Fisica degli esopianeti

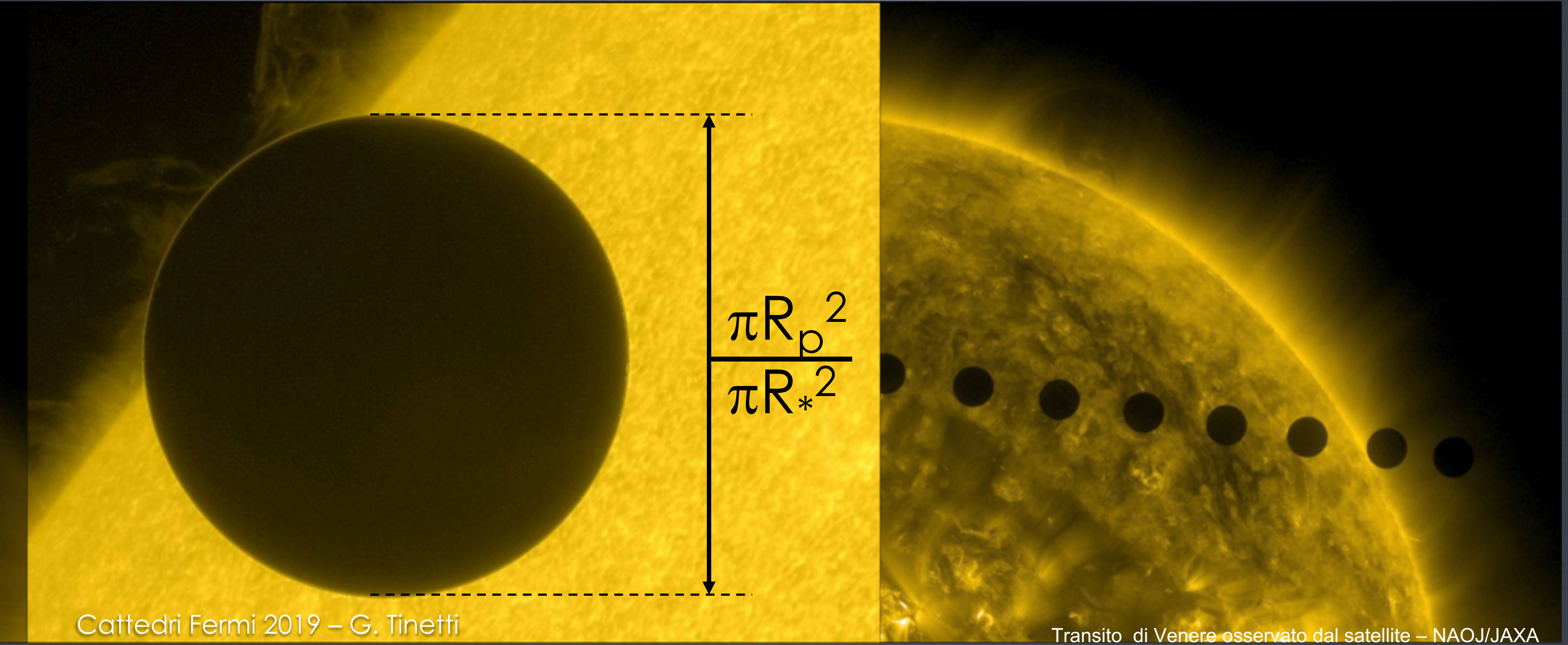
Cattedra Fermi 2019

Tecniche di rivelazione: transito

parte I

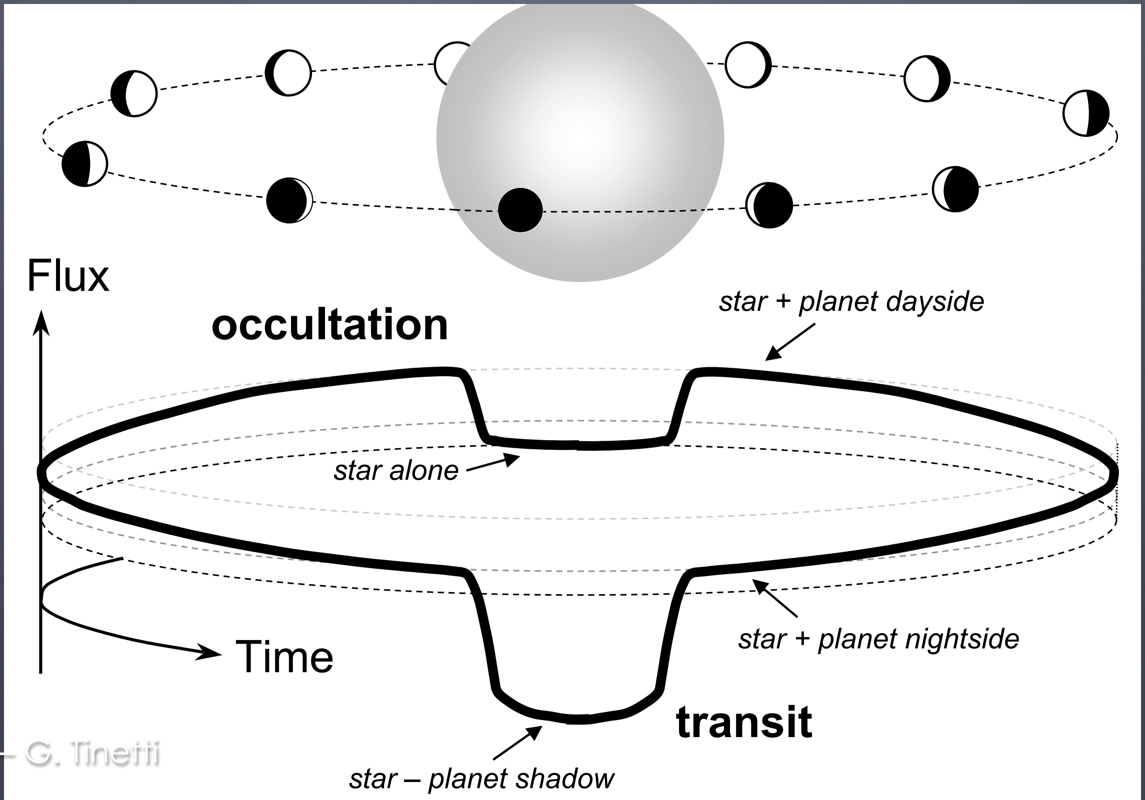
Giovanna Tinetti

Transito di Venere



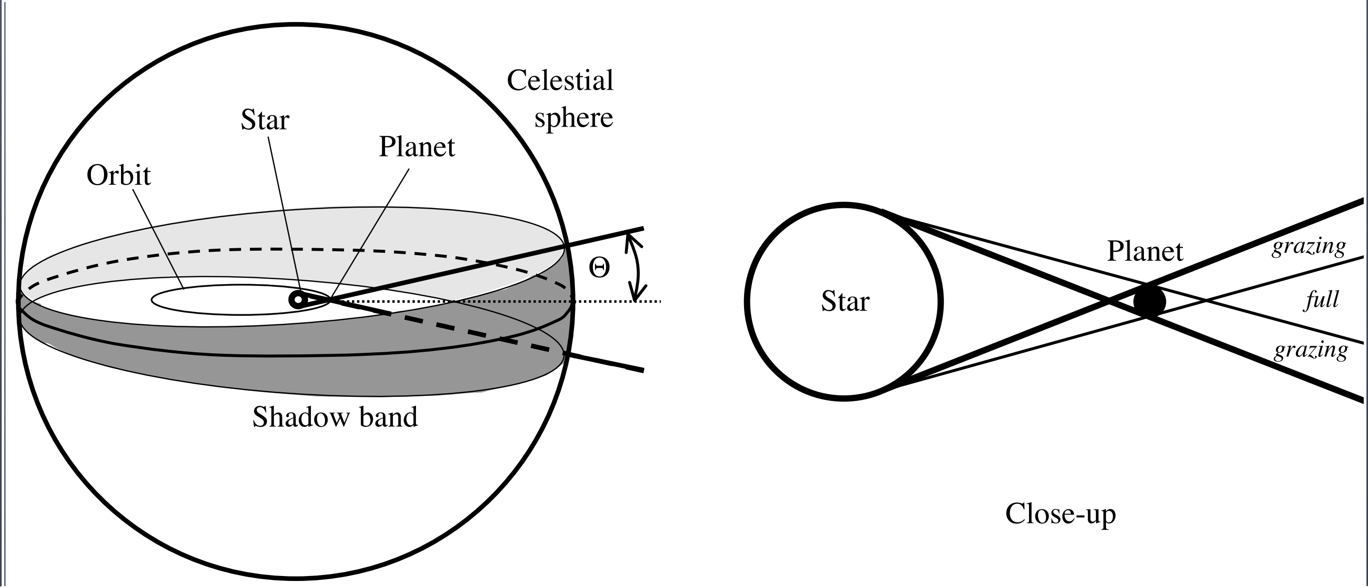
Geometria del transito

Transito ed eclisse



Probabilità di transito

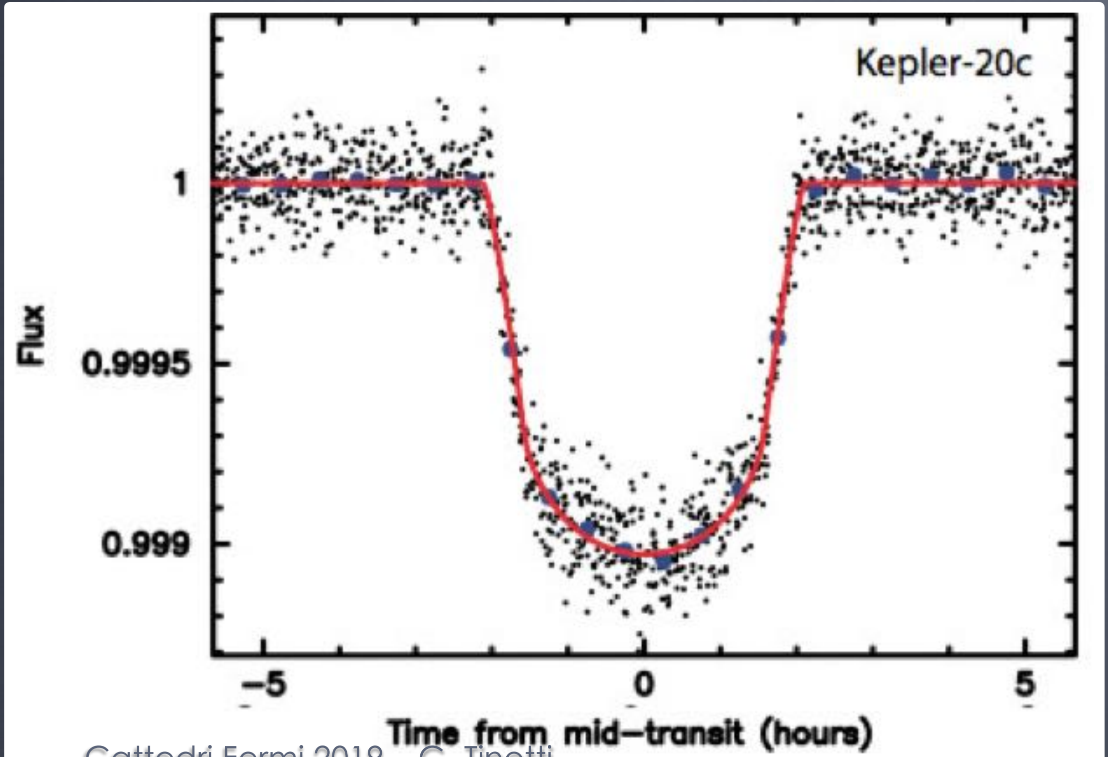
Transito ed eclisse



$$p_{\rm tra} = p_{\rm occ} = \frac{R_\star}{a} \approx 0.005 \left(\frac{R_\star}{R_\odot}\right)\left(\frac{a}{1\,\rm AU}\right)^{-1}$$

