Giant planets near the 5:2 resonance and their influence on terrestrial planets in the habitable zone

E. Pilat-Lohinger (Univ.Vienna)
Aron Süli (Univ.Budapest)
Philippe Robutel (IMCCE)
Florian Freistetter (Univ. Jena)

Motivation

A study of
Extra-solar planetary systems
similar to
our solar system

Classification of the known multi-planet systems (S.Ferraz-Mello, 2005)

- **Class Ia –>** Planets in mean motion resonance
- **Class Ib →** Low-eccentricity near-resonant planet pairs
- **Class II→** Non-resonant planets with significant secular dynamics
- **Class III→** Hierarchical planet pairs

Initial Conditions and Computations

Jupiter: on its orbit

Saturn: a_{sat} = 8 ..... 11 AU

m_{sat} = 1 .... 30xm_{Sat}

Testplanets in the HZ:

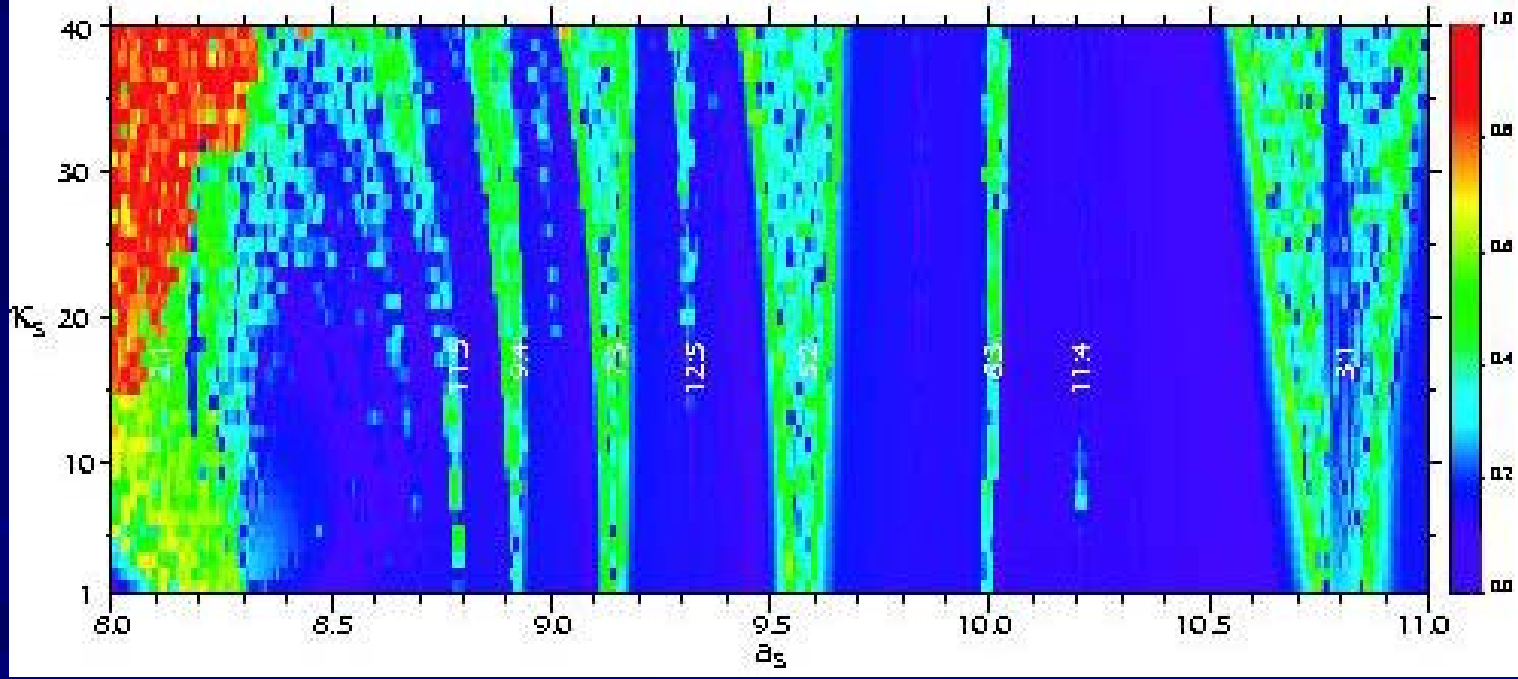
a_{tp} = 0.6 ..... 1.6 AU

Mercury 6 (J. Chambers)

Integration time:

20 mio years

HZ: maximum ecc.


40
30
20
10
1
K_s
8.0
8.5
9.0
9.5
10.0
10.5
11.0
a_s
2,1
11,5
9,4
7,3
12,5
5,2
6,3
11,4
3,1

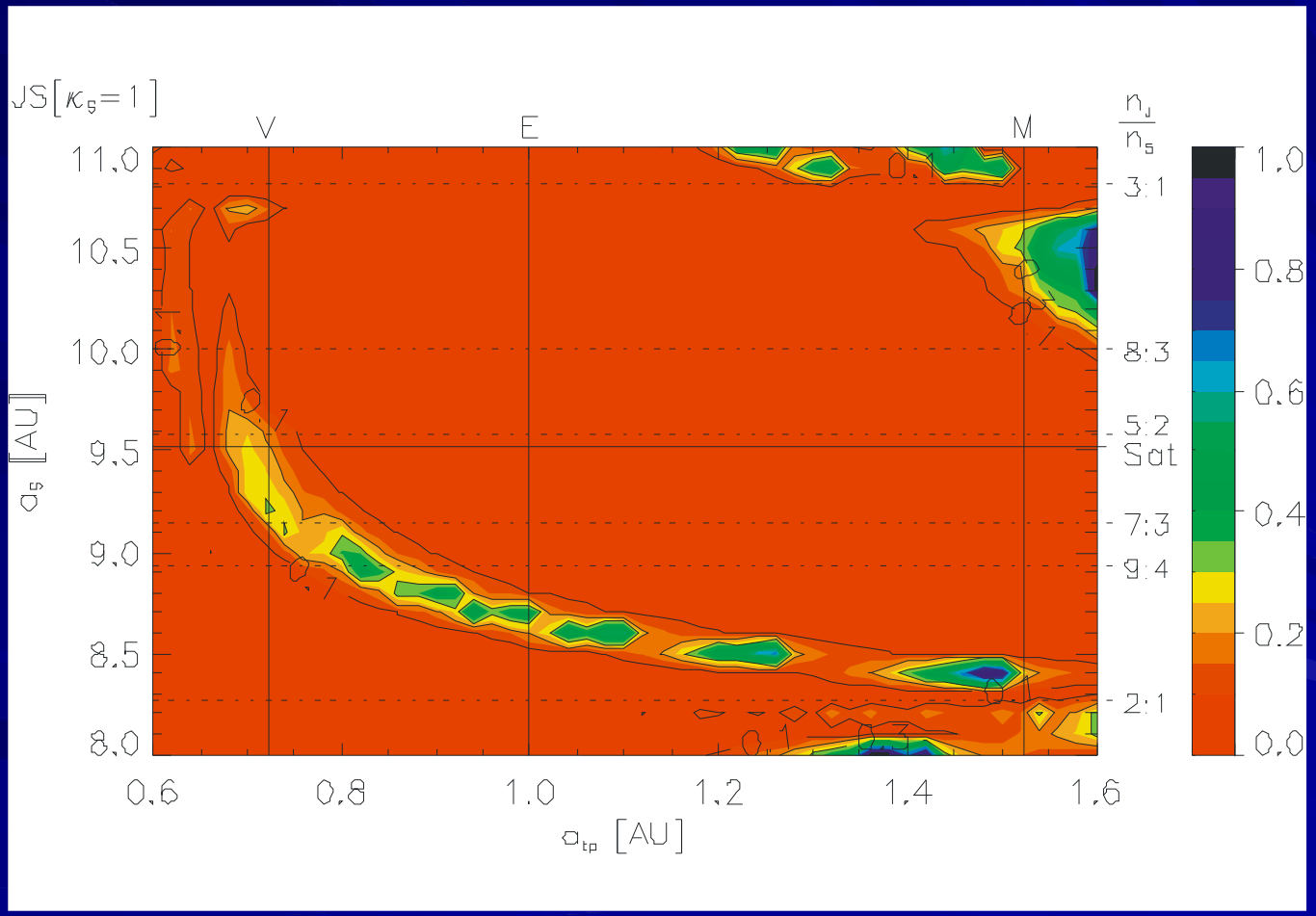
HZ im Sonnensystem:

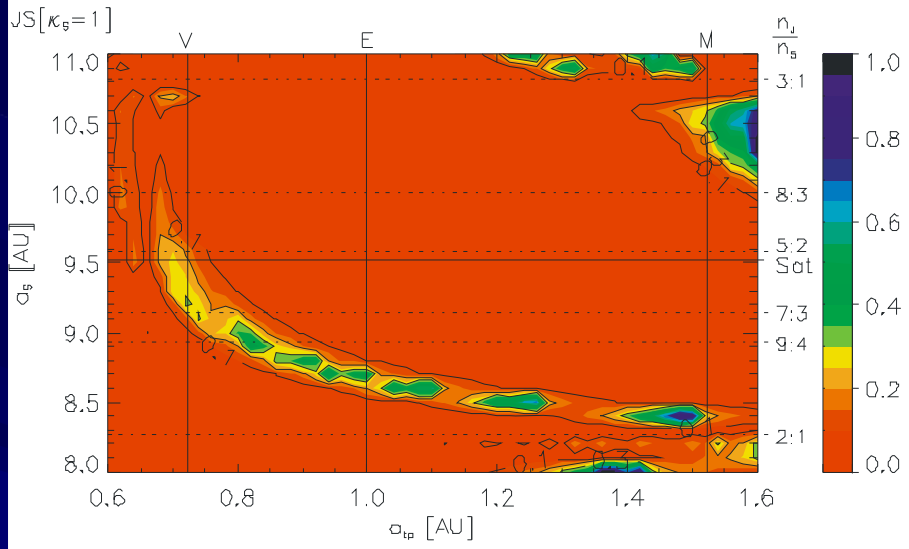
- Kasting: 0.93 – 1.3 AU
- Mischna: 0.93 – 1.7 AU
- Forget: 0.93 – 2 AU

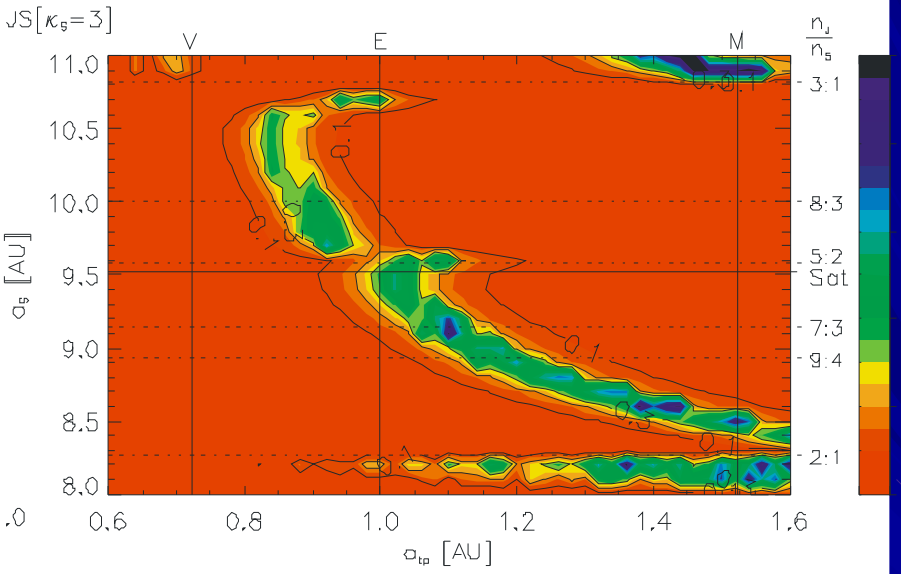
a< 0.93 AU → H_2O becomes a major atmospheric compound and is rapidly lost to space after UV photolysis

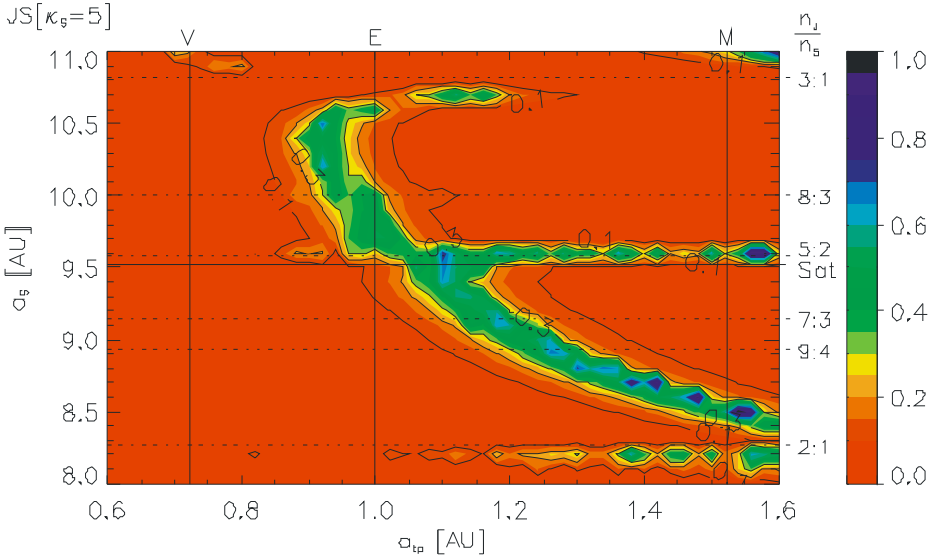
a>1.3 AU → CO2 condensates in the atmosphere producing CO_2-clouds, that can affect significantly the T-CO_2 coupling

