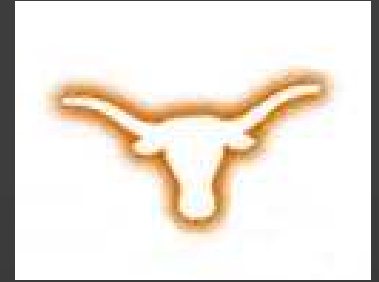




Astronomy 350L
(Fall 2006)



**The History and Philosophy
of Astronomy**

**(Lecture 15: Enlightenment:
Kant/Herschel)**

Instructor: Volker Bromm
TA: Jarrett Johnson

The University of Texas at Austin

Timeline: The Enlightenment Period

1750	1760	1770	1780	1790	1800
<ul style="list-style-type: none">• 1750 Death of J. S. Bach• 1751 First volume of <i>Encyclopédie</i> published	<ul style="list-style-type: none">• 1759 Voltaire, <i>Candide</i>• 1760–1820 Reign of George III of England	<ul style="list-style-type: none">• 1762 Rousseau, <i>Le contrat social</i>	<ul style="list-style-type: none">• 1774 First Continental Congress in Philadelphia• 1774–92 Reign of Louis XVI, king of France• 1775–83 American Revolution• 1776 Declaration of Independence• 1776 Smith, <i>The Wealth of Nations</i>• 1778 La Scala opera house opens, Milan	<ul style="list-style-type: none">• 1781 Kant, <i>Critique of Pure Reason</i>	<ul style="list-style-type: none">• 1788 Gibbon, <i>Decline and Fall of the Roman Empire</i>• 1789–94 French Revolution• 1791 Death of Mozart• 1791 Boswell, <i>The Life of Samuel Johnson</i>• 1791 Haydn, first <i>London Symphonies</i>• 1799 Beethoven, First Symphony

Question:

What is Enlightenment???

Enlightenment Philosophy



- Immanuel Kant (1724-1804)
- *Critique of Pure Reason* (1781):
 - Big Q: What can we know?
- *Theory of the Heavens* (1755):
 - “Island Universes” (galaxies)

Question: What is Enlightenment???

“Enlightenment is man’s emergence from his self-imposed immaturity. Immaturity is the inability to use one’s understanding without guidance from another. This immaturity is self-imposed when its cause lies not in the Lack of understanding, but in lack of resolve and courage to use it without guidance from another. Sapere aude! [dare to know] Have courage to use your own understanding!— that is the motto of the Enlightenment.”

(Kant, 1784)

Enlightenment Philosophy



- Jean-Jacques Rousseau
(1712-1778)
- ***The Social Contract*** (1762):
 - “ Man is born free but everywhere is in chains”
 - Purpose of government: to ensure life, happiness, general welfare
 - bad government: social contract is broken! → Change of government legitimate!

