

Rotational Motion

and
Newton's Universal Law of
Gravitation

Summary of Angular Variables

Displacement $s = r \theta$

Velocity $v = r \omega$

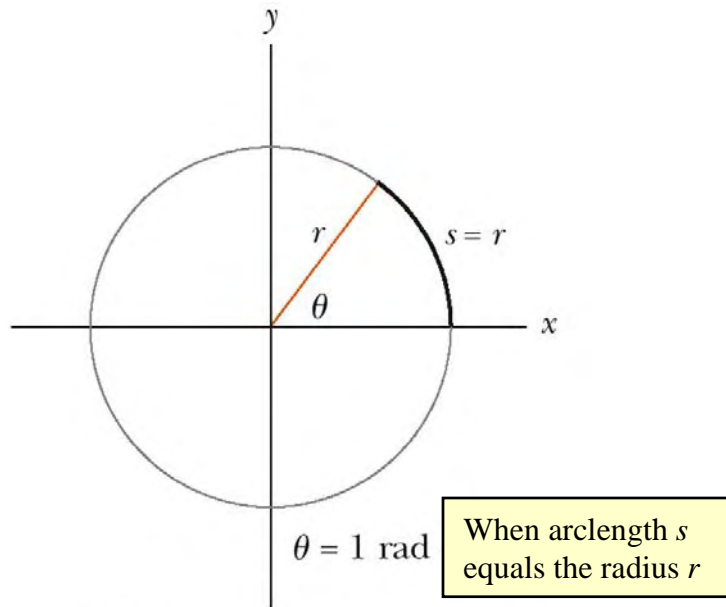
Acceleration $a = r \alpha$

Angular Displacement (theta)

Angular Velocity (omega)

Angular Acceleration (alpha)

Possible units are:
Radians/sec, rpm (revolutions/minute),
degrees/second etc.



$$1 = \frac{2\pi \text{ radians}}{360 \text{ degrees}}$$

Constant Acceleration

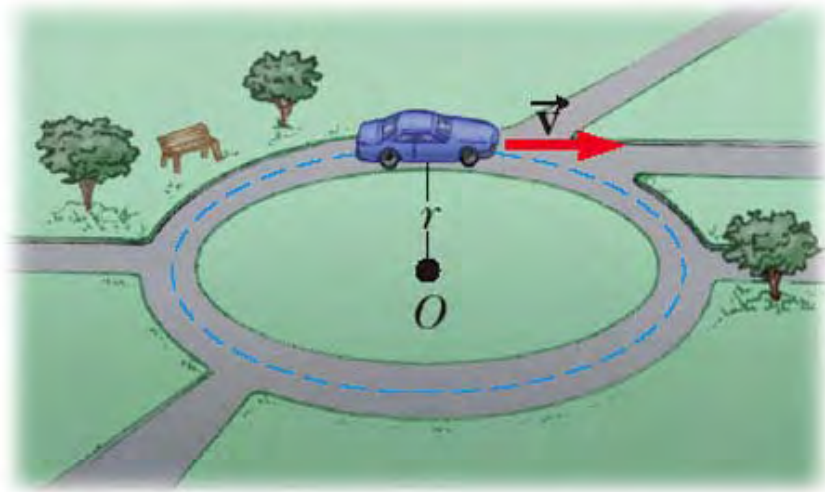
$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v(t) = v_0 + a t$$

Constant Angular Acceleration

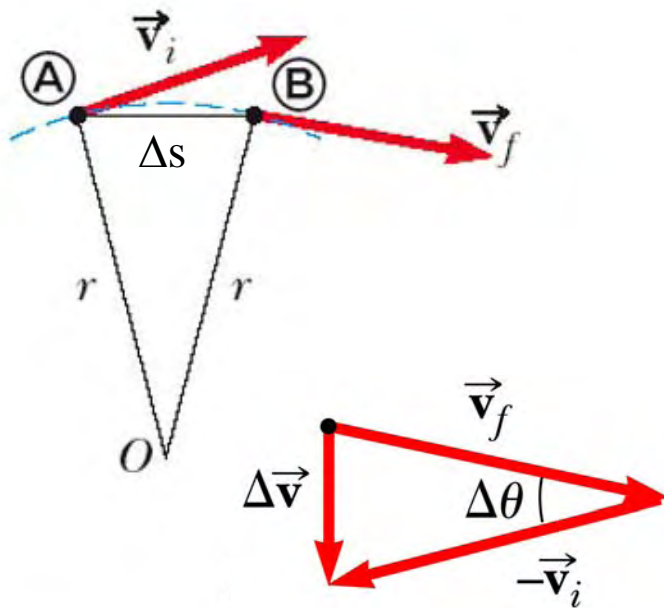
$$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega(t) = \omega_0 + \alpha t$$



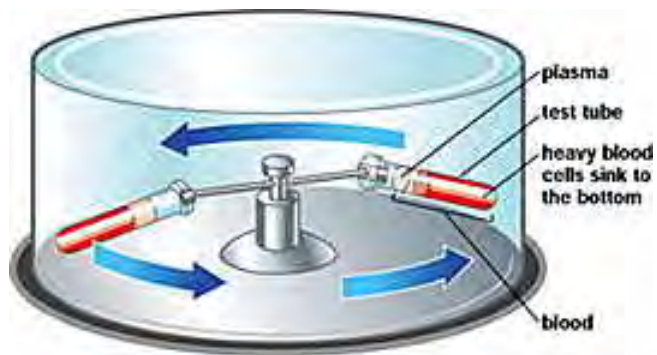
Centripetal Acceleration

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$



$$a_c = \frac{v^2}{r}$$

Direction: inward



Laboratory centrifuge: separate blood cells from plasma



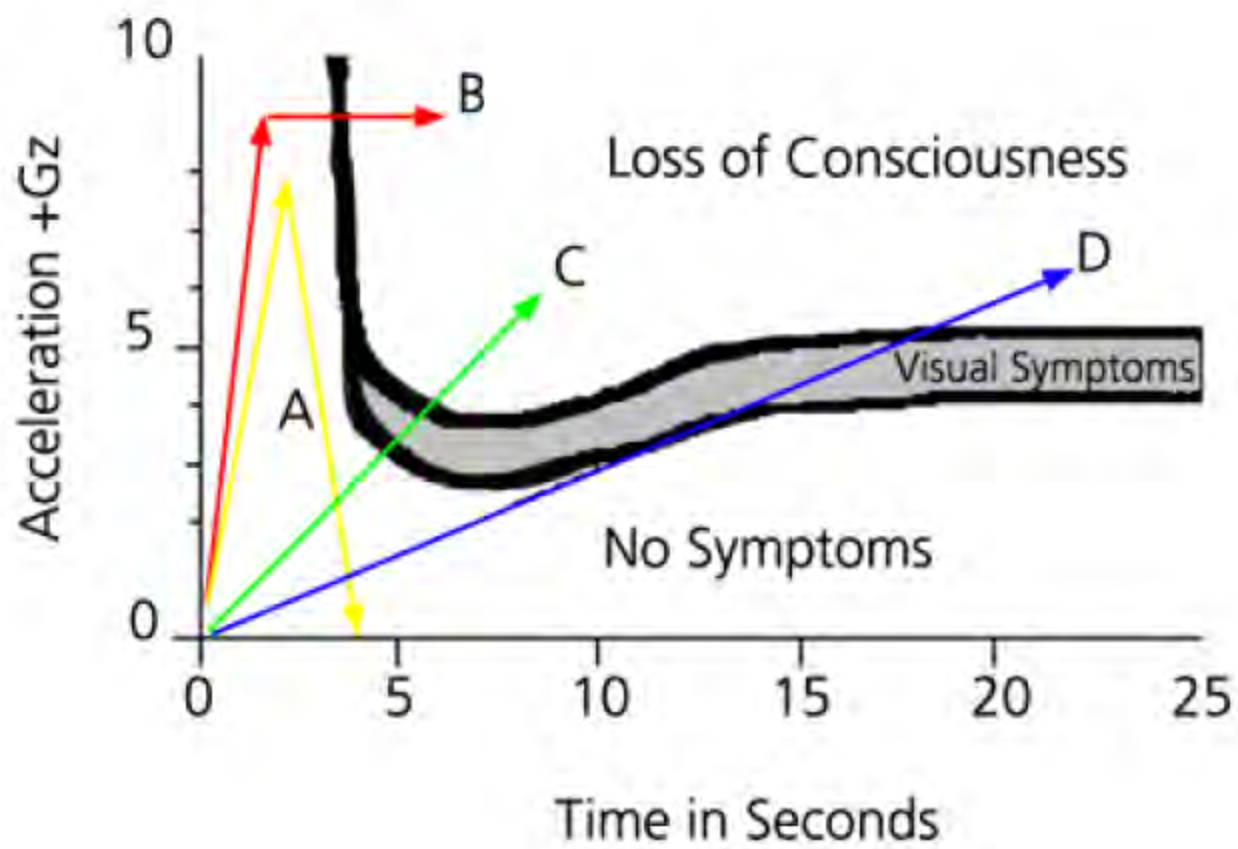
“Aluminum tubes”: centrifuges to separate ^{235}U from ^{238}U



Centrifuge used to train pilots at sustained levels of high gravity (simulated)



