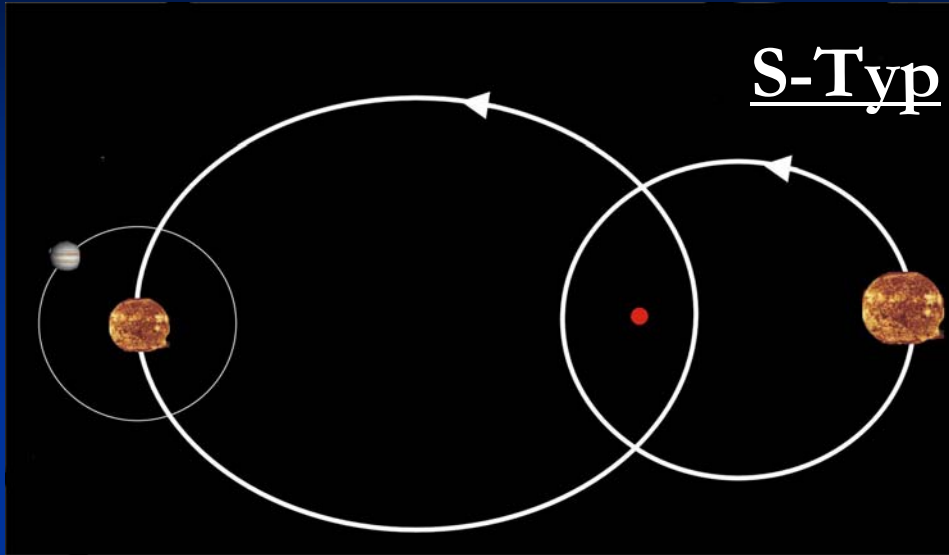


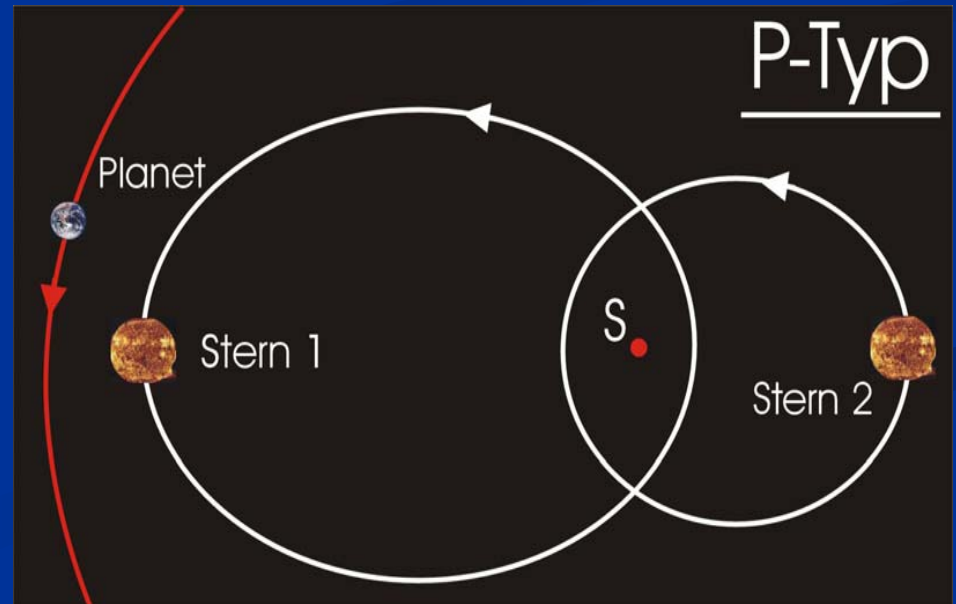
Planetary motion in Binary Star Systems

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and B. Funk (2)

- (1) Institute for Astronomie, Univ.Vienna
- (2) Etvös University, Budapest



Planetary motion in binaries:



General studies of planetary motion in binary systems

- Dvorak R.(1984 and 1986)
- Rabl & Dvorak R. (1988)
- Dvorak R., Froeschle C. & Froeschle Ch. (1989)

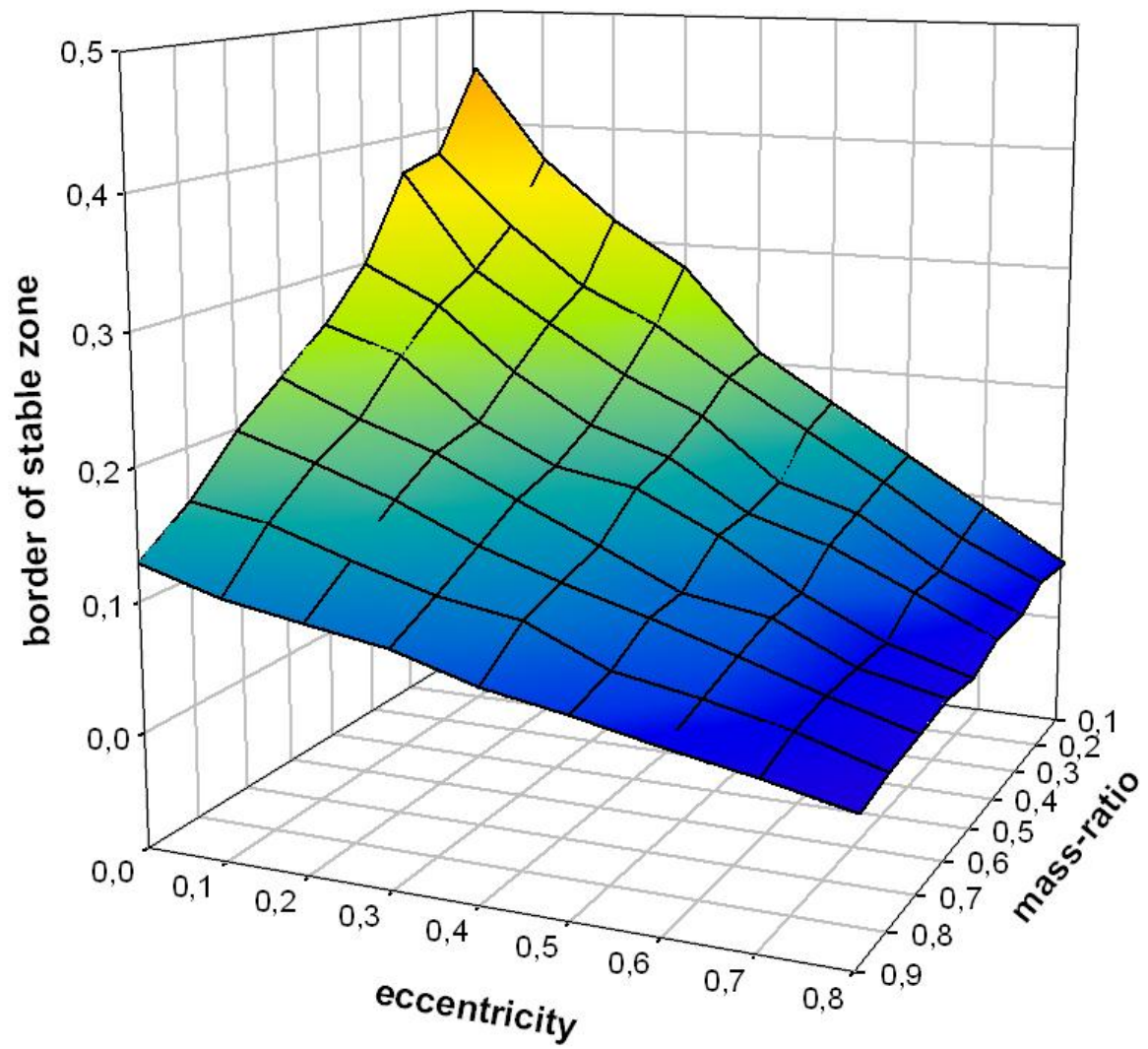
- Holman M. & Wiegert P. (1999)
- Pilat-Lohinger E. & Dvorak R. (2002)

S-type motion

mass-ratio

e_binary	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	0.45	0.38	0.37	0.30	0.26	0.23	0.20	0.16	0.13
0.1	0.37	0.32	0.29	0.27	0.24	0.20	0.18	0.15	0.11
0.2	0.32	0.27	0.25	0.22	0.19	0.18	0.16	0.13	0.10
0.3	0.28	0.24	0.21	0.18	0.16	0.15	0.13	0.11	0.09
0.4	0.21	0.20	0.18	0.16	0.15	0.12	0.11	0.10	0.07
0.5	0.17	0.16	0.13	0.12	0.12	0.09	0.09	0.07	0.06
0.6	0.13	0.12	0.11	0.10	0.08	0.08	0.07	0.06	0.045
0.7	0.09	0.08	0.07	0.07	0.05	0.05	0.05	0.045	0.035
0.8	0.05	0.05	0.04	0.04	0.03	0.035	0.03	0.025	0.02

Stable zone (in units of length) of S-type motion for all computed mass-ratios and eccentricities of the binary. The given size for each (mu,e_binary) pair is the lower value of the studies by Holman &Wiegert (AJ,1999) and Pilat-Lohinger &Dvorak (CMDA, 2002)



Tight Binary Systems

binary	a_{binary} [AU]	e_{binary}	M1 -/M2
Gliese86	~22	?	0.7 - 0.5
γ Cephei	~20	0.4	1.6 - 0.4
HD41004	~23	?	0.7 - 0.4

