A Case Study of Interstellar Material Delivery: α Centauri

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Abstract

Interstellar material has been discovered in our solar system, yet its origins and details of its transport are unknown. Here we present α Centauri as a case study of the delivery of interstellar material to our solar system.

Goals

1. If α Centauri can plausibly be ejecting material at the current time, would we expect this material to arrive at our solar system?
2. What would be the expected characteristics of this material, including arrival direction, velocity, and flux?

Methods

We adopt a three-component, time-independent, axisymmetric potential model of Miyamoto & Nagai (1975). $\Phi = \Phi_b + \Phi_d + \Phi_h$

$$\Phi_{b,h} = -\frac{GM_{b,h}}{\sqrt{x^2+y^2+z^2+b_{b,h}^2}} \qquad \Phi_d = -\frac{GM_d}{\sqrt{x^2+y^2+\left(a_d+\sqrt{z^2+b_d^2}\right)}}$$

Adopt an ejection speed distribution from Bailer-Jones (2018) for a binary star system, which incorporates ejections from planetary systems.

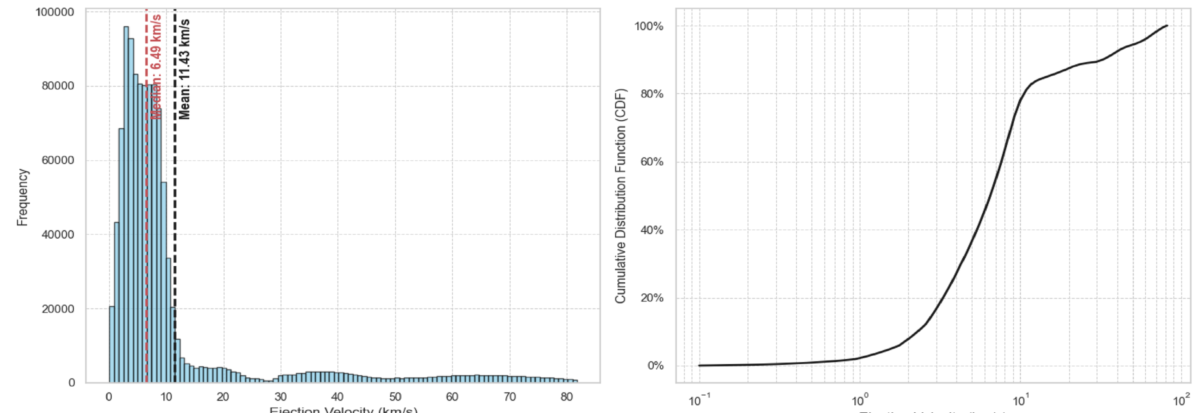


Table 1
The Adopted Values Used to Initialize Our Simulation, Including the ICRS Coordinates of α Centauri Taken from SIMBAD

Parameter	Units	Value	References
M_i, $i = d, b, h$	$10^{10} M_\odot$	7.91, 1.40, 69.80	(3)
a_i, $i = d, b, h$	pc	3500, 0, 0	(3)
b_i, $i = d, b, h$	pc	250, 350, 24000	(3)
$r_\odot$	kpc	8.33 ± 0.35	(4)
$z_\odot$	pc	27 ± 4	(2)
$v_\odot$ (U, V, W)	km s^{-1}	$(11.1^{+0.69}_{-0.75}, 12.24^{+0.47}_{-0.47}, 7.25^{+0.37}_{-0.36})$	(6)
$v_{\odot,\mathrm{circ}}$	km s^{-1}	218 ± 6	(1)
Galactic center equatorial coordinates (α, δ)	(hr:min:s, deg/′/″)	(17:45:37.224, −28:56:10.23)	(5)