Shockwave: Six Flags Over Texas

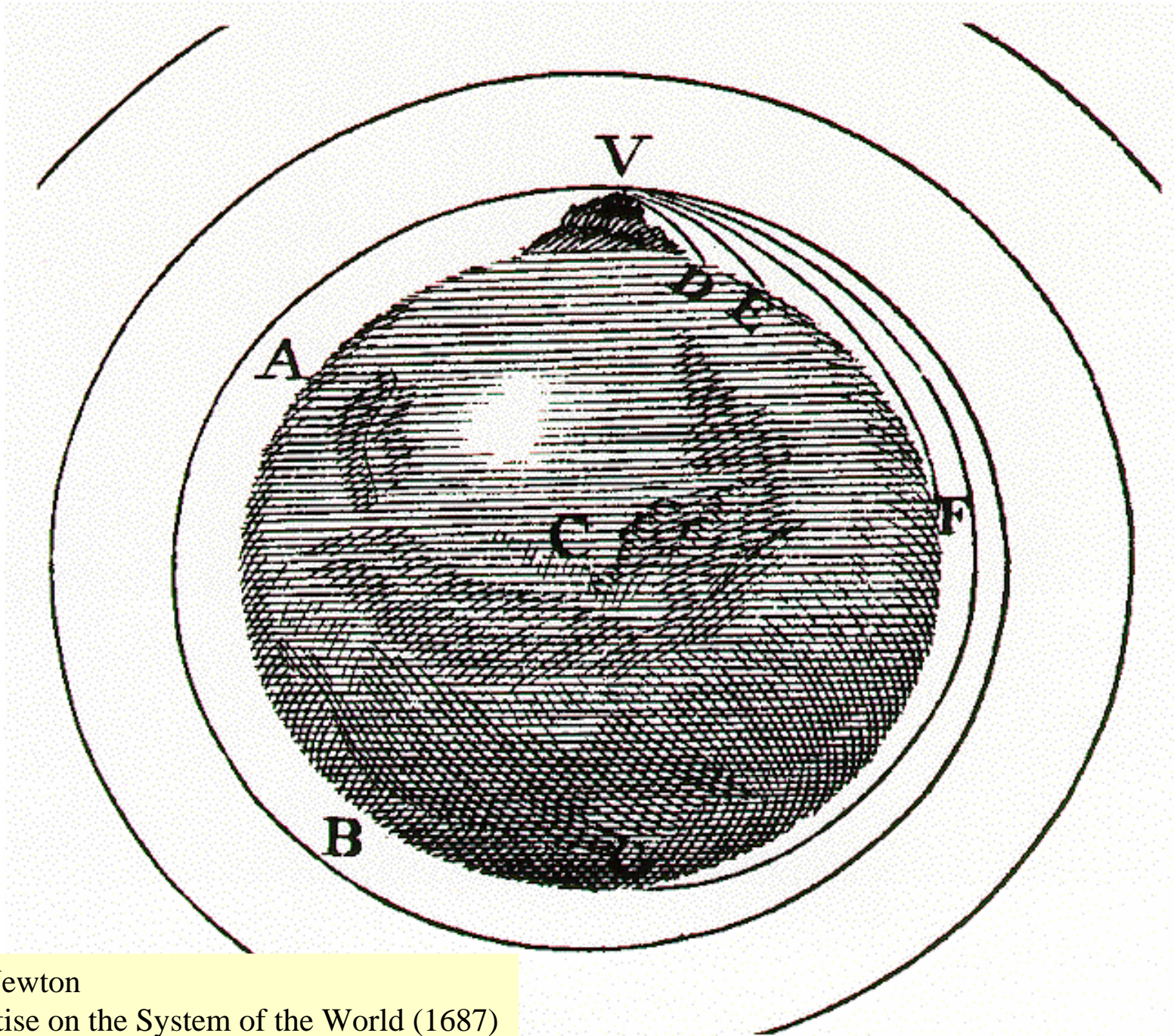




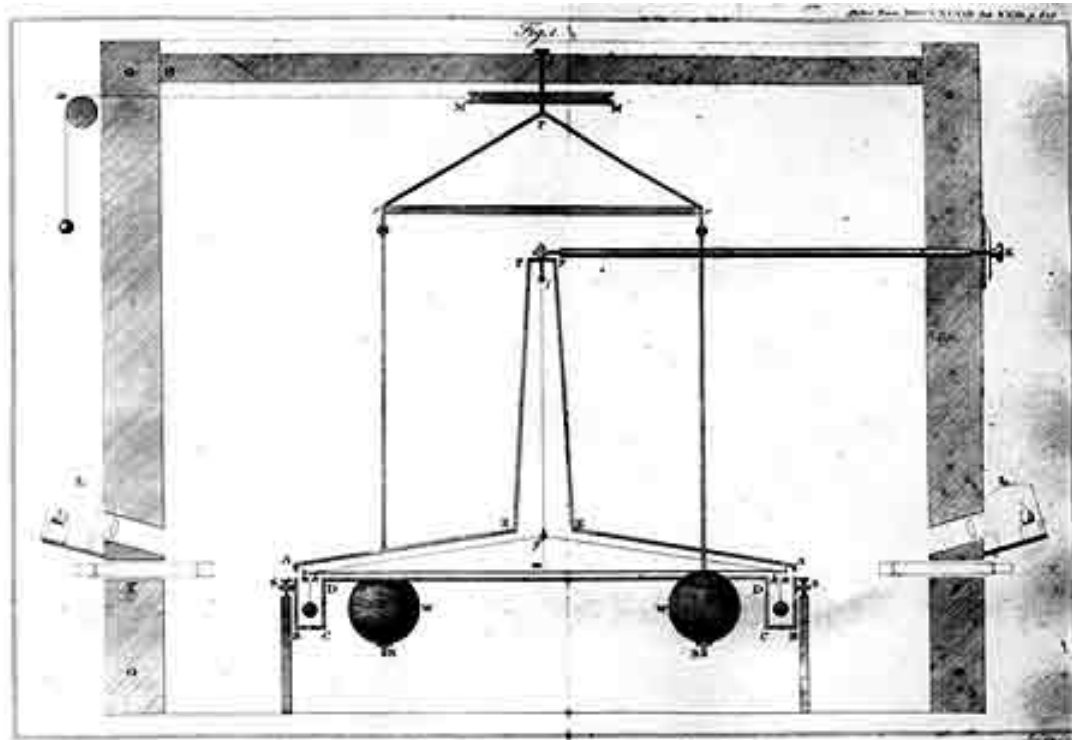
Need stronger
body harness



**Col. John Stapp
(1954)
43 G's**

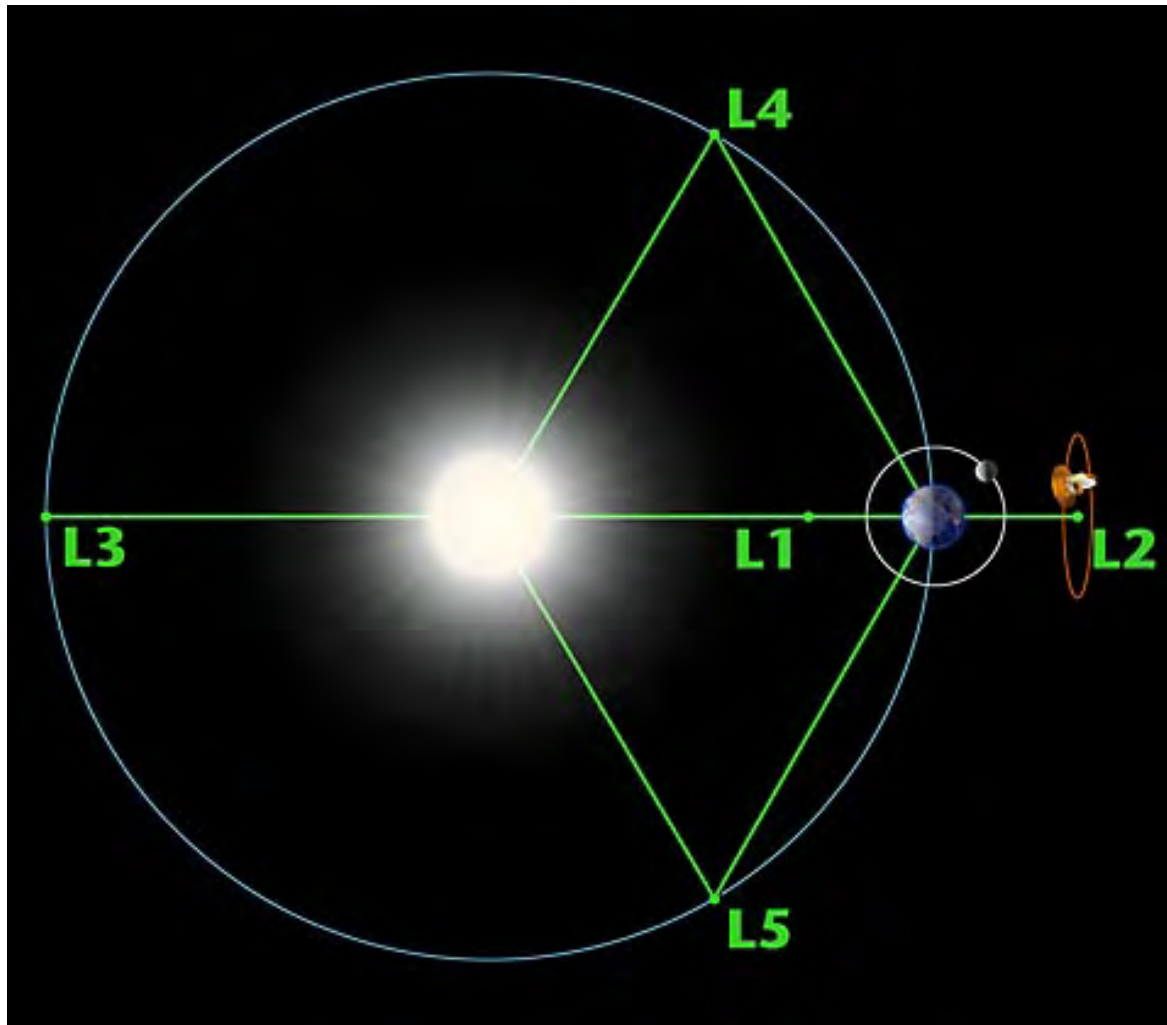


Isaac Newton
A Treatise on the System of the World (1687)

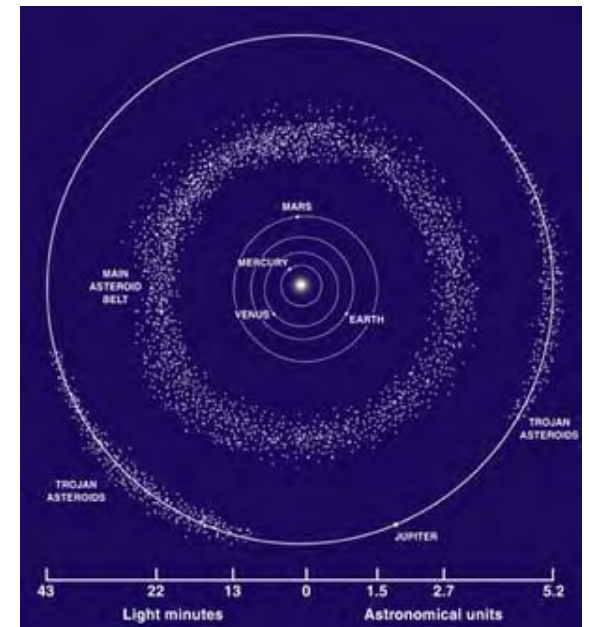


Cavendish apparatus: torsion balance measures gravitational attraction of two masses in the laboratory

