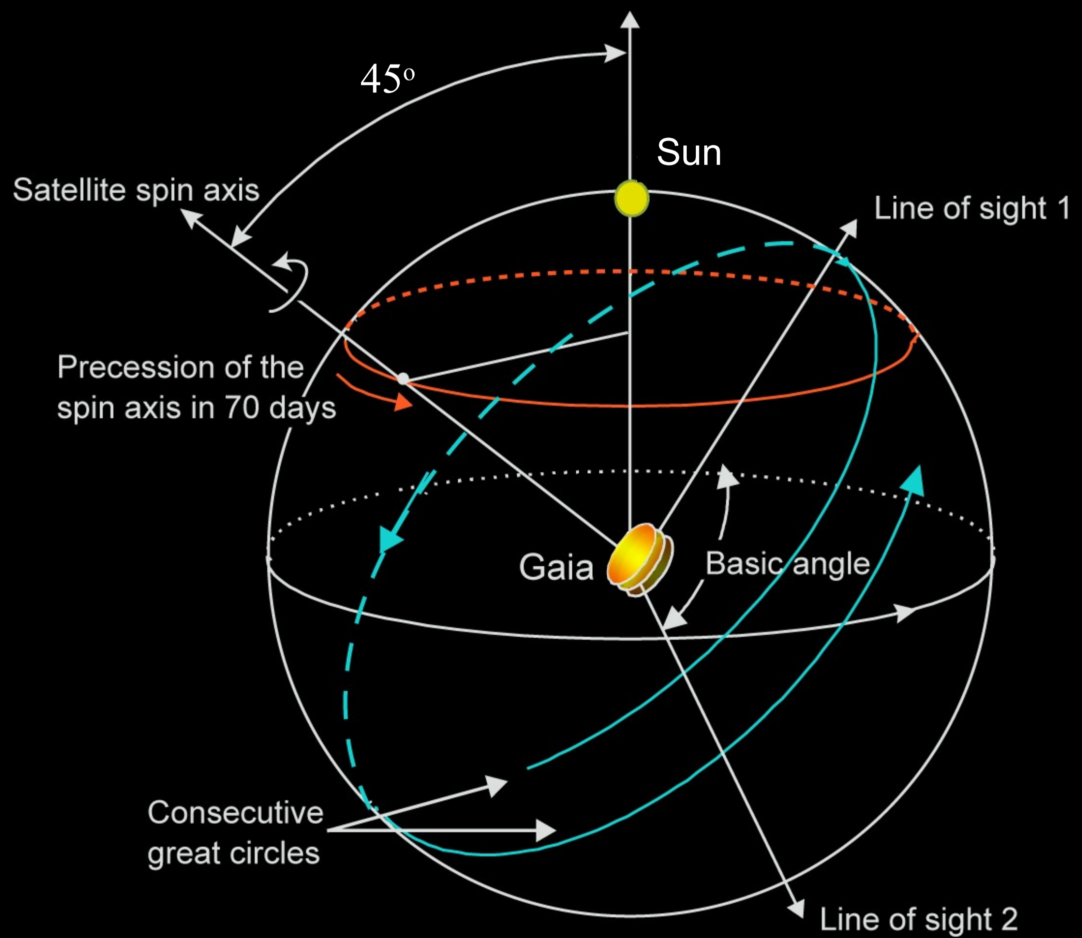
Sky mapper:
- detects all objects to 20 mag
- rejects cosmic-ray events
- field-of-view discrimination

Astrometry:
- total detection noise ~ 6 e$^-$

Photometry:
- spectro-photometer
- blue and red CCDs

Spectroscopy:
- high-resolution spectra
- red CCDs

Sky-Scanning Principle



Spin axis	45° to Sun
Scan rate:	60 arcsec s^{-1}
Spin period:	6 hours

Figure courtesy Karen O'Flaherty

Comments on Astrometric Accuracy

- Massive leap from Hipparcos to Gaia:
  - accuracy: 2 orders of magnitude (1 milliarcsec to 7 microarcsec)
  - limiting sensitivity: 4 orders of magnitude (~10 mag to 20 mag)
  - number of stars: 4 orders of magnitude (10^5 to 10^9)
- Measurement principles identical:
  - two viewing directions (absolute parallaxes)
  - sky scanning over 5 years $\Rightarrow$ parallaxes and proper motions
- Instrument improvement:
  - larger primary mirror: 0.3×0.3 m^2 $\rightarrow$ 1.45×0.50 m^2, $\sigma \propto D^{-(3/2)}$
  - improved detector (IDT $\rightarrow$ CCD): QE, bandpass, multiplexing
- Control of all error sources:
  - aberrations, chromaticity, Solar-system ephemerides, attitude control, …

Načini odkrivanja: spektroskopija

$$r_{\odot} = r_{planet}\,(m_{planet}/M_{\odot})$$

$$v_{\odot} = 2\,\pi\,r_{\odot}/P \qquad v_{planet} = 2\,\pi\,r_{planet}/P$$

$v_{planet} = (GM_{\odot}/r_{planet})^{1/2}$, kjer je $M_{\odot}$ masa zvezde.

$$v_{\odot} = (GM_{\odot}/r_{planet})^{1/2}\,(m_{planet}/M_{\odot})$$

3. Keplerjev zakon mi da r_{planet}, iz zadnje enačbe tako dobim m_{planet}.

Spektroskopija: ocena temperature na planetu

$$(1-a_P)\,[L_{\odot} / (4\pi\, r_P^2)]\,(\pi R_p^2) = (4\pi\, R_P^2)\,\sigma\, T_P^4$$

$$T_P = [(1-a_P)\, L_{\odot} / (16\pi\, \sigma\, r_P^2)]^{1/4}$$

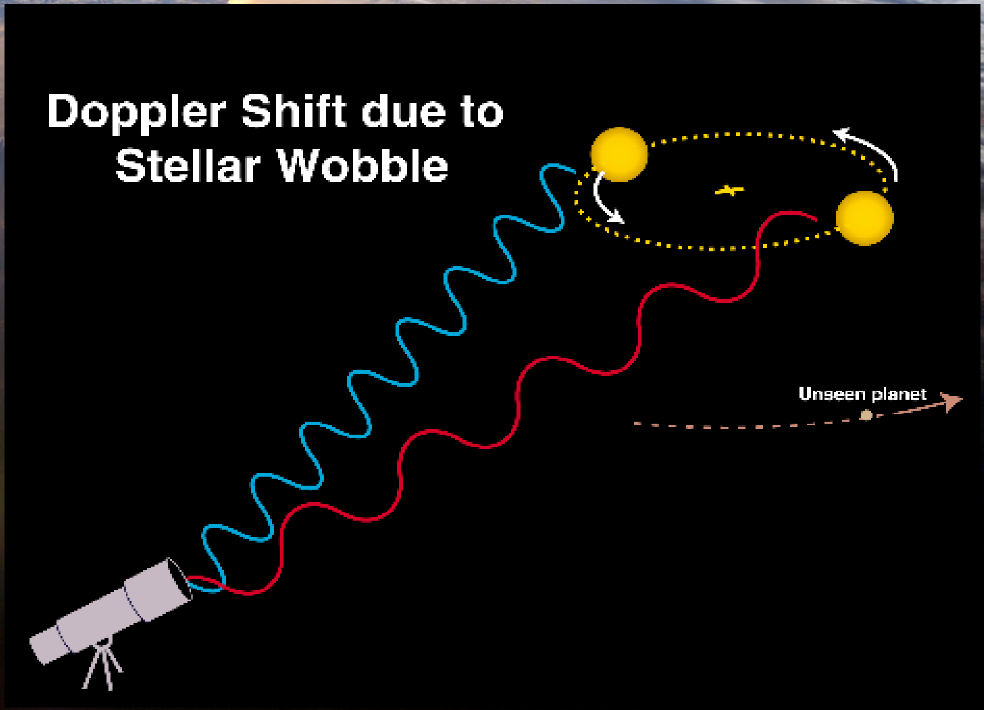
Približevanje/oddaljevanje zvezde: spektroskopija

- Spektroskopska meritev hitrosti preko Dopplerjevega pojava
- gravitacijski vpliv planeta na gibanje zvezde

V dvozvezdju je hitrost lahko >10 km/s

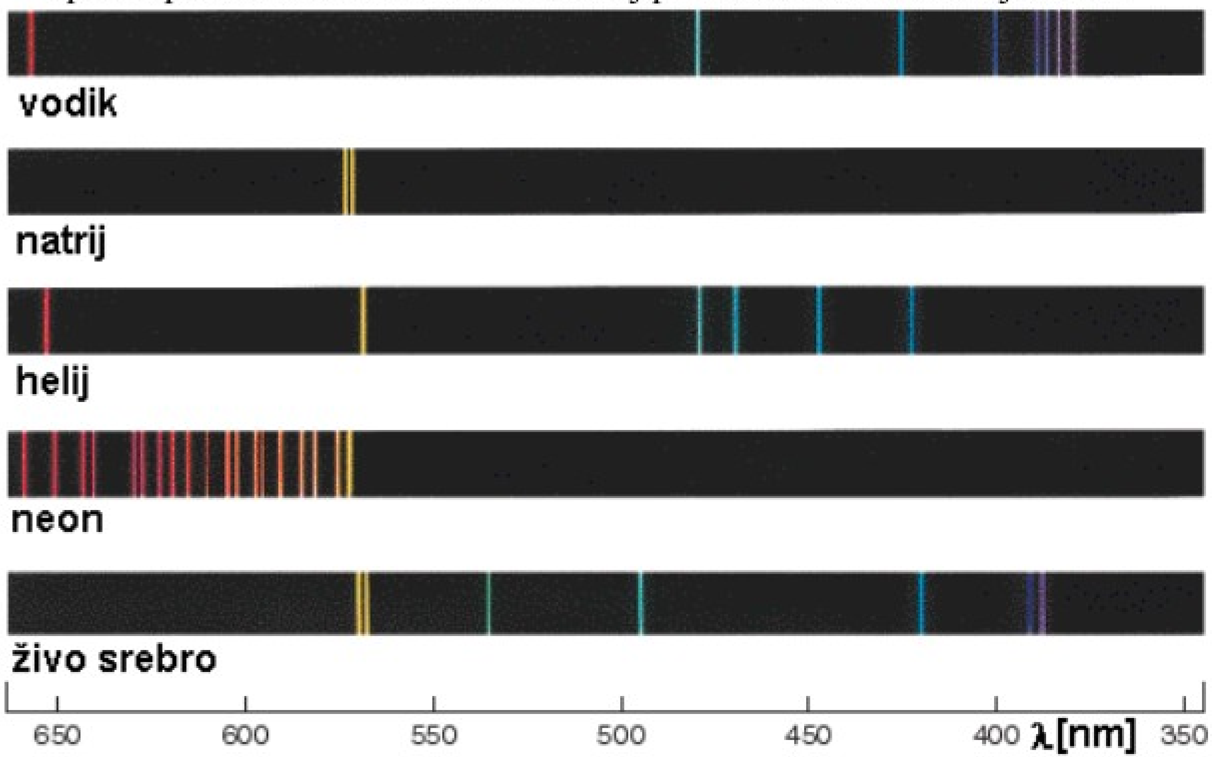
Planeti imajo manjšo maso, zato hitrosti le ~10 m/s.

Potrebujemo izjemno natančen instrument.

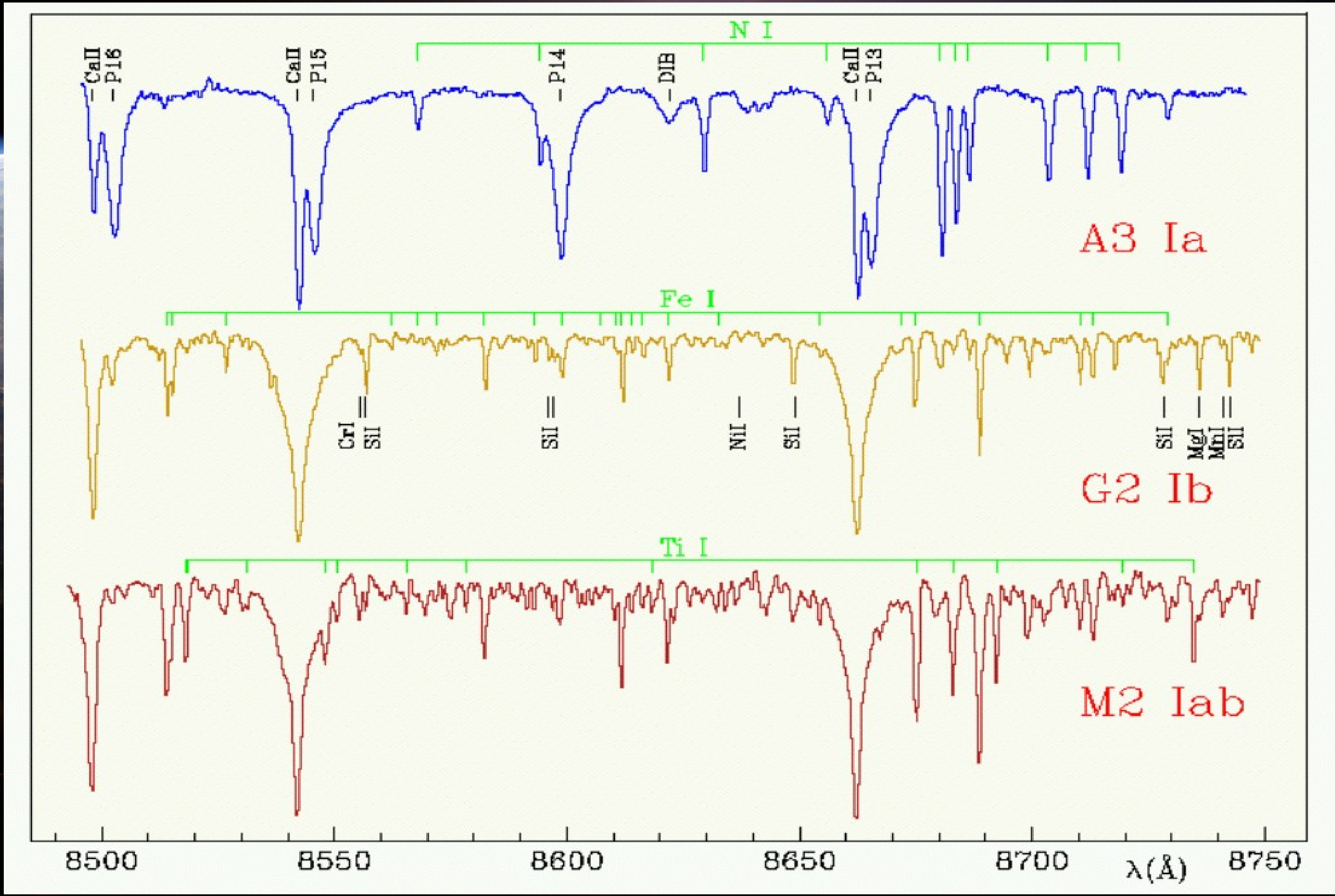


Črte v spektrih zvezd

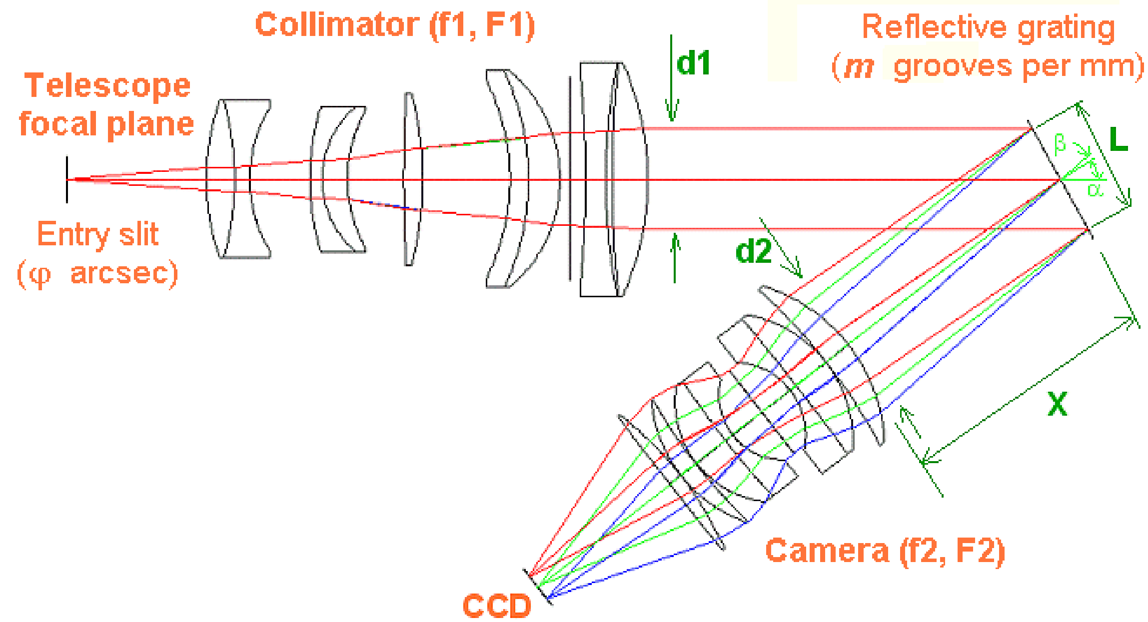
Spektri plinskih svetil so črtasti. Nekaj primerov kaže naslednja slika.



Črte v spektrih zvezd



Interferenčni pogoj



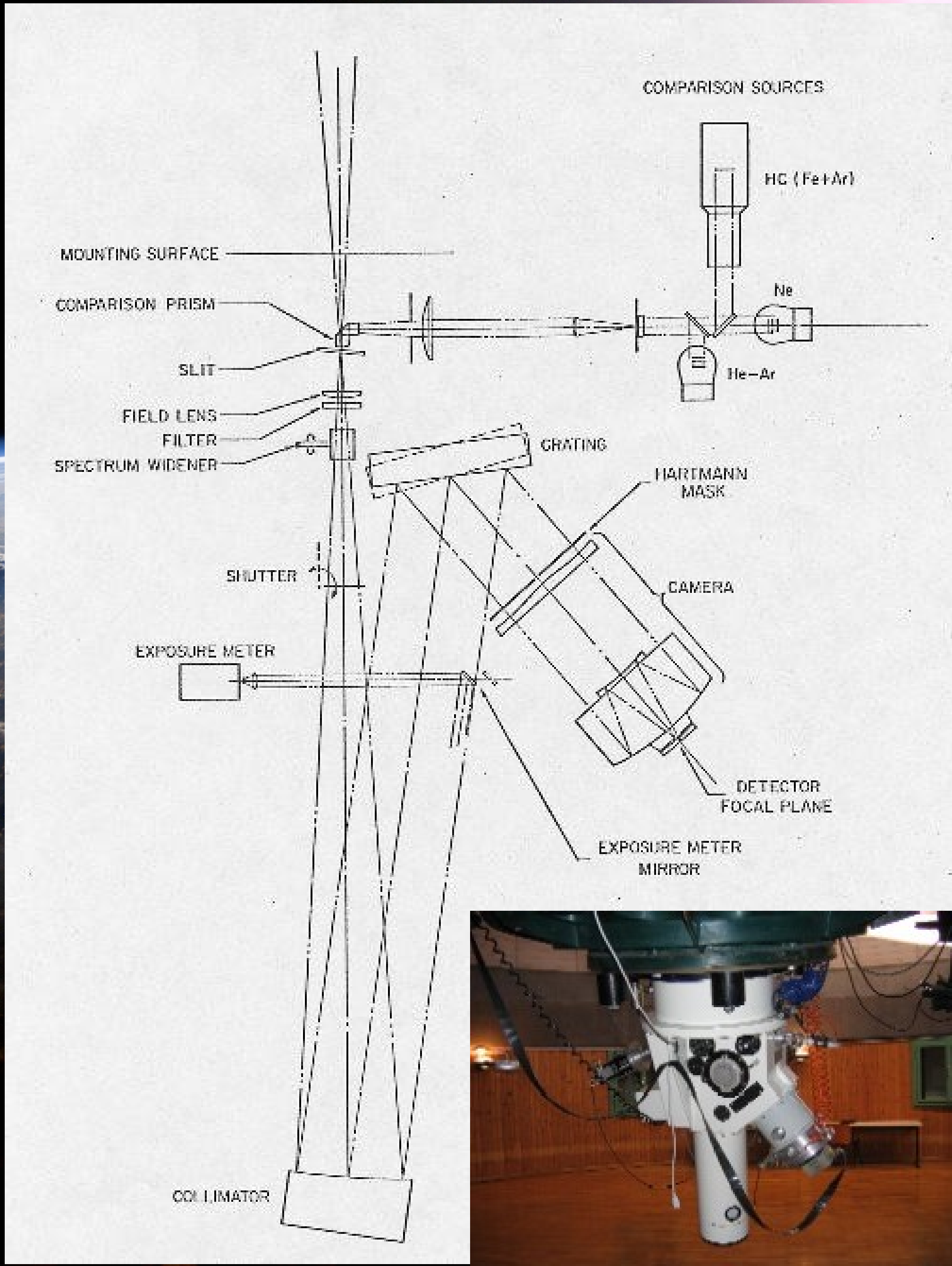
$$\sin\alpha + \sin\beta = km\lambda_o \quad ; \quad k = \pm 1,$$

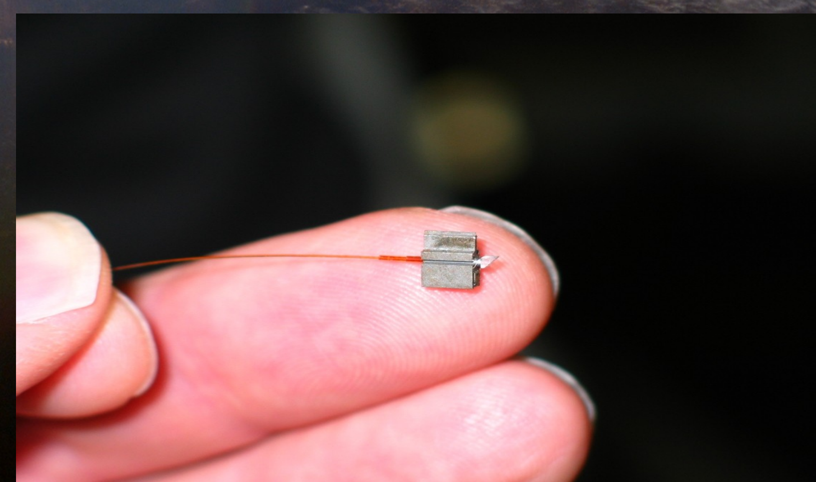
$$\gamma = \alpha - \beta$$

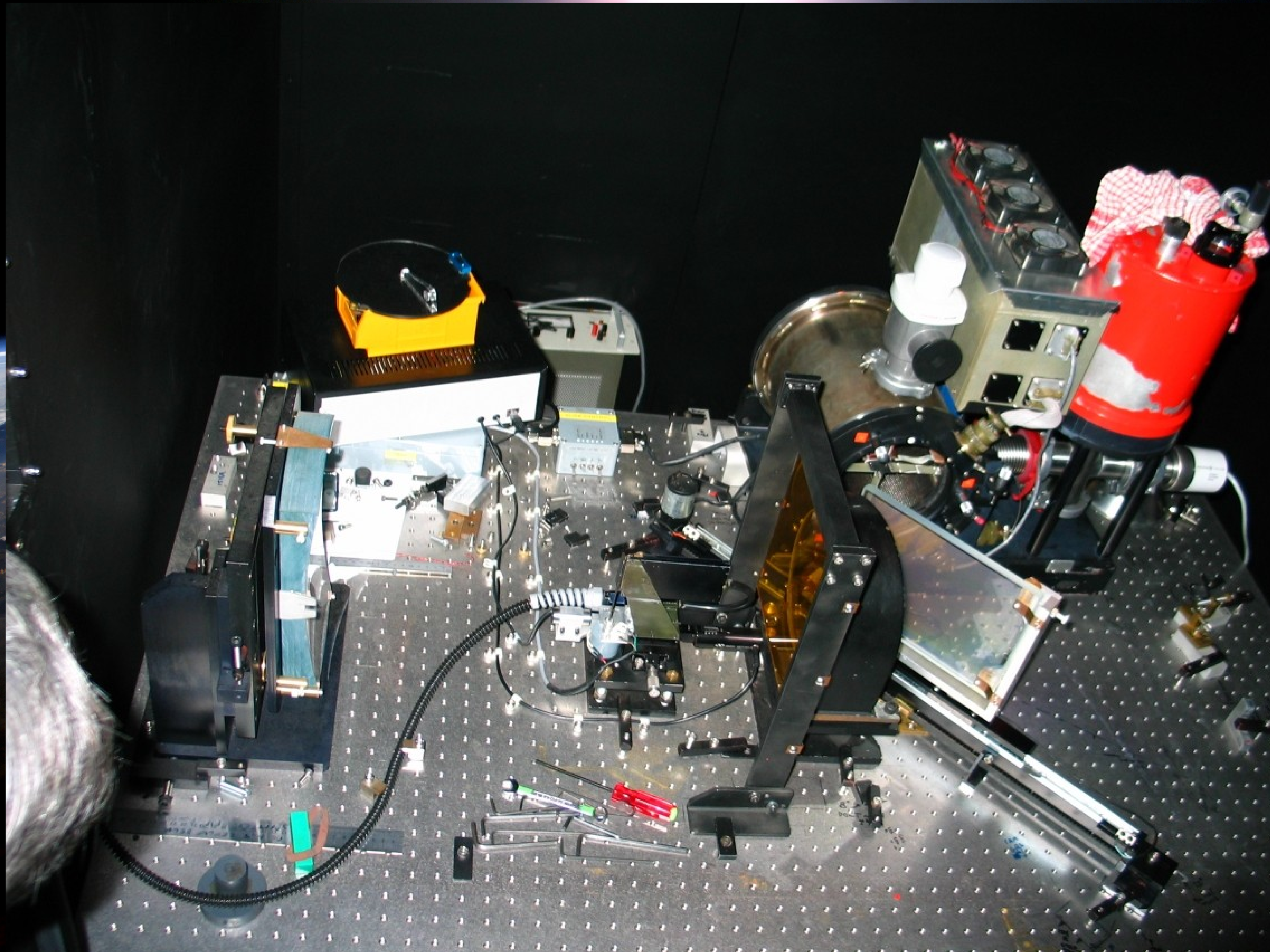
$$SGN(\alpha) = SGN(\beta) \;\; IF \;\; \text{(on same side of normal)}$$