Gliese86

$$m \sin i = 4 \text{ MJ}$$

$$a = 0.11 \text{ AU}$$

$$e = 0.045$$

γ Cephei

$$m \sin i = 1.6 \text{ MJ}$$

$$a = 2.15 \text{ AU}$$

$$e = 0.11 - 0.2$$

HD 41004

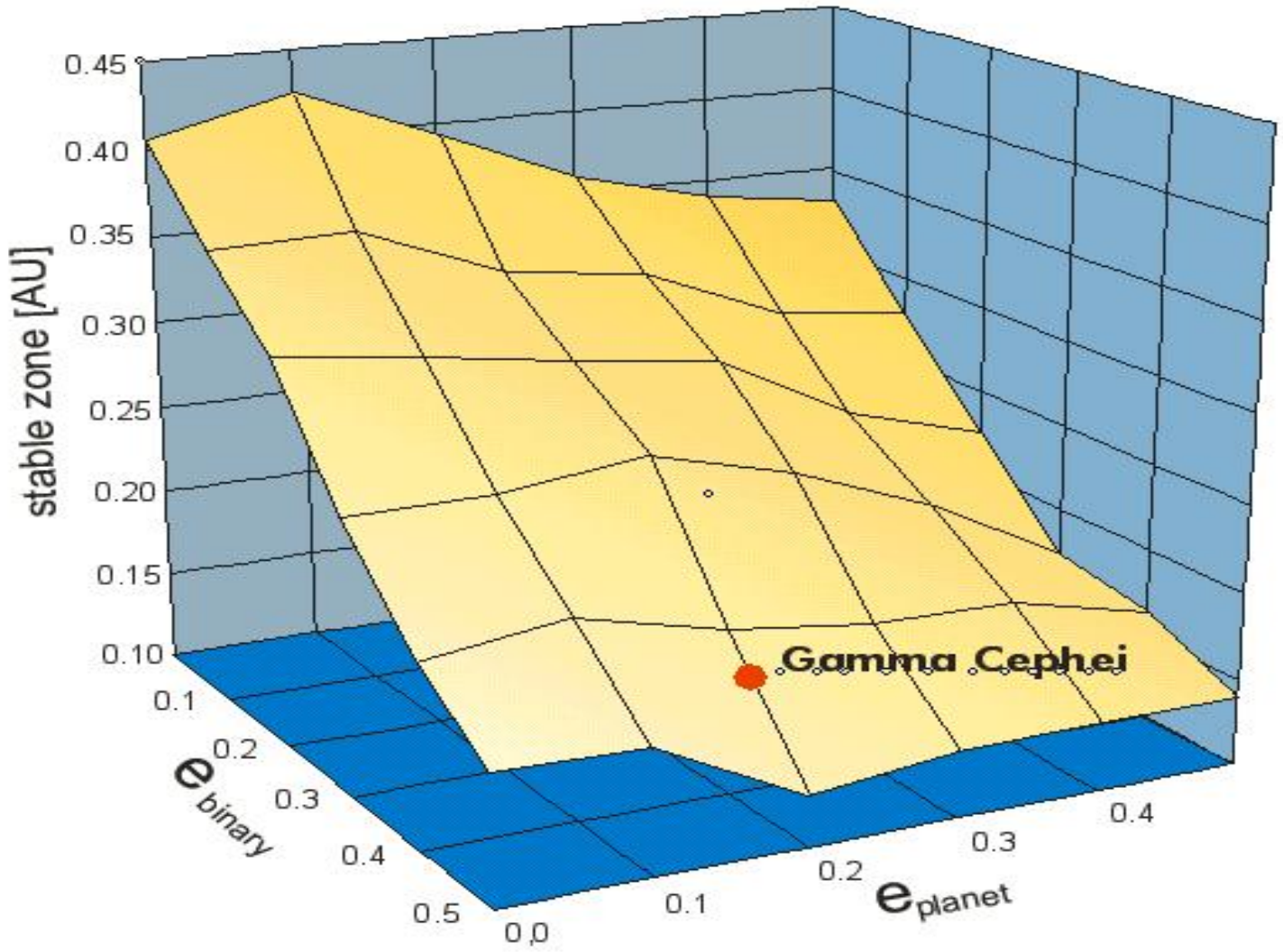
$$m \sin i = 2.3 \text{ MJ}$$

$$a = 1.3 \text{ AU (1.6 or 1.7)}$$

$$e = 0.39 \pm 0.17 \quad ?$$

Stability analysis

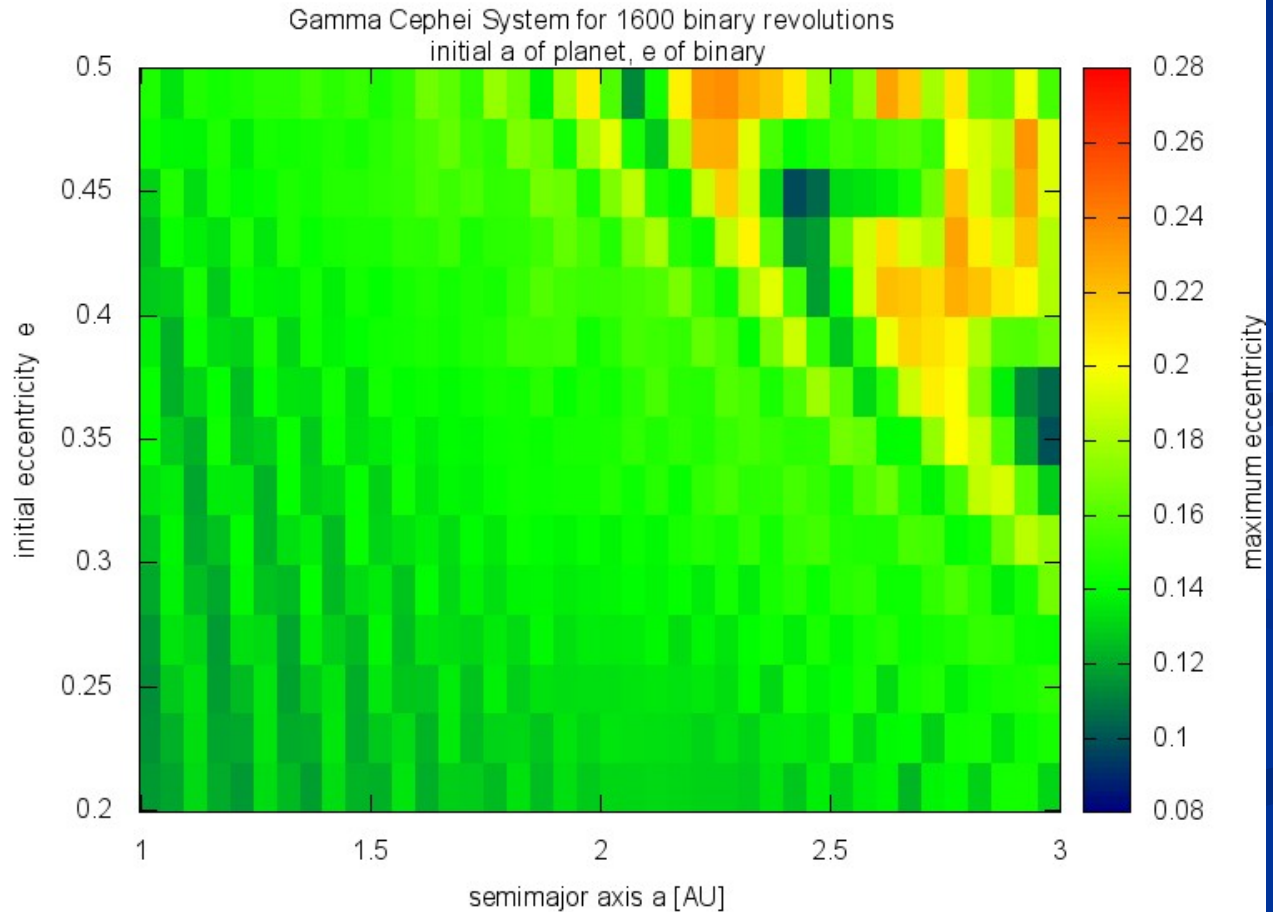
