Towards a better understanding of the apparent source of long-period comets

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Some people say:

It is premature to ask where do the long-period comets come from.

We asked, and are prepared to give the answer for most of over 150 long-period comets investigated by us so far.

In 1950 Jan Oort completed a list of 19 original orbits of well observed long-period comets as an argument for the existence of a cometary cloud.

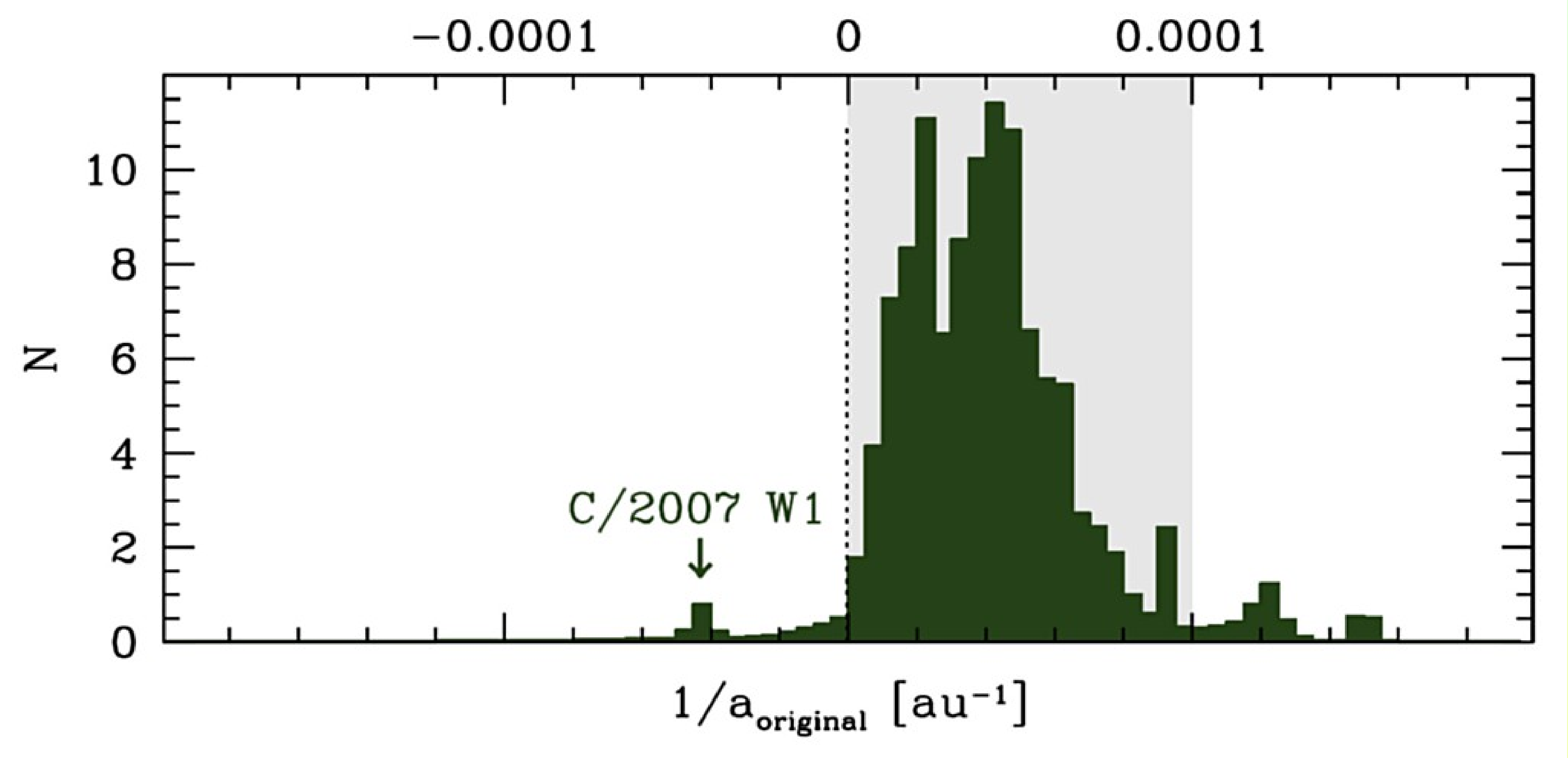
He showed, that their inverse of semi-major axis $1/a_{ori}$ have the distribution apparently peeked near zero, at the positive side.

He concluded that new long-period comets come from distances from 50 000 to 150 000 AU.

He also showed, that perturbations by passing stars can change cometary orbit significantly, making it observable as “dynamically new” long-period comet.

During the last 65 years several new important factors have been revealed in this field.

First, the population of precise original cometary orbits have increased from 19 to several hundreds.



