

Planeti

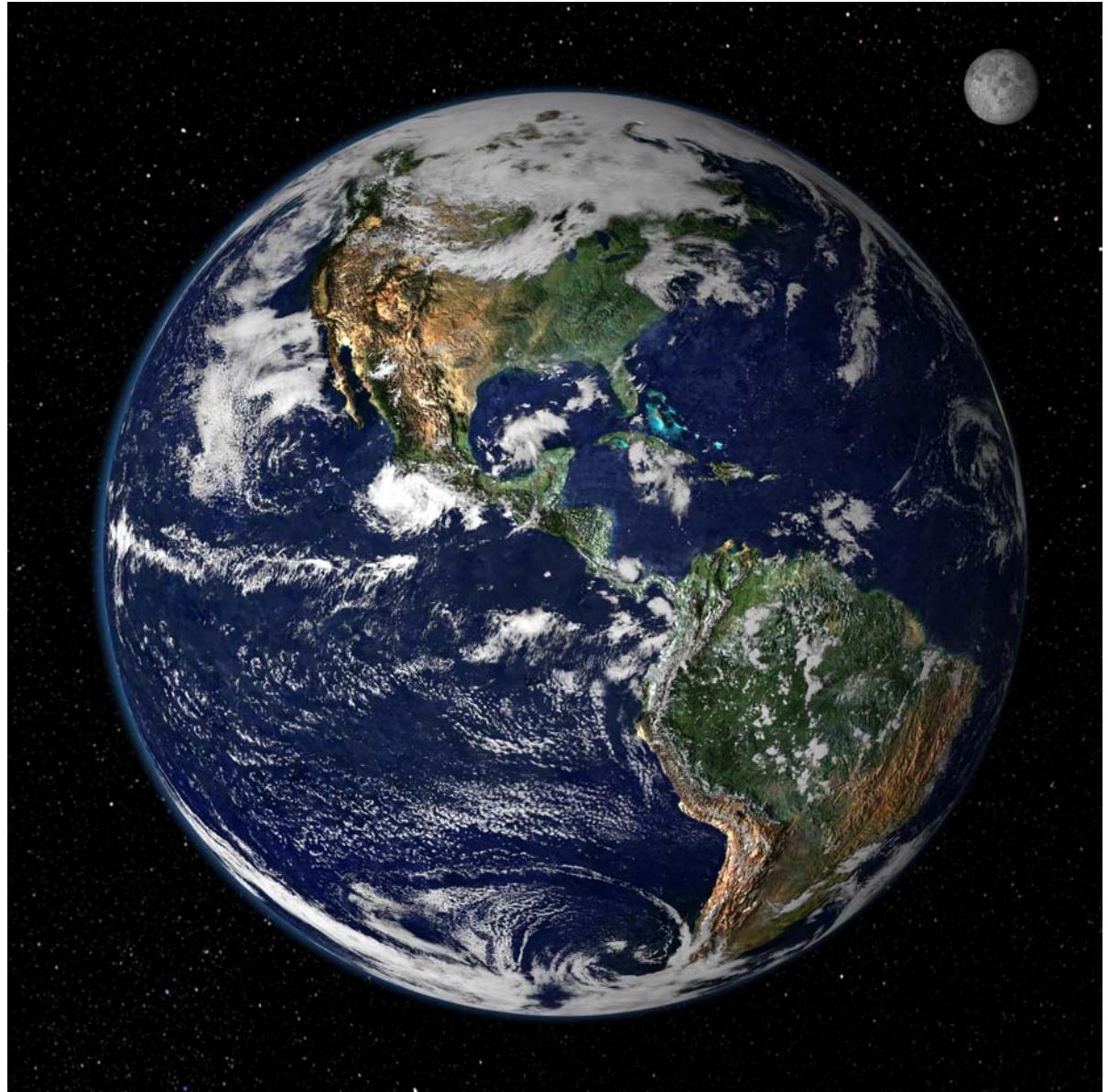
Andreja Gomboc

Fakulteta za matematiko in fiziko

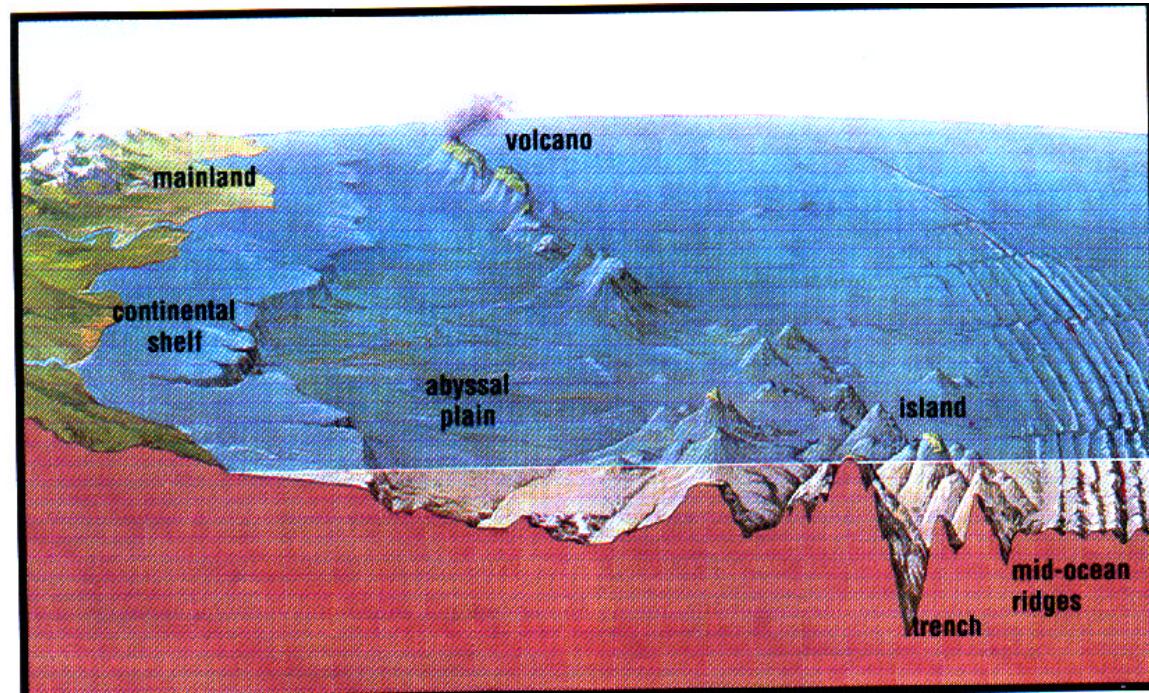
Univerza v Ljubljani

Ljubljana, 17. oktober 2008

Zemlja



■ relief



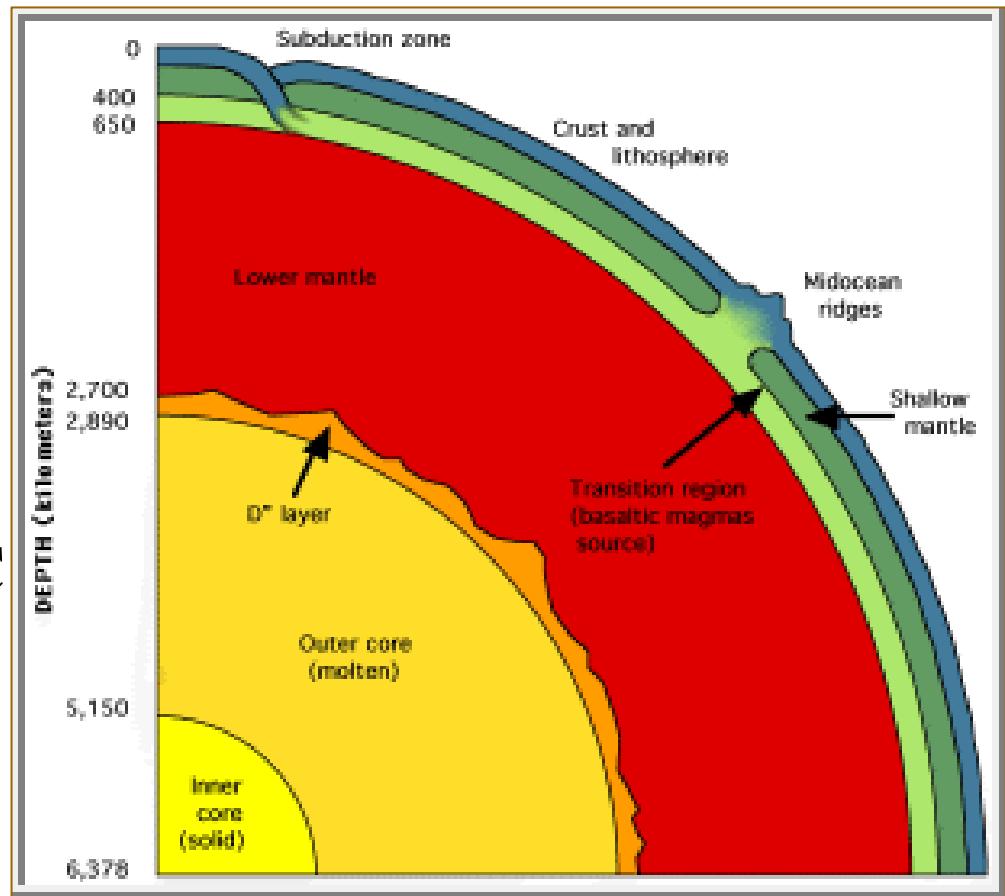
- najvišji vrh 8,8 km
- najglobje brezno 11km

Zgradba

debelina skorje! 22° C

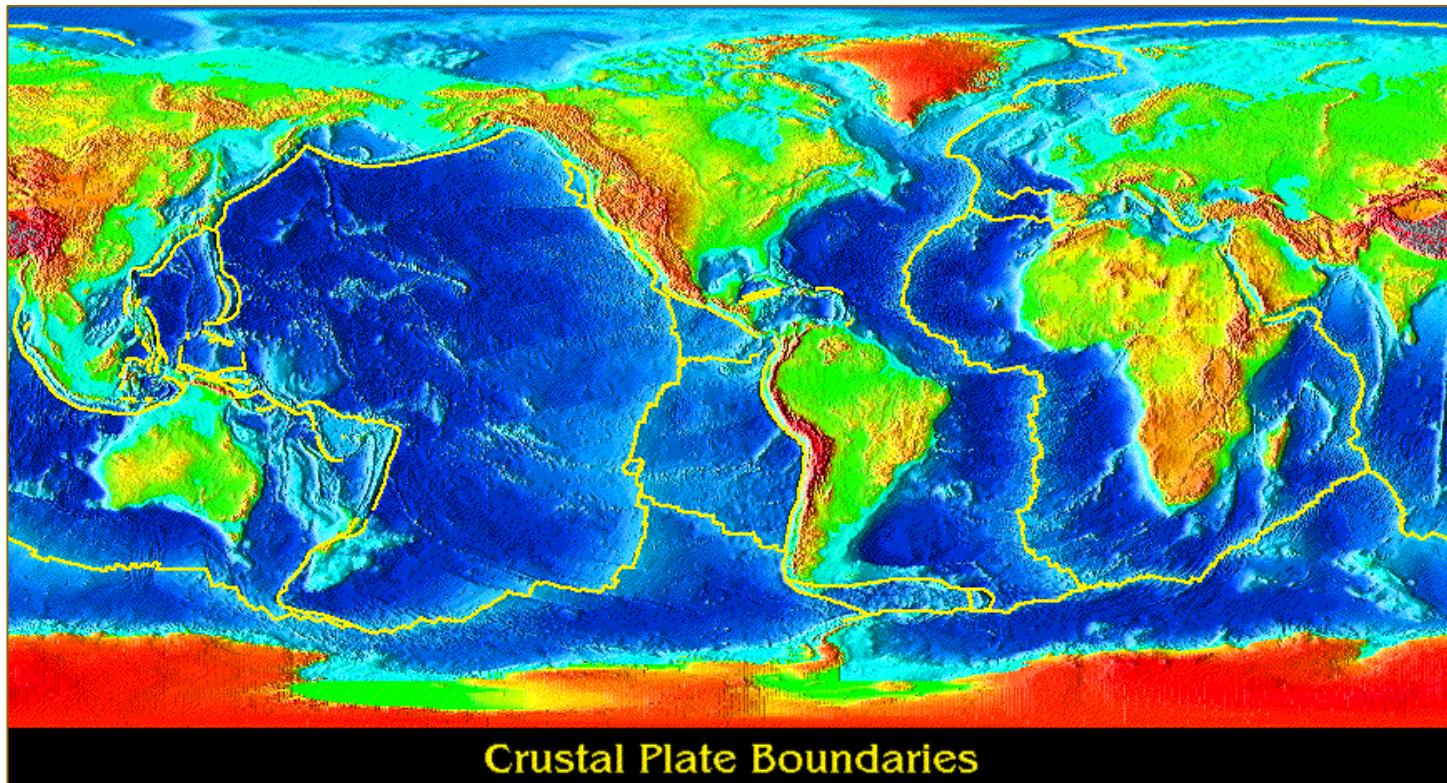
$1500^\circ \text{ C} - 3000^\circ \text{ C}$

4000° C

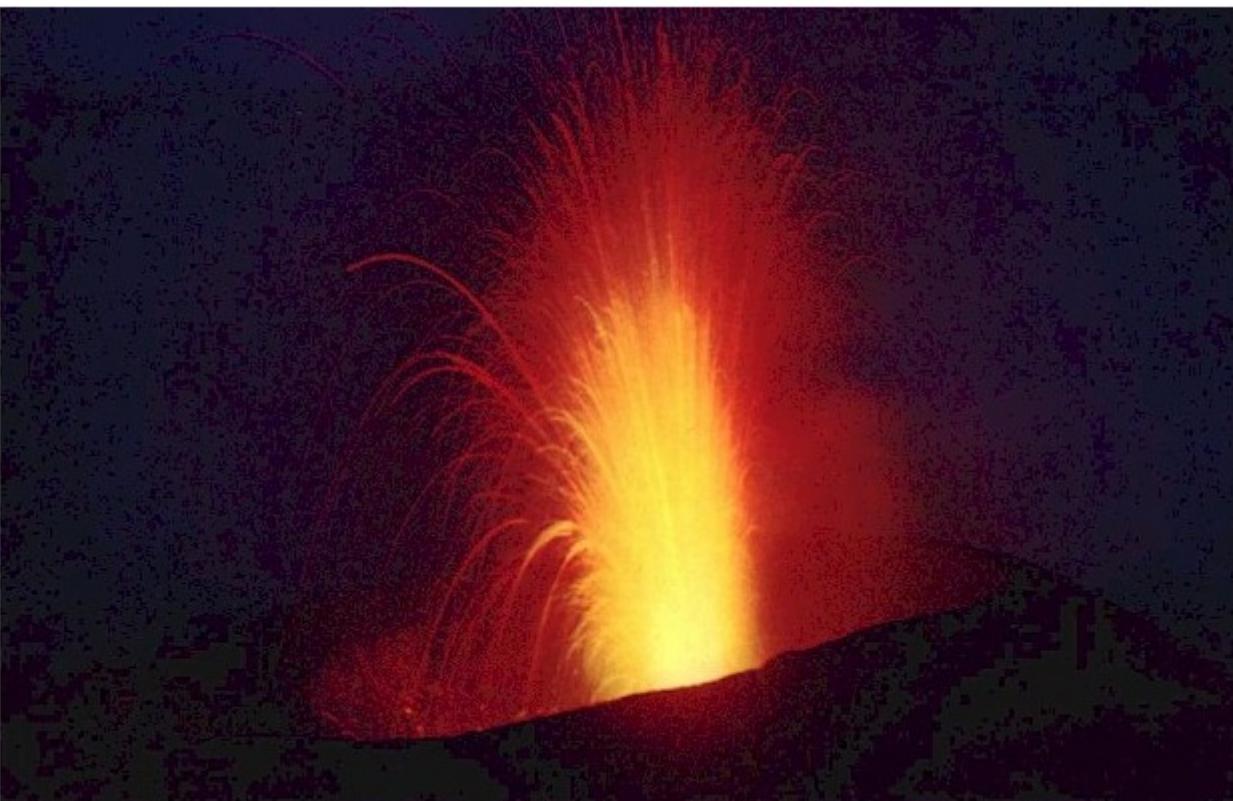


procesi oblikovanja površja

- premiki tektonskih plošč



■ vulkani



■ udarni kraterji

film

(Vir: <http://www.meteorcrater.com/>)



50.000 let, 60.000 km/h, 45 m, 100 tisoč ton, 1,2 km, 200 m

■ erozija (atmosfera in tekoča voda)

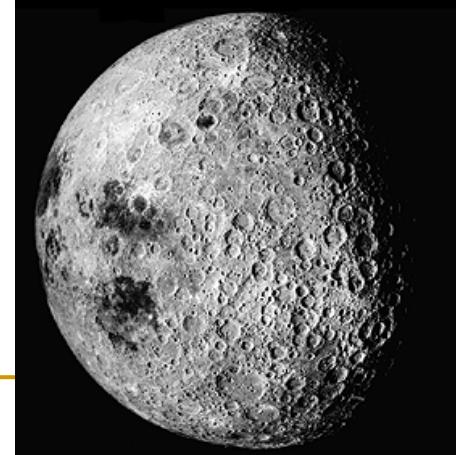


- površje Zemlje
mlado

(udarni kraterji na Zemljji)



- primerjava z reliefom Lune – staro površje



starost Zemlje

- nastanek in starost Osončja
- določanje starosti z radioaktivnimi razpadi



$$N(^{238}\text{U}) + N(^{206}\text{Pb}) = \text{konst.}$$

$[^{206}\text{Pb}] / [^{204}\text{Pb}]$ iz neradioakt. kamnin * $[^{204}\text{Pb}]$ v radioakt. kam.