mass-ratio = 0.2



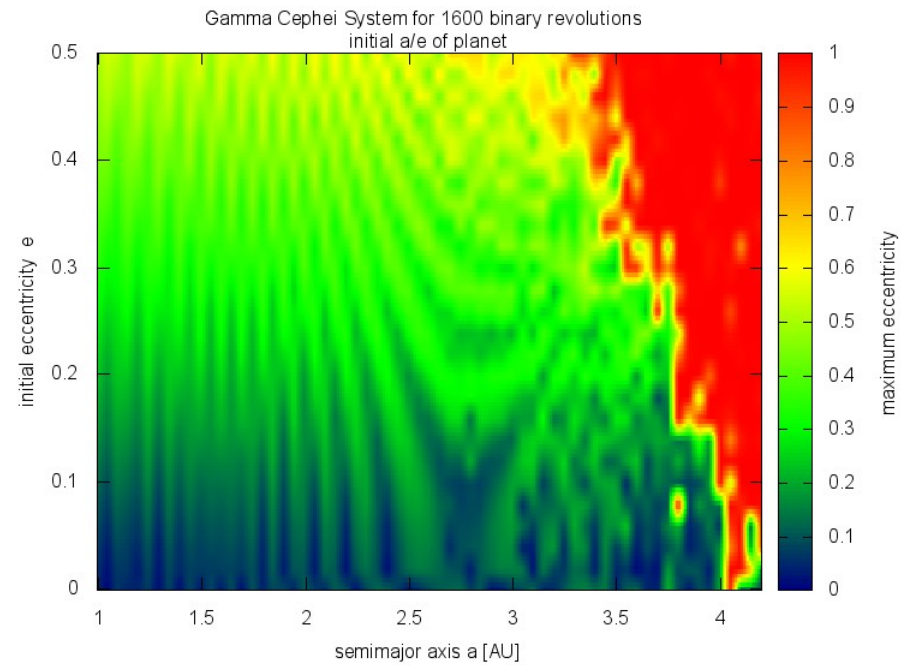
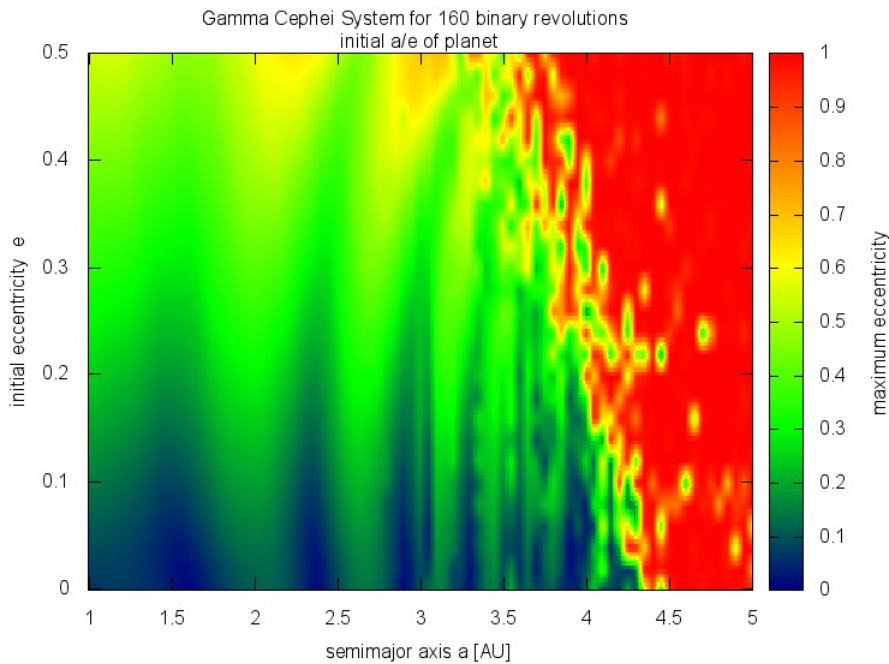
Stability limits

	mass-ratio	border of stable motion
Gamma Cephei:	0.2	3.6 – 3.8 AU
HD41004 AB:	0.36	? (e not known!)
Gliese 86:	0.42	close-in planet

gamma Cephei

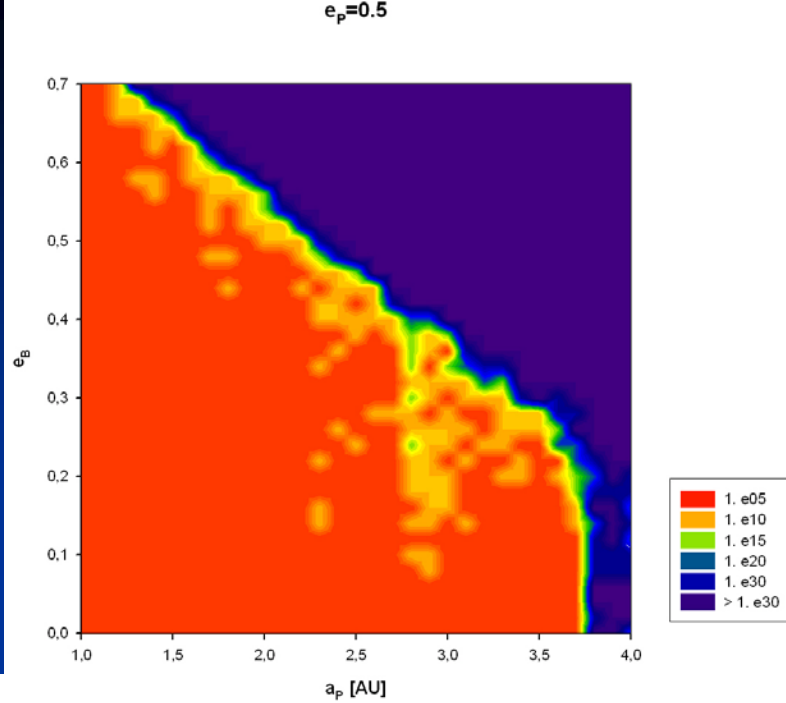


gamma Cephei

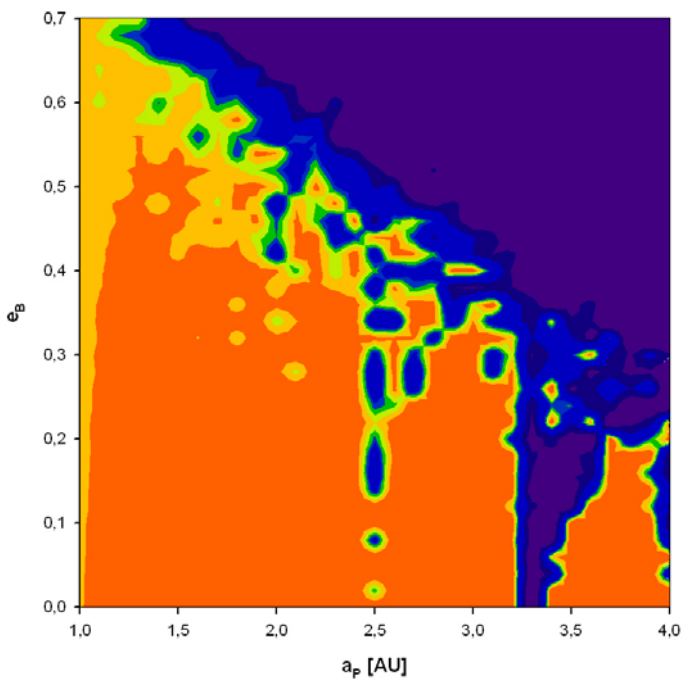


(S. Eggl)

