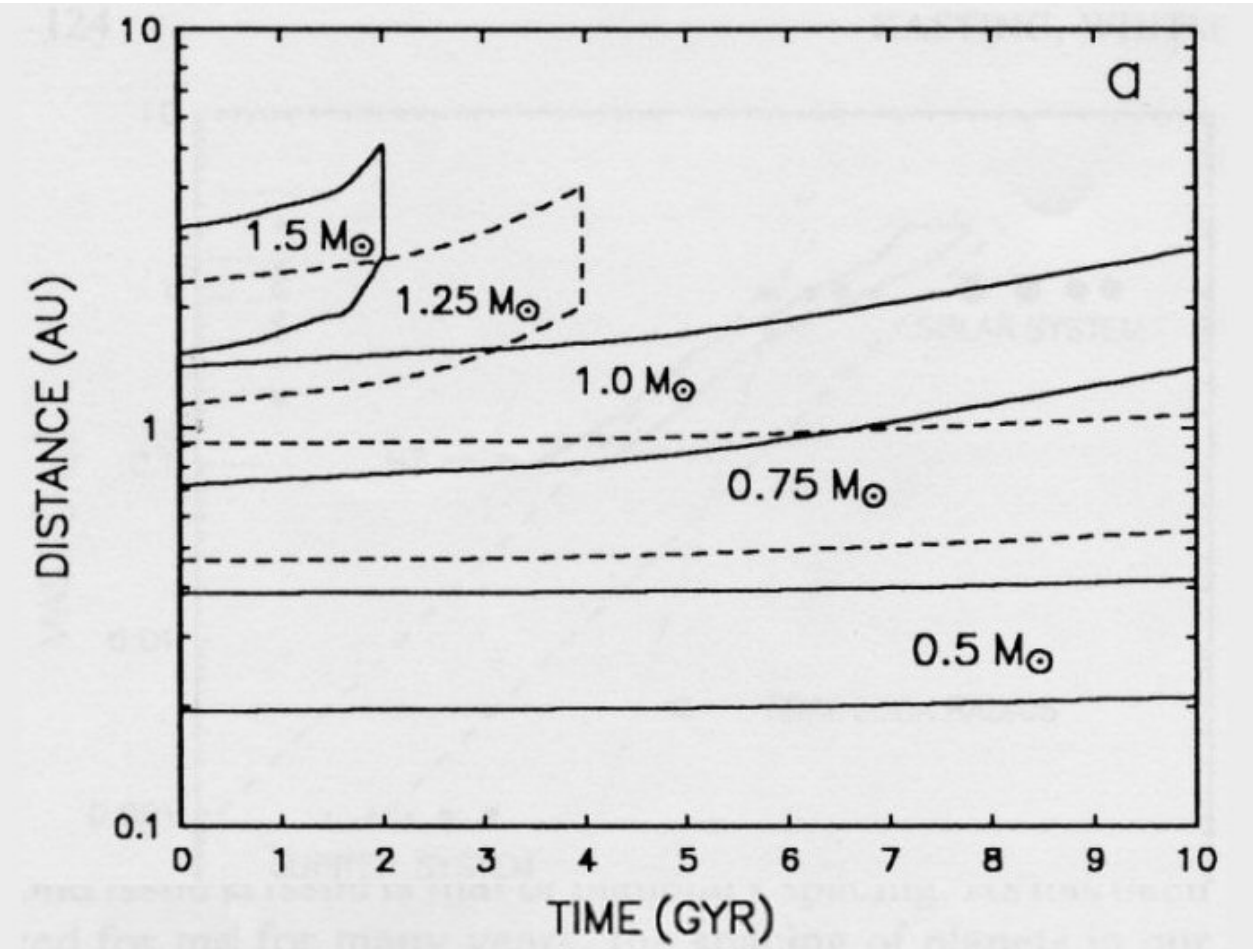
Terrestrial planets: Habitable Zone

- **Zone around a star where liquid water can exist on the surface of such a 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, …)**