$\rightarrow [^{206}\text{Pb}]$ v začetku

okrog 4 milijarde let

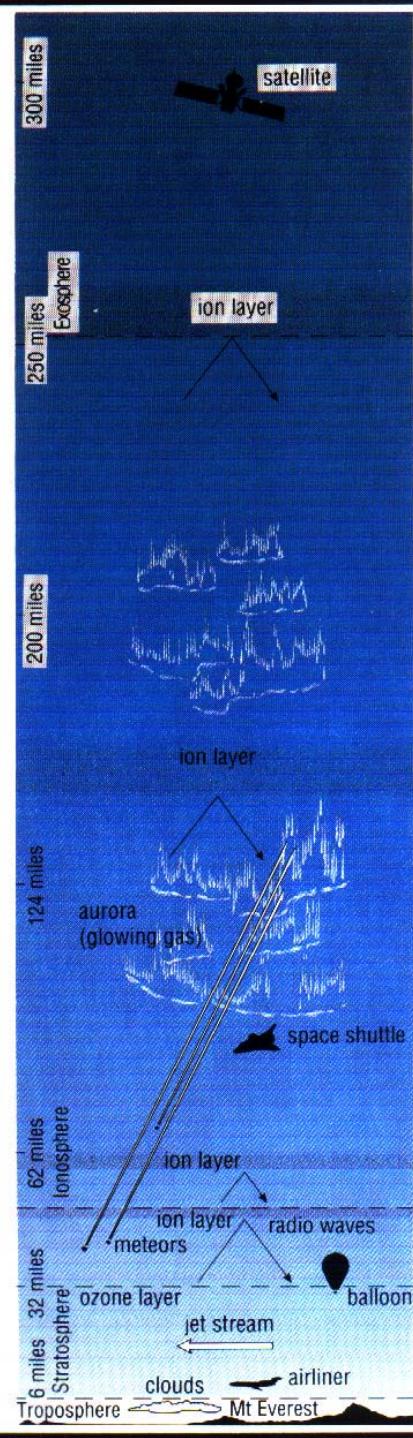
Zemlja kot planet Življenja

- morja
 - pokrivajo 71% površine
 - 97% vse vode
- vir kisika –
70% kisika proizvedejo
mikroorganizmi v morju



Zemlja kot planet Življenja

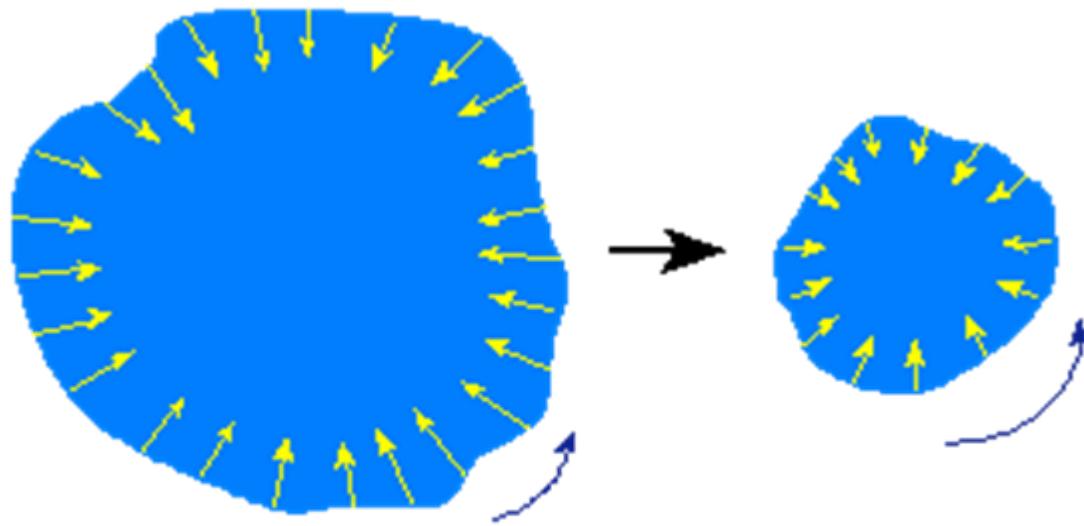
- atmosfera
 - primerna masa planeta
 - primerna oddaljenost od Sonca
 - padavine, vetrovi (površje)
- vloga atmosfere za razvoj življenja



vpliv človeka

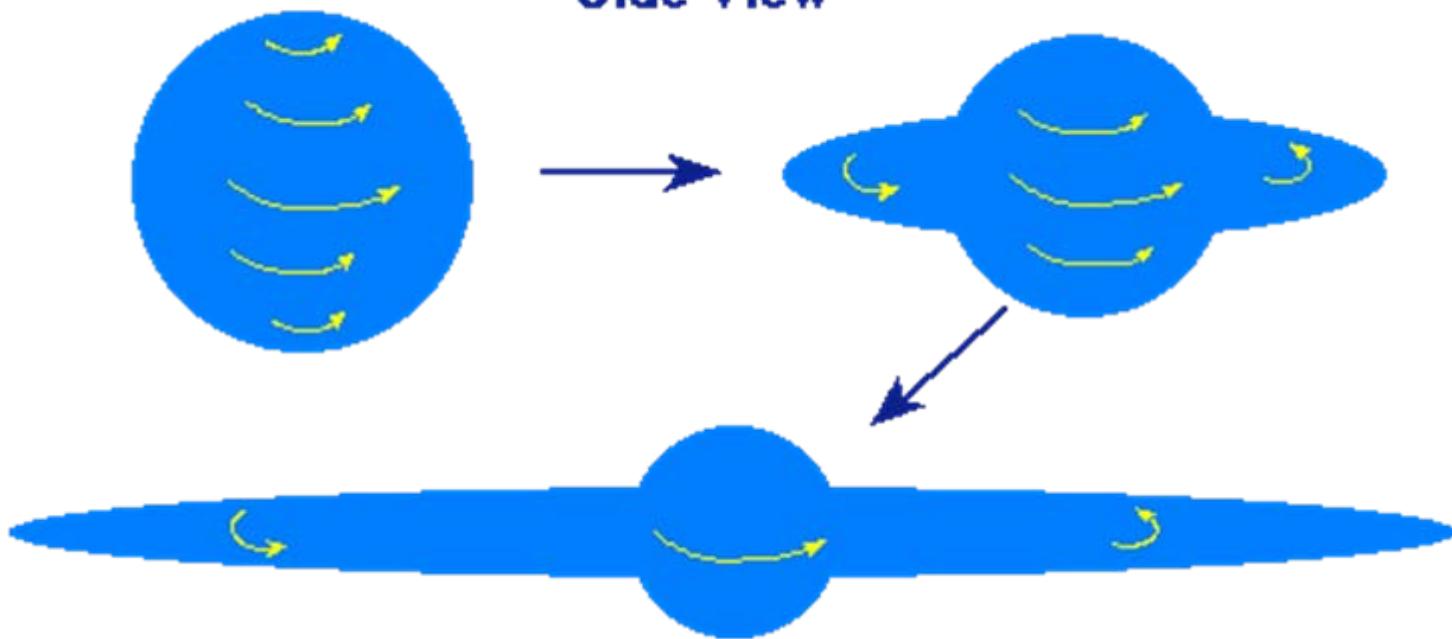


nastanek Osončja



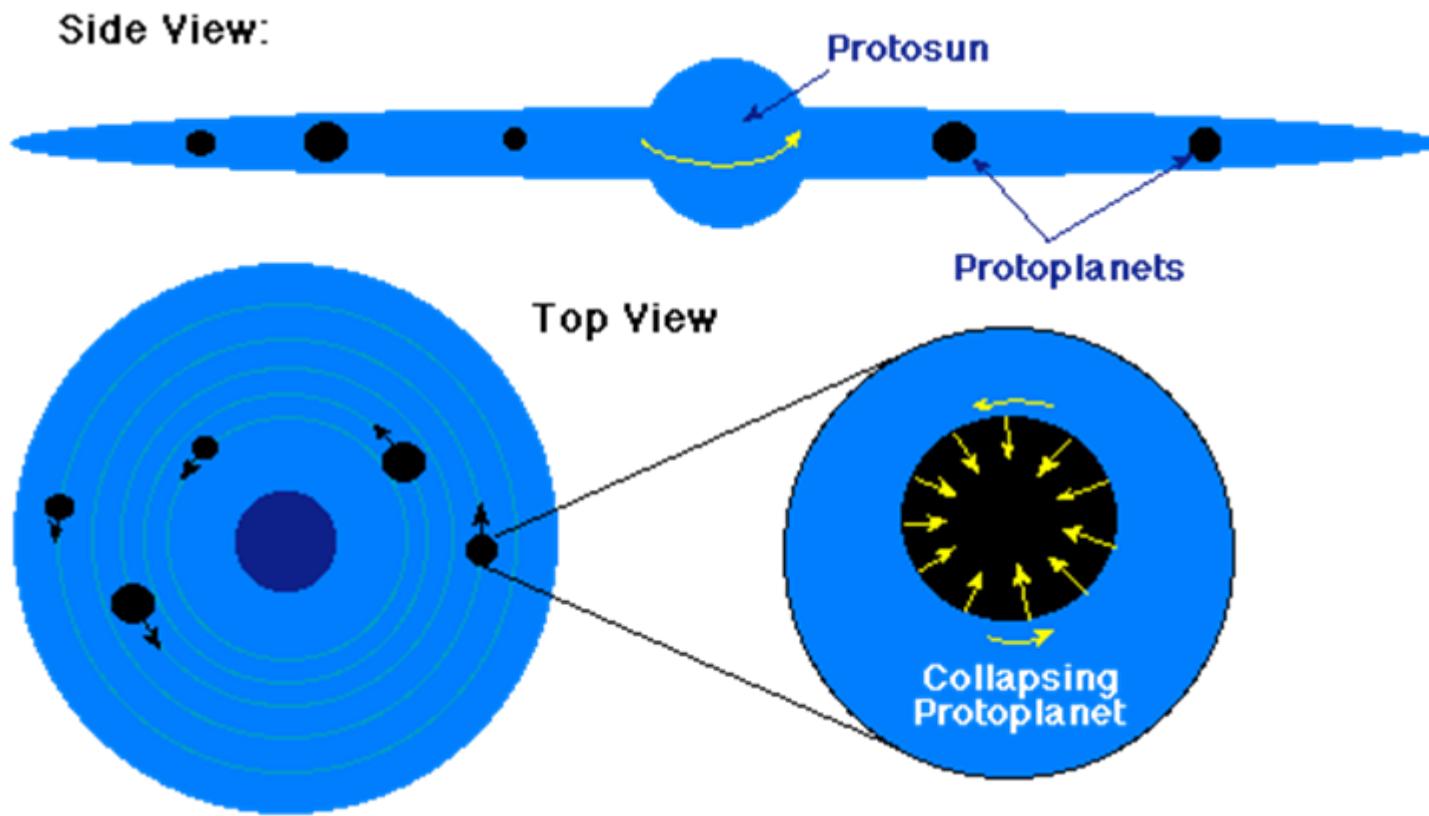
The cloud spins more rapidly as it collapses because of conservation of angular momentum

Side View

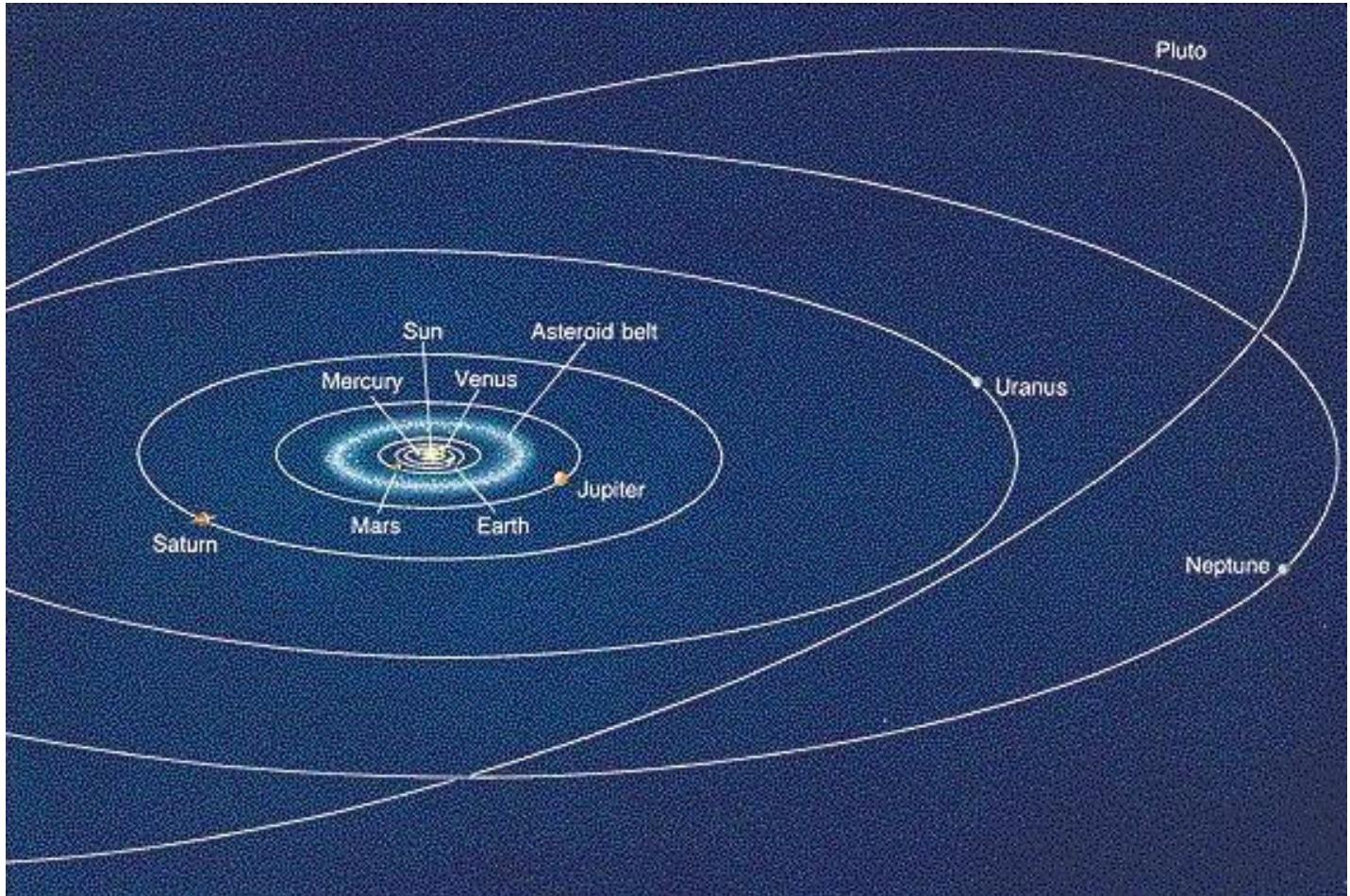


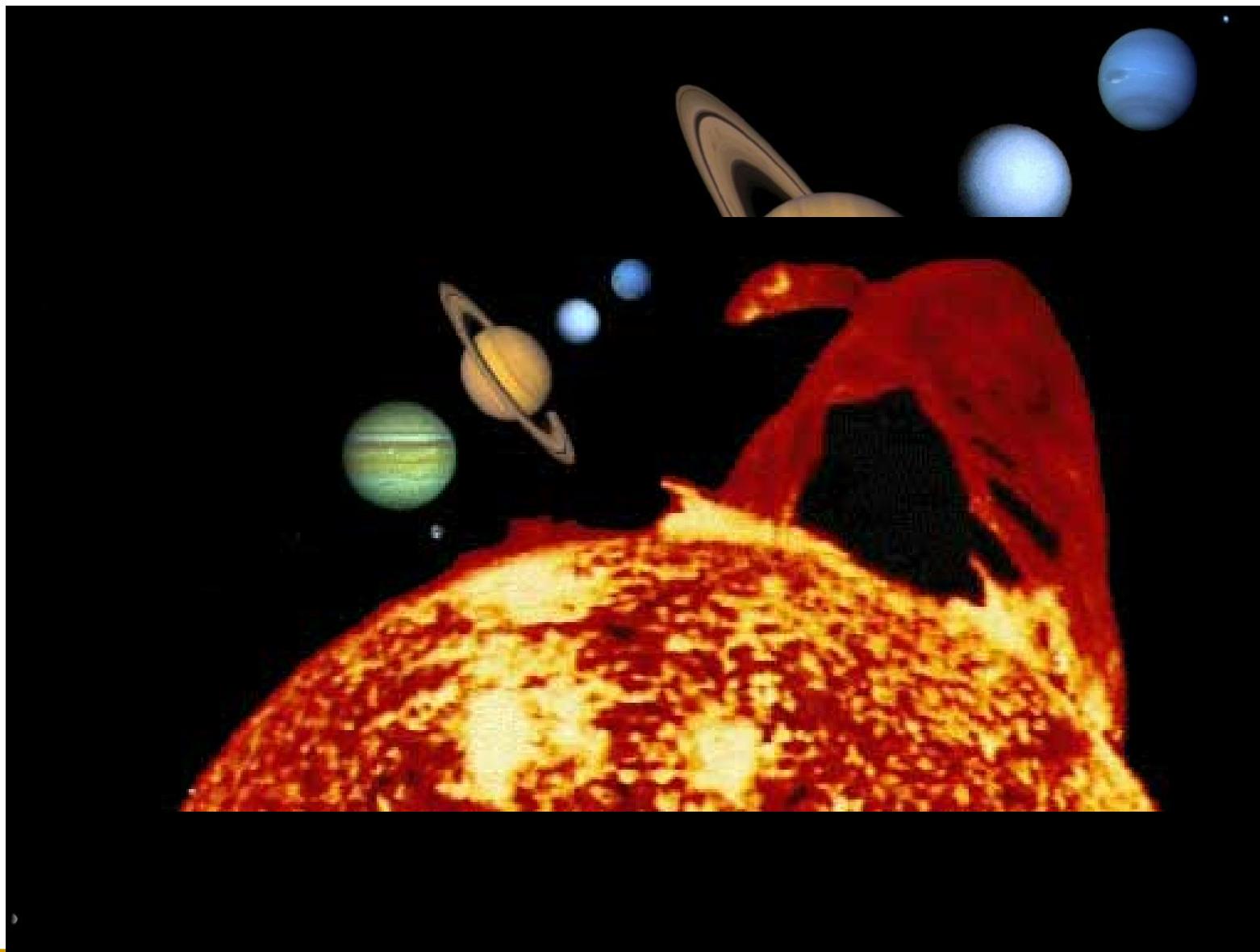
film

film2

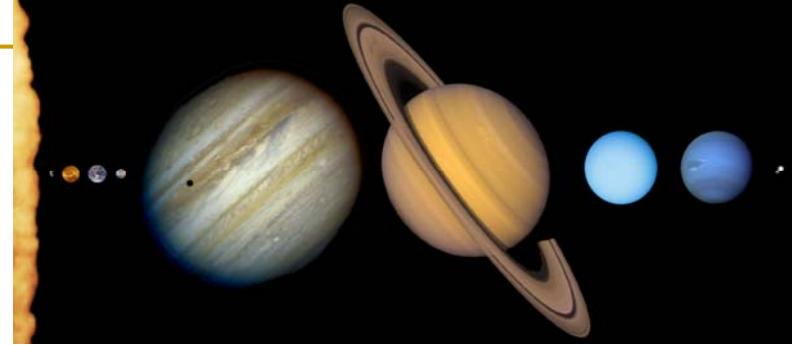


Naše Osončje





elitev planetov



- **velikost:** majhni (Merkur, Venera, Zemlja, Mars, Pluton < 13.000 km)
veliki (Jupiter, Saturn, Uran, Neptun > 48.000 km).
- **oddaljenost od Sonca:** notranji (Merkur, Venera, Zemlja, Mars)
zunanji (Jupiter, Saturn, Uran, Neptun, Pluton).
- **sestava:** skalnati-zemeljski (Merkur, Venera, Zemlja, Mars)
plinasti (Jupiter, Saturn, Uran, Neptun)
Pluton?
- **položaj glede na Zemljo** - bližji Soncu (Merkur, Venera)-mene
Zemlja
bolj oddaljeni (Mars, Jupiter, Saturn, Uran, Neptun, Pluton) - polni
- **zgodovina** - klasični (Merkur, Venera, Mars, Jupiter, Saturn) - vidni s
prostim očesom
moderni (Uran, Neptun, Pluton) - vidni le skozi teleskop

