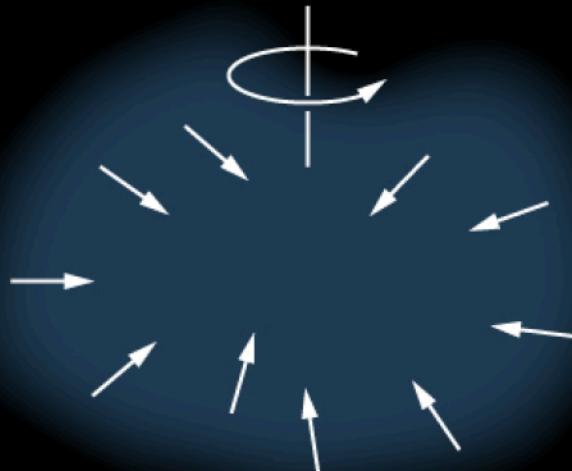




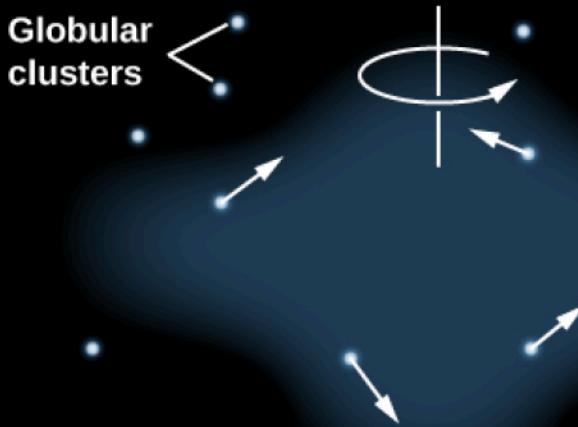
Characteristics of the Milky Way Galaxy

Property	Thin Disk	Thick Disk	Stellar Halo (Excludes Dark Matter)
Stellar mass	$4 \times 10^{10} M_{\text{Sun}}$	A few percent of the thin disk mass	$10^{10} M_{\text{Sun}}$
Luminosity	$3 \times 10^{10} L_{\text{Sun}}$	A few percent of the thin disk luminosity	$8 \times 10^8 L_{\text{Sun}}$
Typical age of stars	1 million to 10 billion years	11 billion years	13 billion years
Heavier-element abundance	High	Intermediate	Very low
Rotation	High	Intermediate	Very low