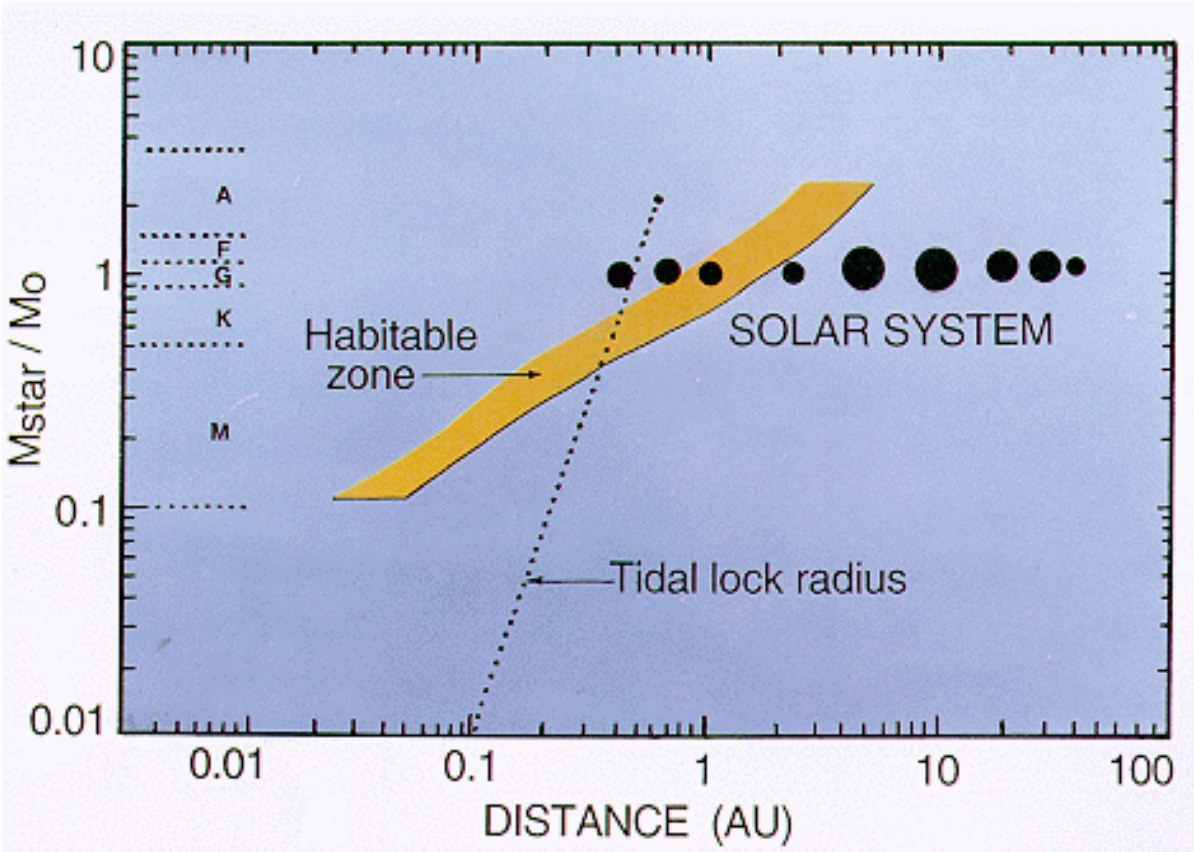
Habitable Zones



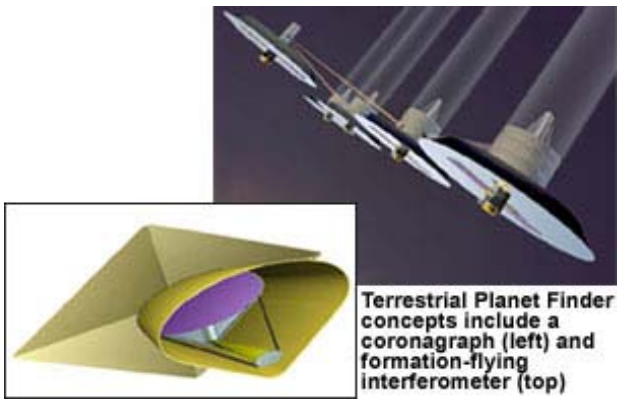
Ref: Kasting, J.F., Whitmire, D.P., Reynolds, R.T.: Habitable Zones around Main Sequence Stars, Icarus, 101, p. 108, 1993

Size of the habitable zone of a planetary system

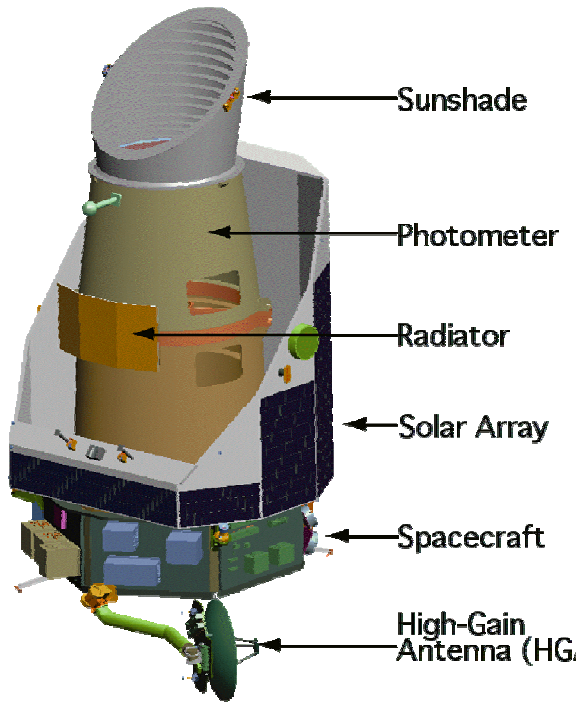
based on the definition given by Kasting et al. (1993).