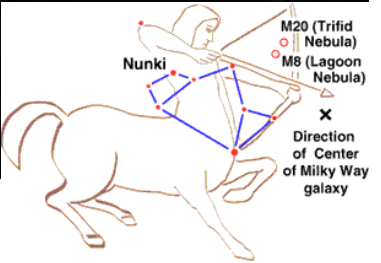
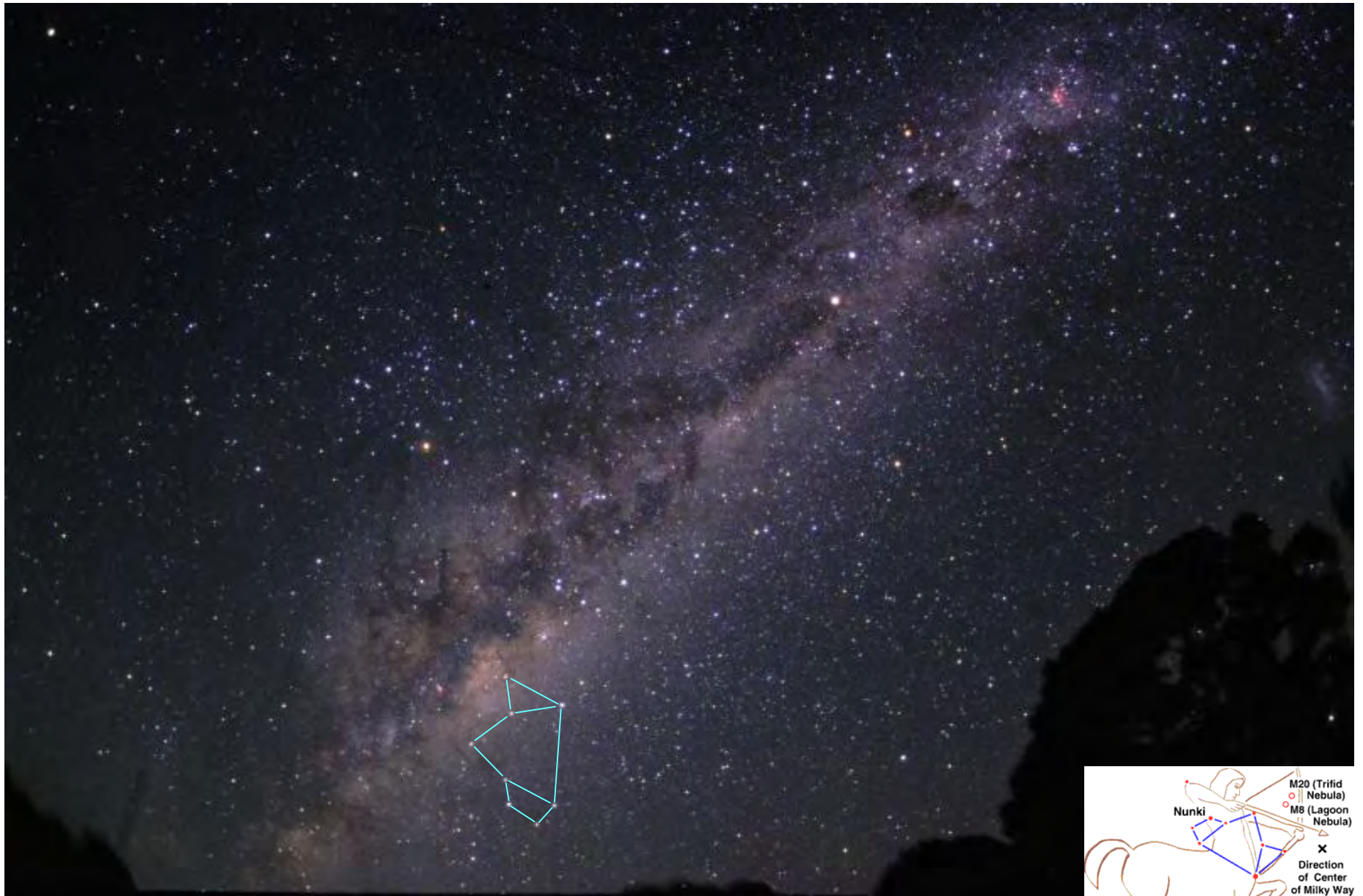
Lagrange Points: Gravitational forces cancel allowing orbit with a fixed relative position.



L4 and L5 are stable equilibrium and stuff (asteroids) tend to accumulate there.









Wide-Field Radio Image of the Galactic Center

$\lambda = 90 \text{ cm}$

(Kassim, LaRosa, Lazio, & Hyman 1999)

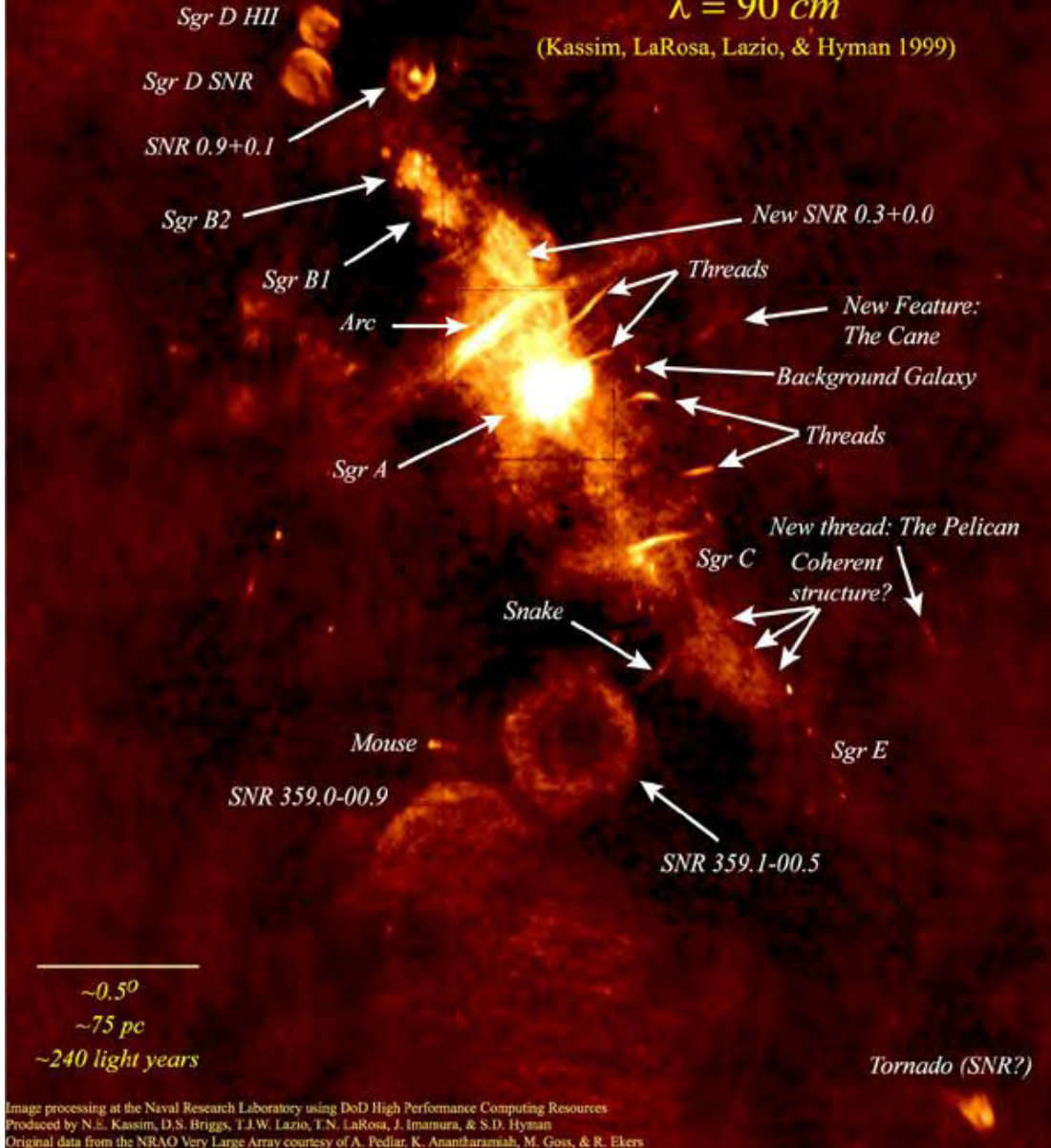
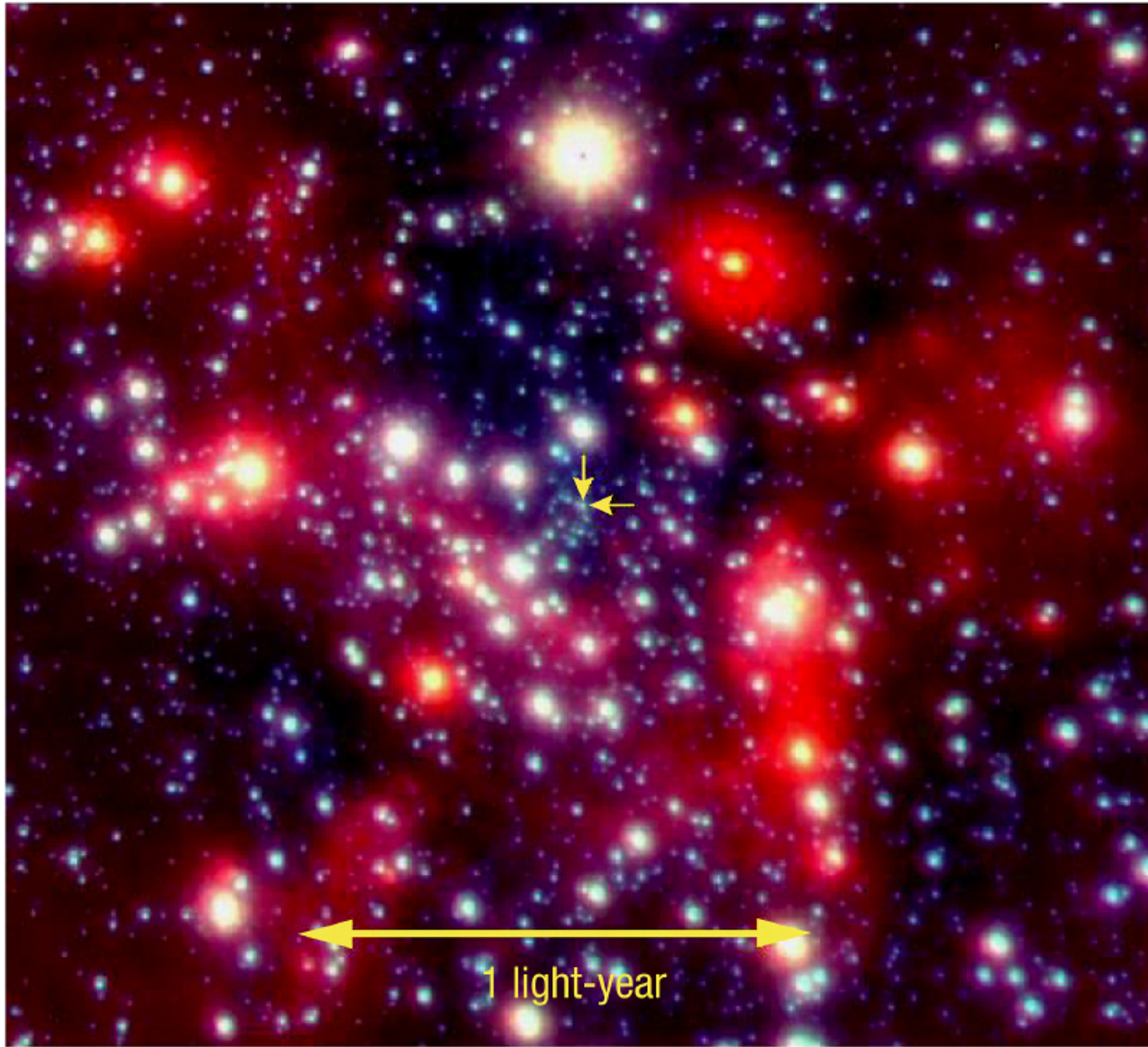