Curva di luce

Grafico luminosità/tempo



Cattedri Fermi 2019 – G. Tinetti

- Prima del transito:

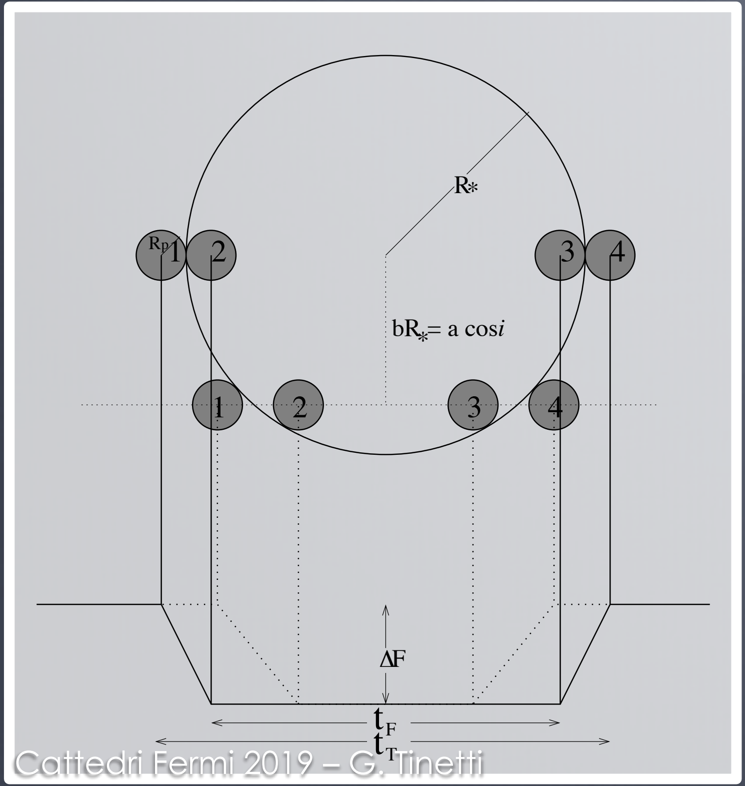
$$F_* + F_p$$

- Durante il transito:

$$F_* + F_p - \pi R_p^2/\pi R_*^2 \times F^*$$

Transito

Parametri chiave



$$T_{\mathrm{tot}} \equiv t_{\mathrm{IV}} - t_{\mathrm{I}}$$

$$T_{\mathrm{full}} \equiv t_{\mathrm{III}} - t_{\mathrm{II}}$$

$$\tau_{\mathrm{ing}} = t_{\mathrm{II}} - t_{\mathrm{I}}$$

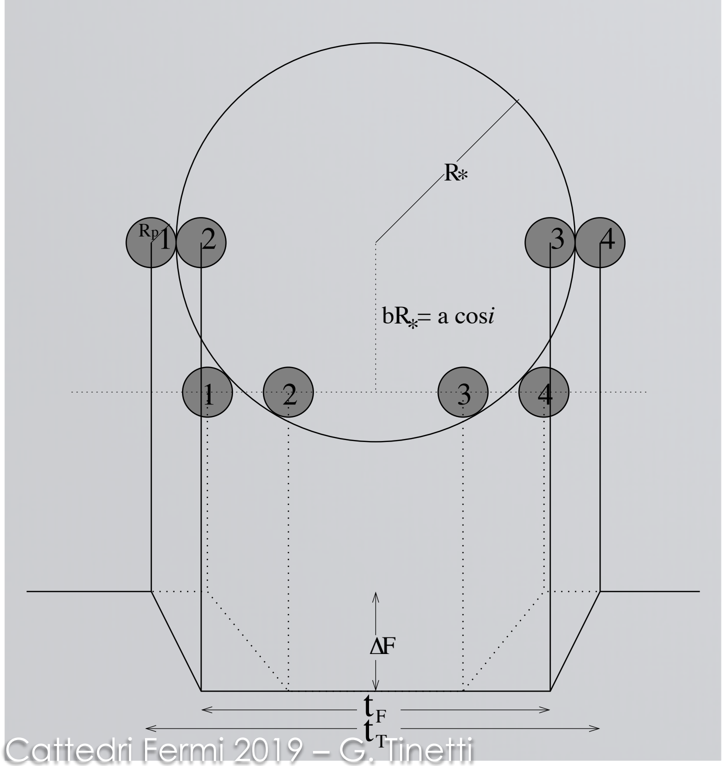
$$\tau_{\mathrm{egr}} = t_{\mathrm{IV}} - t_{\mathrm{III}}$$

$$\frac{R_p}{R_*} = \sqrt{\Delta F}$$

Profondità del transito

Transito

Parametri chiave



$$P^2 = \frac{4\pi^2 a^3}{G(M_* + M_p)}$$

Terza legge Keplero

Profondità del transito

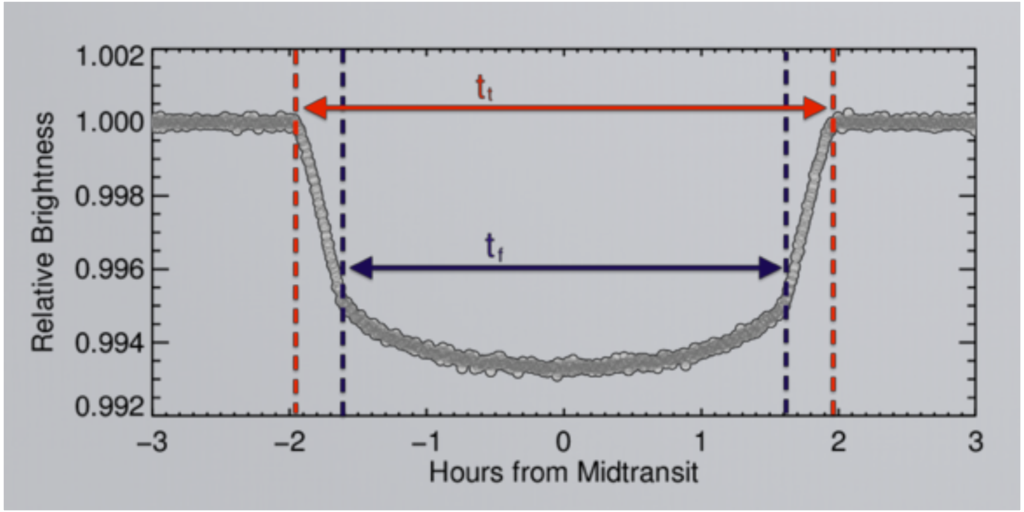
$$\frac{R_p}{R_*} = \sqrt{\Delta F}$$

$$i = \cos^{-1}\left(b\frac{R_*}{a}\right)$$

Inclinazione orbita (geometria transito)

Transito

Parametri chiave: parametro d'impatto (orbita circolare)



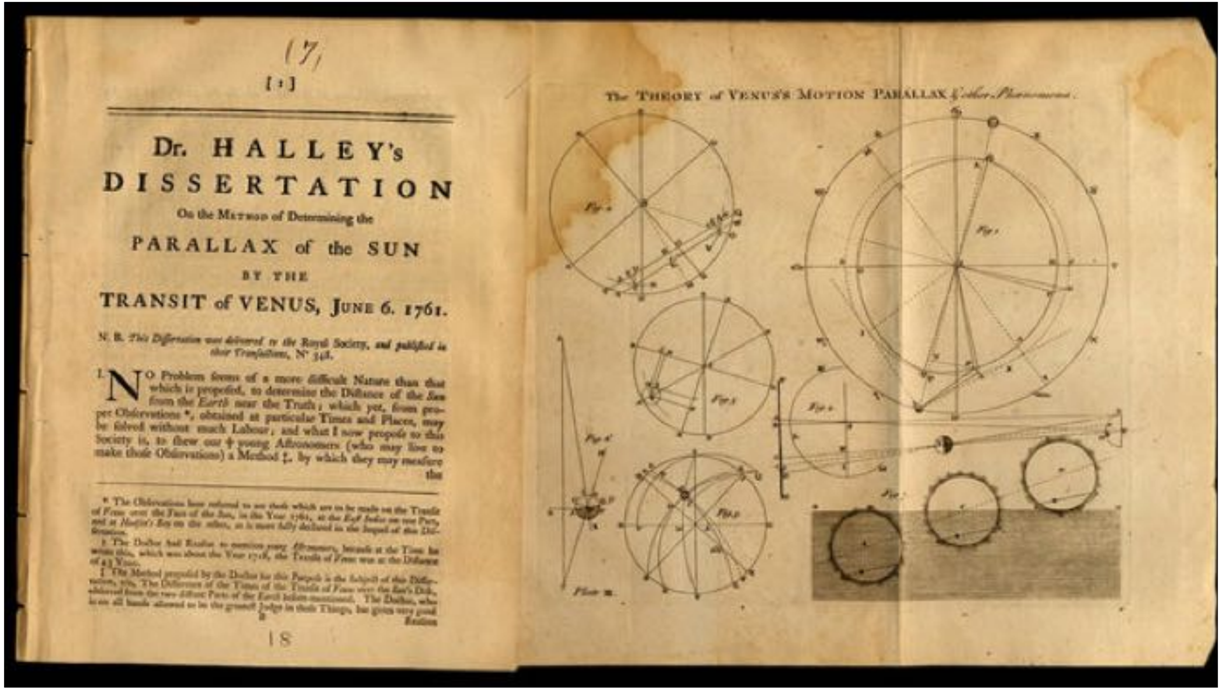
$$b = \left[\frac{\left(1 - \sqrt{\Delta F}\right)^2 - (t_F/t_T)^2 \left(1 + \sqrt{\Delta F}\right)^2}{1 - (t_F/t_T)^2} \right]^{1/2}$$

Parametro d'impatto

Seager & Mallén-Ornelas (2003); Kipping (2008)

Transito di Venere

1761-1769 e la misura della distanza Terra-Sole


(7)

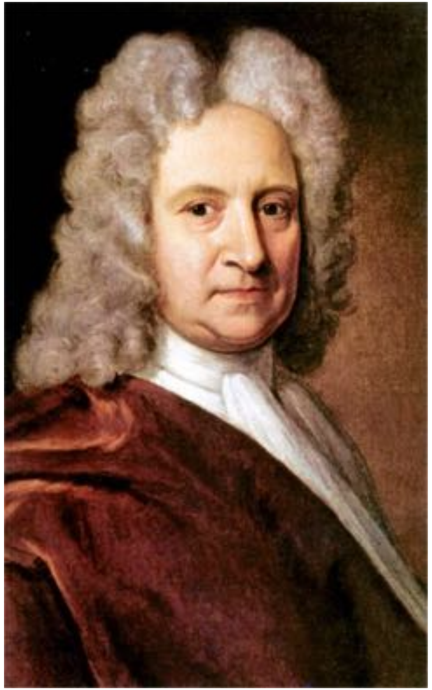
[1]

Dr. HALLEY's
DISSERTATION
On the METHOD of Determining the
PARALLAX of the SUN
BY THE
TRANSIT of VENUS, JUNE 6. 1761.