Political Upheaval: American Revolution



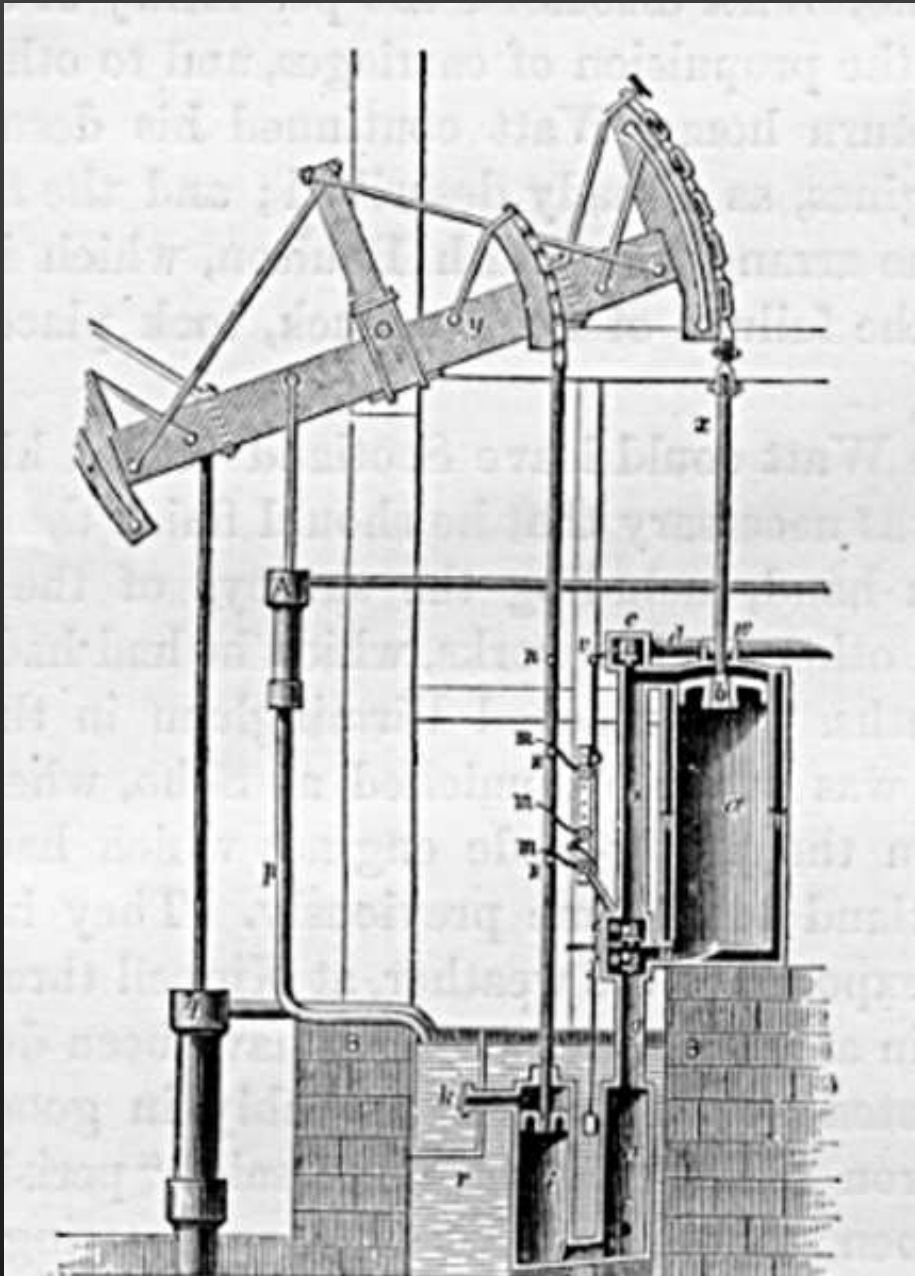
“Life, liberty, and the pursuit of happiness...”

Political Upheaval: French Revolution (1789)



“Liberte, egalite, fraternite!”

Economical Upheaval: Industrial Revolution



- James Watt:
 - Steam Engine (1774)
- beginnings of mass-production (Taylorism)
- Adam Smith (1776):
 - *Wealth of Nations* (“Bible of Capitalism”)
 - Theory of the “invisible hand”