From: Królikowska, 2014, accepted for A&A

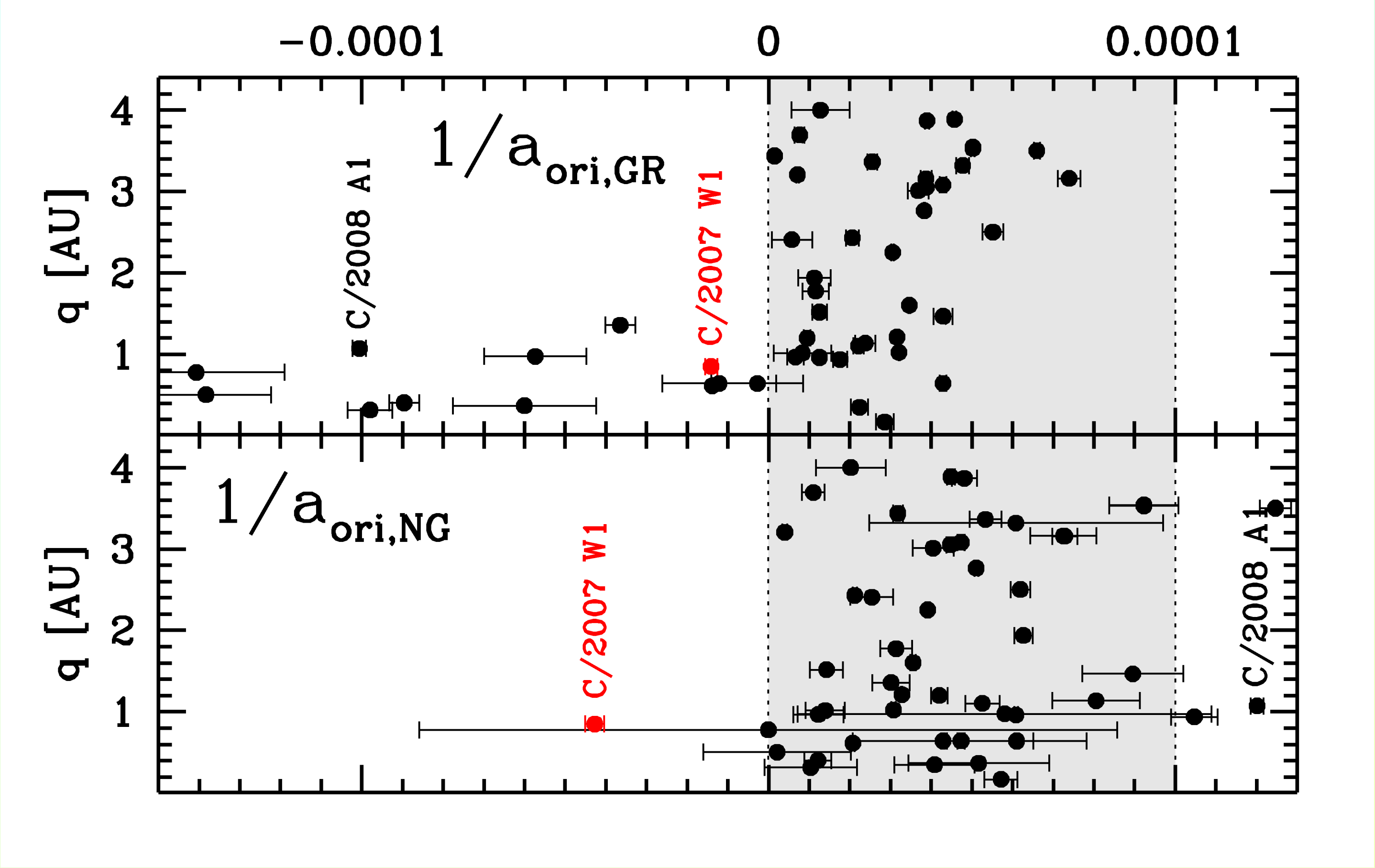
Distribution of $1/a_{ori}$ for 119 LPCs studied by us. The uncertainties of 1/a determinations were incorporated into these histogram by taking the full swarm of clones for each comet, i.e. this distribution is composed of 119 individual normalized 1/a-distributions, each one resulting from the dynamical calculations of 5001 clones.

Second, a new and dominating perturbing force must be included in the model: the gravitational action of our Galaxy. It constantly changes cometary orbits.

It means, that looking at the original orbit elements we no longer can tell the past, for example in terms of previous perihelion or aphelion distances.

Third, we learned how to investigate and in many cases we can successfully determine non-gravitational forces in the motion of long-period comets.

When included in a process of orbit determination this can significantly increase our knowledge on original and future orbits.