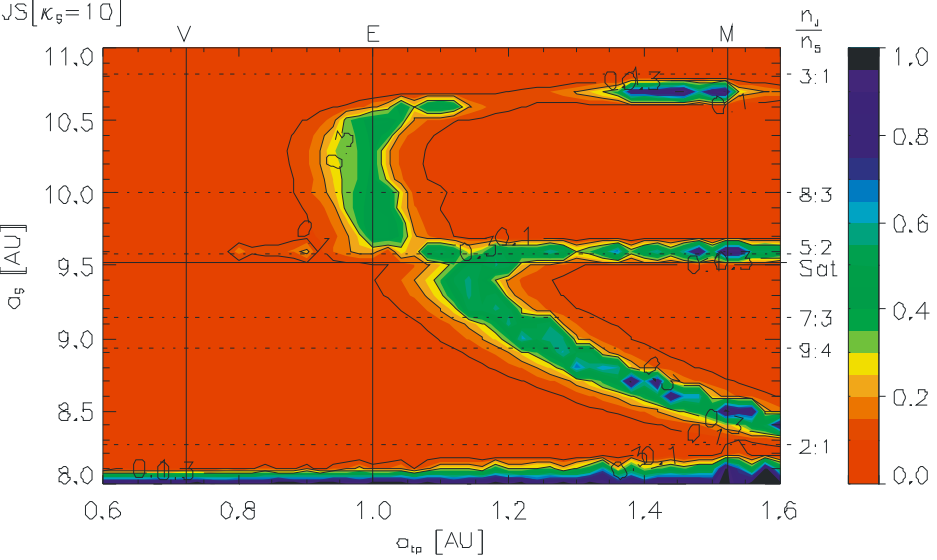
Sun – Jupiter – Saturn

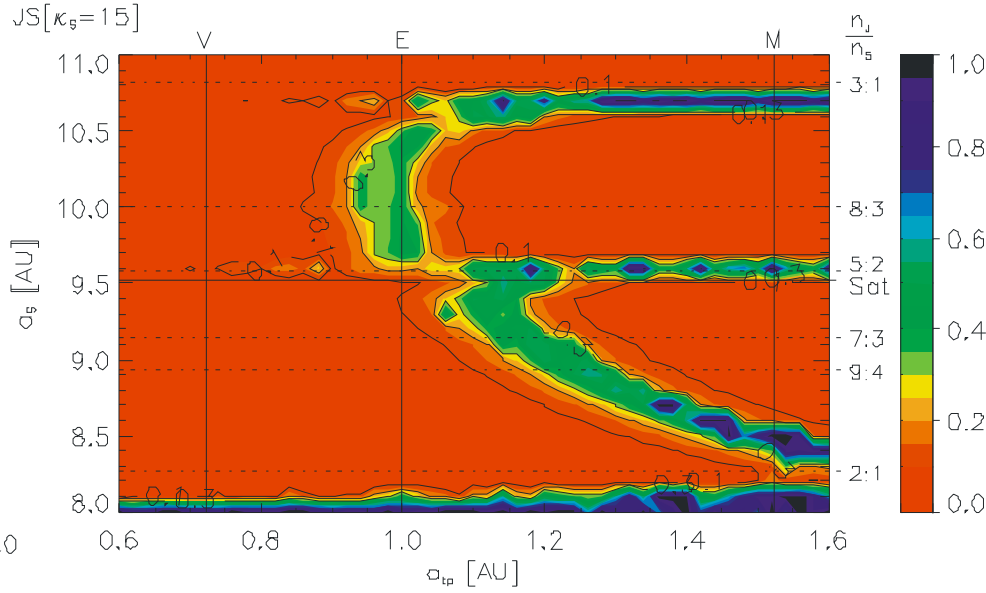


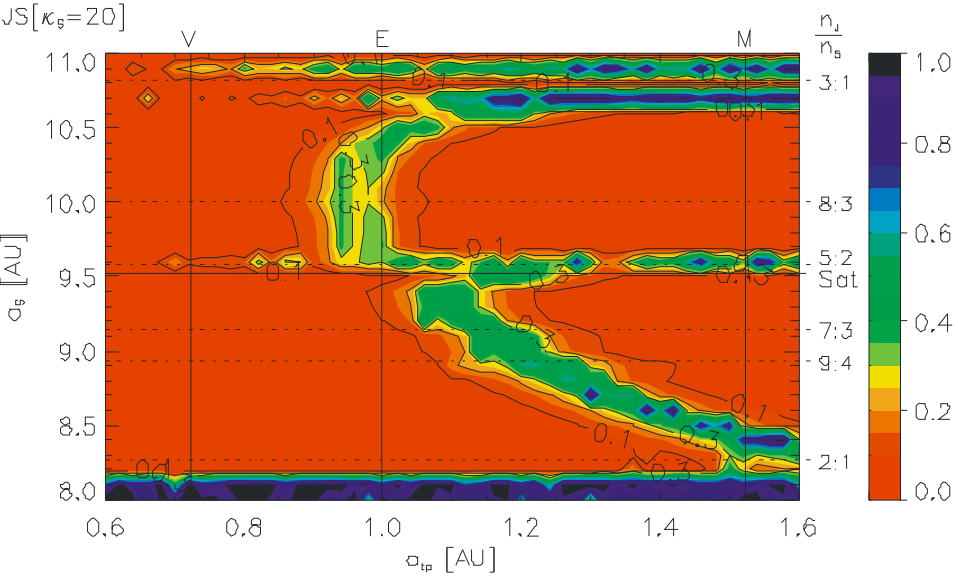

JS[κ_S=1]
V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]
n_J / n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0


JS[κ_S=3]
V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]
n_J / n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1

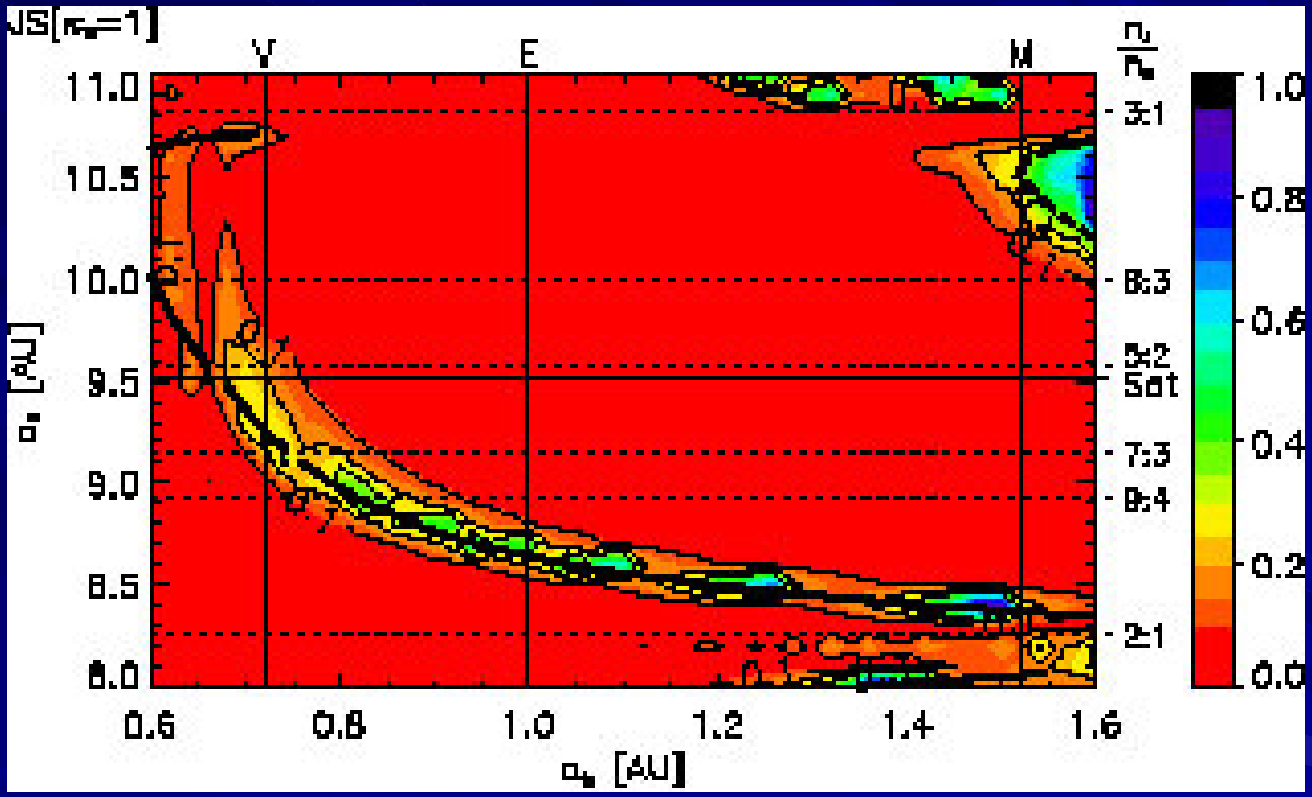

JS[κ_S=5]
V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]
n_J / n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0


JS[κ_S=10]
V
E
M
n_J/n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]

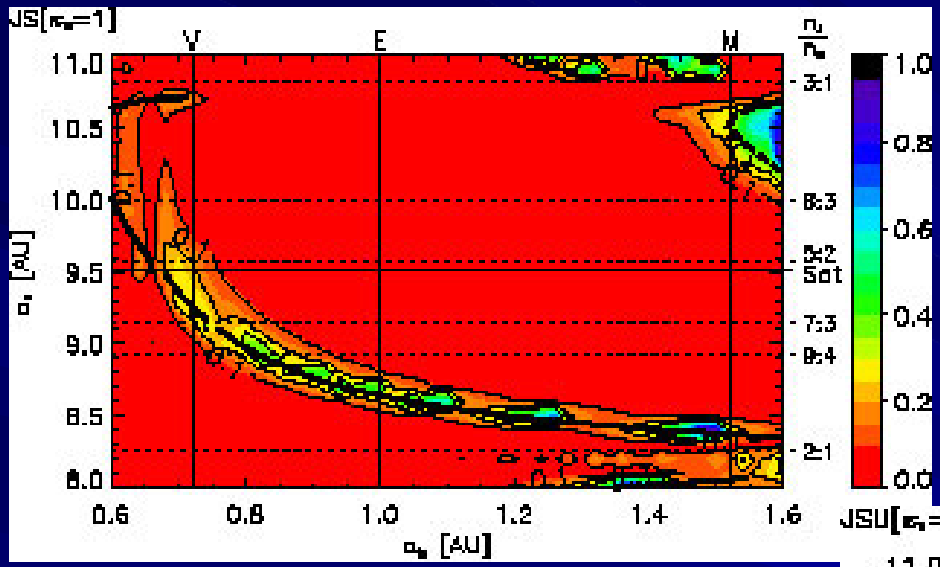

JS[κ_S=15]
V
E
M
n_J/n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]