N. B. *This Dissertation was delivered to the Royal Society, and published in their Transactions, N° 348.*

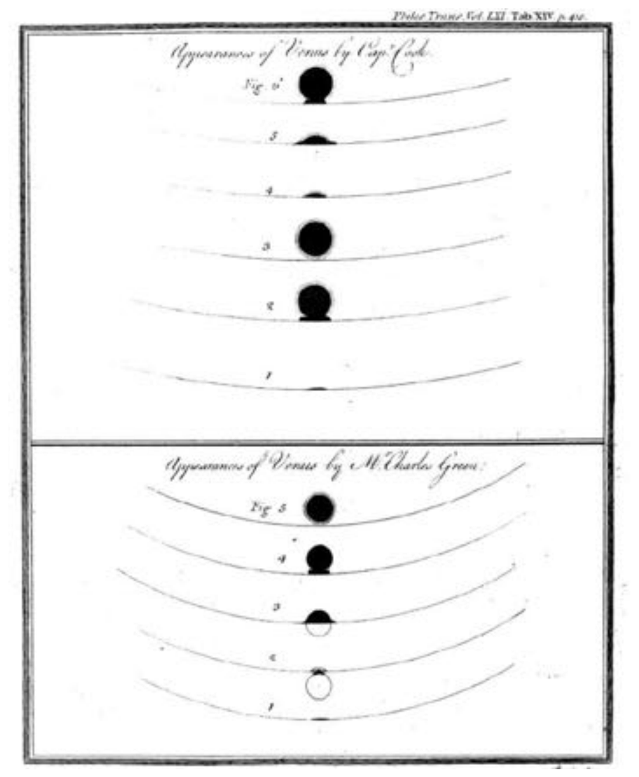
I. NO Problem seems of a more difficult Nature than that which is proposed, to determine the Distance of the *Sun* from the *Earth* near the Truth; which yet, from proper Observations *, obtained at particular Times and Places, may be solved without much Labour; and what I now propose to this Society is, to shew our † young Astronomers (who may live to make those Observations) a Method ‡, by which they may measure the

18



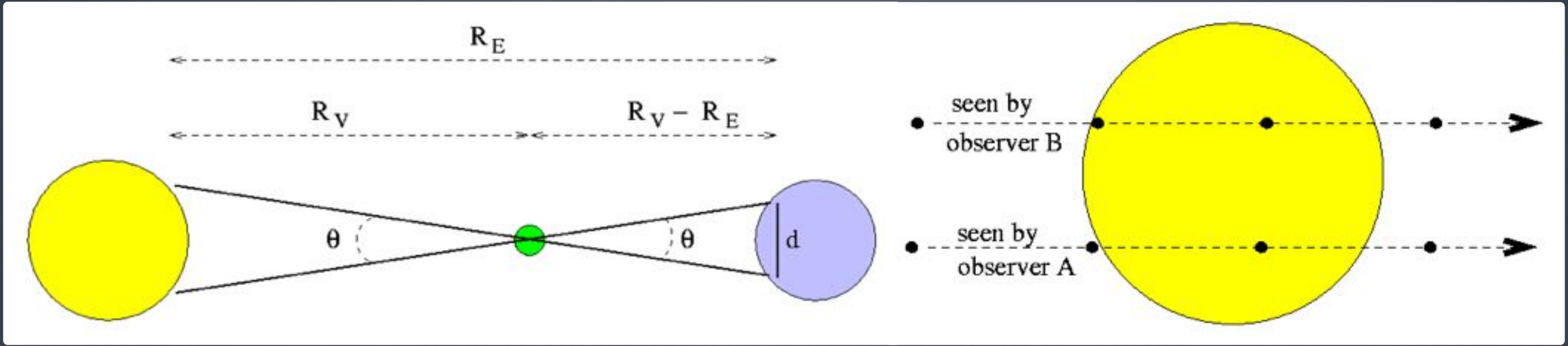
Transito di Venere

1761-1769 e la misura della distanza Terra-Sole



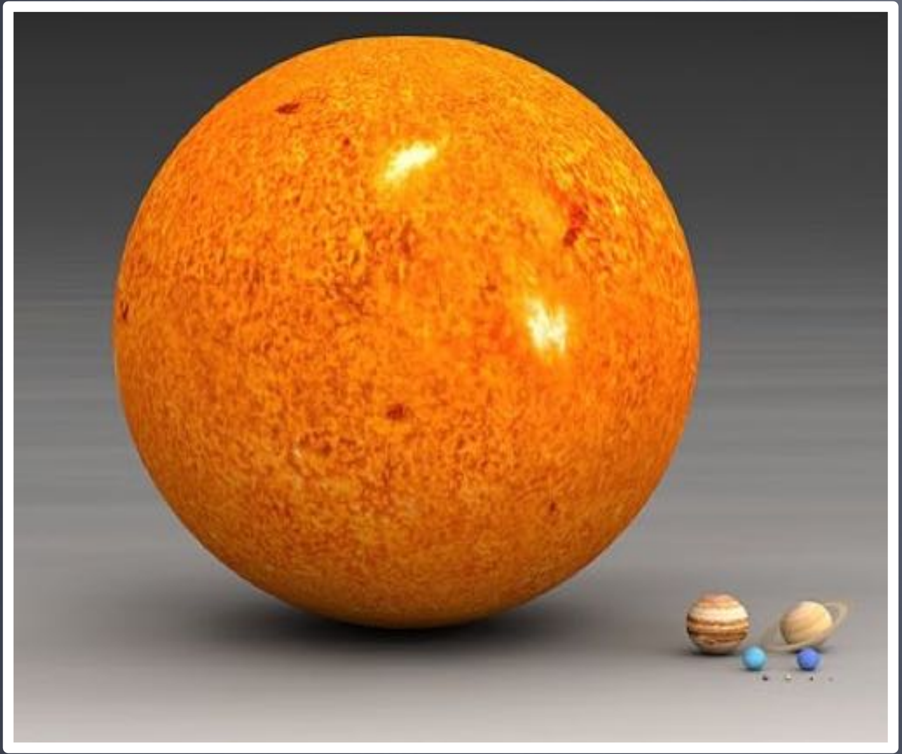
Transito di Venere

1761-1769 e la misura della distanza Terra-Sole



Transito

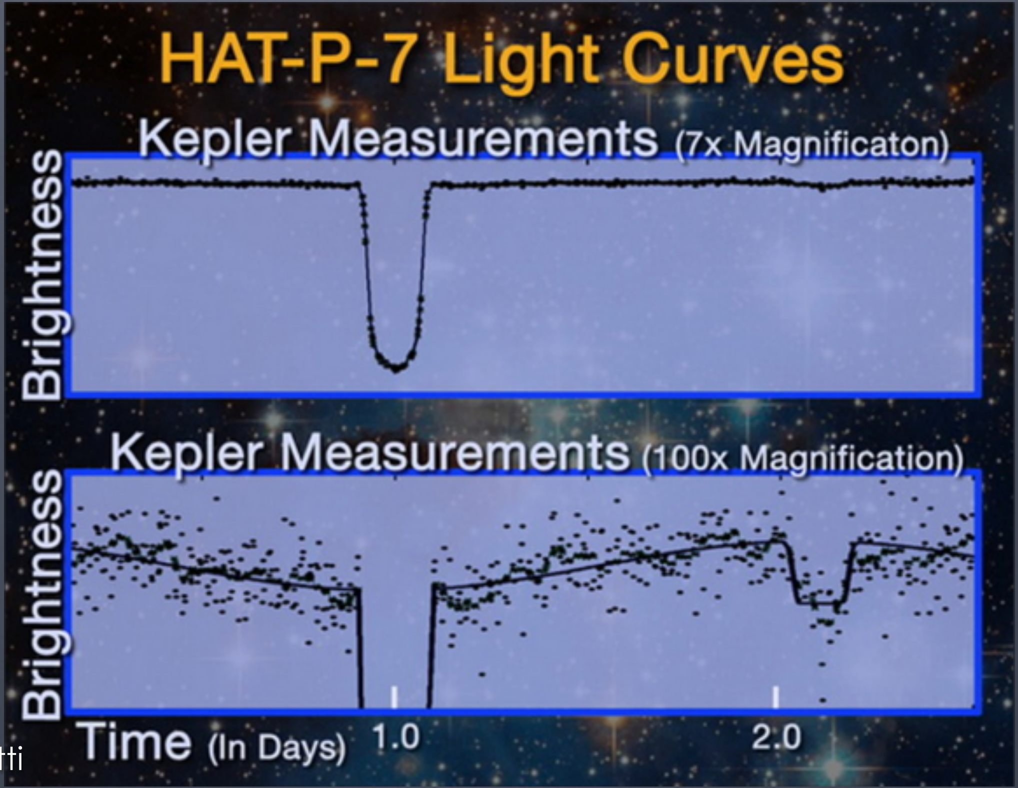
Parametri chiave: profondità del transito



- Sole-Giove
  1%
- Stella M-super-Terra
  ~ 1%
- Sole-Terra
  0.01%

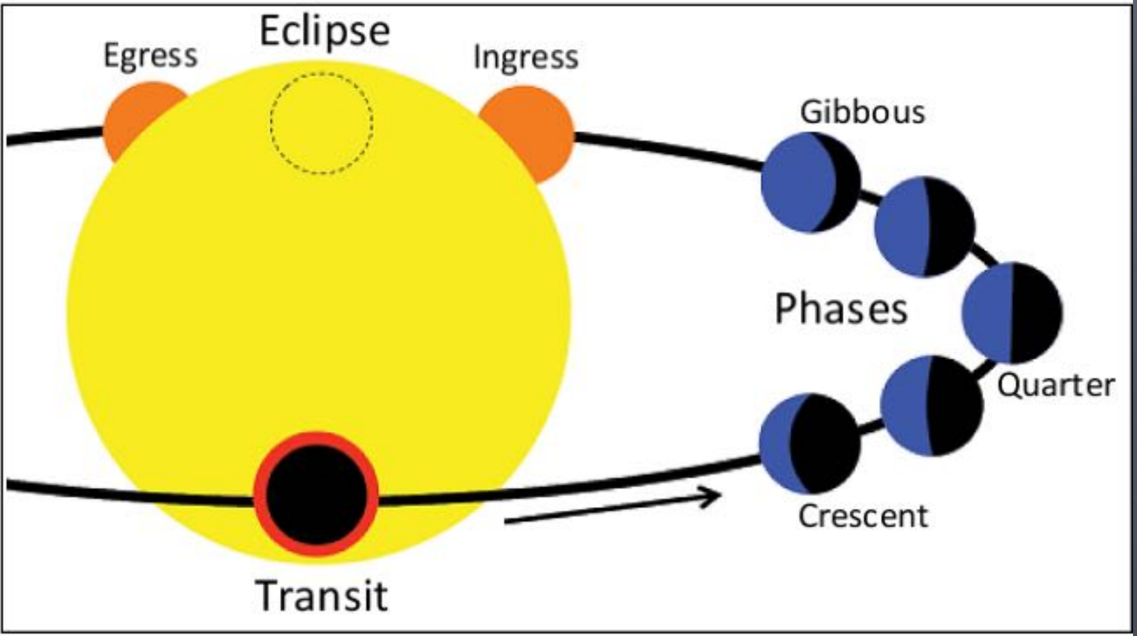
Curve di fase

Osservata con Kepler



Eclisse

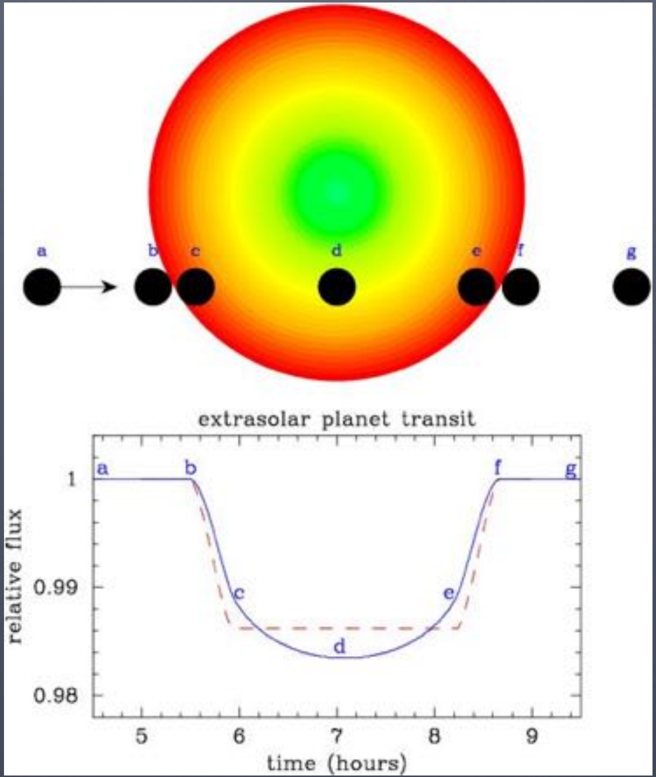
Pianeta nascoto dalla stella



$$F_{\mathrm{II}}(\lambda) = \left(\frac{R_p}{R_\star}\right)^2 \frac{F_p(\lambda)}{F_\star(\lambda)} =$$