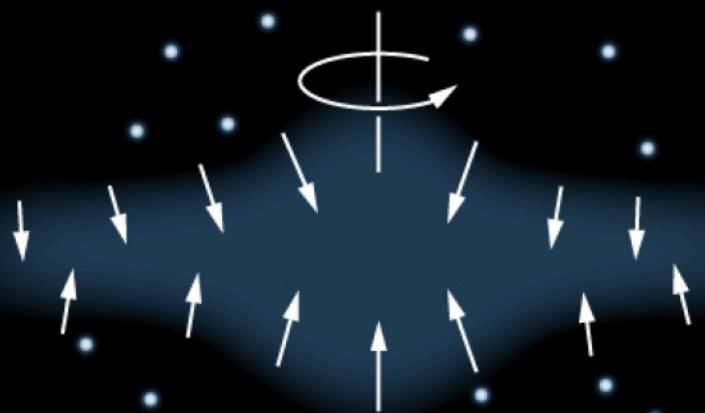
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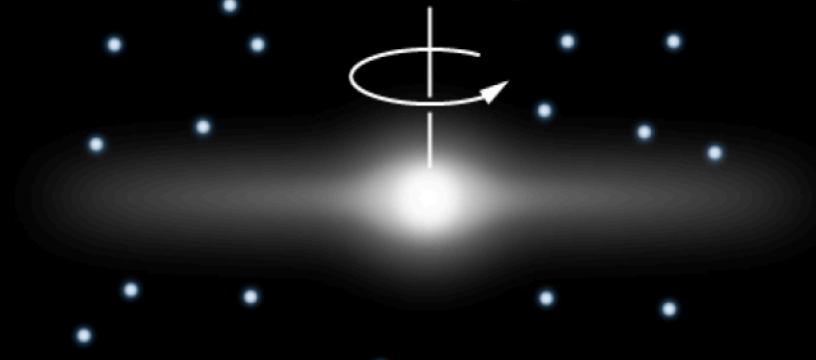
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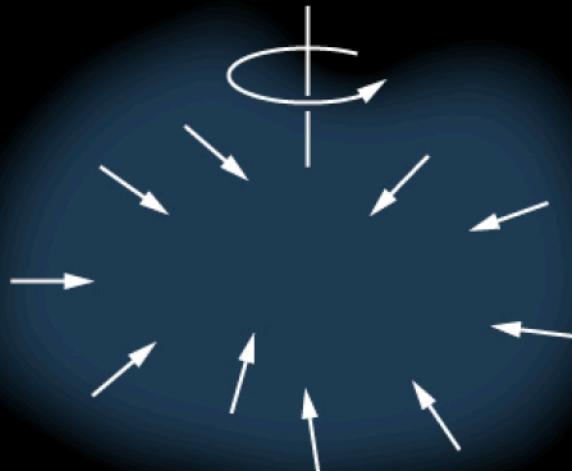
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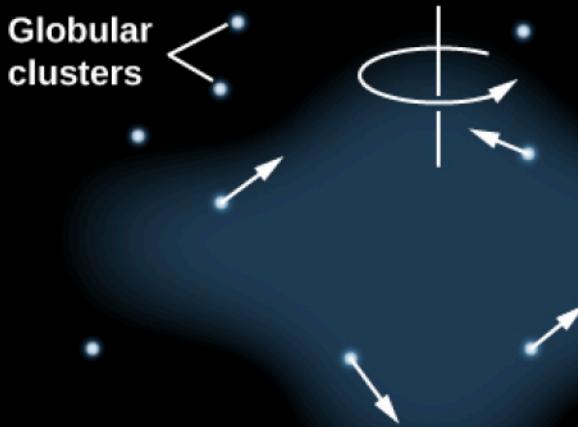