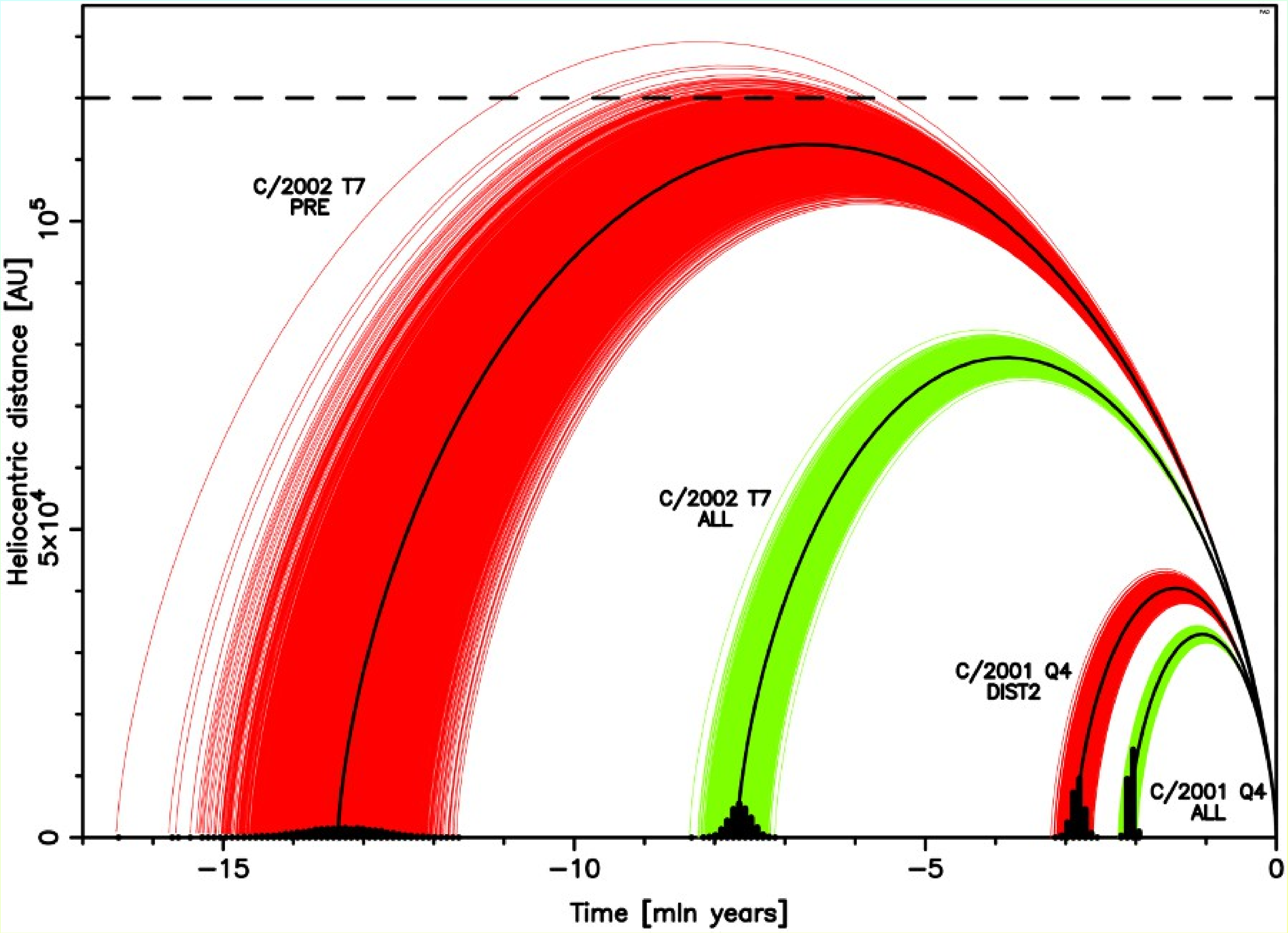


Adapted from: Królikowska & Dybczyński, 2013, MNRAS, *435*, 440

Shifts of $1/a_{ori}$ due to the NG acceleration for 48 LP comets with well-determined NG effects.

Three largest uncertainties of $1/a_{ori,NG}$ belong to comets C/1959 Y1, C/1952 W1 and C/1892 Q1.

Fourth, in case of well observed comets with long intervals covered with astrometric data it can be fruitful to obtain original or future orbits not from the whole set of observations but from shorter arcs, e.g. to exclude observations close to perihelion, where violent nongravitational effects can disturb the comet motion.



From: Królikowska, Dybczyński, Sitarski, 2012, A&A, 544, A119

Taking all this into account, the apparent source region (or regions) of long-period comets as well as the definition of a dynamically new comet are still open questions, as well as the characteristics (if not the existence) of the hypothetical Oort Cloud.

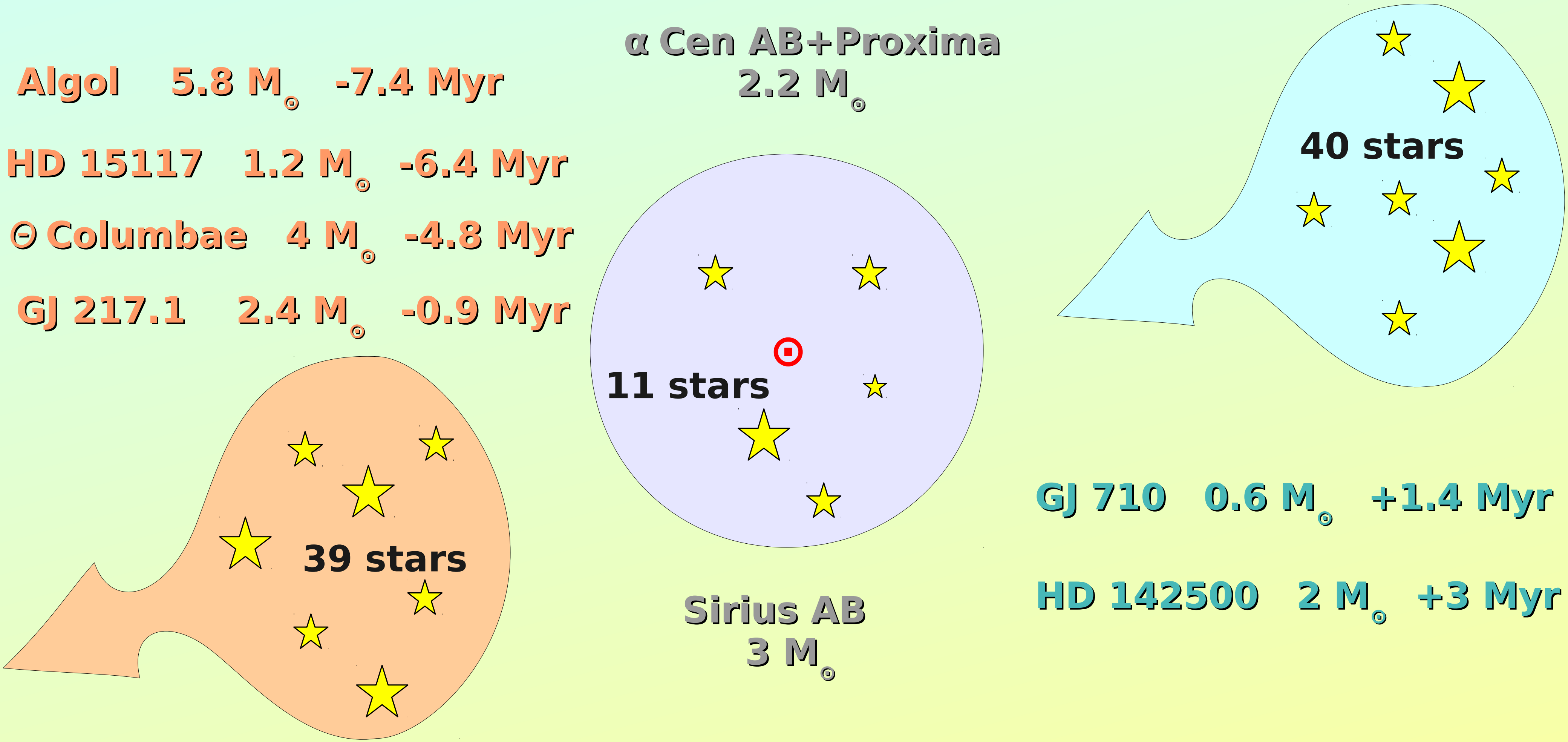
In short: when searching for the source of long-period comets stop looking at $1/a_{ori}$ through a magnifying glass.