merilo

telo:	ekv. premer (1cm~10000km)	oddaljenost od Sonca (1cm~10000km)
Sonce	140 cm	0
Merkur	4.9 mm	58 m
Venera	1.2 cm	108 m
Zemlja	1.3 cm	150 m
Mars	6.8 mm	228 m
Jupiter	14.3 cm	778 m
Saturn	12.2 cm	1.4 km
Uran	5.1 cm	2.9 km
Neptun	4.86 cm	4.5 km
Pluton	2.3 mm	5.9 km
Luna	3.5 mm	38 cm od Zemlje

Temperatura na planetih

Več faktorjev - ravnovesje med prejeto in oddano toploto:

- oddaljenost od Sonca $\propto 1/a^2$
- kaj se zgodi v atmosferi planeta (oblaki, površina-
Merkur, Venera, Zemlja, Mars)
- gravitacijsko krčenje
- radioaktivni razpadi

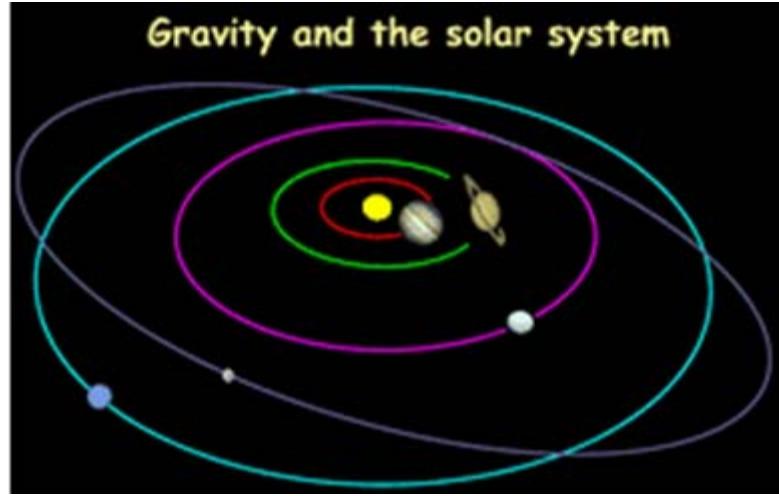
temperatura pada z oddaljenostjo

planet	T (°C)
Merkur	180 (od -170 do 430)
Venera	450
Zemlja	8 (od -15 do 40)
Mars	od -120 do 37
Jupiter	-153
Saturn	-185
Uran	-214
Neptun	-225
Pluton	-236
Luna	od -153 do 107

Gibanje planetov

Gibanje planetov:
gibanje okoli Sonca (elipse):

$$a^3/T^2 = GM_S/4\pi^2$$



Keplerjev zakon

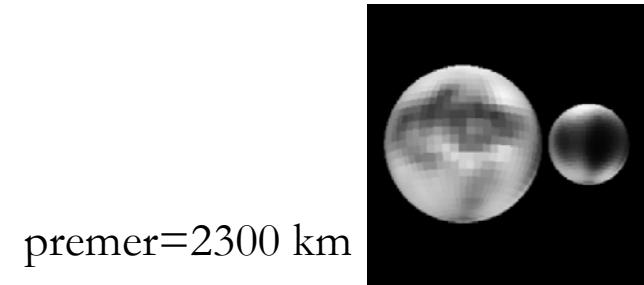
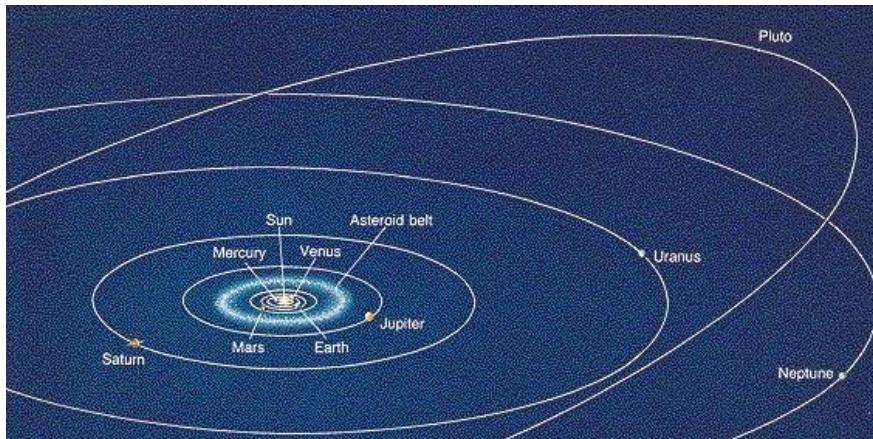
in vrtenje okoli lastne osi

dolžina dneva in leta na posameznem planetu

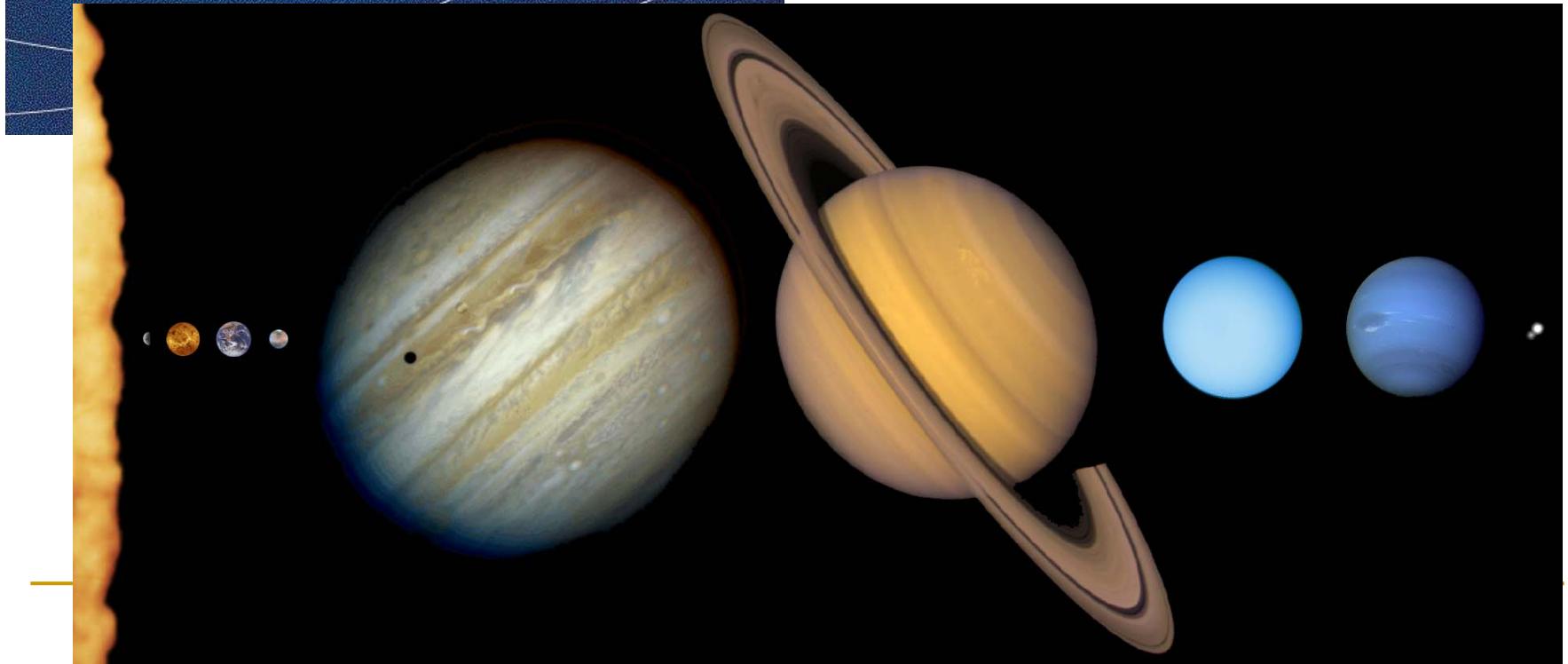
dolžina dneva in let na drugih planetih

Planet	Ekvatorialni premer (km)	Masa (Zemlja..1)	povprečna oddaljenost od Sonca (milijon km)	Orbitalna perioda (pl. leto)	Perioda rotacije (pl. dan)
Sonce	1,392,530	332,948.34	-	-	25.4 dni
Merkur	4,878	0.06	58	88 dni	58.6 dni
Venera	12,104	0.81	108	225 dni	243 dni
Zemlja	12,756	1.00	150	1 leto	1 dan
Mars	6,794	0.11	228	1.9 let	24.6 ur
Jupiter	142,800	317.89	778	11.9 let	9.8 ur
Saturn	120,000	95.14	1,427	29.5 let	10.2 ur
Uran	52,000	14.52	2,870	84.0 let	16-28 ur*
Neptun	48,400	17.25	4,497	164.8 let	18-20 ur
Pluton	3,000	0.10	5,899	247.7 let	6.3 dni

Kaj se je zgodilo Plutonu?



premer=2300 km



odkritje

1781 – W. Herschel odkrije Uran

1846 – Adams in Le Verrier iz orbite Urana
izločijo, da je na tem mestu tudi Pluton?

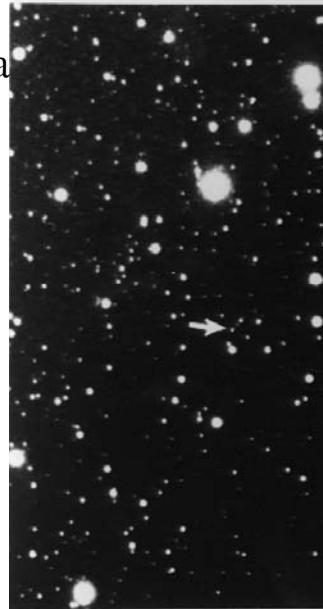
– Percival Lowell napove planet z $10 M_{\oplus}$

1930 – Clyde Tombaugh odkrije
a premajhen!

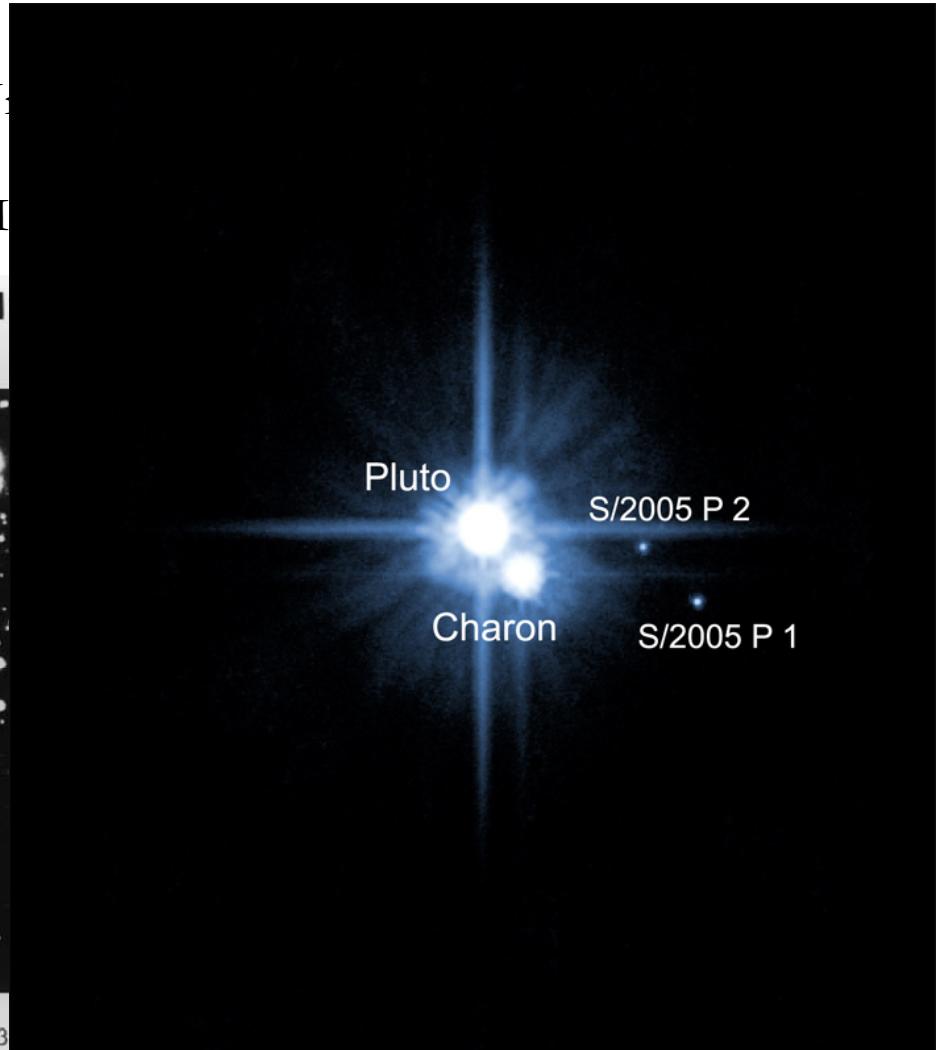
1970 – Lowell zmotil

1978 – Plutonova luna

– $M=0.001 M_{\text{Zemlje}}$
le naključje!