$$\sin(\alpha - \gamma/2) = \frac{km\lambda_o}{2\cos(\gamma/2)}$$

Boller & Chivensov spektrograf

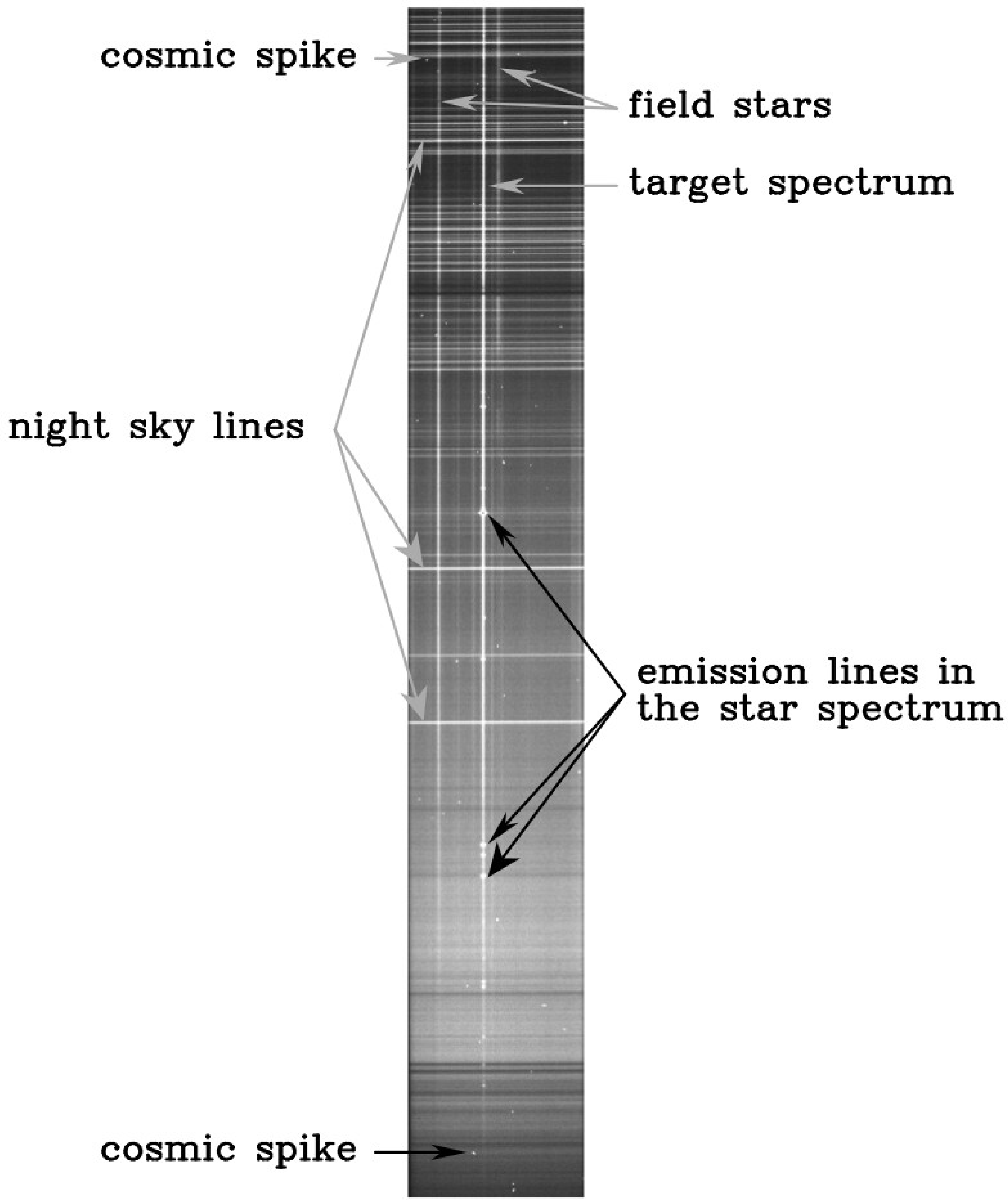




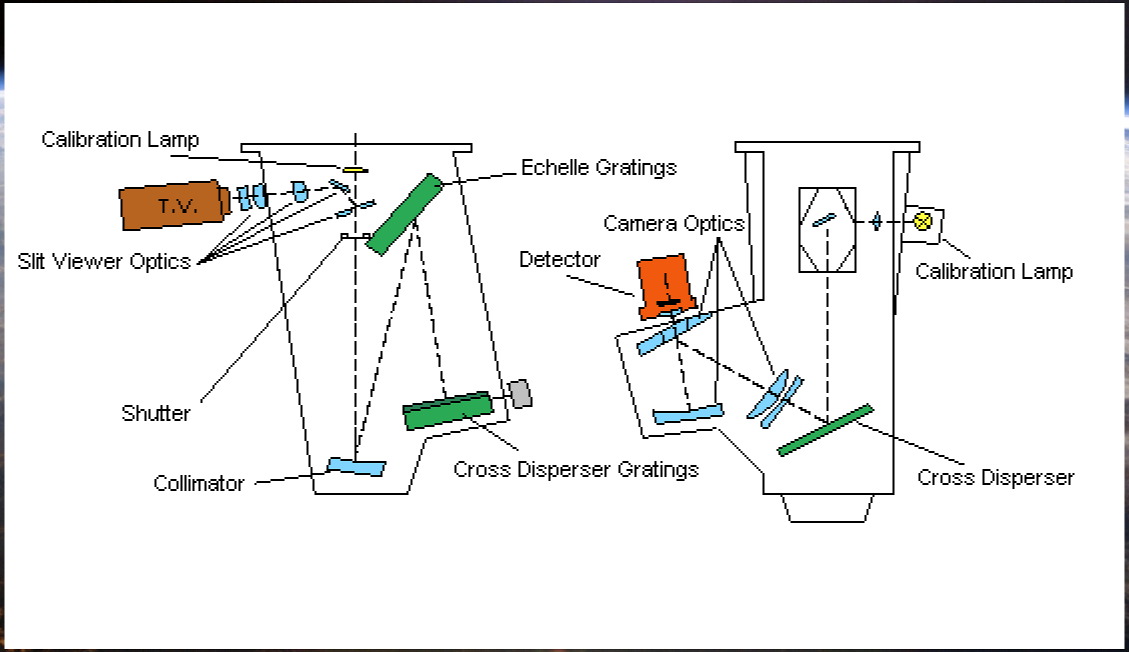


Spektrograf tipa Boller&Chivens

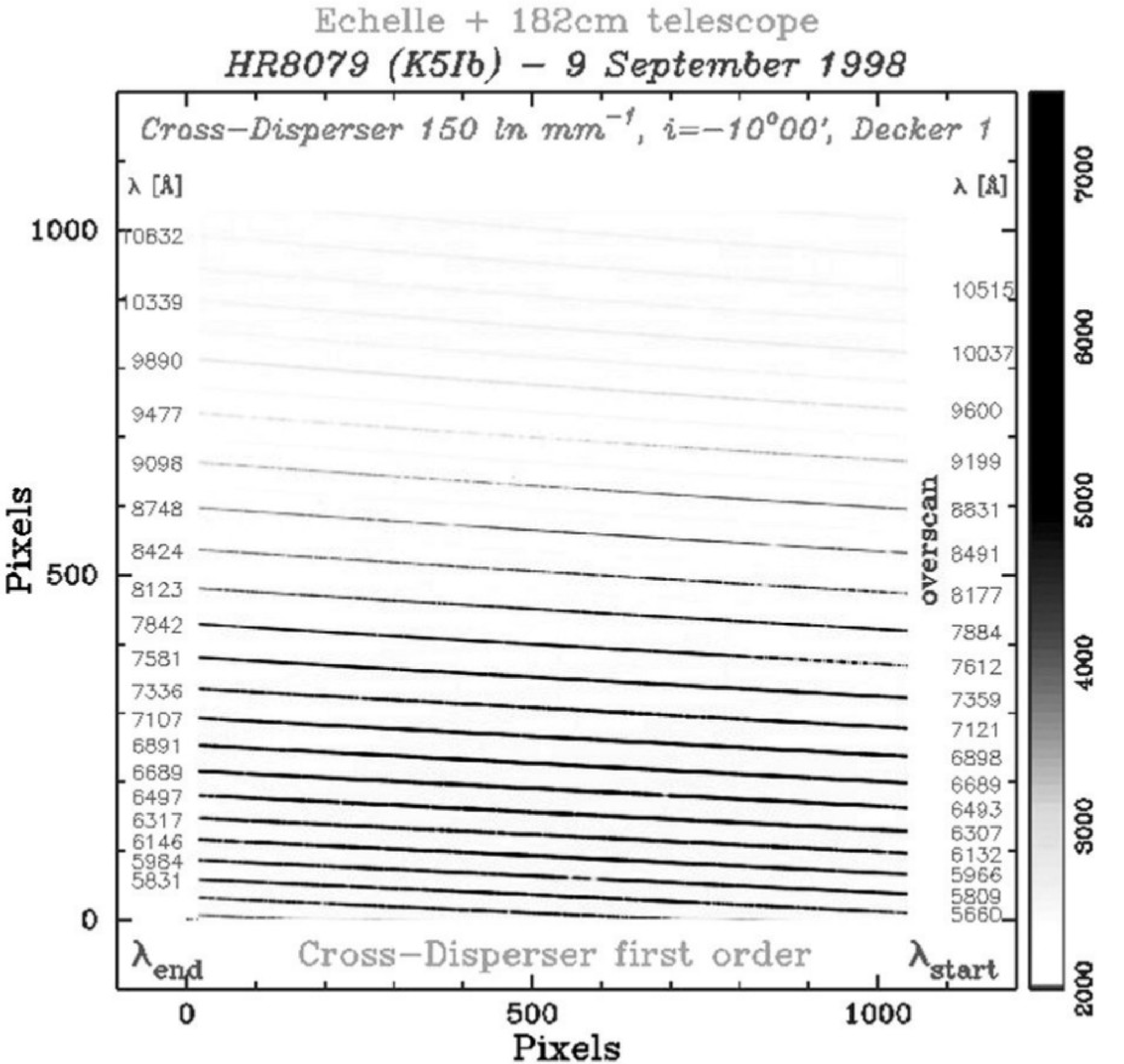
Figure 1: *One of the symbiotic star spectra included in the set of demo images (this is image* **a0012** *of Table 1). Principal features are identified (WIP graphics courtesy T.Tomov).*



Spektrograf tipa echelle



Spektrograf tipa echelle



Približevanje/oddaljevanje zvezde: spektroskopija

Spektrograf HARPS na 3.6-m teleskopu Evropskega južnega observatorija na La Silli.

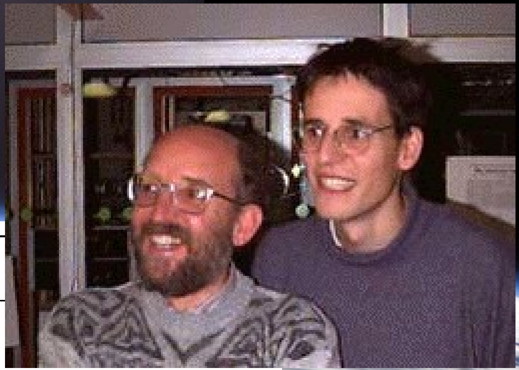
Spektrograf HARPS na ESOvem 3,6-m teleskopu na La Silli

- echellov spektrograf hranjen z optičnimi vlakni
- valovne dolžine 378-691 nm
- 72 redov x 4000 točk/sled = 288000 točk
- λ / d λ = 115.000, vsaka točka po ~1,3 km/s
- V 10 minutah S/N=110 na točko za zvezdo z Mv = 8,5 in tipom G2V.
- Dosegljiva točnost radialne hitrosti: 0,9 m/s.

Najtočnejši spektrograf na svetu.

Zemlji podoben planet

Mayor & Queloz



Astronomy & Astrophysics manuscript no.
(DOI: will be inserted by hand later)

The HARPS search for southern extra-solar planets★

XI. Super-Earths (5 & 8 $M_\oplus$) in a 3-planet system

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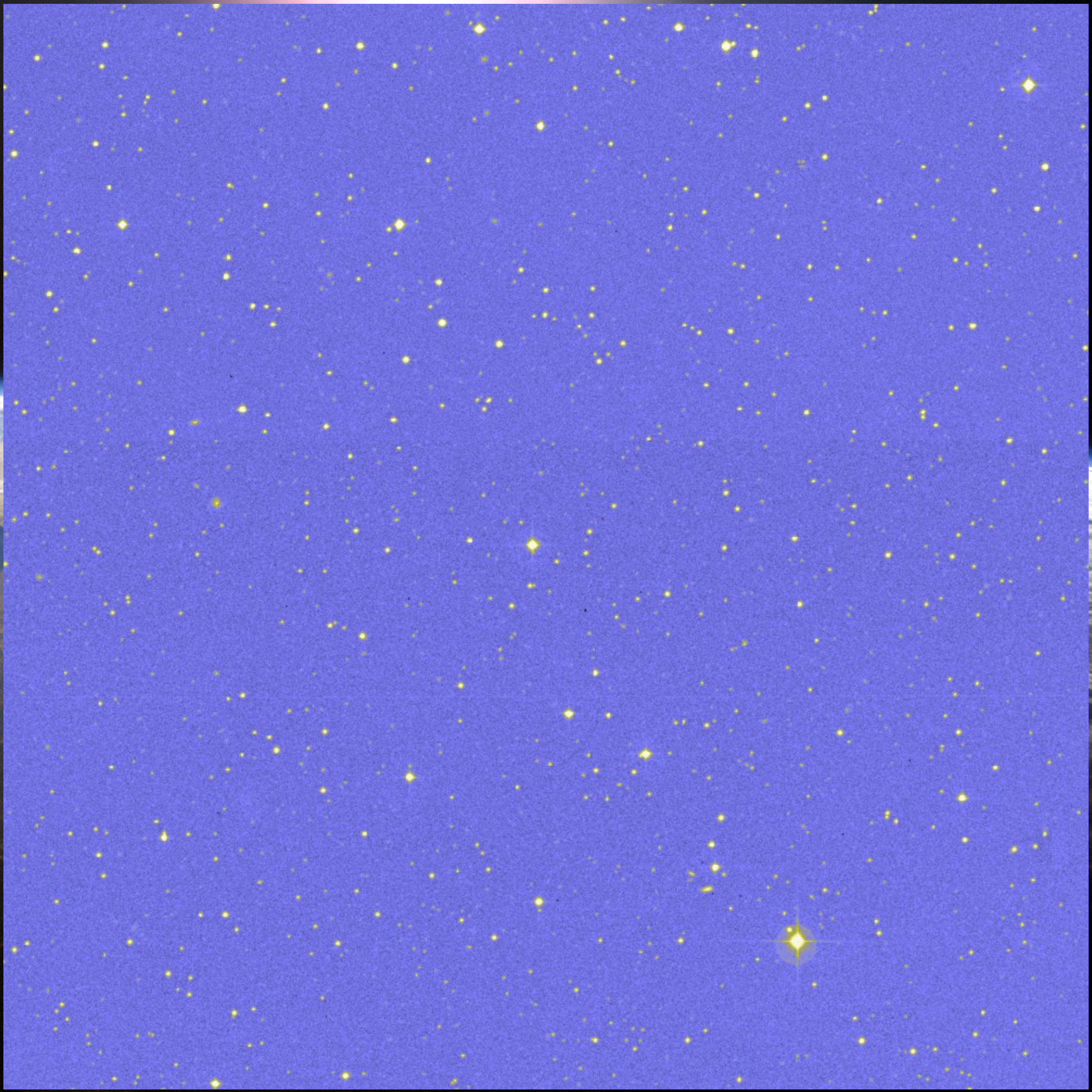
Abstract. This Letter reports on the detection of two super-Earth planets in the Gl 581 system, already known to harbour a hot Neptune. One of the planets has a mass of 5 $M_\oplus$ and resides at the "warm" edge of the habitable zone of the star. It is thus the known exoplanet which most resembles our own Earth. The other planet has a 7.7 $M_\oplus$ mass and orbits at 0.25 AU from the star, close to the "cold" edge of the habitable zone. These two new light planets around an M3 dwarf further confirm the formerly tentative statistical trend for i) many more very low-mass planets being found around M dwarfs than around solar-type stars and ii) low-mass planets outnumbering Jovian planets around M dwarfs.

Key words. stars: individual: Gl 581, stars: planetary systems – techniques: radial velocities – techniques: spectroscopy

Zvezda HO Tehtnice = Gliese 581



Zvezda HO Tehtnice

- hitrost glede na Sonce: 38 km/s (zvezda debelega diska)
- starost vsaj 2 milijardi let (majhna kromosferska aktivnost)
- v atmosferi 2-krat manjši delež kovin kot v Soncu
- masa 0,3 mase Sonca, podobno polmer
- rdeča pritlikava zvezda (površinska temperatura 3600 K)
- izsev 80-krat manjši od Sončevega

Zvezda HO Tehnice

50 opazovanj, točnost 0,9 m/s

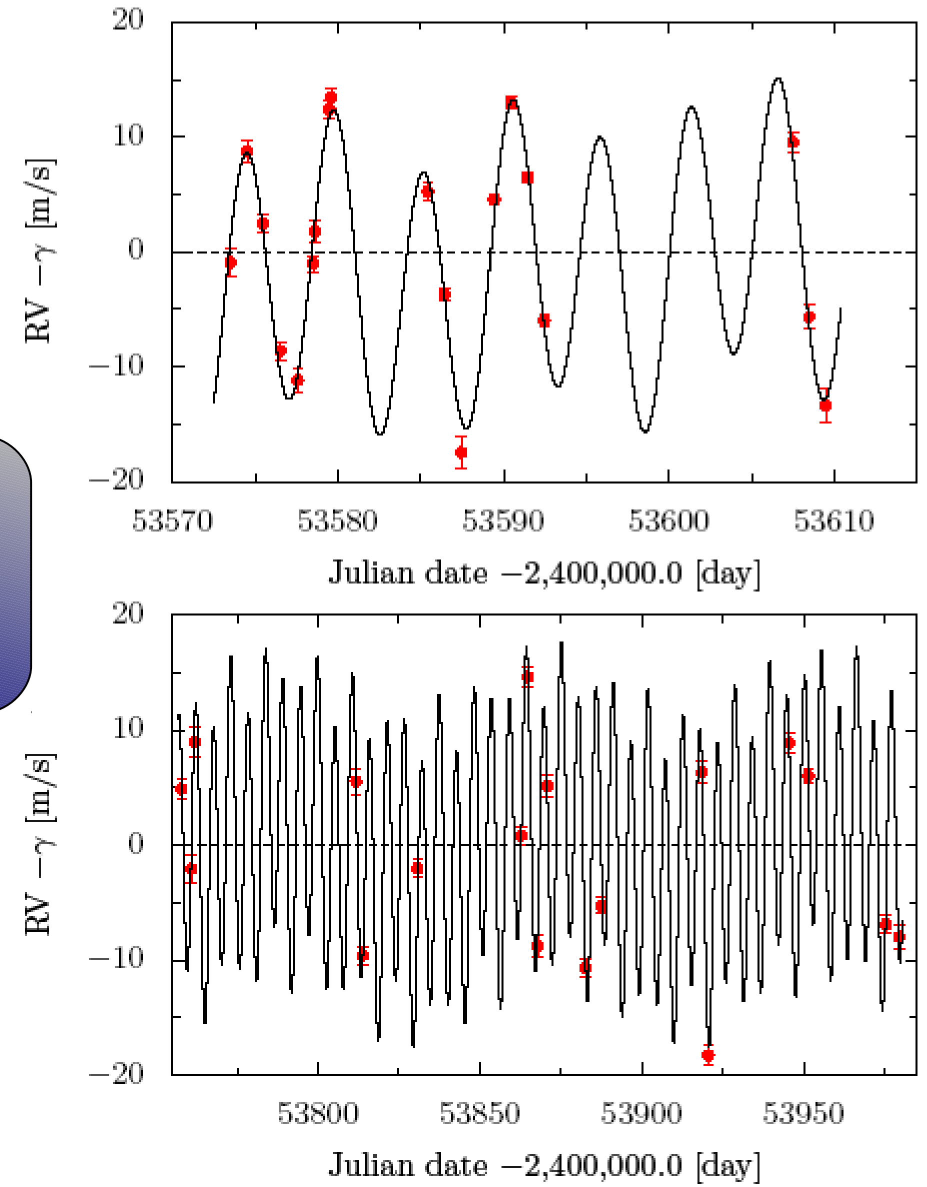


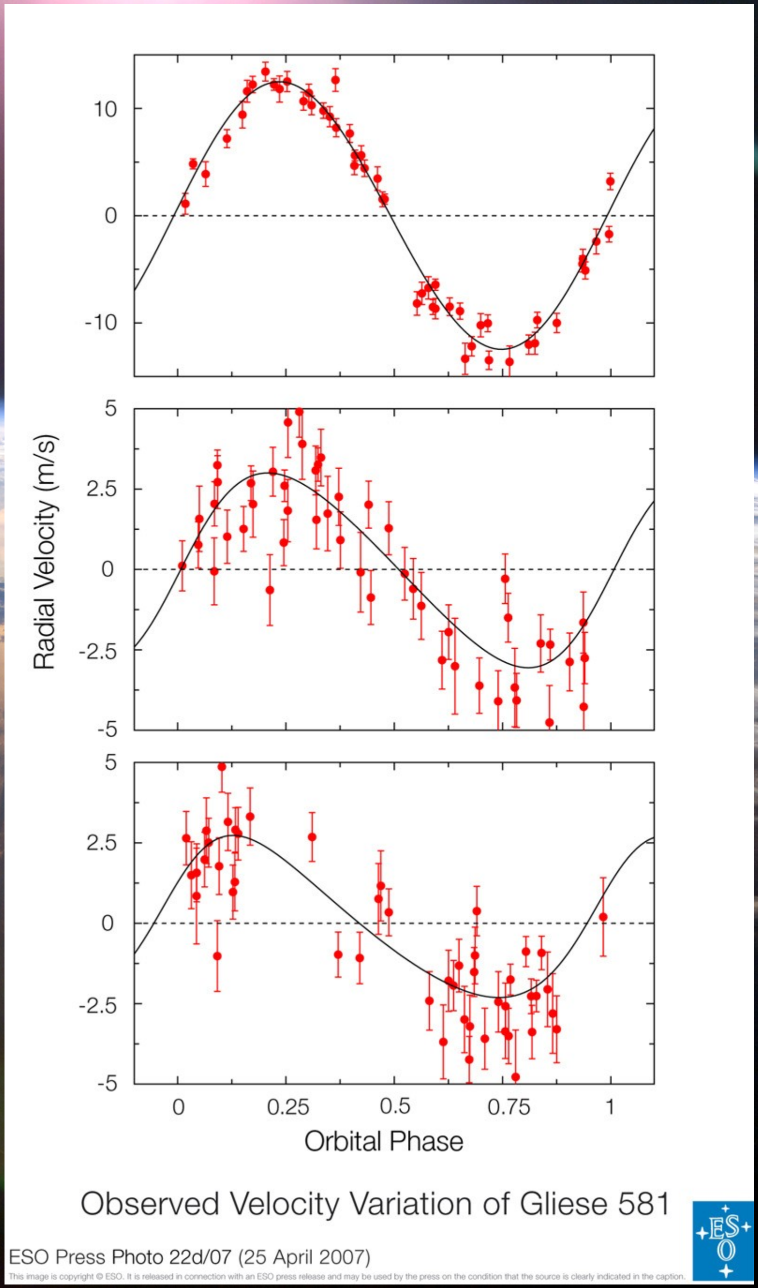
Fig. 4. Temporal display of the 3-planet Keplerian model of Gl 581, on time intervals with dense observational sampling.

Zvezda HO Tehtnice

prvi planet

drugi planet

tretji planet



Zvezda HO Tehtnice

Table 1. Orbital and physical parameters derived from 3-planet Keplerian models of Gl 581 for the free-eccentricity and circular cases. Uncertainties are directly derived from the covariance matrix.

Parameter		Circular case			Free eccentricity case		
		Gl 581 b	**Gl 581 c**	**Gl 581 d**	**Gl 581 b**	**Gl 581 c**	**Gl 581 d**
P	[days]	5.3687±0.0003	12.931±0.007	83.4±0.4	5.3683±0.0003	12.932±0.007	83.6±0.7
T	[JD-2400000]	52999.99±0.05	52996.74±0.45	52954.1±3.7	52998.76±0.62	52993.38±0.96	52936.9±9.2
e		0.0 (fixed)	0.0 (fixed)	0.0 (fixed)	0.02±0.01	0.16±0.07	0.20±0.10
V	[km s^{-1}]		-9.2115 ± 0.0001			-9.2116 ± 0.0002	
ω	[deg]	0.0 (fixed)	0.0 (fixed)	0.0 (fixed)	273±42	267±24	295±28
K	[m s^{-1}]	12.42 ± 0.19	3.01±0.16	2.67±0.16	12.48 ± 0.21	3.03±0.17	2.52±0.17
$a_1 \sin i$	[10^{-6} AU]	6.129	3.575	20.47	6.156	3.557	18.98
$f(m)$	[$10^{-13} M_{\odot}$]	10.66	0.365	1.644	10.80	0.359	1.305
$m_2 \sin i$	[$M_{\rm Jup}$]	0.0490	0.0159	0.0263	0.0492	0.0158	0.0243
$m_2 \sin i$	[$M_{\oplus}$]	15.6	5.06	8.3	15.7	5.03	7.7
a	[AU]	0.041	0.073	0.25	0.041	0.073	0.25
$N_{\rm meas}$			50			50	
Span	[days]		1050			1050	
σ (O-C)	[ms^{-1}]		1.28			1.23	
$\chi^2_{\rm red}$			3.17			3.45	

Sedaj odkrili še četrti planet.

Zvezda HO Tehtnice

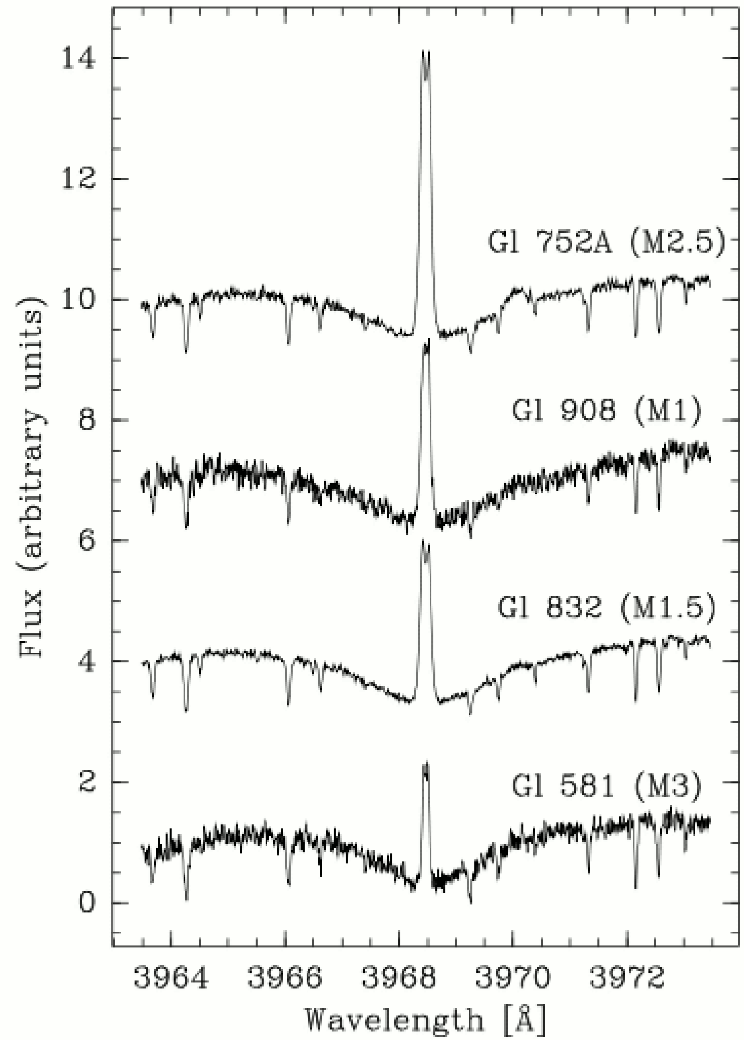


Fig. 1. HARPS spectra of the Ca II H (λ = 3968.47 Å) line region for Gl 581 and three comparison stars with similar spectral type and apparent magnitude. The stars are displayed in order of ascending chromospheric activity, and from top to bottom are Gl 752A, Gl 908, Gl 832 and Gl 581. The chromospheric emission peaks look prominent against the weak blue continuum of these M dwarfs, but they actually denote very weak chromospheric emission relative to the bolometric luminosity. Amongst those 4 stars, Gl 581 has the weakest chromospheric activity.

Zemlji podoben planet

- obhodna doba 12,9 dneva
- masa $\geq$ 5 Zemljinih mas
- polmer ~1,5 Zemljinih polmerov
- površinska temperatura 0 – 40 stopinj Celzija

Velikosti Zemlji podobnih planetov

Internal Structure of Massive Terrestrial Planets

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ABSTRACT

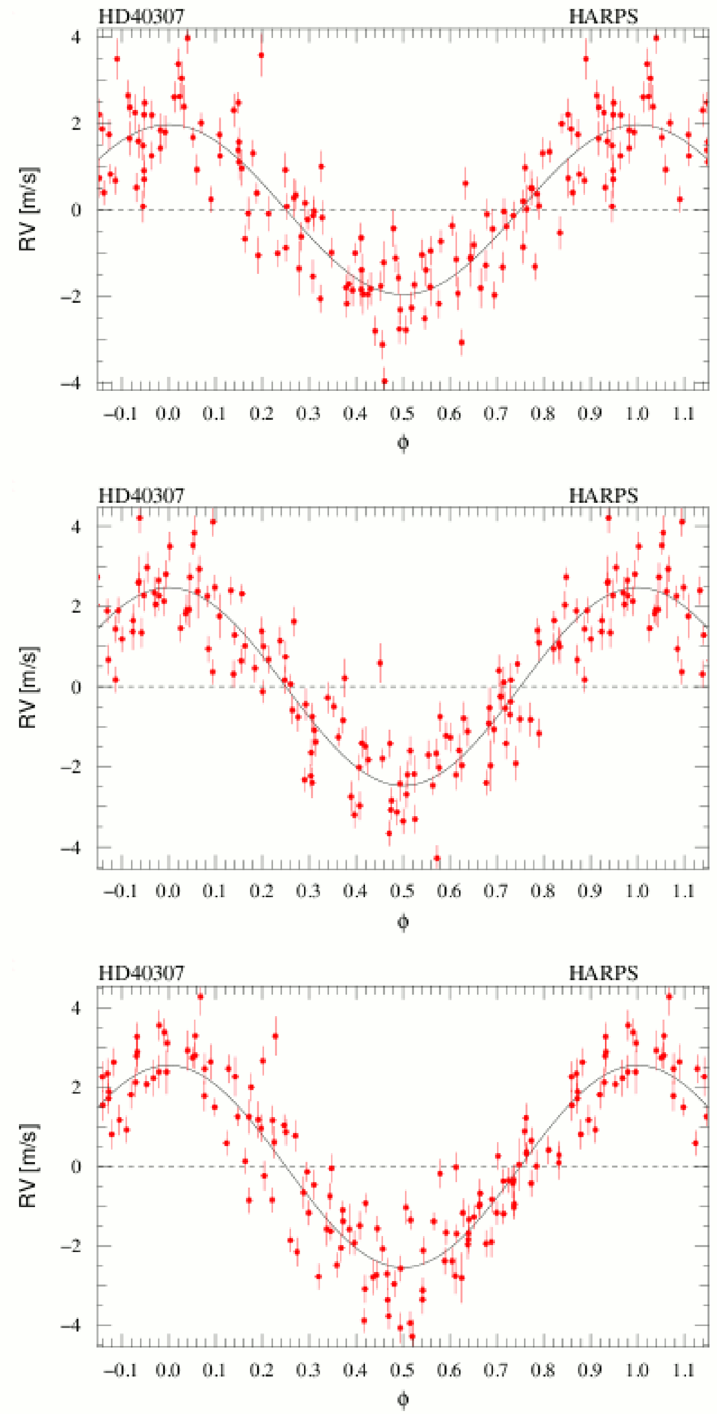
Planetary formation models predict the existence of massive terrestrial planets and experiments are now being designed that should succeed in discovering them and measuring their masses and radii. We calculate internal structures of planets with one to ten times the mass of the Earth (Super-Earths) in order to obtain scaling laws for total radius, mantle thickness, core size and average density as a function of mass. We explore different compositions and obtain a scaling law of $R \propto M^{0.267-0.272}$ for Super-Earths. We also study a second family of planets, Super-Mercuries with masses ranging from one mercury-mass to ten mercury-masses with similar composition to the Earth's but larger core mass fraction. We explore the effect of surface temperature and core mass fraction on the scaling laws for these planets. The scaling law obtained for the Super-Mercuries is $R \propto M^{\sim 0.3}$.