The Birth of Chemistry



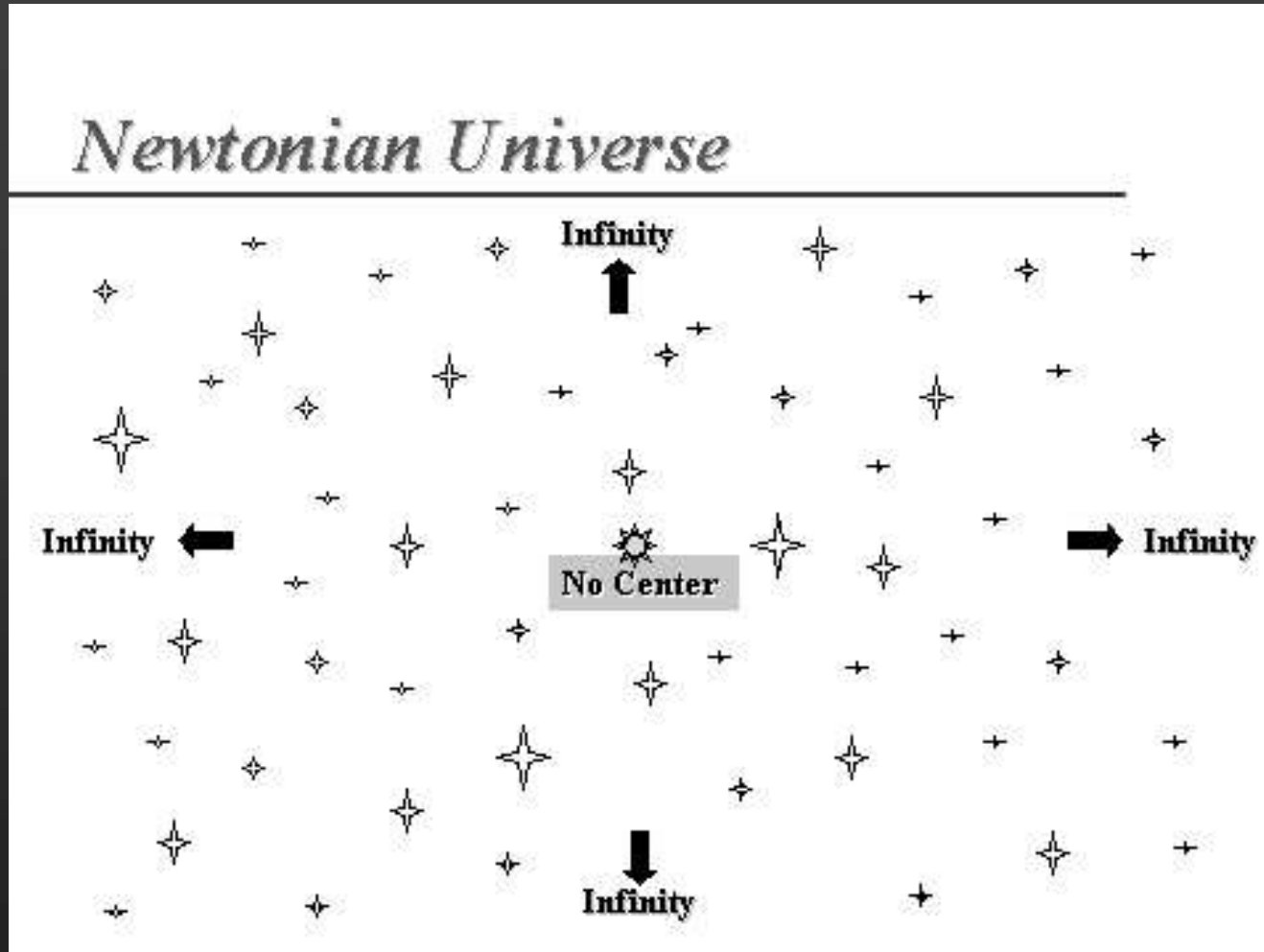
- Antoine Lavoisier (1743-94), discoverer of oxygen

Big Q: Architecture of Stellar System?



- Q: How are stars arranged, and are they really fixed?

Newton's A: Static, infinite Universe!



- Stars are fixed; i.e.: they don't move!

But what about “Milky Way” band of stars?



- Q: How was Milky Way, and other galaxies, discovered?

