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A NEW MECHANISM OF STABILITY HIGHLIGHTED BY THE RECENT PLANETARY SYSTEM HD 73526

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Abstract. Dynamical stability of the recent planetary system HD 73526, in 2:1 mean motion resonance, is not without controversy. Whereas this system has been found at first stable for coplanar orbits, techniques of global dynamics analysis show a quite unstable behavior within its strict observational data. Nevertheless, we find a stabilizing mechanism involving the undetermined observational parameters, namely the orbital inclinations and the longitudes of nodes.

1 Introduction

At first, due to regular variations of angular elements over 1 Myr, dynamical behavior of the HD 73526 2-planets system has been assumed stable (Tinney et al. 2006). However, using the MEGNO technique of global dynamics analysis, we show that, within only the strict observational data, the system has a quite unstable behavior (see Fig. 1a and Fig. 1b). By taking into account the relative inclination between the orbits ($i_r = i_c - i_b$) and the longitudes of nodes (Ω_b and Ω_c), we make into evidence a stabilizing mechanism. We present the 5 following conditions related to this mechanism: (1) a 2:1 Mean Motion Resonance (MMR), (2) non-coplanar orbits, (3) an Apsidal Synchronous Precession (ASP) with (4) an alignment of apsidal lines and (5) relatively high eccentricities. Such a mechanism expresses a case of quasi-periodic solutions of the 3-body problem (Bois & Gayon 2006).

2 Stabilizing mechanism

To identify the dynamical state of the HD 73526 system, we use the MEGNO technique (the acronym of Mean Exponential Growth factor of Nearby Orbits; Cincotta & Simò 2000). This method provides relevant information about the global dynamics and the fine structure of the space phase, and yields simultaneously a good estimate of the Lyapunov Characteristic Numbers with a comparatively small computational effort.

By taking into account the observational data alone (see Table 1), Fig. 1a and Fig. 1b plotted in the $[a_b, a_c]$ parameter space show an ambiguous role of the 2:1 MMR (i.e. neither quite stable, nor quite unstable). Besides, the observational data induce an anti-alignment of apsidal lines (not shown here).

By scanning the undetermined elements, namely i_r and Ω_c, we find one island of stability and only one. It is robust and obtained for $i_r \in [8°, 90°]$ (Fig. 1c). As a result, let us observe that *stability* of the system HD 73526 excludes coplanar orbits. By taking into account i_r and Ω_c values suitable for stability, we obtain indeed a robust valley of stability related to the 2:1 MMR (Fig. 1d). Stability map $[\tilde{\omega}_b, \tilde{\omega}_c]$ (for initial conditions coming from the stability zone of Fig. 1c) shows that longitudes of periastron, $\tilde{\omega}_b$ and $\tilde{\omega}_c$ (with $\tilde{\omega} = \omega + \Omega$), on average precess at the same rate (it is an apsidal synchronous precession, ASP, Bois et al. 2005) according to an apsidal alignment (contrary to the strict observational case). This is confirmed in Fig. 1e where one can see that the relative apsidal longitude $\Delta\tilde{\omega}$ librates about 0°. Despite relatively high eccentricities (especially for the inner orbit; $e_b \in [0.2, 0.55]$ and $e_c \in [0, 0.3]$; see Fig. 1f) and small semi-major axes, relative distances between the two planets remain sufficiently large to avoid close approaches.

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Table 1. Orbital parameters of the HD 73526 planetary system (Tinney et al. 2006).

Planet	$m_P \sin i_l$ (m_J)	a (AU)	e	ω (deg)	M (deg)
b	2.9	0.66	0.19	203	86
c	2.5	1.05	0.14	13	82

Mass of the central star: $M_* = 1.08\, M_\odot$.