α Centauri

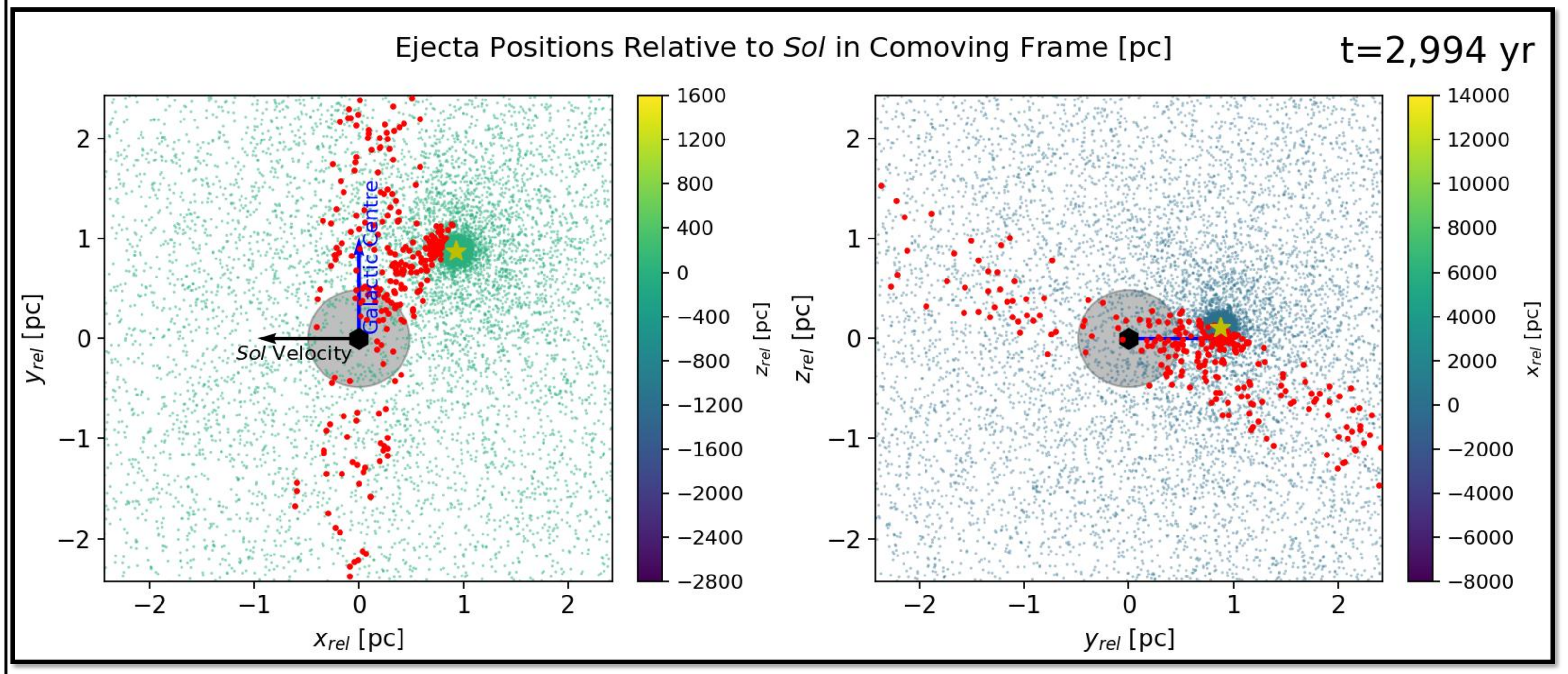
Star System	α (deg)	μ_α (mas yr^{-1})	δ (deg)	μ_δ (mas yr^{-1})	Parallax (mas)	v_r (km s^{-1})	References
* alf Cen	219.873833	−3608	−60.83222194	686	742	−22.3	(7)

Note. CRS should be defined as International Celestial Reference System.

References. (1) J. Bovy (2015); (2) B. Chen et al. (2001); (3) B. Dauphole & J. Colin (1995); (4) S. Gillessen et al. (2009); (5) M. J. Reid & A. Brunthaler (2004); (6) R. Schönrich et al. (2010); (7) M. Wenger et al. (2000).