Več Zemlji podobnih planetov

Mayor idr. 2008

Zvezda HD40307 ima tri:

- mase
  4,2, 6,9 in 9,2 M_{Zemlje}
- obhodne dobe
  4,3, 9,6 in 20,5 dneva
- površinske temperature
  540, 340, 210 °C



All Catalogs

update : **16 May 2012**

All Candidates detected	**770 planets**
Candidates detected by radial velocity or astrometry *update : 16 May 2012*	561 planetary systems 707 planets 97 multiple planet systems
Transiting planets *update : 16 May 2012*	198 planetary systems 234 planets 31 multiple planet systems
Candidates detected by microlensing *update : 22 March 2012*	14 planetary systems 15 planets 1 multiple planet systems
Candidates detected by imaging *update : 05 April 2012*	27 planetary systems 31 planets 2 multiple planet systems
Candidates detected by timing *update : 12 May 2012*	12 planetary systems 17 planets 4 multiple planet systems

Candidates detected by timing update : 12 May 2012

<< Back to the Index Catalog | **Data Catalog** | Histograms | Correlation Diagrams | Planet Table

(sorted by **increasing period of the closest planet**) **Statistics :** 12 planetary systems / 17 planets / 4 multiple planet systems

Planet Data (- ALL FORMATS) MORE DATA >>

PLANET	M[.sin*I*] (M_{Jup}) - stats	RADIUS (R_{Jup}) - stats	PERIOD (days) - stats	SEM-MAJ AXIS (AU) - stats	ECC.	INCL. (deg) - stats	STATUS	DISCOV. (year)	UPDATE
PSR 1719-14 b	~ 1	~ 0.4	0.090706293	0.0004	< 0.06	-	R	2011	31/08/11
PSR 1257 12 b	7e-05	-	25.262	0.19	0	-	R	1992	22/12/10
c	0.013	-	66.5419	0.36	0.0186	53	R	1992	22/12/10
d	0.012	-	98.2114	0.46	0.0252	47	R	1992	22/12/10
KOI-872 c	0.376	-	57.004	0.2799	0.0145	87.25	R	2012	12/05/12
V391 Peg b	3.2	-	1170	1.7	0	-	R	2007	14/09/07
UZ For(ab) d	7.7	-	1900	2.8	0.05	-	R	2011	08/06/11
HU Aqr(AB) b	5.4	-	2359	3.45	0.075	-	R	2009	02/12/11
c	5.9	-	5646	6.18	0.29	-	R	2011	02/12/11
NN Ser (ab) d	2.28	-	2830	3.39	0.2	-	R	2009	13/10/10
c	6.91	-	5660	5.38	0	-	R	2010	13/10/10
NY Vir b	2.3	-	2900	3.3	-	-	R	2011	20/12/11
HW Vir c	8.5	-	3321	3.62	-	-	R	2008	16/09/10
b	19.2	-	5767	5.3	-	-	R	2008	16/09/10
RR Cae b	4.2	-	4350	5.3	0	-	R	2012	23/01/12
DP Leo b	6.05	-	10230	8.19	0.39	-	R	2009	18/11/10
PSR B1620-26 b	2.5	-	~ 36525	~ 23	-	-	R	1994	23/12/10

- **Basic data :**

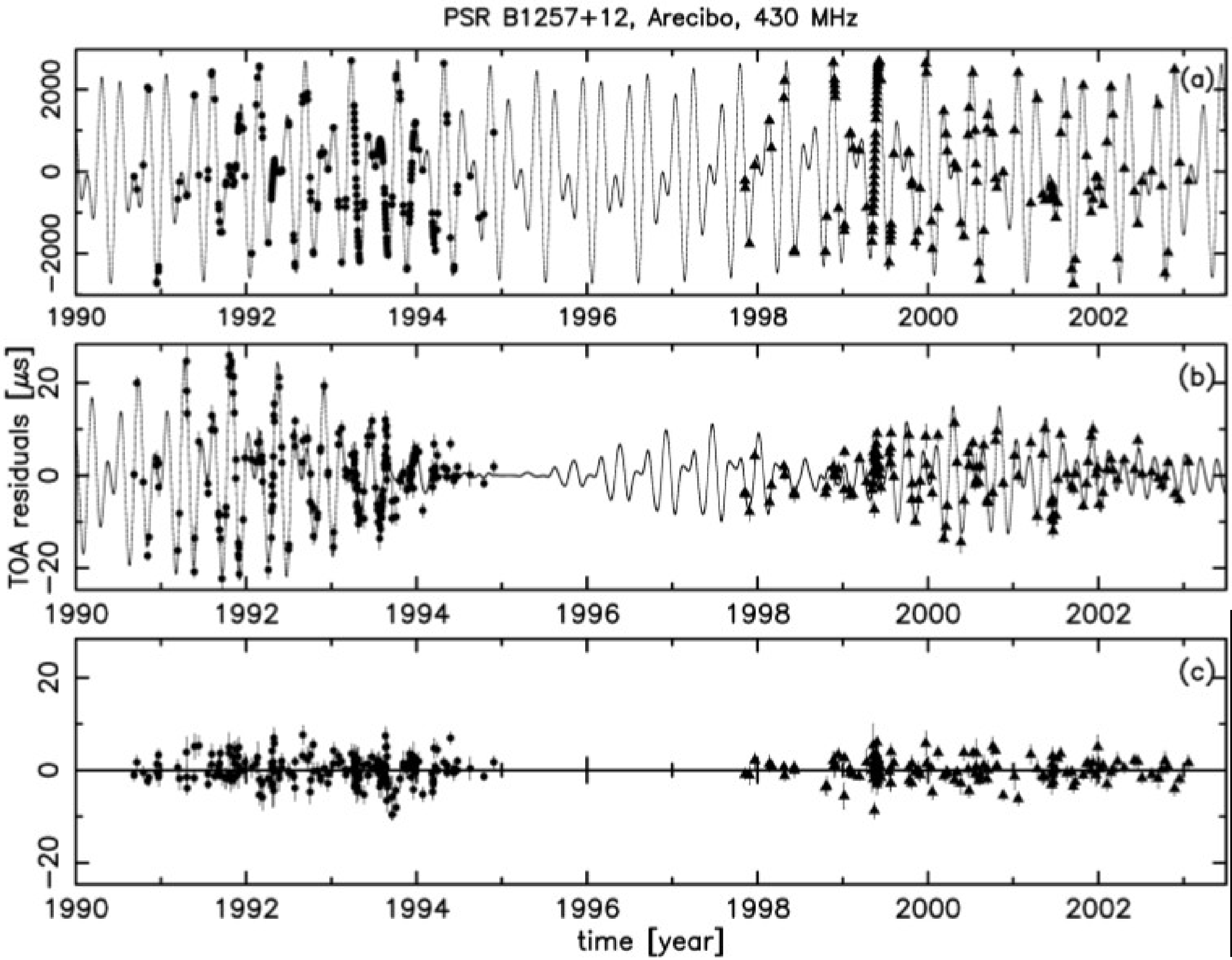
Name	PSR 1257 12
Distance	~ 500 *pc*
Age	~ 1 *Gyr*
Right Asc. Coord.	13 00 04
Decl. Coord.	+12 40 56

- **More data :**
  - Basic data (from Simbad)
  - Most recent ref (from ADS)

3 PLANETS

- **Basic data :**

Name	PSR 1257 12 b		PSR 1257 12 c		PSR 1257 12 d	
Discovered in	1992		1992		1992	
Mass	7e-05 M_J	ref.	0.013 M_J	ref.	0.012 (± 0.0006) M_J	ref.
Semi major axis	0.19 *AU*	ref.	0.36 *AU*	ref.	0.46 *AU*	ref.
Orbital period	25.262 (± 0.003) *days*	ref.	66.5419 (± 0.0001) *days*	ref.	98.2114 (± 0.0002) *days*	ref.
Eccentricity	0	ref.	0.0186 (± 0.0002)	ref.	0.0252 (± 0.0002)	ref.
ω	0 *deg.*	ref.	250.4 (± 6) *deg.*	ref.	108.3 (± 5) *deg.*	ref.
$T_{max\ VR}$	49765.1 (± 0.2) *HJD 2.400.000*	ref.	49768.1 (± 0.1) *HJD 2.400.000*	ref.	49766.5 (± 0.1) *HJD 2.400.000*	ref.
Inclination	-		53 (± 4) *deg.*	ref.	47 (± 3) *deg.*	ref.
Update	22/12/10		22/12/10		22/12/10	



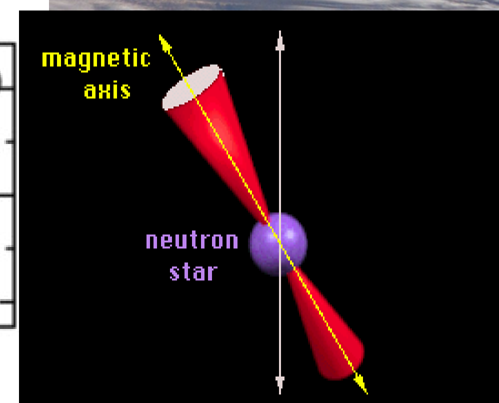


Figure 1. The best-fit, daily-averaged TOA residuals for three timing models of PSR B1257+12 observed at 430 MHz. The solid line marks the predicted TOA variations for each timing model. *(a)* TOA residuals after the fit of the standard timing model without planets. TOA variations are dominated by the Keplerian orbital effects from planets B and C. *(b)* TOA residuals for the model including the Keplerian orbits of planets A, B and C. Residual variations are determined by perturbations between planets B and C. *(c)* Residuals for the model including all the standard pulsar parameters and the Keplerian and non-Keplerian orbital effects.

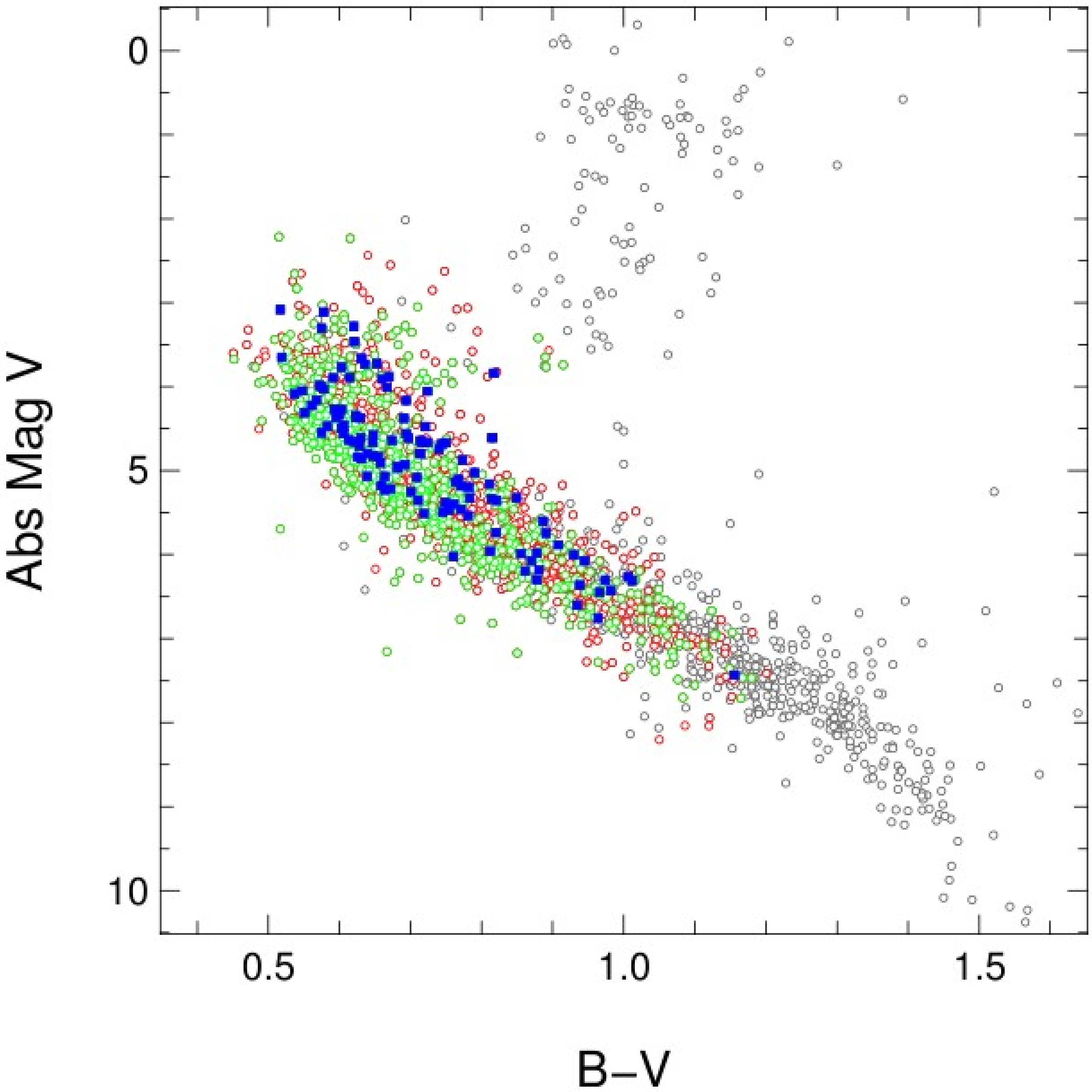


Fig. 1. HR-diagram of Hipparcos 2008 catalogue (black) , CORALIE volume limited sample (red), HARPS sample of low activity stars (green) and stars with planetary systems (blue)

HARPS: zadnji rezultati

Mayor idr. 2011

HARPS: zadnji rezultati

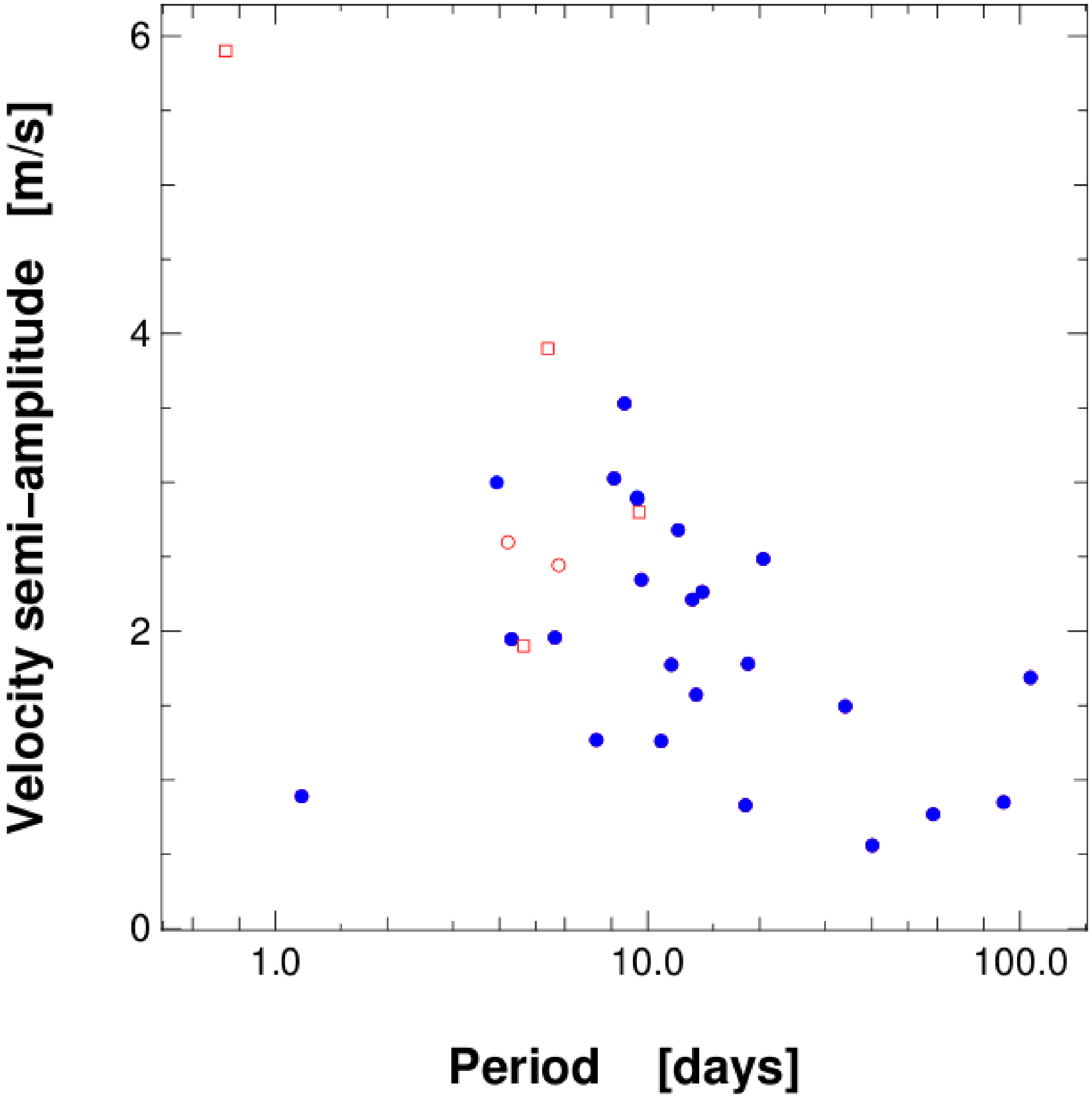


Fig. 2. Radial-velocity semi-amplitude K as a function of orbital period for super-Earths ($M < 10\,M_{\oplus}$) hosted by solar-type stars. HARPS detection are plotted as blue dots and objects from the literature in red symbols (circles for the southern sky and square for the northern sky).

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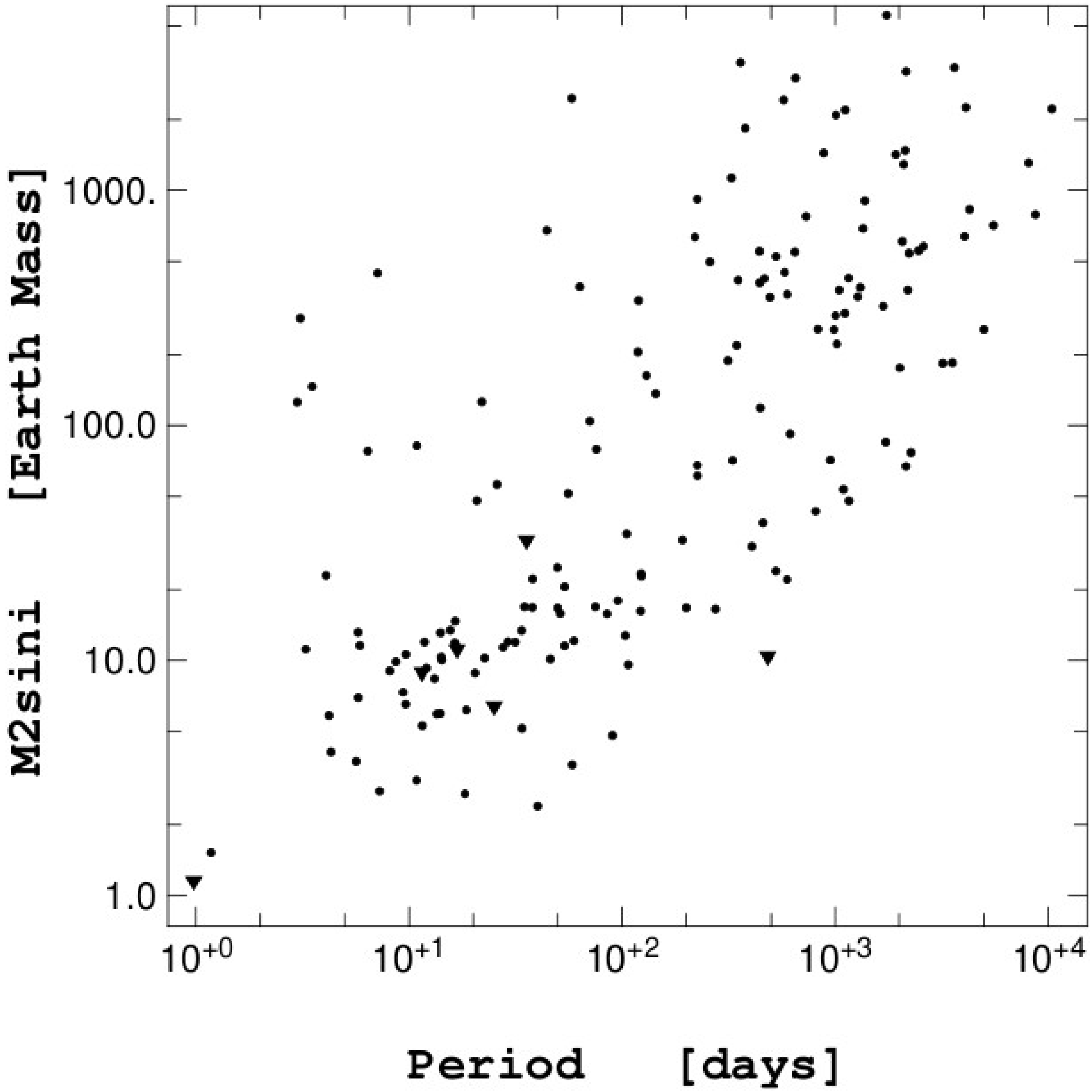


Fig. 5. Plot of the 155 planets (dots) and 6 candidates (triangles) of the considered HARPS+CORALIE sample in the $m_2 \sin i - \log P$ plane .

HARPS: zadnji rezultati

Mayor idr. 2011

HARPS: zadnji rezultati

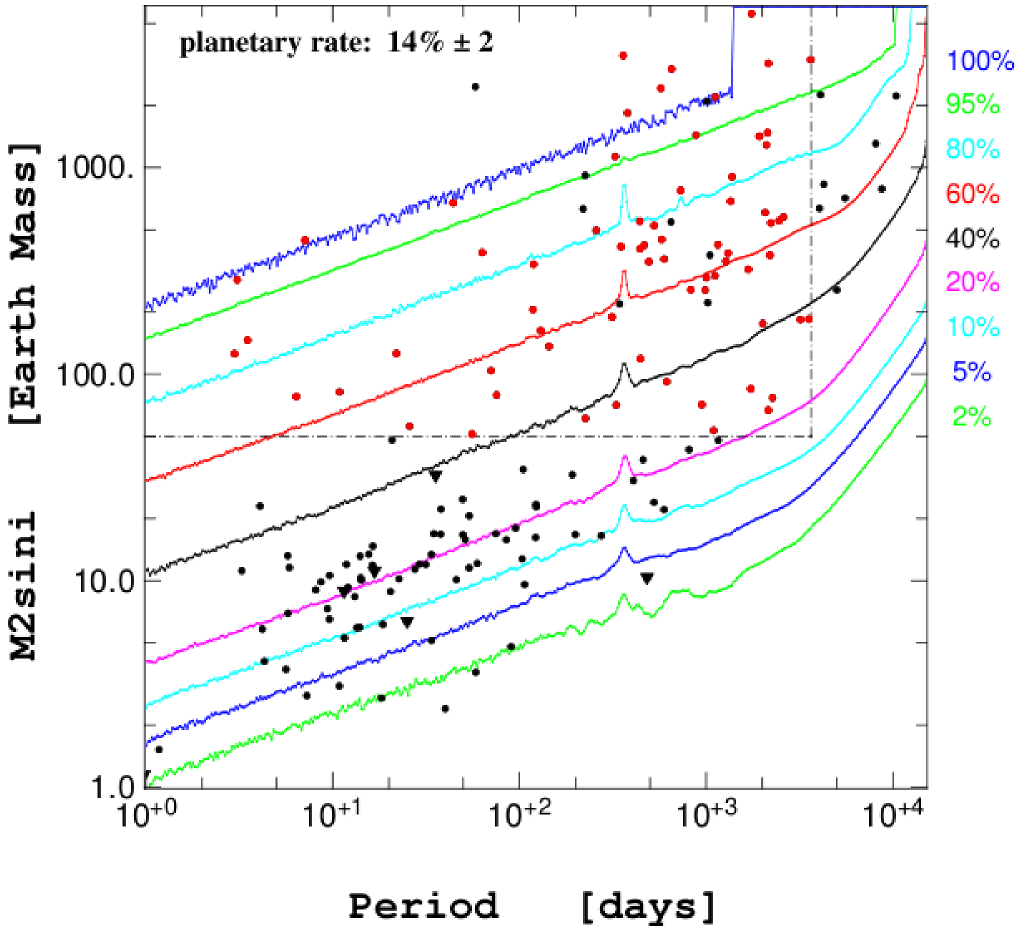
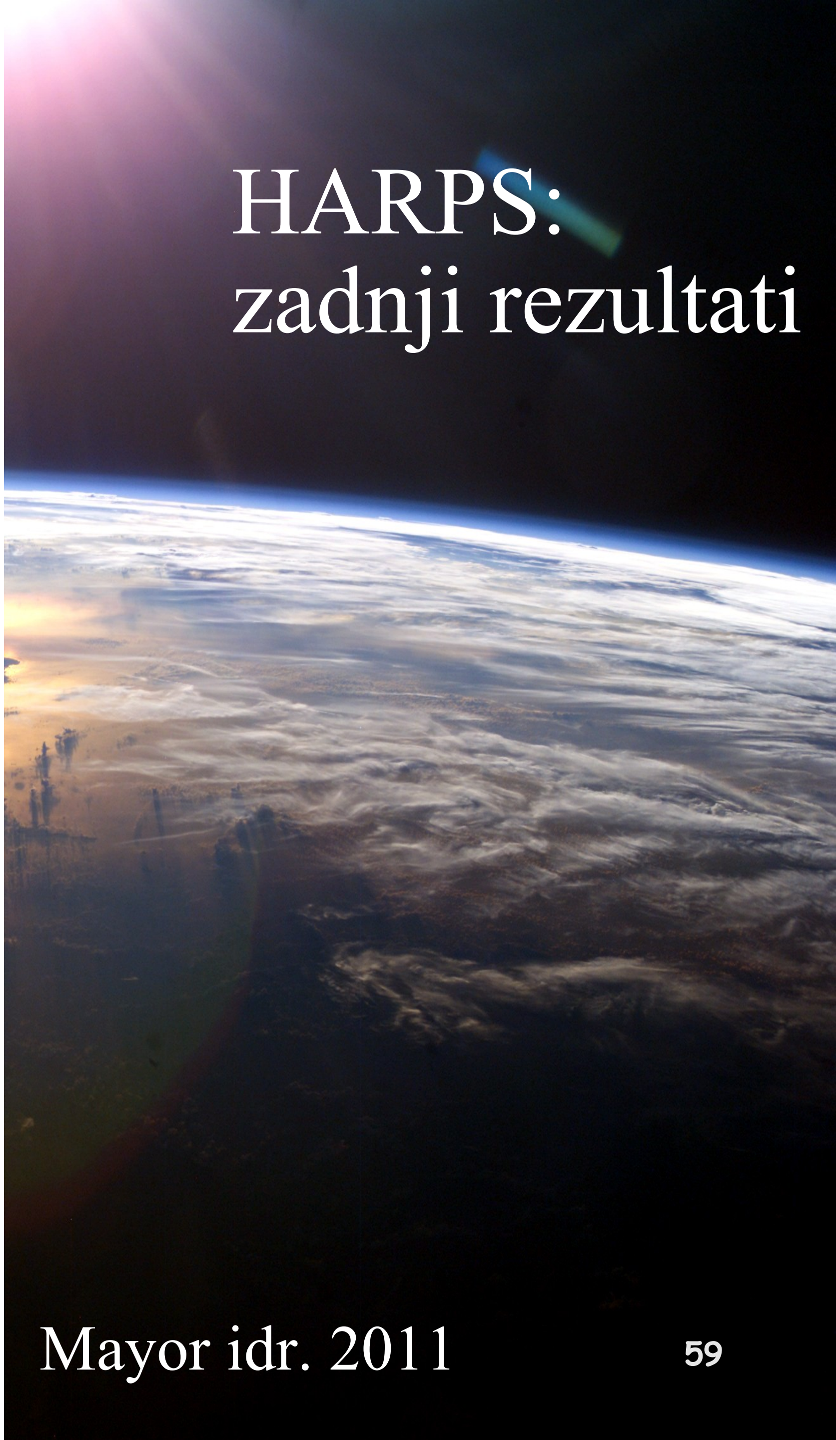


Fig. 6. Same as Fig. 5 with detection probability curves superimposed. These detection probabilities are valid for the whole sample of 822 stars. After correcting for the detection bias, the fraction of stars with at least one planet more massive than 50 $M_\oplus$ and with a period smaller than 10 years is estimated to be 14 ± 2 %. The red points represent the planets which have been used to compute the corrected occurrence rate in the box indicated by the dashed line. The planets lying outside the box or being part of a system already taken into account are excluded; they are shown in black.



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HARPS: zadnji rezultati

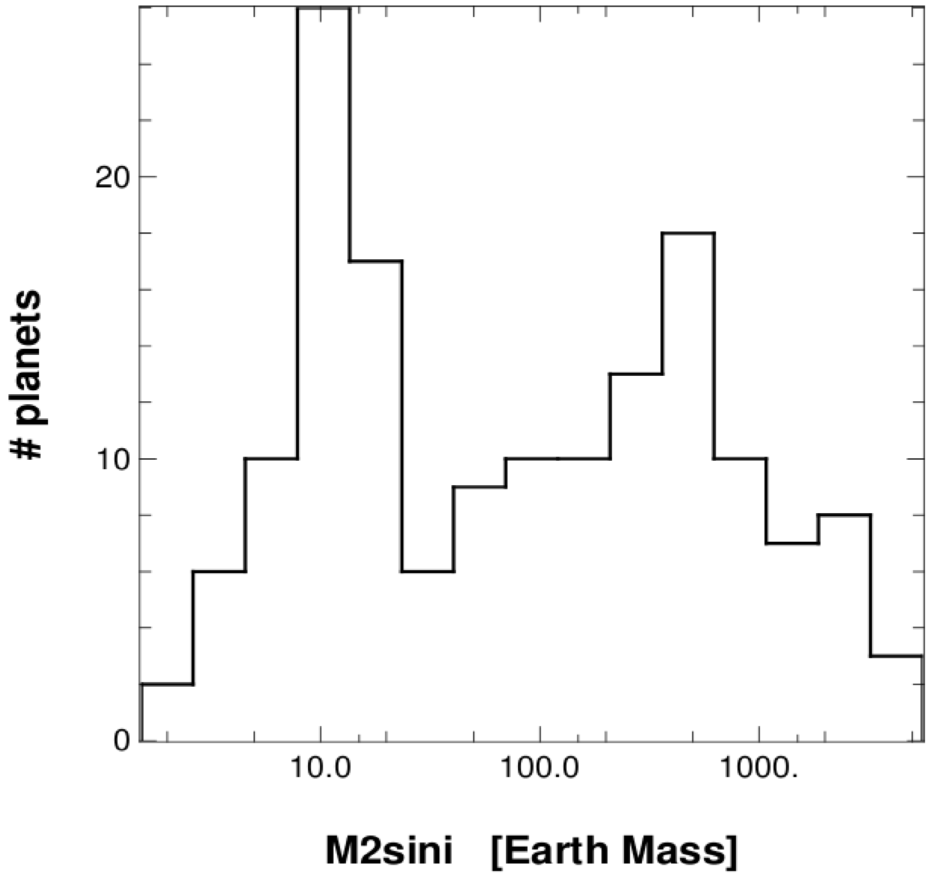

Fig. 10. Observed mass histogram for the planets in the combined sample. Before any bias correction, we can already notice the importance of the sub-population of low-mass planets. We also remark a gap in the histogram between planets with masses above and below ~30 $M_{\oplus}$.

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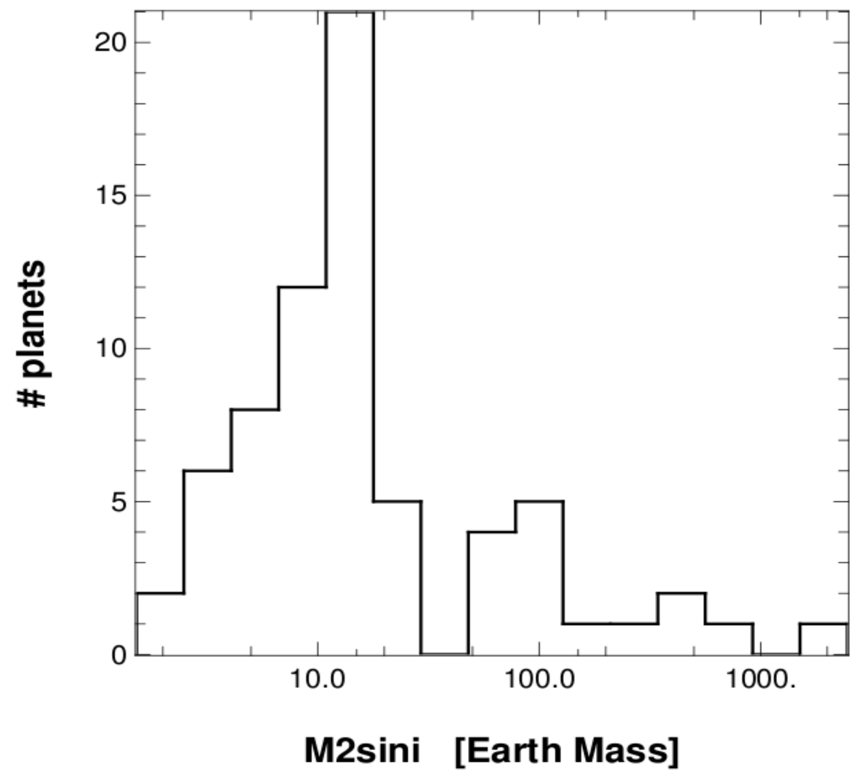

Fig. 11. Same as Fig. 10 but for planets with periods smaller than 100 days. We see the dominance of low-mass planet with short orbital periods.

