

Dark Matter Caustics and Their Effect on the Oort Cloud

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Outline

- Dark matter caustics
- Effects on the Oort cloud

1. Dark matter caustics

Caustics is a general phenomenon in a **collisionless flow with zero velocity dispersion**. The density profile near a surface caustic is

$$\rho(\sigma) = \frac{A}{\sqrt{\sigma}} \Theta(\sigma)$$

For example, rainbow is a caustic, the bright lines under water on a sunny day is also caustics.



A rainbow near New Physics Building

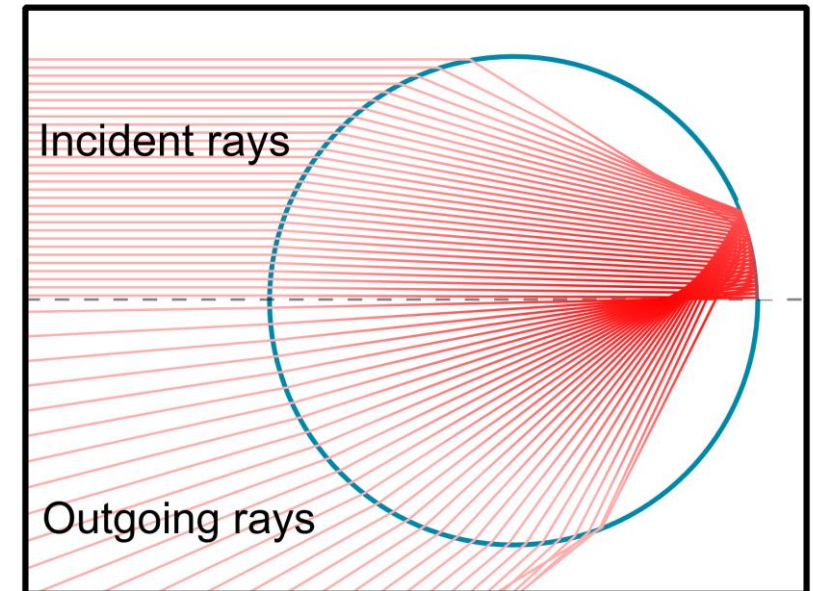


Fig 1: Rainbow caustic. From Wikipedia.³

1. Dark matter caustics

- 1.2 Caustic in the Galaxy

Consider a rotating turnaround sphere.