JS[κ_S=20]
V
E
M
n_J/n_S
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a_S [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a_tp [AU]

Sun – Jupiter – Saturn

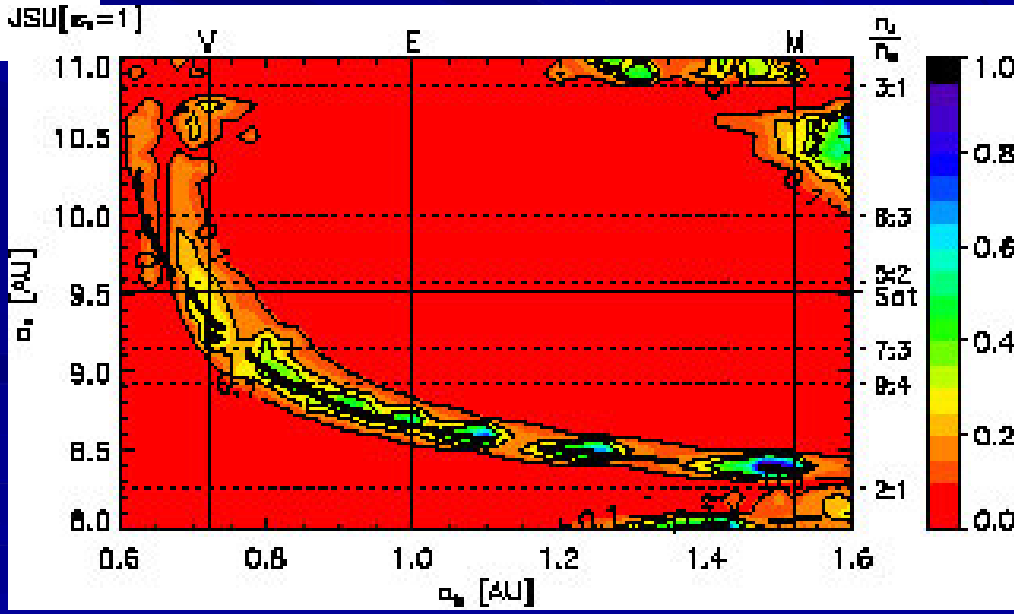


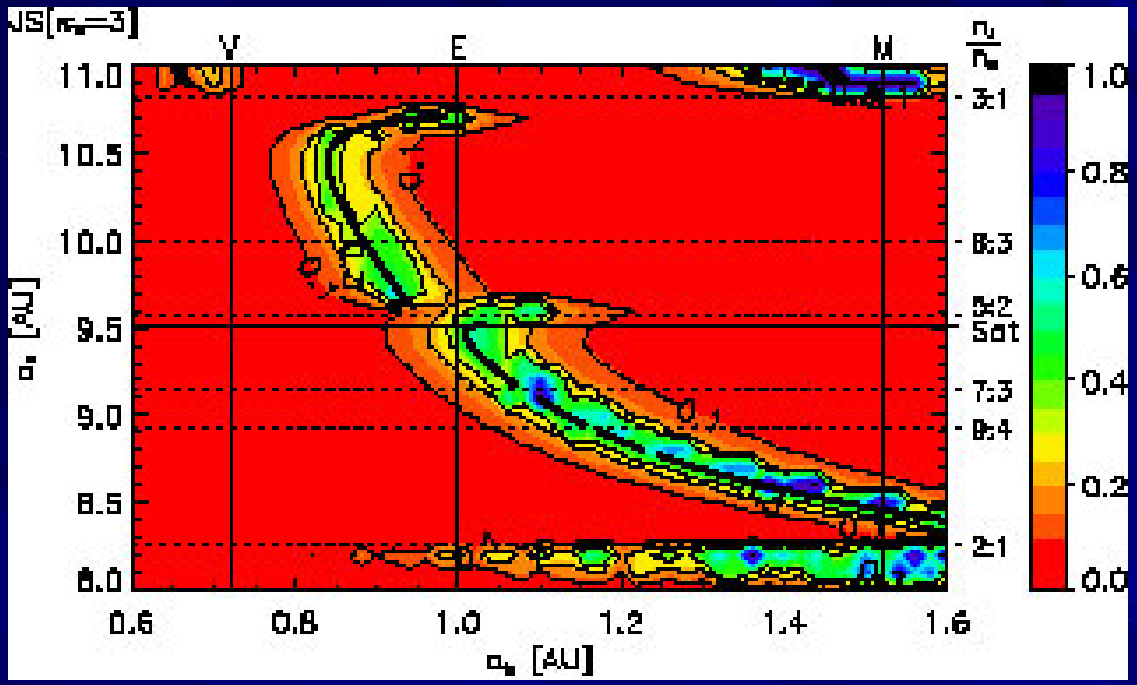
Influence of a third giant planet

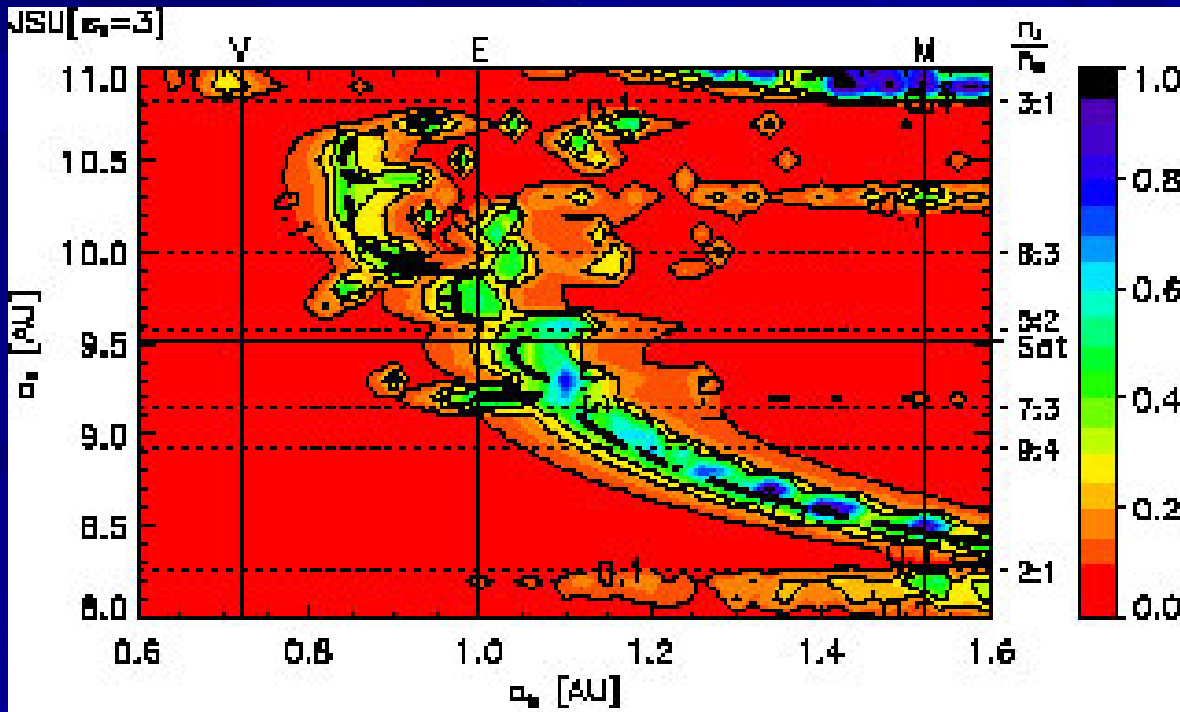