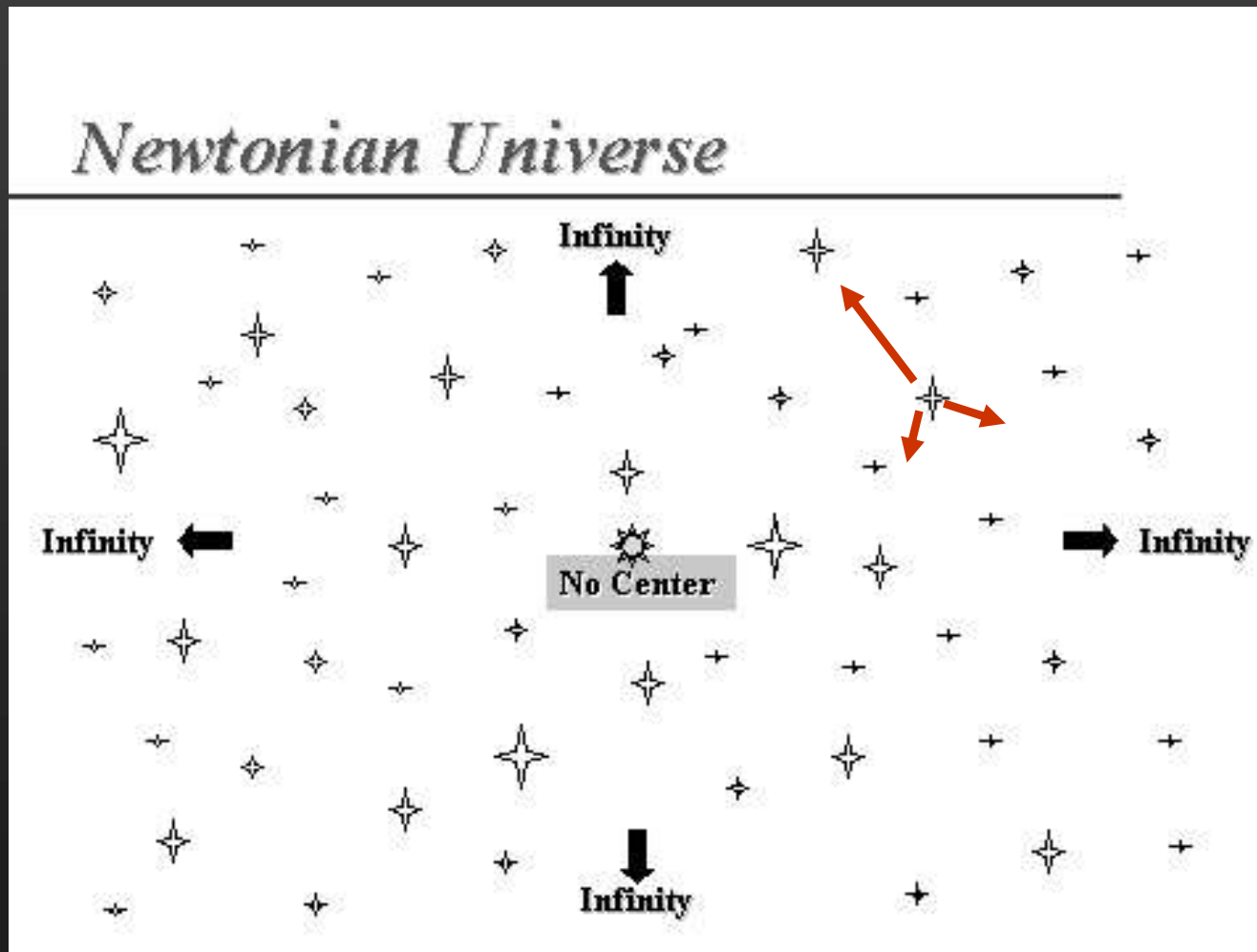
But what about “nebulous patches” of stars?



- Many “islands of stars” !

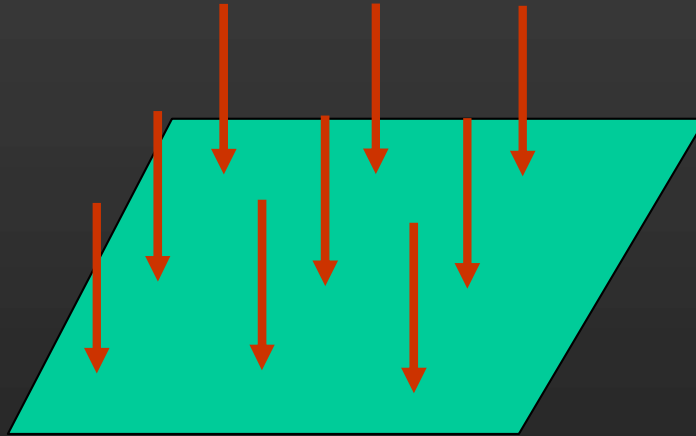
Newton: A Static Universe

- Q: Is such a Universe possible (is it stable)?