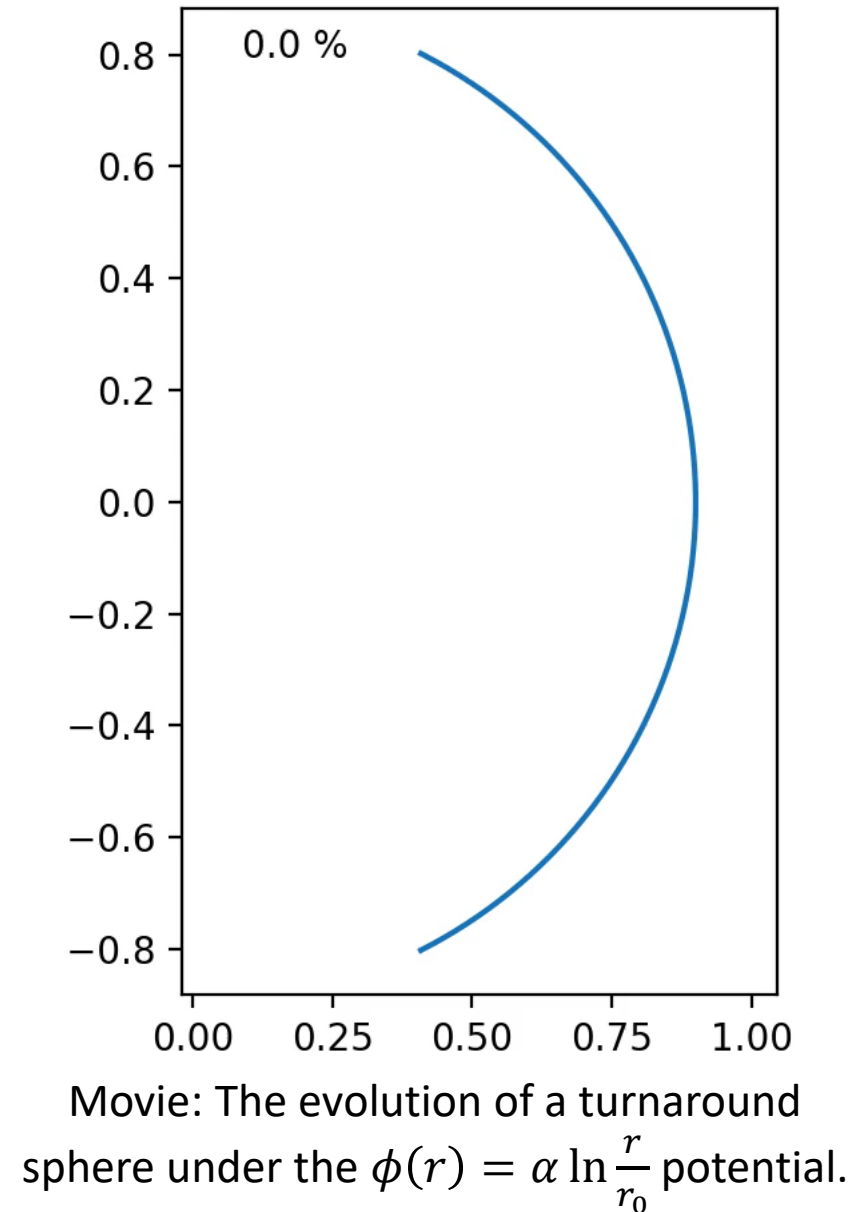
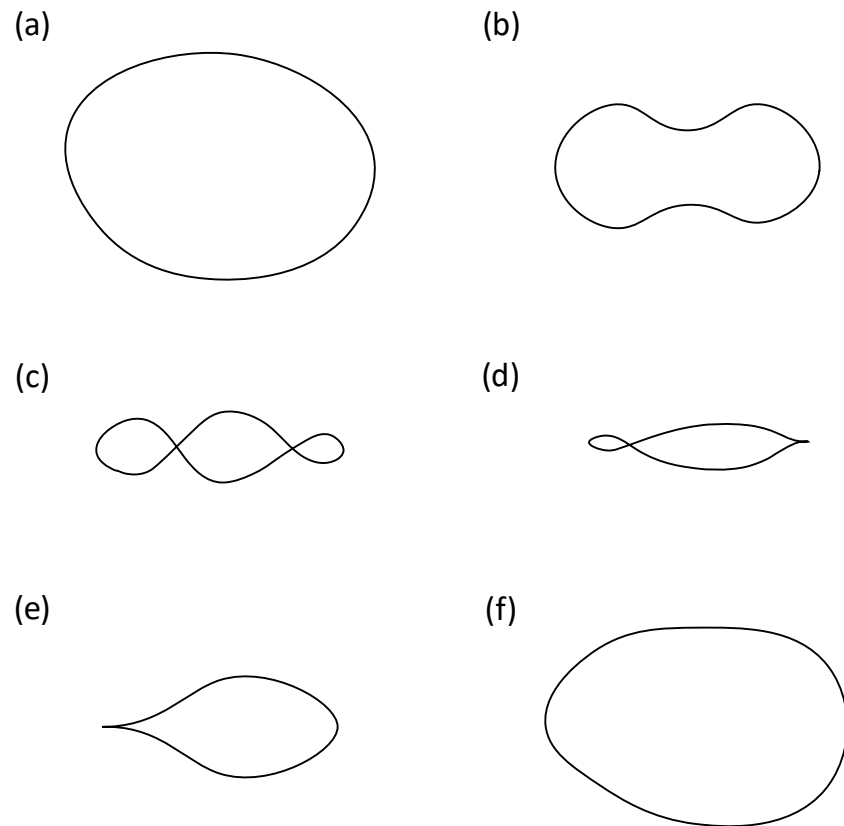