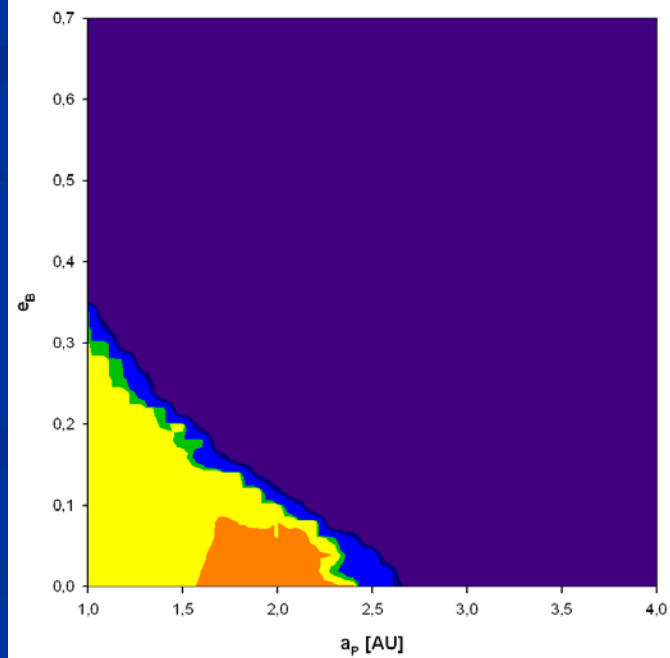
HD41004 AB



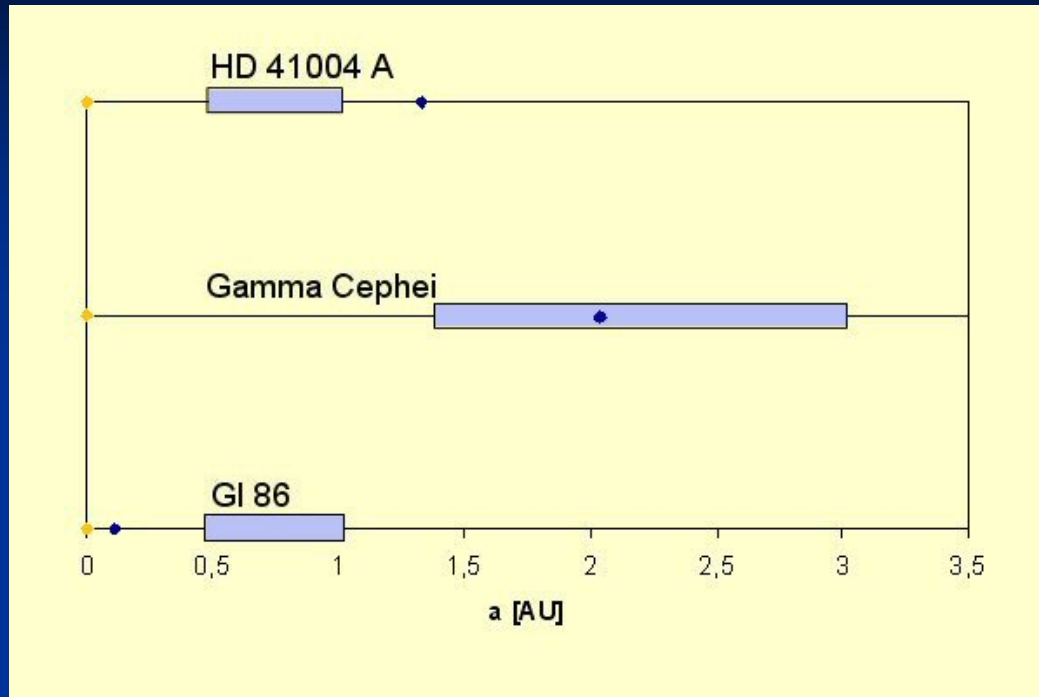
$e_p=0.39$



$e_p=0.74$



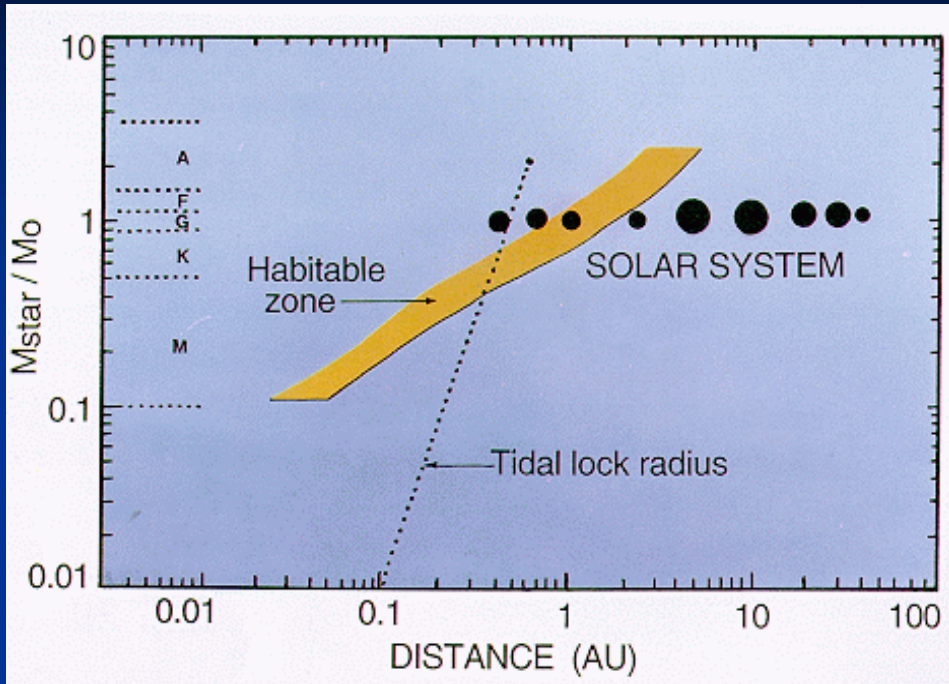
Habitable Zone



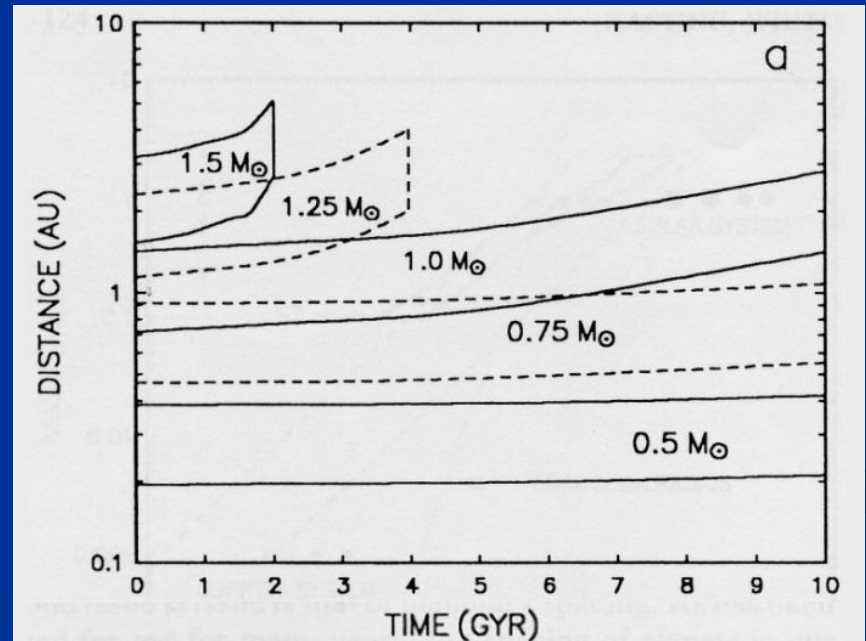
Zone around a star where liquid water can exist on the surface of a terrestrial-like planet

- This zone depends on:
 - the spectraltype , the mass , the age, of the star
 - the orbit of the planet
 - the mass, the composition, the atmosphere ,of the planet
 - the parameters of other planets in this system (mass, orbit, ...)

The Habitable Zone



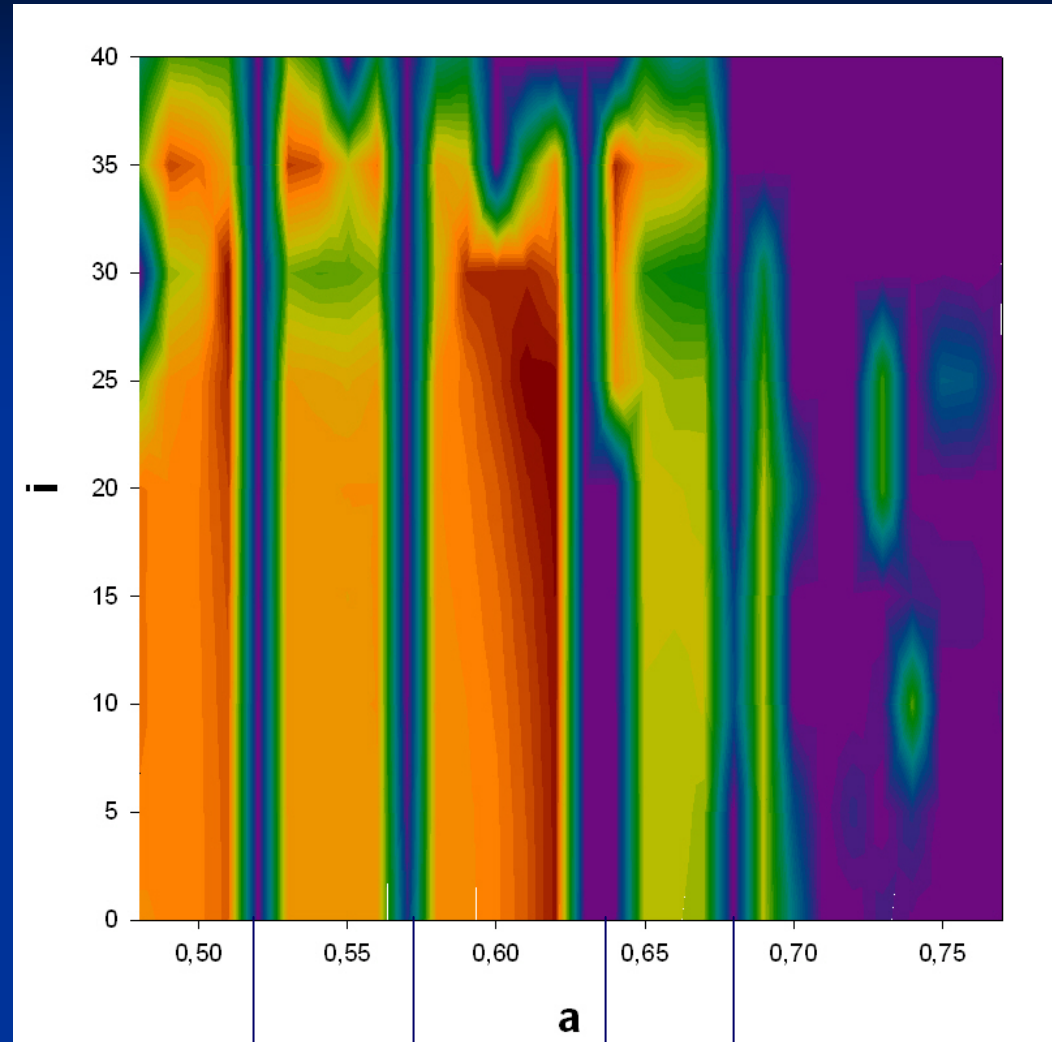
based on the definition given by Kasting et al. (1993).



Ref: Kasting, J.F., Whitmire, D.P., Reynolds, R.T.: Habitable Zones around Main Sequence Stars, *Icarus*, 101, p. 108, 1993

HZ of HD41004 A

red: low ecc.
blue: high ecc.