Image processing at the Naval Research Laboratory using DoD High Performance Computing Resources
 Produced by N.E. Kassim, D.S. Briggs, T.J.W. Lazio, T.N. LaRosa, J. Itamura, & S.D. Hyman
 Original data from the NRAO Very Large Array courtesy of A. Pedlar, K. Anantaramiah, M. Goss, & R. Ekers

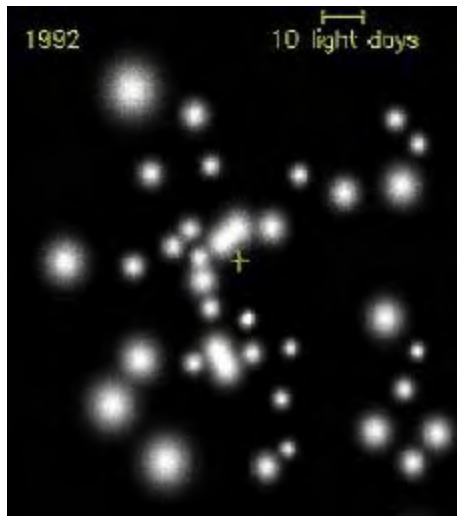


The Centre of the Milky Way
(VLT YEPUN + NACO)

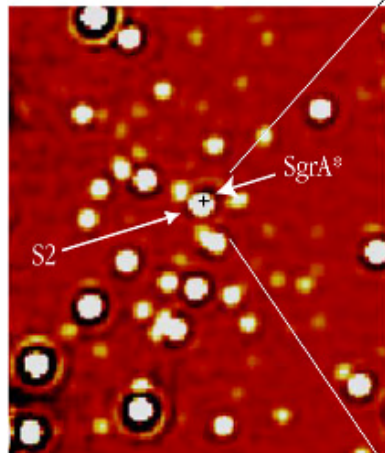
ESO PR Photo 23a/02 (9 October 2002)

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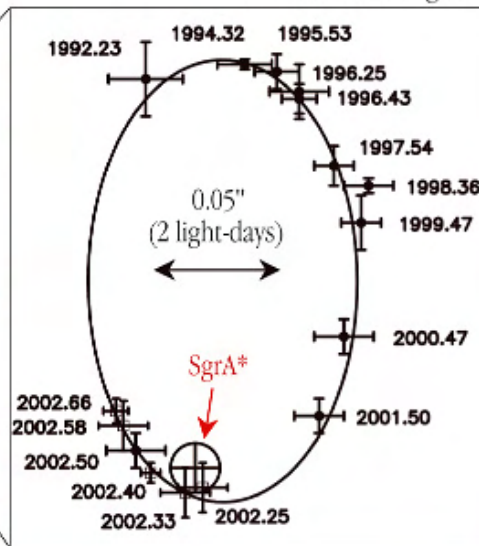




NACO May 2002



S2 Orbit around SgrA*



S2:
closest approach = 17 light-hours
speed: 5000 km/s

Black hole:
 2.6 ± 0.2 million \times mass of Sun

The Motion of a Star around the Central Black Hole in the Milky Way

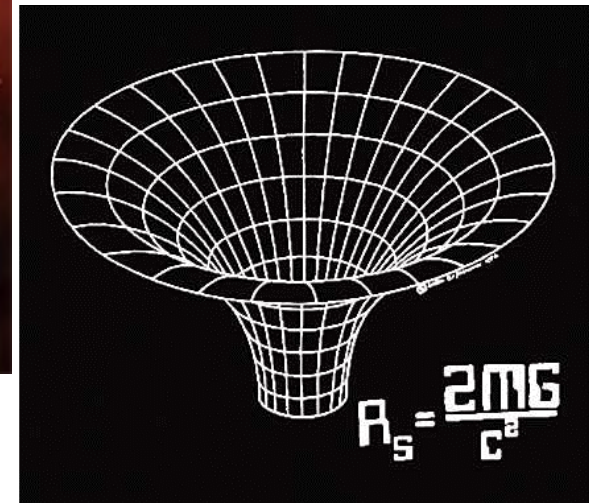
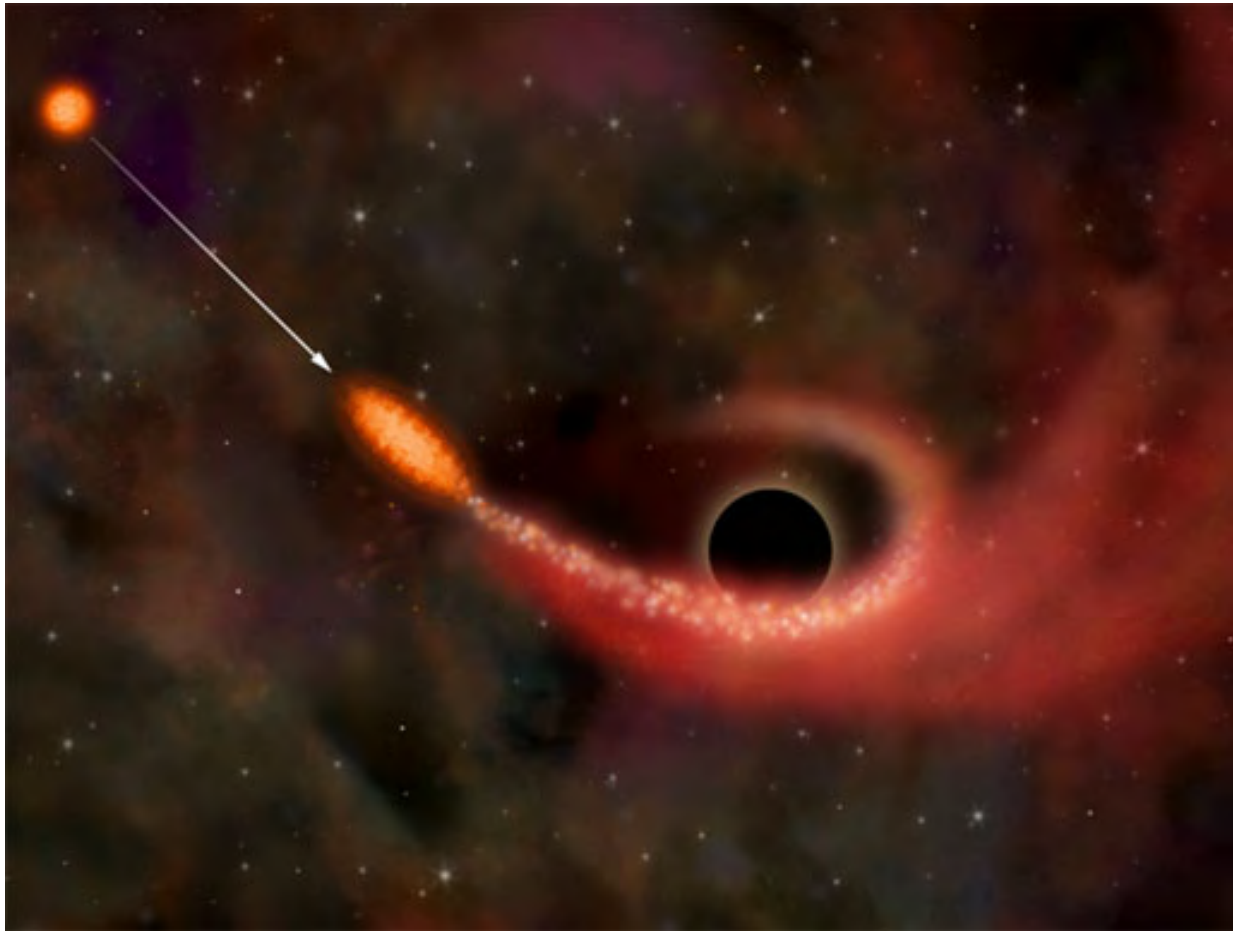
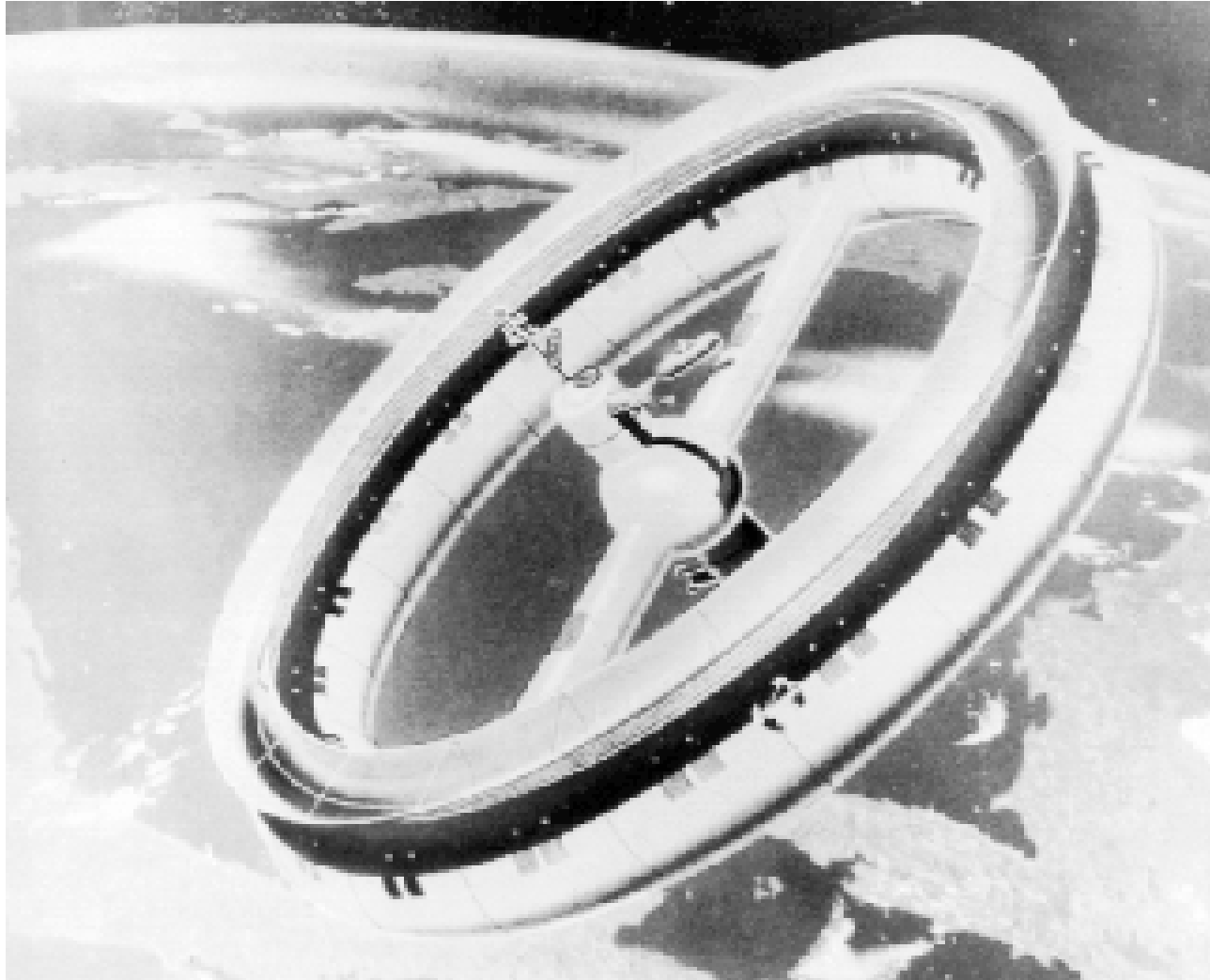


Diagram of a black hole warping spacetime, from a T-shirt. The radius of the black hole, R_s , is $R_s = 2MG/c^2$, where G is Newton's constant, M is the mass of the black hole, and c is the speed of light.