Newton: A Static Universe

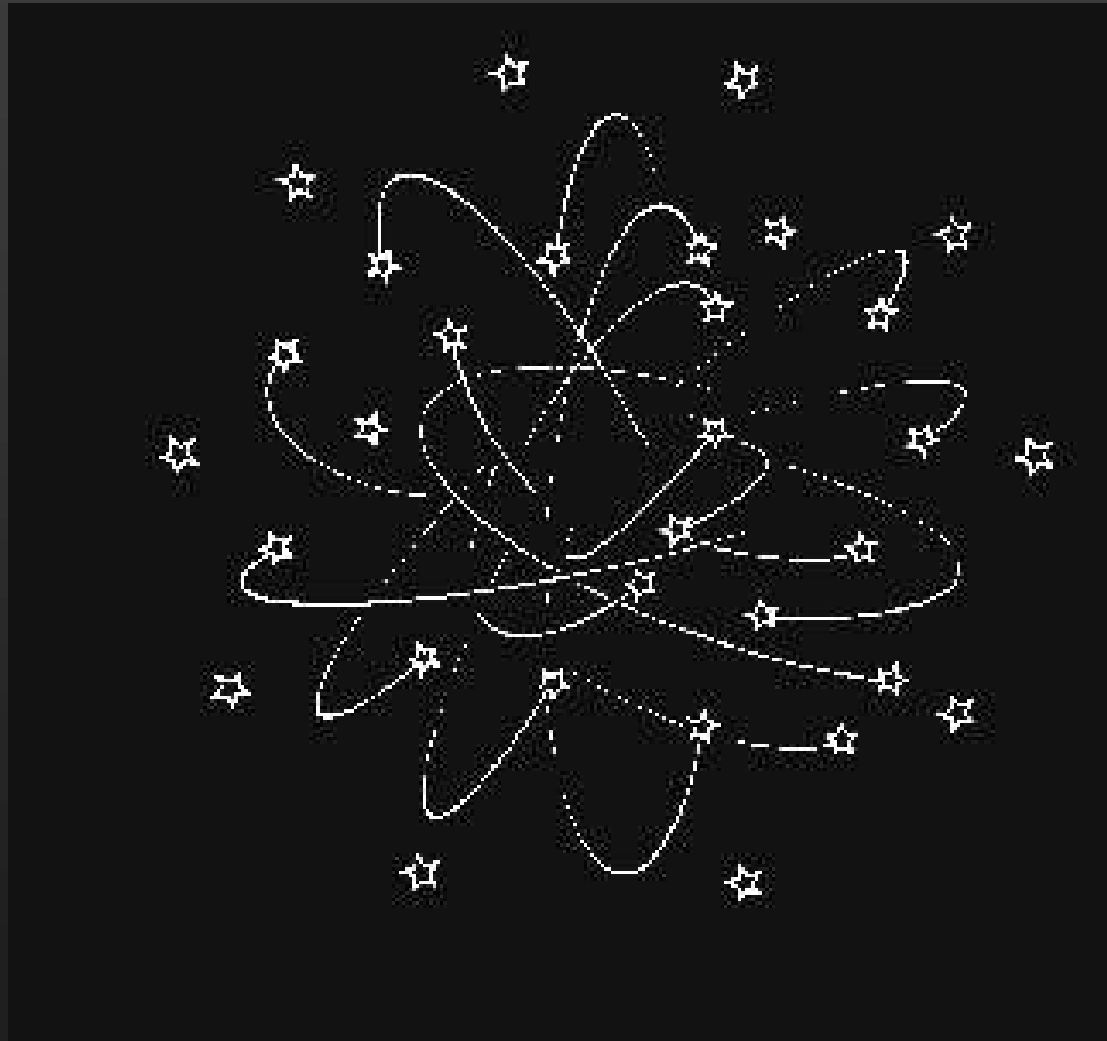
- Can stellar system be stable under gravity?