HARPS: zadnji rezultati

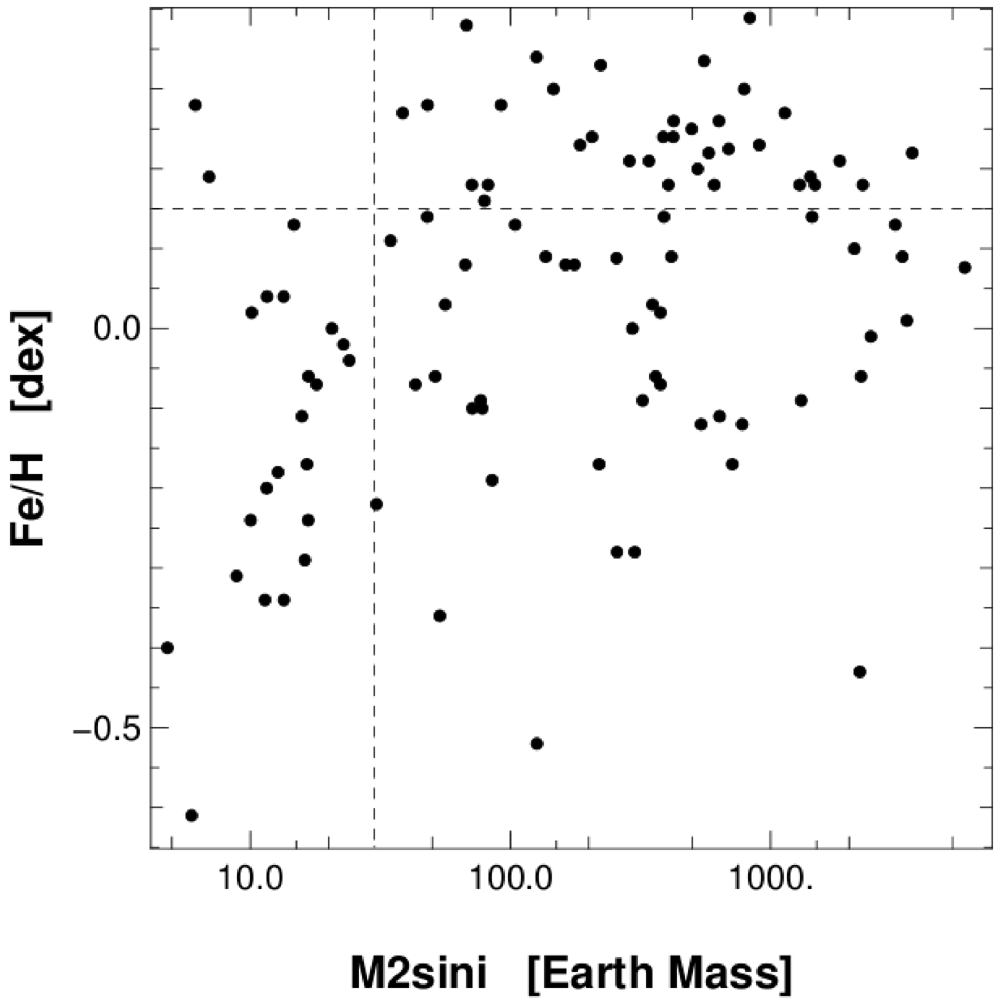

Fig. 17. Estimation of the planetary-mass limit between the two regimes for the metallicity dependance of host stars. A vertical line at 30 $M_\oplus$ distinguishes the two populations. We should note that such a limit also corresponds to the gap in the mass distribution (see Fig. 10 and 12). On the right side of the vertical line we do not observe significant changes of the metallicity distribution above 30 M⊕. We remark that stars with metallicity exceeding 0.15 are for their huge majority associated with planets more massive than 30 $M_\oplus$.

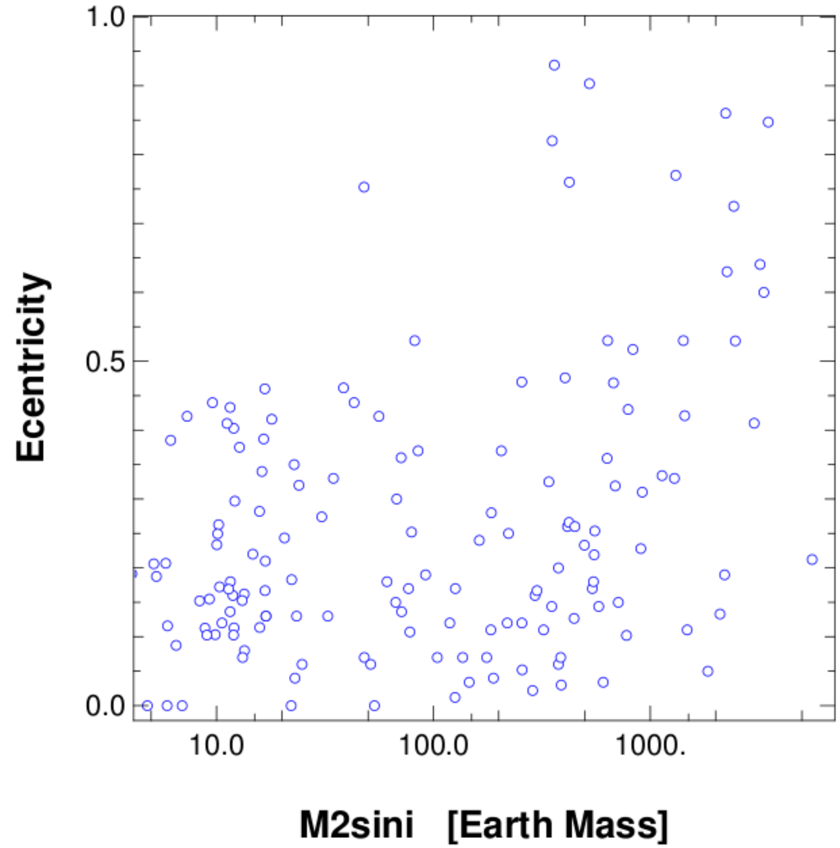

Fig. 15. Mass-eccentricity diagram for the planets in the combined sample.

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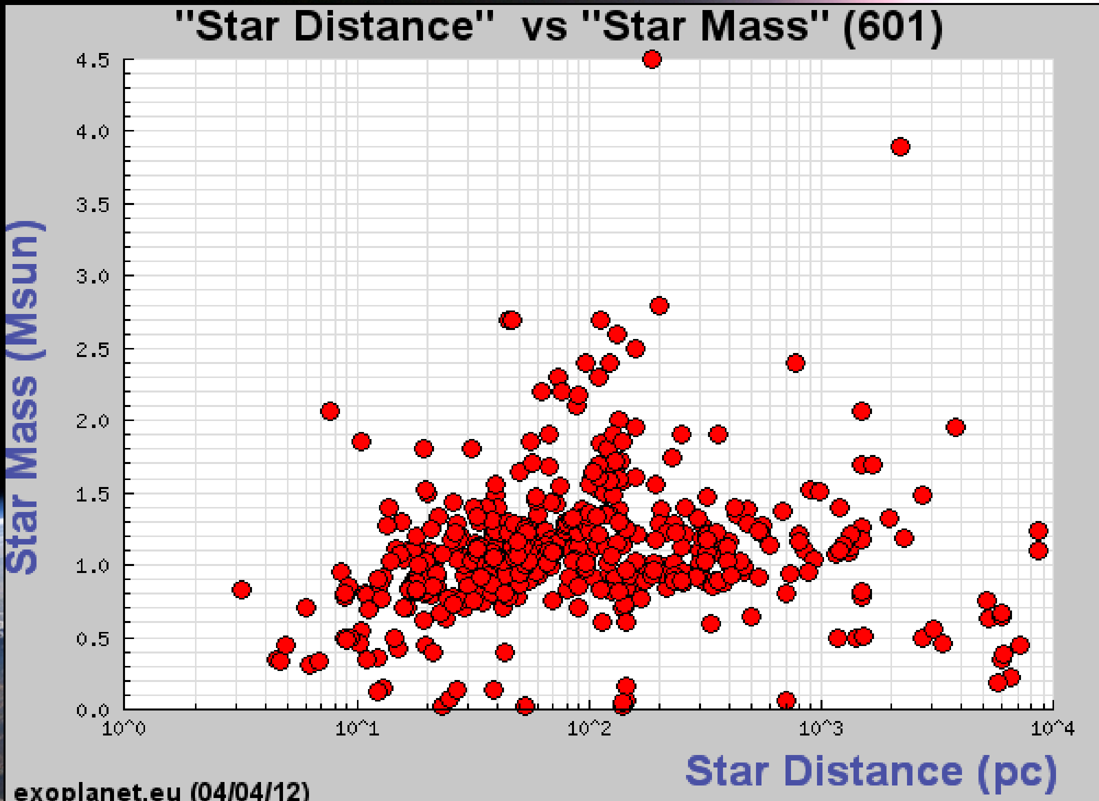


HARPS: zadnji rezultati

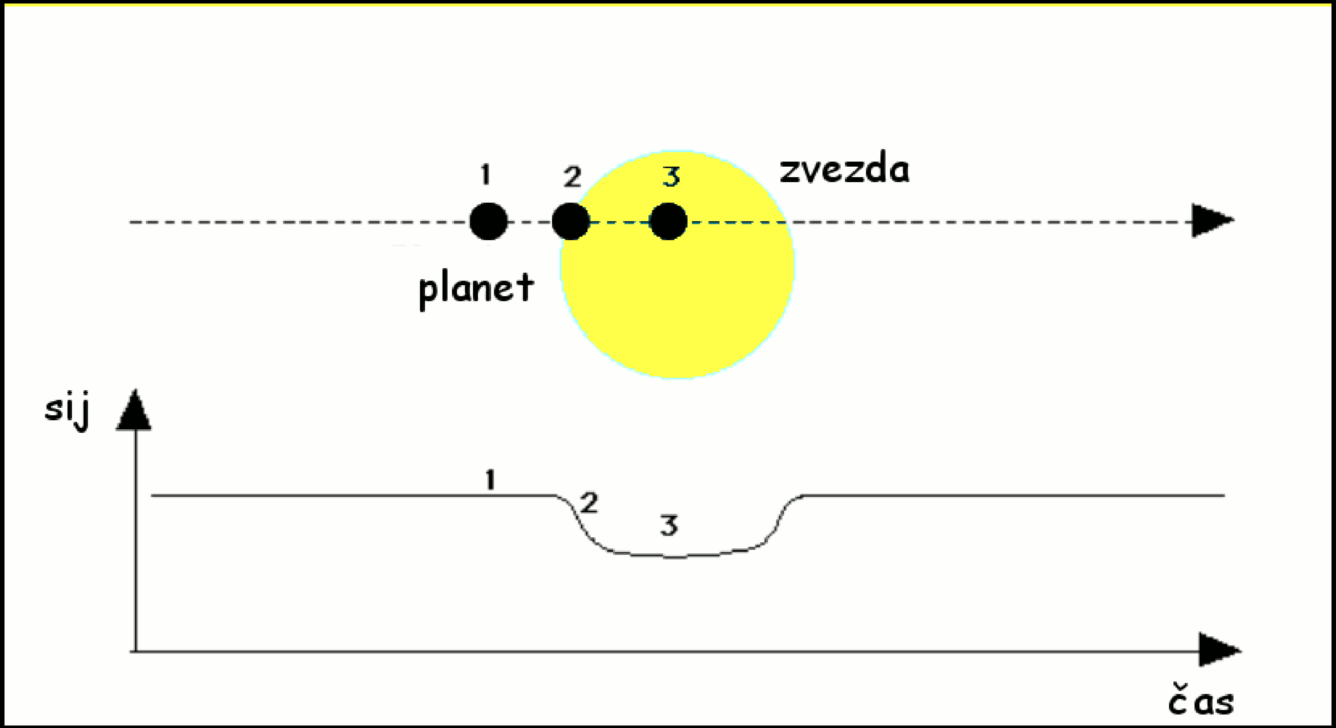
Orjaški planeti (masa nad 50 Zemljinih, orbitalna perioda pod 10 let) so prisotni ob 14% zvezd.

Nad-Zemlje in Neptuni (masa pod 30-40 Zemljinih) s periodami 40..80 dni so prisotni ob 50% zvezd.

Mayor idr. 2011

Opazovanje potemnitve zvezde

Planet prekrije del ploskve zvezde.

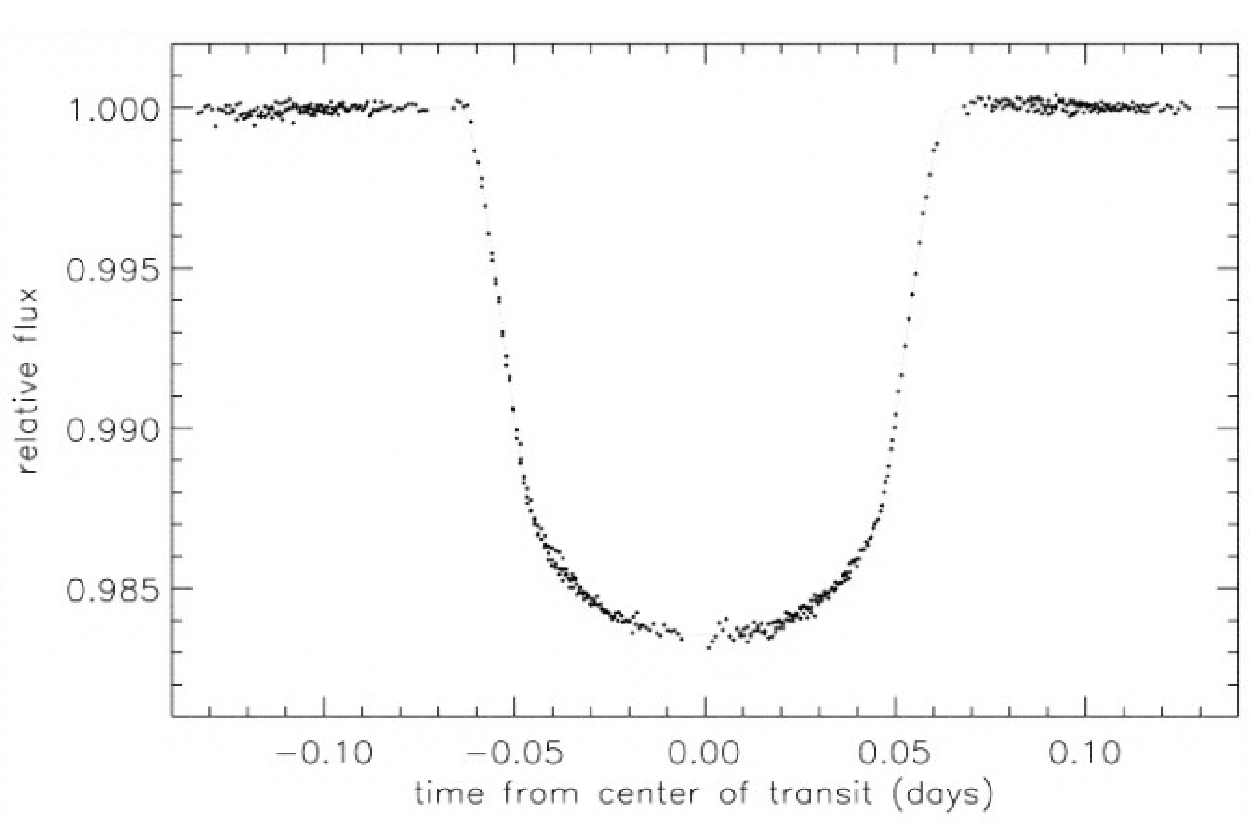


$$(j_{\text{zunaj prehoda}} - j_{\text{med prehodom}})/j_{\text{zunaj prehoda}} = (\pi\, R_{\text{planet}}^2) / (\pi\, R_{☼}^2) = (R_{\text{planet}} / R_{☼})^2$$

Delež potemnitve zvezde ob prehodu planeta.

Opazovanje potemnitve zvezde

Planet prekrije del ploskve zvezde.



- detekcija nemogoča z Zemlje:
  - atmosferske motnje spreminjajo svetlost zvez
  - kratko-periodični dogodki … potrebno sodelovanje mnogo zemeljskih teleskopov
- svetlost zvezd se spreminja tudi iz drugih razlogov (npr. spreminjanje Sončeve akitvnosti, vrtenje in pege):
  - variacije na časovnih skalah ur so na srečo manjše od spremembe svetlosti zaradi prehoda (sprememba izseva … ~100ppm)
- zakaj HST ni v redu:
  - ni specializirana misija
  - veliko premajhno zorno polje

COnvection, ROtation & planetary Transits

CHARACTERISTICS

Mini-satellite from the CNES PROTEUS series

Afocal telescope equipped with 4 CCDs

Stellar seismology and search for extrasolar planets

Polar circular orbit, altitude 896 km

Click here to increase or decrease font size: A A A A

The project main steps

After 826 days in orbit, the COROT spacecraft is in good health and performs very well.

The COROT space telescope is a mission of astronomy led by CNES in association with French laboratories (CNRS) and with several international partners (European countries, Brazil).

The spacecraft, belonging to the **Proteus** series, is equipped with a 27-cm diameter afocal telescope and a 4-CCD camera sensitive to tiny variations of the light intensity from stars.

The COROT instrument will make it possible, with a method called **stellar seismology**, to probe the inner structure of the stars, as well as to detect many **extrasolar planets**, by observing the periodic micro-eclipses occurring when these bodies transit in front of their parent star.

Understand the COROT mission objectives viewing an animation

By its high photometric performances and its observing runs covering five months without interruption, the COROT experiment aims to be a pioneer mission in the discovery of telluric extrasolar planets, bodies with properties comparable to those of the rocky planets of the solar system. Its launch was successful on december 27th, 2006.

Latest Update 06/03/2009

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- The Odyssey of Life
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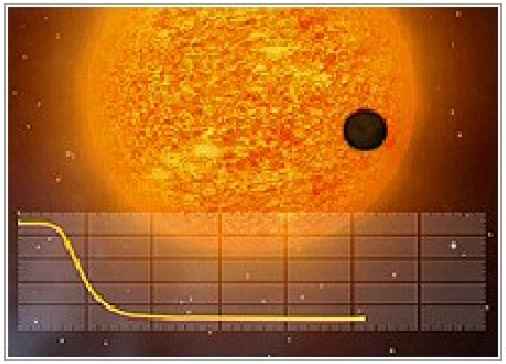


Planet transit in front of a star

COROT discovers smallest exoplanet yet, with a surface to walk on

3 February 2009

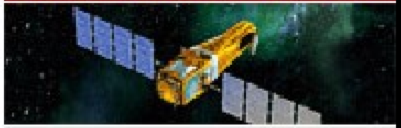
COROT has found the smallest terrestrial planet ever detected outside the Solar System. The amazing planet is less than twice the size of Earth and orbits a Sun-like star. Its temperature is so high that it is possibly covered in lava or water vapour.

About 330 exoplanets have been discovered so far, most of which are gas giants with characteristics similar to Jupiter and Neptune.

The new find, COROT-Exo-7b, is different: its diameter is less than twice that of Earth and it orbits its star once every 20 hours. It is located very close to its parent star, and has a high temperature, between 1000 and 1500°C. Astronomers detected the new planet as it transited its parent star, dimming the light from the star as it passed in front of it.

The density of the planet is still under investigation: it may be rocky like Earth and covered in liquid lava. It may also belong to a class of planets that are thought to be made up of water and rock in almost equal amounts. Given the high temperatures measured, the planet would be a very hot and humid place.

Searching for exoplanets



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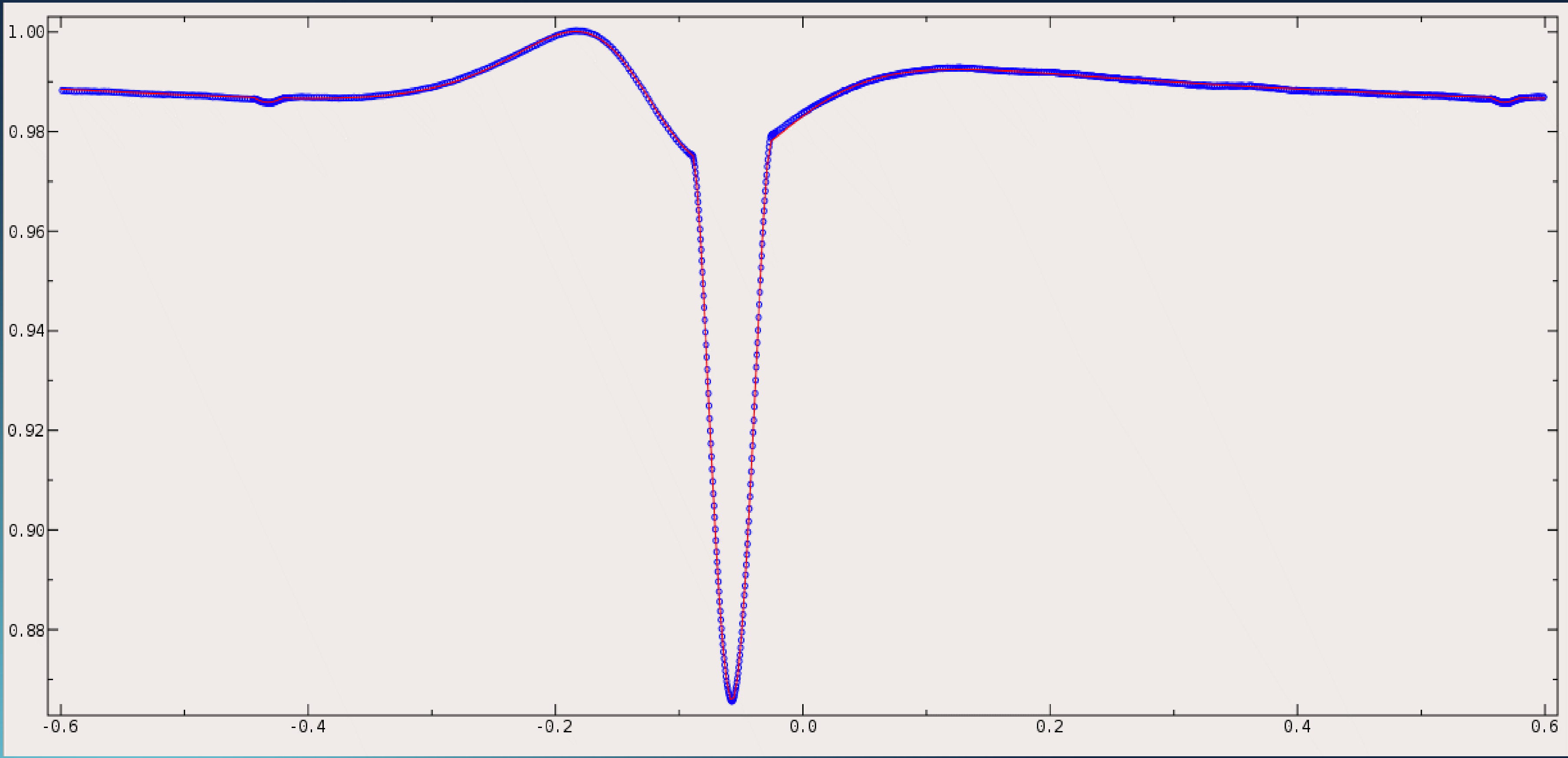
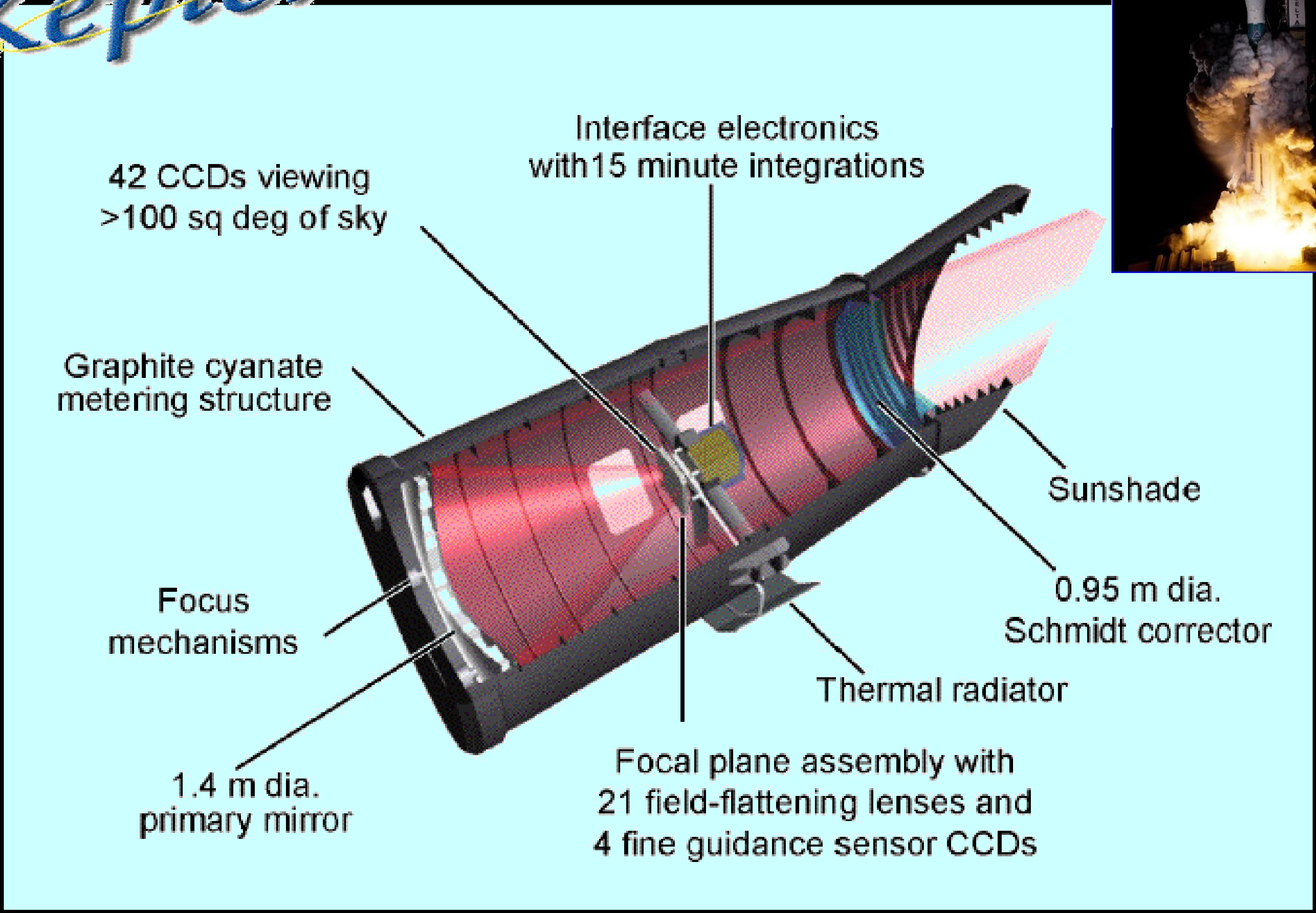


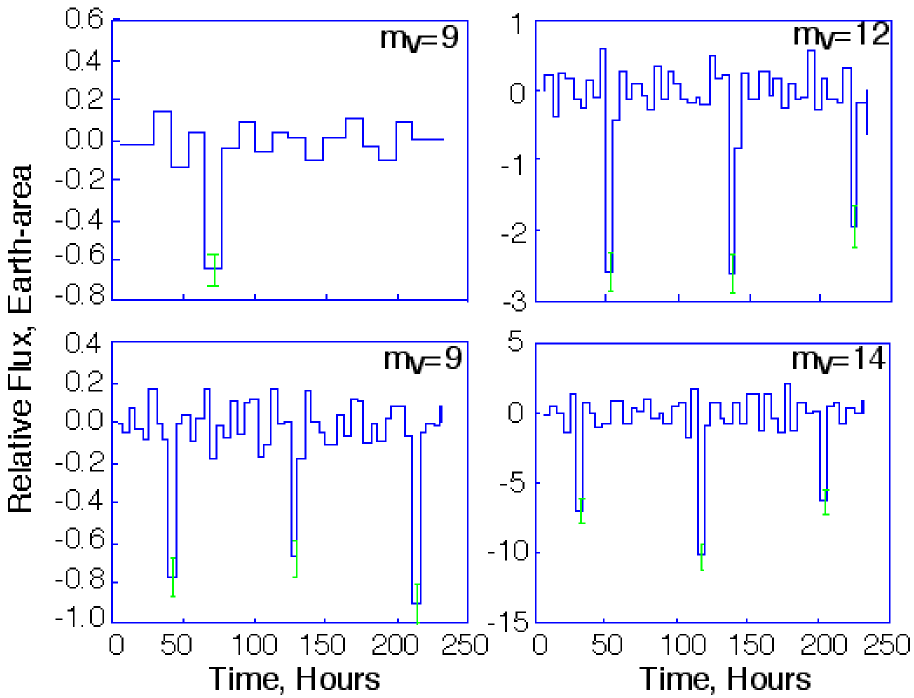
Francoski satelit Corot, Andrej Prša idr. (2009)

Kepler

6. marec 2009



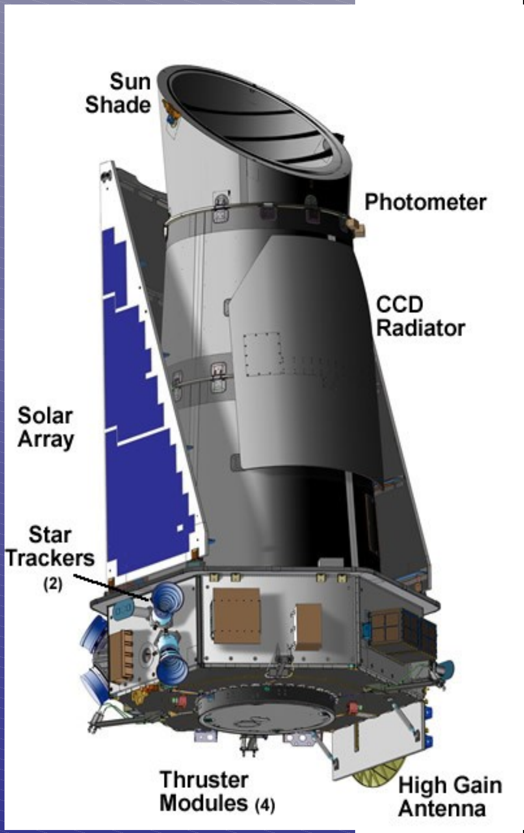
- direktnoopazovanje:
  - prehod planeta preko zvezdine ploskvice
  - periodično je zvezda je videti nekoliko temnejša



6,5h integracija, 20E-6 točnost
Za zvezdo 12. magnitude.