Oscuramento al bordo

Effetti sulla curva di luce



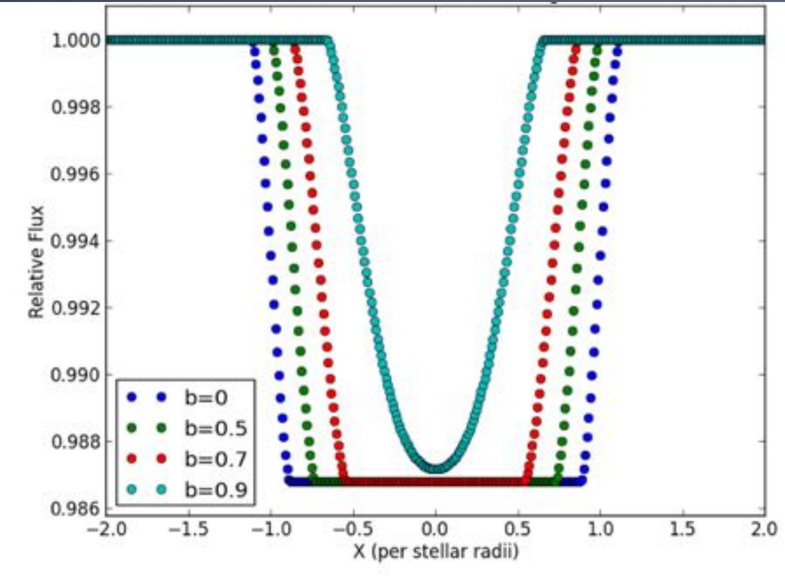
La curva di luce appare + arrotondata.

L'effetto è più forte nel visibile/UV, sparisce nell'IR

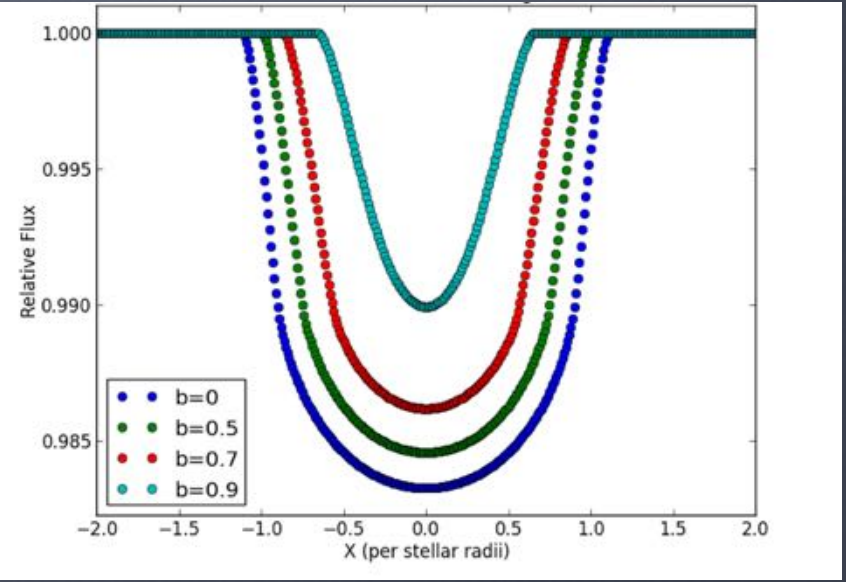
Oscuramento al bordo

Effetti sulla curva di luce

Senza oscuramento



Con oscuramento

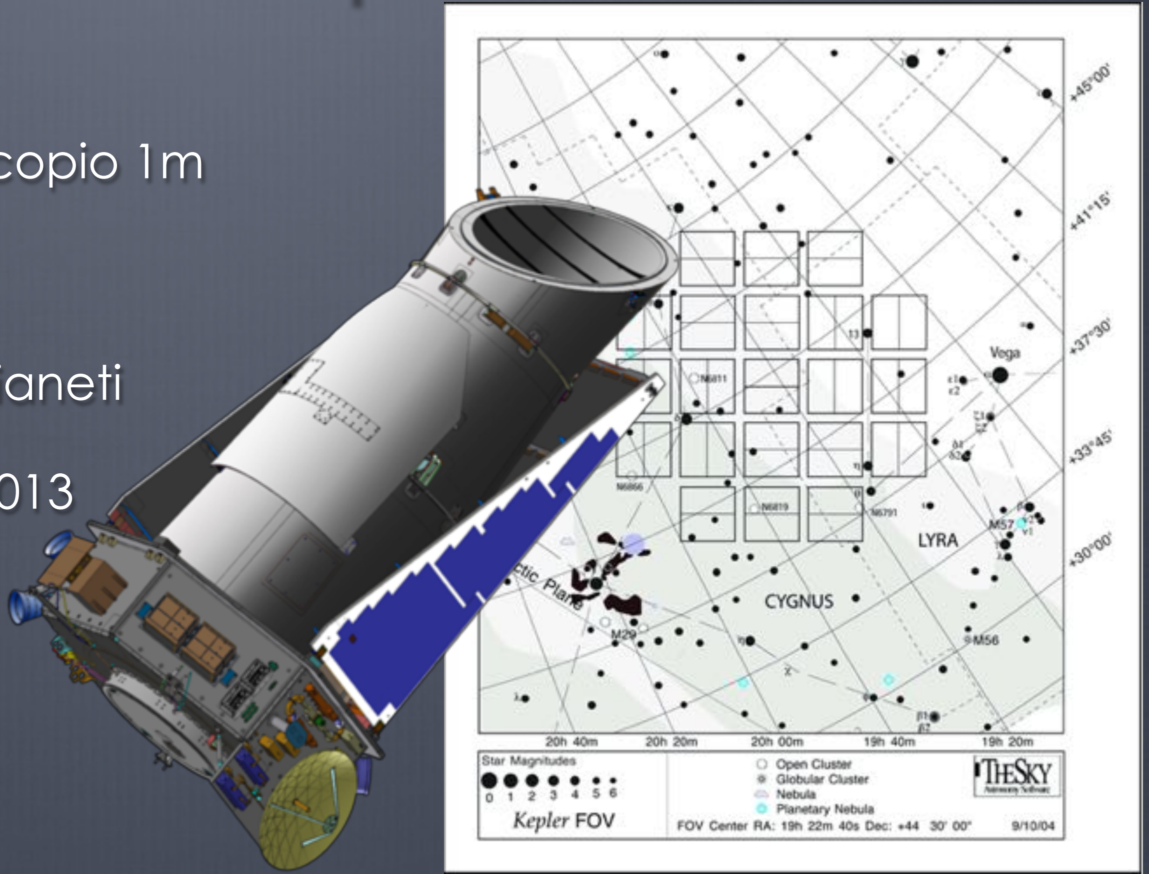


Corot (ESA-CNES)

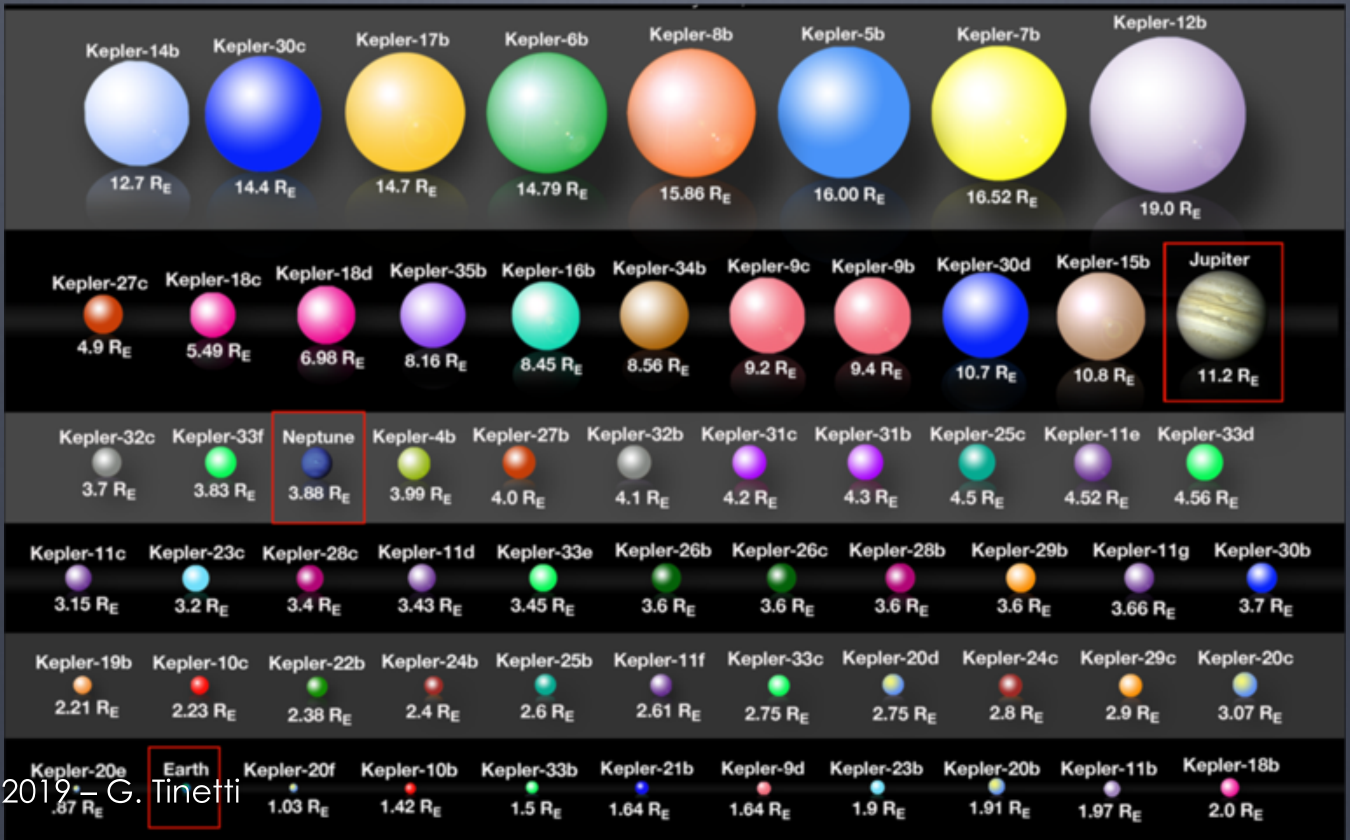
- Orbita polare, telescopio 30-cm
- Lanciato nel 2006
- ~30 pianeti scoperti