VON BRAUN'S
SPACE STATION
1952



S112E05823

**ISS altitude
is 354 km**

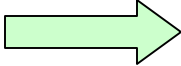
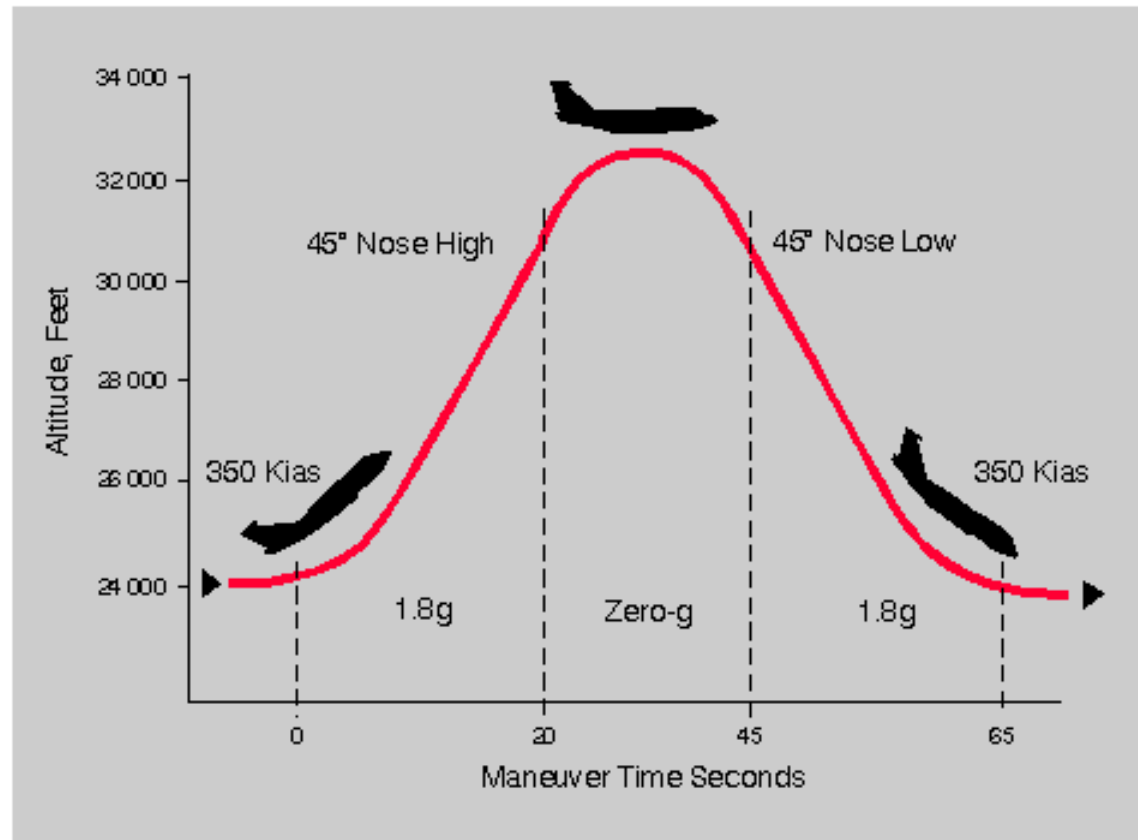


TABLE 7.1

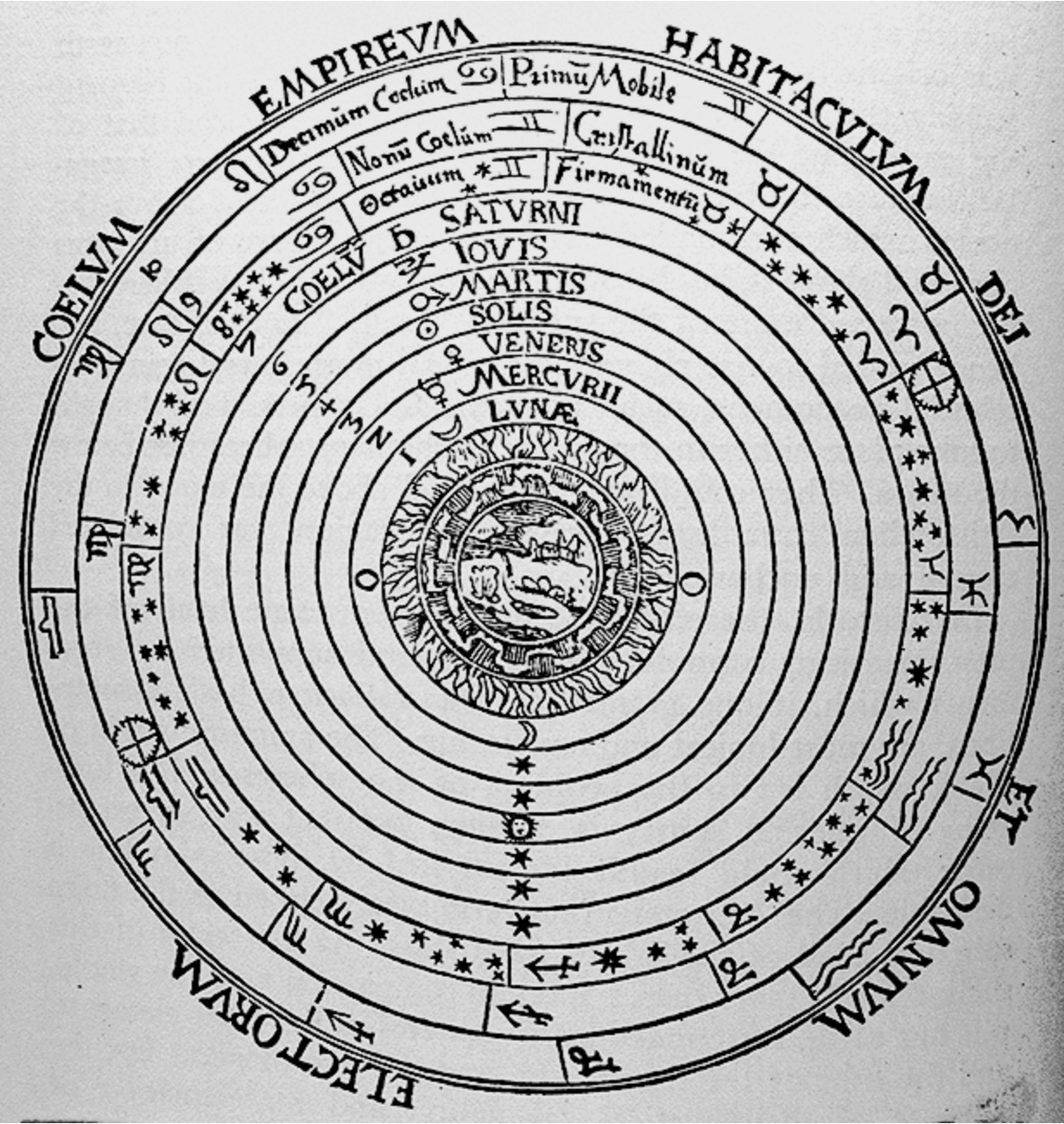
**Free-Fall Acceleration g at
Various Altitudes**

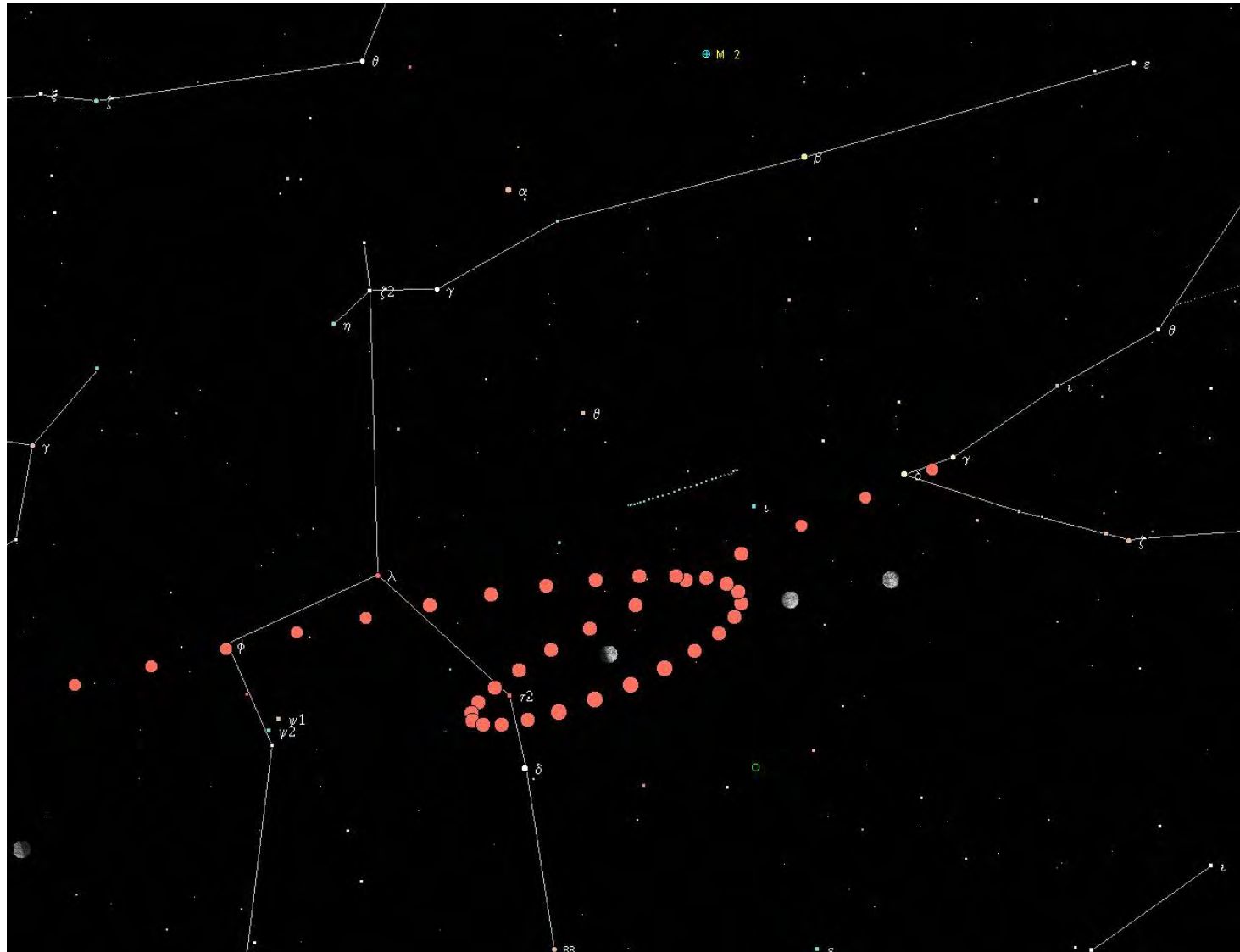
Altitude (km)^a	g (m/s²)
1 000	7.33
2 000	5.68
3 000	4.53
4 000	3.70
5 000	3.08
6 000	2.60
7 000	2.23
8 000	1.93
9 000	1.69
10 000	1.49
50 000	0.13

^aAll figures are distances above Earth's surface.