The planned space projects promise that in the next few decades there will be a chance to find some of these rocky planets, if they exist around the sun´s closest neighbours



Terrestrial Planet Finder concepts include a coronagraph (left) and formation-flying interferometer (top)



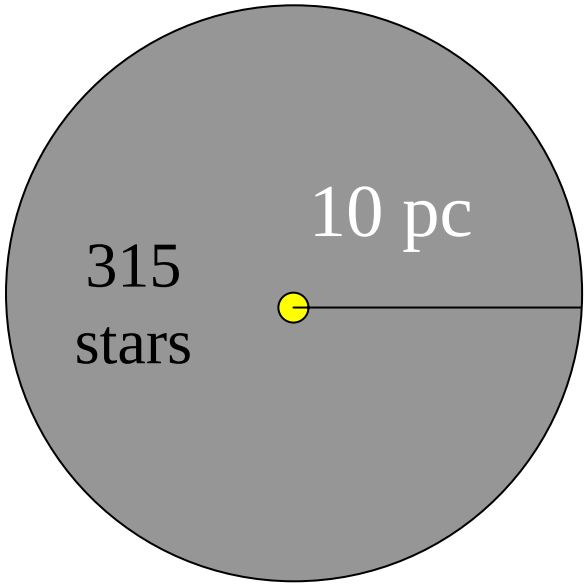
TPF – *Terrestrial Planet Finder* – NASA, planned launch: 2012-2015

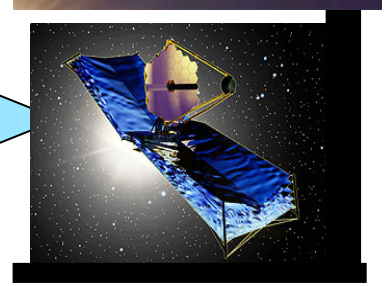
KEPLER Mission – NASA – planned launch: 2007

COROT – *COnvection ROtation and planetary Transits*

CNES, ESA, and other countries, planned launch: 2006

Target Stars for Darwin/TPF





Lifetime

Temperature

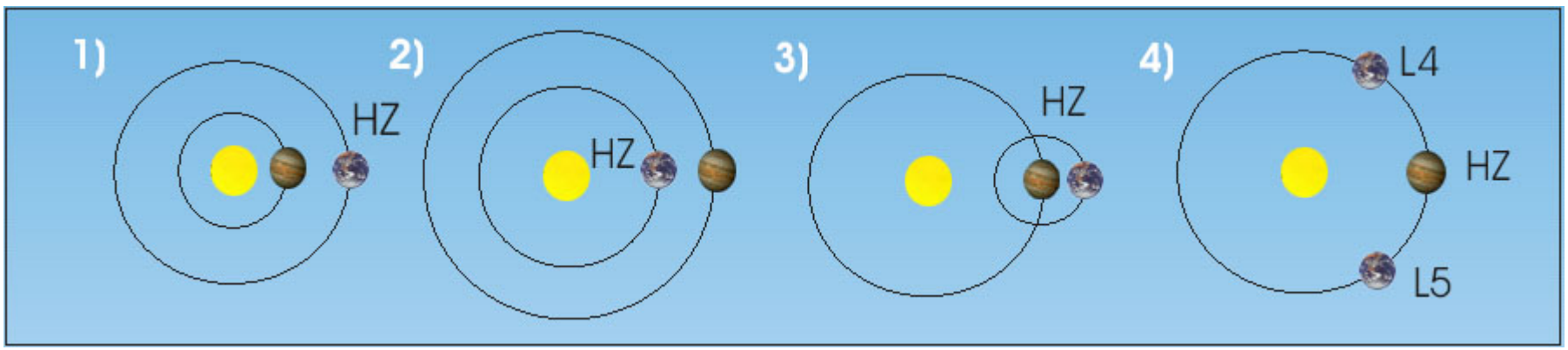
The Habitable Zone from the Dynamical Point of View

- **Long-term stability of the planets orbit**
- **small eccentric motion**

  about 60% have eccentricities > 0.2

  40% have eccentricities > 0.3
- **the appropriate distance to the host-star**

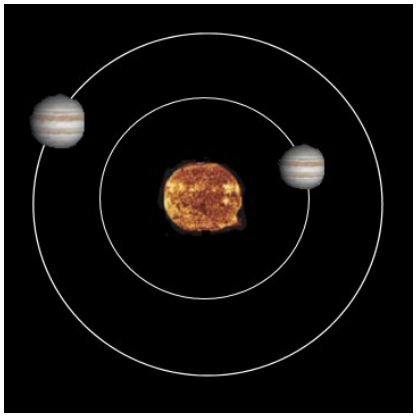
Types of Habitable Zones:



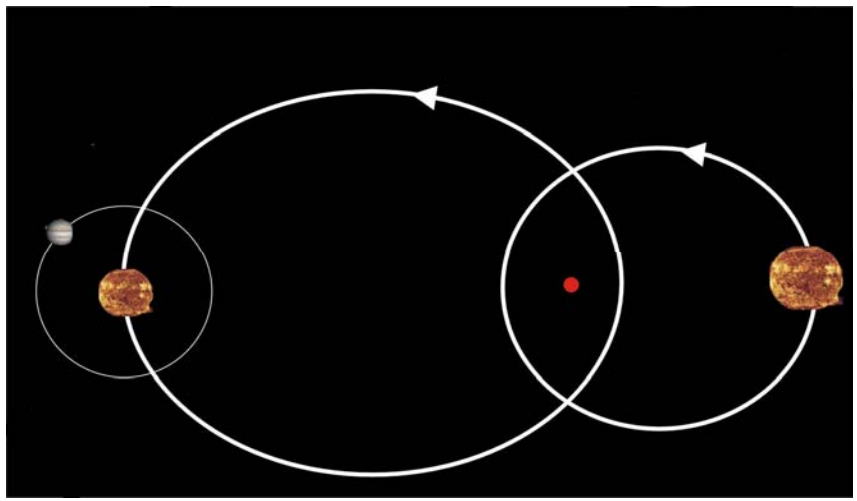
(1) Hot-Jupiter type

(2) Solar system type

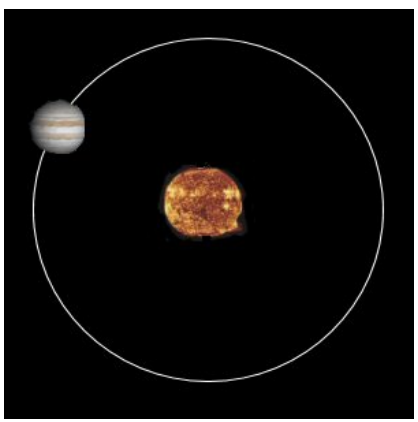
(3)+(4) giant planet type: habitable moon or trojan planet