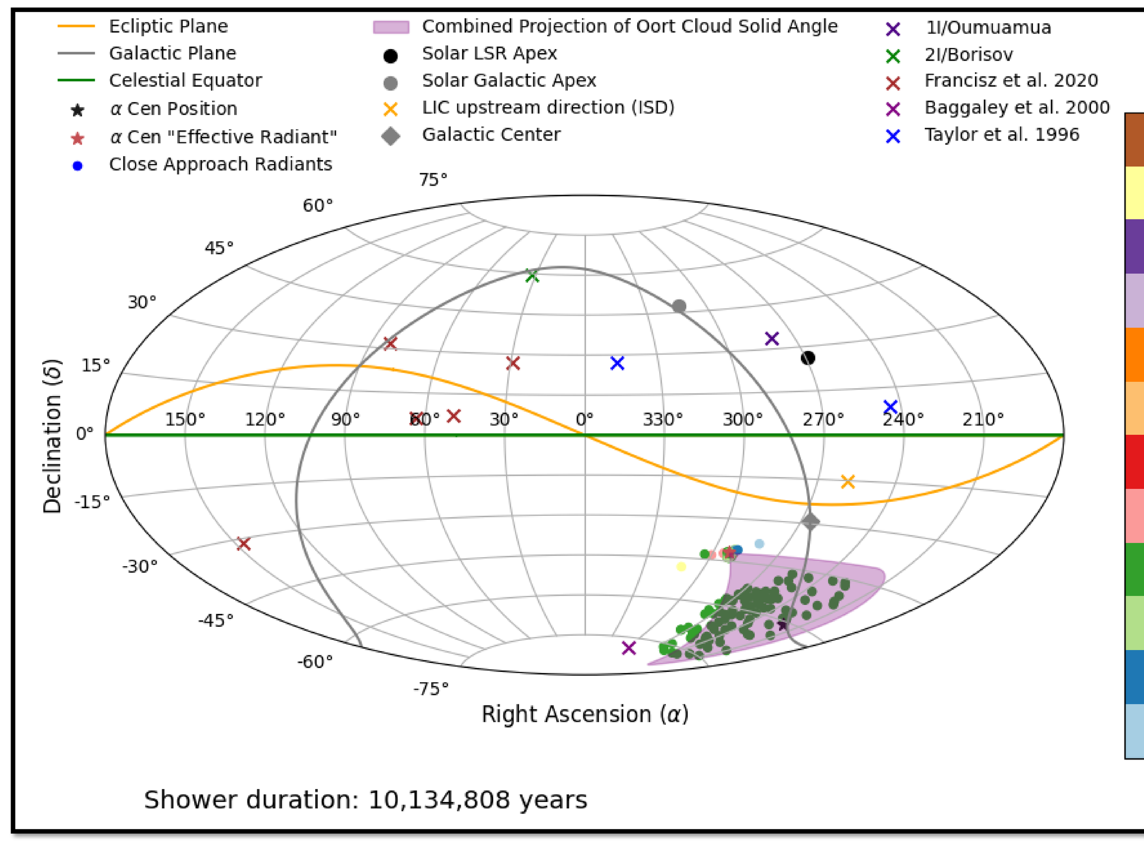
Results

Initializing our model with the parameters here in Table 1, we simulate α Centauri and the Sun moving through the galactic potential from -100 Myr to 10 Myr (where t=0 is the current epoch). We eject 10,000 particles every 1 Myr from α Centauri and monitor whether any pass within 100,000 au from the Sun. We see 0.03% of the total ejecta reach the solar system (350/1,090,000).



View the full animations here!

The expected radiant of α Centauri meteors at the current time ((α,δ)=(292° ± 1°,−43° ± 2°)) largely corresponds to α Centauri's effective radiant, set by that system's velocity relative to the Sun. However, as α Centauri's closest approach nears; the radiant will move and have a larger spread ((α, δ)=(249°±17°, −61°±8°)) resulting from the increased range of allowable ejection speeds and directions near the closest approach when the solar system's apparent cross section is largest.



Conclusions

1. Material from α Centauri can reach and likely is already within our solar system.
2. Most material arriving from α Centauri has traveled for <10 Myr in the ISM.
3. Material that reaches us typically left α Centauri with low (v_∞<2 km s^{-1}) asymptotic speeds.
4. The α Centauri "shower" is concentrated during a ~10 Myr period, peaked at t≈28,000 yr.
5. Typical arrival velocity at the Sun is Δv=32.50 km s^{-1} (similar to the current relative velocity of α Centauri (Δv=32.37 km s^{-1})).
6. Typical heliocentric velocities of the material pulled into the solar system at 1au is 53 km s^{-1}.
7. The expected radiant of α Centauri meteors at the current time is concentrated around its effective radiant.

Implications

1. Particles larger than a few microns in size are expected to survive the journey.
2. If α Centauri ejects material at a rate comparable to our own solar system:
   I. We estimate the current number of α Centauri particles >100 m in diameter within our Oort Cloud to be 10^6. However, the probability of an observation is 10^{-6} (these values will increase by x10 in ~28,000 years).
   II. Using a mass equivalence, ~10 meteors >100 μm from α Centauri may currently be entering Earth's atmosphere every year (also x10 in ~28,000 years).
3. Meteors from α Centauri are extremely rare events. Outnumbered by those originating in our solar system ($1{:}10^{12}$). Nevertheless, understanding the properties of particles that could be arriving from α Centauri will aid in the detection of these elusive but potentially highly informative visitors.

Future Work

Though the flux of interstellar material into our Solar System may be low, it is not zero. As global observational capabilities grow, the number of known interstellar objects will only increase, particularly with new large-scale surveys like the Vera C. Rubin Observatory coming online. This work is only a very early step in understanding the properties of particles that could be arriving from α Centauri which may aid in the detection of these elusive but potentially highly informative visitors.

Acknowledgements: This work was supported in part by the NASA Meteoroid Environment Office under Cooperative Agreement No. 80NSSC24M0060, and by the Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant program (grant No. RGPIN-2024-05200). This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.