Fig 2: Schematic plot of evolution of a turnaround sphere

1. Dark matter caustics

- 1.3 Inner caustics
 - The inner caustic is always a torus.
 - The poloidal cross section is a D_{-4} catastrophe.
 - 2 more flows within the caustic surface.
- 1.4 Self-similar infall model
 - Caustic ring radius
$$a_n \approx \frac{40}{n} \text{ kpc}$$
 - The 5th caustic is close to the Sun.
 - a_5 growth with $v_c = 1 \text{ km/s}$.

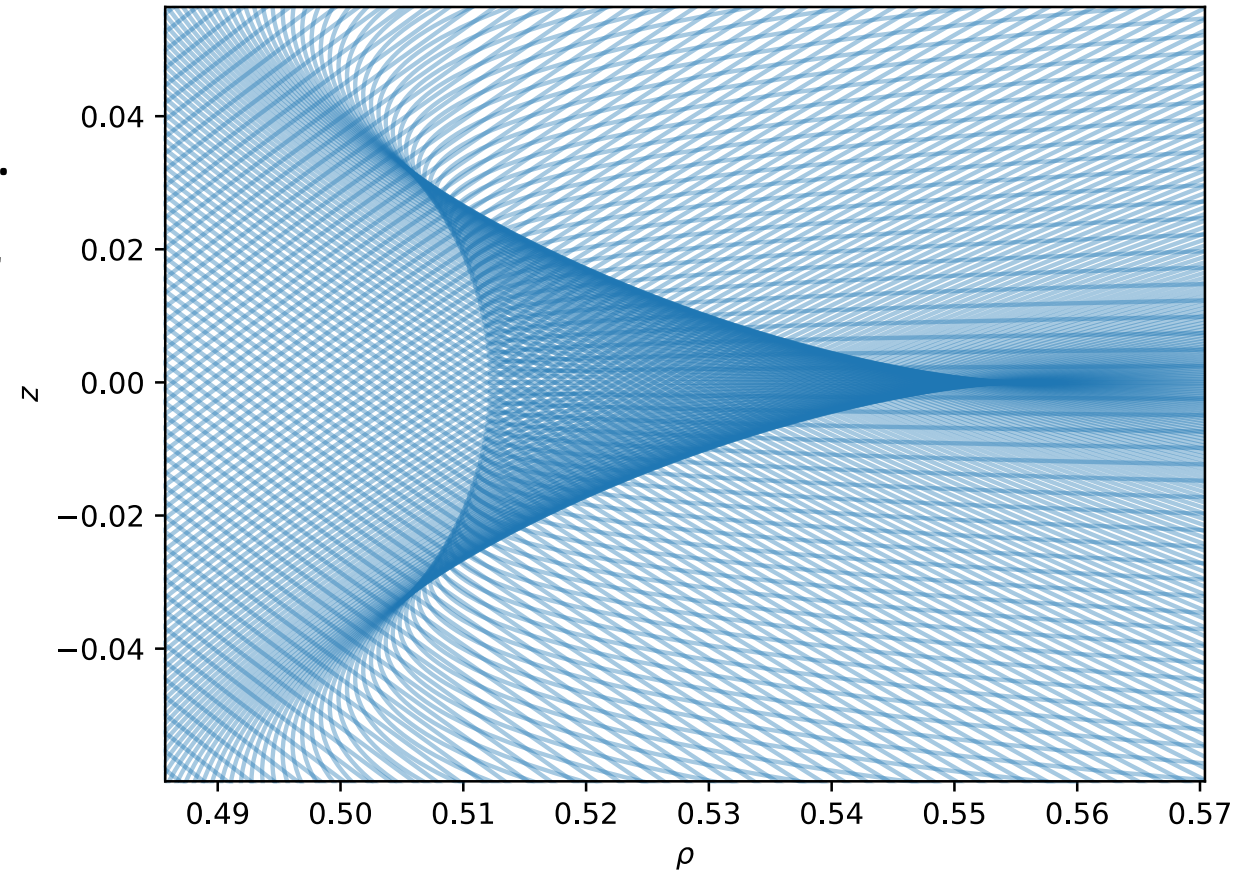


Fig 3: Motion in ρ - z plane of 500 different trajectories from a turnaround sphere under potential $\phi(r) = v_{\text{rot}}^2 \ln \frac{r}{r_0}$

2. Effects on the Oort cloud

- 2.1 Radial Motion of the Sun

- Radial equation of motion

$$\ddot{r}(t) = -8\pi GA\sqrt{r - a(t)}\Theta(r - a(t)) - g_{\text{eff}}$$

- Caustic modifies the minimum of the effective potential.
- The Sun tracks the caustic surface.