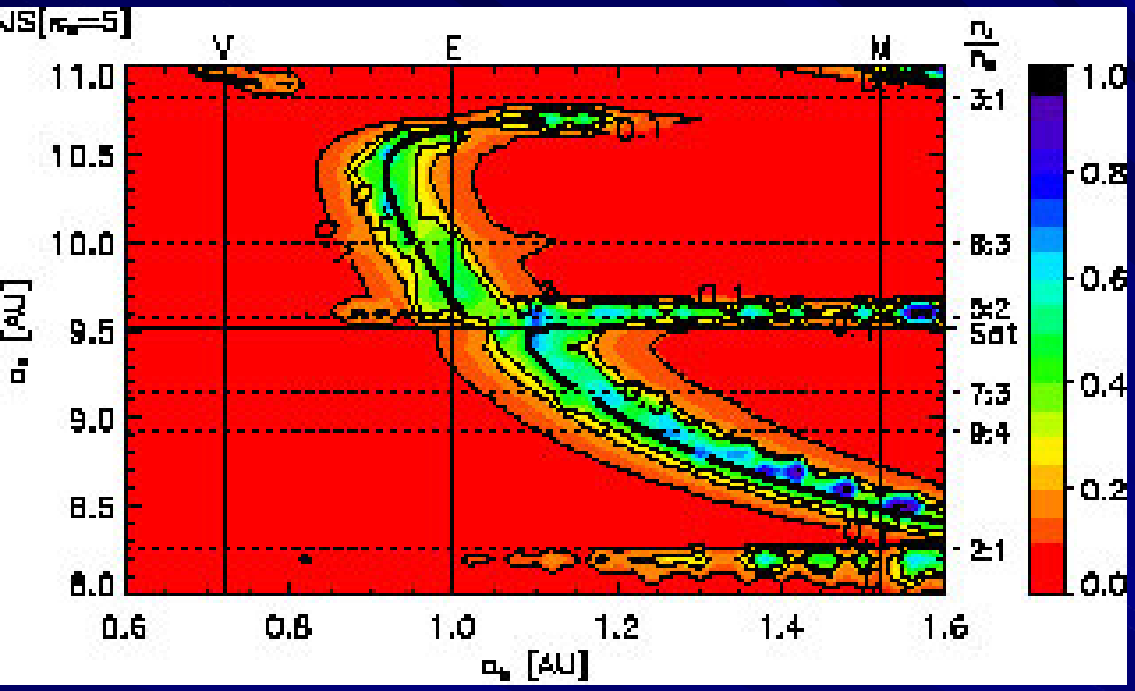
Jupiter -- Saturn

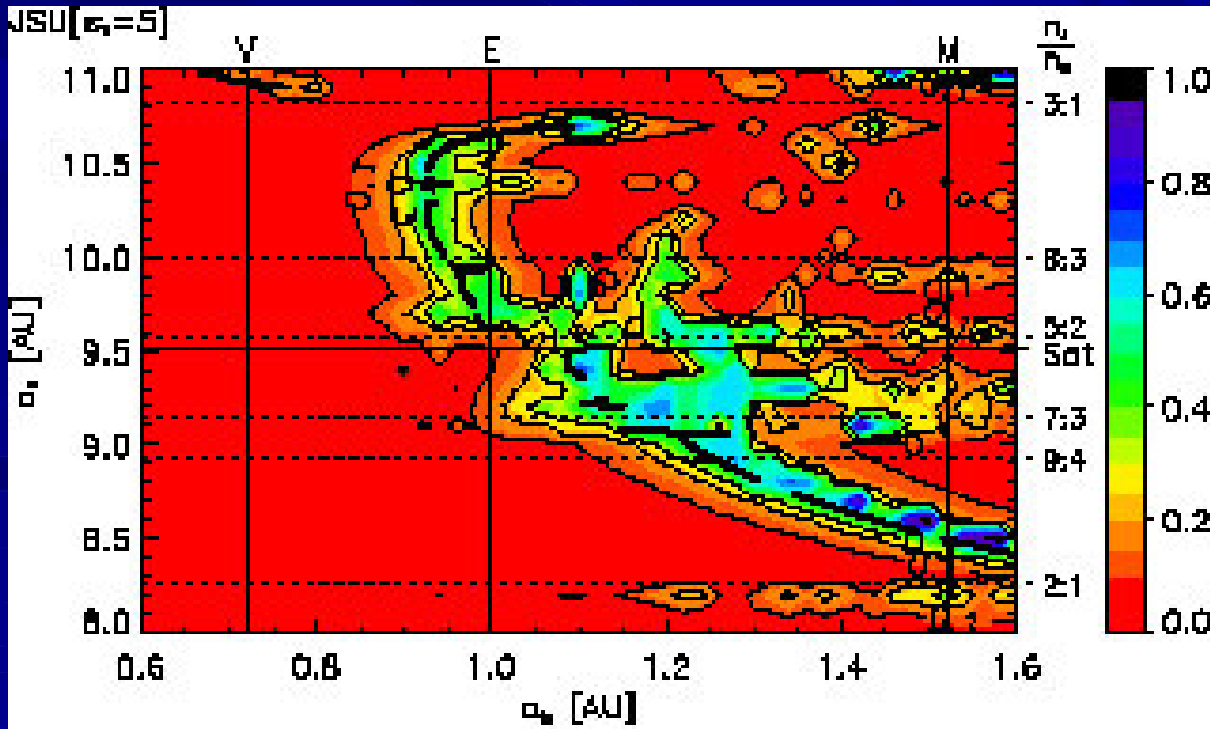
Jupiter – Saturn -Uranus

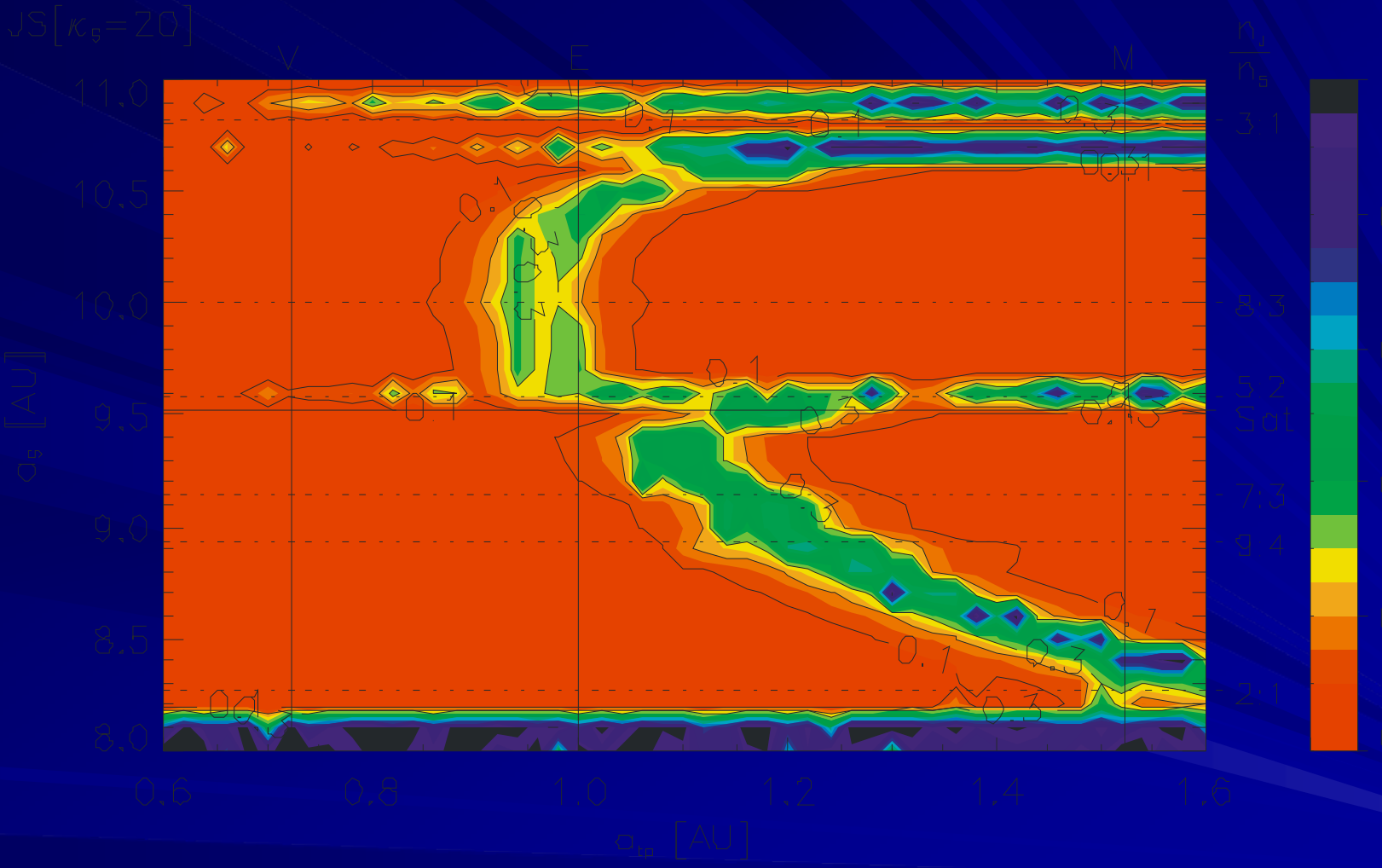



V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
0.6
0.8
1.0
1.2
1.4
1.6
[AU]
1.0
0.8
0.6
0.4
0.2
0.0
3:1
8:3
5:2
Sat
7:3
9:4
2:1
0.1