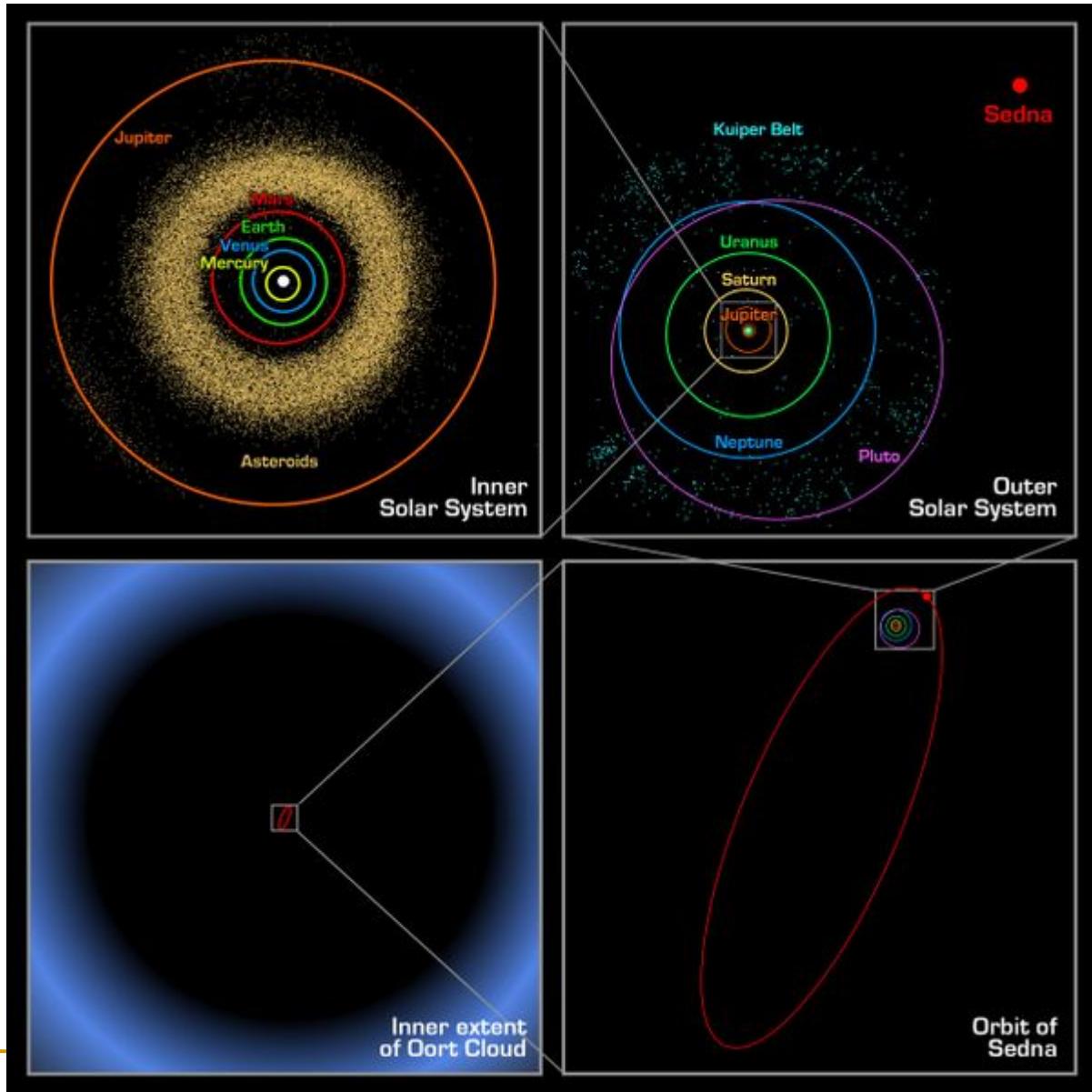


January 23

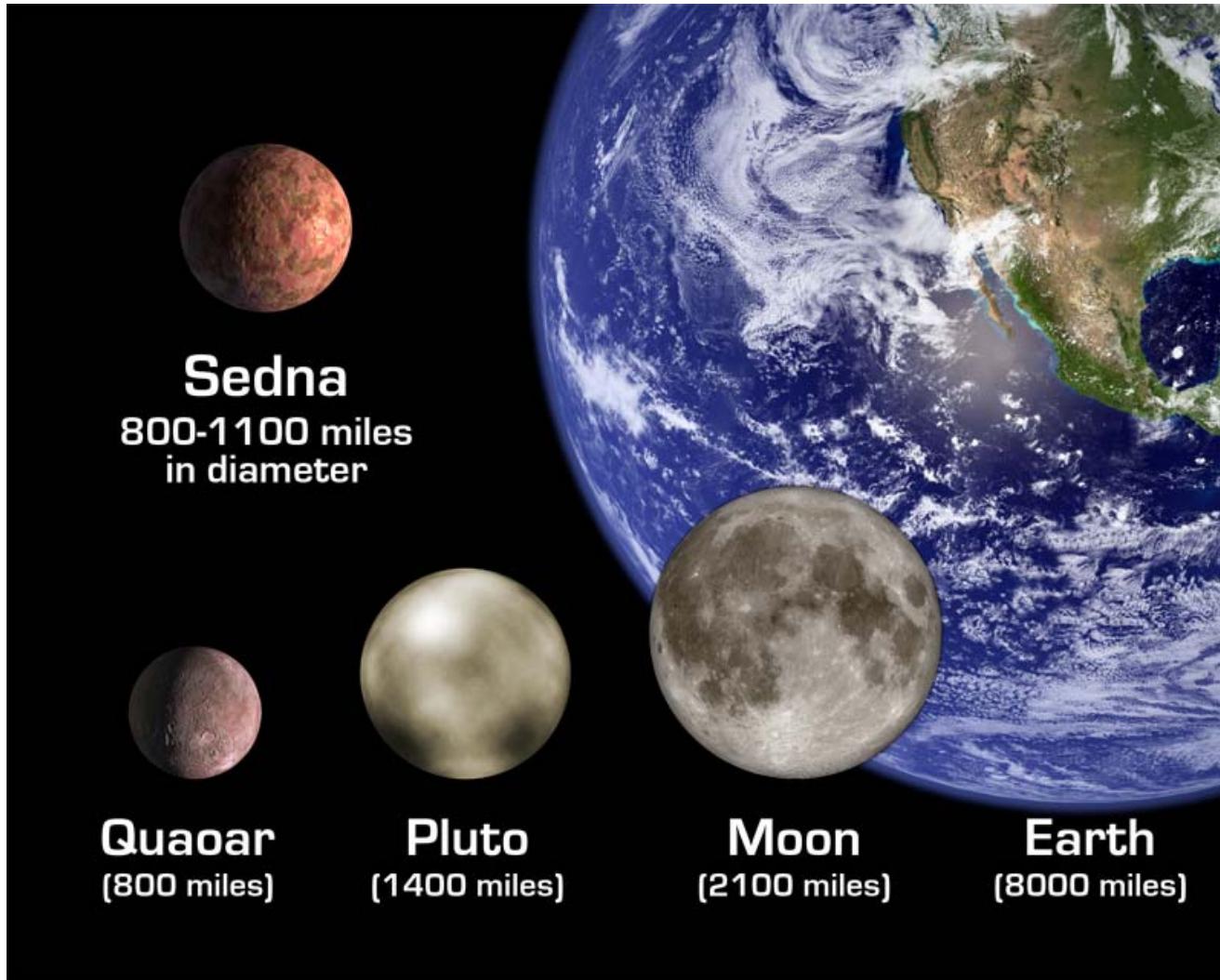


TNO – TransNeptunian Objects

- 1990-ta: Jewitt in Luu odkrijeta prvega, nato ~ 1000 , vsi majhni
- 2002: Varuna 1000 km, Quaoar 1300 km
- 2003: Sedna 2000 km
- 2005: 2003 UB₃₁₃ (Eris) >2300 km



definicija planeta?



IAU 2006: “Pluton je pritlikav planet.”

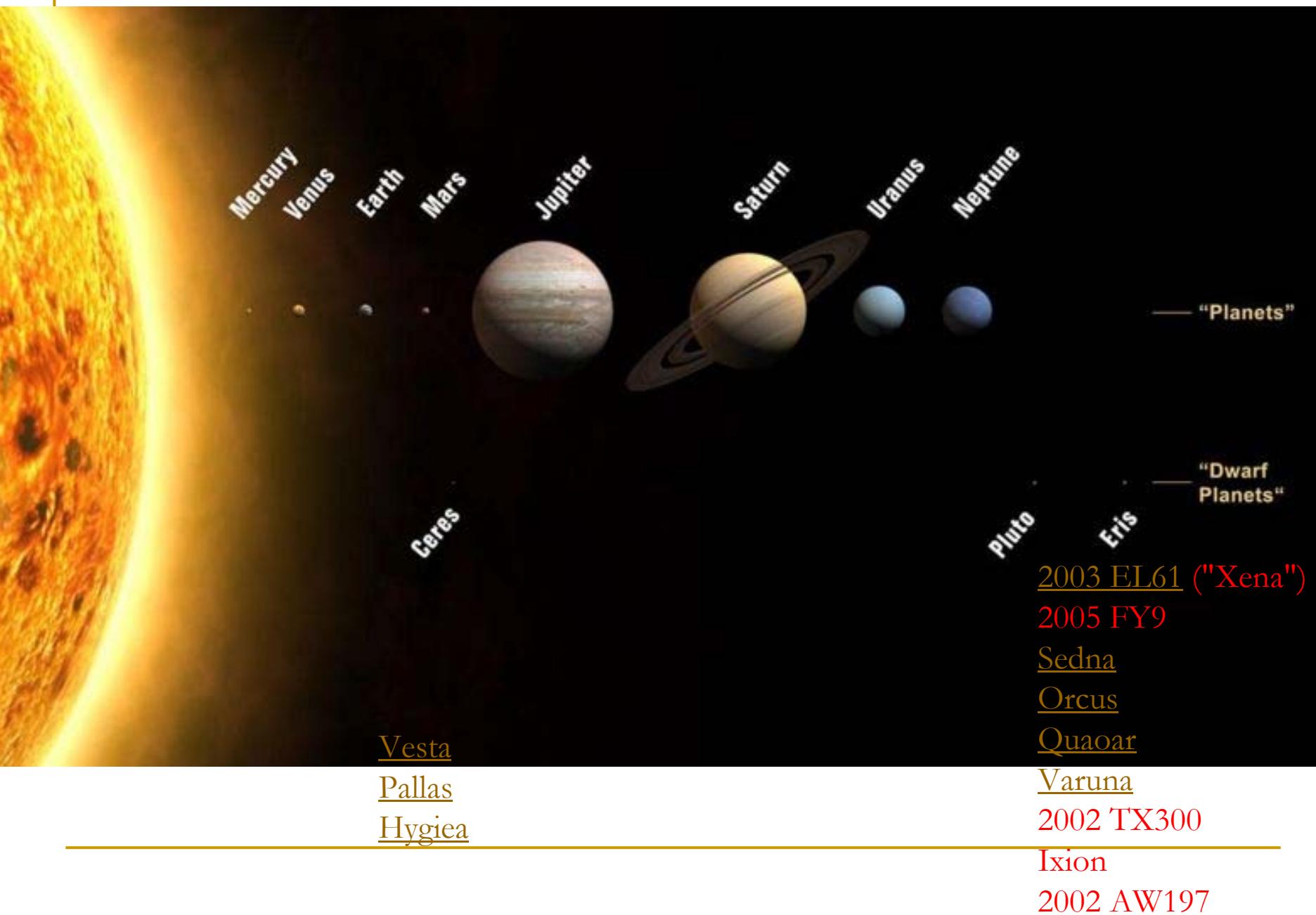
- International Astronomical Union – ustanovljena 1919 – mednarodni standardi: meje med ozvezdji, imena objektov ipd.
- Praga, avg. 2006: tri skupine: planeti, pritlikavi planeti, majhna telesa
- planet je telo, ki je:
 1. na tirnici okoli Sonca,
 2. pod vplivom lastne gravitacije okroglo,
 3. “očistilo” svojo tirnico okoli Sonca

Pluton ne izpolnjuje 3. pogoja in spada med pritlikave planete!

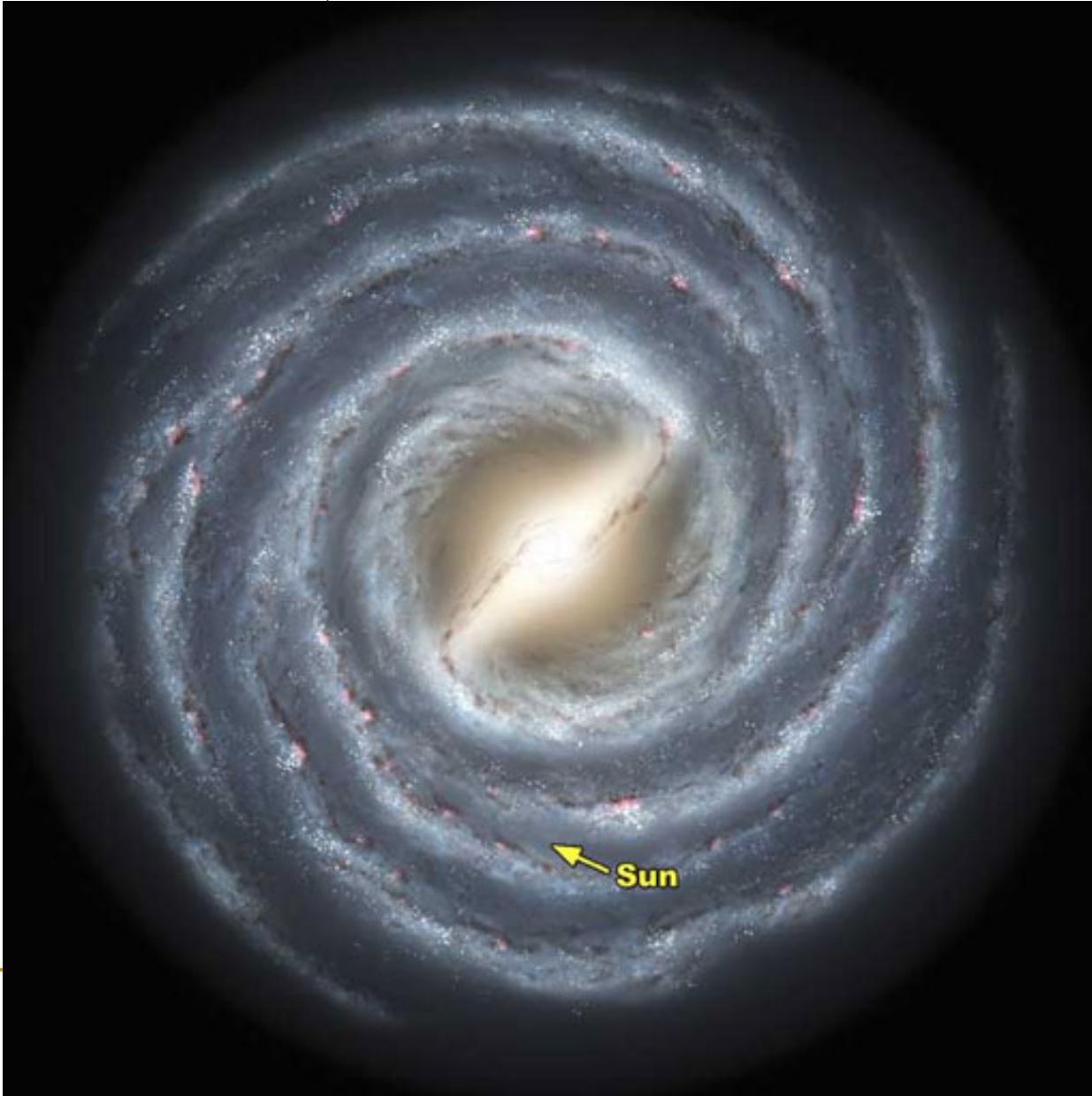
"What's in a name?
That which we call a rose
By any other name
would smell as sweet."

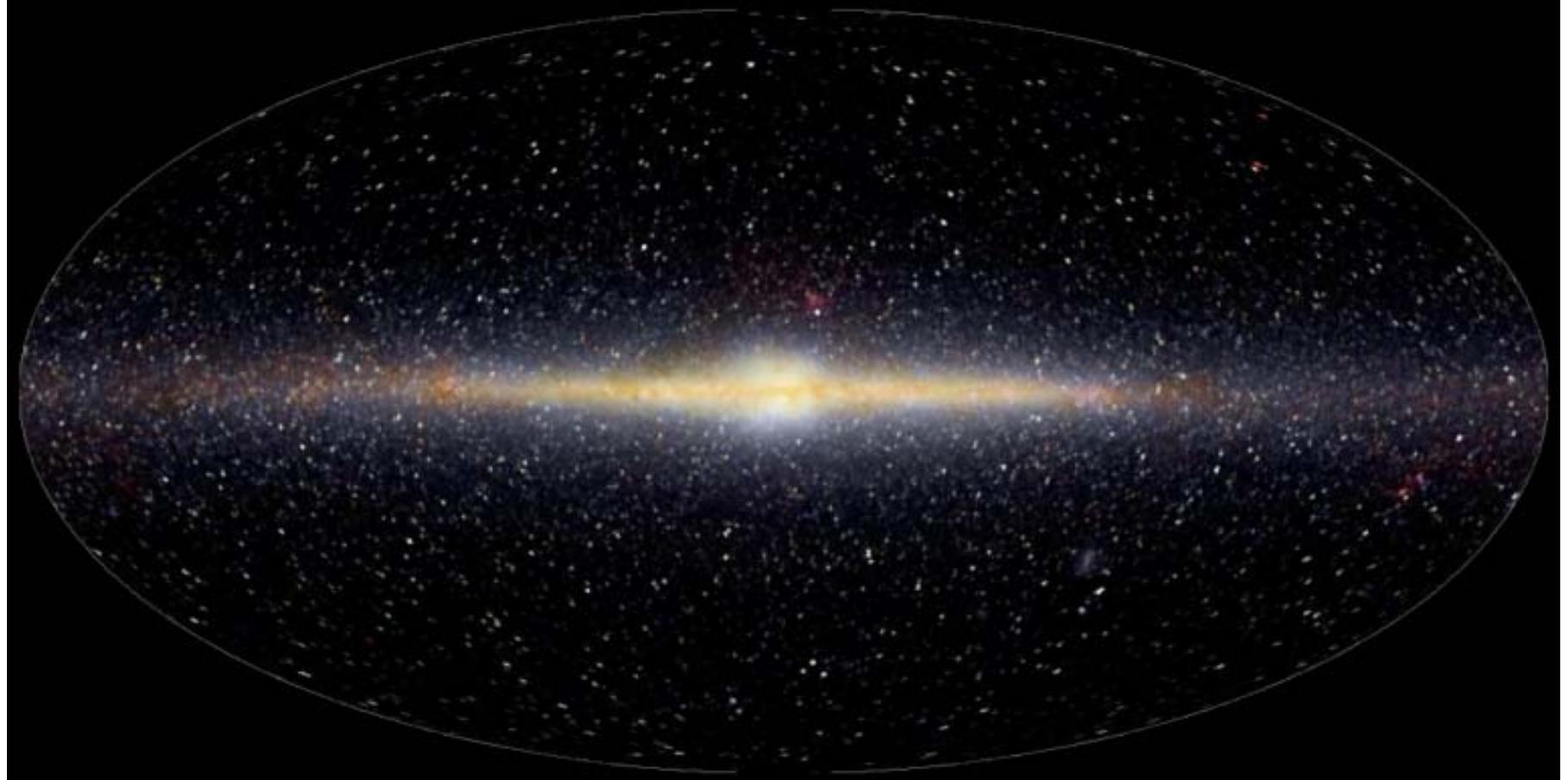
W. Shakespeare:
Romeo and Juliet (II, ii, 1-2)





mi in Galaksija





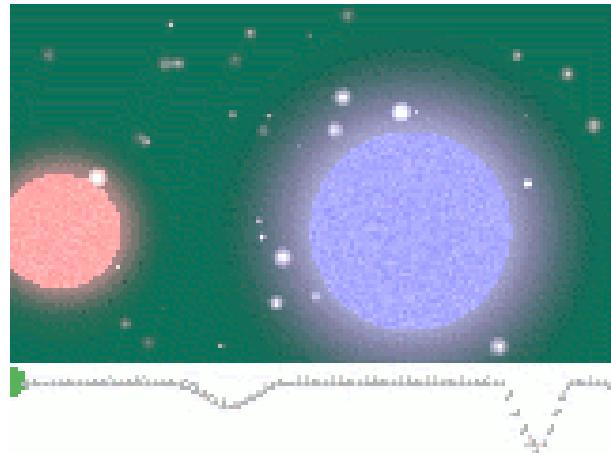
The Deep Sky



Kako “videti” planet okrog druge zvezde?