NASA Kepler

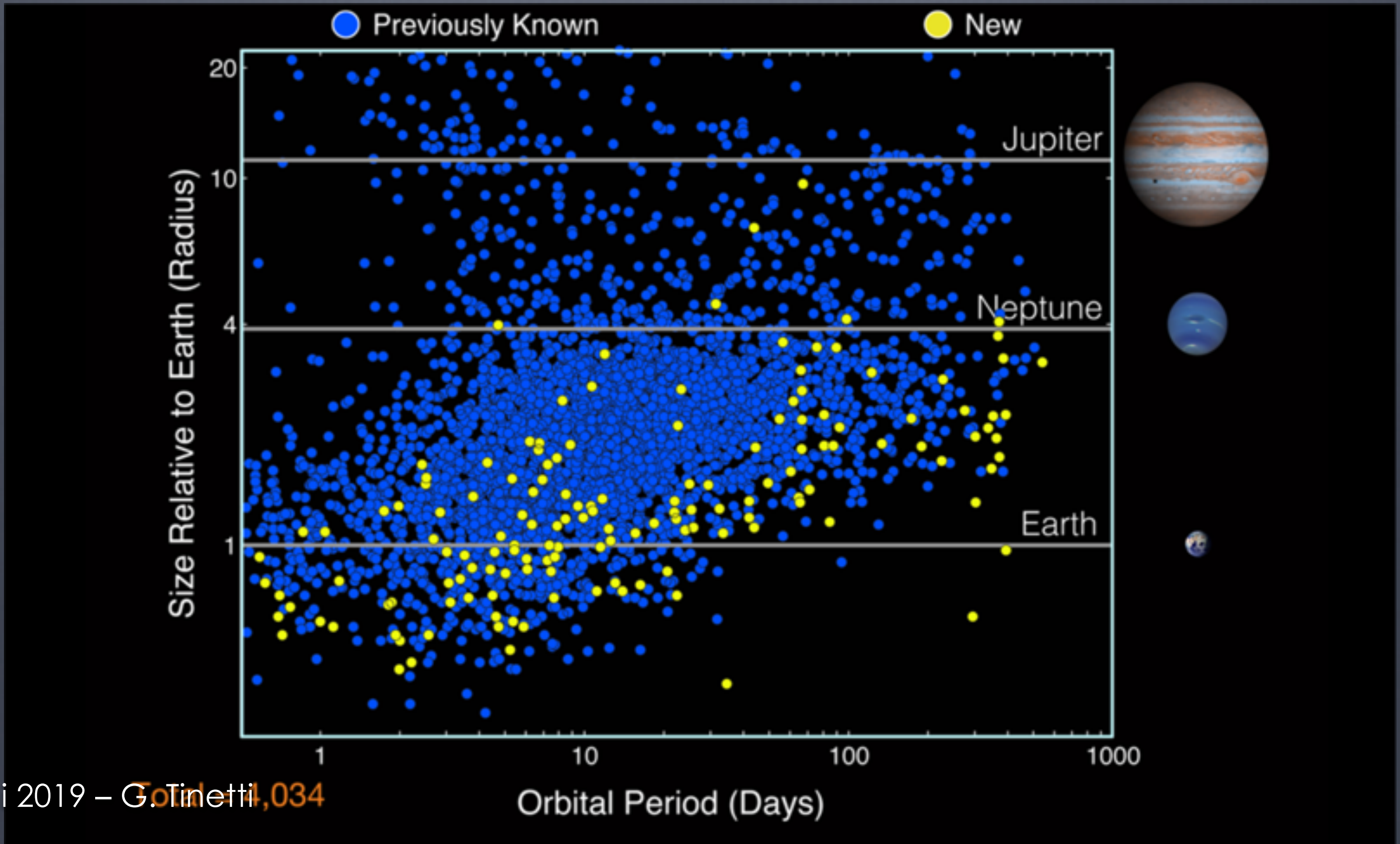
- Orbita eliocentrica, telescopio 1m
- Lanciato nel 2009
- Ha scoperto migliaia di pianeti
- Missione K2 cominciata 2013
- Precisione vicino 0.01%



I pianeti di Kepler

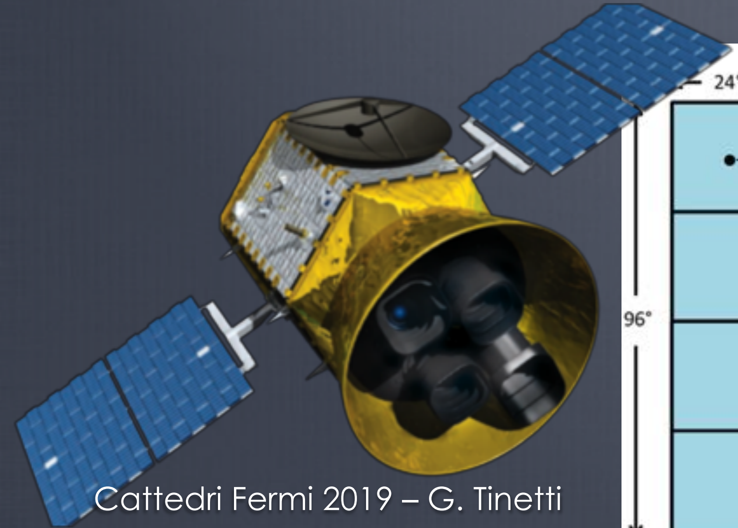


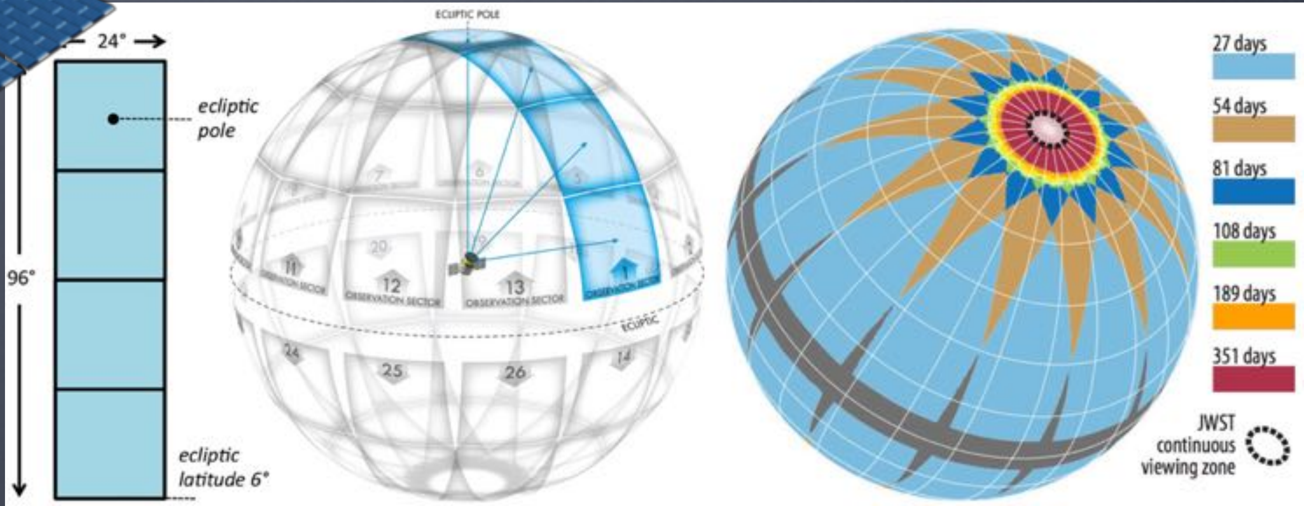
I pianeti di Kepler



NASA TESS

- Lanciato nel 2018, orbita molto eccentrica
- Scoprirà migliaia di pianeti intorno a stelle brillanti





Transiti visti da Terra

Strumenti da Terra per la misura del transito

NGTS

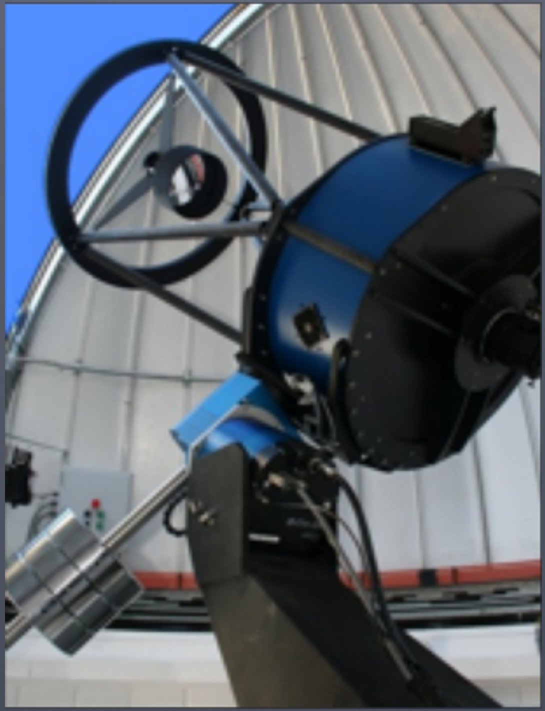
Hat-NET

Super-WASP

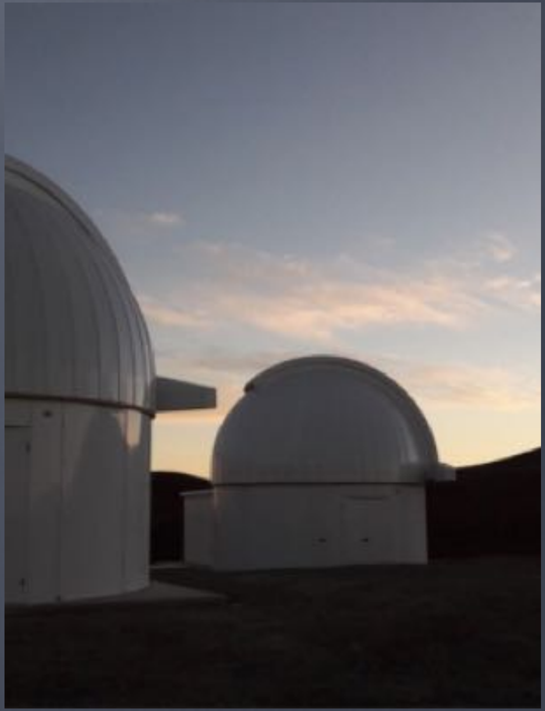
Transiti visti da Terra

Strumenti da Terra per la misura del transito (stelle M)