- A: No! Analogue: Balance infinitely many needles exactly on their tips! An unstable situation!

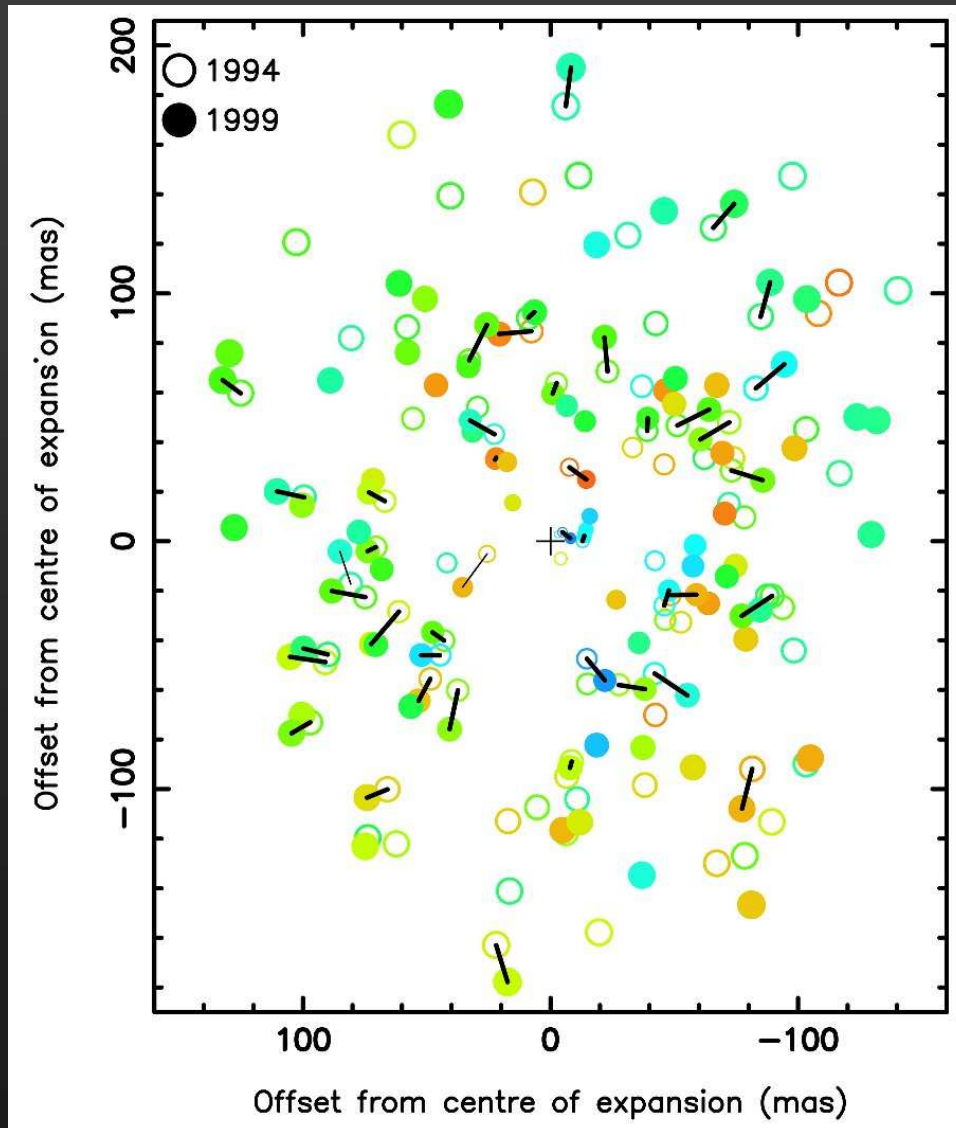
Newton: A Static Universe

- A: No, stars would begin to move around randomly!