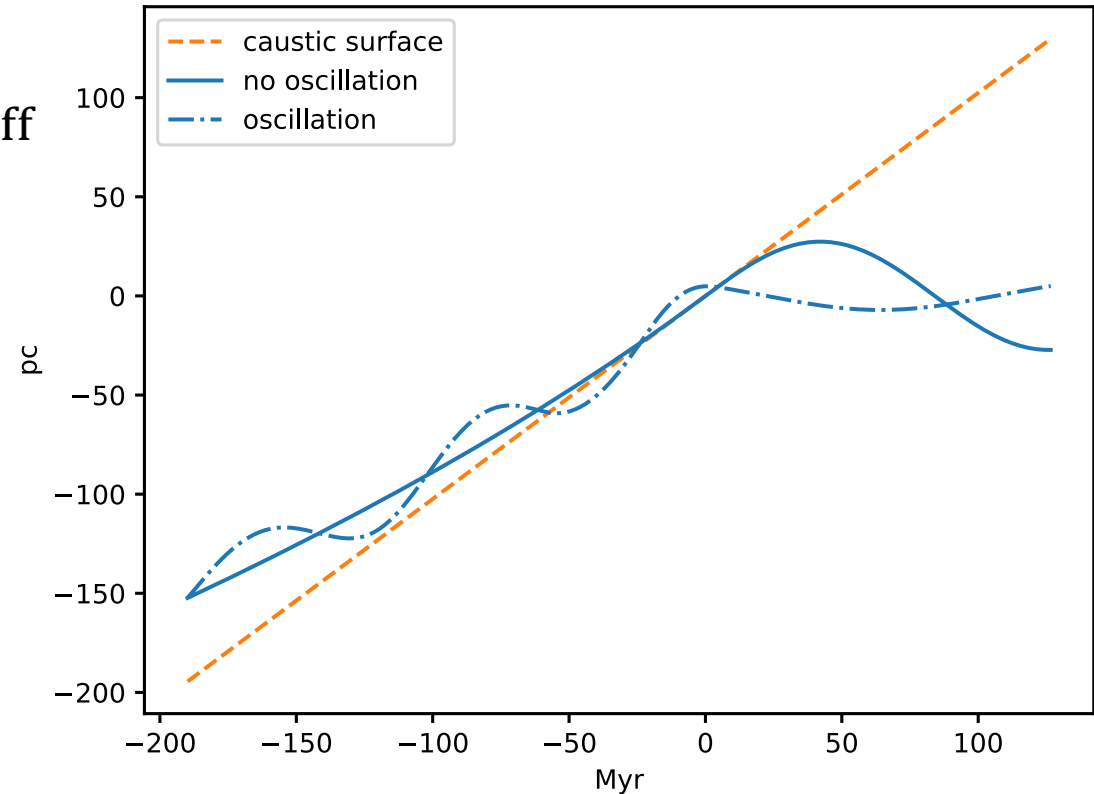
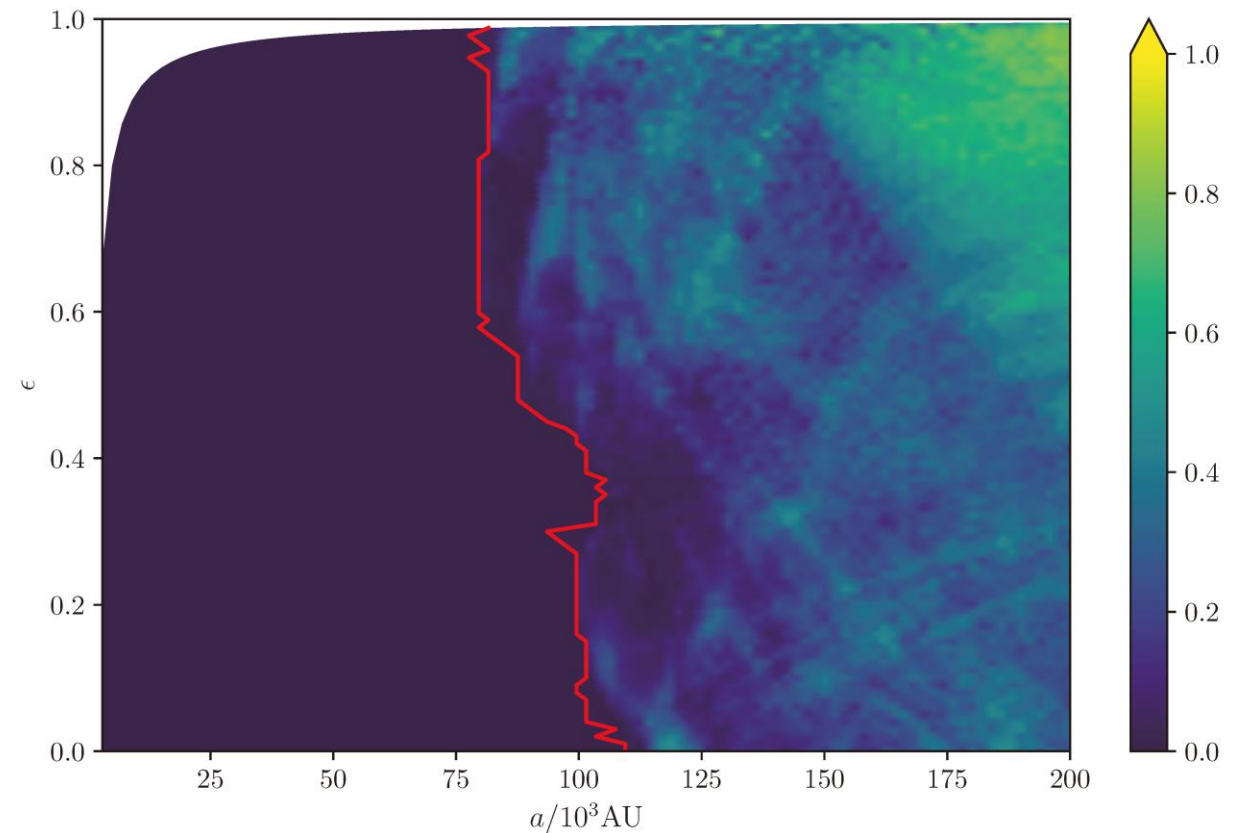


Fig 4: Radial motion of the Sun near a caustic

2. Effects on the Oort cloud

- 2.2 Numerical results - Escape probability
 - $A = 2 \times 10^{-2} \text{ kg}/(\text{m}^2 \cdot \sqrt{\text{kpc}})$
 - Start to escape from $a \sim 10^5 \text{ AU}$.
 - θ dependent.
 - May cross many times.