MEarth



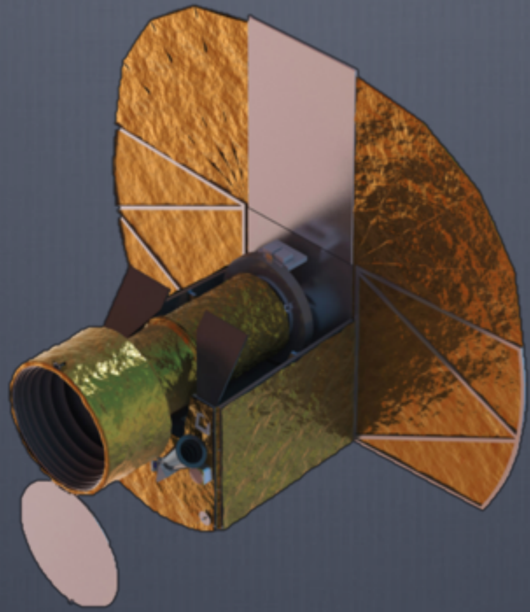
Trappist

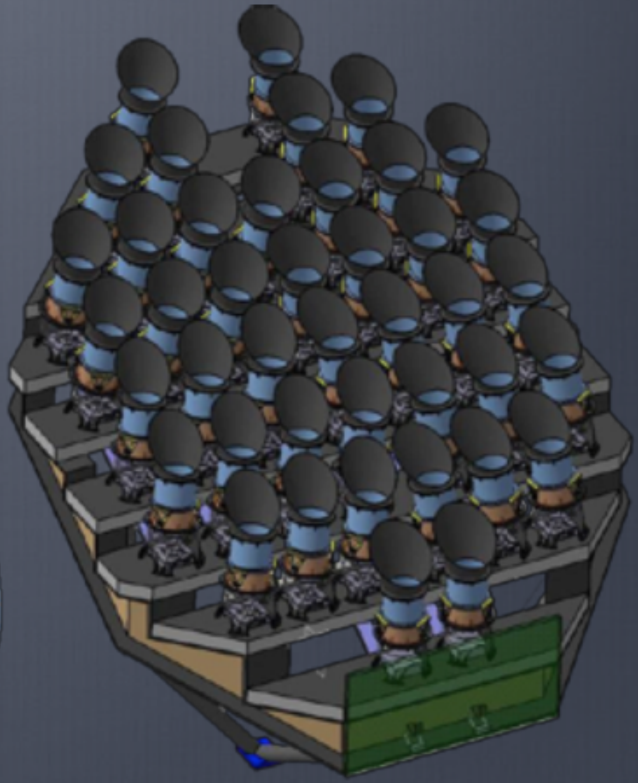


Speculoos

ESA Cheops e PLATO

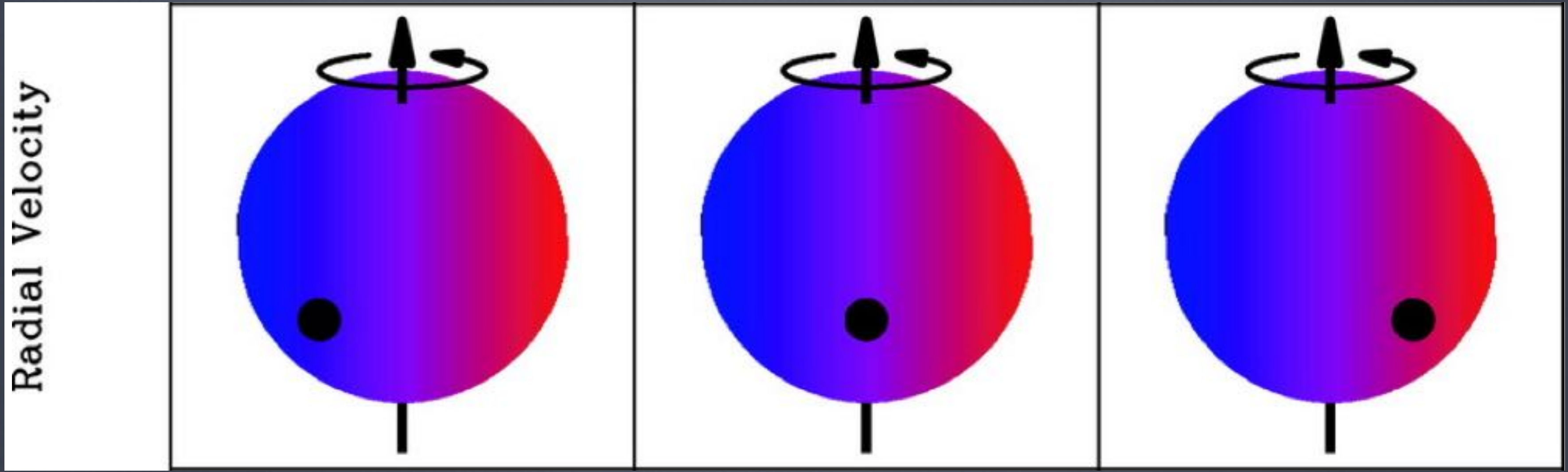
- Satelliti per lo studio dei transiti che verranno lanciati nel 2019 e 2026





Effetto Rossiter-McLaughlin

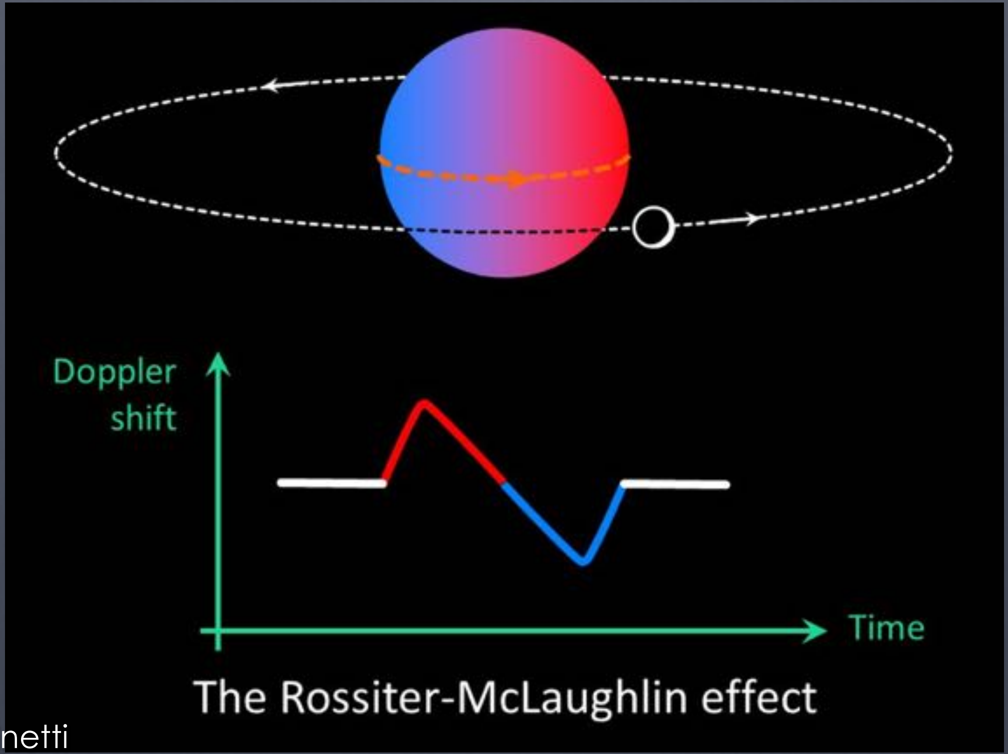
Pianeti in transito osservati con velocità radiale



