Probing the Radial Distribution of the Kuiper Belt using Stellar Occultations. A. Doressoundiram[1] F. Roques[1] and Y. Boissel[1], [1]Observatoire de Paris, LESIA, 92195 Mendon cedex, France.

Introduction: The Trans-Neptunian Objects (TNOs) are the frozen leftovers from the formation period of the outer solar system [1]. The current total mass in the Kuiper Belt is estimated to be around 0.03-0.3 Earth masses [2], but there is evidence that a much larger mass (10-40 M_{Earth}) was originally present at the time of formation [3].

The direct observation of the TNOs does not allow reaching two important informations, the population of the small objects and the external part of the disc. However, by extrapolation of the density of matter in the solar system and by comparison with known circumstellar discs, one can think that the distribution of sizes is extended to objects of size much lower than one kilometer and that the Kuiper belt spreads beyond 50 AU.

The occultation method: A very powerful method to detect tiny and invisible objects by the direct method is to seek their transit in front of a star, that is the serendipitous stellar occultation method ([4] and references therein). Stellar occultation can detect kilometric objects beyond the orbit of Neptune.

Serendipitous occultations, on the other hand, have no other competing methods, as the magnitudes of the corresponding objects, *V*~35 or fainter, is unreachable through classical ground-based imaging [4]. Such occultations reveal the vertical and radial distribution of the TNOs as far as 50 AU and beyond. Also, it provides information on size distribution down to hectometer-sized objects.

Observations and data analysis: We conducted a survey for serendipitous occultations in 17-20 May 2005 using the high-speed, triple-beam imaging photometer ULTRACAM [5], mounted at the visitor focus of the 8.2-m Very Large Telescope in Chile. The stars were chosen to ensure a small angular diameter, which is critical to obtain diffraction's fringes. A total of ~4.0 million frames were obtained on the nights between 17/05/2005 and 20/05/2005, simultaneously in g' (0.48 μm) and r' (0.63 μm) SDSS filters.

The reduced data consist in two lightcurves of the two observed stars in each field. thus totalizing 5 runs or continuous lightcurves. This leads to nearly 19 hours of data for each star.

We used the same method for the analysis as described in [6]. This means that we search for deviant points from the mean standard deviation of the lightcurve. and found no occultation event. However these results bring strong constraints on the Kuiper belt structure.

Discussion and conclusions: A first way to interpret these results is to compare them with theoretical study done in [7]. This study shows that the limit on a detectable TNO with a 8 meters telescope is, in optimum conditions, 80 meters radius. In the data presented above, in the higher SNR intervals (where SNR is better than 200), a 130 meters TNO is detectable. The figure 4 of [7] allows deriving from this, a maximum value of the slope of the differential size distribution of the Kuiper belt population of 3.4 (assuming a break in the size distribution at 1 km radius).

Another way to derive constraints on the Kuiper Belt from this zero-detection without hypothesis on the size distribution, is to consider two parameters, the scanned sky area S_c and the size of detectable objects, r_d. The observation gives an upper limit of the density of objects larger than the detectable object (r_d) on the scanned sky area (S_c deg^2). The derived maximum density of TNOs larger than 200 meters, at 50 AU, is one per 3.58 10^{-10} deg^2.

Others researches for occultation by TNOs have been conducted during the last years:

- [6] found no object in the known Kuiper Belt, in a 10 hours-stars run: They announced detection of two objects farther than 100 AU and one at 15 AU (see next sub-section).
- [8] announced zero detection during a 5 hour-stars run.
- [9] announced possible dips events in RXTE data of Scopius 1, interpreted as four objects of 60-100 meters occulting TNOs in a 72ksec data set.
- A two years campaign with TAOS [10] provides also an upper limit on kilometre-sized objects.

All these results are summarised in the figure 1. They are compared with the collisional equilibrium size distribution [11] and the size distribution inferred by Bernstein et al.'s observations [12].

Extended Kuiper Belt. The above research is done in the distance of the known Kuiper Belt, i.e. near 50 AU. The diffraction fringes observed with two wavelengths give access to the distance of the occulting objects. Fits of diffraction fringes allowed [6] to find two small objects farther than 100 AU (one object of 320-meters at 140 AU and one object of 300-meters at 210 AU). These results suggested the existence of an extended cold Kuiper Belt. These detections, together with the observations described in this work, give information on the possible cold disk: 50-200 AU. Two objects of 300 meters detected in 42 hours translate into 10^{12} objects, i.e. roughly one lunar mass.

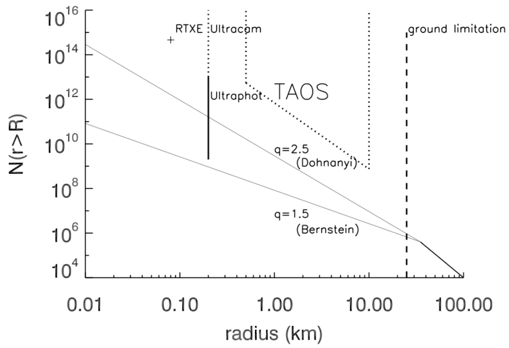

Figure 1: Cumulative size distribution diagram giving constraints on the size distribution of TNOs inferred from observations performed so far (RTXE, Ultracam and TAOS, see text). Also is indicated on the curve what the ULTRAPHOT project would detect (see text). The surface on the ecliptic is supposed to be 360° x 15° = 5400°^{2}.

References:

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