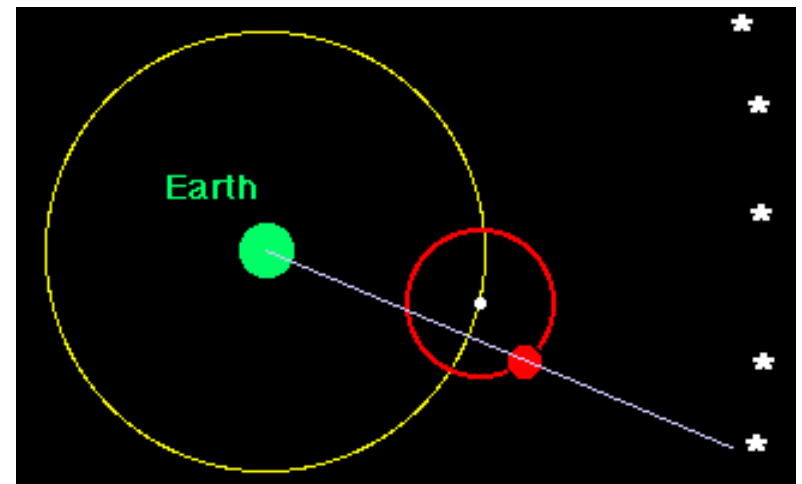
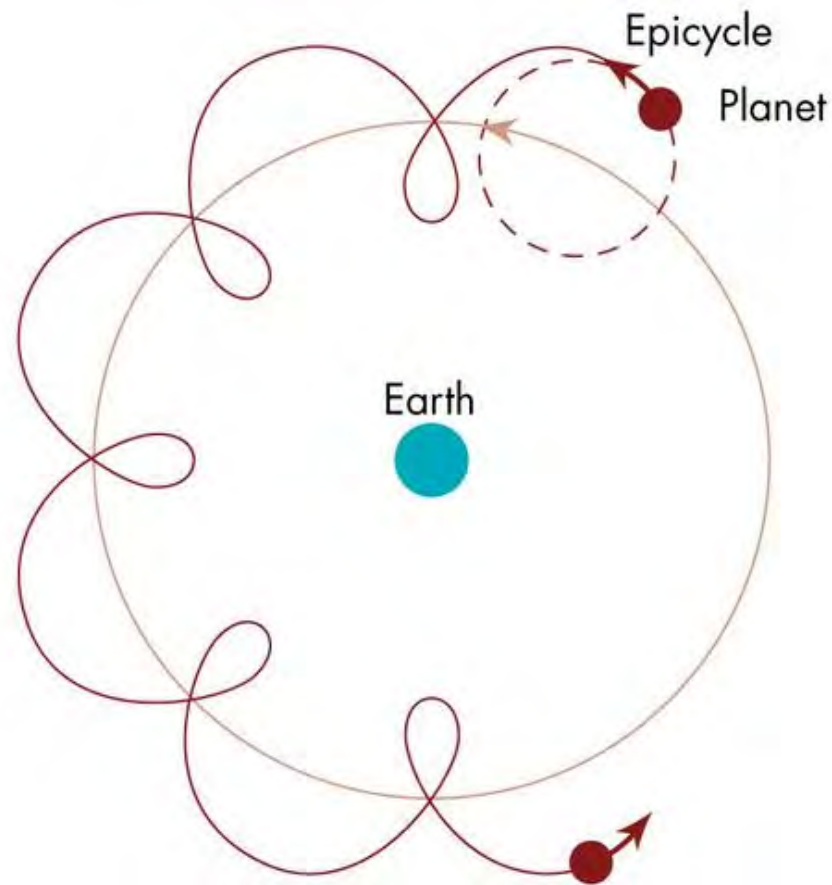


Claudius Ptolemy

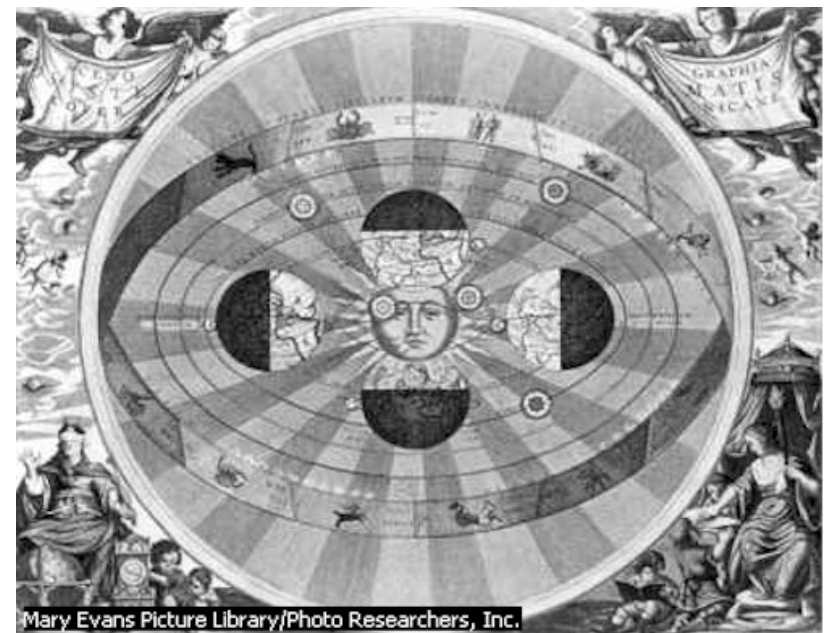
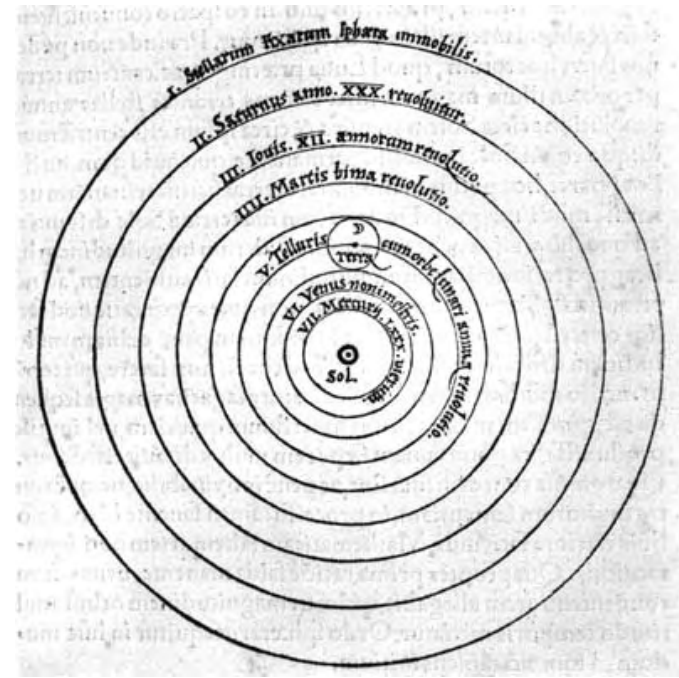




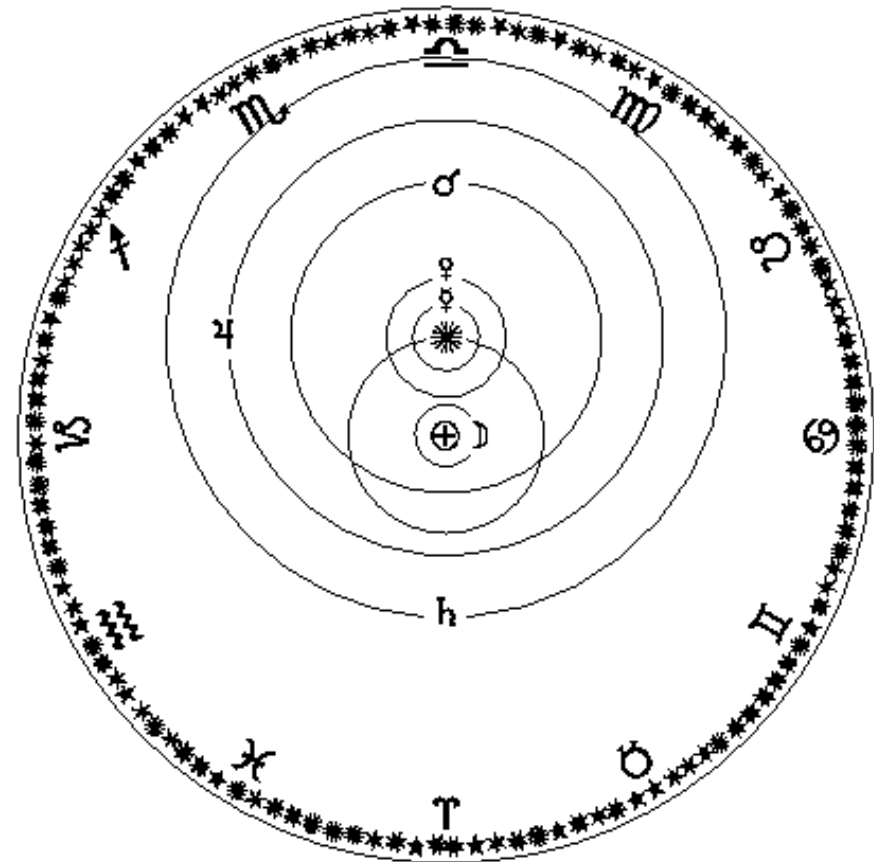
Epicycles: successfully used to describe planetary motion (such as retrograde) in earth-centered system.