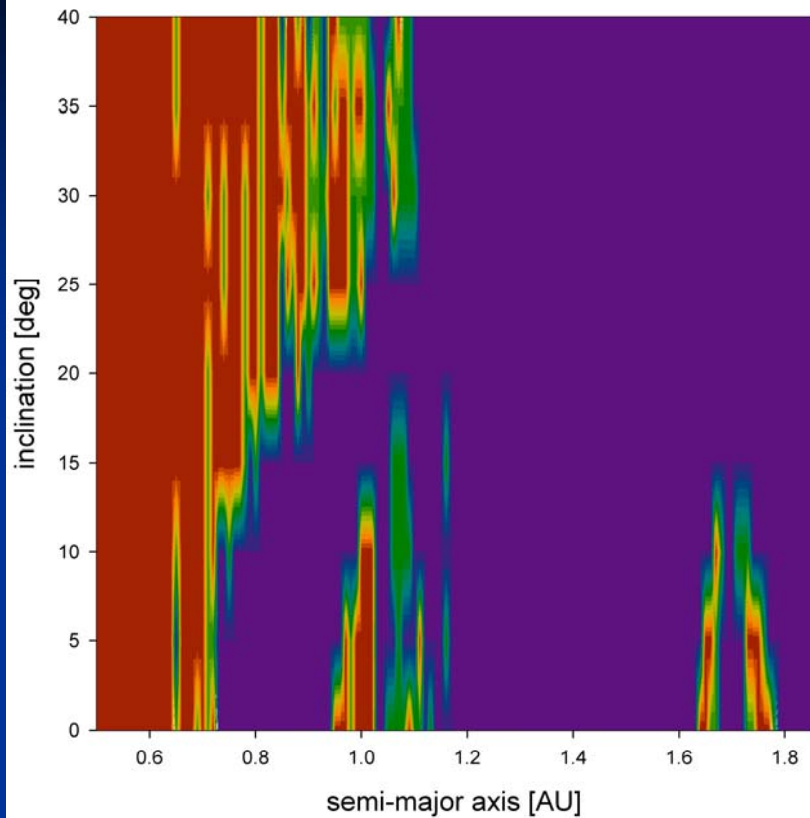


4:1

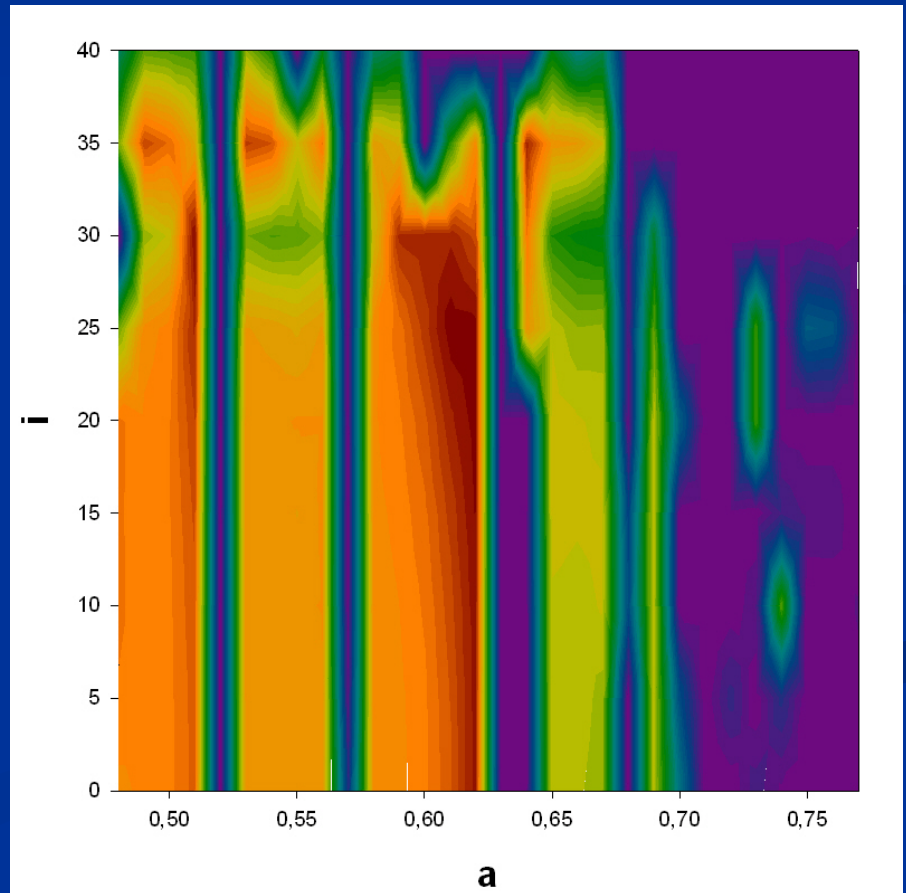
7:2

3:1

8:3

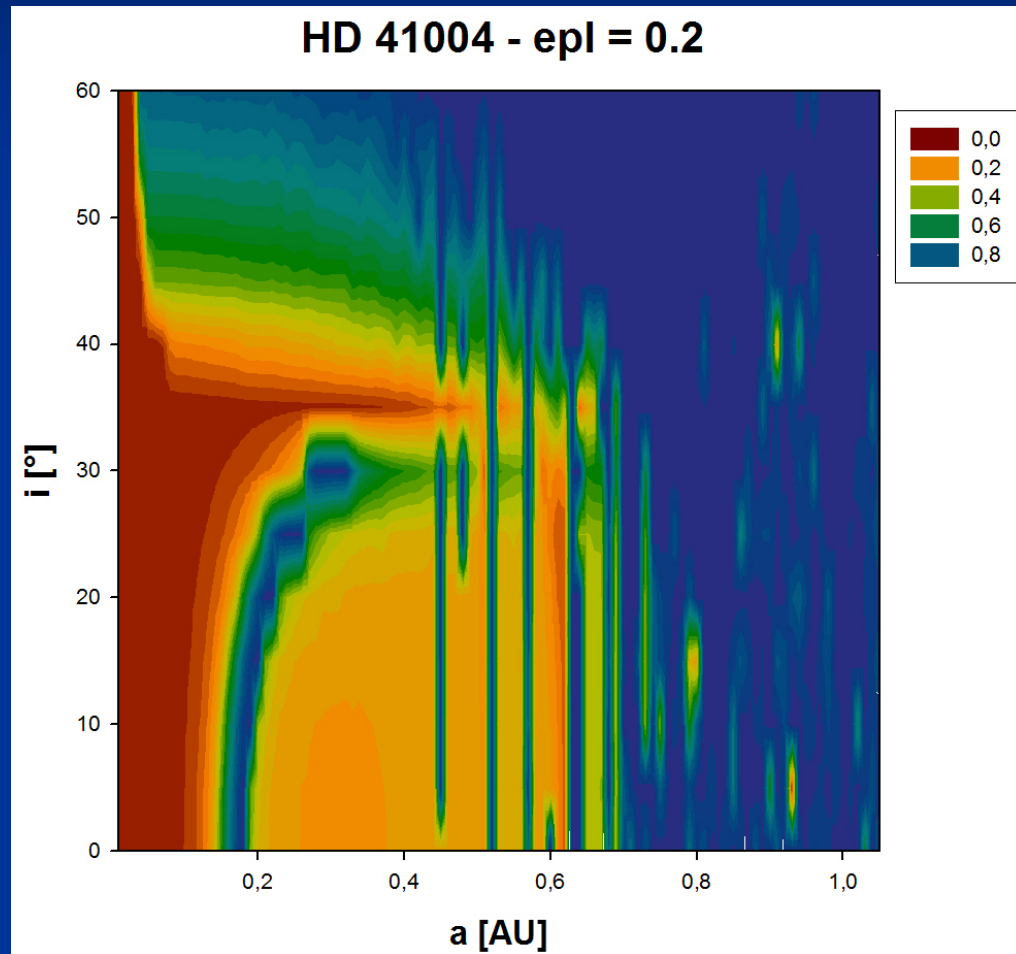


gamma Cep
 $e_b=0.44$
 $e_{pl}=0.209$



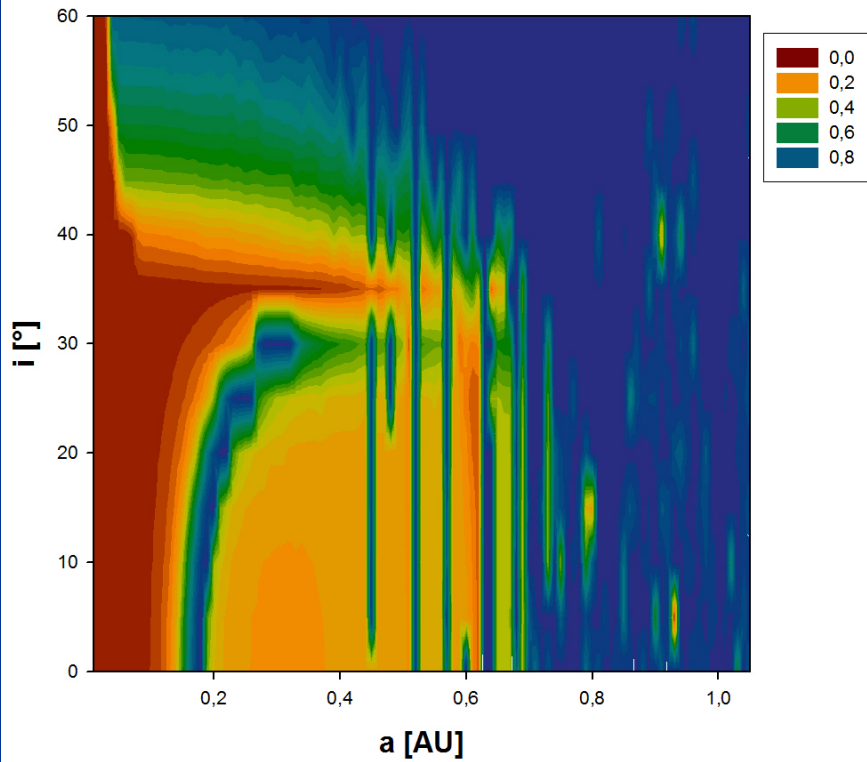
HD41004
 $e_b=0.2$
 $e_{pl}=0.22$

old orbital parameters; $eb=0.2$, $eP = 0.2$,