Gaudi, Winn 2007

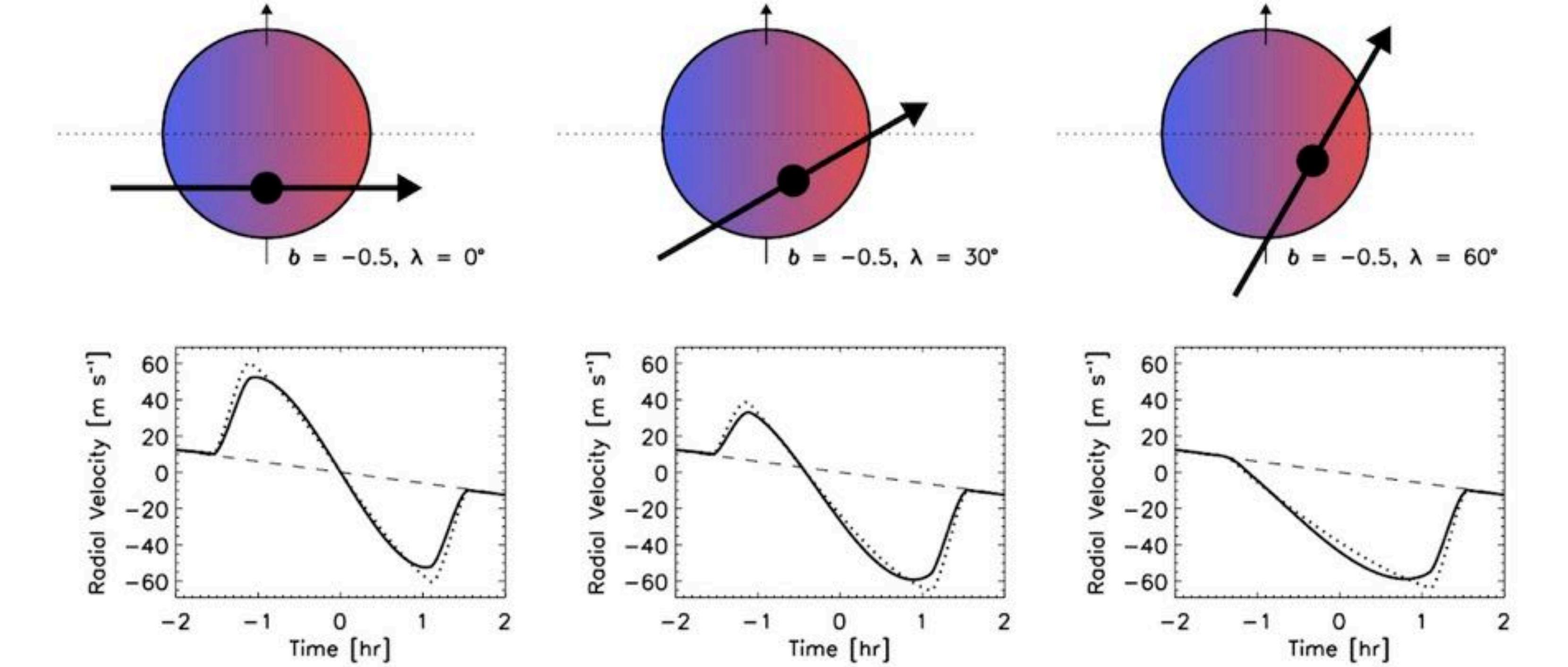
Effetto Rossiter-McLaughlin

Pianeti in transito



Effetto Rossiter-McLaughlin

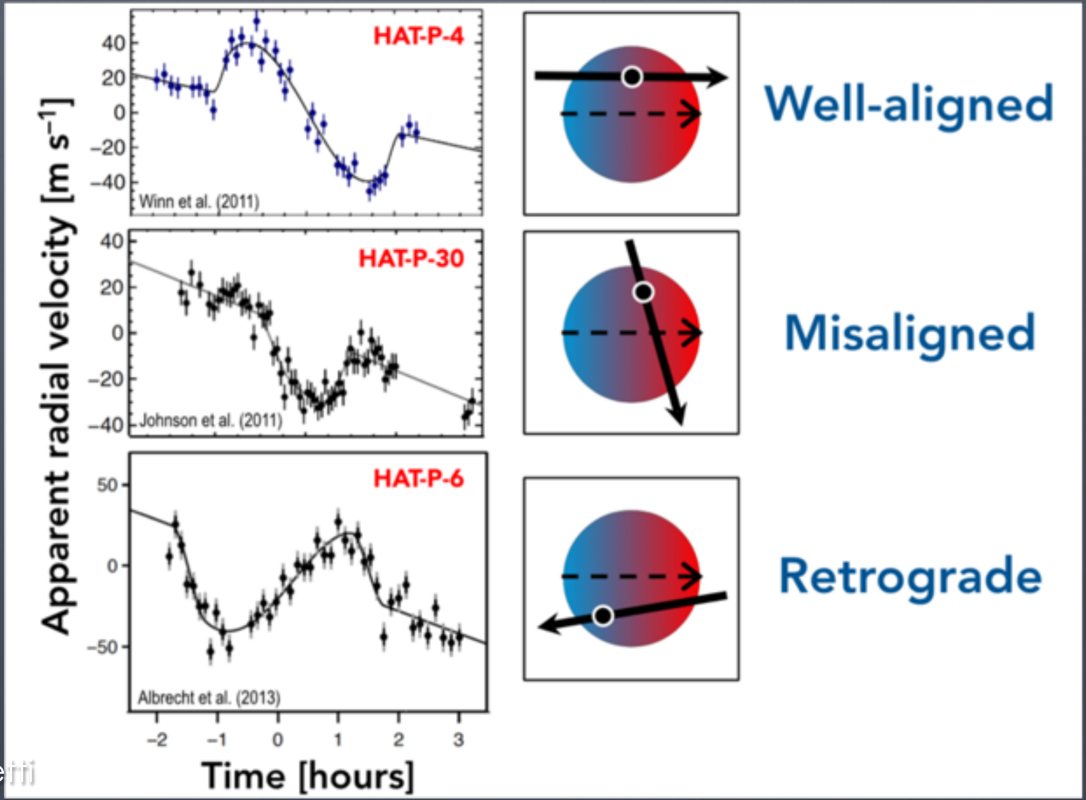
Allineamento spin-orbita



Gaudi, Winn 2007

Allineamento spin-orbita

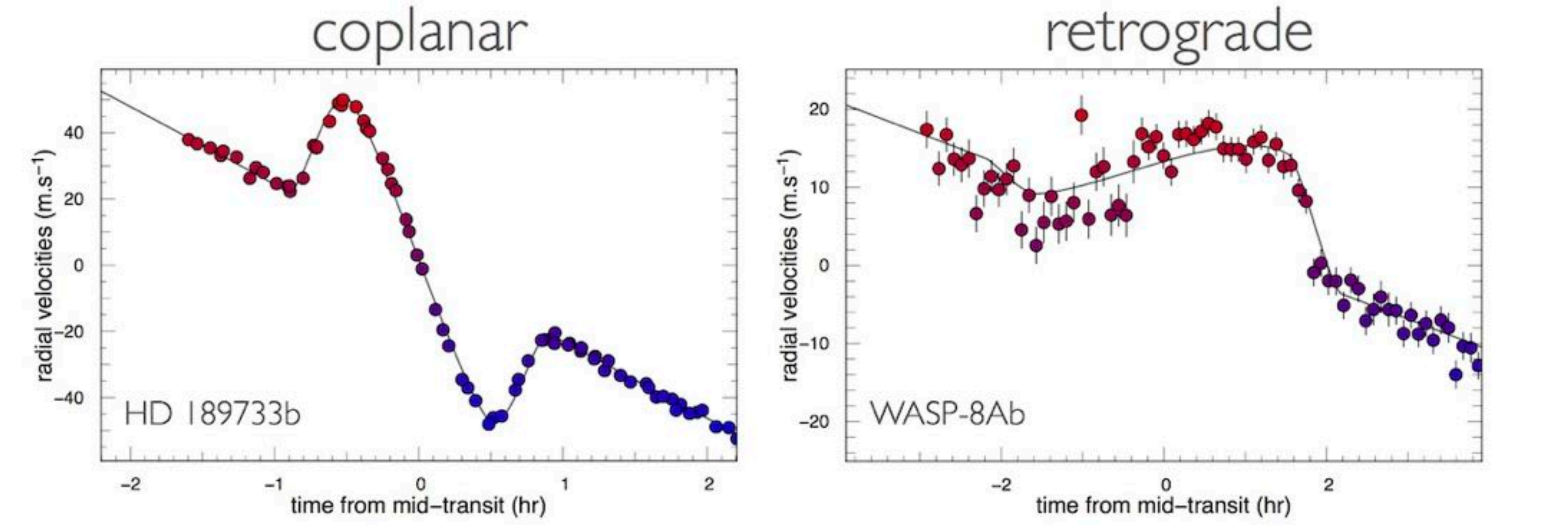
Alcuni esempi



Gaudi, Winn 2007

Allineamento spin-orbita

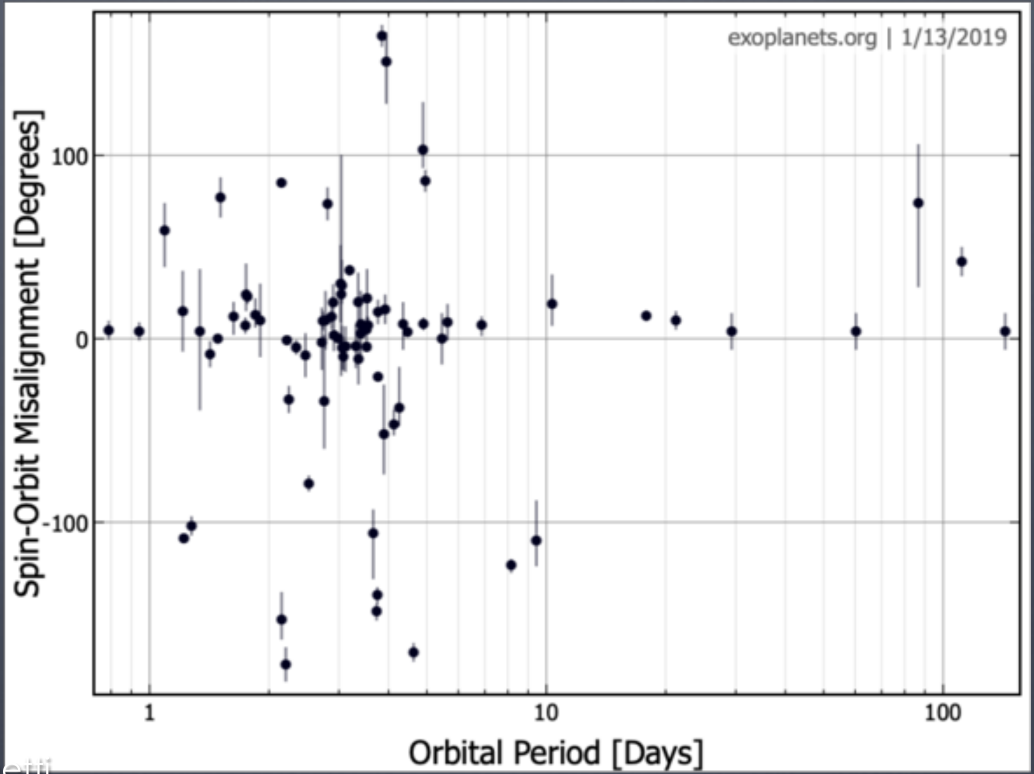
Alcuni esempi



Gaudi, Winn 2007

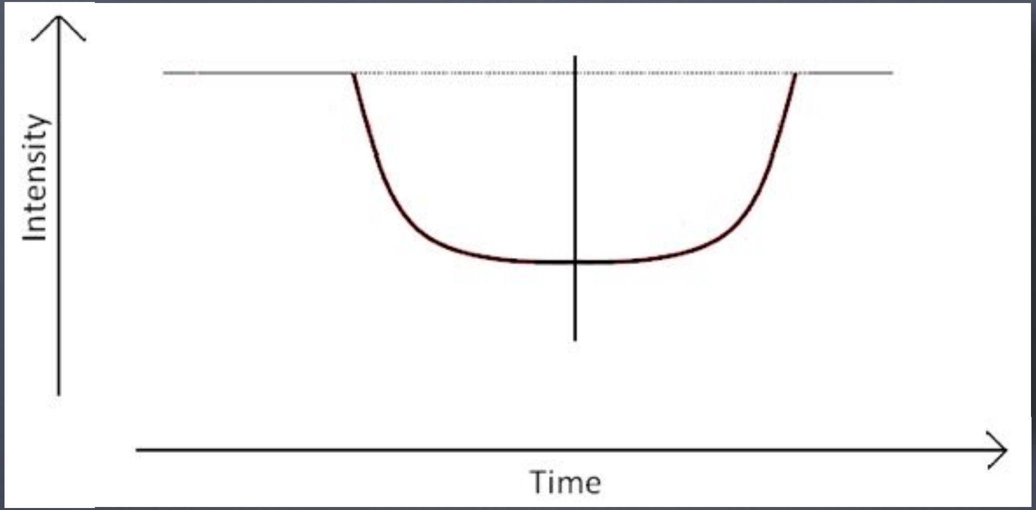
Allineamento spin-orbita

Alcuni pianeti non hanno lo spin-orbita allineato



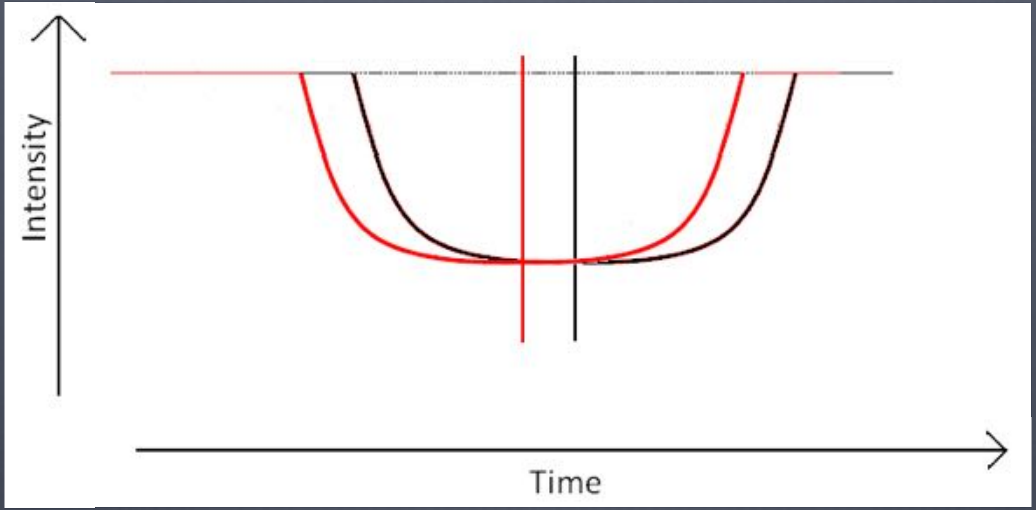
TTV – Transit Time Variation

Per scoprire nuovi pianeti



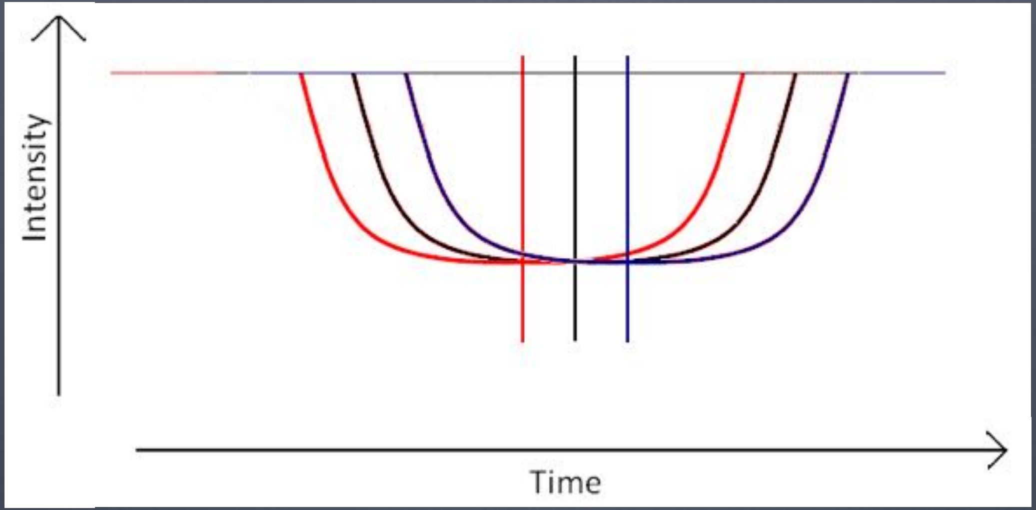
