A5 5 Between Suns: The Empty Space Between Oort Clouds

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Abstract

We estimate whether the Sun's outer Oort cloud overlaps the nearest stellar system's (Alpha Centauri's) analogous reservoir, i.e., its hypothetical outer Oort cloud. Because Oort clouds are theoretical and not directly imaged [1], we adopt canonical sizes and a mass-scaling motivated by tidal/Hill arguments [2]. Using present-day separations $D \sim (2.6 - 2.76) \times 10^5$ AU [3] and $R_{\mathrm{OC}} \sim 10^5$ AU [4] for the Sun (with the neighbour's radius $R_{\mathrm{OC},\star} = R_{\mathrm{OC},\odot}(M_\star/M_\odot)^{1/3}$ [2]), we find no overlap. Along the line connecting the systems, the linear gap is $\sim 3.4 \times 10^4 - 5.0 \times 10^4$ AU. This remains true when enforcing the gravitational balance (L1) limit and even under an extreme, enlarged Solar Oort cloud. This provides a clear gravitational boundary for the outer Solar System and a baseline for interpreting long-period comets and interstellar visitors.

Introduction

The Oort cloud is a distant, roughly spherical reservoir of icy bodies that is inferred, not directly imaged [1, 5]. Its existence around the Sun is supported by the orbital distribution of long-period comets. No extrasolar Oort cloud (including any around Alpha Centauri) has been directly detected to date [1, 6].

Question: Given typical outer radii $\sim 10^5$ AU [4] and the Sun–Alpha Centauri separation $\sim (2.6 - 2.76) \times 10^5$ AU [3], do the two systems' outer Oort clouds overlap? If not, how large is the "empty" (i.e., non-bound) interval between them along the line of centres?

Theory and Method

Let D be the Sun–neighbour separation, $M_\odot$ the solar mass, $M_\star$ the neighbour's mass, $R_{\mathrm{OC},\odot}$ the Solar outer Oort radius, and $R_{\mathrm{OC},\star}$ the neighbour's. For Sun–Alpha Centauri we treat the inner binary A+B as a single point mass $M_\star$

at its barycentre; this slightly shifts L1 but not whether a gap exists. The neighbour's outer radius is taken to follow the standard tidal/Hill scaling [2]

$$R_{\mathrm{OC},\star} = R_{\mathrm{OC},\odot} \left(\frac{M_\star}{M_\odot} \right)^{1/3}. \tag{1}$$

A naive overlap is predicted if

$$R_{\mathrm{OC},\odot} + R_{\mathrm{OC},\star} \geq D, \tag{2}$$

and otherwise the simple linear gap along the line of centres is

$$g_{\mathrm{simple}} = D - R_{\mathrm{OC},\odot} - R_{\mathrm{OC},\star}. \tag{3}$$

However, along that line neither cloud can extend past the collinear gravitational balance (L1) point. Placing L1 by equating accelerations gives [7]

$$x_{\mathrm{L1}} = \frac{D}{1 + \sqrt{M_\star/M_\odot}}, \tag{4}$$

measured from the Sun.

The effective one-dimensional extents toward each other are then

$$R_{\text{eff},\odot} = \min\left(R_{\text{OC},\odot},\, x_{\text{L1}}\right), \qquad (5)$$
$$R_{\text{eff},\star} = \min\left(R_{\text{OC},\star},\, D - x_{\text{L1}}\right), \qquad (6)$$

and the L1-limited (true) gap is

$$g_{\text{true}} = D - R_{\text{eff},\odot} - R_{\text{eff},\star}. \qquad (7)$$

Inputs

We adopt $R_{\text{OC},\odot} = 10^5\,\text{AU}$ as the baseline Solar value (with an "extreme" check at $1.5 \times 10^5\,\text{AU}$) [4]. For the combined Alpha Centauri A+B inner binary, we take a total mass $M_\star \approx 2.0\,M_\odot$ [8], treating it as a single point mass at the A+B barycentre. Via Equation (1) this gives

$$R_{\text{OC},\star} = R_{\text{OC},\odot} 2^{1/3} \approx 1.26 \times 10^5\,\text{AU}.$$

Three Sun–neighbour separations are examined:

$$D = 260\,000,\ 268\,770,\ \text{and}\ 276\,000\,\text{AU} [3].$$

Results

The equations above are evaluated once to place L1 (Equation 4), then to enforce the caps (Equations 5 and 6), and finally to compute the gaps (Equations 3 and 7). Because $R_{\text{OC},\odot} = 10^5\,\text{AU}$ and $R_{\text{OC},\star} \approx 1.26 \times 10^5\,\text{AU}$ are both smaller than their respective L1 caps at these D, the L1 limit does not tighten the result and $g_{\text{true}} = g_{\text{simple}}$.

D (AU)	x_{L1} (AU)	g_{simple} (AU)	g_{true} (AU)
260 000	107 696	34 008	34 008
268 770	111 328	42 778	42 778
276 000	114 323	50 008	50 008

Table 1: Baseline gaps with and without the L1 cap.

To check robustness, we repeat the calculation at $D = 268\,770\,\text{AU}$ with an enlarged Solar radius $R_{\text{OC},\odot} = 1.5 \times 10^5\,\text{AU}$. The L1 cap then cuts the Solar extent to $R_{\text{eff},\odot} = 111\,328\,\text{AU}$, and the L1-limited gap becomes $g_{\text{true}} = 31\,450\,\text{AU}$. The qualitative conclusion that there is no overlap remains unchanged.

Discussion

"Empty" space here means an interval along the Sun–Alpha Centauri line that is not part of either system's long-lived, bound outer Oort reservoir. Interstellar dust or passing comets may traverse it, but stable membership in either cloud is not expected there. The inference depends only on present-day separation and on canonical outer radii; anisotropy [9], Galactic tides, stellar encounters, and the hierarchical architecture of Alpha Centauri will modulate the detailed shape of each cloud [2, 5] but do not erase a gap of tens of thousands of AU under current conditions. In particular, Proxima Centauri's distant, eccentric orbit around the A+B pair adds a slow additional perturbation to the outer regions of any Alpha Centauri Oort cloud, but at the present separation it does not significantly modify the Hill surfaces along the Sun–Alpha Centauri line considered here.

It is essential to note that both Solar and Alpha Centauri Oort clouds are theoretical: their sizes are constrained by dynamics rather than by direct imaging [1], which is consistent with the modelling choices made here.

Conclusion

With $R_{\text{OC},\odot} = 10^5\,\text{AU}$, $R_{\text{OC},\star} \approx 1.26 \times 10^5\,\text{AU}$ from the $M^{1/3}$ scaling, and separations D near $(2.6 - 2.76) \times 10^5\,\text{AU}$, the Solar System's and Alpha Centauri's outer Oort clouds do not overlap. The implied linear gap is $\sim (3.4 - 5.0) \times 10^4\,\text{AU}$, and it remains $\sim 3.1 \times 10^4\,\text{AU}$ even if the Solar outer radius is pushed to $1.5 \times 10^5\,\text{AU}$ and the L1 boundary is enforced.

This outcome is fully consistent with the current, purely dynamical status of Oort clouds. In short, this shows where the Sun's comet cloud effectively ends and will help with future studies of long-period comets and interstellar objects.

References

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