System Characteristics:

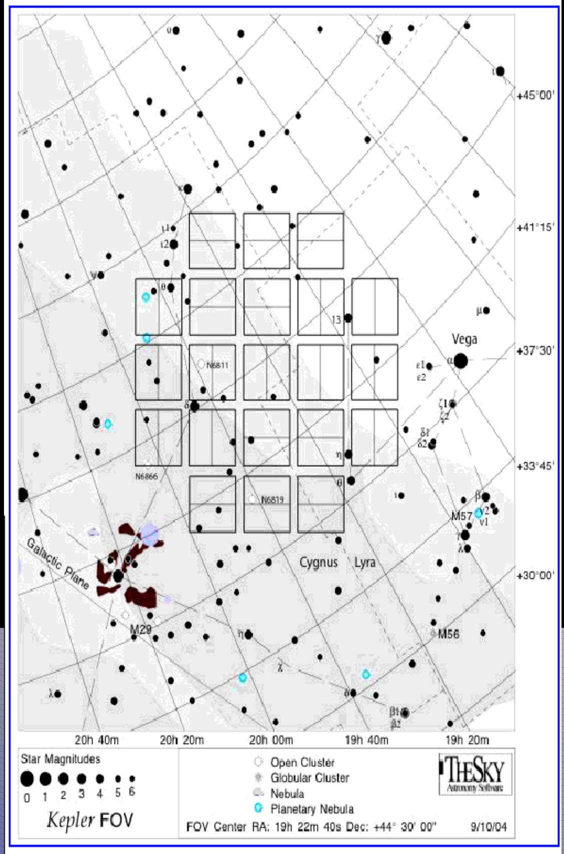
- Spacebased Photometer: 0.95-m aperture
- Primary mirror: 1.4 meter diameter, 85% light weighted
- Detectors: 95 mega pixels (42 CCDs with 2200x1024 pixels)
- Bandpass: 430-890 nm FWHM
- Dynamic range: 9th to 16th magnitude stars
- Fine guidance sensors: 4 CCDs located on science focal plane
- Attitude stability: <9 milli-arcsec, 3 sigma over 15 minutes.
- Science data storage: >60 days
- Uplink X-band: 7.8125 bps to 2 kbps
- Downlink X-band: 10 bps to 16 kbps
- Downlink Ka-band: Up to 4.33125 Mbps
- Photometric One-Sigma Noise Performance:
- Total noise with solar-like stellar variability and photon
- shot noise for an mv=12 star: < 2x10-5
- Flight segment and instrument mass: 1071 kg, maximum expected (10/06)
- Flight segment and instrument power: 771 W, maximum expected (10/06)



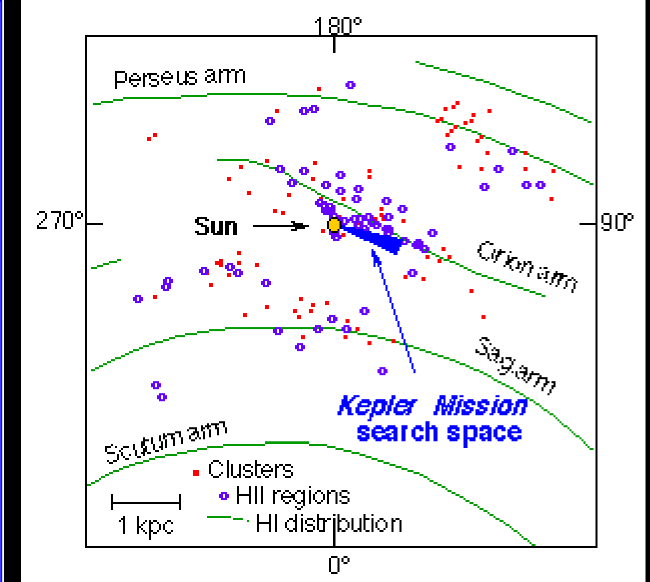
Kepler

pričakovani rezultati

v 4 letih misije:



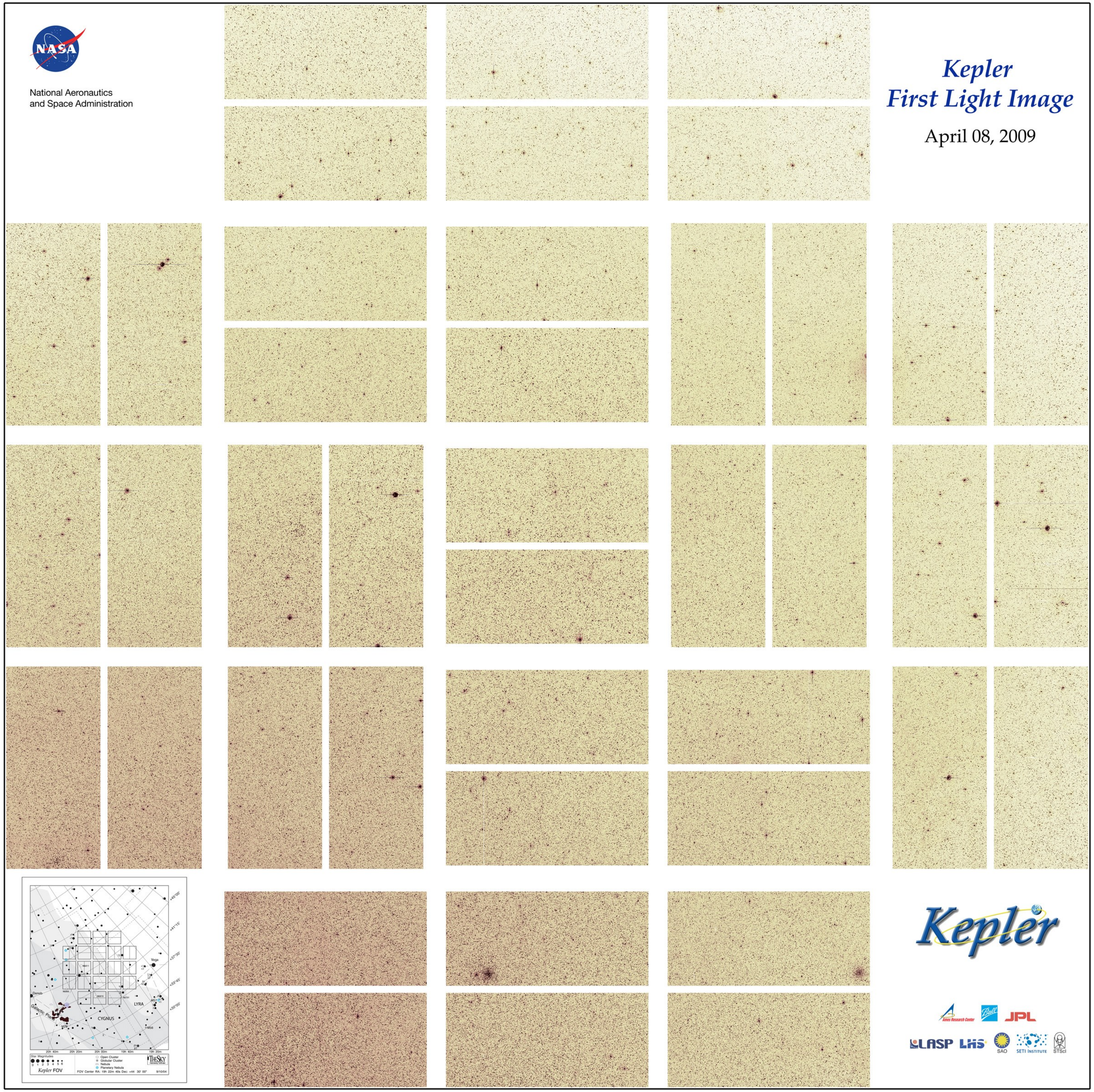
Location of the *Kepler Mission* FOV on the Sky

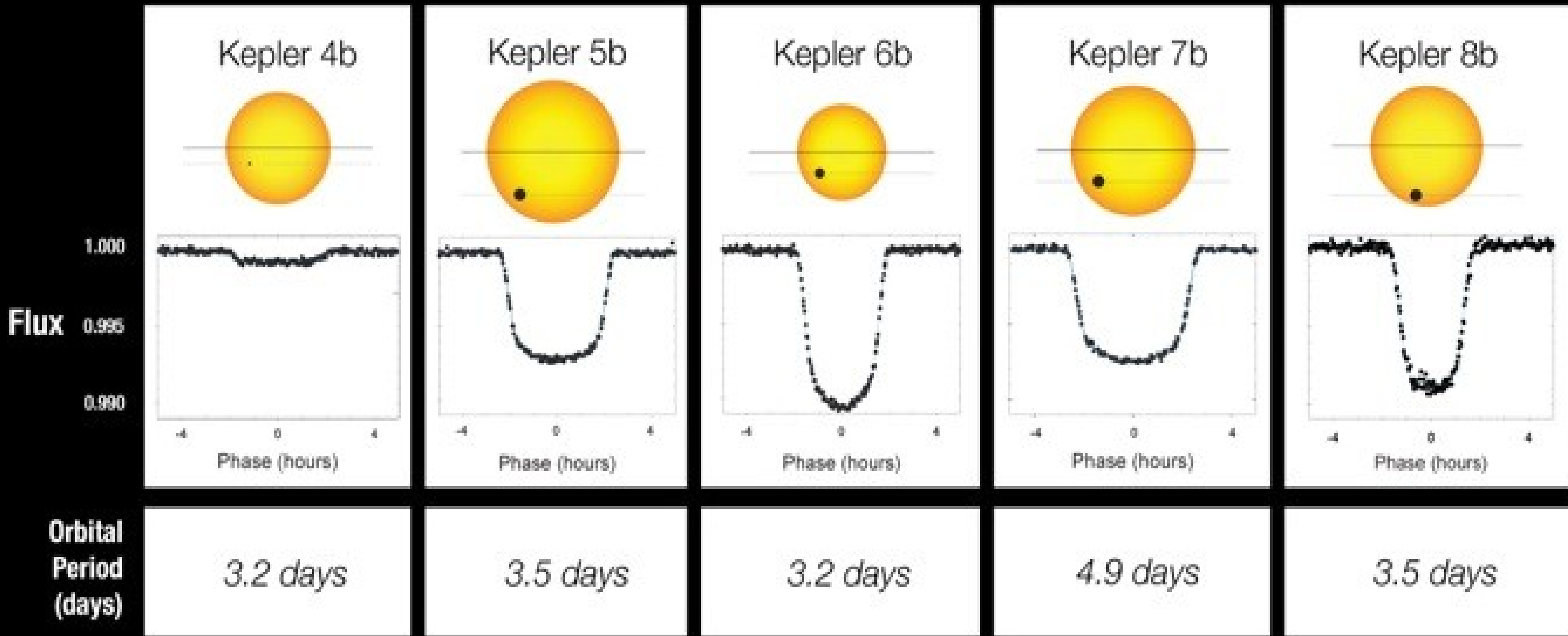


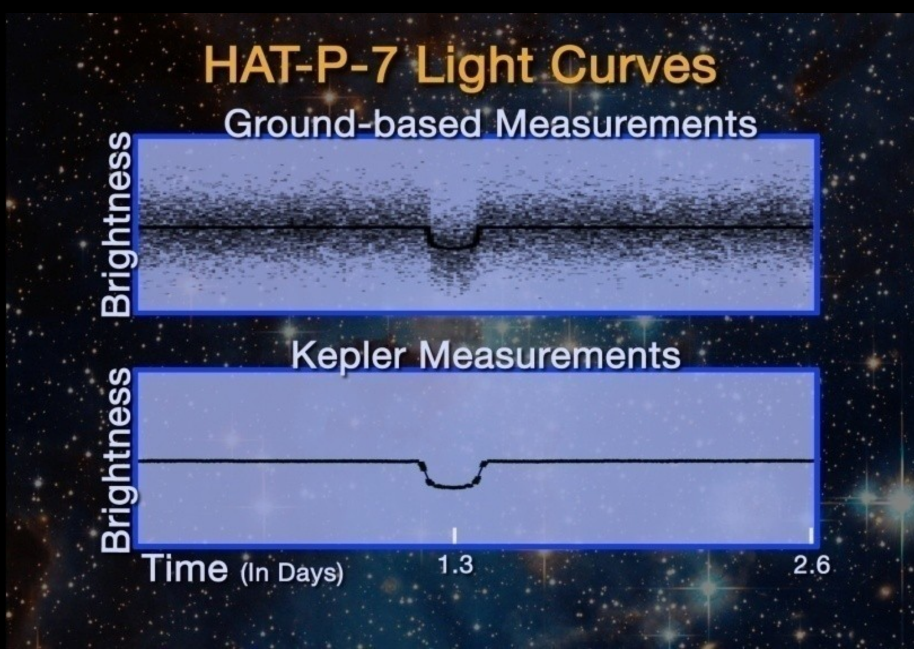
Extended Solar Neighborhood

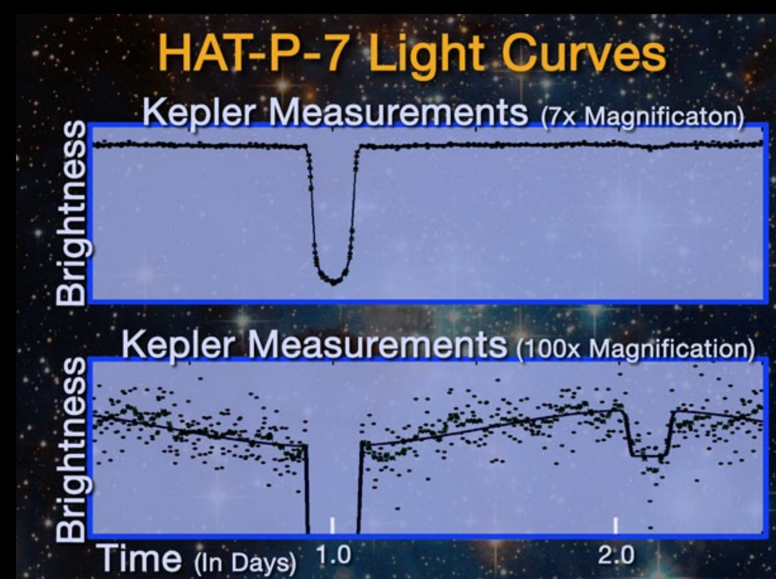
The stars sampled are similar to the immediate solar neighborhood. Young stellar clusters, ionized HII regions and the neutral hydrogen, HI, distribution define the arms of the Galaxy.

- 50 planetov z $R \sim R_z$
- 185 planetov z $R \sim 1.3\ R_z$
- 640 planetov z $R \sim 2.2\ R_z$
- 12% sistemov z dvema ali več planeti

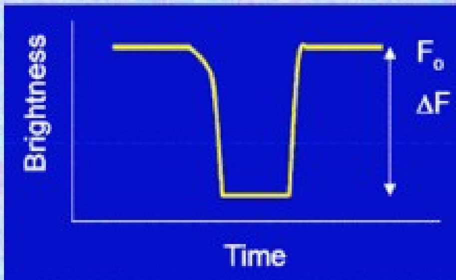

National Aeronautics
and Space Administration
Kepler
First Light Image
April 08, 2009
CYGNUS
LYRA
Vega
Kepler FOV
JPL


Kepler 4b
Kepler 5b
Kepler 6b
Kepler 7b
Kepler 8b
Flux
1.000
0.995
0.990
-4
0
4
Phase (hours)
Orbital Period (days)
3.2 days
3.5 days
3.2 days
4.9 days
3.5 days


HAT-P-7 Light Curves
Ground-based Measurements
Brightness
Kepler Measurements
Brightness
Time (In Days)
1.3
2.6

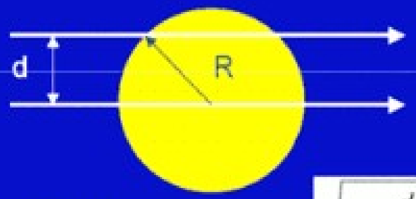

HAT-P-7 Light Curves
Kepler Measurements (7x Magnificaton)
Brightness
Kepler Measurements (100x Magnification)
Brightness
Time (In Days)
1.0
2.0

Transit Depth and Duration



$$\frac{\Delta F}{F_0} = \left(\frac{r_{pl}}{R_*}\right)^2$$

- Jupiter - 0.1
- Neptune - 0.001
- Earth - 0.0001
- Neptune, star of type M - 0.01

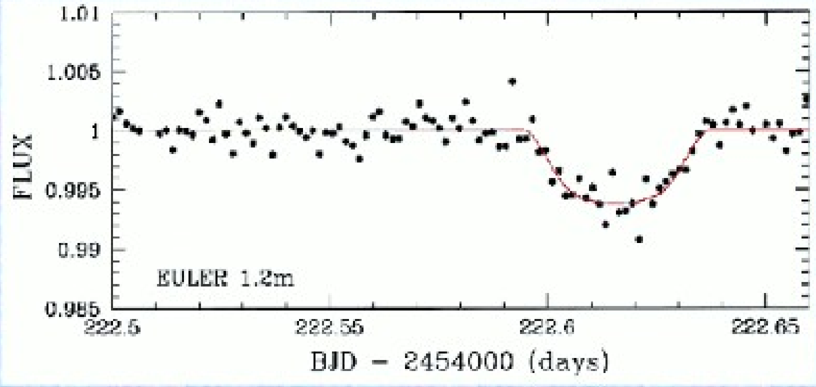


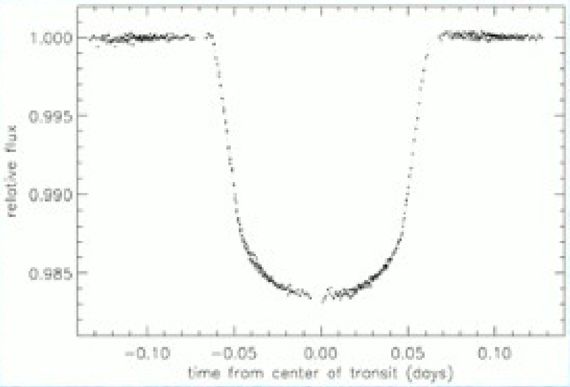
$$\tau(hrs) = 13\left(\frac{R_*}{R_{sun}}\right)\left(\frac{P}{1yr}\right)^{1/3}\left(\frac{M_*}{M_{sun}}\right)^{-1/3}$$

τ = 3 hours for P=3 days

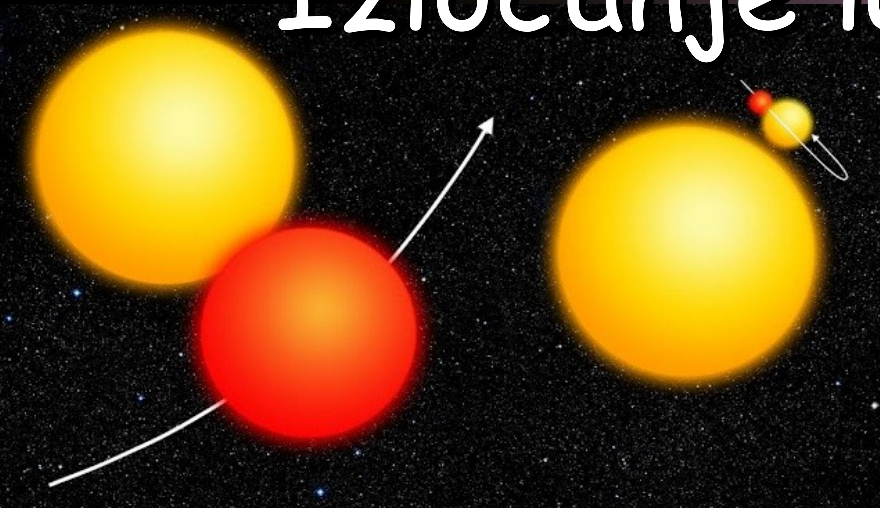
Reduction of τ by $\sqrt{1-\frac{d^2}{R_*^2}}$ for a non-central transit

Warning!
Prone to a variety of astrophysical false alarms



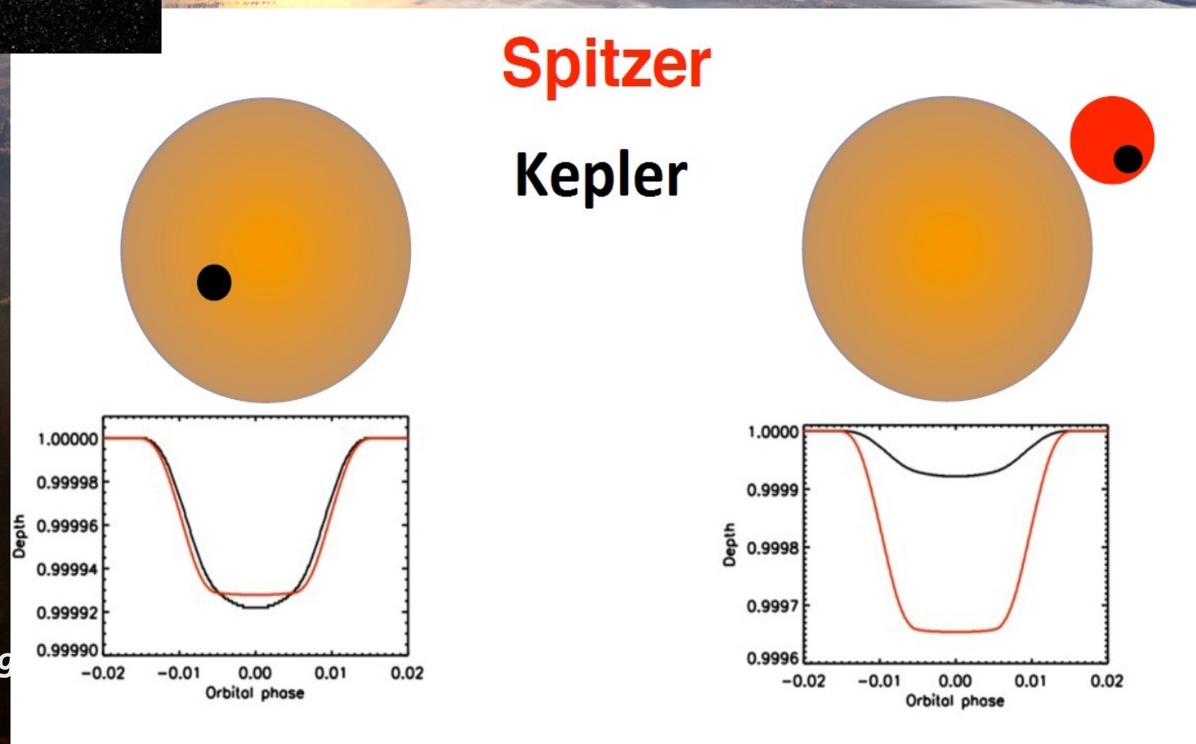


Izločanje lažnih detekcij



V polju je lahko temna dvojna zvezda.

Prehodi v vidnem in IR so pri planetu enako globoki

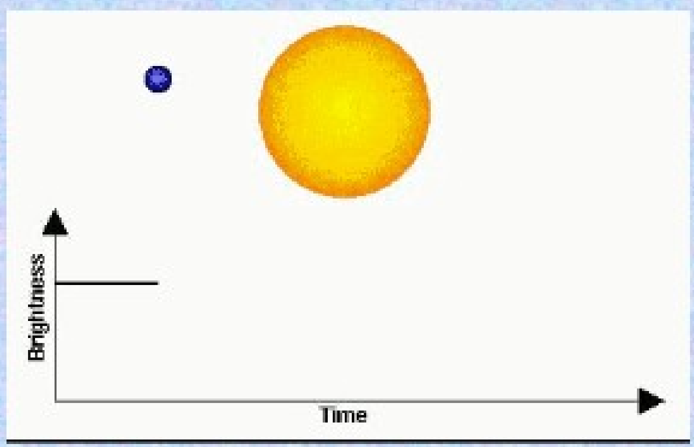


Transit Photometry

* Observable: decrease of stellar brightness, when planet moves across the stellar disk

* Condition of observability: planetary orbit must be (almost) perpendicular to the plane of the sky

* The method allows a determination of parameters that are not accessible with Doppler spectroscopy, e.g. ratio of radii, orbital inclination, limb darkening of the star



Probability of Eclipses:

$$P_{\rm tr} = 0.0045 \left(\frac{1\rm AU}{a}\right)\left(\frac{R_* + R_{pl}}{R_\odot}\right)\left[\frac{1 + e\cos(\frac{\pi}{2} - \varpi)}{1 - e^2}\right]$$

It is easier to detect an eclipse by a planet on a tight orbit

Must combine with RV in order to derive mass and radius of the planet

Mission
- About the Mission
- Kepler Discoveries
- Kepler Team
  - Co-Investigators
  - Science Working Group
  - Participating Scientists
  - Guest Observer Office
  - Project Office
  - Science Office
  - Science Operations Center
  - Other Institutions and NASA Sites
    - Team Plaques
  - Kepler Team from Ball Aerospace & Technologies, Inc.
- Kepler Awards
- Manager's Updates
- Johannes Kepler
- Kepler Twitter
- Kepler Facebook
- FAQ
- nasa.gov/kepler

Search

Kepler Team

Andrej Prsa
Science Working Group Member

Dept. of Astronomy and Astrophysics at Villanova University, PA

Dr Andrej Prsa is a research assistant professor in the Dept. of Astronomy and Astrophysics at Villanova University, PA. His current research focuses on modeling and analysis of eclipsing binary stars.

Eclipsing binaries are fundamentally important for stellar astrophysics. Their geometric orientation allows us to determine masses, radii and temperatures of their components, and distances to a remarkable accuracy. Dr Prsa wrote and maintains the modeling code PHOEBE (http://phoebe.fiz.uni-lj.si) and the artificial intelligence based solution estimator EBAI (http://phoebe.fiz.uni-lj.si/?q=node/104). He serves as chair of the Kepler Eclipsing Binary Working Group. The group produced a catalog (http://astro4.ast.villanova.edu/aprsa/kepler) of over 2000 eclipsing binaries observed by Kepler. The scientific significance of this sample is unprecedented in accuracy and astrophysical impact: detailed modeling yields statistics on orbital periods, amplitudes, galactic distribution, distances, ages, a mass-radius relationship across the H-R diagram, and membership in triple and multiple stellar systems. Careful studies of binary stars are important for planet hunting as well: when diluted with light from a nearby source, light curves of eclipsing binaries may be confused for planet transits. Precise modeling of light curve shapes contributes to vetting the transit candidates and thus contributing to the Kepler core program.

Homepage: http://astro4.ast.villanova.edu/aprsa

Characteristics of planetary candidates observed by *Kepler*, II: Analysis of the first four months of data

Borucki idr. (tudi Andrej Prša) 2011

Abstract. On 1 February 2011 the *Kepler* Mission released data for 156,453 stars observed from the beginning of the science observations on 2 May through 16 September 2009. There are 1235 planetary candidates with transit like signatures detected in this period. These are associated with 997 host stars. Distributions of the characteristics of the planetary candidates are separated into five class-sizes; 68 candidates of approximately Earth-size ($R_p < 1.25\ R_\oplus$), 288 super-Earth size ($1.25\ R_\oplus < R_p < 2\ R_\oplus$), 662 Neptune-size ($2\ R_\oplus, < R_p < 6\ R_\oplus$), 165 Jupiter-size ($6\ R_\oplus < R_p < 15\ R_\oplus$), and 19 up to twice the size of Jupiter ($15\ R_\oplus < R_p < 22\ R_\oplus$). In the temperature range appropriate for the habitable zone, 54 candidates are found with sizes ranging from Earth-size to larger than that of Jupiter. Six are less than twice the size of the Earth. Over 74% of the planetary candidates are smaller than Neptune. The observed number versus size distribution of planetary candidates increases to a peak at two to three times Earth-size and then declines inversely proportional to area of the candidate. Our current best estimates of the intrinsic frequencies of planetary candidates, after correcting for geometric and sensitivity biases, are 5.4% for Earth-size candidates, 6.8% for super-Earth size candidates, 19.3% for Neptune-size candidates, 2.4% for Jupiter-size candidates, and 0.15% for very-large candidates; a total of 0.341 candidates per star. Multi-candidate, transiting systems are frequent; 17% of the host stars have multi-candidate systems, and 33.9% of all the candidates are part of multi-candidate systems.

Characteristics of planetary candidates observed by *Kepler*, II: Analysis of the first four months of data

Borucki idr. (tudi Andrej Prša) 2011

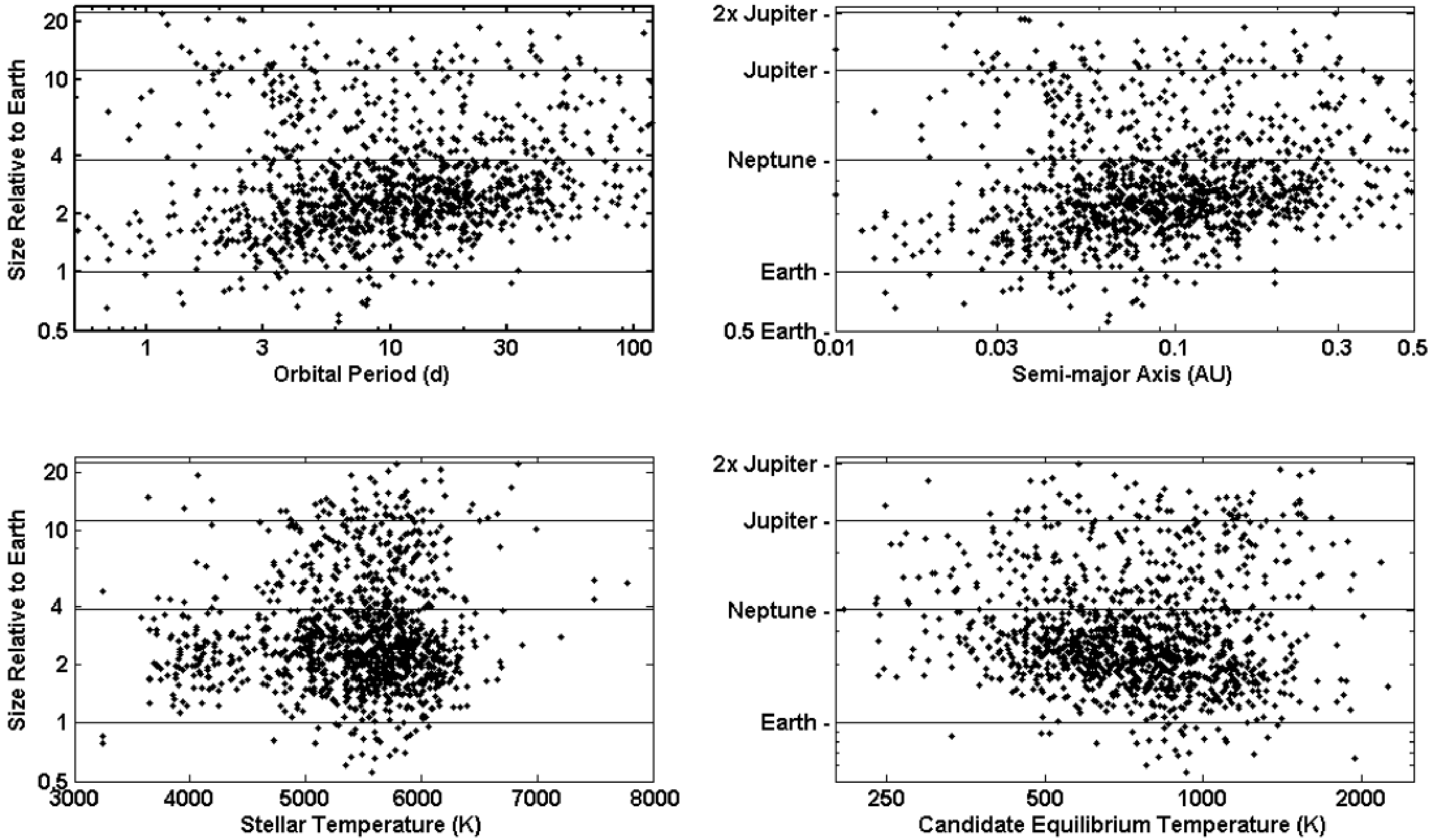


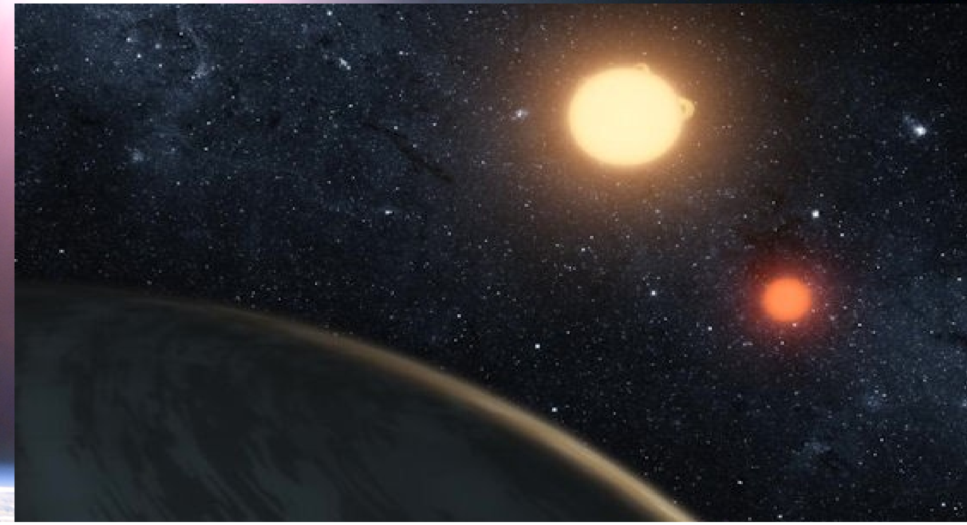
Figure 3. Candidate size versus orbital period, semi-major axis, stellar temperature, and candidate equilibrium temperature[3]. Uncertainties in candidate size are mostly due to the uncertainty in stellar sizes, i.e., approximately 25%. Horizontal lines mark ratios of candidate sizes for Earth-size, Neptune-size , and Jupiter-size relative to Earth-size.