 $ap=1.3$ AU

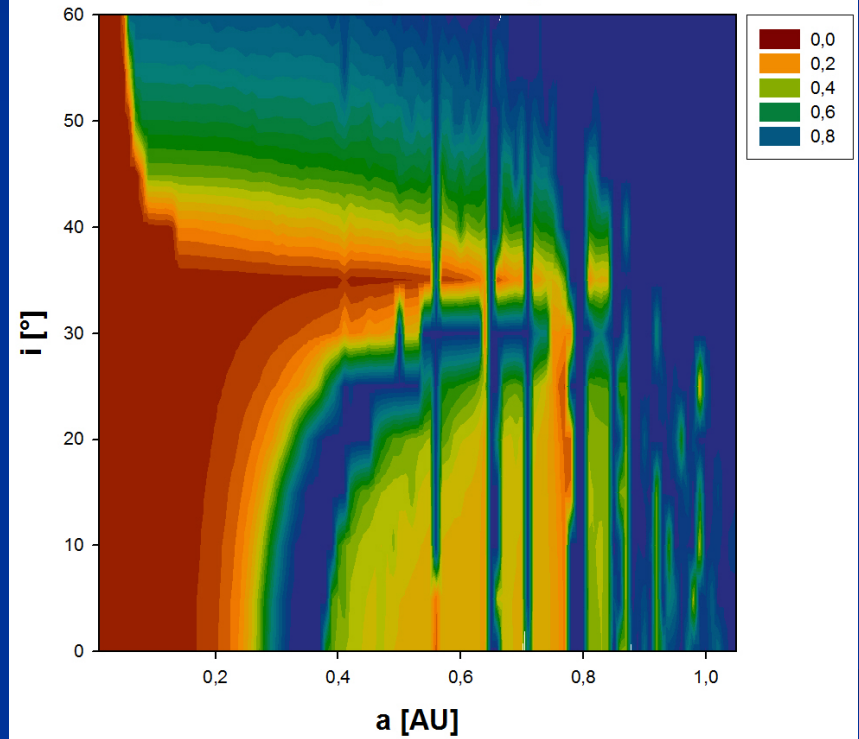


Comparison of old and new $a_{\text{GiantPlanet}}$

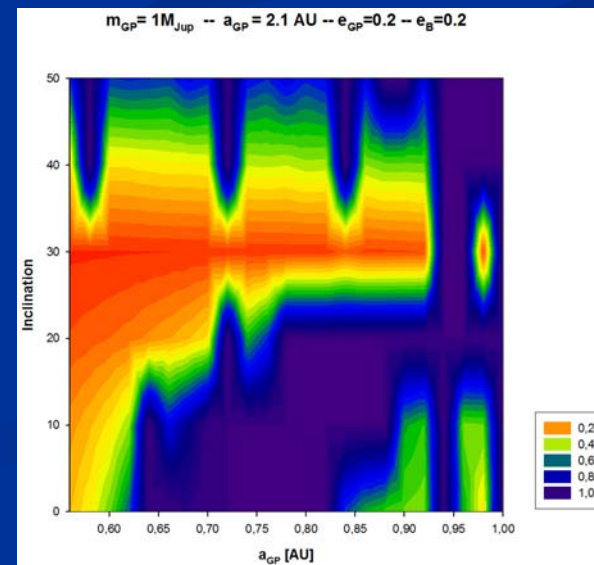
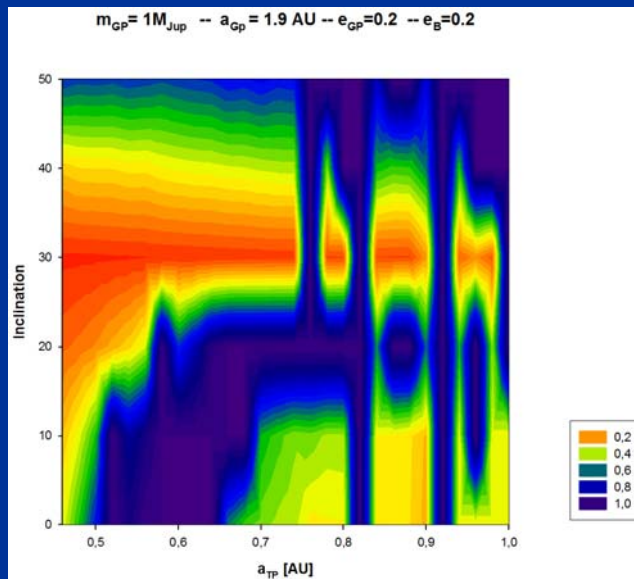
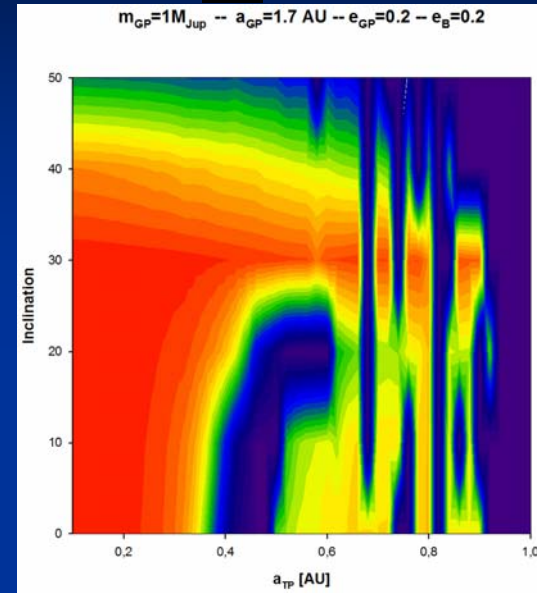
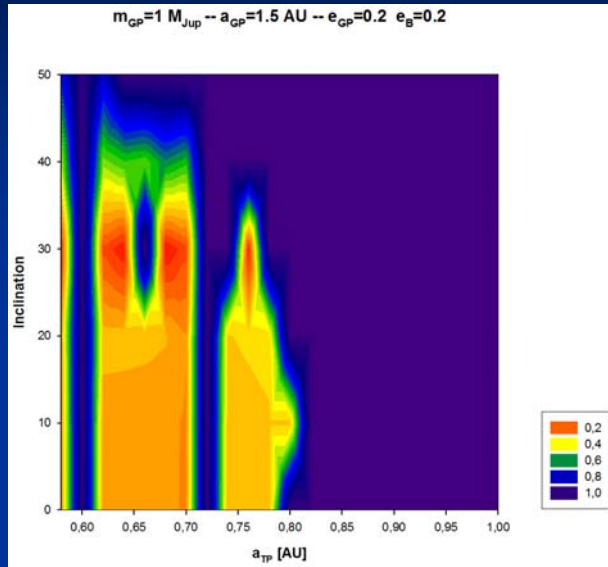
HD 41004 - $e_{\text{pl}} = 0.2$