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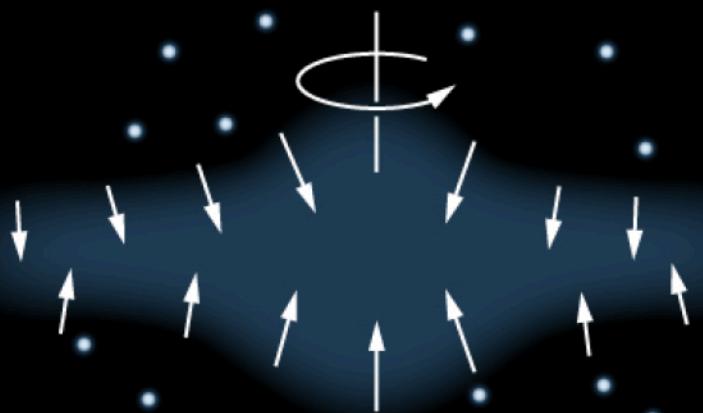
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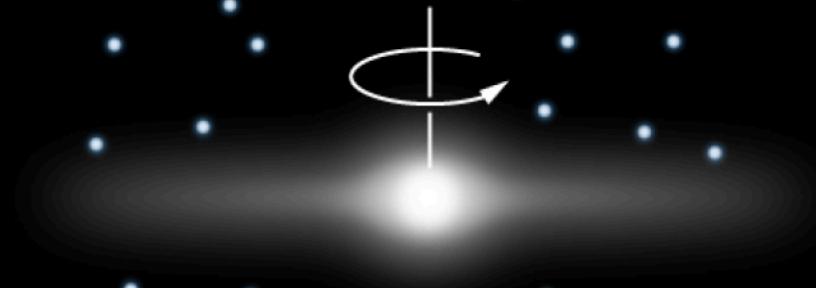
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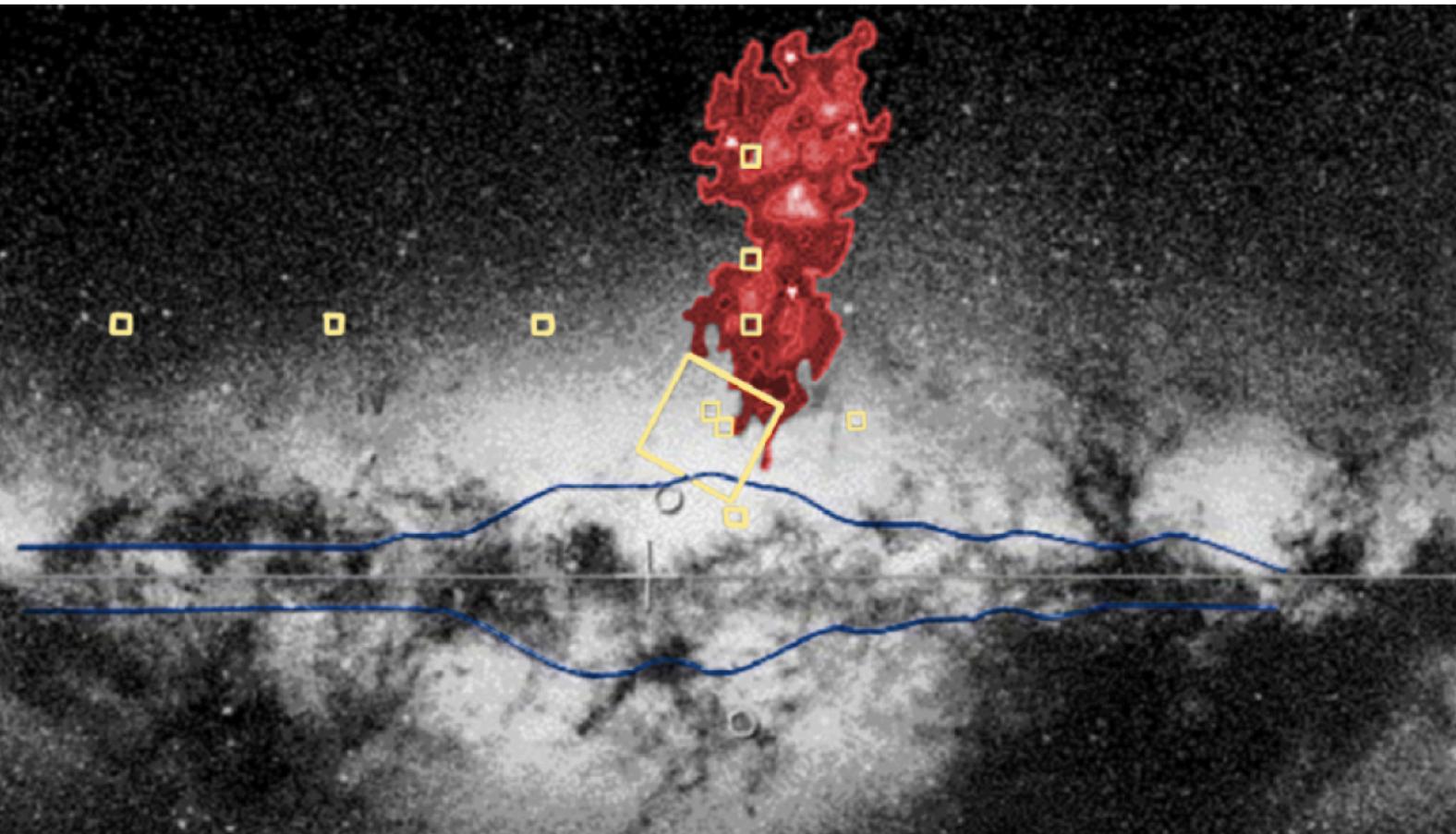