Just compute past orbits of the observed long-period comets with their uncertainties.

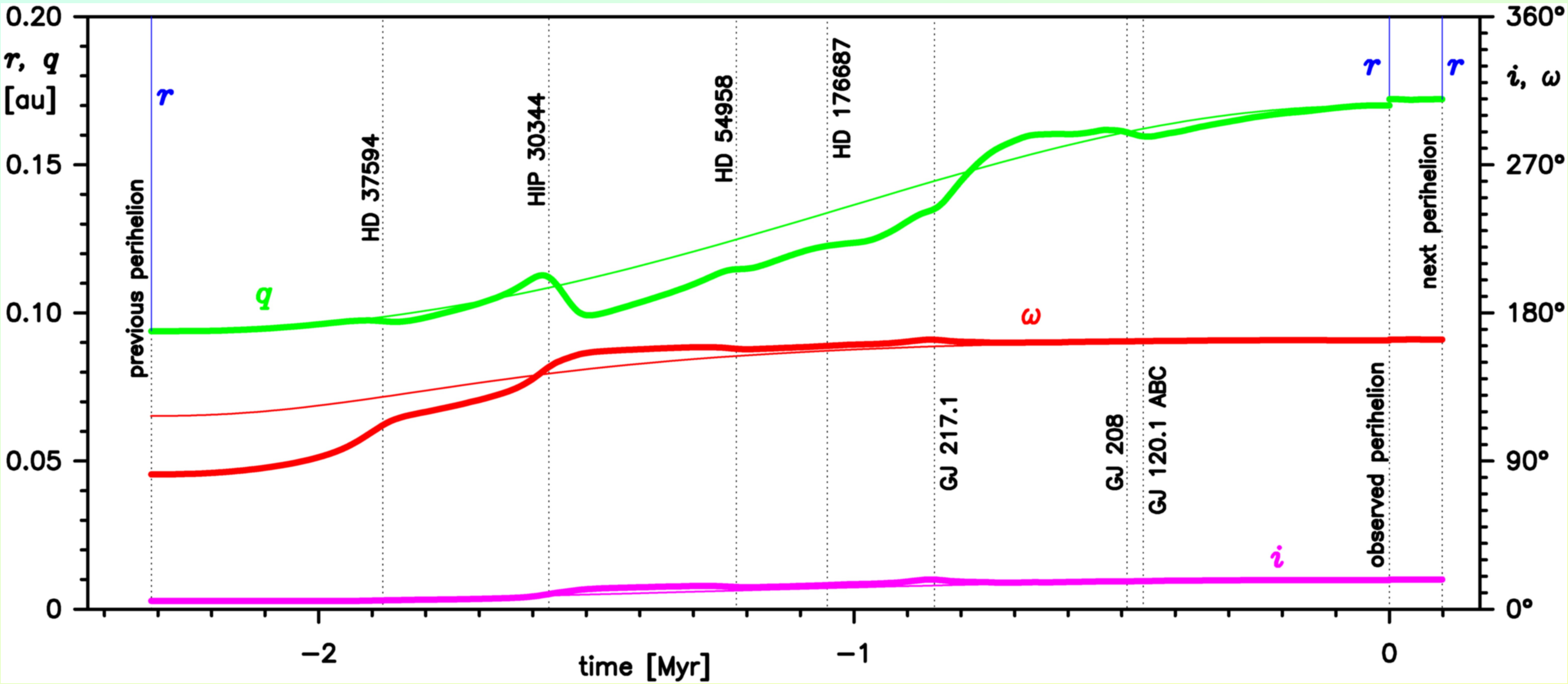
The prescription:

- Determine as precise as possible the original orbit of each comet, including non-gravitational effects wherever they are determinable.
- Clone the nominal orbit, creating thousands of accompanying bodies to propagate observational uncertainties.
- For all of them calculate „original”, barycentric orbits at 250 AU from the Sun.
- Follow the motion of each clone one orbital period backwards, taking into account all perturbing forces: Galactic tides and real stellar perturbers.
- Make nice pictures.