V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
0.6
0.8
1.0
1.2
1.4
1.6
[AU]
1.0
0.8
0.6
0.4
0.2
0.0
3:1
8:3
5:2
Sat
7:3
9:4
2:1
0.1

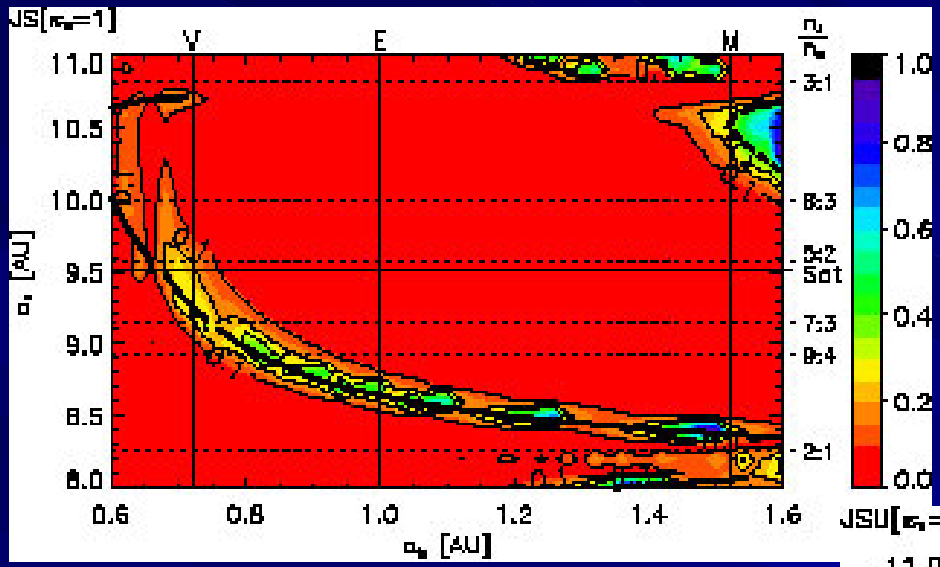

V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
0.6
0.8
1.0
1.2
1.4
1.6
0.1
0.1
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0


V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
0.6
0.8
1.0
1.2
1.4
1.6
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0



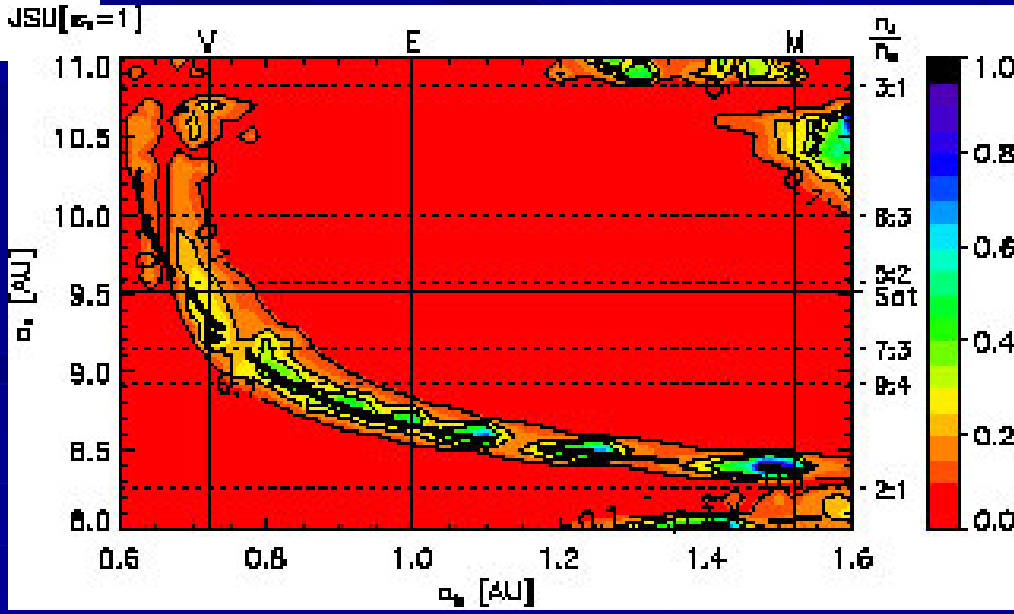
JS[κ5=20]
V
E
M
11.0
10.5
10.0
9.5
9.0
8.5
8.0
a5 [AU]
0.6
0.8
1.0
1.2
1.4
1.6
a10 [AU]
n1/n5
3:1
8:3
5:2
Sat
7:3
9:4
2:1
1.0
0.8
0.6
0.4
0.2
0.0