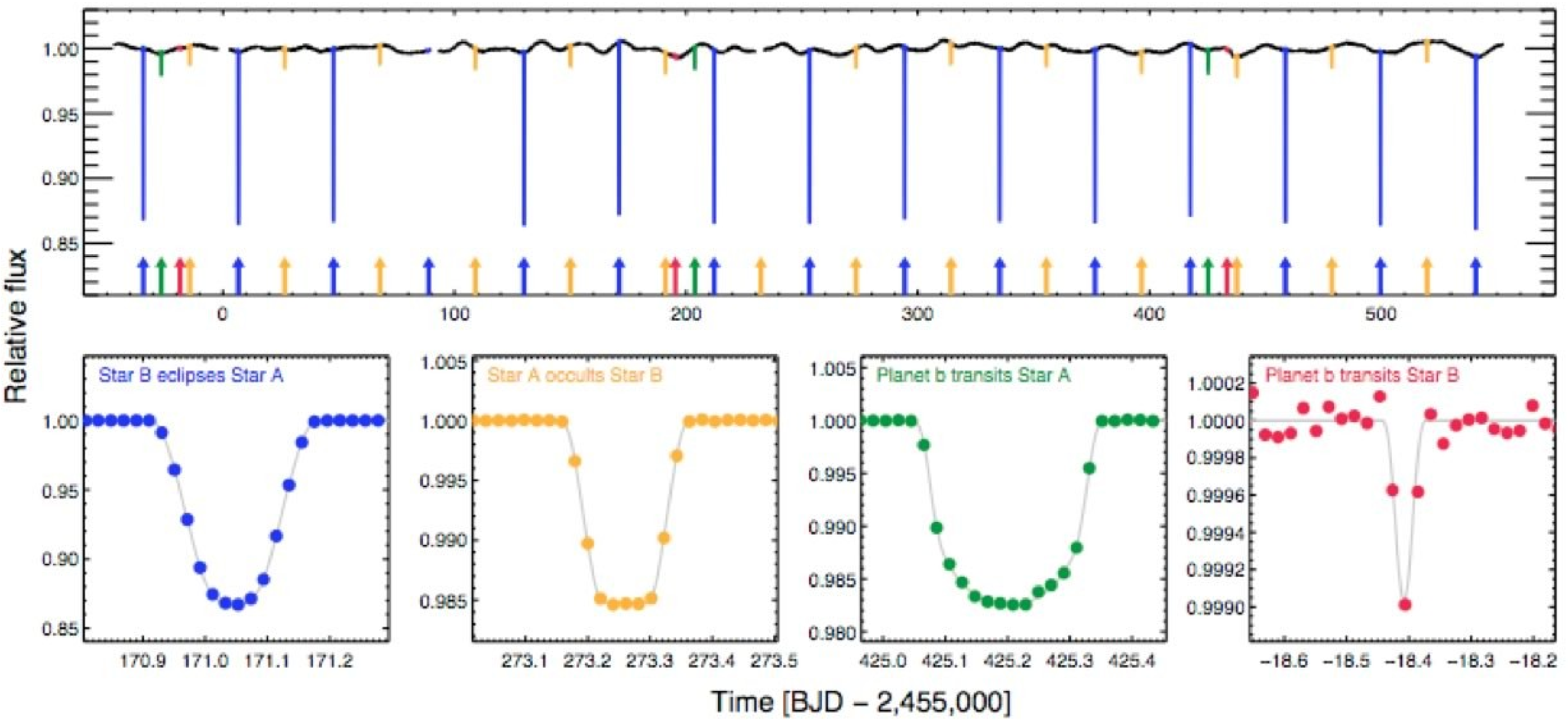
Doyle idr. (tudi Andrej Prša) 2011

Dvojna zvezda

s planetom

Kepler 16b





Kepler 22b: Zemlji podobni planet

Zvezda 2MASS J19165219+4753040

ozvezdje Labod

d=160 pc

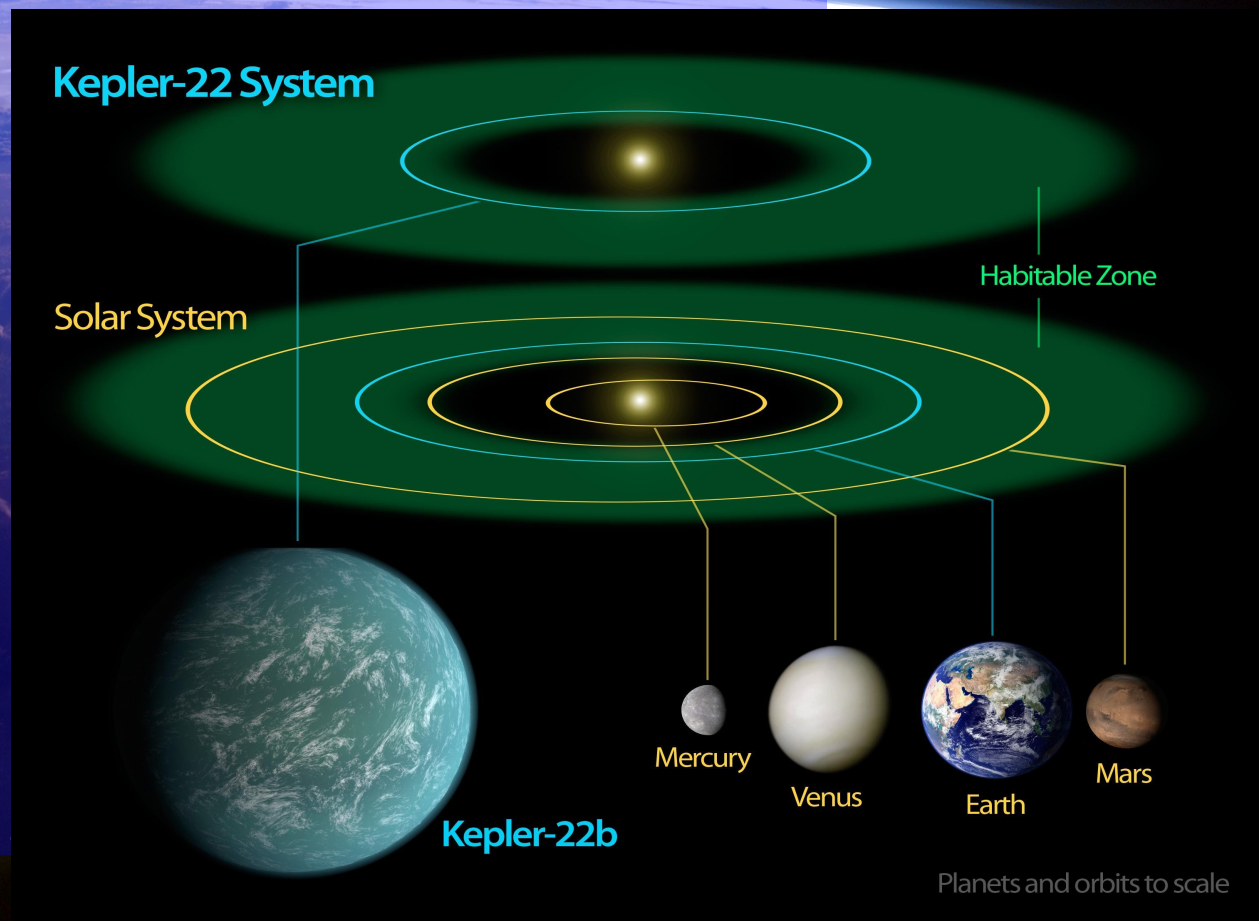
G5V, $L = 0.8\ L_{sonce}$

a = 0.85 a.e.

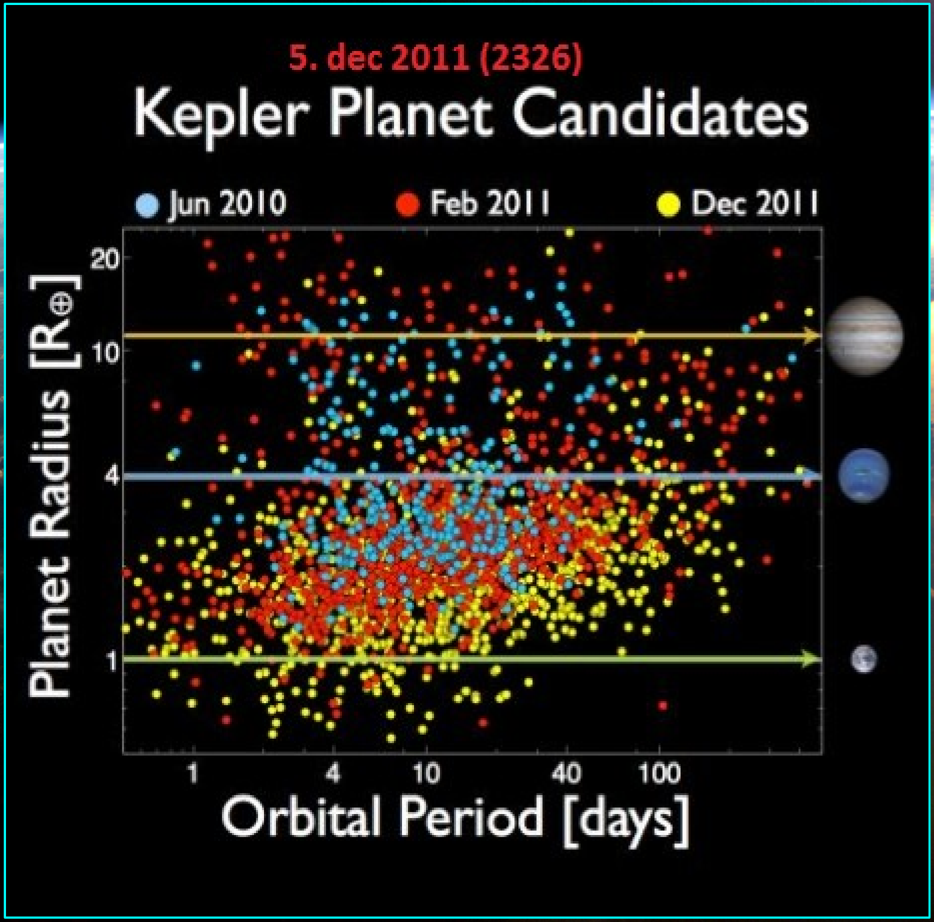
P = 229 dni

$R = 2.4\ R_{zemlje}$

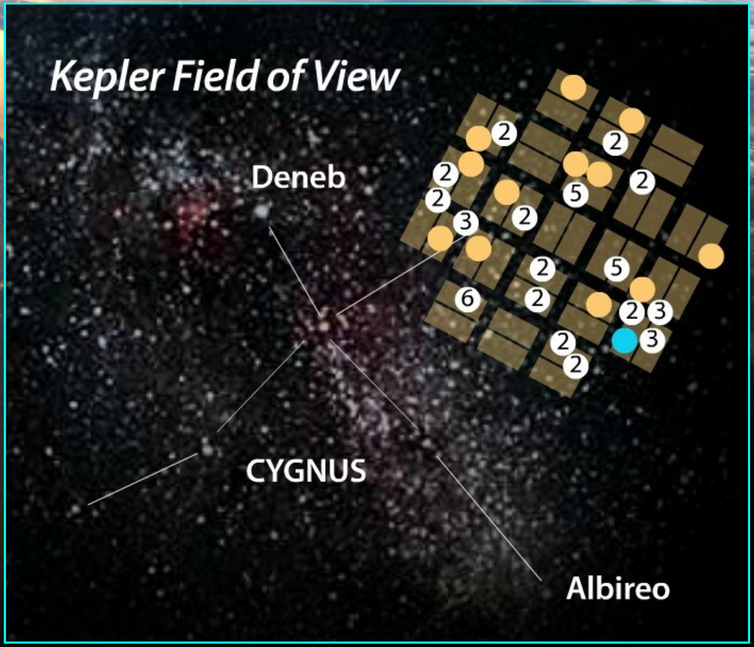
T ~ 20 °C



Povzetek Keplerjevih rezultatov

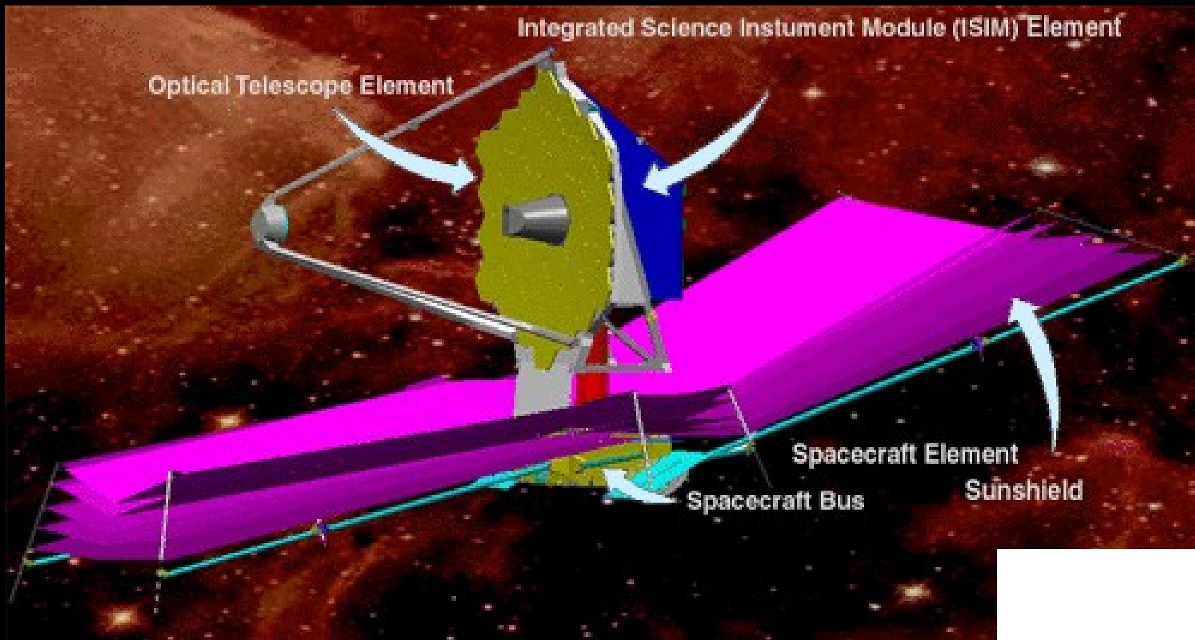


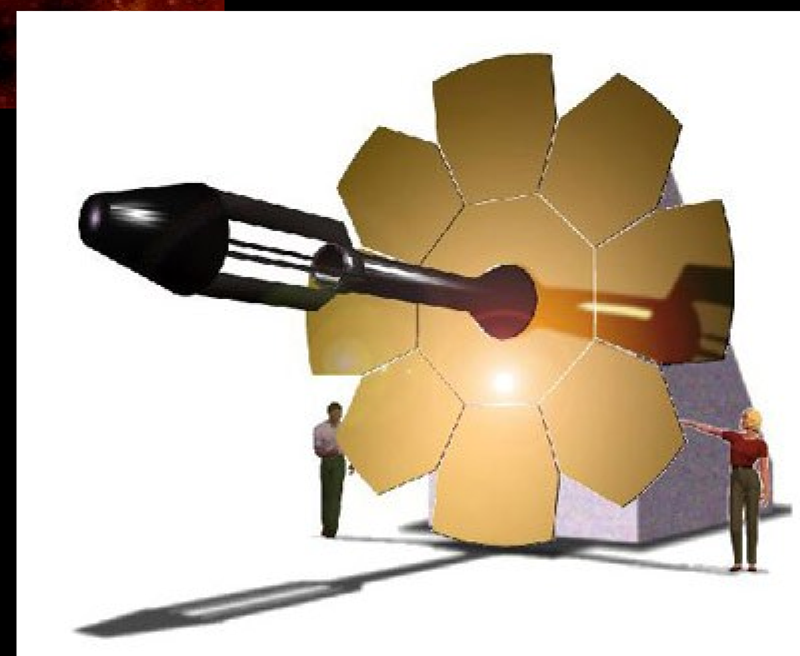
2165 dvojnih zvezd
2326 kandidatov za planete
61 potrjenih planetov
precej večplanetarnih sistemov



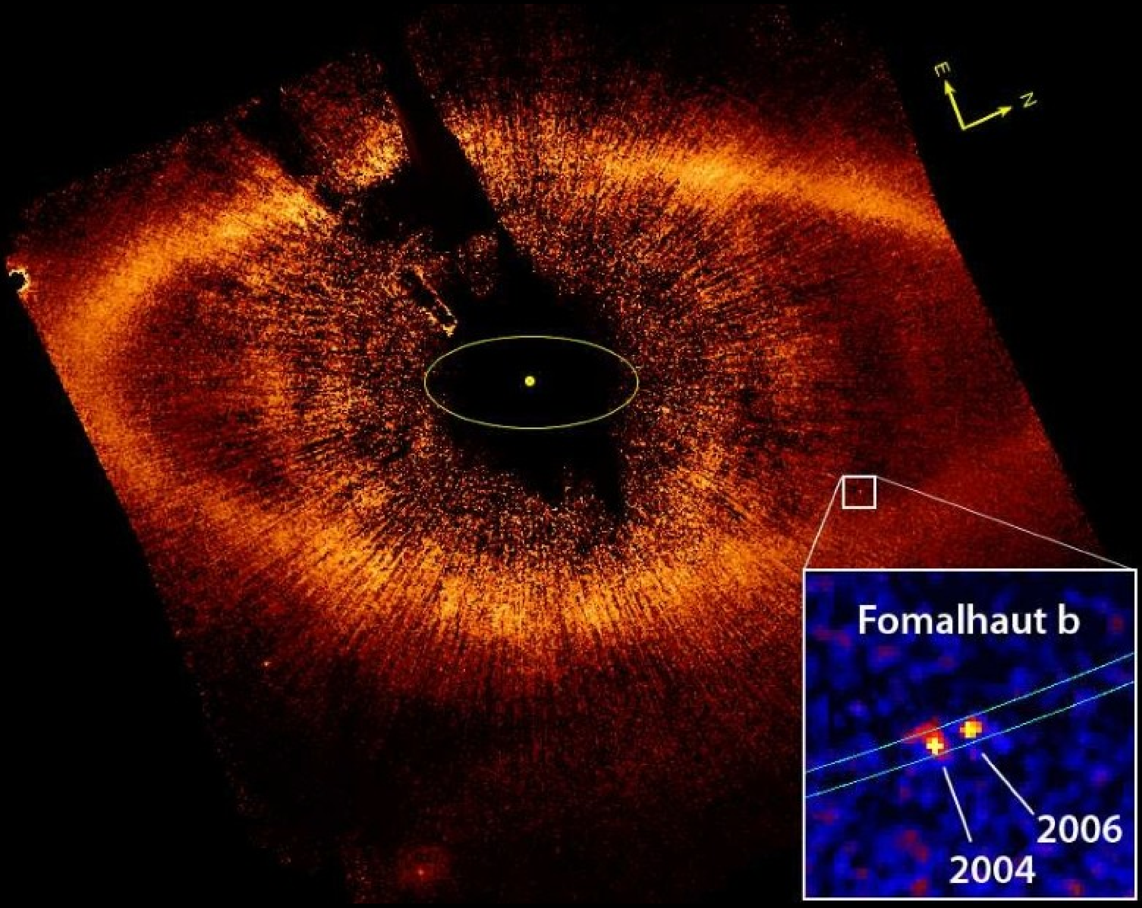
James Webb Space Telescope (NASA, 2011)

- zrcalo in oprema:
  - 6.5 metrsko zrcalo z aktivno optiko
  - inštrumenti občutljivi v IR delu spektra
- znanstveni cilji:
  - oblika Vesolja
  - nastanek in razvoj galaksij
  - rojstvo in razvoj zvezd
  - nastanek in razvoj planetnih sistemov


Integrated Science Instument Module (ISIM) Element
Optical Telescope Element
Spacecraft Element
Sunshield
Spacecraft Bus



Opazovanje odbite svetlobe planeta (z zastrto svetlobo zvezde)



ZVEZDA FORMALHAUT

izsev planeta: 0,34 10^{-6} L_{SONCE}

polmer planeta: 1,2 $R_{JUPITER}$

temperatura planeta: 130 °C

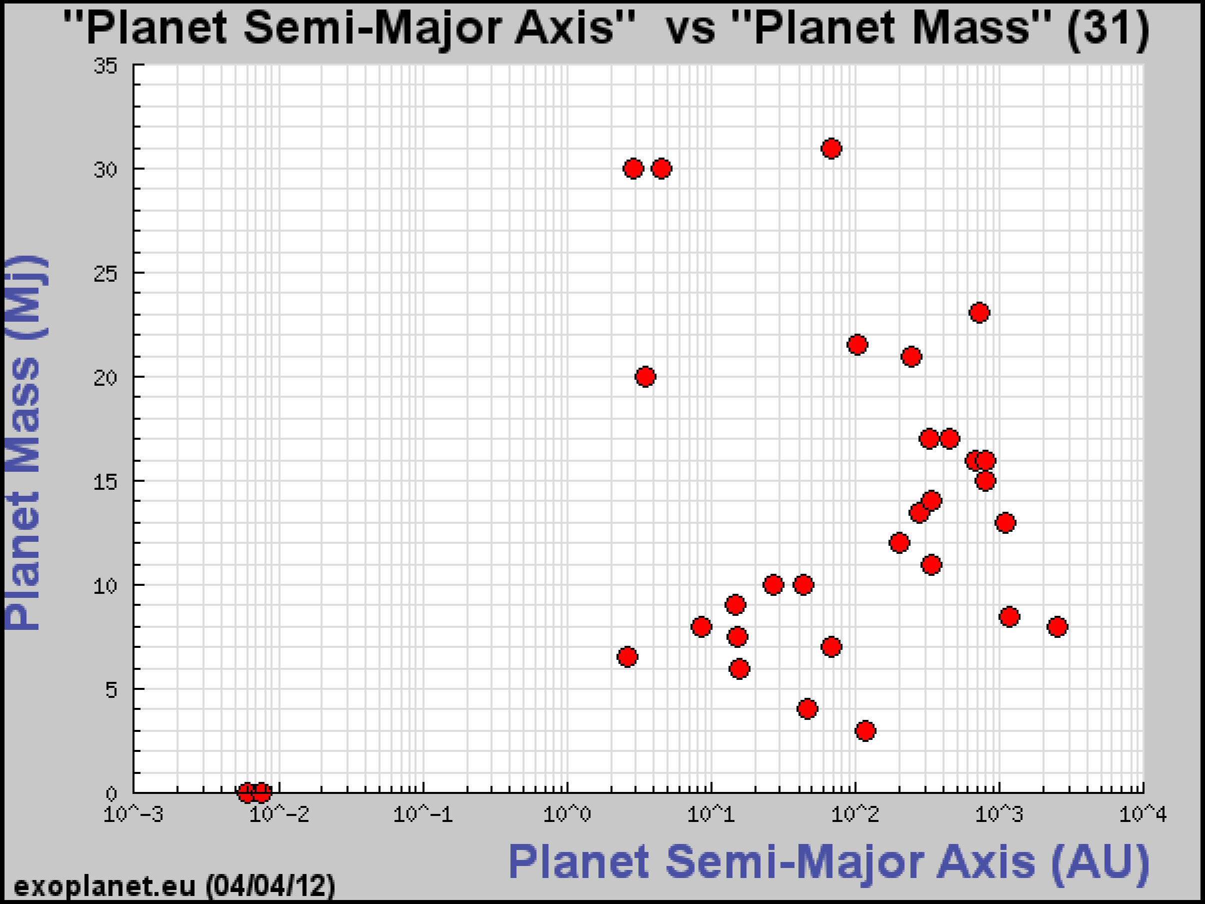
razdalja od zvezde: 115 a.e.

orbitalna perioda: 872 let

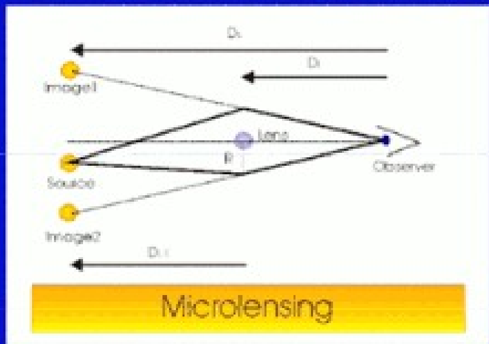
Kalas idr. 2008

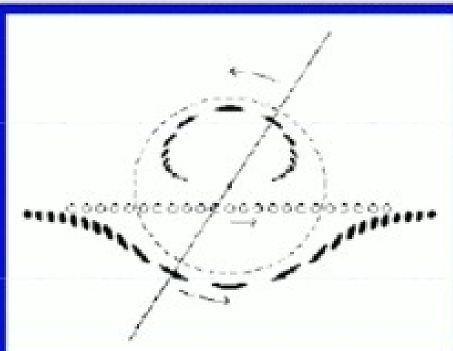
Opazovanje odbite svetlobe planeta (z zastrto svetlobo zvezde)

Planeti odkriti z direktnim slikanjem: 25 planetov okoli 22 zvezd.



Gravitational Microlensing

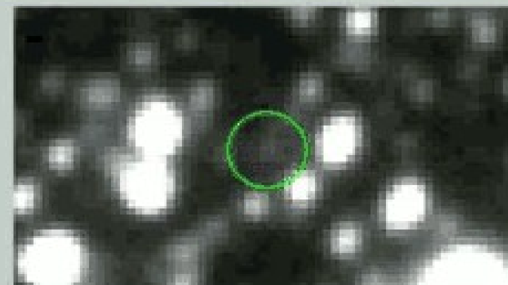


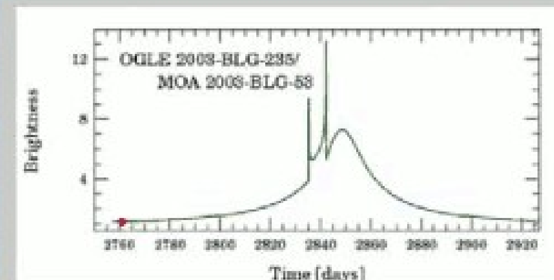


A gravitational lens creates two Images of a background star. Geometry of a lensing event is defined by location of trajectory of the lensed star with respect to the Einstein ring of the lens:

$$R_E^{\ 2} = \frac{4GM_L D}{c^2} \qquad D = \frac{D_{LS} D_L}{D_S}$$

Shapes and locations of source images change according to position changes of the lensed star with respect to the lens and its Einstein ring





The presence of a planet around the lensing star further modifies the light curve of the background star

- An appropriate geometry occurs very infrequently (need to observe millions of stars) and the phenomenon is not repeatable
- The method is sensitive to Earth-mass planets

Direktna svetloba Zemlji podobnih planetov

Improved precision on the radius of the nearby super-Earth 55 Cnc e★

Michaël Gillon[1], Brice-Olivier Demory[2], Björn Benneke[2], Diana Valencia[2], Drake Deming[3], Sara Seager[2], Christophe Lovis[4], Michel Mayor[4], Francesco Pepe[4], Didier Queloz[4], Damien Ségransan[4], Stéphane Udry[4]

[1] Institut d'Astrophysique et de Géophysique, Université de Liège, Allée du 6 Août 17, Bat. B5C, 4000 Liège, Belgium
[2] Department of Earth, Atmospheric and Planetary Sciences, Department of Physics, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, USA
[3] Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA
[4] Observatoire de Genève, Université de Genève, 51 Chemin des Maillettes, 1290 Sauverny, Switzerland

Received date / accepted date

ABSTRACT

We report on new transit photometry for the super-Earth 55 Cnc e obtained with *Warm Spitzer*/IRAC at 4.5 μm. An individual analysis of these new data leads to a planet radius of $2.21^{+0.15}_{-0.16}$ $R_\oplus$, which agrees well with the values previously derived from the MOST and *Spitzer* transit discovery data. A global analysis of both *Spitzer* transit time-series improves the precision on the radius of the planet at 4.5 μm to 2.20 ± 0.12 $R_\oplus$. We also performed an independent analysis of the MOST data, paying particular attention to the influence of the systematic effects of instrumental origin on the derived parameters and errors by including them in a global model instead of performing a preliminary detrending-filtering processing. We deduce an optical planet radius of 2.04 ± 0.15 $R_\oplus$ from this reanalysis of MOST data, which is consistent with the previous MOST result and with our *Spitzer* infrared radius. Assuming the achromaticity of the transit depth, we performed a global analysis combining *Spitzer* and MOST data that results in a planet radius of 2.17 ± 0.10 $R_\oplus$ ($13,820 \pm 620$ km). These results point to 55 Cnc e having a gaseous envelope overlying a rocky nucleus, in agreement with previous works. A plausible composition for the envelope is water which would be in super-critical form given the equilibrium temperature of the planet.