Hunting for Stellar Motions

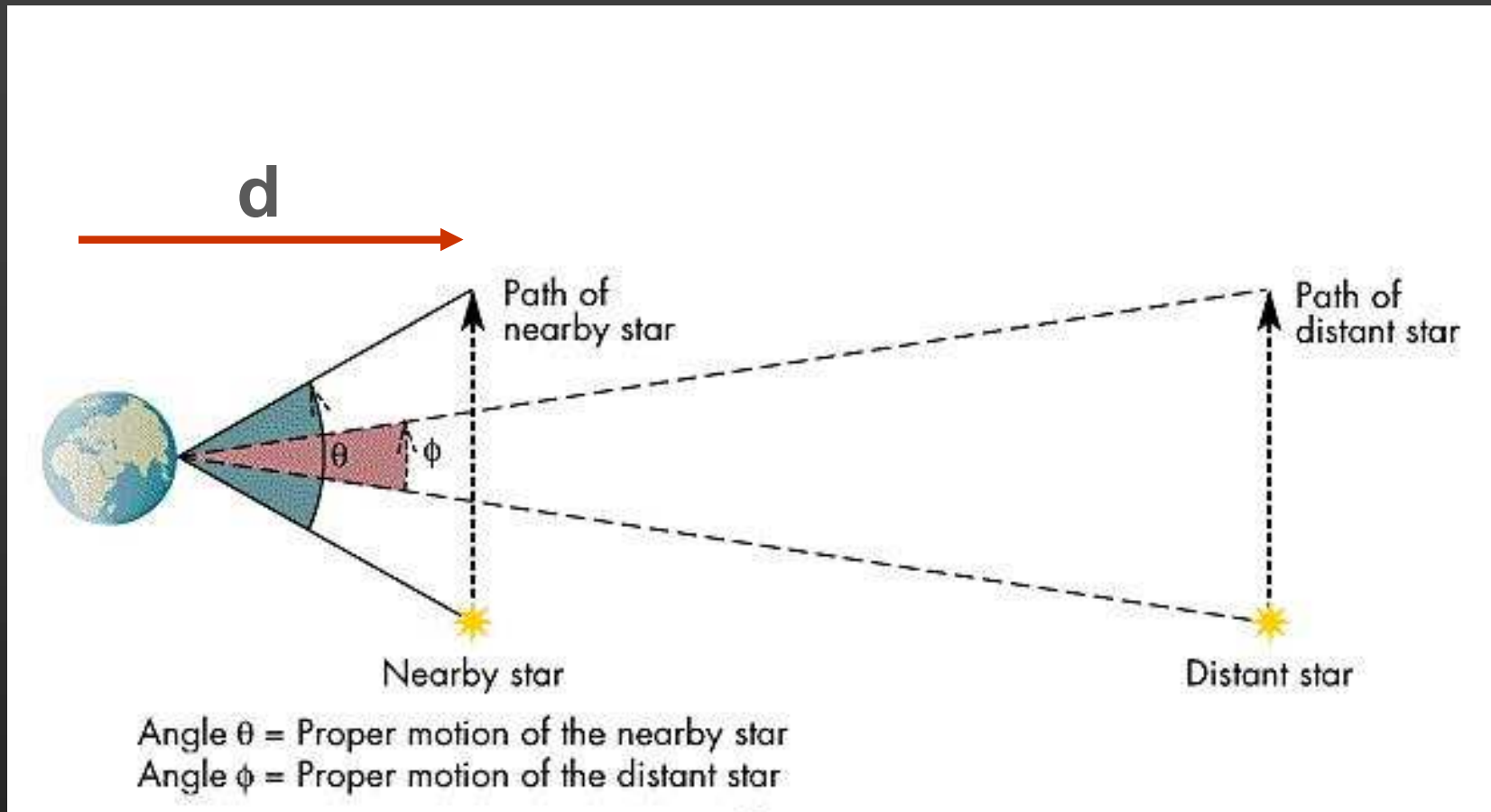
- Slow shift in angular positions → proper motions