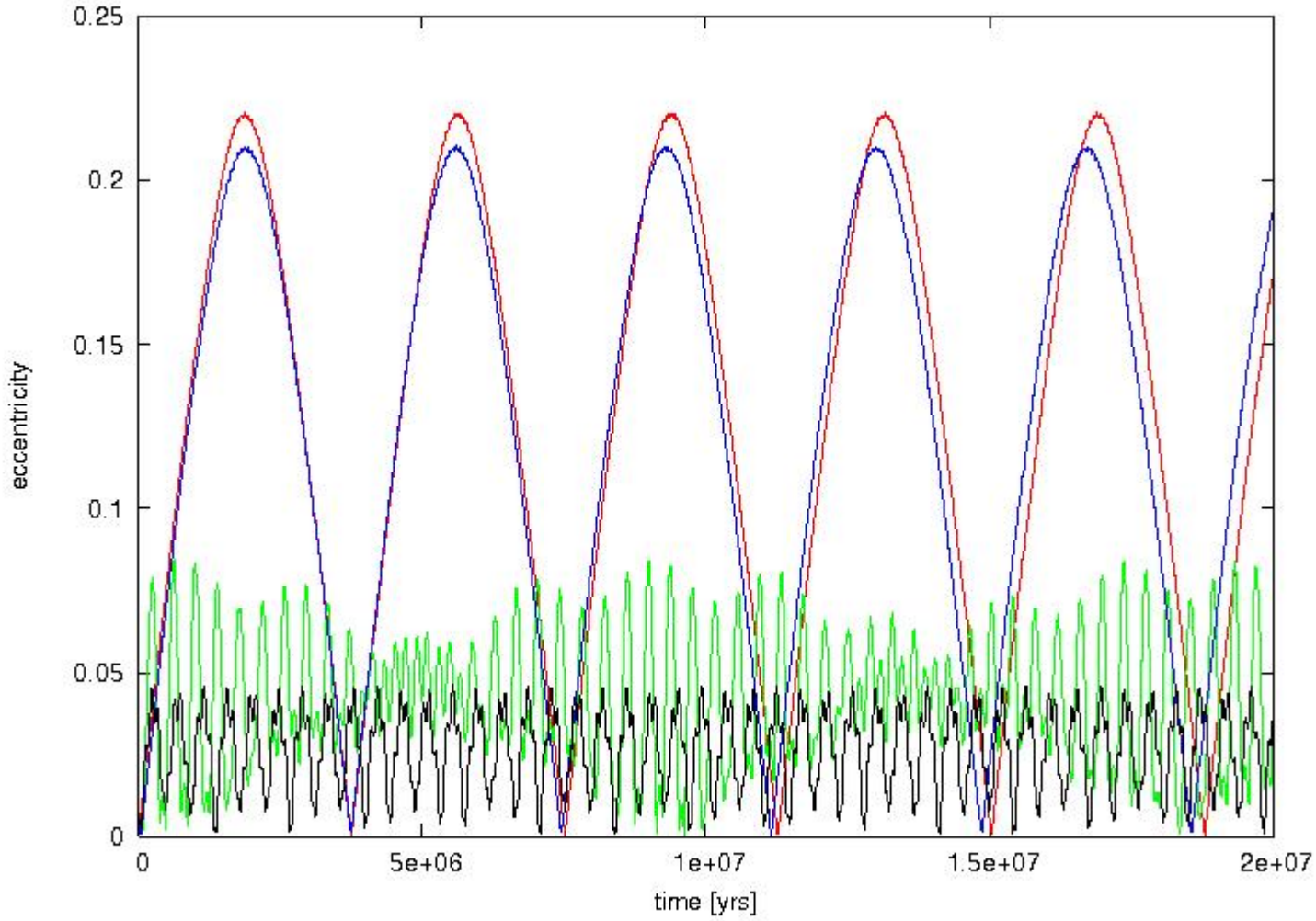
Influence of a third giant planet

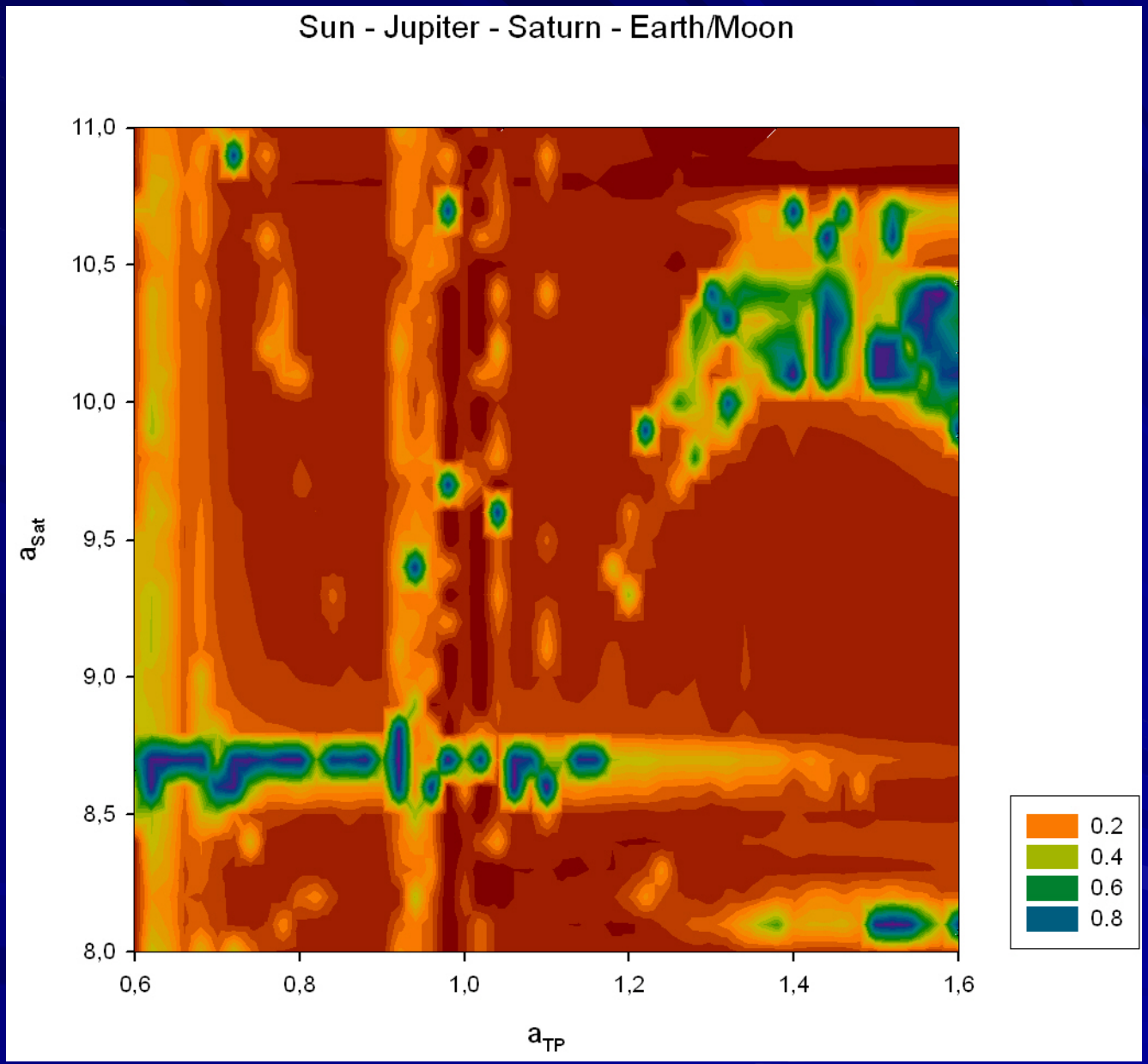


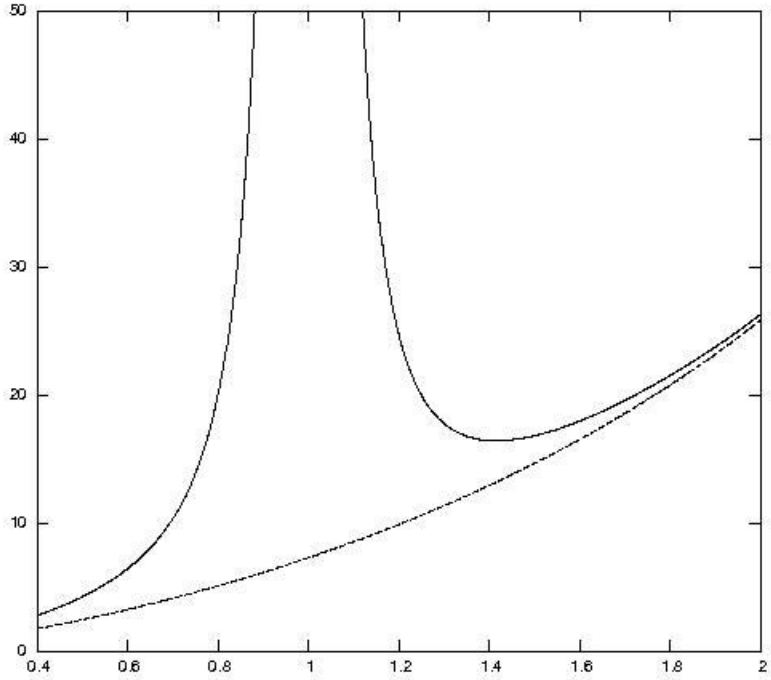
Jupiter -- Saturn

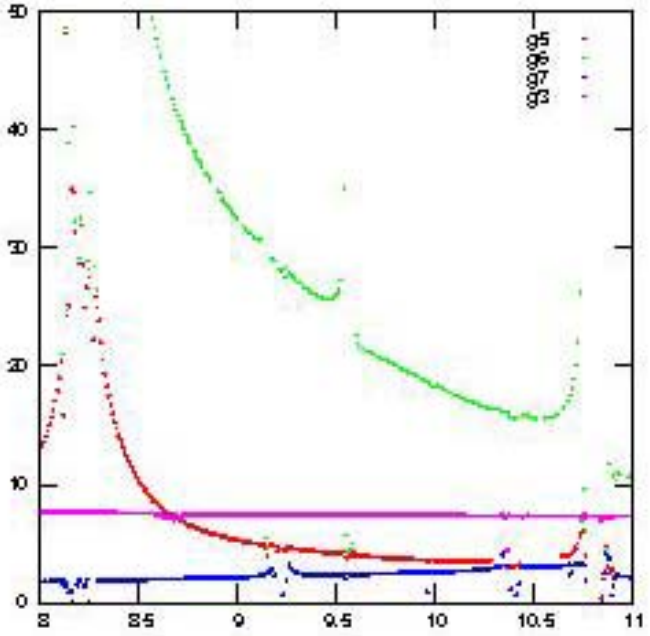
Jupiter – Saturn -Uranus

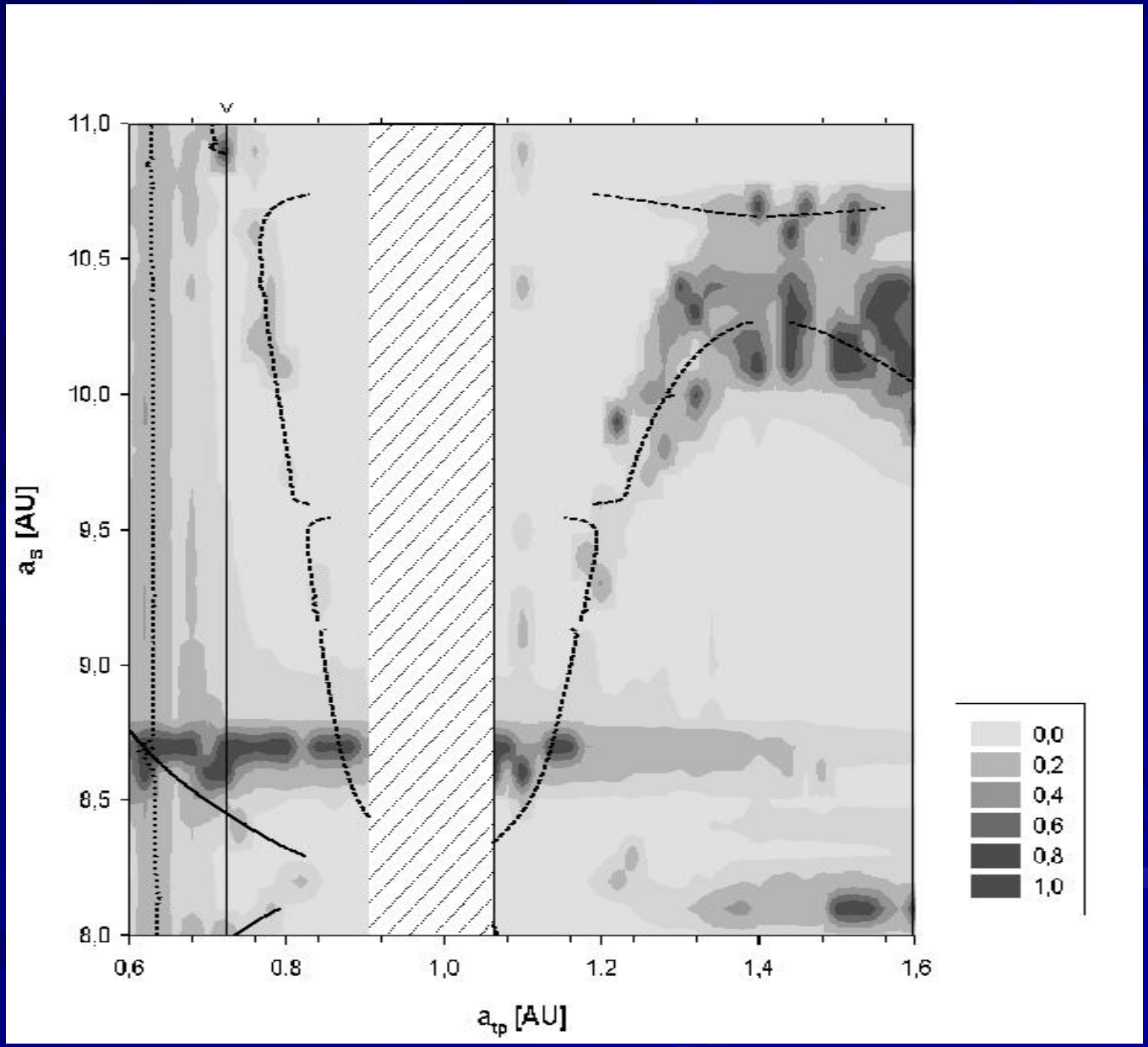


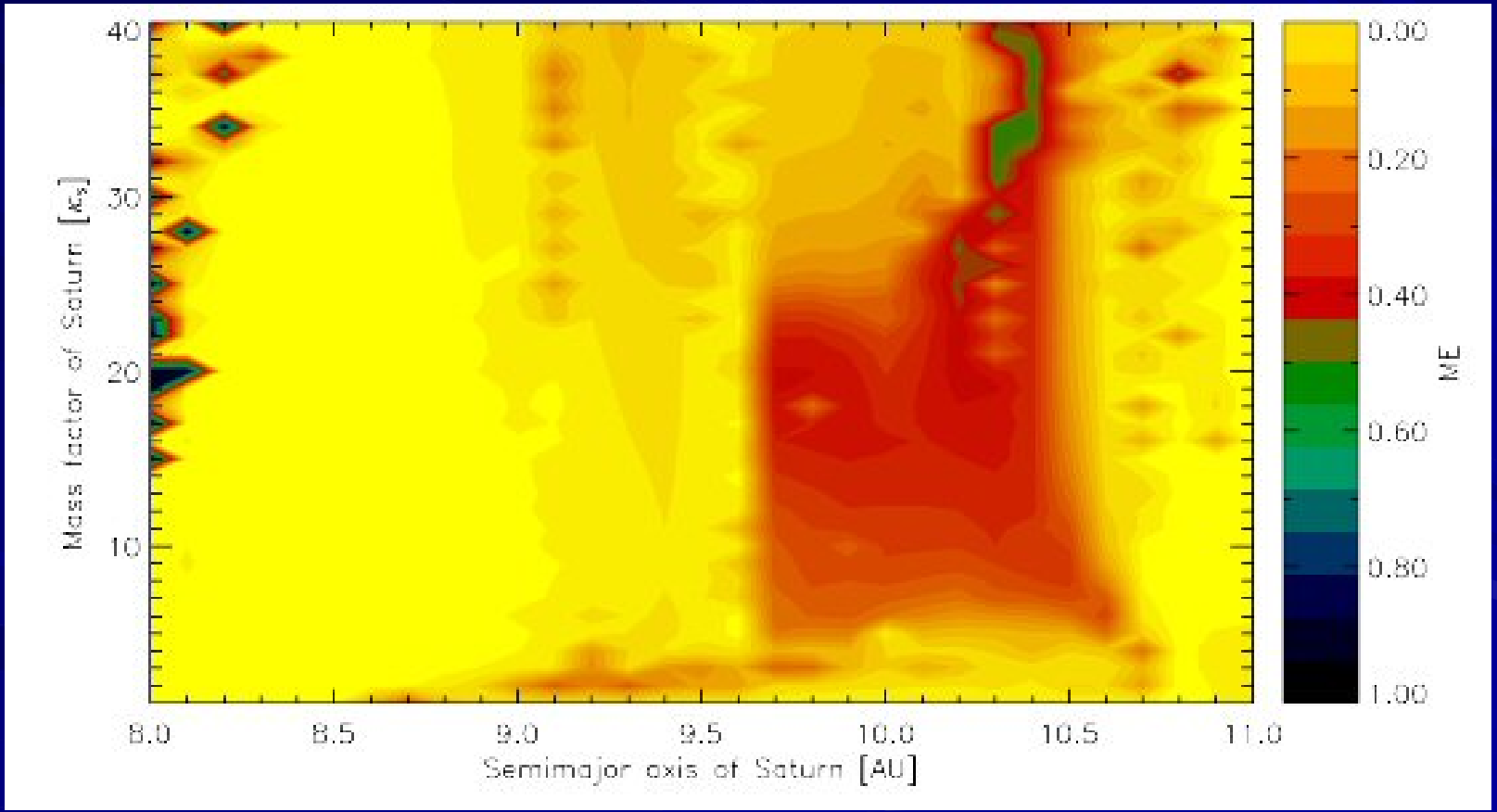

0.25
0.2
0.15
0.1
0.05
0
eccentricity
0
5e+06
1e+07
1.5e+07
2e+07
time [yrs]


Sun - Jupiter - Saturn - Earth/Moon
11,0
10,5
10,0
9,5
9,0
8,5
8,0
a_{Sat}
0,6
0,8
1,0
1,2
1,4
1,6
a_{TP}
0.2
0.4
0.6
0.8


50
40
30
20
10
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


50
40
30
20
10
0
8
8.5
9
9.5
10
10.5
11


11,0
10,5
10,0
9,5
9,0
8,5
8,0
a_s [AU]
0,6
0,8
1,0
1,2
1,4
1,6
a_{tp} [AU]
0,0
0,2
0,4
0,6
0,8
1,0

Sun-Jupiter-Saturn-Uranus

Influence on an Earth-like planet at 1 AU