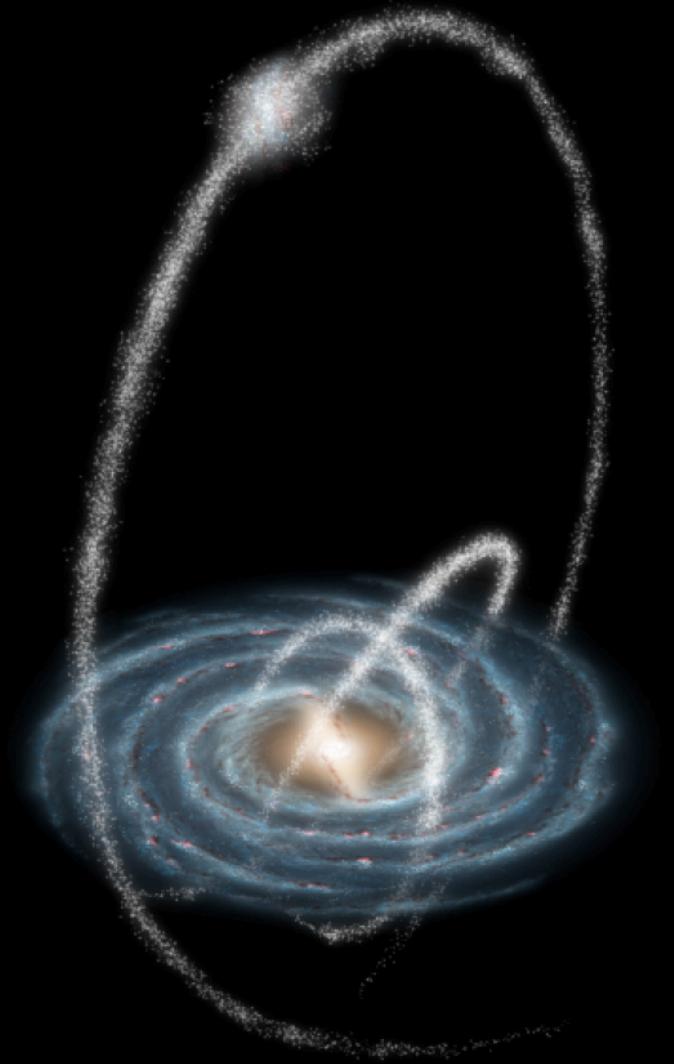
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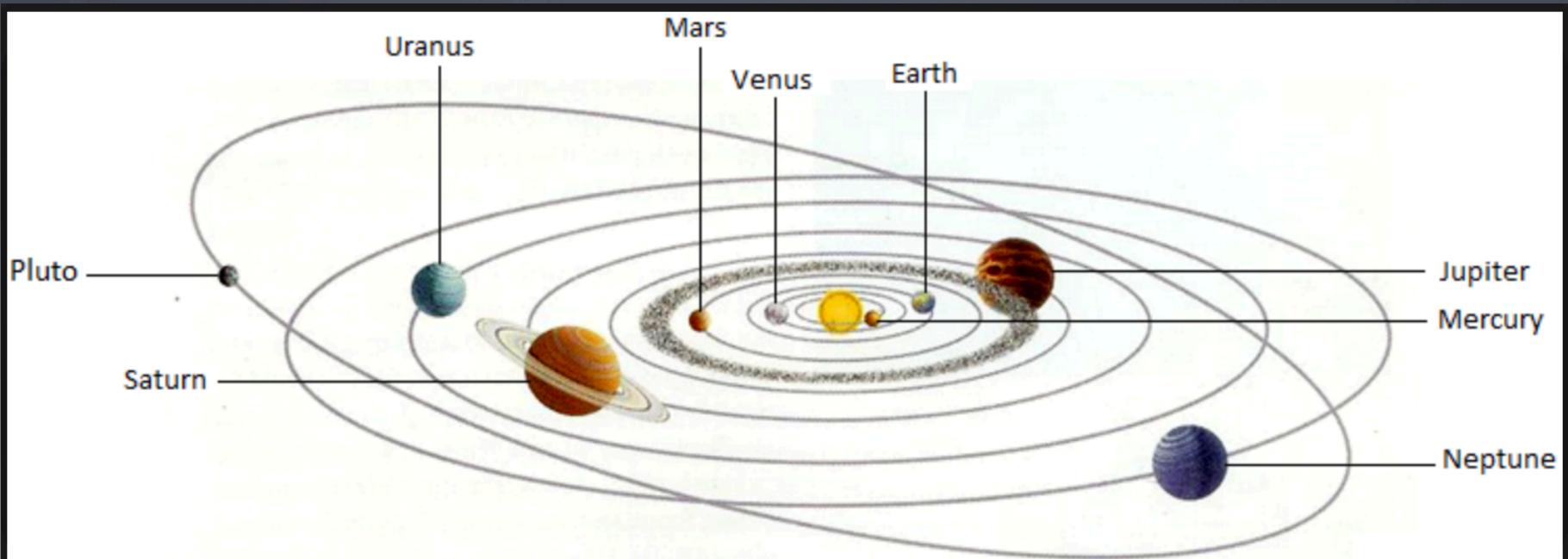