2. Effects on the Oort cloud

- 2.3 Numerical results - Probability of fall within 50 AU
 - Star to fall in at small distance.
 - Galactic tidal field has minor effect.
 - Strong θ dependence.
 - Overall probability $\sim 3 \times 10^{-4}$.

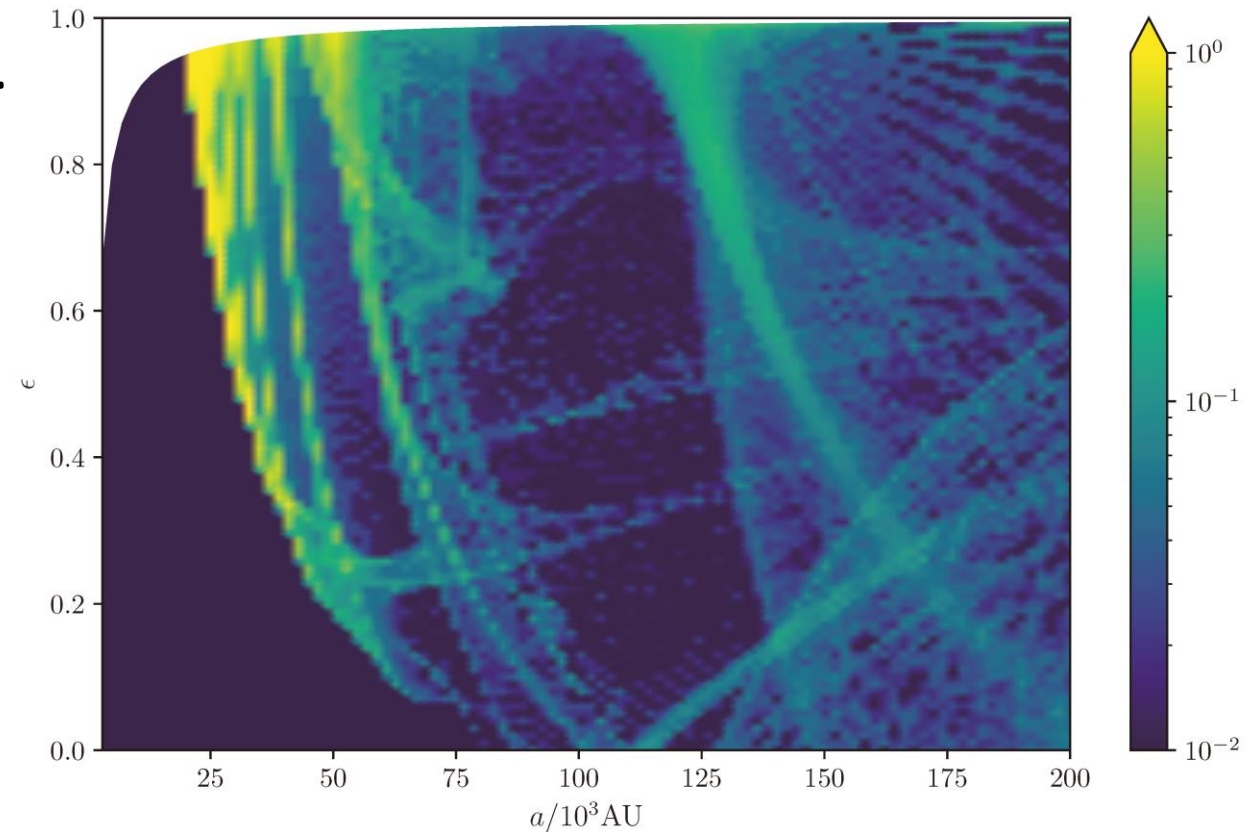


Fig 6: Probability of fall within 50 AU

Summary

- Caustic is a general phenomenon of cold dark matter.
- The inner caustic, caustic ring, always forms if there is an overall vorticity.
- The passage of a caustic ring has nontrivial effects to the comets in the Oort cloud.

Reference

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