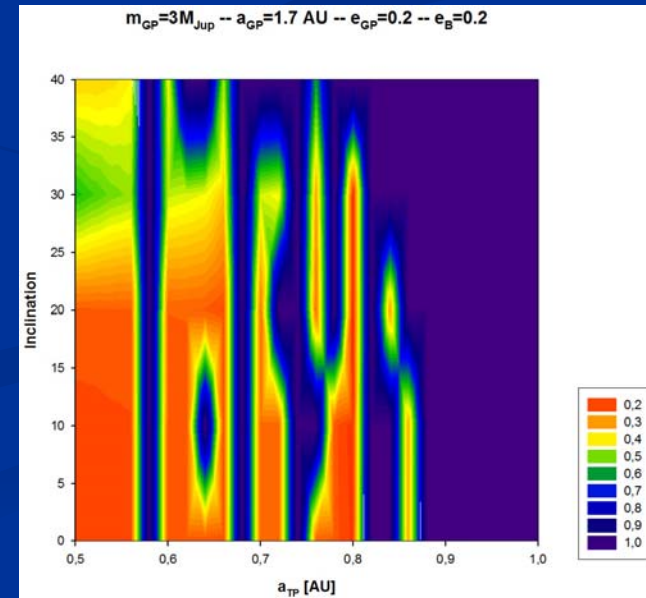
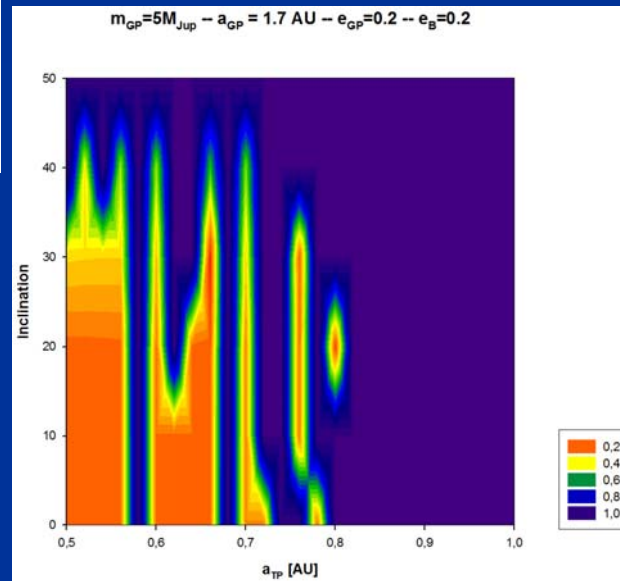
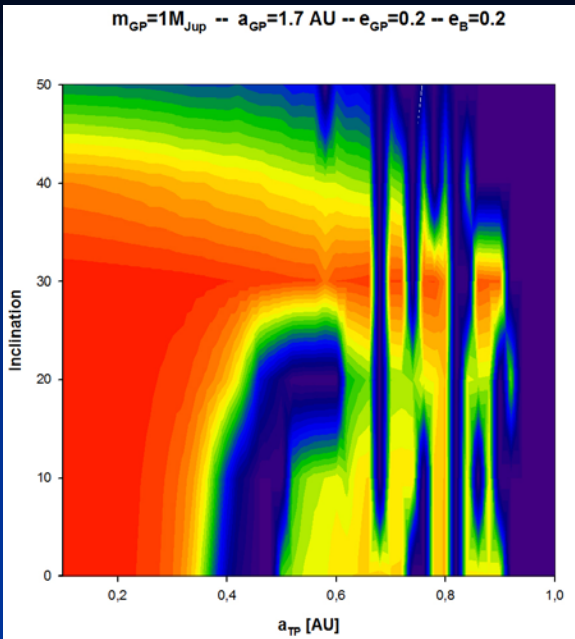
HD 41004 - $e_{\text{pl}} = 0.2, a_{\text{pl}} = 1.64$



Variation in a_{GP}

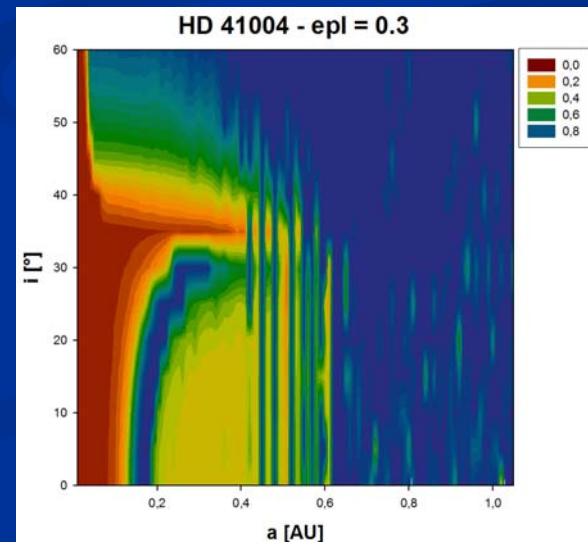
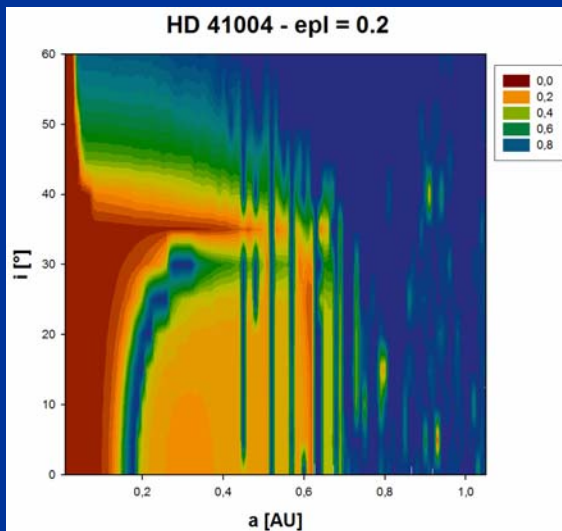
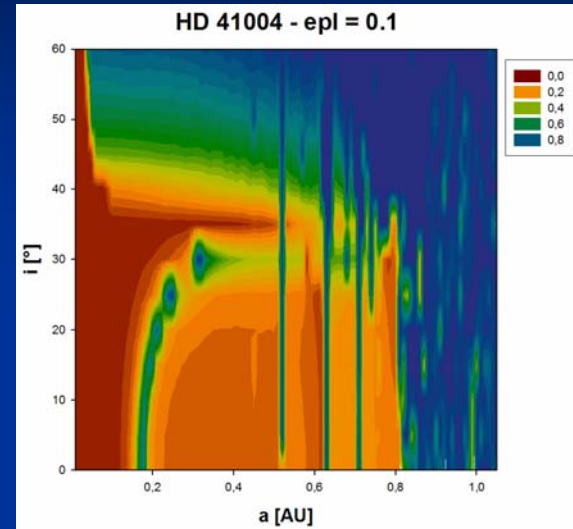
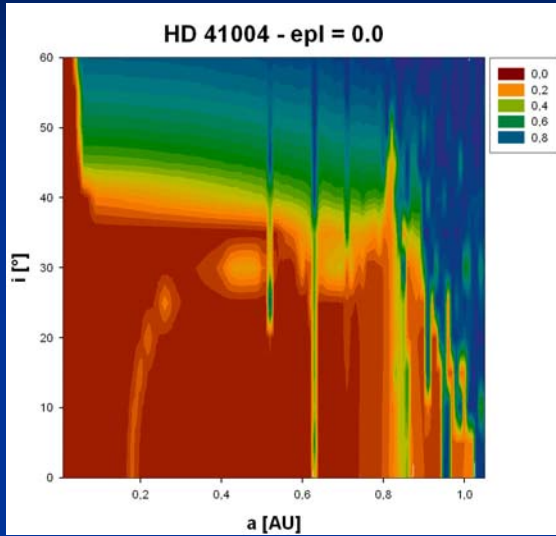


Variation of m_{GP}



Results: $e_{\text{Binary}}=0.2$ $e_{\text{Planet}}=0 \rightarrow 0.3$

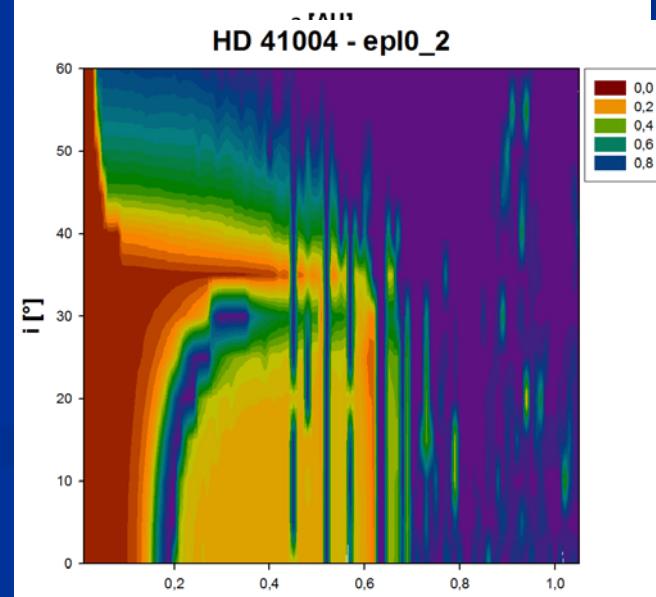
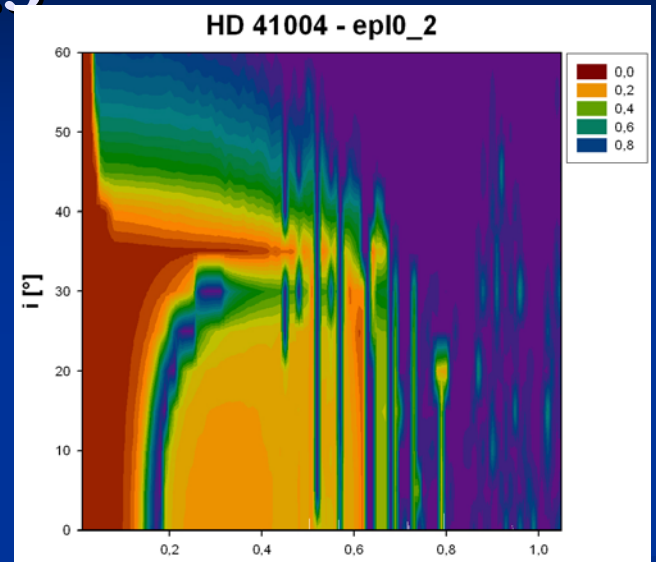
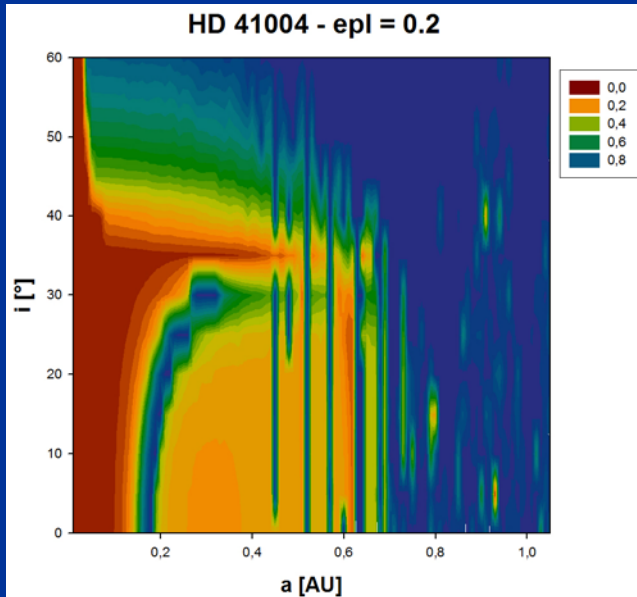
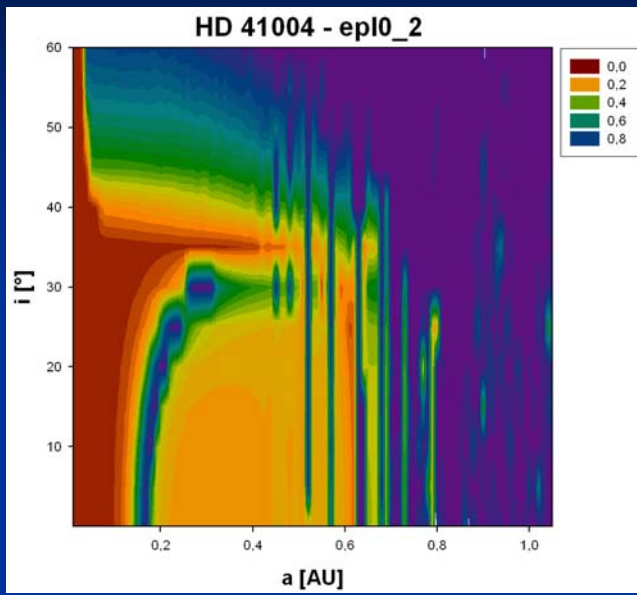
$a_{\text{Planet}} = 1.3$