Nicolas Copernicus



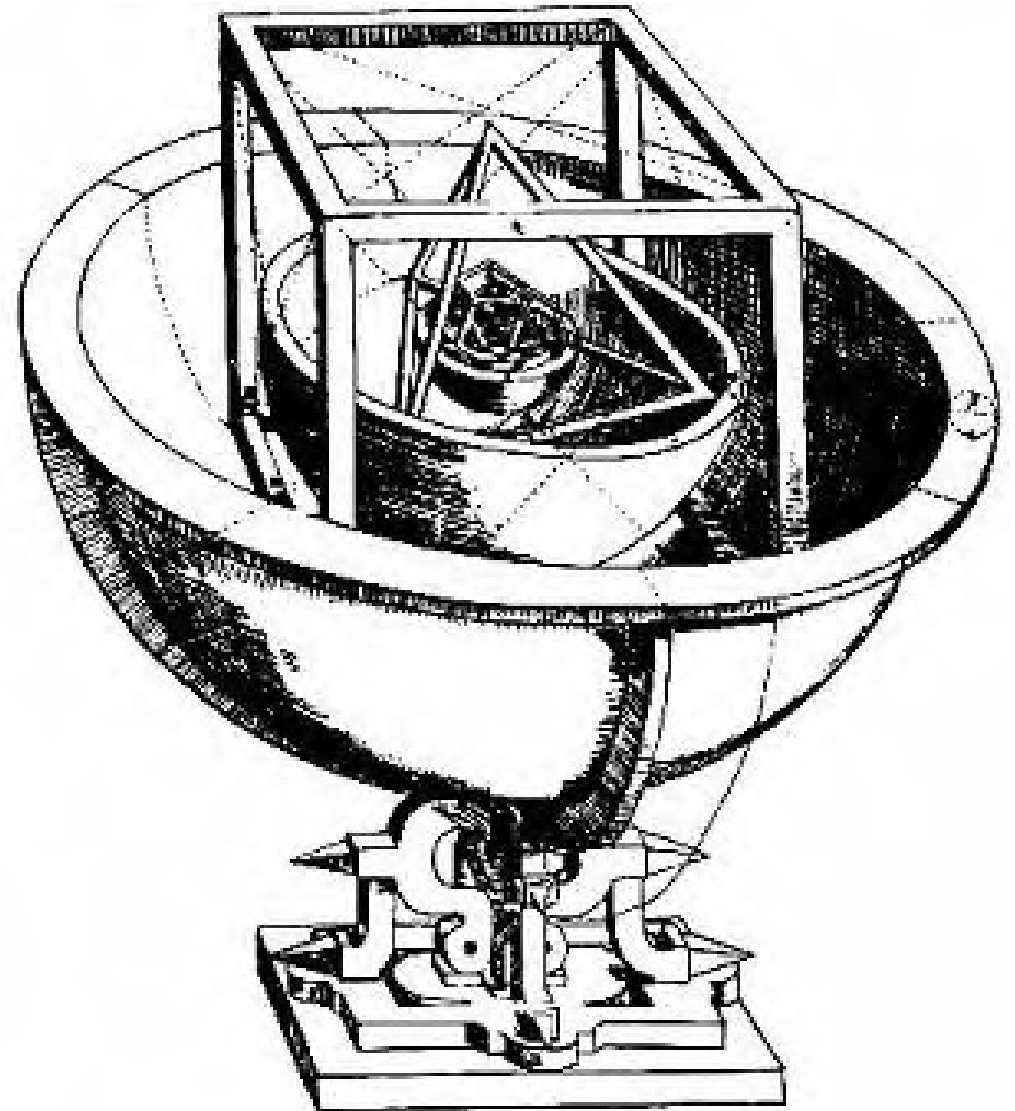
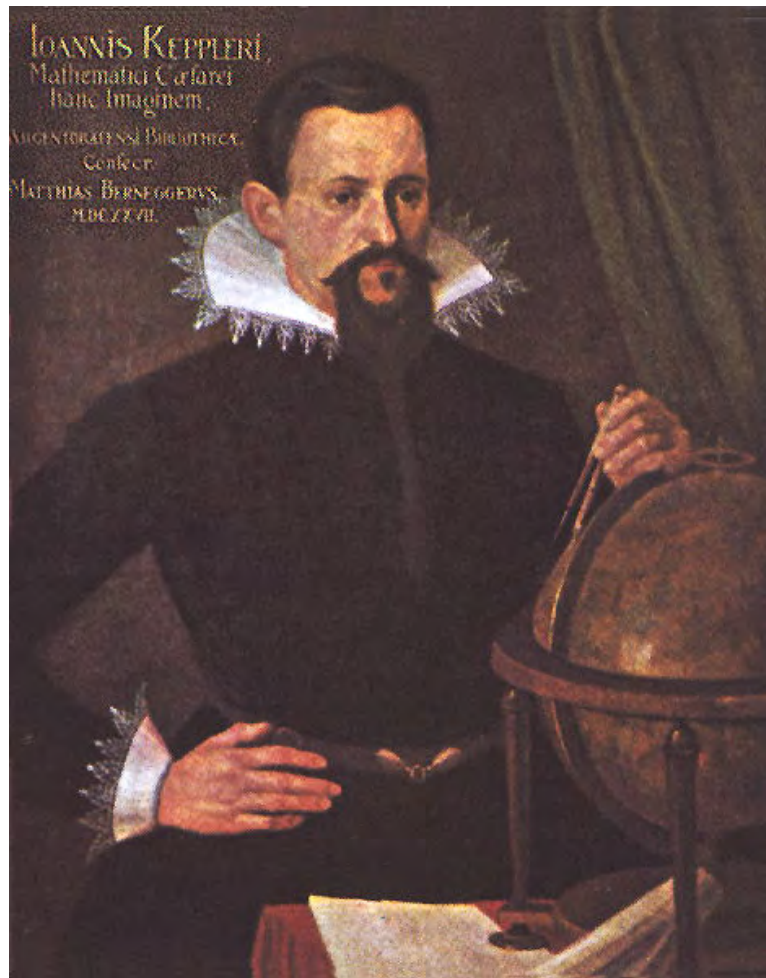
Tycho Brahe

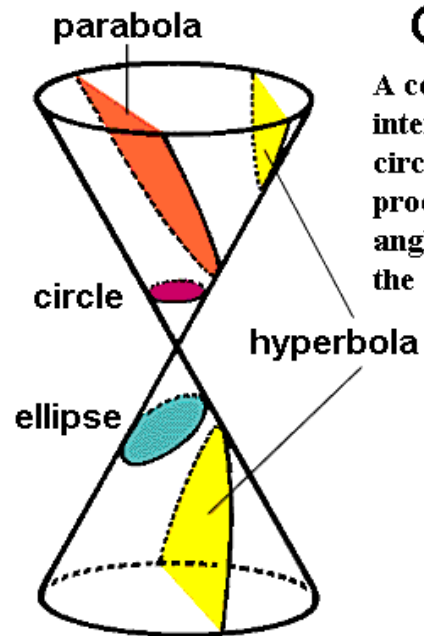


Mixed geocentric+heliocentric.

More epicycles!