Key words. binaries: eclipsing – planetary systems – stars: individual: 55 Cnc - techniques: photometric

Direktna svetloba Zemlji podobnih planetov

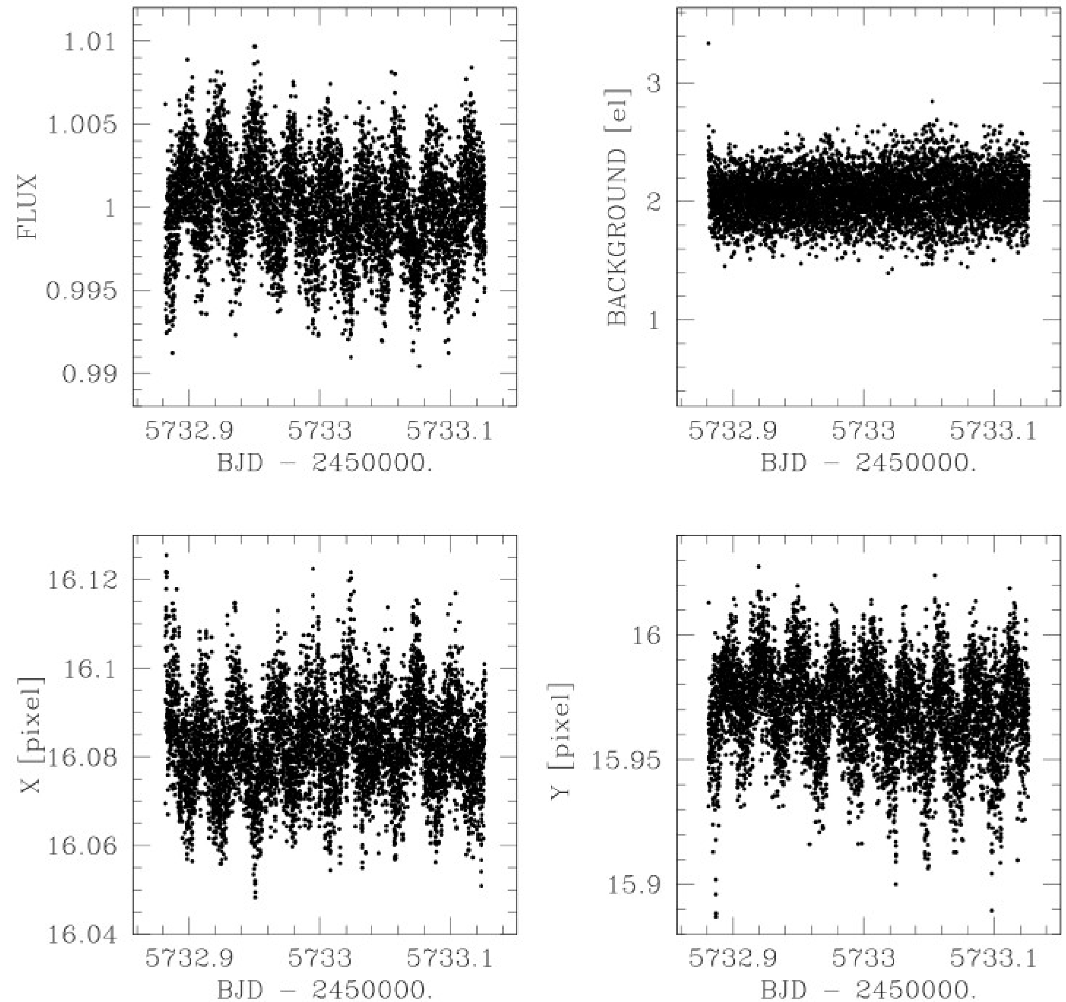


Fig. 1. *Top left*: raw light curve obtained for 55 Cnc with *Warm Spitzer* at 4.5 μm. *Top right*: corresponding background time-series. *Bottom*: corresponding time-series for the *x* (*left*) and *y* (*right*) positions of the stellar center. The correlation between measured stellar counts and the stellar image positions is clearly noticeable. This 'pixel-phase' effect is well-known for the InSb *Spitzer*/IRAC detectors (e.g. Knutson et al. 2008).

Direktna svetloba Zemlji podobnih planetov

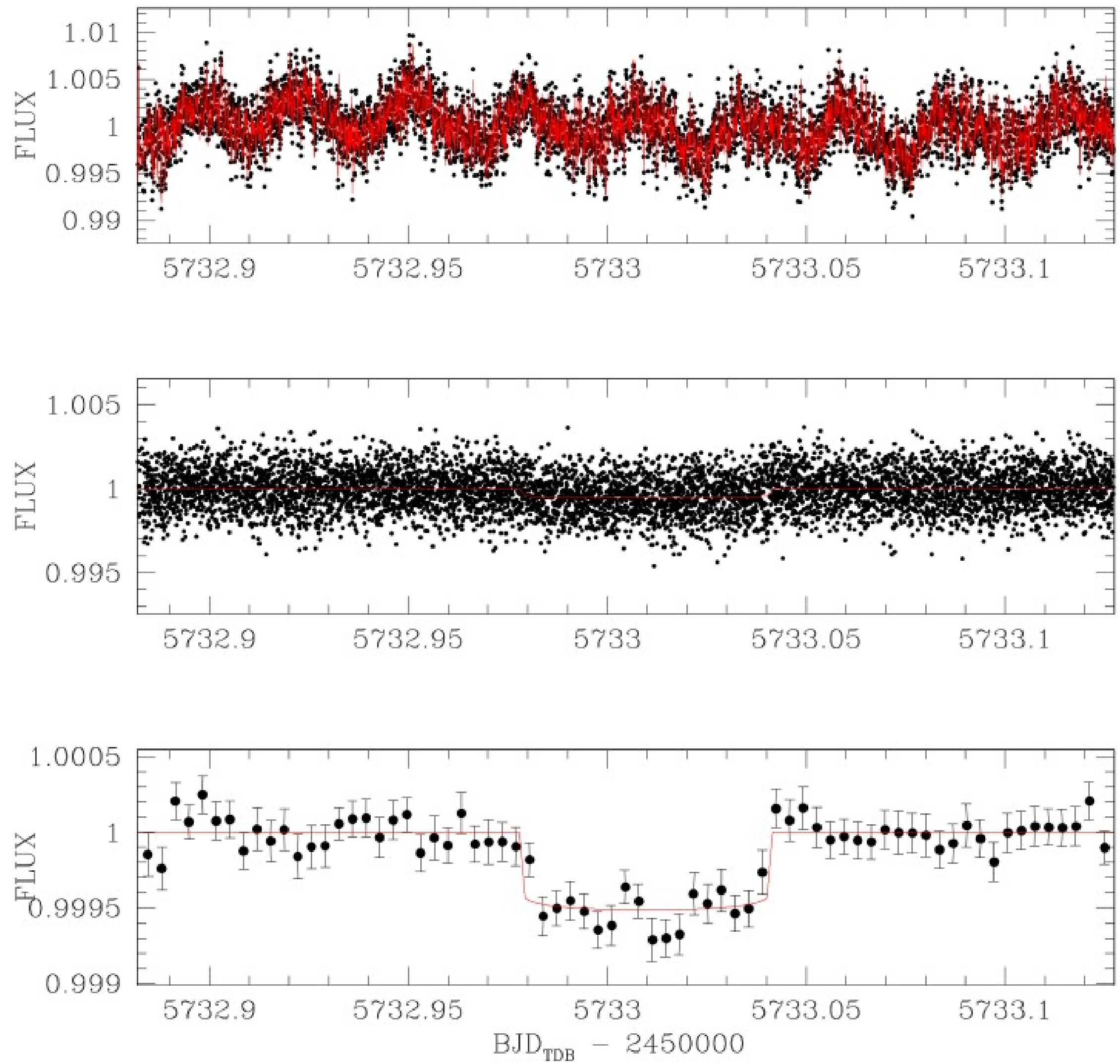


Fig. 2. *Top*: raw light curve for the second transit of 55 Cnc e observed by *Warm Spitzer*, with the best-fit global model superimposed. *Middle*: same light curve after division by the best-fit baseline model, with the best-fit transit model superimposed. *Bottom*: idem after binning per intervals of 5 min.

Direktna svetloba Zemlji podobnih planetov

Accepted to ApJL on April, 6th 2012
Preprint typeset using LaTeX style emulateapj v. 8/13/10

DETECTION OF THERMAL EMISSION FROM A SUPER-EARTH

Brice-Olivier Demory[1], Michaël Gillon[2], Sara Seager[1,3], Bjoern Benneke[1], Drake Deming[4] and Brian Jackson[5]

Accepted to ApJL on April, 6th 2012

ABSTRACT

We report on the detection of infrared light from the super-Earth 55 Cnc e, based on four occultations obtained with *Warm Spitzer* at 4.5 μm. Our data analysis consists of a two-part process. In a first step, we perform individual analyses of each dataset and compare several baseline models to optimally account for the systematics affecting each lightcurve. We apply independent photometric correction techniques, including polynomial detrending and pixel-mapping, that yield consistent results at the 1-σ level. In a second step, we perform a global MCMC analysis including all four datasets, that yields an occultation depth of 131 ± 28 ppm, translating to a brightness temperature of $2360 \pm 300\,K$ in the IRAC-4.5 μm channel. This occultation depth suggests a low Bond albedo coupled to an inefficient heat transport from the planetary dayside to the nightside, or else possibly that the 4.5 μm observations probe atmospheric layers that are hotter than the maximum equilibrium temperature (i.e., a thermal inversion layer or a deep hot layer). The measured occultation phase and duration are consistent with a circular orbit and improves the 3-σ upper limit on 55 Cnc e's orbital eccentricity from 0.25 to 0.06.

Subject headings: planetary systems - stars: individual (55 Cnc, HD 75732) - techniques: photometric

Direktna svetloba Zemlji podobnih planetov

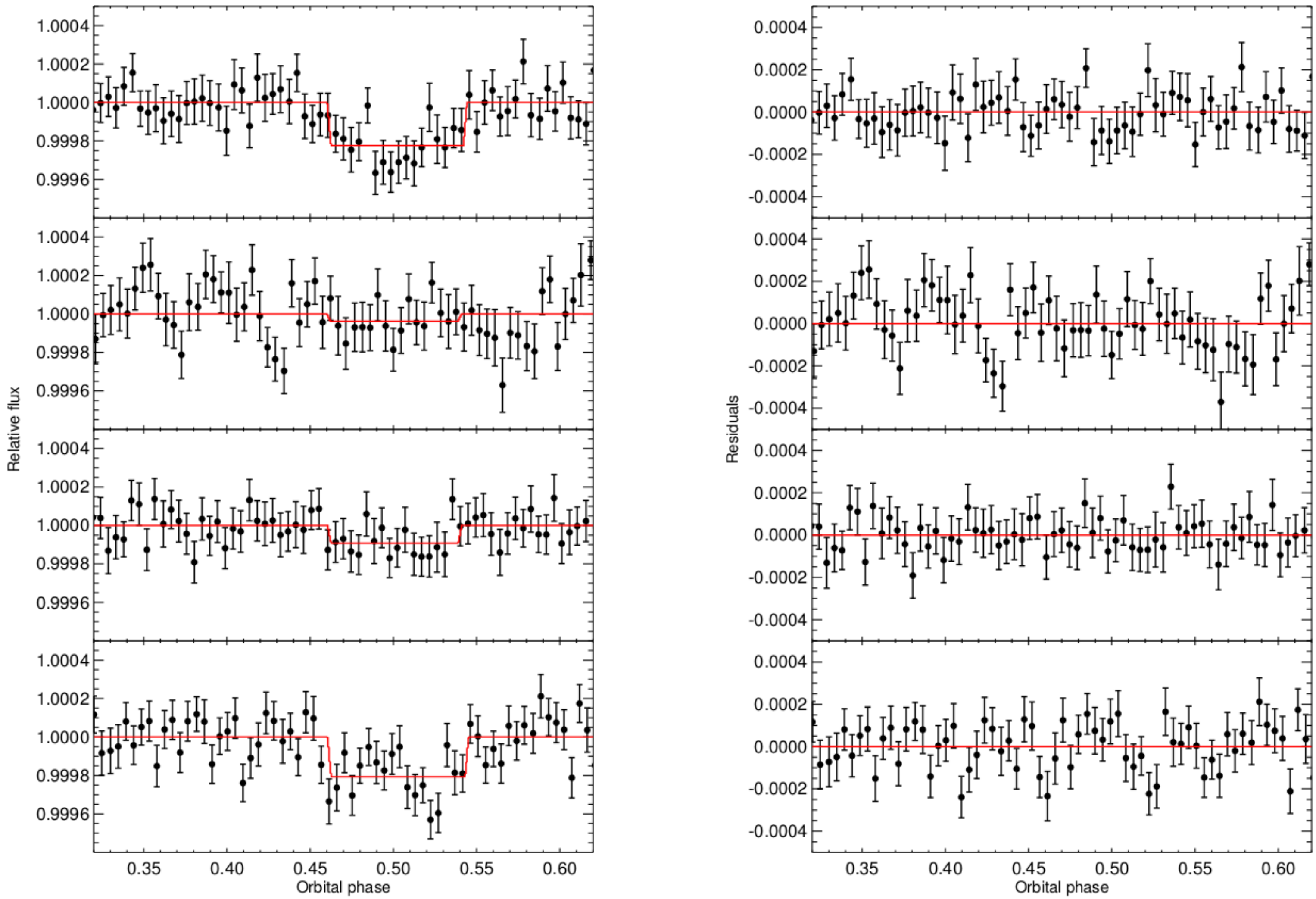
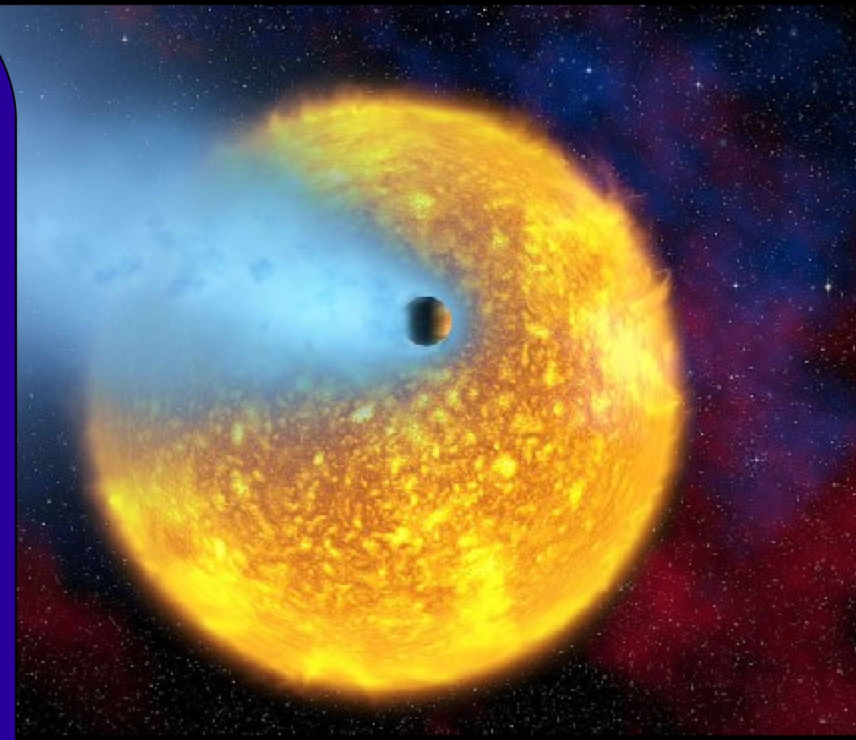


FIG. 2.— Left: lightcurves obtained during the independent analysis of each AOR (see Sect. 3) divided by the best-fit baseline models. Right: residuals for each AOR. AORs are displayed from first (top) to fourth AOR (bottom). Lightcurves are binned per 5 min. Individual detections in each AOR are consistent both in phase and duration.

Planet ob zvezdi HD 209458 ima atmosfero

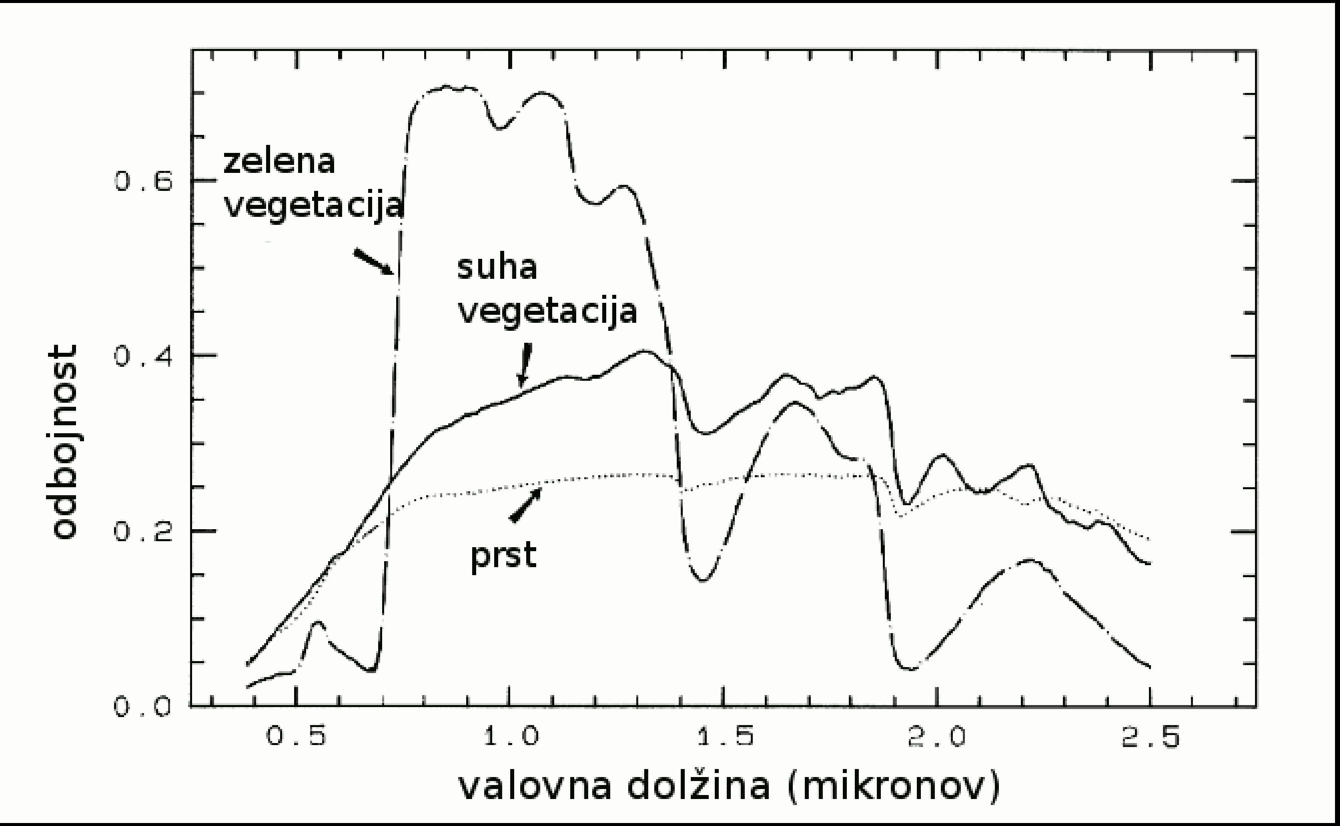
Ob prehodu planeta preko zvezdine ploskvice opazimo poleg geometrijskega pokritja dela zvezde še dodatno absorpcijo zaradi natrija, vodika in ogljika v planetovi atmosferi.

Oddaljenost od Zemlje: 160 sv.l.
masa planeta: $0.7\ M_{Jupiter}$
polmer planeta: $1.5\ R_{Jupiter}$
planet izgublja: $\sim 10^7$ kg/s



Niso (še) odkrili O_2!

Odbita svetloba s planeta: odkrivanje vegetacije



POTREBOVALI BI POLJE 150 3-metrskih TELESKOPOV

Arnold idr. 2009

Are There Other Worlds?

- The debate on the 'Plurality of Worlds' and extraterrestrial life is as old as the earliest written records of Western Thought.
- Over the last 25 Centuries, the viewpoint of Mankind has kept on shifting.

Naslednjih nekaj prosojnic si sposodimo pri dr. Alessandru Sozzetti-ju

The Atomists' View

"In some worlds there is no Sun and Moon, in others they are larger than in our world, and in others more numerous. In some parts there are more worlds, in others fewer (...); There are some worlds devoid of living creatures or plants or any moisture."

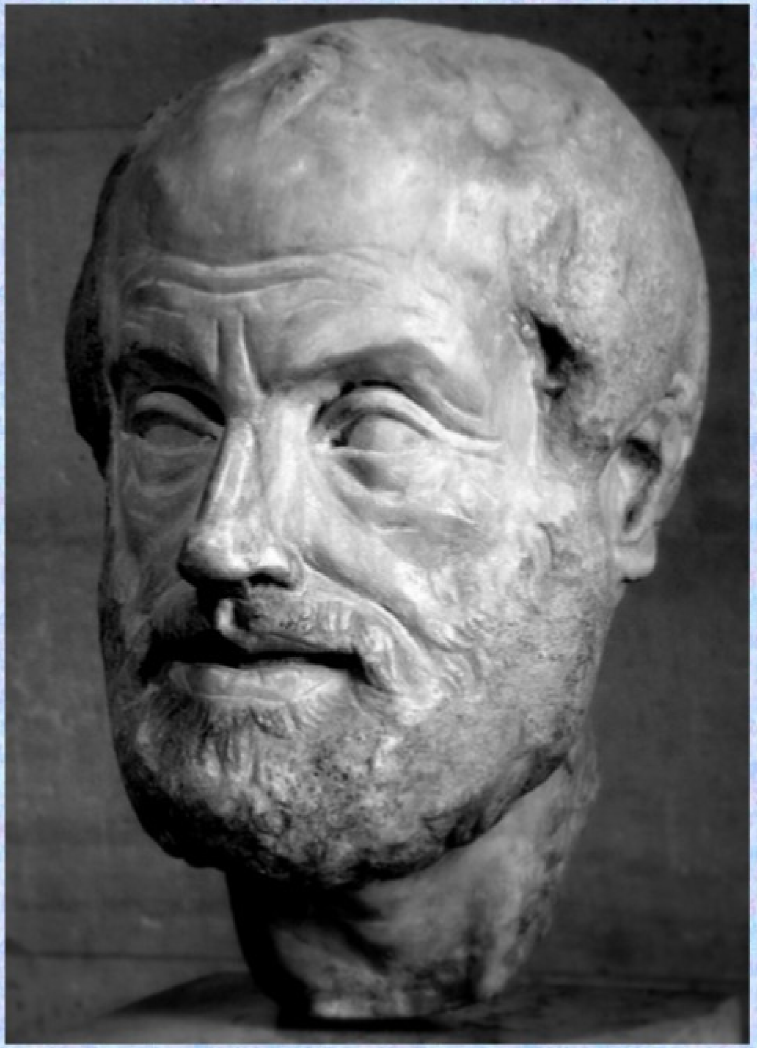
Democritus, ca. 450 B.C.

"There are infinite worlds both like and unlike this world of ours...We must believe that in all worlds there are living creatures and planets and other things we see in this world."

Epicurus, c. 300 B.C

Aristotle's View

"There cannot be more worlds than one."
Aristotle, De Caelo, ca 350 B.C.



Aristotle's world is *geocentric, unchanging,* and *unique*.

He's not very interested in extrasolar planets.

Unfortunately ("Ipse Dixit"), his influential views hold up for about 1500 years!

Early Renaissance

- In 1277, Etienne Tempier, the bishop of Paris, condemned the belief “that the First Cause cannot make many worlds”.
- Ca. 1300, William of Ockham also supported the plurality of worlds

Renaissance Theologians…

- *"As to the question whether Christ by dying on this earth could redeem the inhabitants of another world, I answer that he is able to do this even if the worlds are infinite, but it would not be fitting for Him to go into another world that he must die again".*

  William of Vorilong (ca.1450)

Renaissance Martyrs…

The year 1584

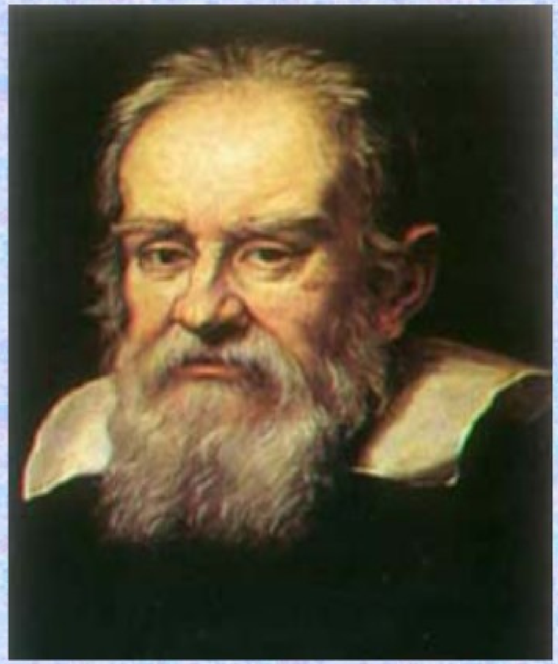
"There are countless suns and countless earths all rotating around their suns in exactly the same way as the seven planets of our system *We see only the suns because they are the largest bodies and are luminous, but their planets remain invisible to us because they are smaller and non-luminous.*

The countless worlds in the universe are no worse and no less inhabited than our Earth"

Giordano Bruno
in De L'infinito
Universo E Mondi

Renaissance Scholars…

"I [regard]…as false and damnable the view (Kepler's) of those who would put inhabitants on Jupiter, Venus, and Saturn, and the moon, meaning by 'inhabitants' animals like ours and men in particular."



Kepler did not believe the stars making up the Milky Way (as discovered by Galileo) are of the same brightness or status as our sun, or that they may have planets.

Kant's View

In 1755 the German philosopher Immanuel Kant suggested that a nebula in slow rotation, gradually pulled together by its own gravitational force and flattened into a spinning disk, gave birth to the Sun and planets.

Or hadn't been Leucippus, ca. 450 B.C.?

"The worlds come into being as follows: many bodies of all sorts and shapes move from the infinite into a great void; they come together there and produce a single whirl, in which, colliding with one another and revolving in all manner of ways, they begin to separate like to like."

And There Comes Fermi…

- In 1950, having lunch at LANL with Teller, suddenly asks: 'Where is everybody?'

- Otherwise put: The size and age of the universe suggest that many technologically advanced extraterrestrial civilizations ought to exist. However, this hypothesis seems inconsistent with the lack of observational evidence to support it.

1960: Drake's Equation

$$N = N^* \times f_p \times n_e \times f_\ell \times f_i \times f_c \times L/T_g$$

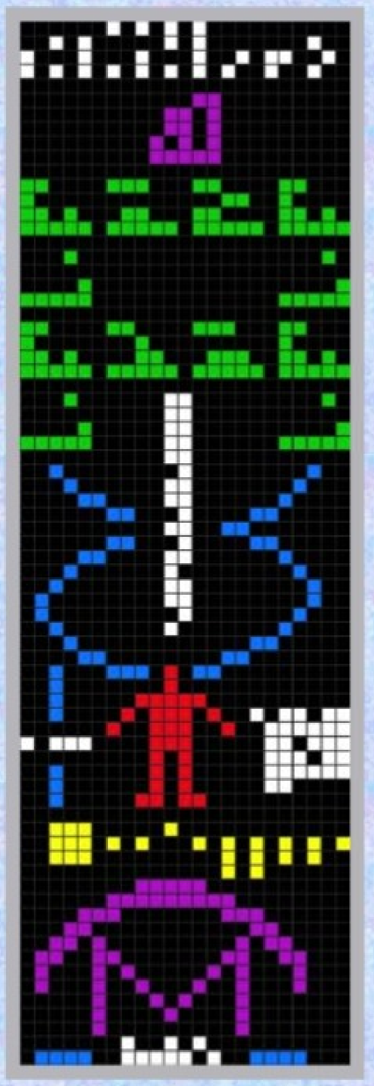
- **N** is the number of civilizations in our galaxy with which we might hope to be able to communicate;
- **N**□ is the total number of stars in our galaxy
- f_p is the fraction of those stars that have planets
- n_e is the average number of planets that can potentially support life per star that has planets
- f_ℓ is the fraction of the above that actually go on to develop life at some point
- f_i is the fraction of the above that actually go on to develop intelligent life
- f_c is the fraction of civilizations that develop a technology that releases detectable signs of their existence into space
- L is the length of time such civilizations release detectable signals into space.
- T_g is the age of the Galaxy

'Not an answer to Fermi's Paradox, rather a way to organize our ignorance of the subject'
(Carl Sagan, 1966)

Anthropic Reasoning Strikes Back

Physicists, biologists, chemists and science fiction writers, theologians…

- **1986:** Barrow & Tipler publish an influential book concluding N << 1 (statistically).
- **1986:** N >> 1, but distance/duration preclude direct contact (Isaac Asimov)
- **2000:** Rare Earth: complex life is uncommon in the Universe (Ward & Brownlee)
- **2002:** Webb analyses 50 solutions to the Fermi Paradox and concludes we're alone in our Galaxy

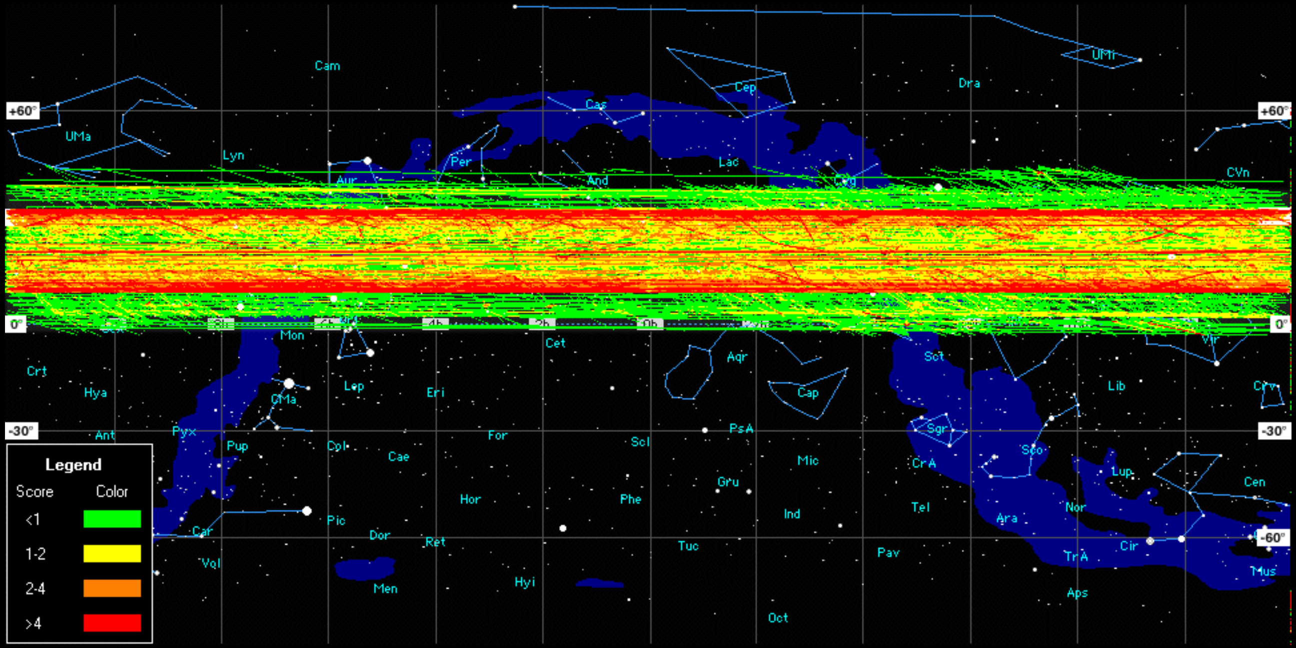


The lecturer's view

- when you're dealing with so little concrete information in such a vastness, it is impossible to be entirely convincing one way or the other (sophistry does not pay!).
- Absence of evidence is not evidence of absence!
- Stick to the observations, and move on from there!