- 40 Multi-planet systems



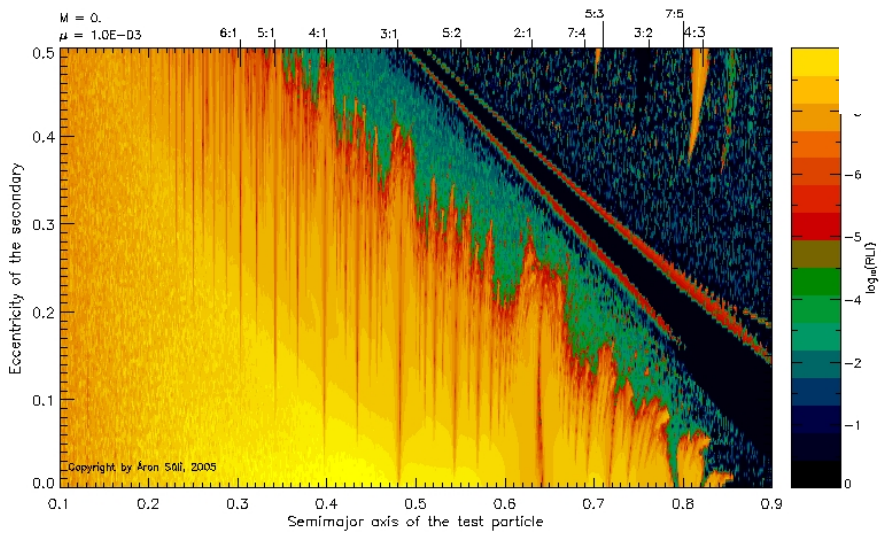
- 40 planets in binaries

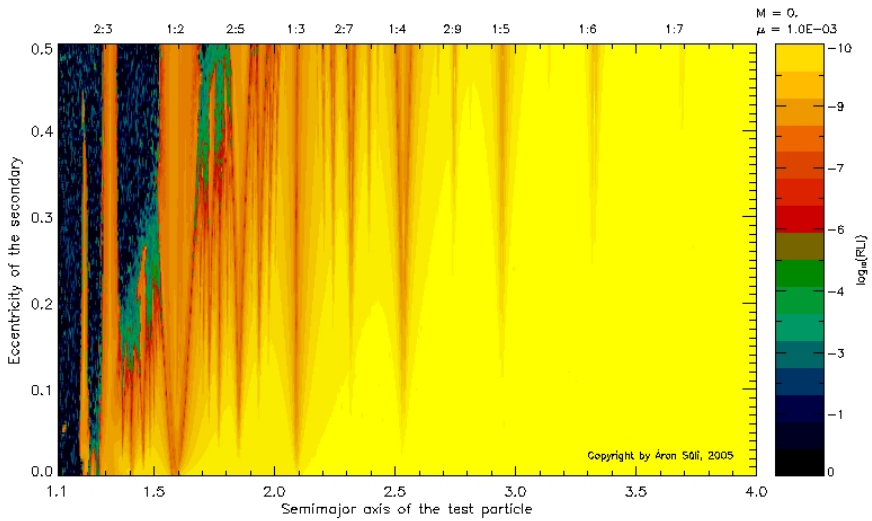


- Single-Star - Single-Planet

Stability maps

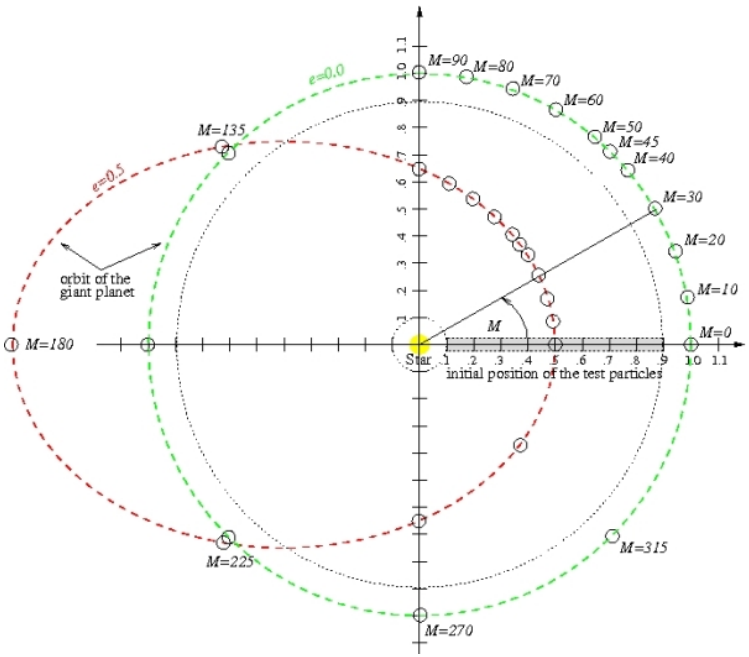
Inner region **(Solar system type)**





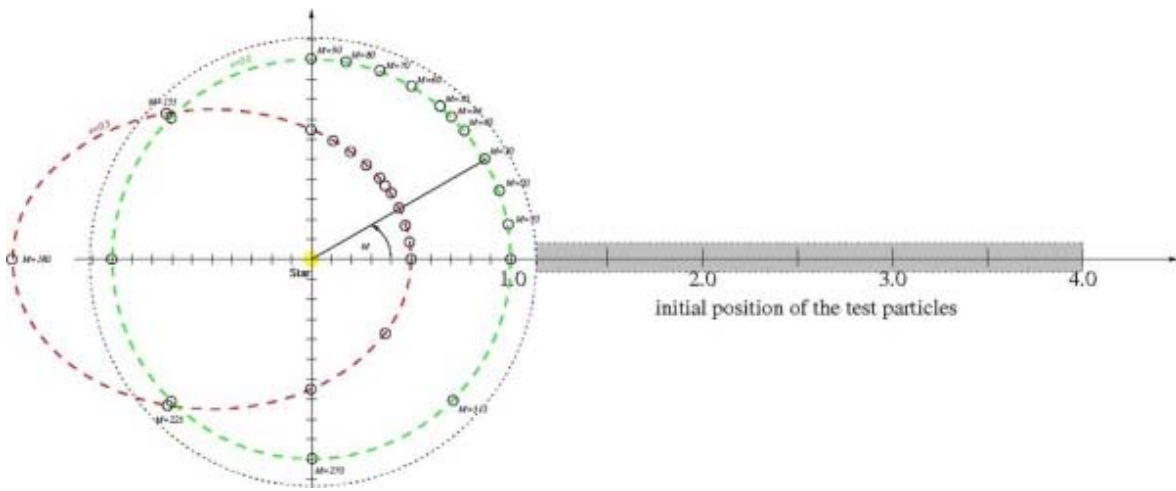
Outer region
(Hot-Jupiter-type)

Computations



distance star-planet: 1 AU
variation of
- **a_tp:**[0.1,0.9] [1.1,4] AU
- **e_gp:** 0 – 0.5
- **M_gp:** 0 and 180 deg
- **M_tp:** [0, 315] deg