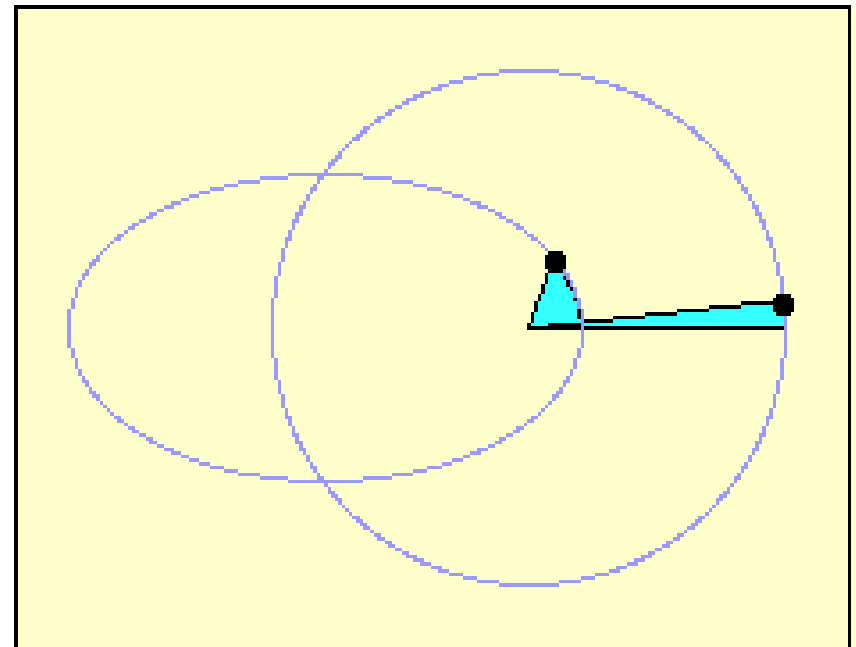
Johannes Kepler

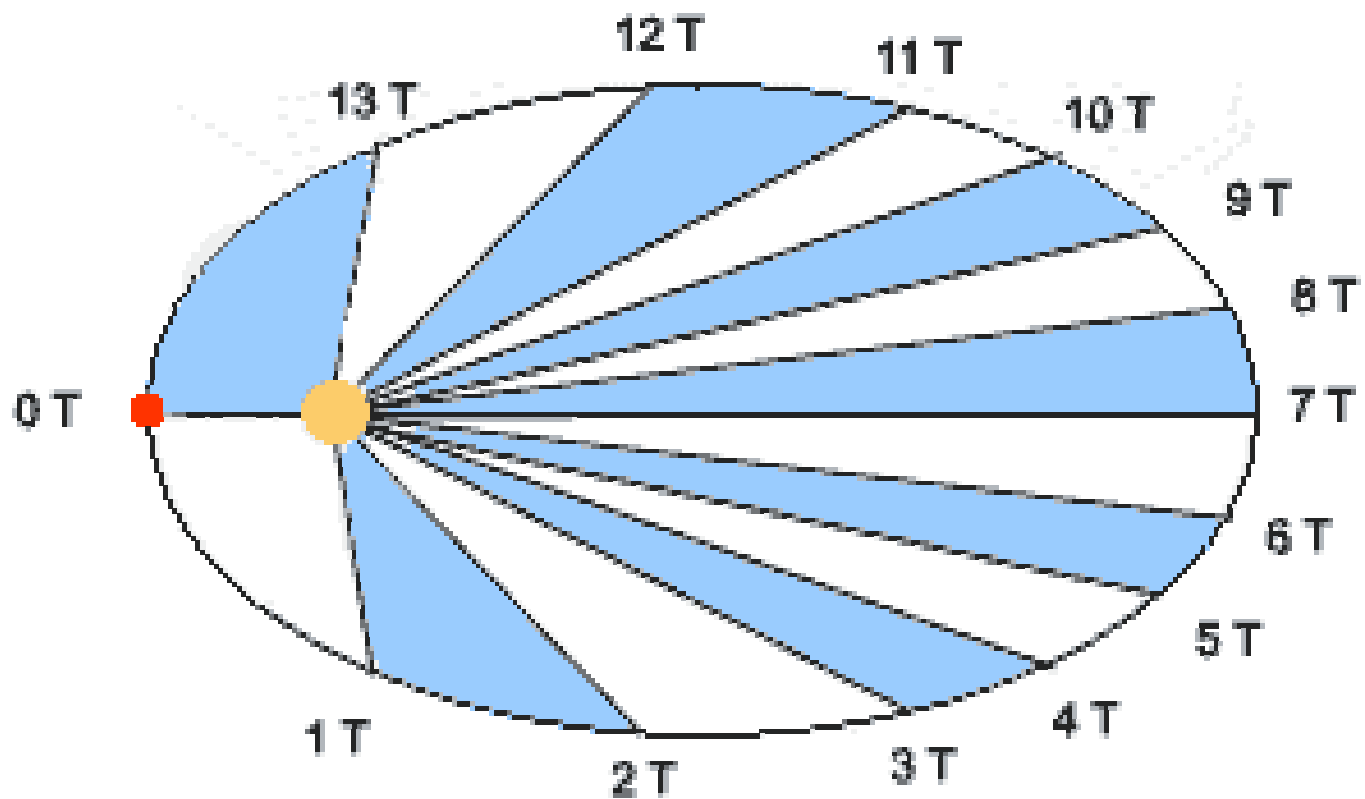




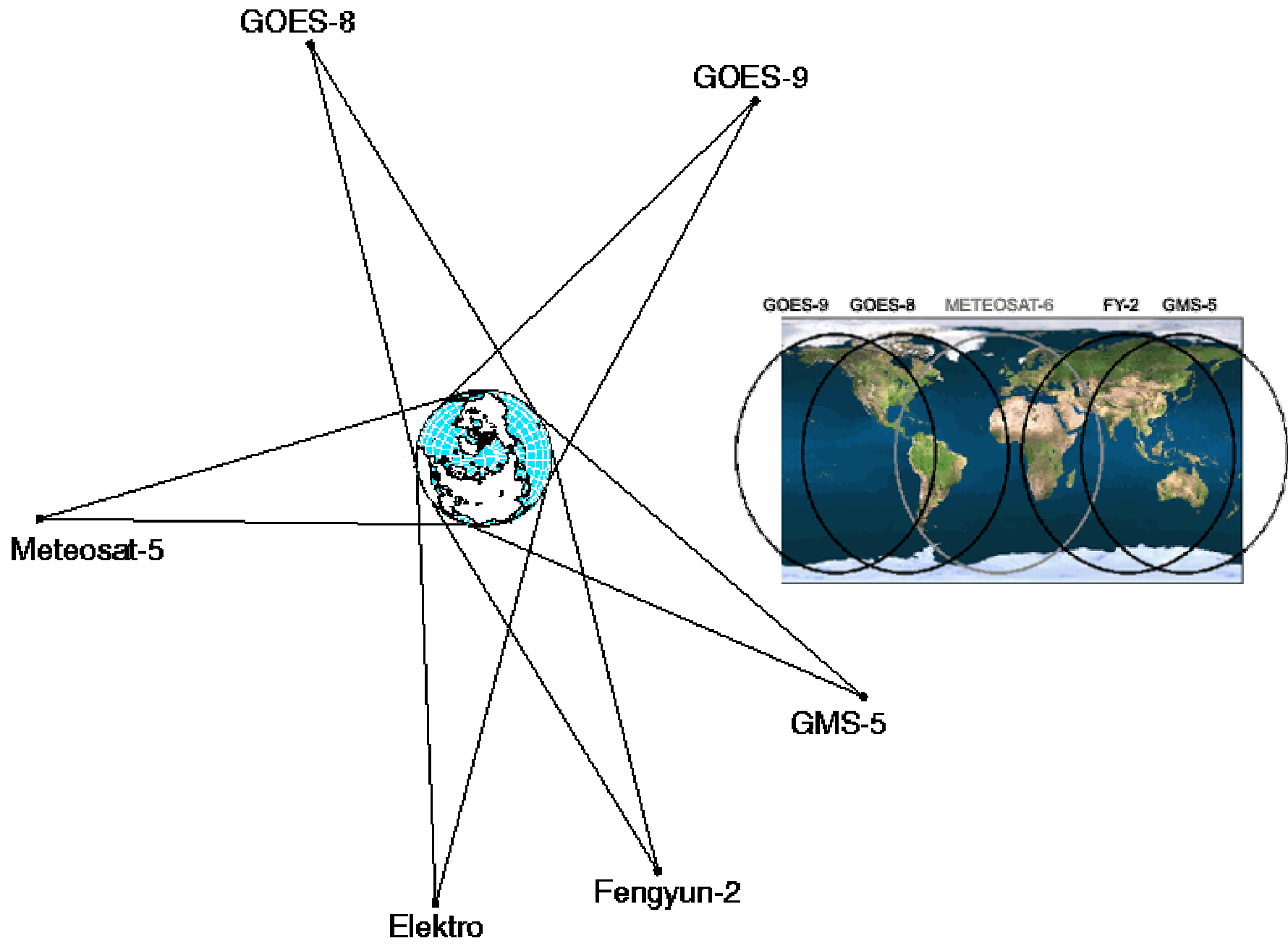
Conic Sections

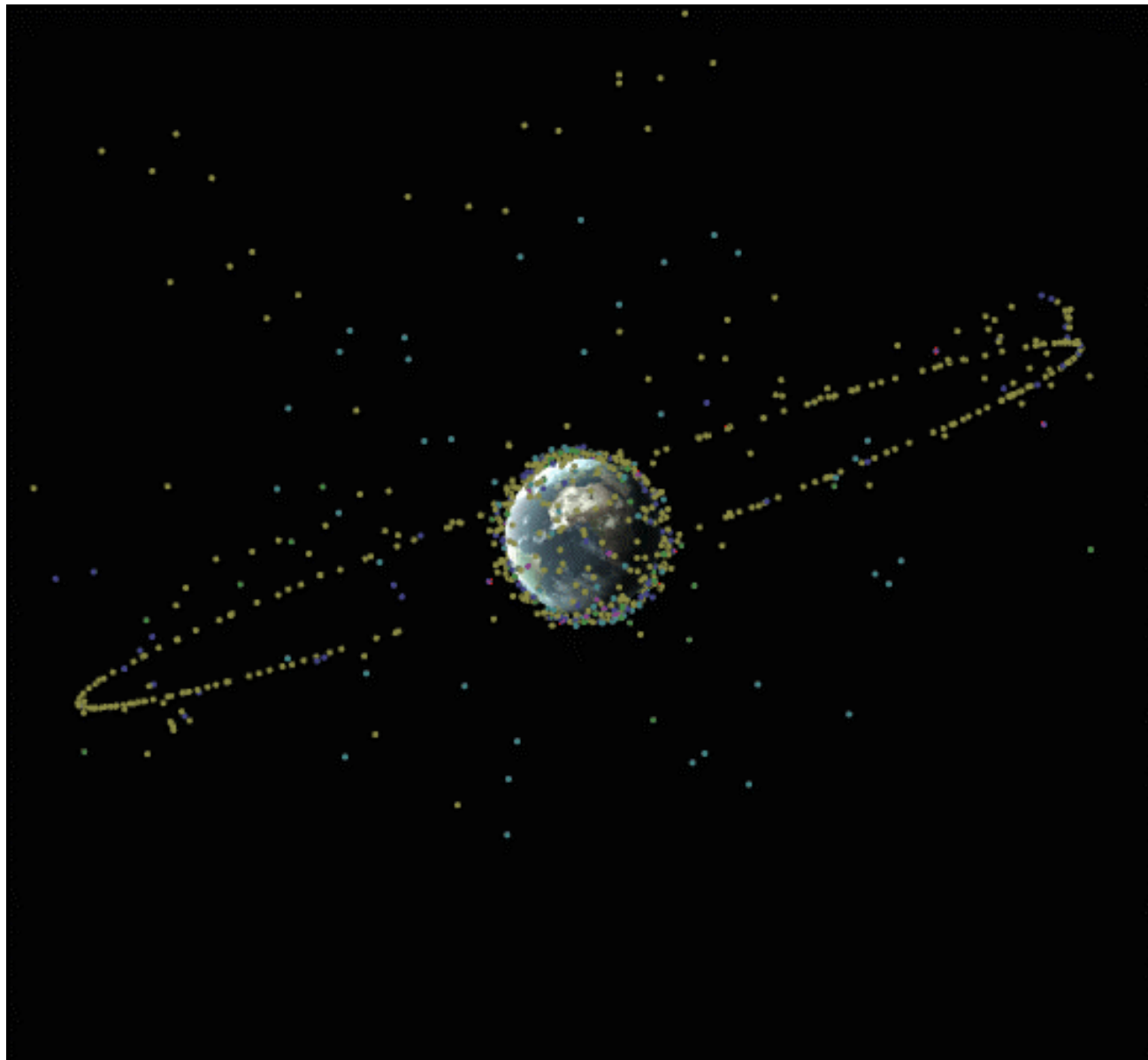
A conic section is formed by the intersection of a plane with a right circular cone. The "kind" of curve produced is determined by the angle at which the plane intersects the surface.



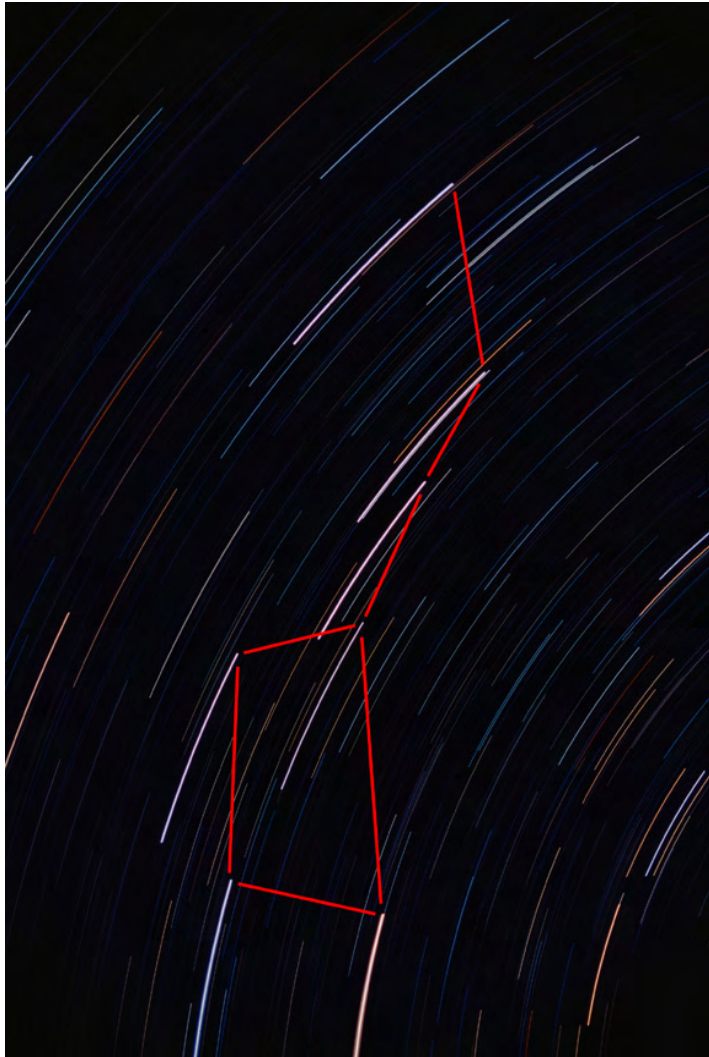


T = any unit of time (hour, day, week, etc.)





Star Trails



Point camera at sky, leave lens open

What would a geosynchronous satellite look like among star trails?