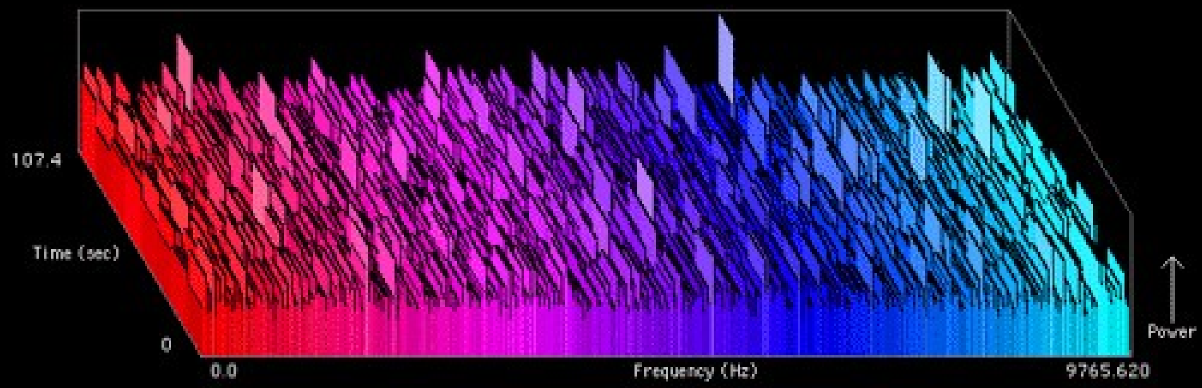
- Življenje na Marsu
  - dosedanje raziskave (Viking, meteorit iz Marsa) so dale negativne, a nepopolne rezultate

- SETI … iskanje inteligentnega življenja
    - detekcija radijskih signalov (Arecibo)



SETI

- analiza radijskih signalov (screensavers)
- preveritev zadetkov (cross-checking)
- identifikacija kandidatov ⇒ zaenkrat še nič



Moderna meglična teorija

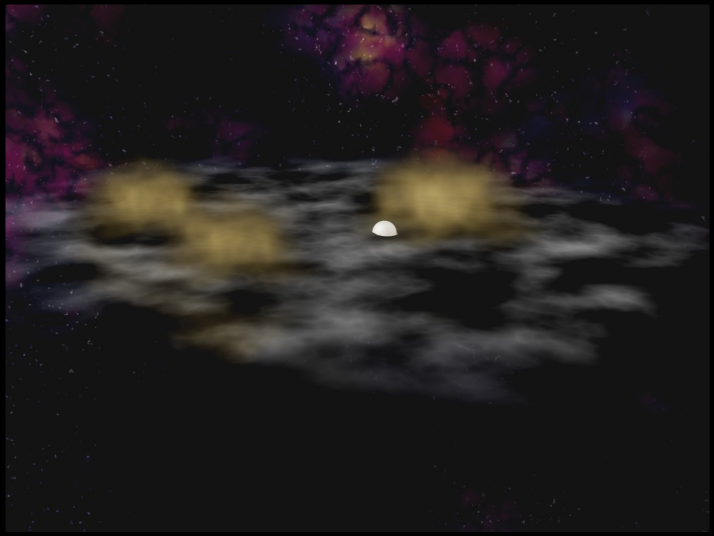
gravitacijski kolaps meglice

- diskasta struktura zaradi vrtenja

- koncentracija mase v središču – protozvezda

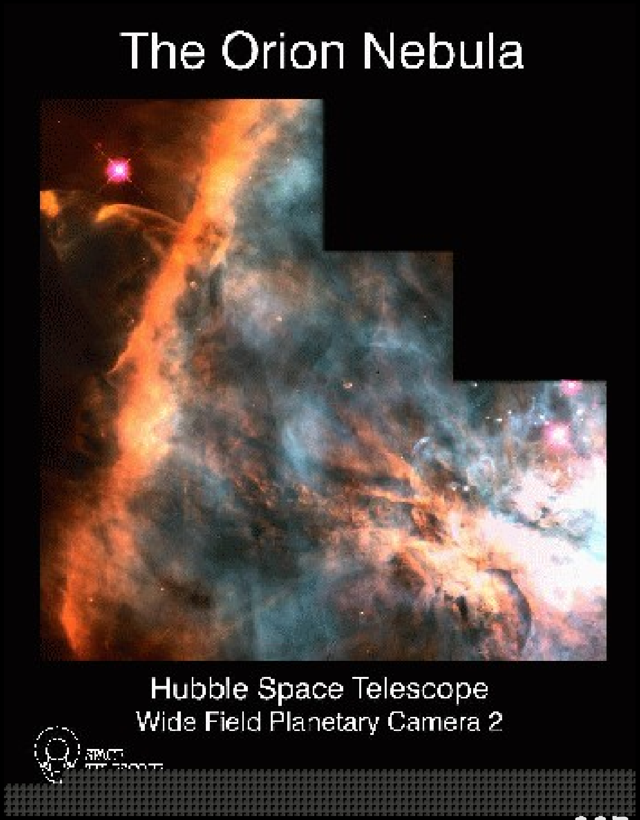
- tanjšanje diska

- lokalne koncentracije snovi v disku - protoplaneti

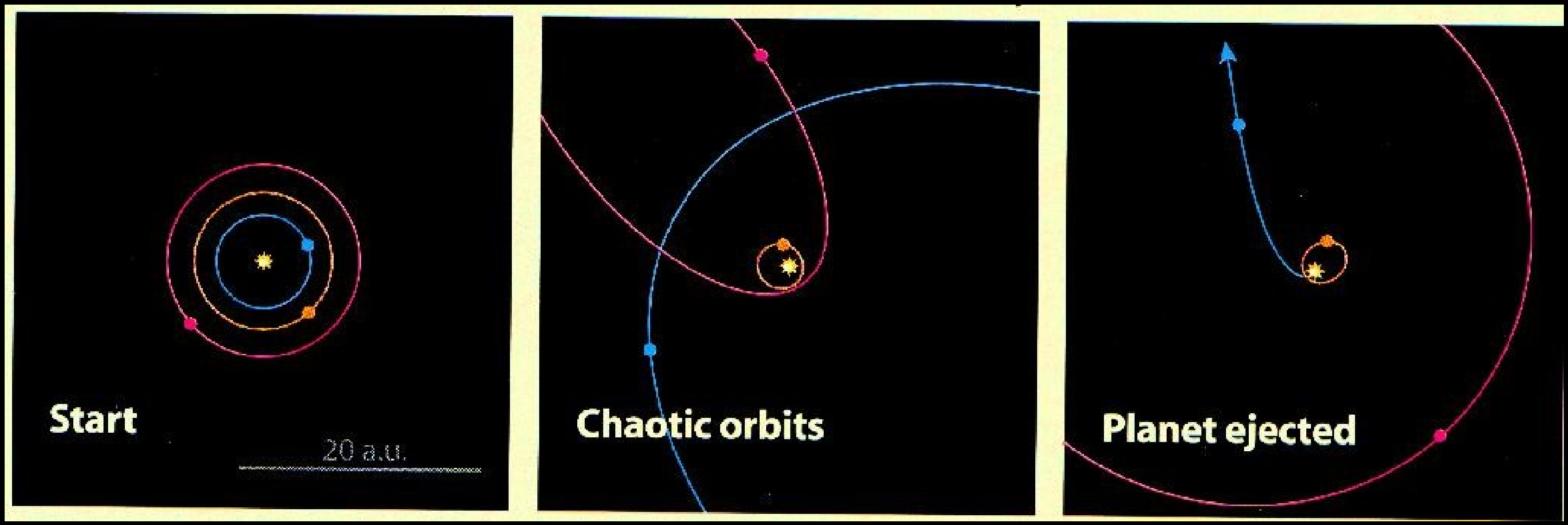


Moderna meglična teorija nastanka Osončja

- medzvezdna snov + galaktični krak + bližnja supernova
  - lokalne nestabilnosti in kolapsi
  - mnogo protozvezd
  - obdajajoči redek plin

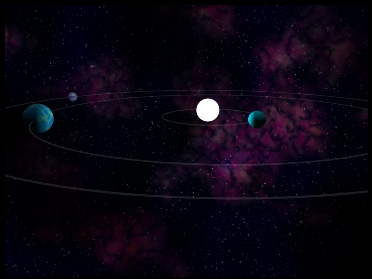


- Sistem treh ali več orjaških planetov
- Ob bližnjih srečanjih medsebojne gravitacjske motnje
- Nekateri zletijo ven, tirnice ostalih postanejo močno ekscentrične



- Druge razlage velike ekscentričnosti:
  - Gravitacijske motnje mimoidoče zvezde
  - Gravitacijske motnje protoplanetarnega diska
  - Gravitacijske motnje zvezde spremljevalke
- Krožne tirnice planetov v našem Osončju niso naključje!
  - Če Jupiter ne bi imel krožne tirnice, Zemlje in Marsa danes ne bi bilo v Osončju
  - V sistemih, kjer imajo orjaški planeti močno ekscentrične orbite, ni malih planetov

Moderna meglična teorija



- splošnost teorije
  - medzvezdne meglice in supernove so "pogosti" pojavi
  - pogostost "našega" planetnega sistema (pravi začetni pogoji), vsaka 10^5 zvezda ?
  - pogostejši sistemi: zvezda + 1 (nekaj) orjaških planetov
  - kmalu možnost preveritve

Nastanek zvezde je dokaj buren proces

UK Astrophysical Fluids facility:
The Formation of Stars and Brown Dwarfs
and the Truncation of Protoplanetary Discs in a Star Cluster

Zvezda HO Tehtnice

Basic data :

V* HO Lib -- Variable Star

query around with radius 10 arcmin

Other object types: * (BD,GCRV,GEN#,G,GJ,GSC,HIC,HIP,JP11,LPM,MCC,8pc,PLX,UBV,Wolf,Zkh,[RHG95]) , PM* (Ci,LFT,LHS,LTT,NLTT) , V* (V*,NSV)

ICRS coord. (ep=2000 eq=2000) : 15 19 26.8250 -07 43 20.209 (~Unknown) [27.21 14.51 77] A 1997A&A...323L..49P

FK5 coord. (ep=2000 eq=2000) : 15 19 26.825 -07 43 20.21 (~Unknown) [27.21 14.51 77] A 1997A&A...323L..49P

FK4 coord. (ep=1950 eq=1950) : 15 16 50.36 -07 32 24.9 (~Unknown) [158.85 85.25 76] A 1997A&A...323L..49P

Gal coord. (ep=2000 eq=2000) : 354.0776 +40.0187 (~Unknown) [27.21 14.51 77] A 1997A&A...323L..49P

Proper motions *mas/yr* [error ellipse]: -1224.55 -99.51 A [3.13 1.68 76] 1997A&A...323L..49P

Radial velocity / Redshift / cz : km/s -9.5 [0.5] / z -0.000032 [0.000002] / cz -9.50 [0.50] D 2001MNRAS.328...45M

Parallaxes *mas*: 159.52 [2.27] A 1997A&A...323L..49P

Spectral type: M3

Fluxes (2) :

B 12.17 [~] D ~

V 10.56 [~] D ~

essential notes:

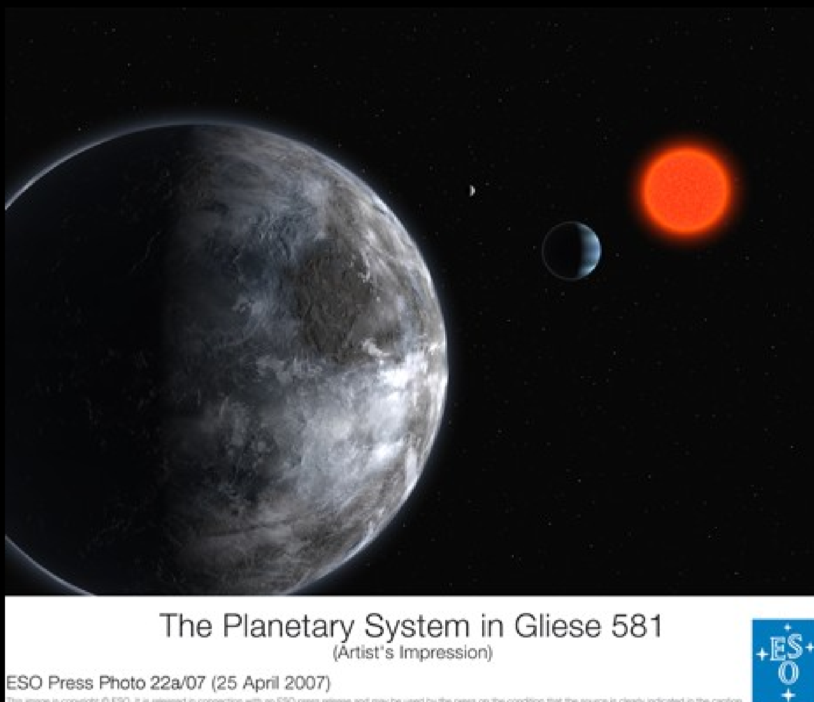
- possible super-earth companion detected, see Gl 581c in the Extrasolar Planets Encyclopaedia [*27-Apr-2007*].
- A substellar companion GJ 581b discovered by Bonfils et al.(astro-ph/0509211), see also Gl 581 in the Extrasolar Planets Encyclopaedia. [*08-Oct-2005*]

Identifiers (26) :

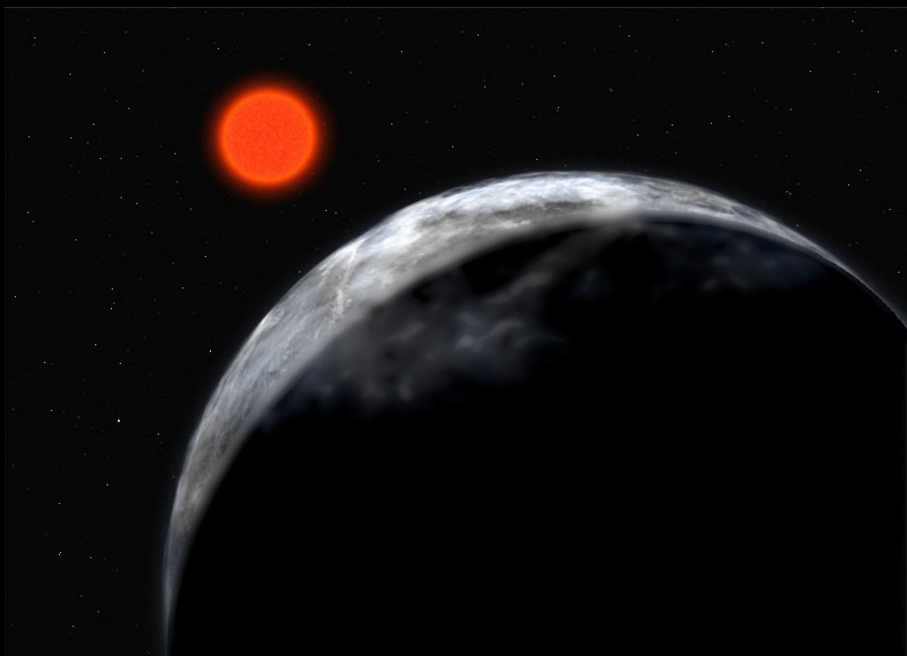
V* HO Lib	GJ 581	LPM 564	UBV M 5243
BD-07 4003	GSC 05594-00593	LTT 6112	UBV 13194
Ci 20 923	HIC 74995	MCC 159	Wolf 562
GCRV 8863	HIP 74995	NLTT 39886	[illegible]
GEN# -0.00704003	JP11 273	[illegible]	[illegible]
G 152-9	LFT 1195		
G 151-46	LHS 394		

Podatkovna baza Simbad

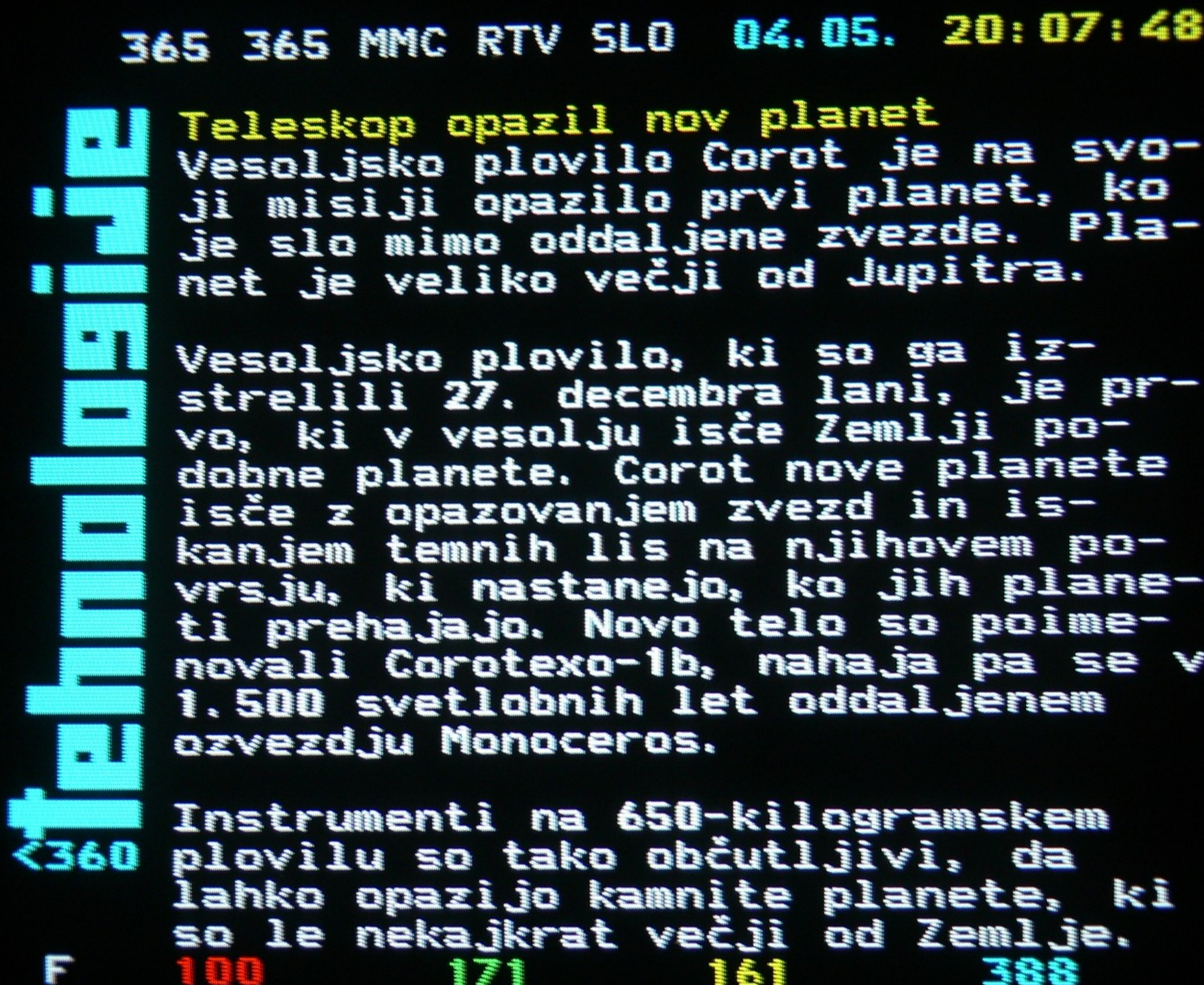
ESO Press Release



Popravljen ESO Press Release



CoRoT


365 365 MMC RTV SLO 04.05. 20:07:48

tehnologije

Teleskop opazil nov planet

Vesoljsko plovilo Corot je na svoji misiji opazilo prvi planet, ko je šlo mimo oddaljene zvezde. Planet je veliko večji od Jupitra.

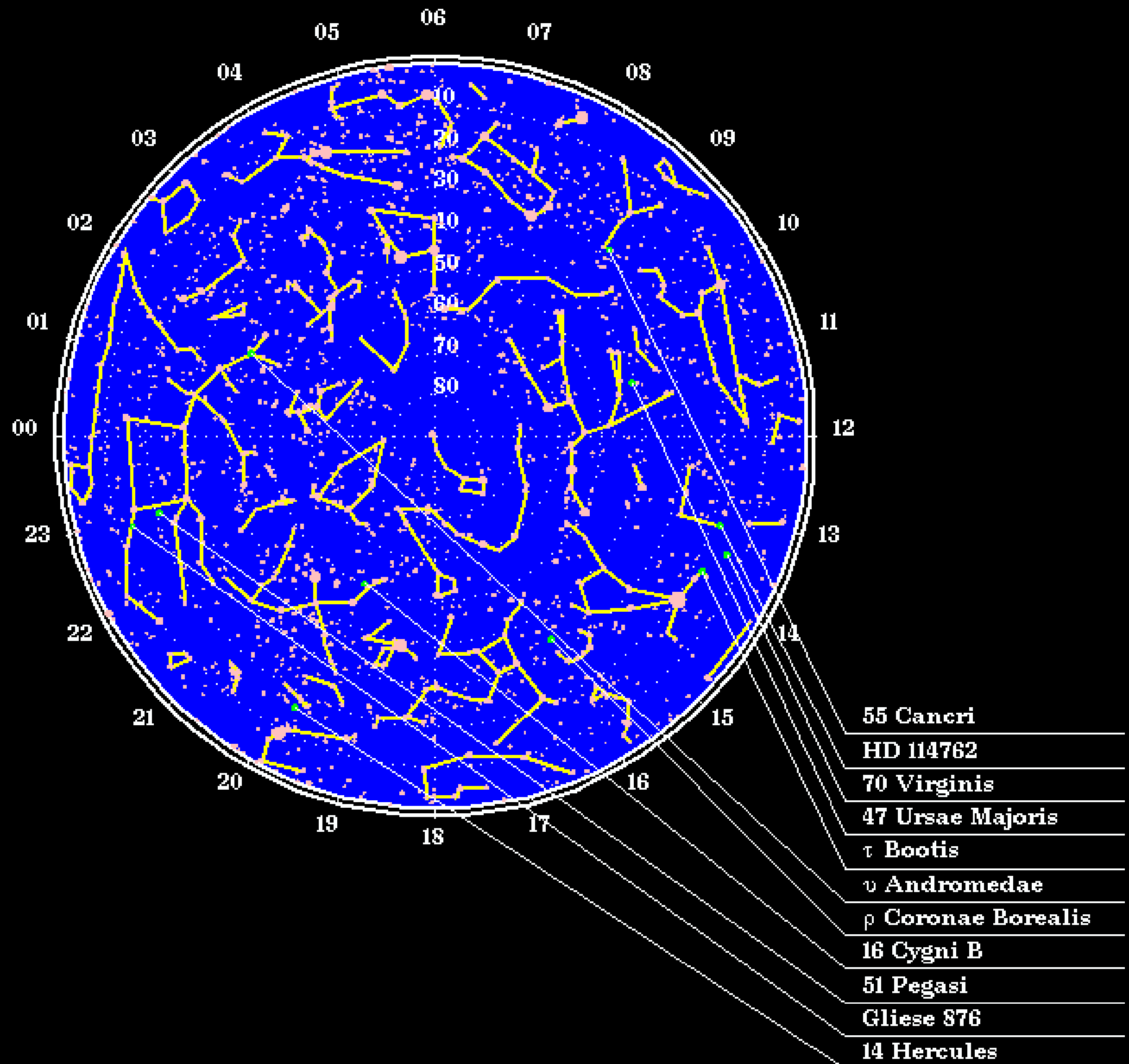
Vesoljsko plovilo, ki so ga izstrelili 27. decembra lani, je prvo, ki v vesolju išče Zemlji podobne planete. Corot nove planete išče z opazovanjem zvezd in iskanjem temnih lis na njihovem površju, ki nastanejo, ko jih planeti prehajajo. Novo telo so poimenovali Corotexo-1b, nahaja pa se v 1.500 svetlobnih let oddaljenem ozvezdju Monoceros.

Instrumenti na 650-kilogramskem plovilu so tako občutljivi, da lahko opazijo kamnite planete, ki so le nekajkrat večji od Zemlje.

<360

F 100 171 161 388

They are everywhere!



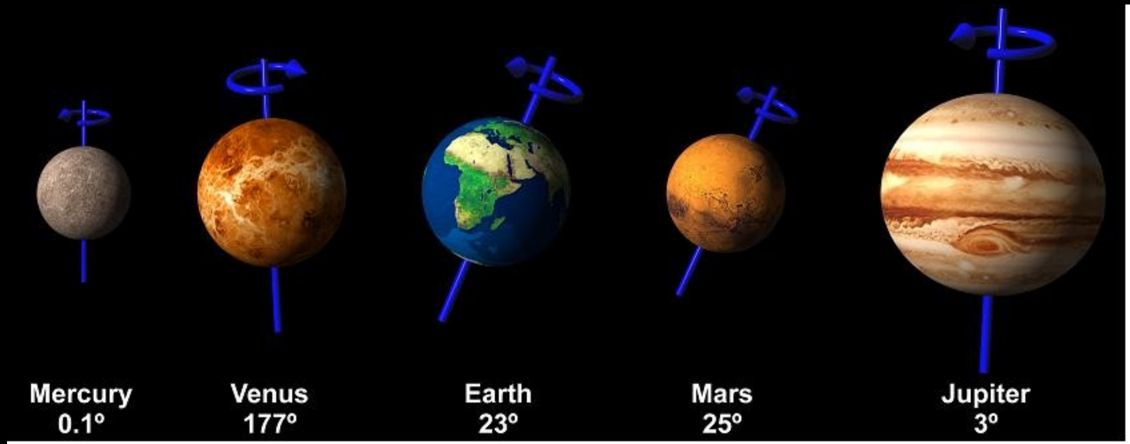
S.G. Korzennik (CfA, © 1997,1998)

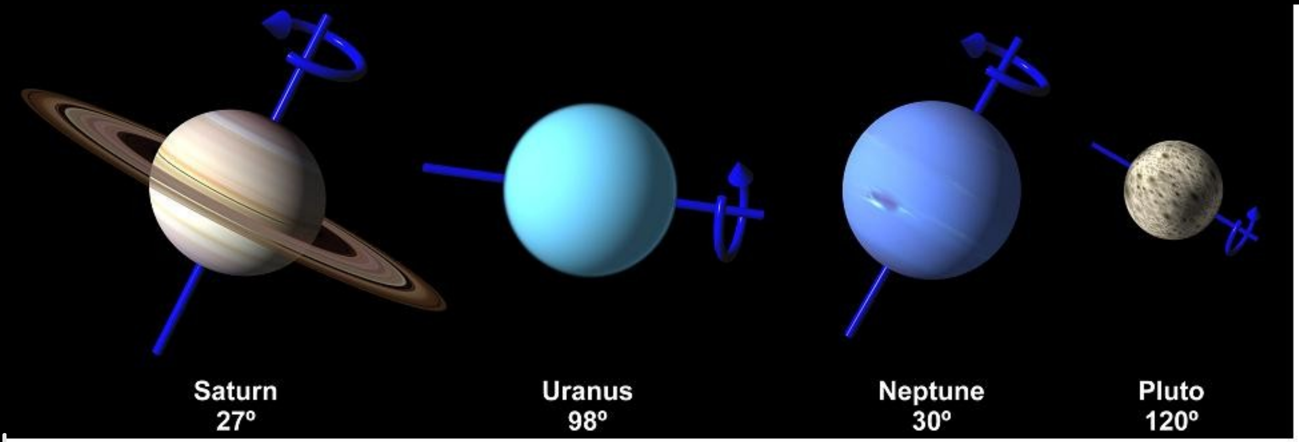
Planeti okoli drugih sonc

Definicija planeta?
(veliko zgodovine)

	Oddaljenost (AE)	Nagib tirnice	Ekscentričnost tirnice	Nagib osi rotacije
Merkur	0.39	7	0.206	0.1°
Venera	0.72	3.4	0.007	177.4°
Zemlja	1.0	0.0	0.017	23.45°
Mars	1.5	1.9	0.093	25.19°
Jupiter	5.2	1.3	0.048	3.12°
Saturn	9.5	2.5	0.056	26.73°
Uran	19.2	0.8	0.046	97.86°
Neptun	30.1	1.8	0.010	29.56°
Pluton	39.5	17.2	0.248	119.6°

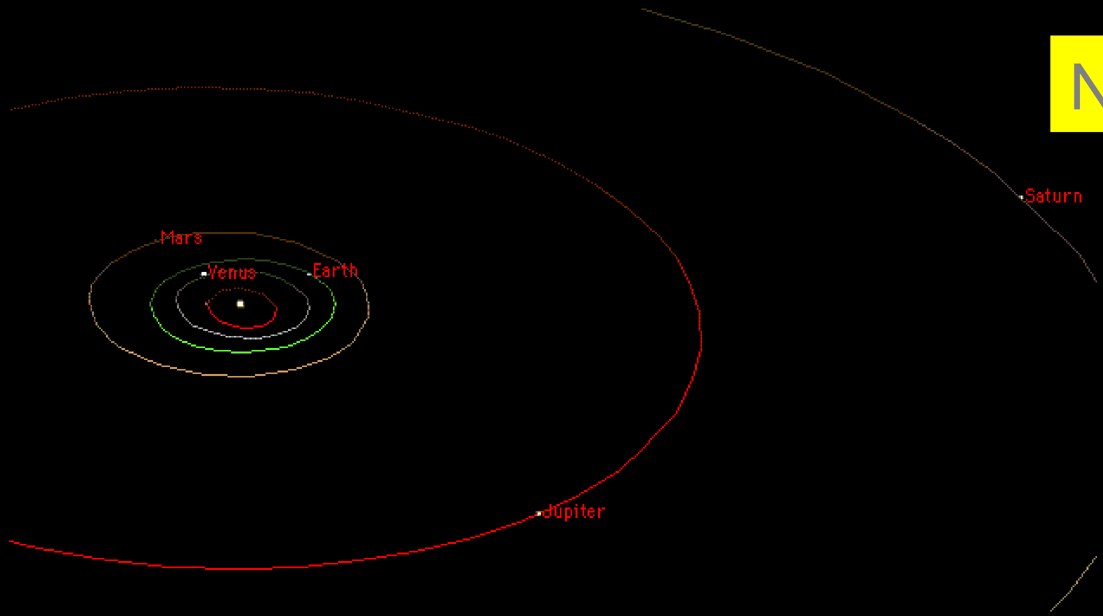
- Nagibi tirnic:

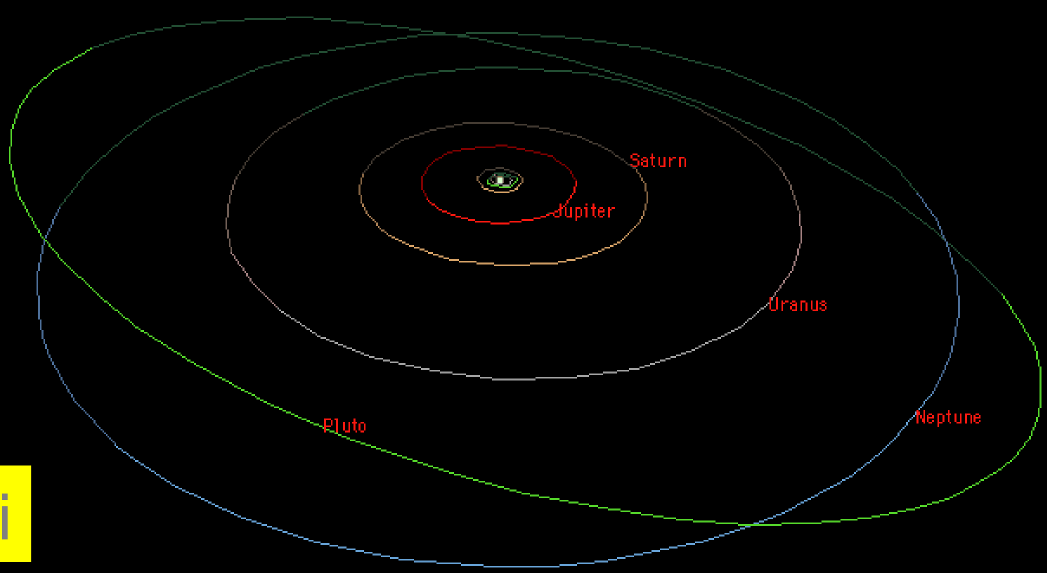




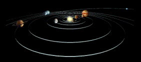
Pl

Notranji planeti





Zunanji planeti



Planeti okoli drug

Velika vprašanja

- Izvor Osončja?
- Pogostost planetnih sistemov?
- Pogostost zemeljskih planetov?
- Življenje še kje v Osončju? Zakaj je Zemlja izjema?
- Je življenje še kje v vesolju? Izjema ali pravilo? Inteligentno življenje?

Hvala za pozornost!