- daleč
- zvezda veliko svetlejša

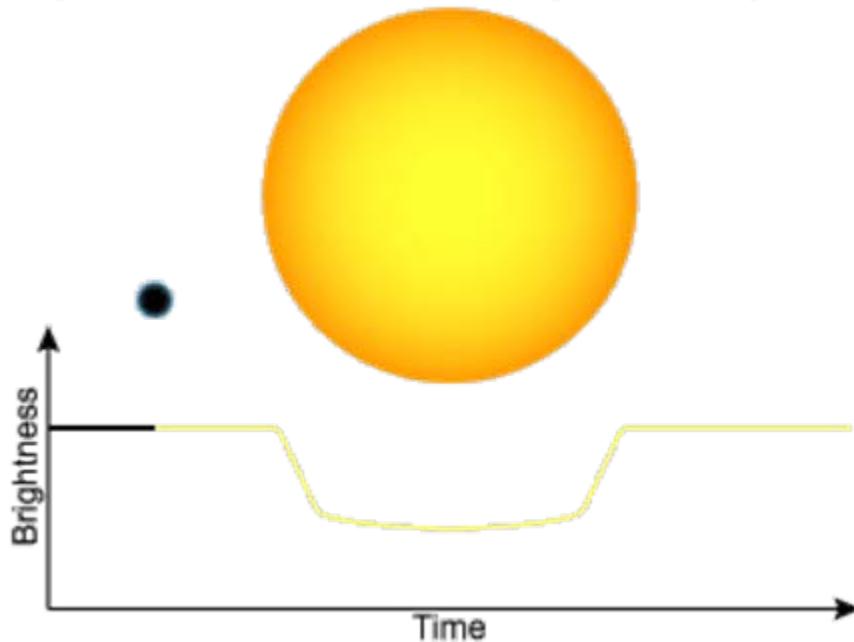
Pri dvojnih zvezdah:



tranzitna metoda

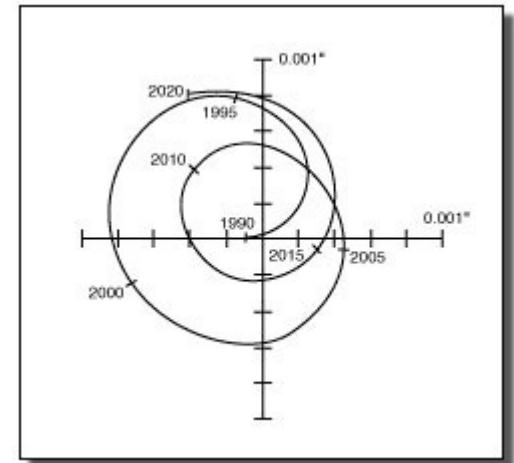
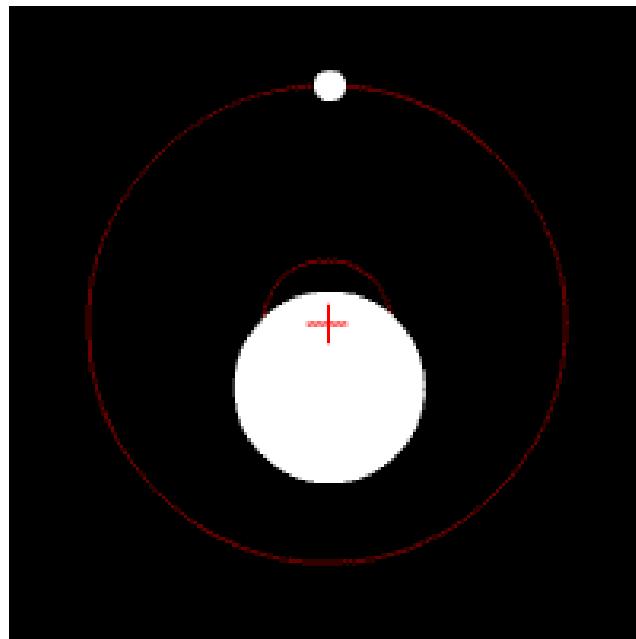
planet prekrije zvezdo

Light Curve of a Star During Planetary Transit

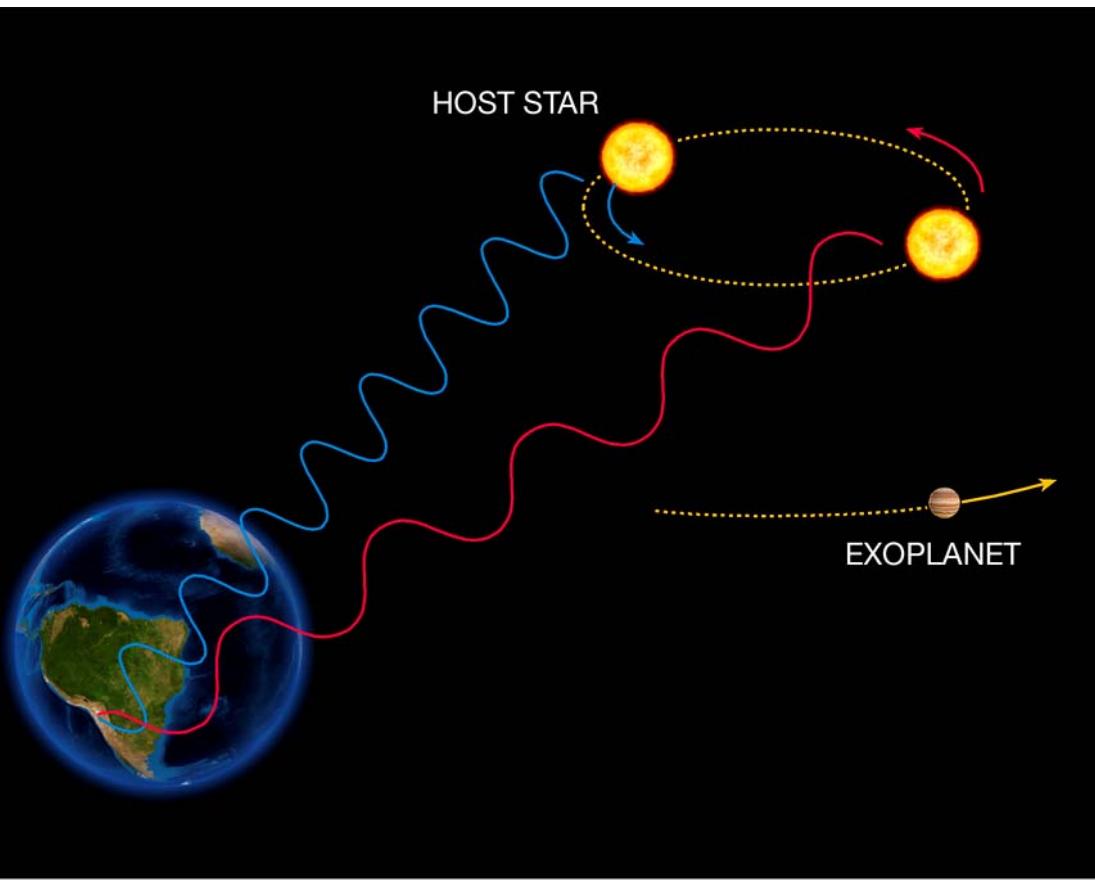


astrometrija

- točno merjenje položaja
- gravitacijski vpliv planeta na gibanje zvezde



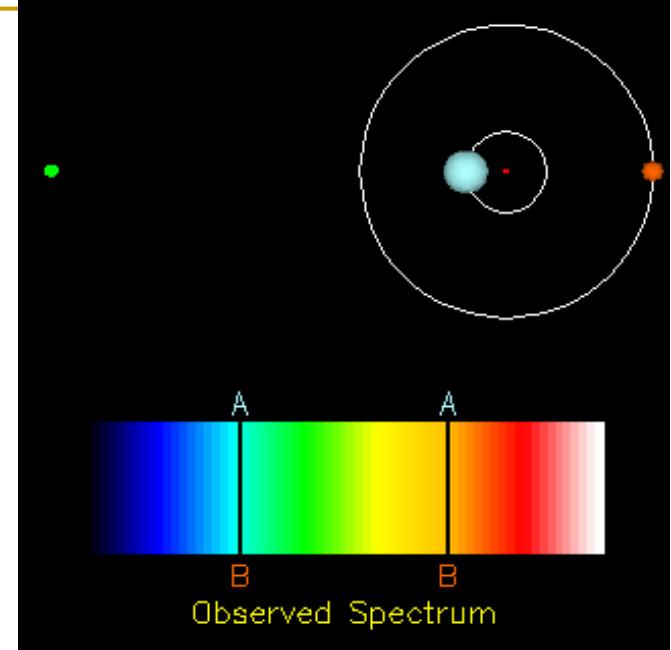
radialna hitrost



The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

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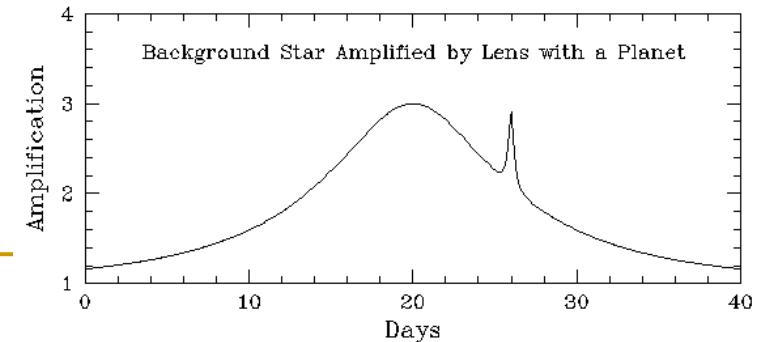
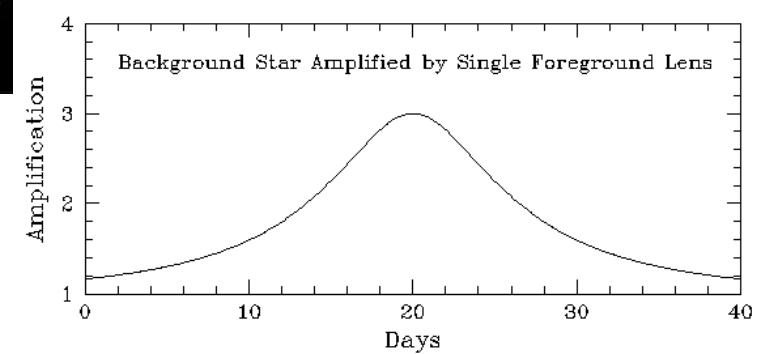
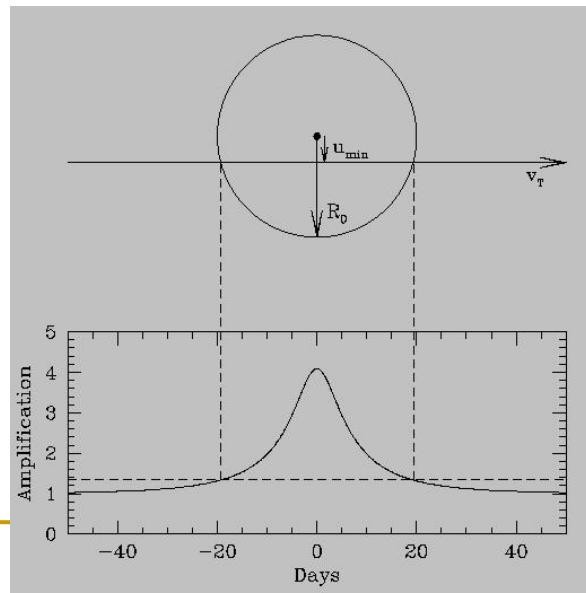
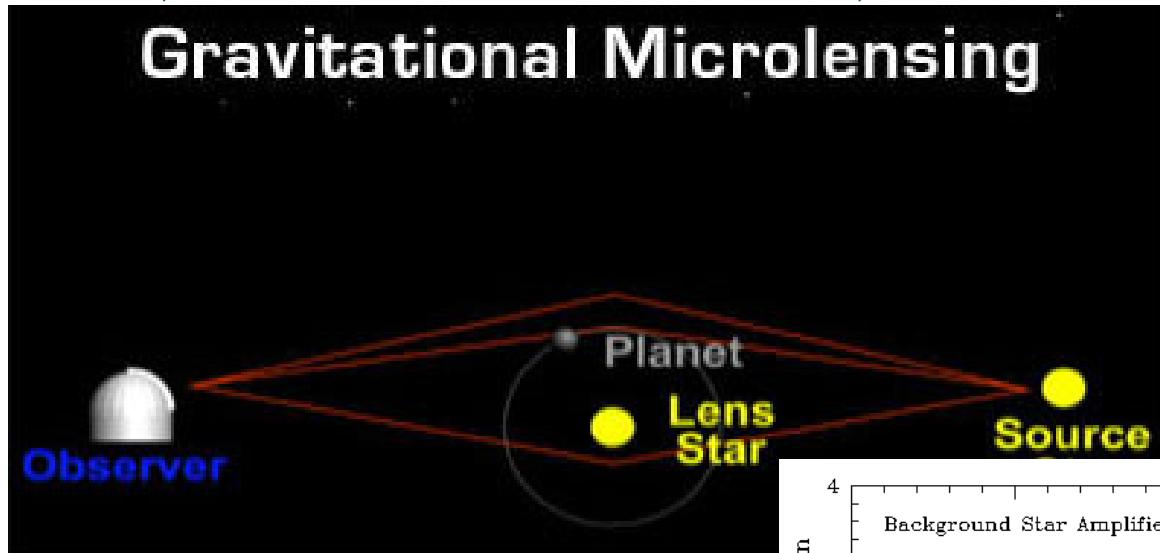
merjenje Dopplerjevega
premika spektralnih črt:

$$\Delta\nu/\nu = v/c$$



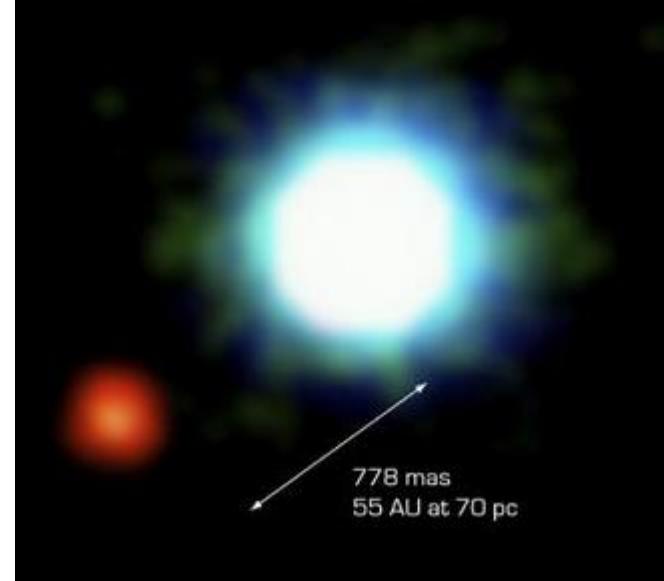
gravitacijsko mikrolečenje

Gravitational Microlensing

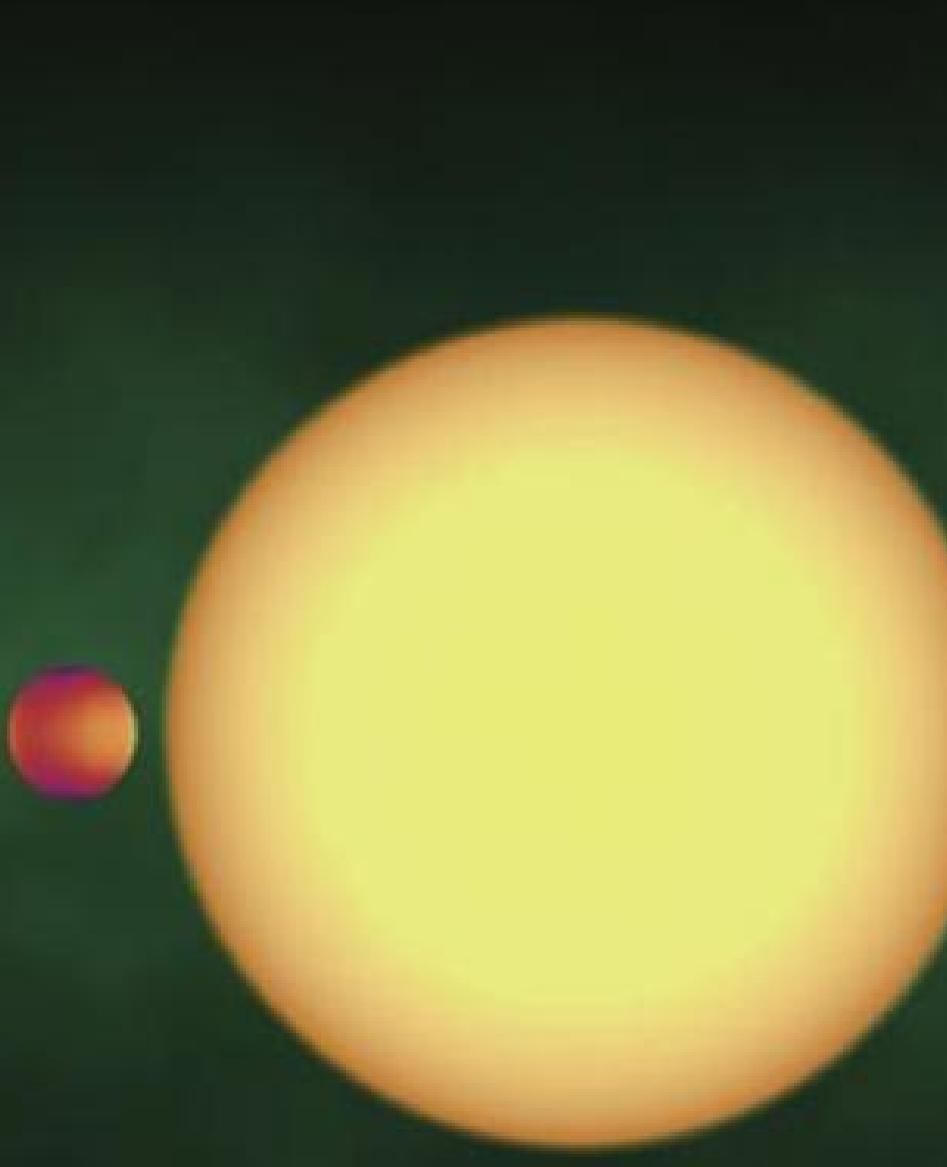
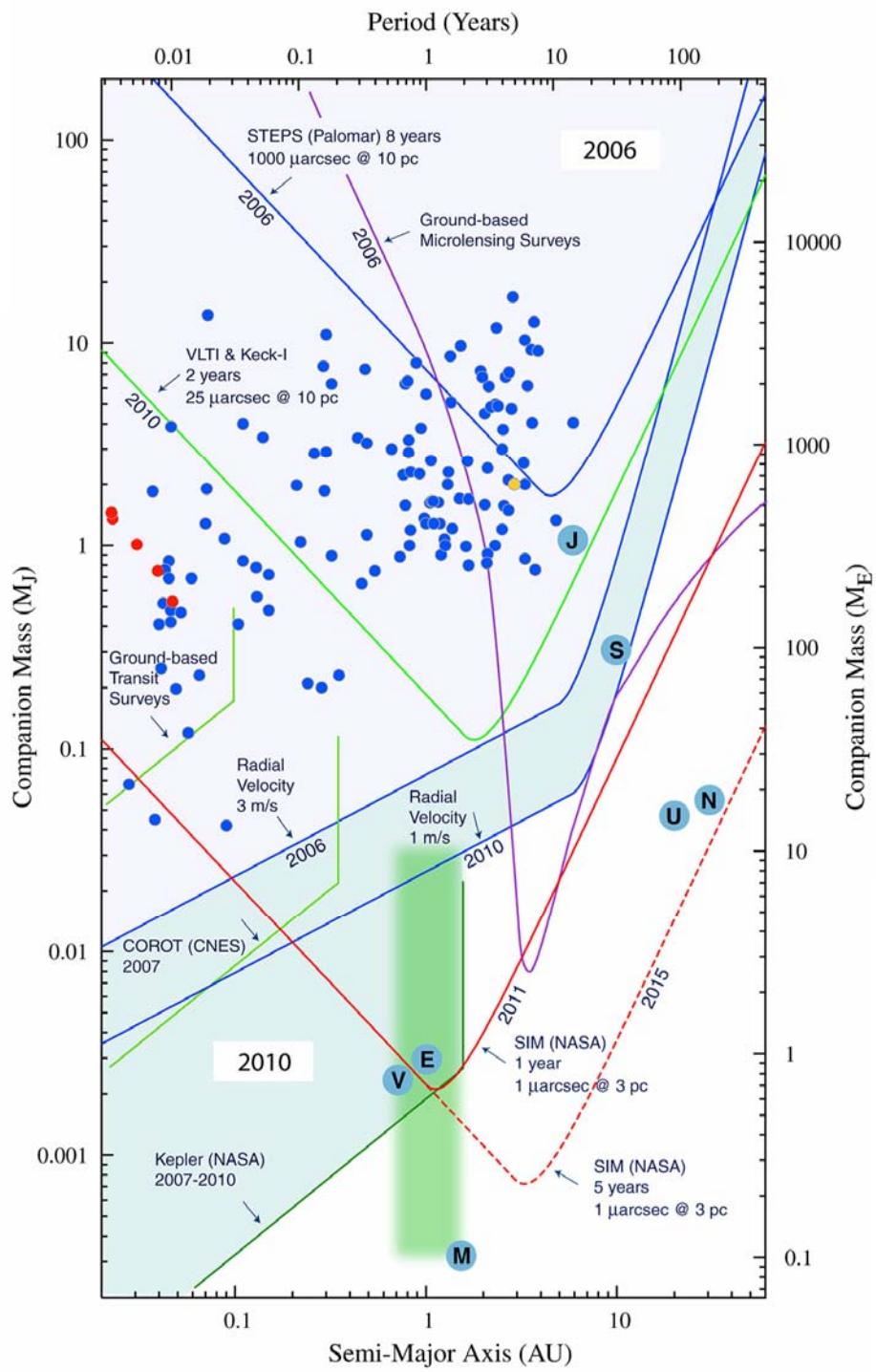


Planeti v drugih osončjih

- odkritje: 1855?, 1890?, 1950-60?, 1988 (2003!), 1991?
- 1992: Wolszczan in Frail: planeti okrog pulzarja PSR 1257+12
- 1995: Mayor in Queloz: 1. planet okoli zvezde glavne veje 51 Pegaza
- poznanih \sim 240 planetnih sistemov
 - 293 (?) planetov
 - 26 večplanetnih sistemov



2M1207: rjava pritlikavka in planet, posneto z VLT



do 31. 8. 2004
modre – radialna hitrost
rdeče – transit
rumene - mikrolečenje

pozicije na nebu

imenovanje:

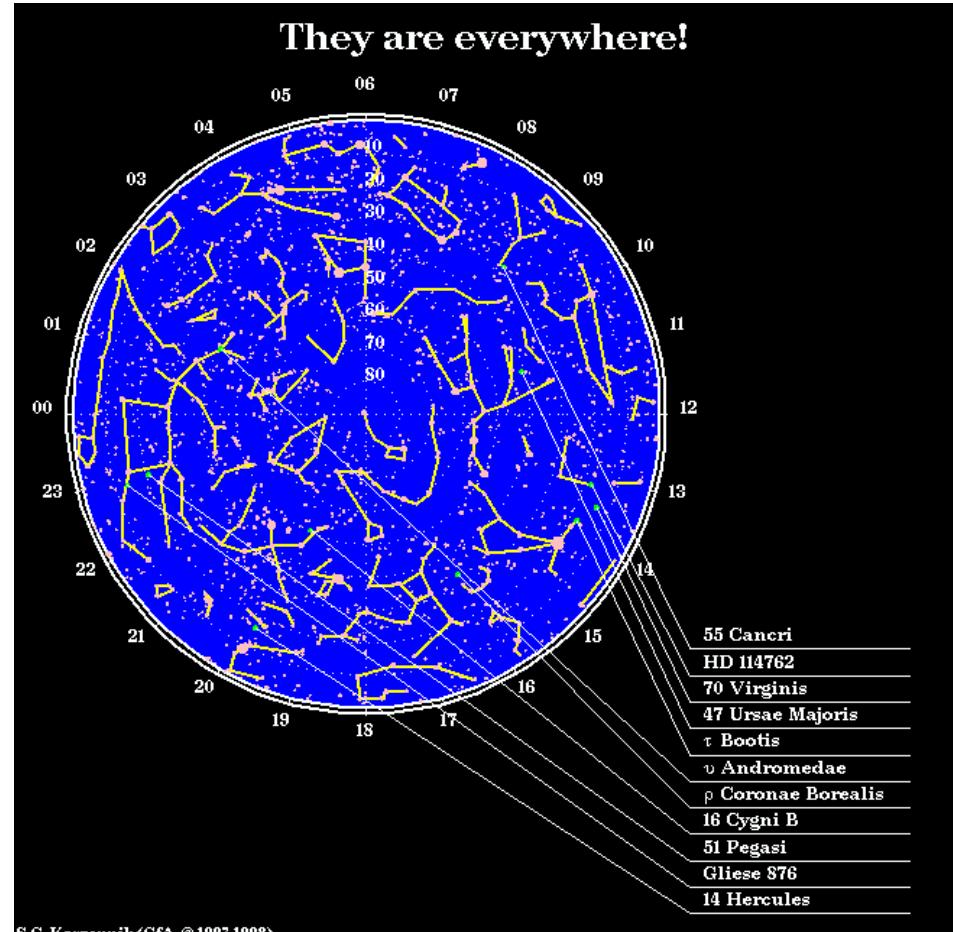
ime zvezde b,c...

po vrstnem redu odkritja

nekateri imajo vzdevke:

Osiris, Bellerophon, Ymir

IAU: nepraktično

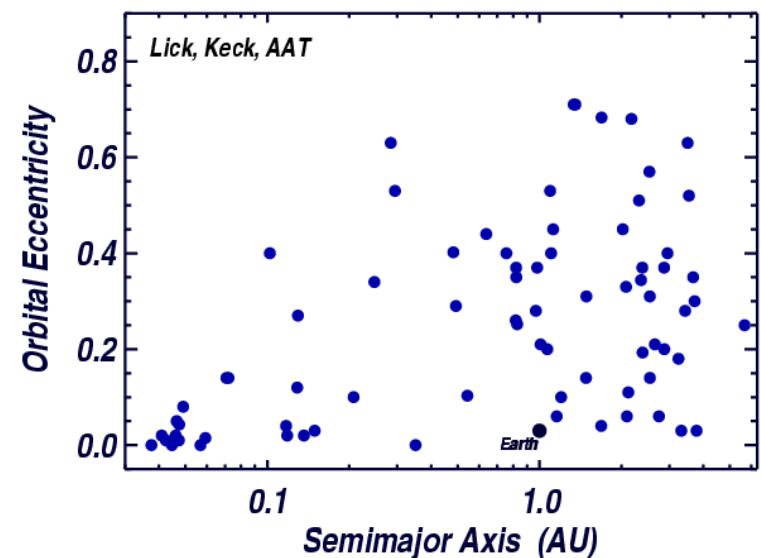


S.G. Korzennik (CfA, © 1997, 1998)

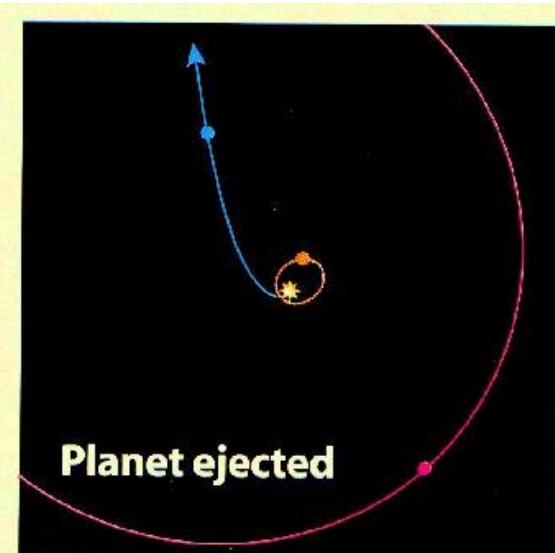
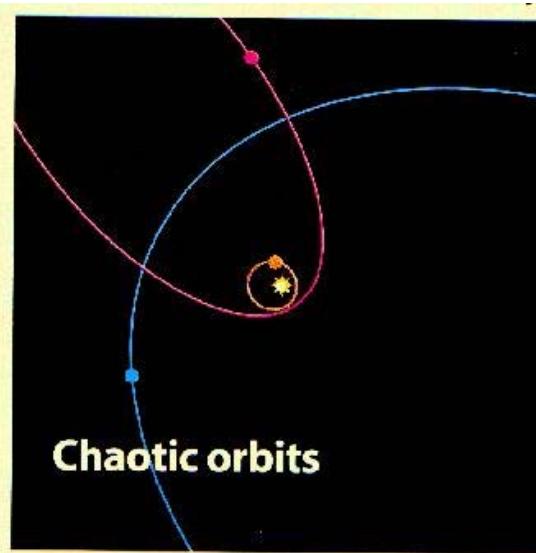
lastnosti

- večina okrog F,G,K zvezd (posledica iskanja)
- pričakovanja: rdeče pritlikavke M in vroče O manj
- večina $> 10 M_{\text{Zemlje}}$ in bližje zvezdi (občutljivost metode): “vroči Jupitri”
- pričakovanja: več majhnih planetov kot velikih
- ekscentričnost tirnic!

$$\epsilon = \frac{a - b}{a}$$



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

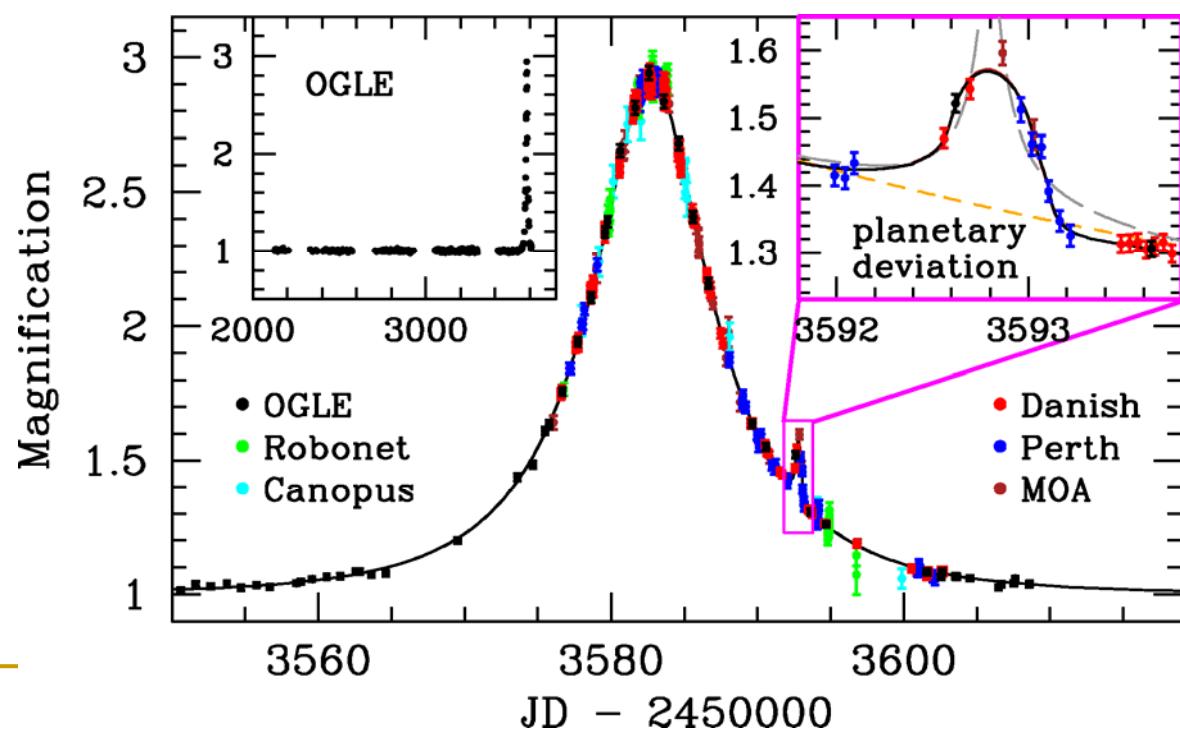


- Druge razlage velike ekscentričnosti:
 - Gravitacijske motnje mimoidoče zvezde
 - Gravitacijske motnje protoplanetarnega diska
 - Gravitacijske motnje zvezde spremjevalke
- Krožne tirnice planetov v našem Osončju niso naključje!
 - Če Jupiter ne bi imel krožne tirnice, Zemlje in Marsa danes ne bi bilo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

OGLE-2005-BLG-390Lb

- $5.5 M_{\text{Zemlje}}$ – okrog MS zvezde
- 2.6 AU, 21.000 sv. let proti središču Galaksije
- najhladnejši?