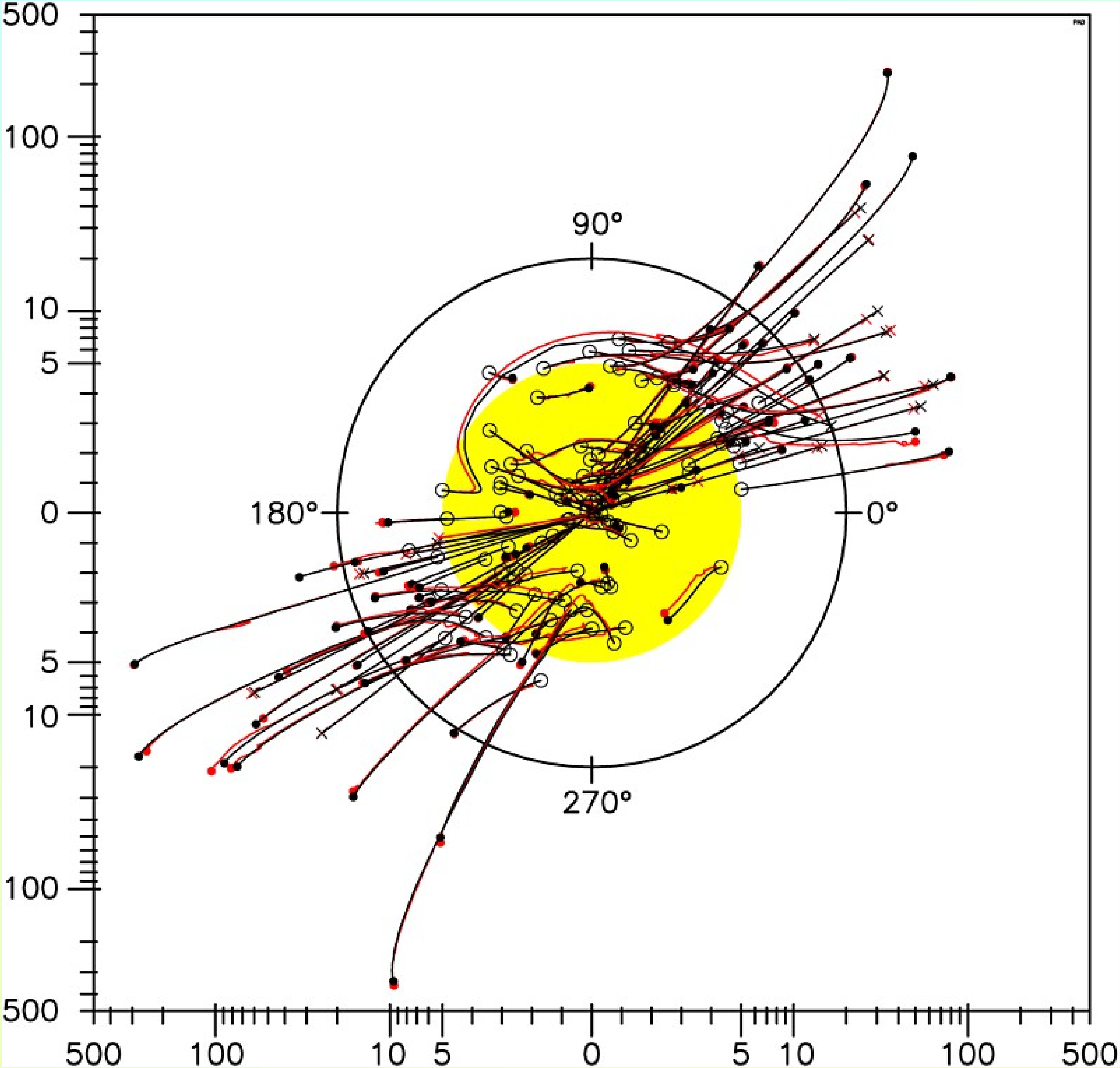
Current, past and future stellar visitors



Example: C/2006 P1 McNaught



The example of a comet orbital evolution - the famous comet C/2006 P1 McNaught. Thin lines - stellar perturbations excluded, thick lines - full model. Angular elements are in the Galactic frame. Several individual stellar perturbations are indicated.



A comparison of the backward orbit evolution for one orbital period of 119 long-period comets under the influence of Galactic and stellar perturbations (red plots) and only Galactic action (black plots). Distance from the center equals an osculating perihelion distance in AU while the phase angle equals an argument of perihelion. An open circle marks a current perihelion while each full dot marks the previous one (crosses=escape).

What do we expect from GAIA mission?

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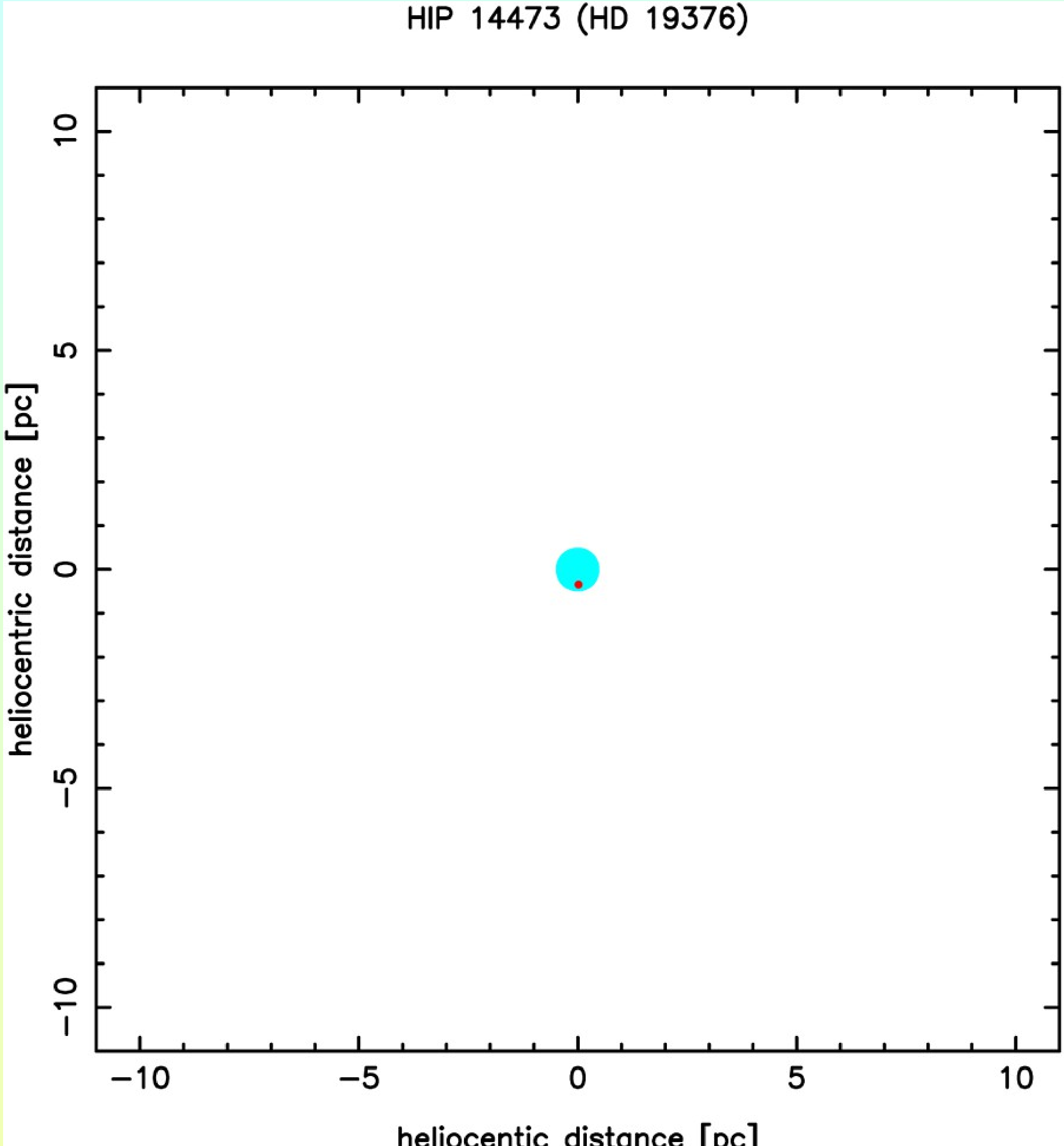
Example: in the latest version of the Hipparcos catalogue (HIP2,van Leeuwen, 2007) the parameters of the star HIP 14473 are:

- α = 03:06:48.03679
- δ = -05:03:03.5843
- μ_{α} = 0.78 ± 2.10 mas
- μ_{δ} = 0.59 ± 1.61 mas
- π = 7.56 ± 1.19 mas

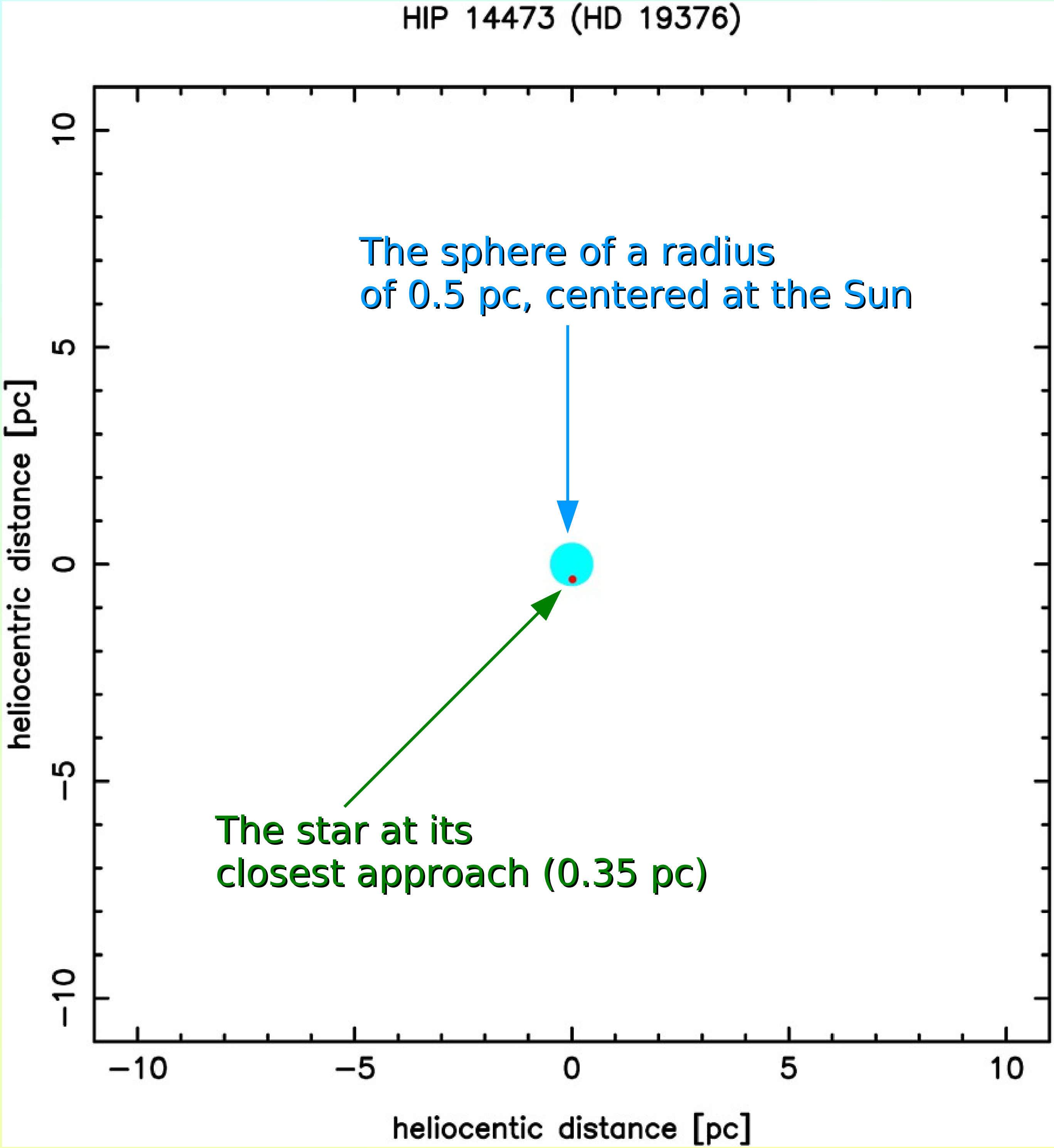
augmented with v_r = 34.20 ± 1.2 km/s from another source.