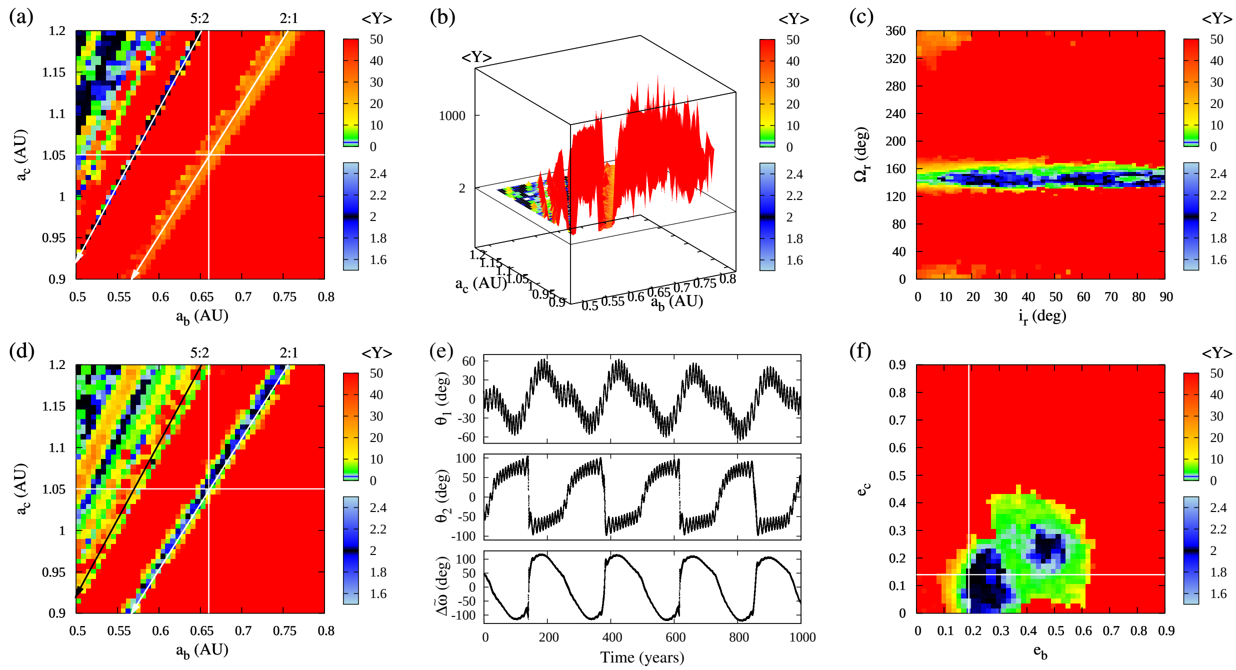

Fig. 1. Dynamical states of the HD 73526 planetary system. In all figures, black and dark-blue colors represent stable orbits ($< Y >= 2 \pm 3\%$ and $< Y >= 2 \pm 5\%$ respectively, with $< Y >$ the MEGNO indicator value) while warm colors highly unstable orbits. The intersection of horizontal and vertical lines indicates the "observational" point while neighbourhood of MMR is located by black and white arrows. Resolution of the grid is 50x50. The reference system is given by the orbital plane of the planet b at t=0 (by convention, we have adopted $i_b = 0°$ and $\Omega_b = 0°$ in such a way that $i_r = i_c$ and $\Omega_r = \Omega_c$). Panels (a) and (b): Stability maps in the $[a_b, a_c]$ parameter space in 2-D (a) and 3-D (b) where peaks express magnitude of instability. Panel (c): Stability map in the undetermined parameters $[i_r, \Omega_r]$. Panels (d) and (f): Stability maps in the $[a_b, a_c]$ and $[e_b, e_c]$ parameter spaces respectively, with $i_c = 24°$ and $\Omega_c = 144.67°$. Panel (e): Librations of the MMR variables θ_1 $(\lambda_b - 2\lambda_c + \tilde{\omega}_b)$ and θ_2 $(\lambda_b - 2\lambda_c + \tilde{\omega}_c)$ and the relative apsidal longitude $\Delta\tilde{\omega}$ around 0° ($i_c = 24°$ and $\Omega_c = 144.67°$).

3 Conclusion

With the second condition of stability, namely orbits necessarily non-coplanar, added to the combination MMR / ASP / high eccentricities, the HD 73526 planetary system has revealed a mechanism that has not been observed nor analyzed before. The question of formation and evolution of such planetary configurations arises then as a new stake for future.

References

Bois, E., et al. 2005, 1st ISSI Team Meeting, H. Lammer (Ed.), in press

Bois, E., & Gayon J. 2006, A&A Letters, in preparation

Cincotta, P., & Simò, C. 2000, A&AS, 147, 205

Tinney, C. G., et al. 2006, ApJ, 647, 594