-220° C



Gliese 581

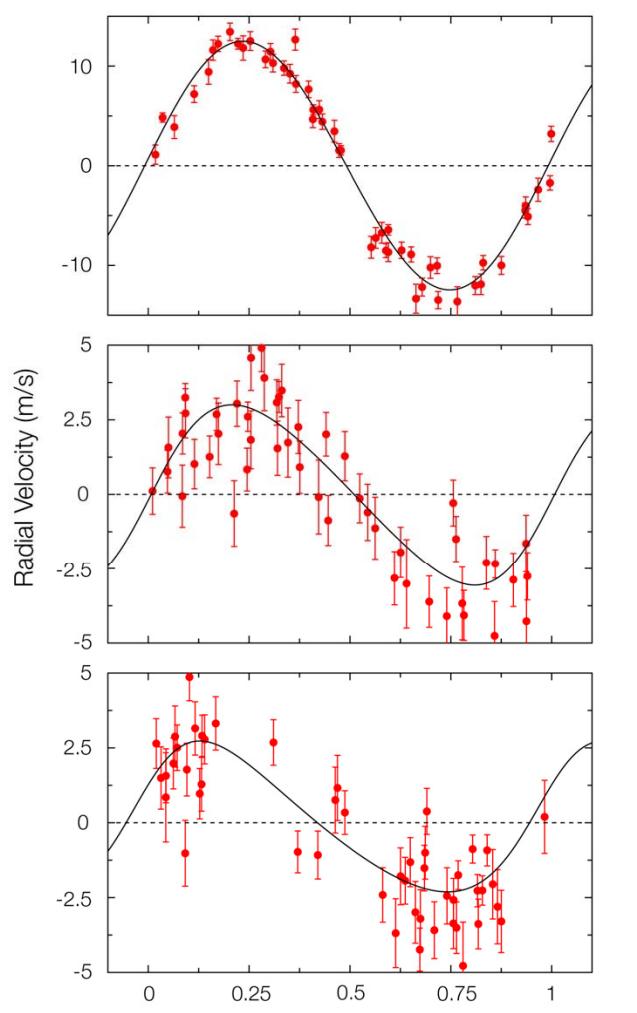
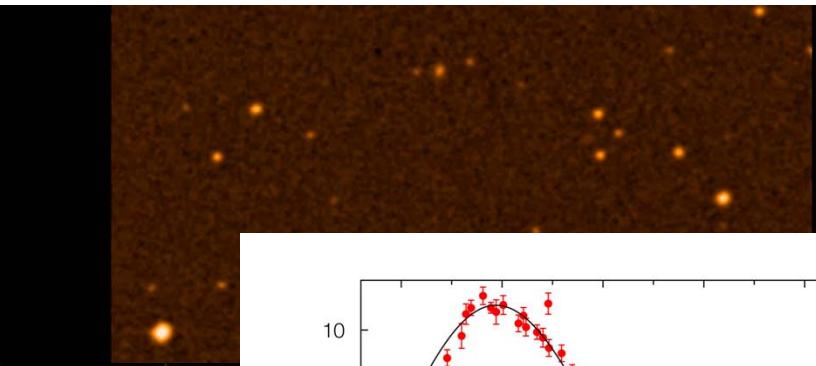
20 sv. let daleč, 3 planeti
581d z $5M_{\oplus}$, 0.25 au v "habitable zone"



The Planetary System in Gliese 581
(Artist's Impression)

ESO Press Photo 22a/07 (25 April 2007)

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Udry et al, A&A 2007
Observed Velocity Variation of Gliese 581

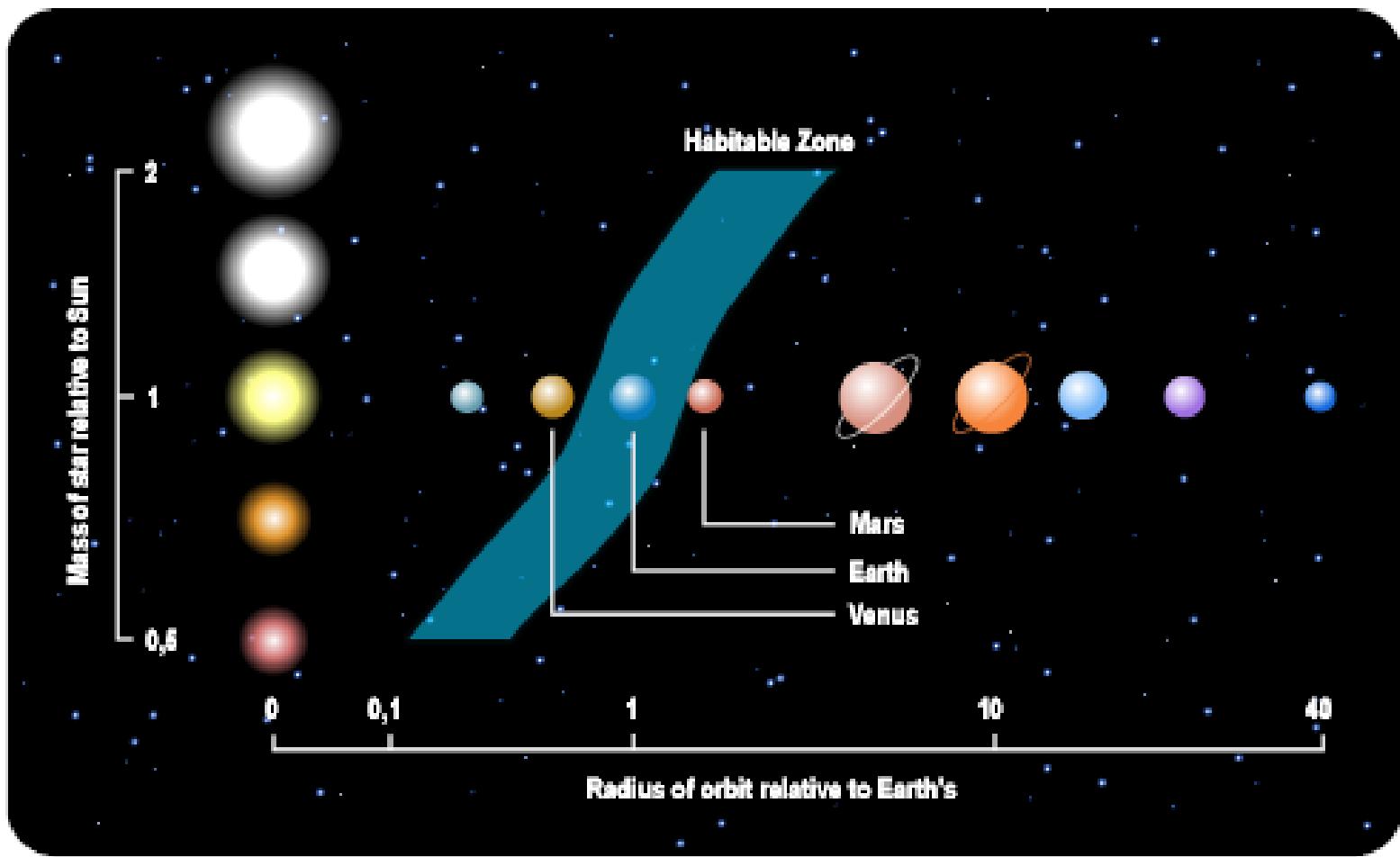


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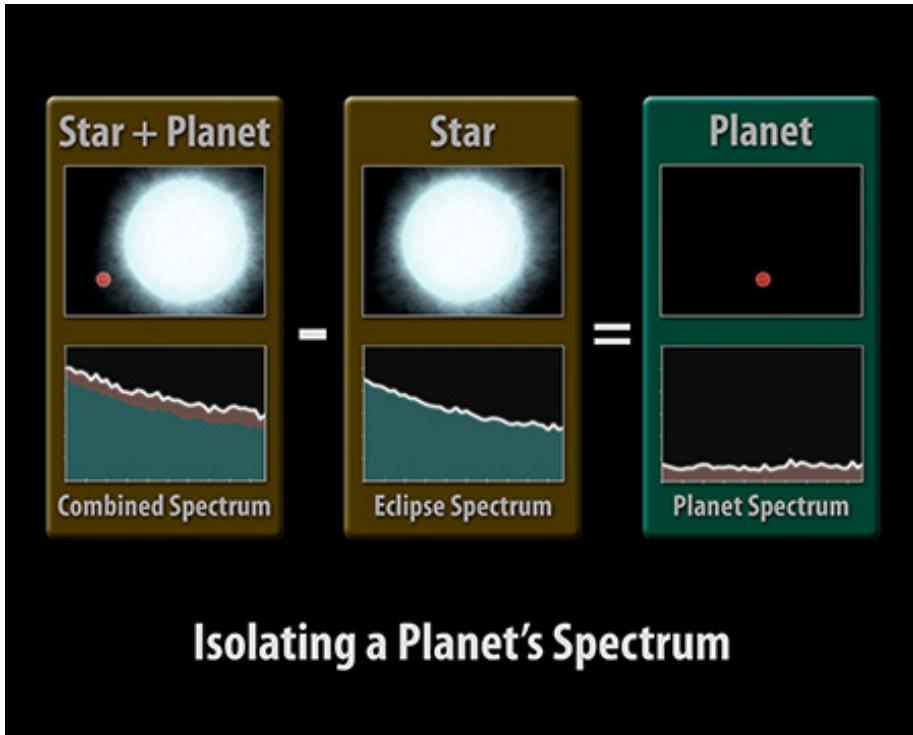
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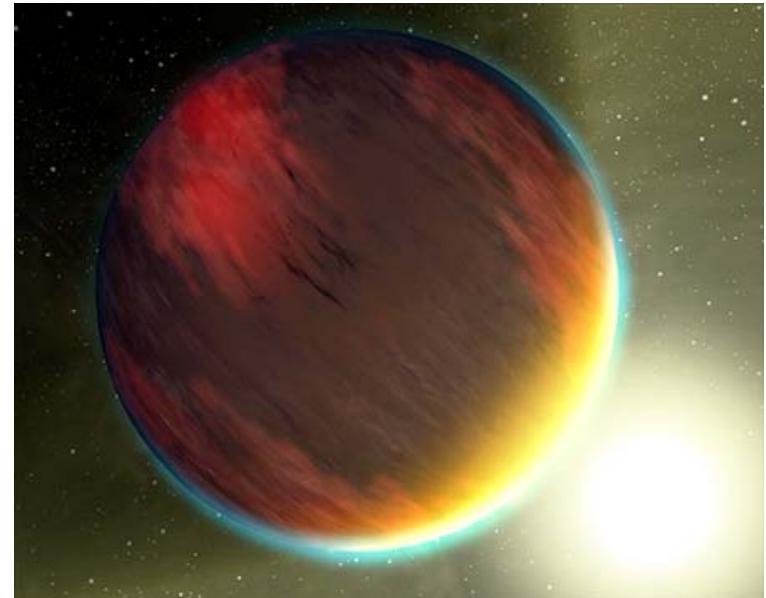
“Habitable zone” - naselitvena cona – cona Zlatolaske



spekter



spekter HD209458b in HD
189733b – silikatni oblaki,
vodna para?

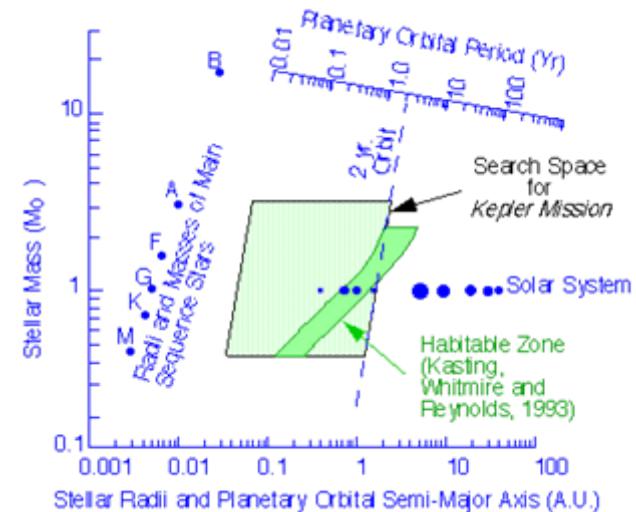
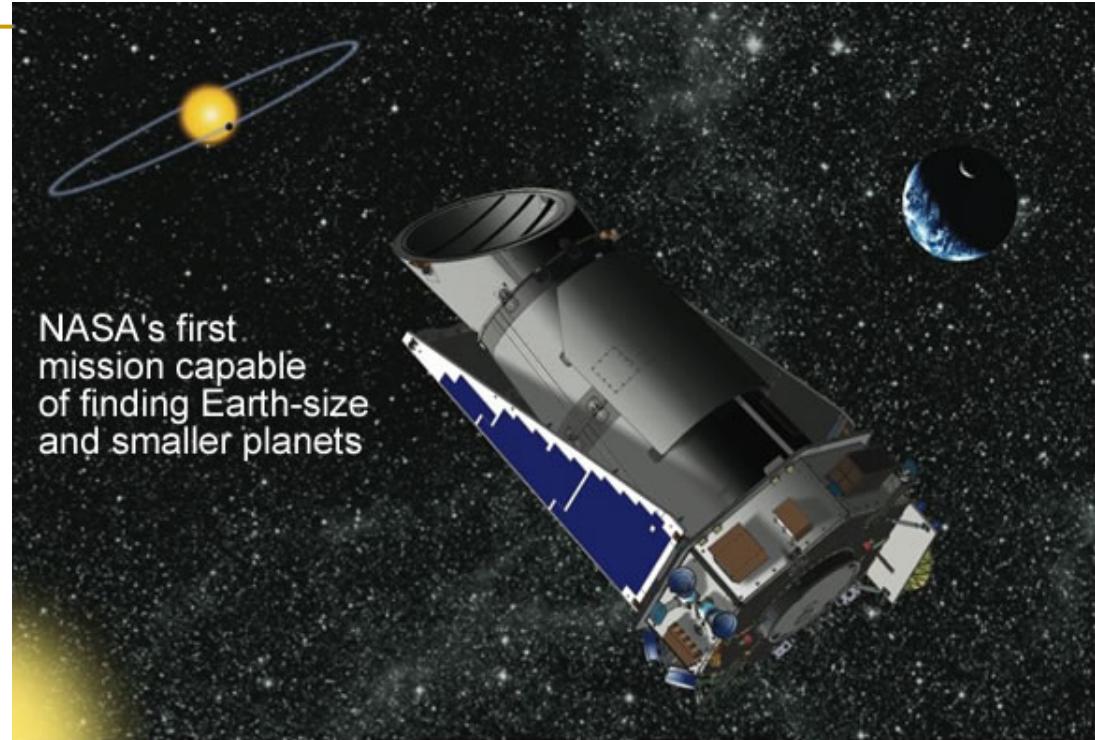


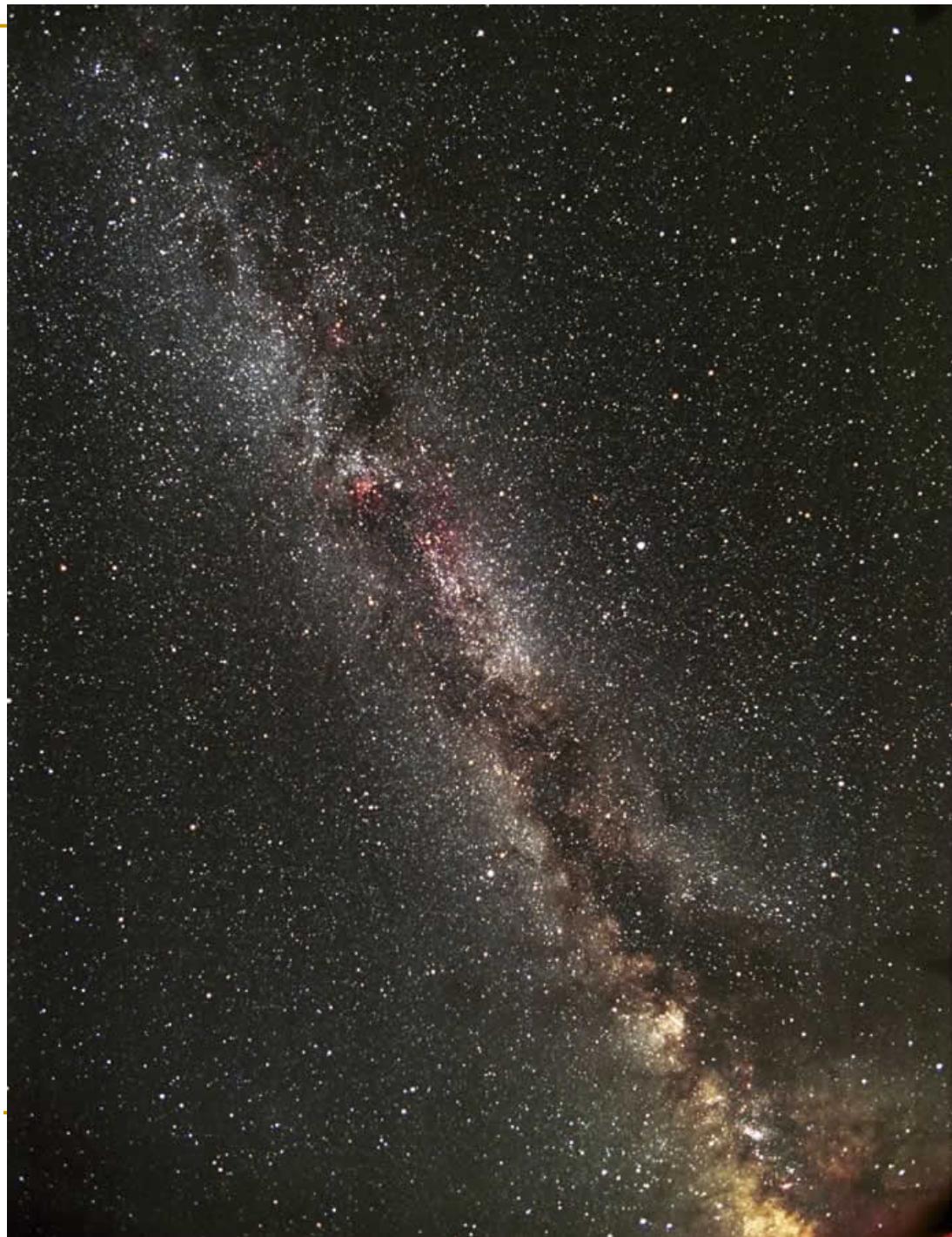
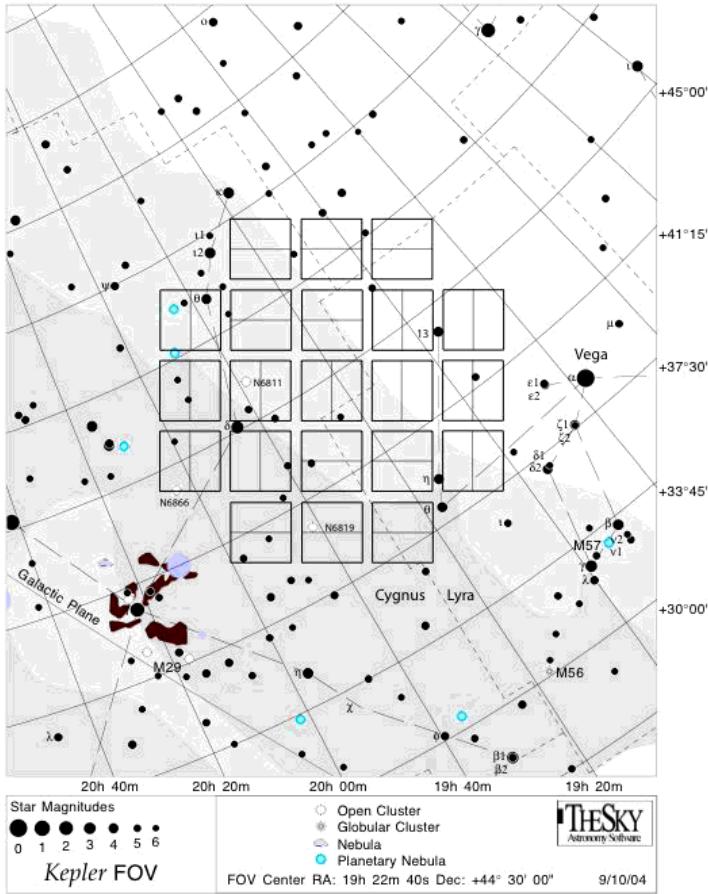
Projekti iskanja planetov



