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No active Centaurs in the Outer Solar System Origins Survey

Nahuel Cabral (1), Aurélie Guilbert-Lepoutre (2), Wesley Fraser (3), Michael Marsset (4), Kathryn Volk (5) and the OSSOS team
(1) Institut UTINAM, UMR 6213 / CNRS - UBFC, 25000 Besancon, France
(2) LGL-TPE, UMR 5276 / CNRS - Universit Claude Bernard Lyon 1 - ENS, 69690 Villeurbanne, France
(3) Astrophysics Research Centre, School of Mathematics and Physics, Queens University Belfast, Belfast BT7 1NN, UK
(4) Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA 02139, USA
(5) University of British Columbia, Vancouver, BC V6T 1Z1, Canada

1. Introduction

Within the known Centaur population, 10 to 20% of objects display cometary activity. While trying to identify the origin of Centaurs' activity, Jewitt (2009) noticed that the physical and orbital properties of active Centaurs are such that their activity should be thermally driven. Guilbert-Lepoutre (2012) studied the phase transition between amorphous and crystalline water ice as a possible source for Centaurs activity. They found that crystallization can indeed be a source of activity in the giant planet region, possibly triggered at heliocentric distances as large as 16 au, but most efficient for heliocentric distances up to 10-12 au. Crystallization-driven activity would only be sustained for a limited time, typically hundreds to thousands of years. In the best case scenarios, it could be sustained for up to tens to hundreds of thousand years. These results imply that if crystallization is the source of Centaurs' activity, these should have suffered from a recent orbital change. Fernandez et al. (2018) showed that while all Centaurs may come from the same source region, they have a wide range of dynamical histories, and do not contribute to the same comet populations. They found that active Centaurs experienced drastic drops in their perihelion distances in the recent past. Assuming that crystallization drives the activity of Centaurs, the framework would be as follows: after a drastic change in orbital parameters, a Centaur would need to adjust to new thermal conditions, at which point phase transitions could be triggered and produce some observable cometary activity.

2. Centaurs in the OSSOS sample

In this work, we search for cometary activity among Centaurs recently detected by the Outer Solar System Origins Survey (OSSOS). We use the simple but practical definition of Centaurs proposed by Jewitt (2009). Those are defined as objects whose orbits satisfy the following criteria: (i) their perihelion distance q must be between 5.2 and 30 au, (ii) their semi-major axis a must be below 30 au, (iii) they must not be in a 1:1 long-term stable mean-motion resonance with a planet (i.e. we exclude in particular Jupiter and Neptune Trojans). Known Centaurs, active or inactive, and the 20 OSSOS detections are shown on Figure 1. The perihelion distance of 4 of these OSSOS Centaurs is below 10 au, where cometary activity is prone to be initiated, and 5 additional objects have a perihelion distance between 10 and 12 au, i.e. in the region where cometary activity is still possible according to Guilbert-Lepoutre (2012). We performed a dedicated search for cometary activity, using several methods, and including the deeper Col-OSSOS data when available, which did not allow to detect any coma around any of those Centaurs.

We have tracked the past dynamical evolution of the OSSOS Centaurs in order to assess whether any of them would have suffered from a drastic orbital change able to induce cometary activity. To do so, we have integrated the orbit of each OSSOS Centaur backwards for 10^5 years with clones showing the best-fit orbit, and the 3σ minimum and maximum semimajor axis orbits allowed by the astrometry. The integrations are stopped when the clone reaches a heliocentric distance smaller than 4 au because the simulations only include the Sun and the 4 giant planets as massive perturbers (the mass of the terrestrial planets is added to the Sun). The simulations were performed using the rmvs3 routine in the SWIFT integrator package with a timestep of 30 days.

While some OSSOS Centaurs evolved smoothly in the past 10^5 years, at distances in the giant planet region where cometary activity would not be expected from thermal evolution models, we also found objects suffering from drastic changes in orbital parameters.

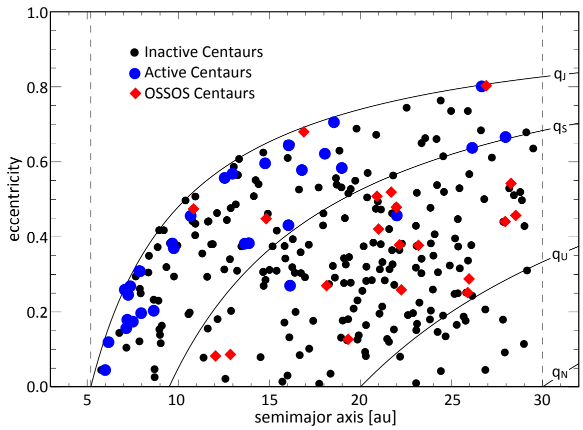

Figure 1: Semi-major axis vs. eccentricity of the orbits of Centaurs, inactive or active (small black dots and large blue dots respectively). Centaurs detected by OSSOS are shown with red diamonds. Solid curves show the orbits having perihelia distances equal to the semi-major axis of Jupiter (q_J), Saturn (q_S), Uranus (q_U) and Neptune (q_N). Dashed lines show semimajor axis limits of 5.2 and 30au.

The best candidate, K13J64C, had a drop in its perihelion distance of more than 6 au about 2×10^4years ago. Even if in theory such a drop would be able to trigger cometary activity, a- it happened too long ago for effects to be still seen today, and b- the object remains much too far from the Sun for crystallization to be triggered.

3. Conclusion

We searched for cometary activity among the 20 Centaurs detected by the Outer Solar System Origins Survey (Bannister et al. 2016, 2018). Though some objects are close enough to the Sun to be potentially active, no coma can be detected either in the OSSOS dataset, or the Col-OSSOS data when available. The analysis of their past orbital evolution shows that none of the OSSOS Centaurs meets the thermal requirements for being active due to the crystallization of amorphous water ice. The properties of OSSOS Centaurs support (or at least do not provide any evidence against) the current scenario in which crystallization of amorphous water ice is the source for cometary activity amongst Centaurs.

Was OSSOS particularly unlucky in finding only Centaurs relatively stable on a timescale of 10^5years? Compared to Transneptunian Objects, Centaurs have different detectability because OSSOS detections are motion-rate dependent. With an upper limit for the motion rate set at 15"/hr, OSSOS necessarily focusses on objects detectable at more than 10 au, though it did detect objects inside that limit. In this regard, OSSOS may be biased toward more stable orbits found beyond Saturn (Tiscareno & Malhotra 2003, Di Sisto & Brunini 2007), i.e. with perihelion distances larger than 10 au. More generally, we could argue that this stability bias is likely to be inherent in the Centaur discoveries by all surveys. There have been no surveys that adequately target the motion rate for objects in the 5-10 au region (where Centaurs with more unstable orbits can be found) in a well-characterized manner. The sensitivity of asteroid surveys drops beyond 5 au, and TNO surveys optimise cadence for objects typically beyond Saturn. So we could argue that this is a weakness of the entire known Centaur dataset, not just of OSSOS. **We finally argue that a dedicated survey is required to actually understand the origin of Centaurs' activity.**

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