- How to measure the mass of the central supermassive black hole?
- How to measure the mass of the galaxy?

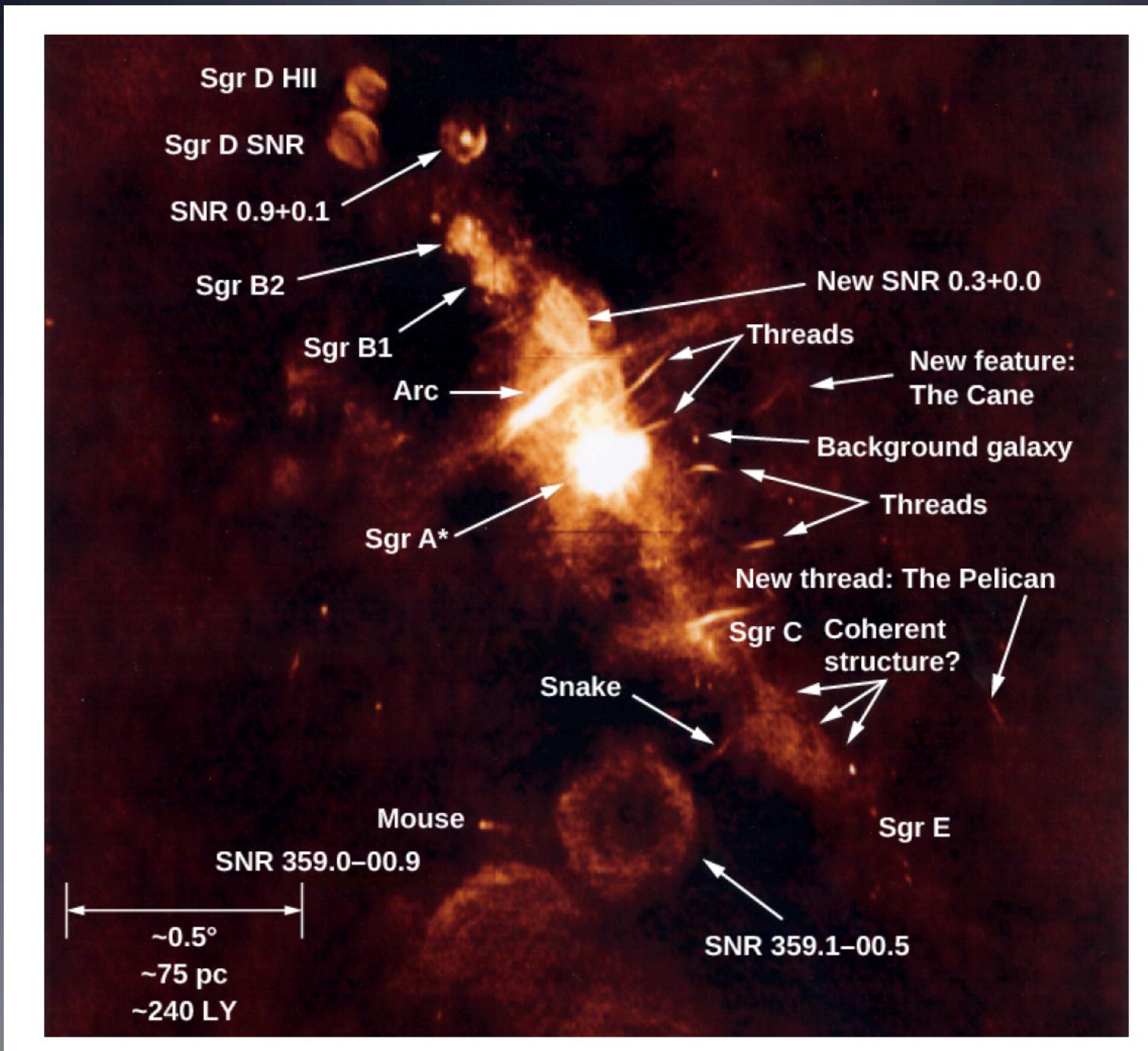
Kepler's laws!