Dynamical model:
restricted 3 body problem

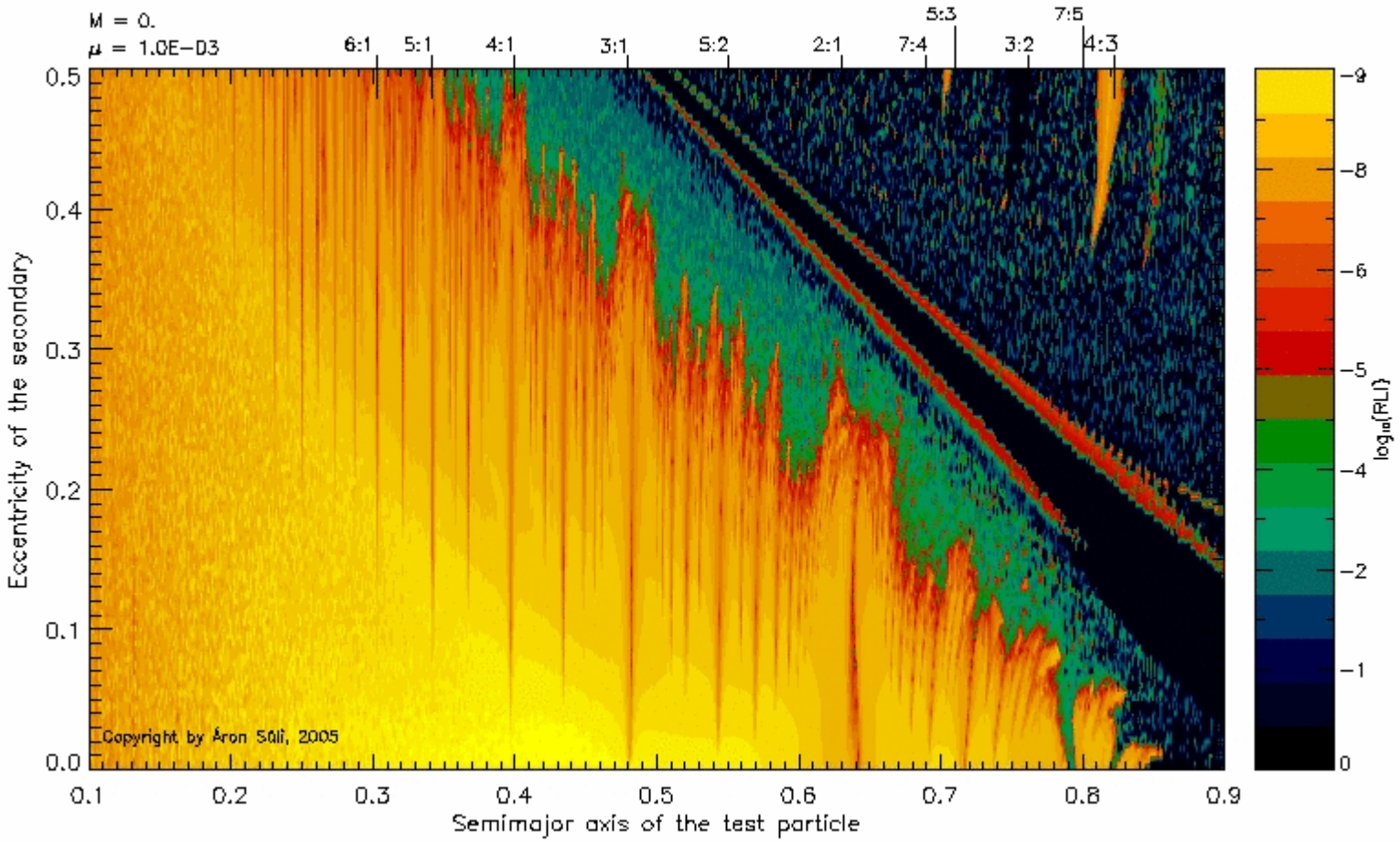


Methods:

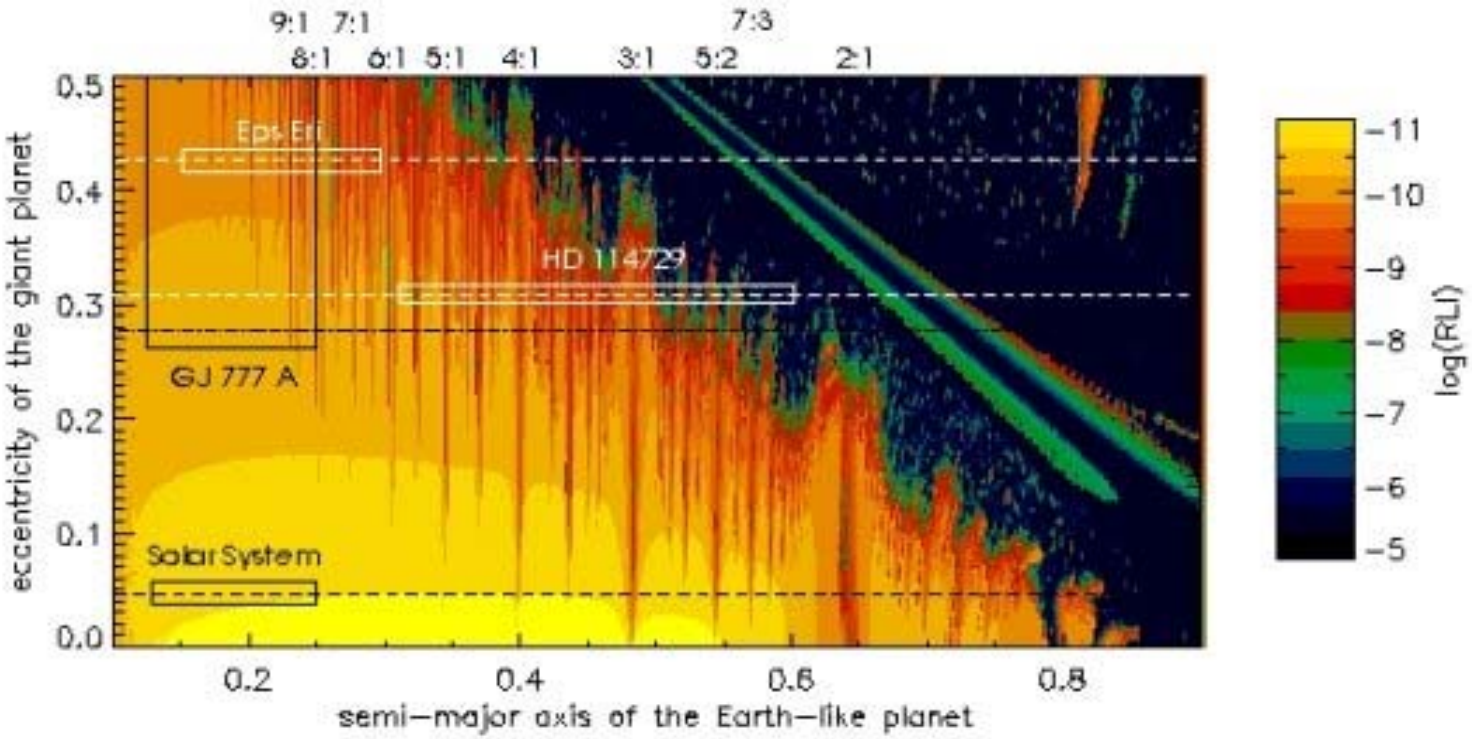
(i) Chaos Indicator:
- FLI (Fast Lyapunov)
- RLI (Relative Lyapunov)

(ii) Long-term computations
- e-max

ANIMATION


M = 0.
μ = 1.0E-03
6:1
5:1
4:1
3:1
5:2
2:1
7:4
5:3
3:2
7:5
4:3
0.5
0.4
0.3
0.2
0.1
0.0
Eccentricity of the secondary
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Semimajor axis of the test particle
Copyright by Áron Süli, 2005
−9
−8
−6
−5
−4
−2
−1
0
log10(RLI)