Kepler (NASA, feb 2009)

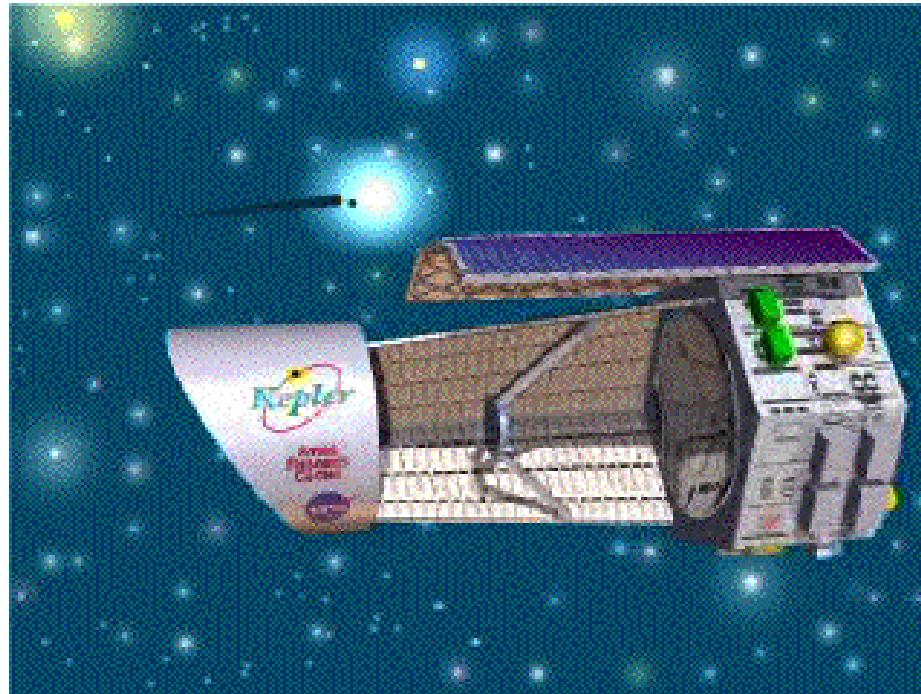
- specializirana misija za detekcijo kamnitih planetov velikosti Zemlje
 - testiral bo hipotezi:
 - večina zvezd glavne veje ima kamnite planete v habitatni koni
 - v povprečju sta med 0.5 in 1.5 a.e. dva zemeljska planeta





- detekcija nemogoča z Zemlje:
 - atmosferske motnje spreminjajo svetlost zvezd
 - kratko-periodični dogodki ... potrebno sodelovanje mnogo zemeljskih teleskopov
 - boljše, ker tudi v IR
- svetlost zvezd se spreminja tudi iz drugih razlogov (npr. spremenjanje Sončeve akitnosti, 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

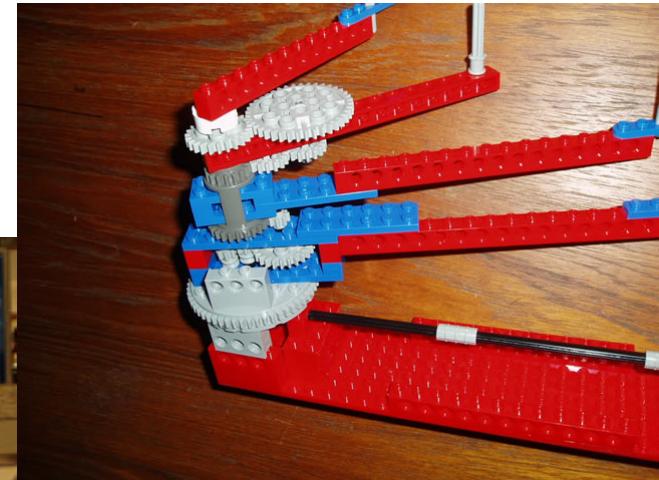




<http://kepler.nasa.gov/ed/sim/>
<http://kepler.nasa.gov/ed/>

Kepler

- <http://kepler.nasa.gov/ed/>

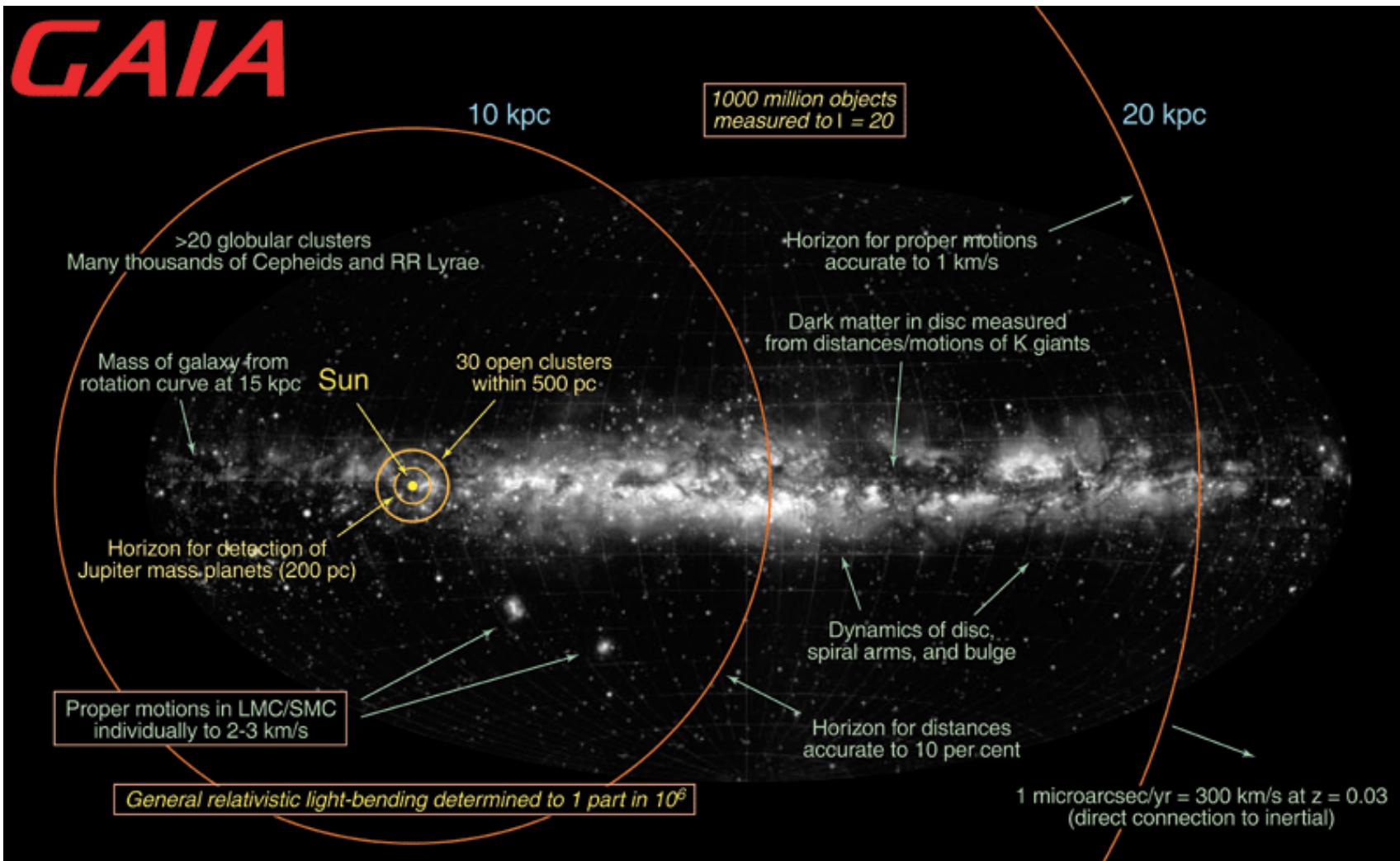


več

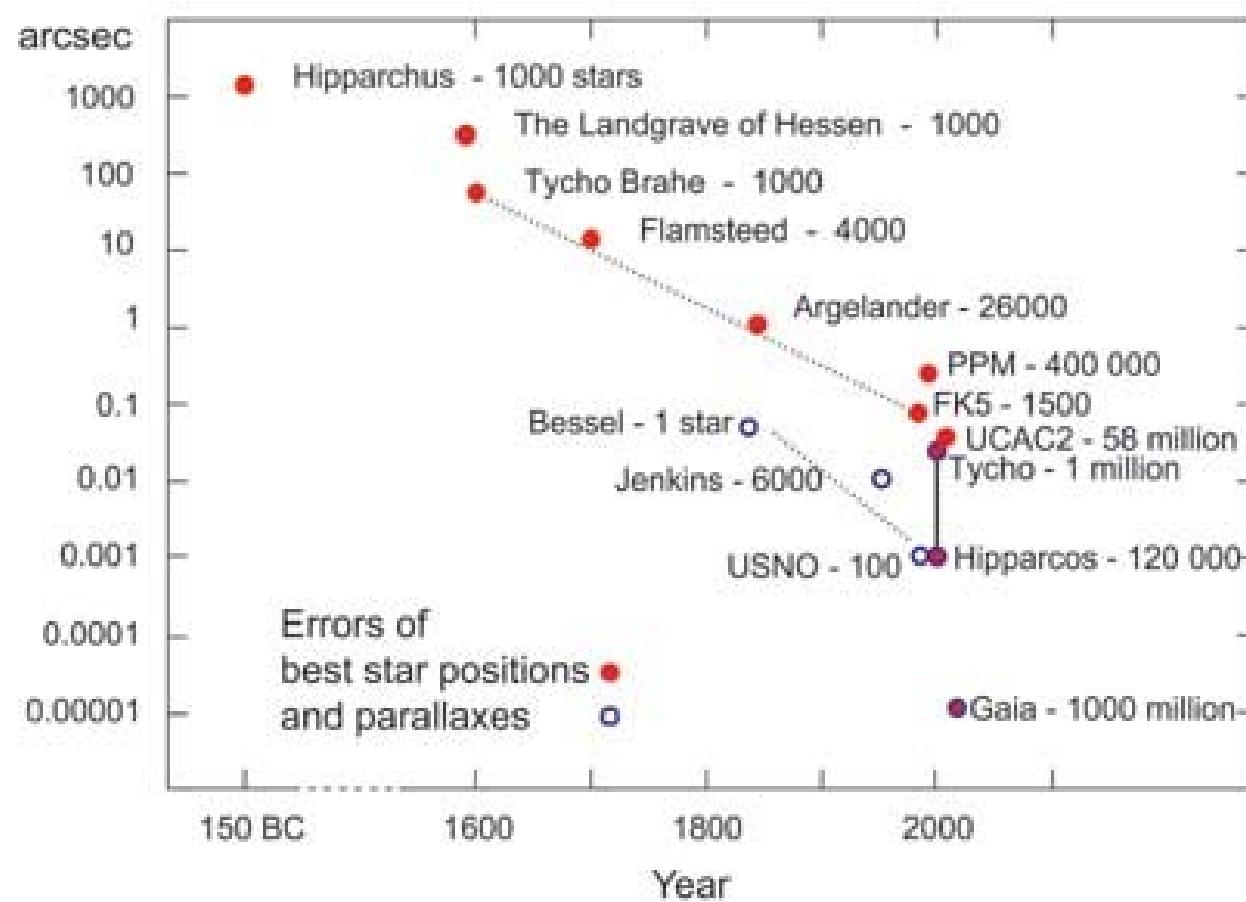
satelit Gaia – leta 2011-12



GAIA

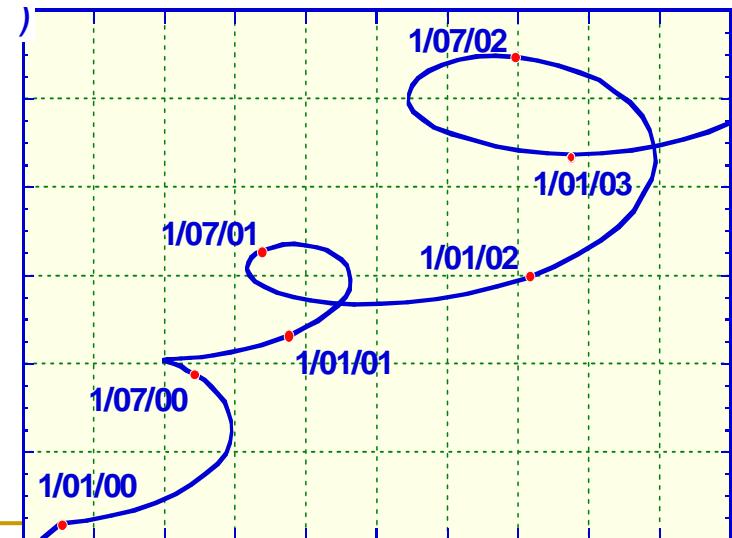


napredek v astrometriji



Exo-Planets: Expected Discoveries

- Astrometric survey:
 - monitoring of hundreds of thousands of FGK stars to ~ 200 pc
 - detection limits: $\sim 1M_J$ and $P < 10$ years
 - complete census of all stellar types, $P = 2\text{--}9$ years
 - masses, rather than lower limits ($m \sin i$)
 - multiple systems measurable, giving relative inclinations
- Results expected:
 - 10–20,000 exo-planets (~ 10 per day)
 - displacement for 47 UMa = 360 μas
 - orbits for ~ 5000 systems
 - masses down to $10 M_{\text{Earth}}$ to 10 pc
- Photometric transits: ~ 5000 ?

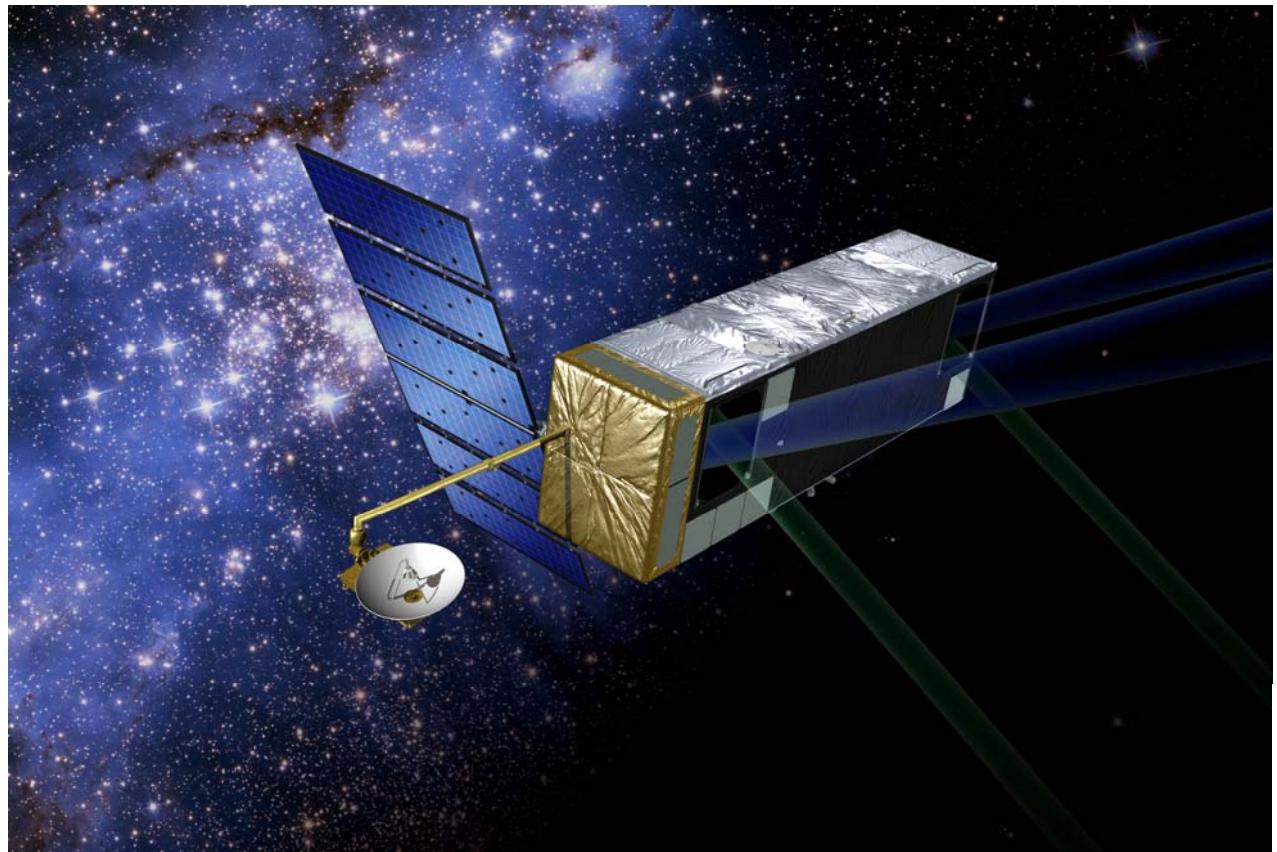


SIM

PLANETQUEST

SIM PlanetQuest

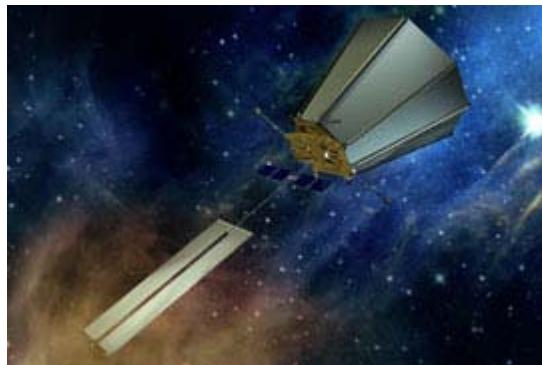
[Astronomers' Site >](#)



TPF



- 2 observatorija v vesolju: koronograf in infrared interferometer



JWST



- NASA, 2013
- 6.5-m
- naslednik HST



KONEC