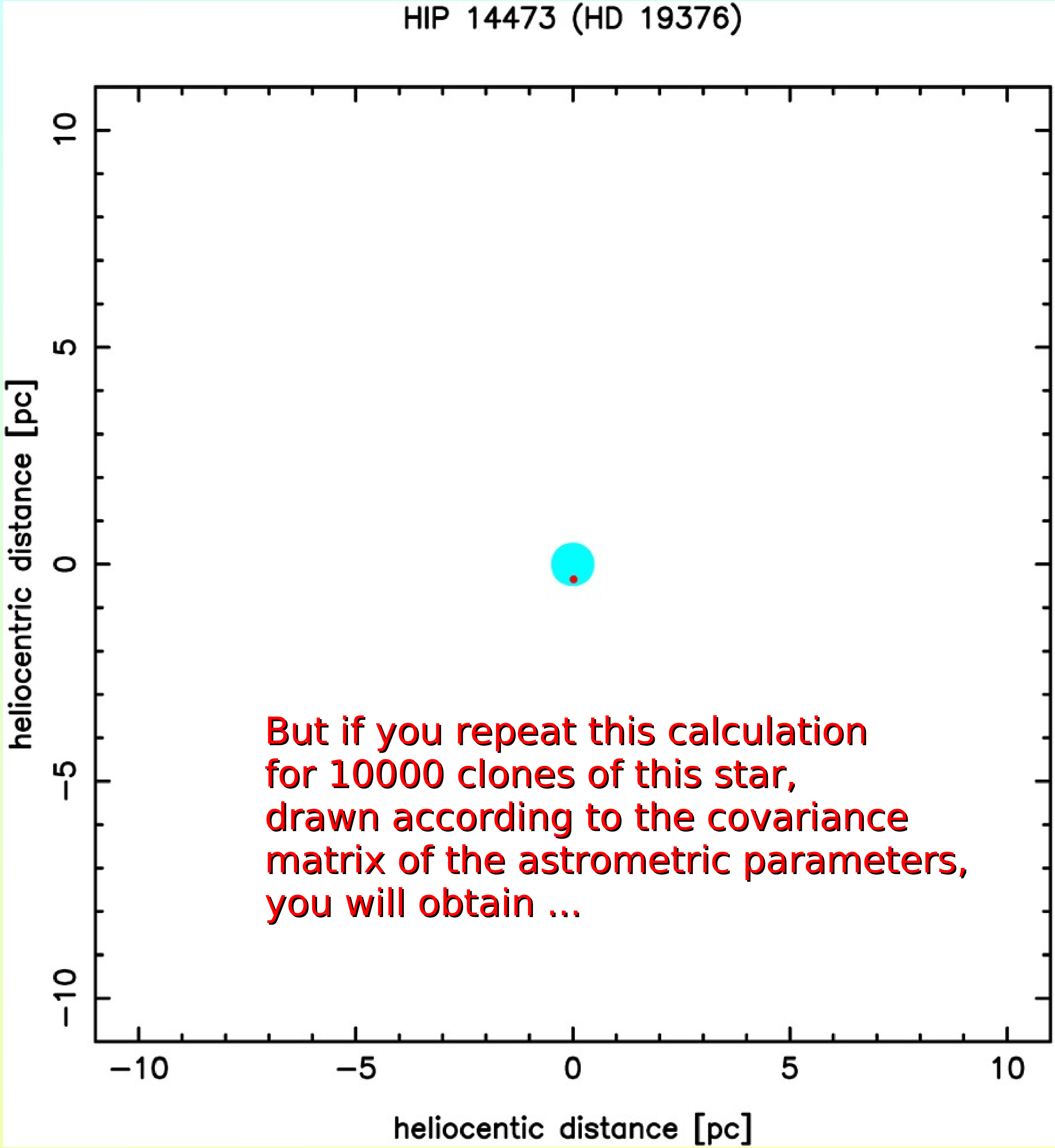
What do we expect from GAIA mission?

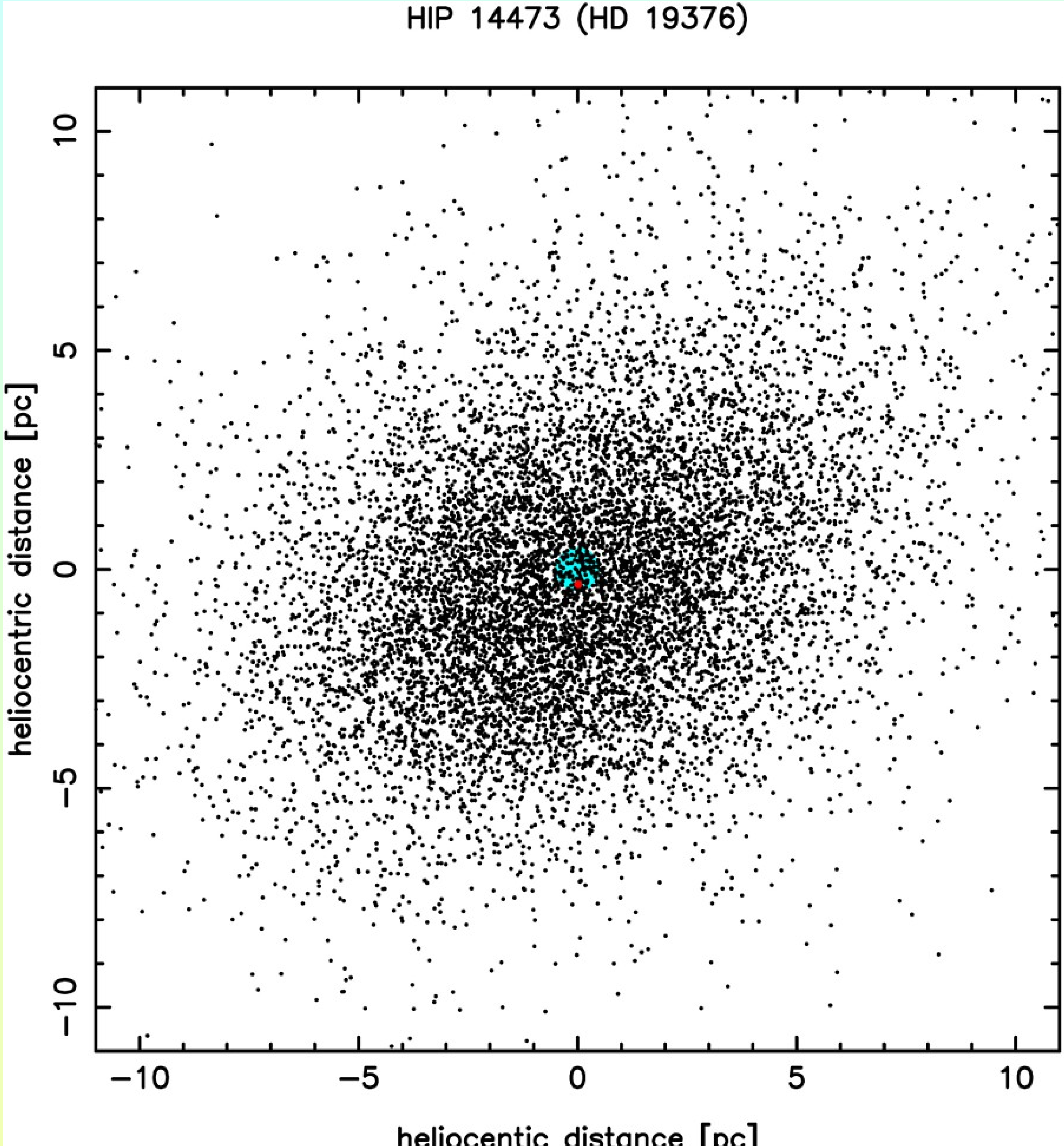
If you calculate the spatial position and velocity of HIP 14473 (at a distance of 132 pc from the Sun) and follow numerically its motion (and the motion of the Sun) under the influence of the global Galactic potential for 3.7 Myr towards the past, you will find **its closest distance from the Sun to be 0.35 pc (72000 AU)**.