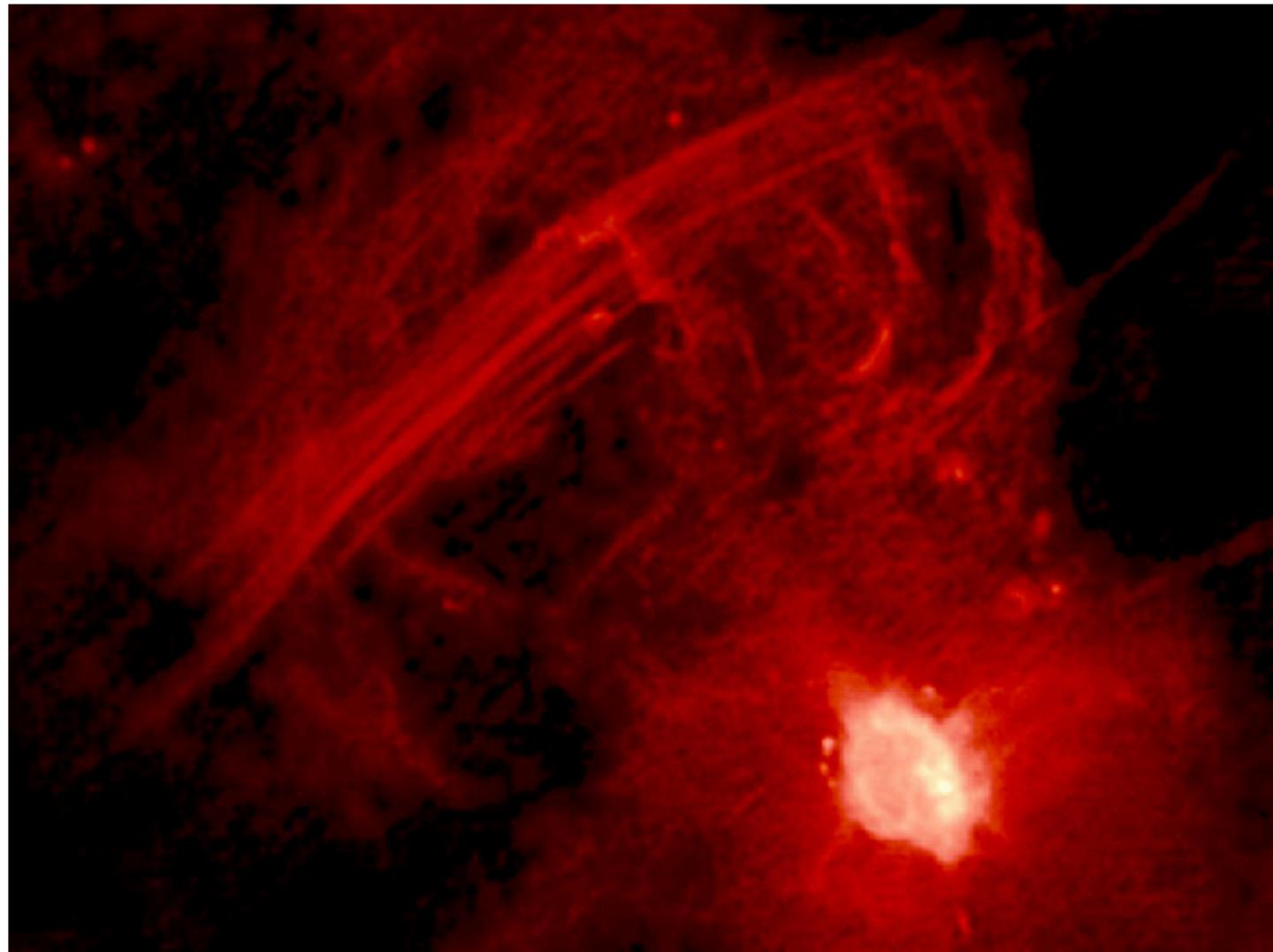


$$T^2 = \frac{4\pi^2}{GM} a^3$$

