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Stable 'Islands' in the chaotic Centaurs' region and possible physical consequences

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Abstract

Minor bodies in between the giant planets are called Centaurs, among them, in particular we consider the ones with a semi-major axis contained within 5.5 au and 30.2. These bodies are in chaotic orbits and the majority of them migrates outside the region within ~6 Myr (average orbital lifetime), Centaurs outside the orbit of Saturn (specifically Centaurs with a>13.1 au and outside the J4:1 mean motion resonance) have longer average lifetimes which can reach 100 million years. Most of them are evoluted Trans-Neptunian objects (TNOs), and after becoming Centaurs, they can then become Near-Earth Objects or TNOs again. It is important to study their orbital evolution, which might also affect their surface physical characteristics, i.e., Centaurs, in a colour-colour photometric diagram present a bimodal behavior. Investigation of their peculiar orbits and origins can give hints to their photometric colors and thus taxonomy. Some Centaurs stay longer among the Giant planets and for the potentially active ones this can delay or completely inhibit their activity or even never making started, thus possible comets will be not observer if not for a long time (>10 Myrs). Our preliminary results of their orbital evolution of Centaurs which do not migrate into the inner solar system show that the most stable orbits (SOs) show that in the (a-e) phase space SOs are found in two particular sub-regions: (i) 22 au < a < 29 au and e<0.8 and (ii) 16 au < a < 17 au and e > 0.6. Additionally, SOs in the (a-i) phase space generally have i>40°.

1. Introduction

Known Centaurs are on average larger bodies than Main belt asteroids. They have a semi-major axis, 5.5 au < a < 30.2 au. There is the lack of general agreement, but this is one accepted general definition. Trans-Neptunian Objects (TNOs) are among their major sources and therefore, they usually have a lower physical density than the asteroids with a<3.6 au (main belt asteroids and the majority of the NEAs). Centaurs can become active and can contains a significant amount of water (Guilberte-Lepoutre, 2012; Galiazzo, Silber & Dvorak, 2019). Centaurs have a lifetime less than 10 Myr, but the larger ones, which are after 13.1 au can have significantly longer dynamical lifetimes (Galiazzo, Wiegert & Aljbaae 2016). These bodies are also sources of Near-Earth Objects (NEOs) and their physical characteristics (both surface and interior) become important because they are sources of Earth impactors (Napier 2015; Galiazzo, Silber & Dvorak, 2019) too. Generally they present a bimodal behaviour in their surface color properties (Peixinho, 2012), but discriminating their orbital behaviours and origins can give more hints to their physical distributions.

2. Methods

We use the Lie-Integrator (Hanslmeier & Dvorak, 1984, Eggl & Dvorak, 2010) for orbital propagation. We consider a simplified solar system (all the planets, apart from Mercury, whose mass is added to the Sun). Preliminary results come from data in Galiazzo, Silber & Dvorak, 2019, where 319 Centaurs (data from JPL Small-Body Database Search Engine: http://ssd.jpl.nasa.gov/sbdbquery.cgi, are forward integrate for 30 Myr. Then we propagate backward (BP = backward propagation) and forward (FP) again. For BP we consider the entire known centaur region and integrate for at least 100 Myr, considering 20 clones for each Centaur (randomly distributed among their elements, as done in Galiazzo, Silber & Dvorak, 2019). For FP, we consider the orbit of only the known Centaurs in the "stable-" regions found from Galiazzo, Silber & Dvorak, 2019, see Table 1.

3. Summary and Conclusions

From data in Galiazzo, Silber & Dvorak, 2019 we have extrapolated the initial "stable-"orbits where Centaurs can live longer.

Table 1: "stable-"regions (orbital regions which are not sources of Mars-crossing bodies) in (a-e) phase-space and (a-i) phase-space. Semi-major axis in au, inclination in sexagesimal degrees.

a-e	a-i
5.5-8 x 0-0.05	5.5-8 x 0-10
5.5-8 x 0.9-1	5.5-30.2 x 40-180
11-30.2 x 0-0.35	8-23 x 35-40
12-30.2 x 0-0.6	23-30.2 x 0-35
13-30.2 x 0-1	

Centaurs can survive without significantly changing their orbits for more than 30 Myr, see an example in Fig. 1. Future studies of us will constrain the more the stable islands of the Centaurs and foreseen possible correlations with physical properties. First results about these correlations can be seen in Fig. 2 (stable bodies seem to have extreme colors).

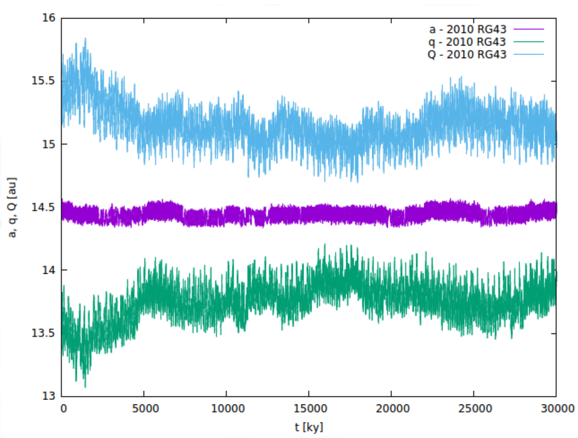

Figure 1: Orbital evolution of a stable Centaur (2010 RG43). Semi-major axis, perihelion and aphelion vs time.

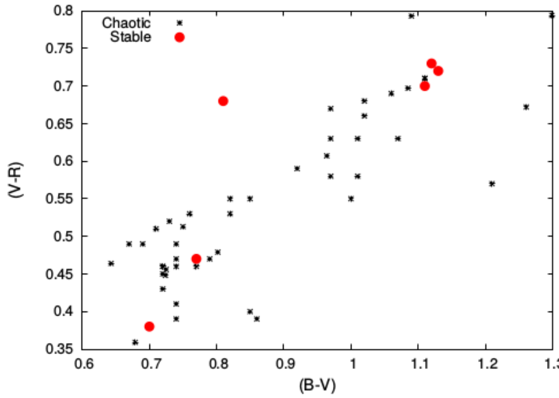

Figure 2: Color-color (B-V vs V-R) diagram for Chaotic Centaurs (black square) and Stable Centaurs (red circles). Colors from Hainaut & Delsanti 2002, Tegler et al. 2008, Peixinho et al. 2003, Tegler et al. 2015, Galiazzo et al., 2016, and Jewitt 2015.

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