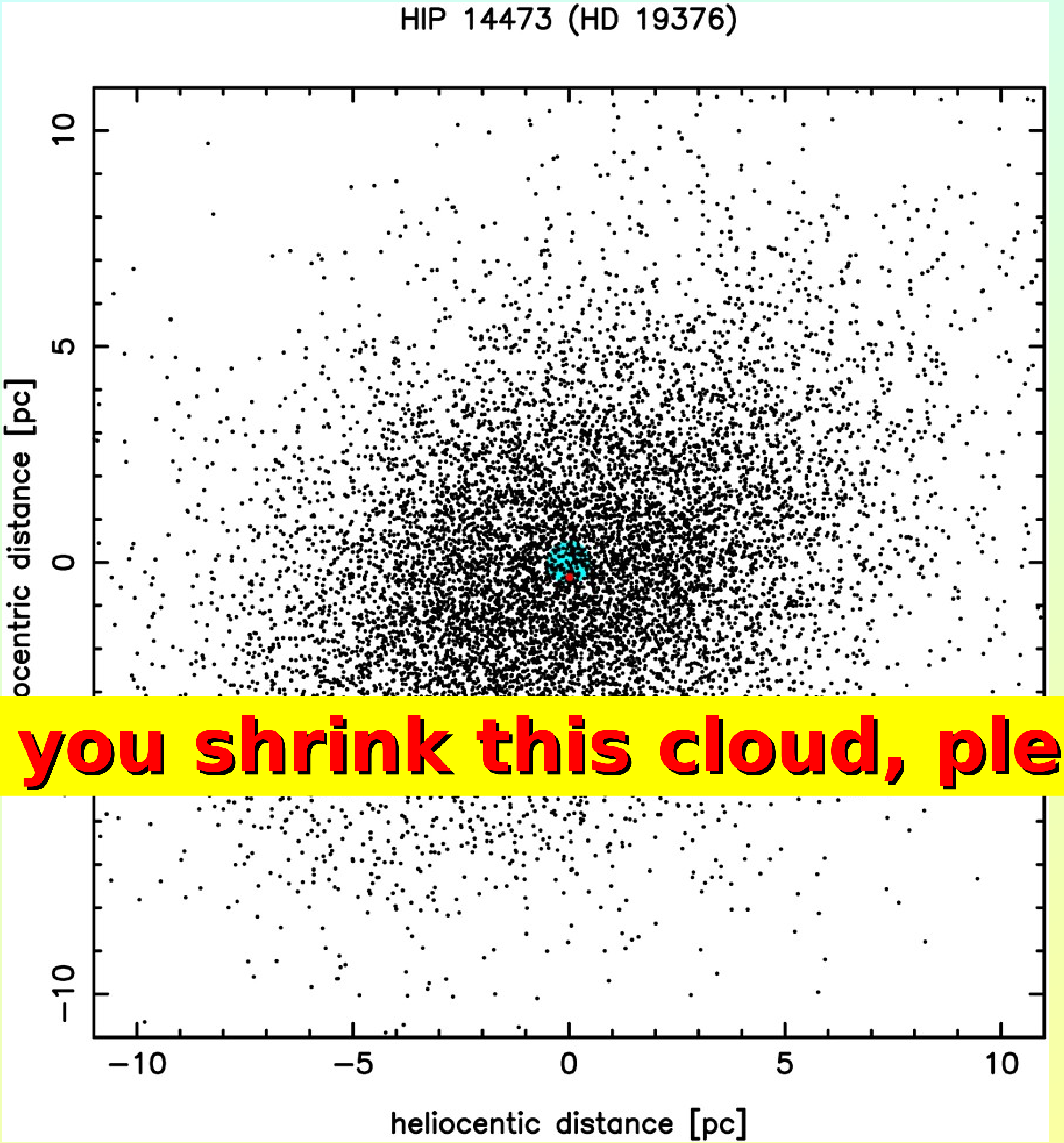
HIP 14473 (HD 19376)
10
5
0
−5
−10
heliocentric distance [pc]
−10
−5
0
5
10
heliocentic distance [pc]


HIP 14473 (HD 19376)
The sphere of a radius
of 0.5 pc, centered at the Sun
The star at its
closest approach (0.35 pc)
heliocentric distance [pc]
heliocentic distance [pc]
10
5
0
−5
−10
−10
−5
0
5
10


HIP 14473 (HD 19376)
heliocentric distance [pc]
heliocentic distance [pc]
10
5
0
−5
−10
But if you repeat this calculation
for 10000 clones of this star,
drawn according to the covariance
matrix of the astrometric parameters,
you will obtain ...



HIP 14473 (HD 19376)
heliocentric distance [pc]
heliocentic distance [pc]
−10
−5
0
5
10



Could you shrink this cloud, please!