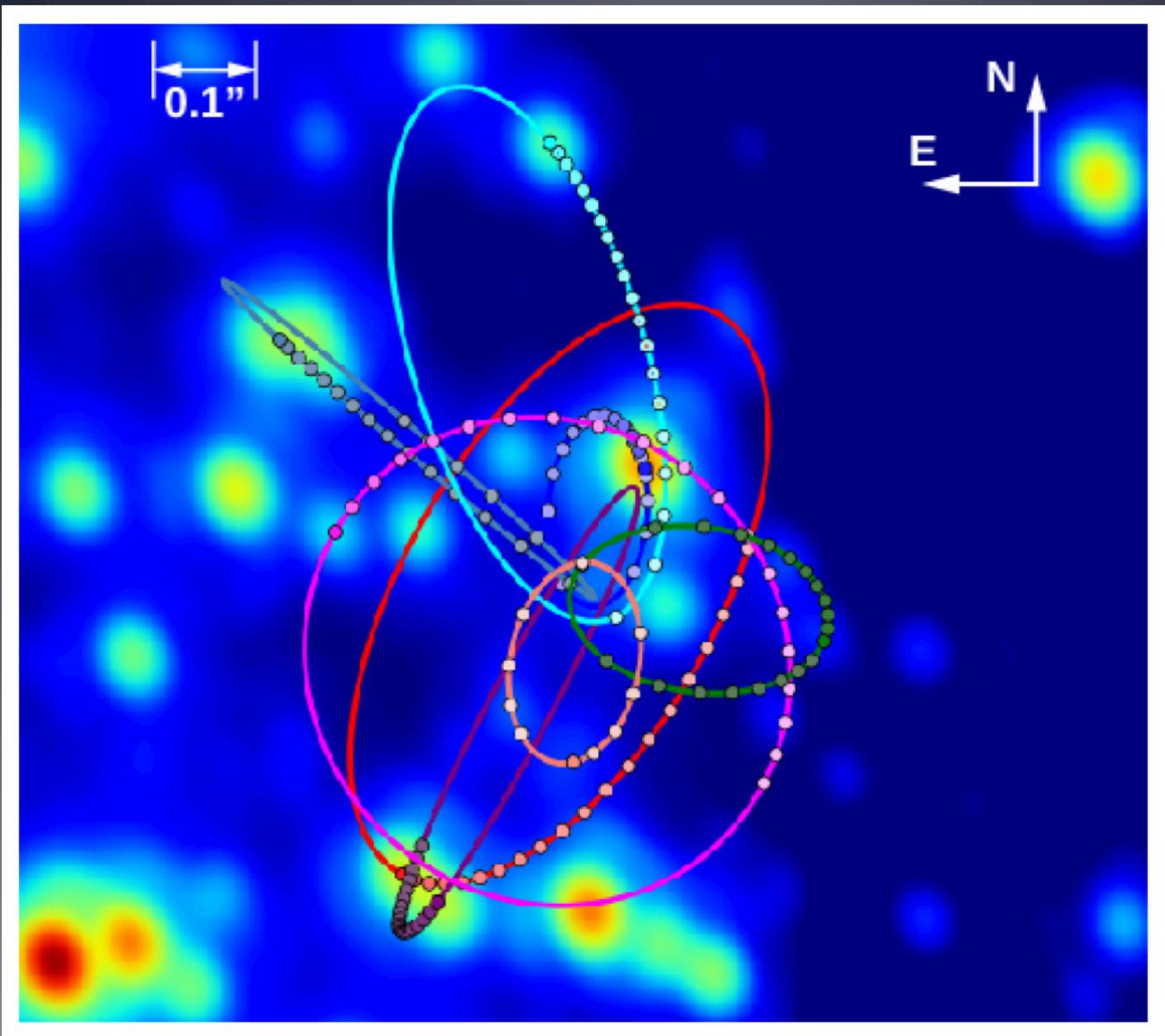
Planetary Data Applied to Kepler's Third Law