How to use the catalogue

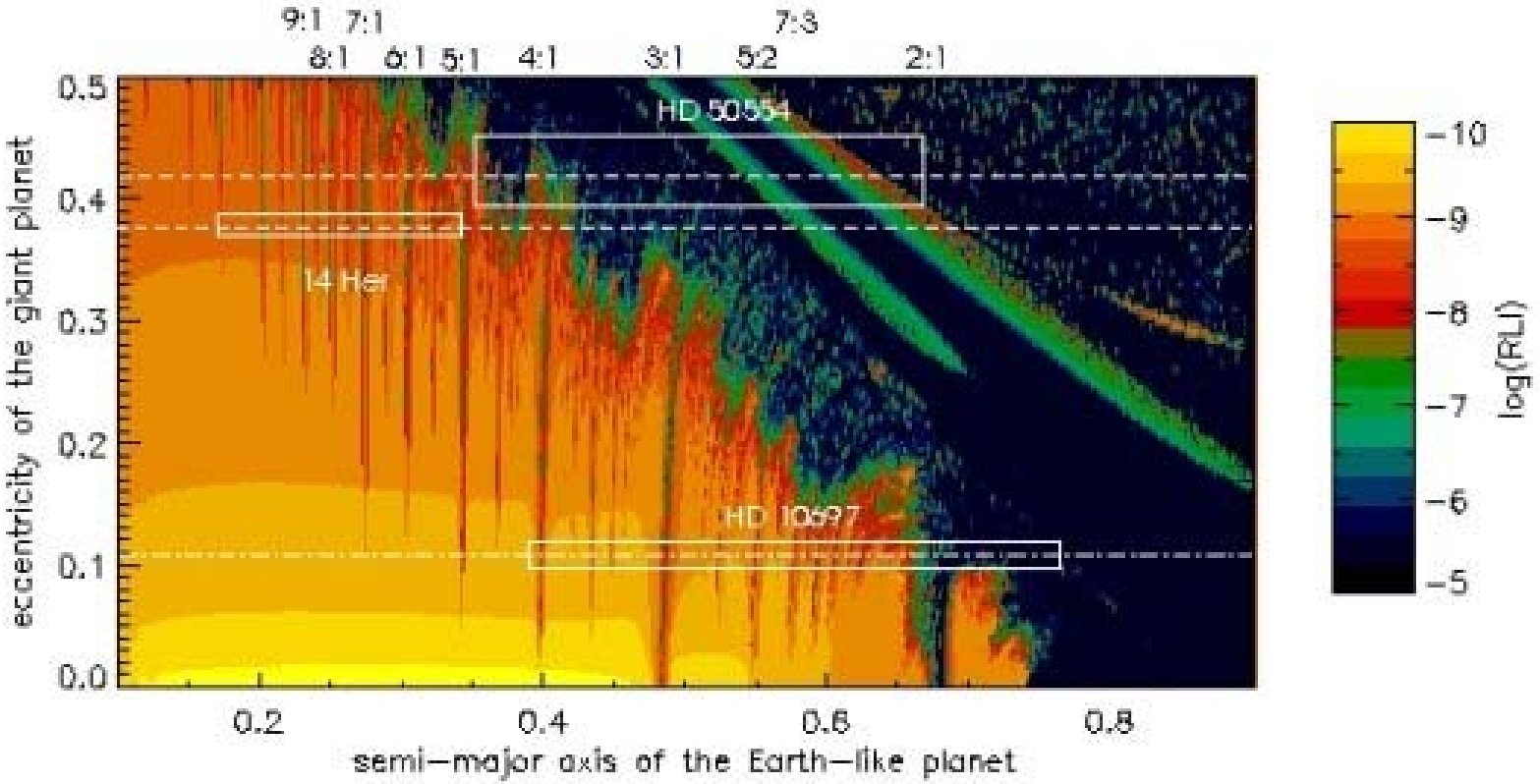


HD114729: m_p=0.82 [Mjup]
(0.93 [Msun]) a_p= 2.08 AU
e_p=0.31

μ=0.001

HZ: 0.7 – 1.3 AU

μ= 0.005



HD10697: m_p= 6.12 [Mjup]

(1.15 Msun) a_p = 2.13 AU

e_p = 0.11

HZ: 0.85 – 1.65 AU

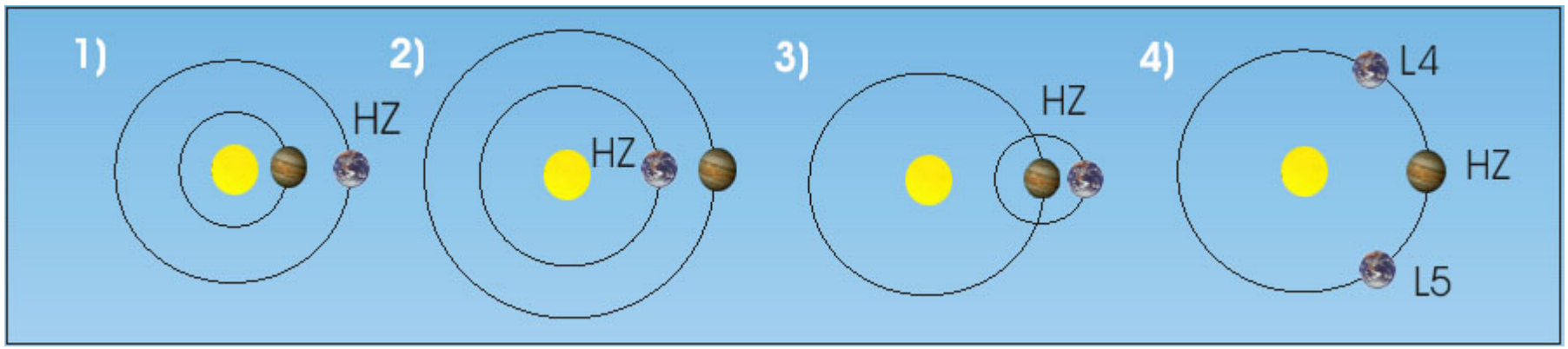
The EXOCATALOGUE:

http://www.univie.ac.at/adg/

Details:

Sándor, Zs., **Süli**, A., **Érdi**, B., **Pilat-Lohinger**, E. and **Dvorak**, R.: *"A Stability Catalogue of the Habitable zones in Extrasolar Planetary Systems"*, Monthly Notices of the Royal Astronomical Society (MNRAS), 2006

From the dynamical point of view there are four possible configurations for terrestrial like planets



1) The giant planet moves close to the central star.

2) Solar configuration:

3) Satellite configuration (e.g. Europa):

4) Trojan configuration:

…Like the Jupiter-Trojans

Two groups of asteroids close to L4 and L5

1. L_1, L_2 and L_3 (not stable) lie on a straight line connecting the primaries
2. L_4 and L_5 (stable for $\mu < 1{:}25$) are at the third vertex of an equilateral triangle (Sun-Jupiter-Asteroid)