TTV

Per scoprire nuovi pianeti



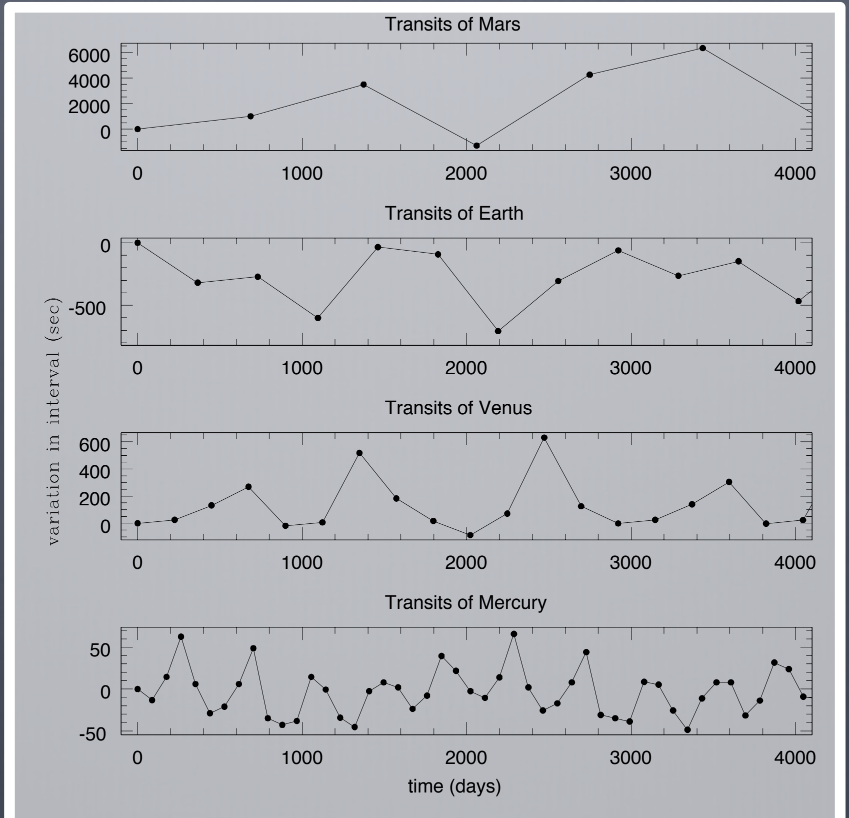
TTV

Per scoprire nuovi pianeti



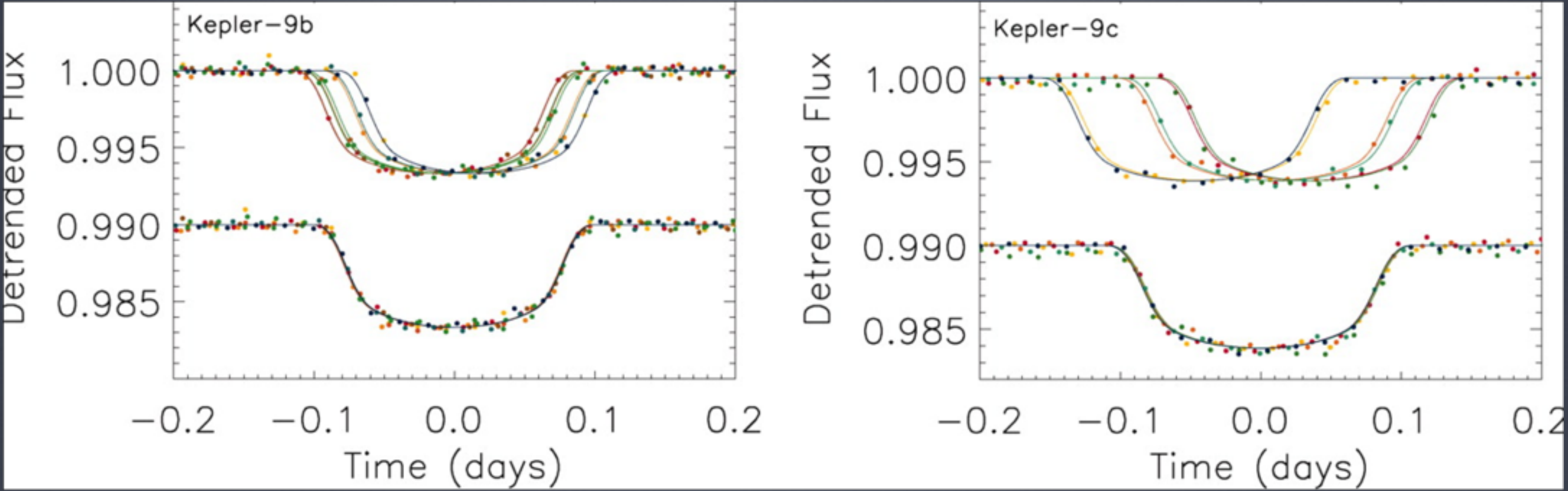
TTV per scoprire pianeti

Simulazioni sistema solare



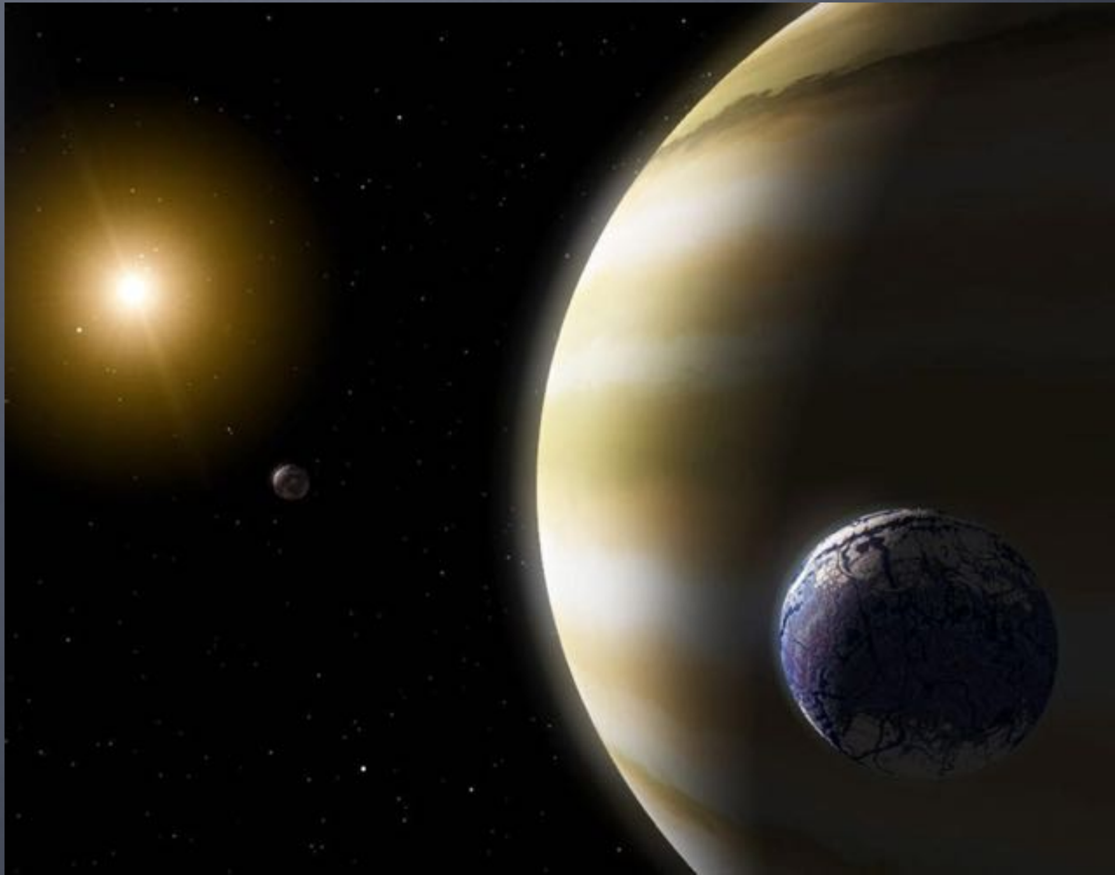
TTV per scoprire pianeti

Alcuni esempi



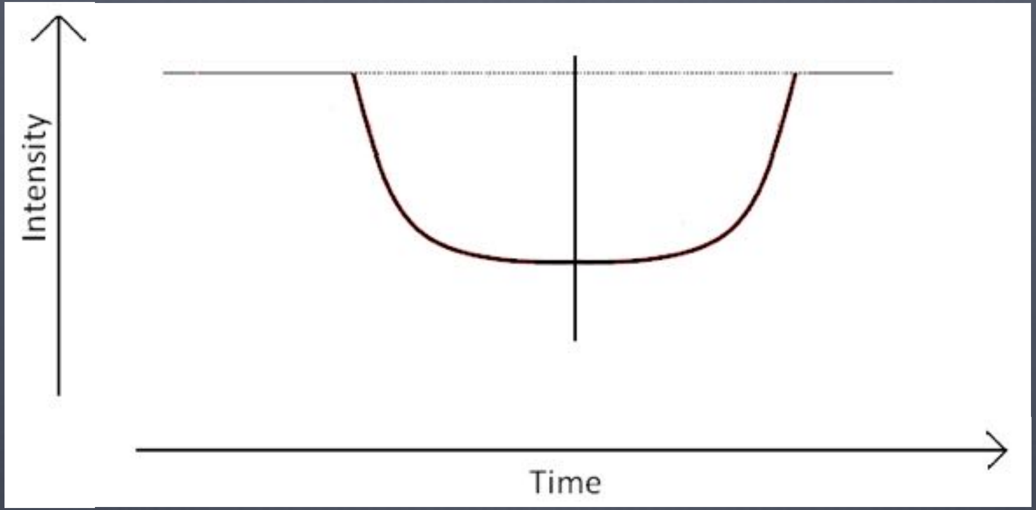
Esolune: TDV + TTV

- Occorre avere TTV e TDV



TDV – Transit Duration Variation

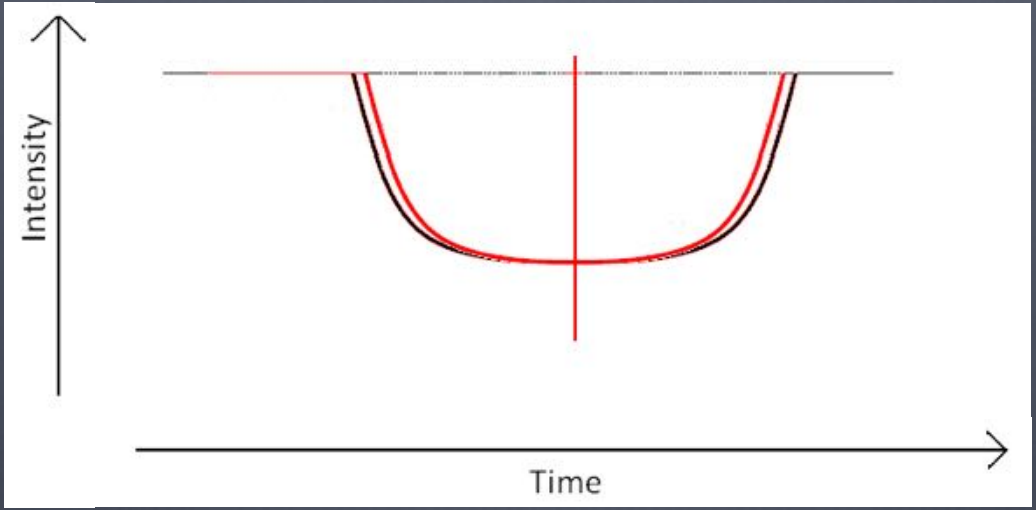
Per scoprire nuove lune in combinazione TTV



Kipping (2009)

TDV

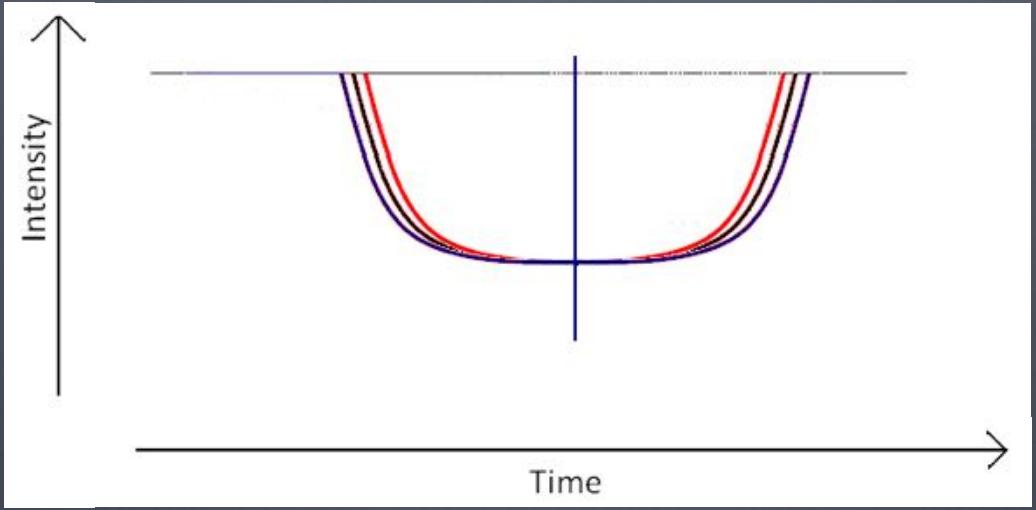
Per scoprire nuove lune in combinazione TTV



Kipping (2009)

TDV

Per scoprire nuove lune in combinazione TTV



Kipping (2009)