Planet	Mean Distance from Sun, r (10^6 km)	Period, T (Earth Years)	r^3/T^2 (10^{24} km3/yr2)
Mercury	57.9	0.241	3.34
Venus	108.2	0.615	3.35
Earth	149.6	1.0	3.35
Mars	227.9	1.88	3.35
Jupiter	778.3	11.86	3.35
Saturn	1427	29.5	3.34
Uranus	2870	84.0	3.35
Neptune	4497	165	3.34
Pluto	5900	248	3.33

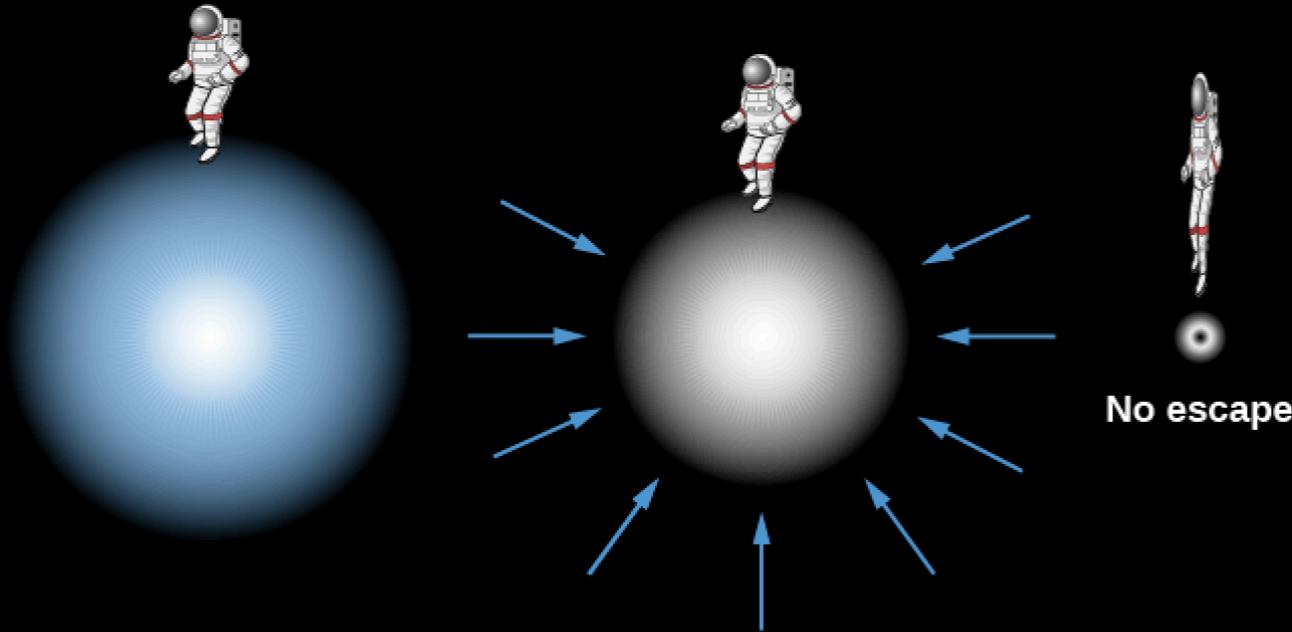




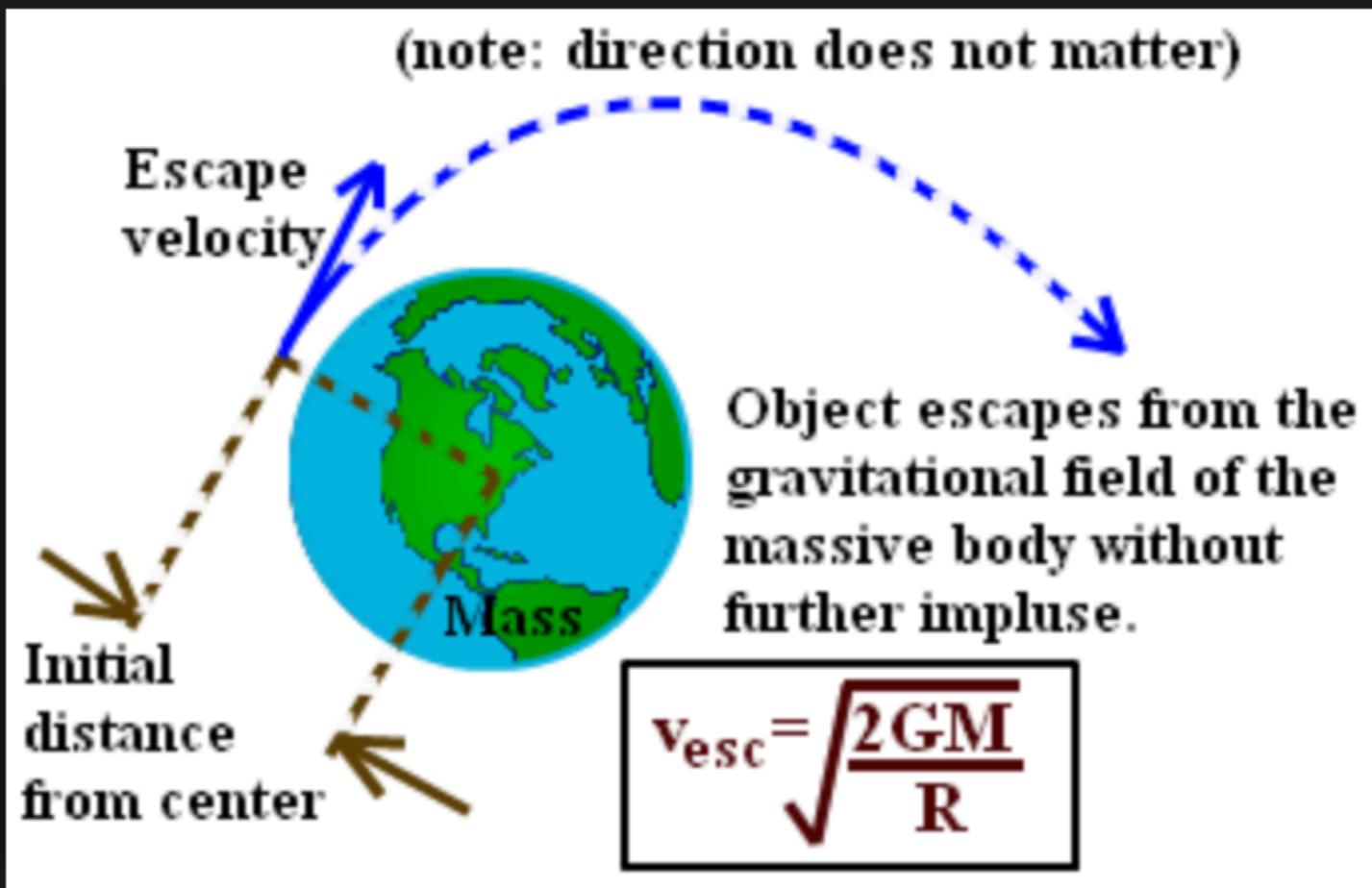
Galactic center orbits



Black holes: gravity high enough (large mass, small volume) that light cannot escape



Black holes: gravity high enough (large mass, small volume) that light cannot escape



Some black holes accrete:
We can see heated accretion disk