(B. Funk)

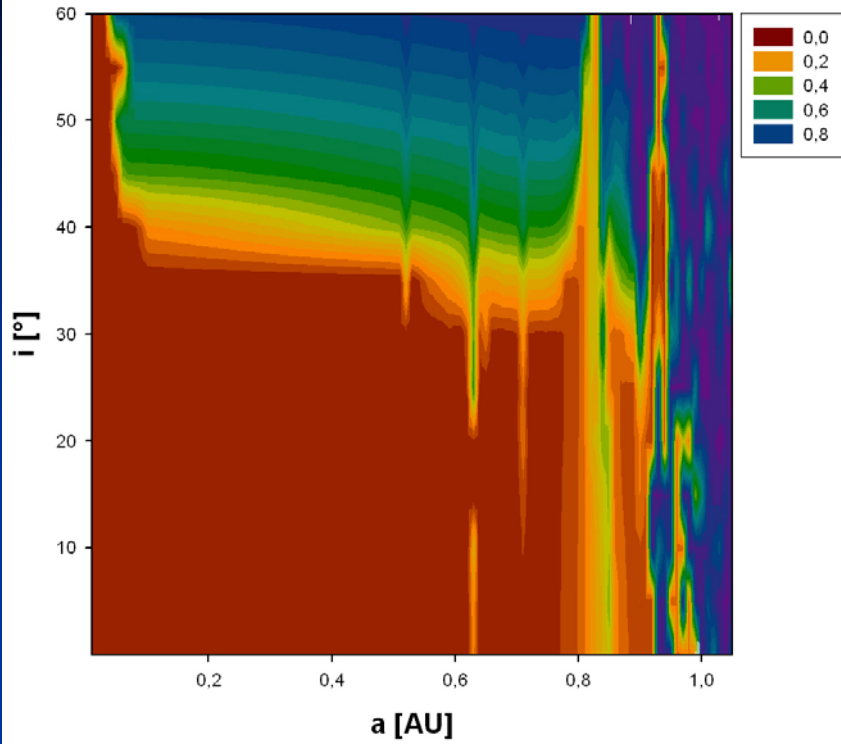
Results: $e_{\text{Binary}}=0 \rightarrow 0.3$ $e_{\text{Planet}}=0.2$

$a_{\text{Planet}} = 1.3$

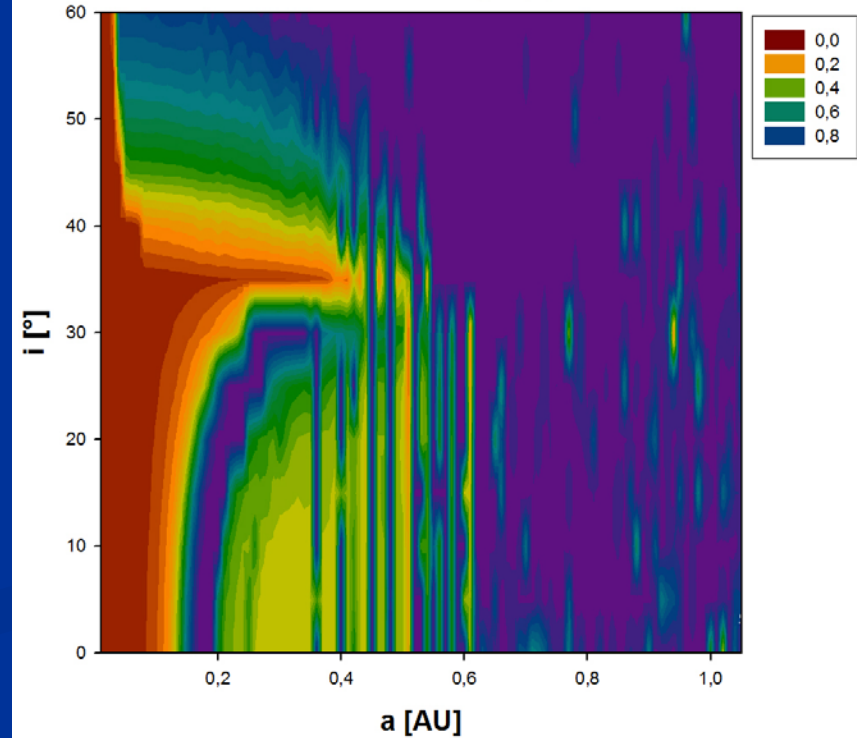


(B.Funk)

HD 41004 - epl0_0

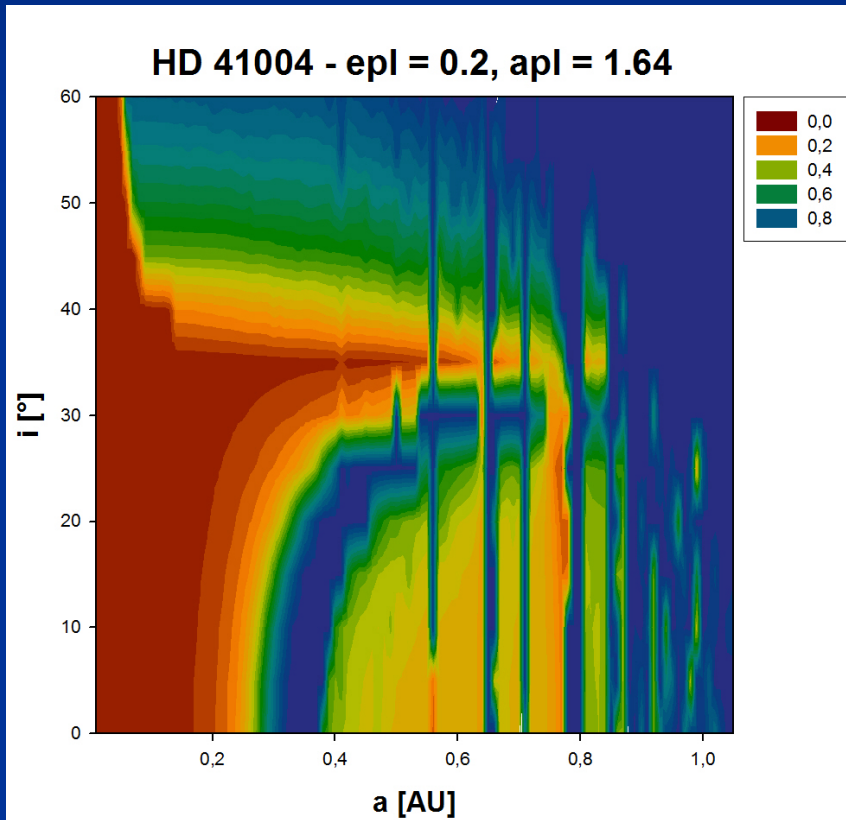


HD 41004 - epl0_3



(B. Funk)

Conclusions



- Region of nearly circular motion exists – size and position depends on
 - $a_{\text{giant planet}}$
 - $e_{\text{giant planet}}$
 - $m_{\text{giant planet}}$
 - No strong dependence on i for $i < 25$
- Stable circular motion for close-in planets
- at $i = 35^\circ - 40^\circ$ stable Kozai region