- unsuccessful search initially

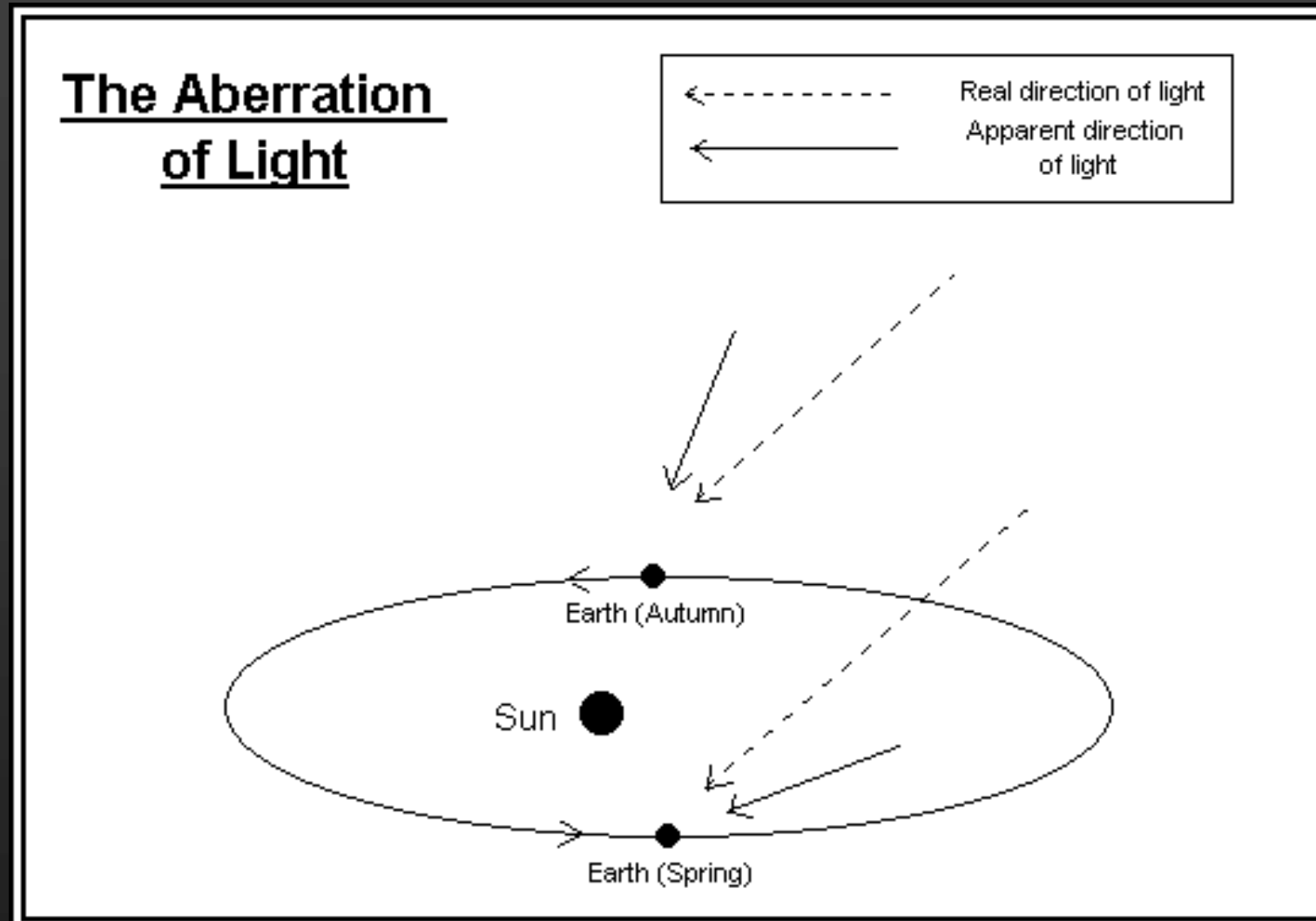
→ proper motions are exceedingly small due to large distance to the stars!

Hunting for Stellar Motions



- proper motion $\propto 1/d$

Serendipity: Bradley's Discovery of Aberration



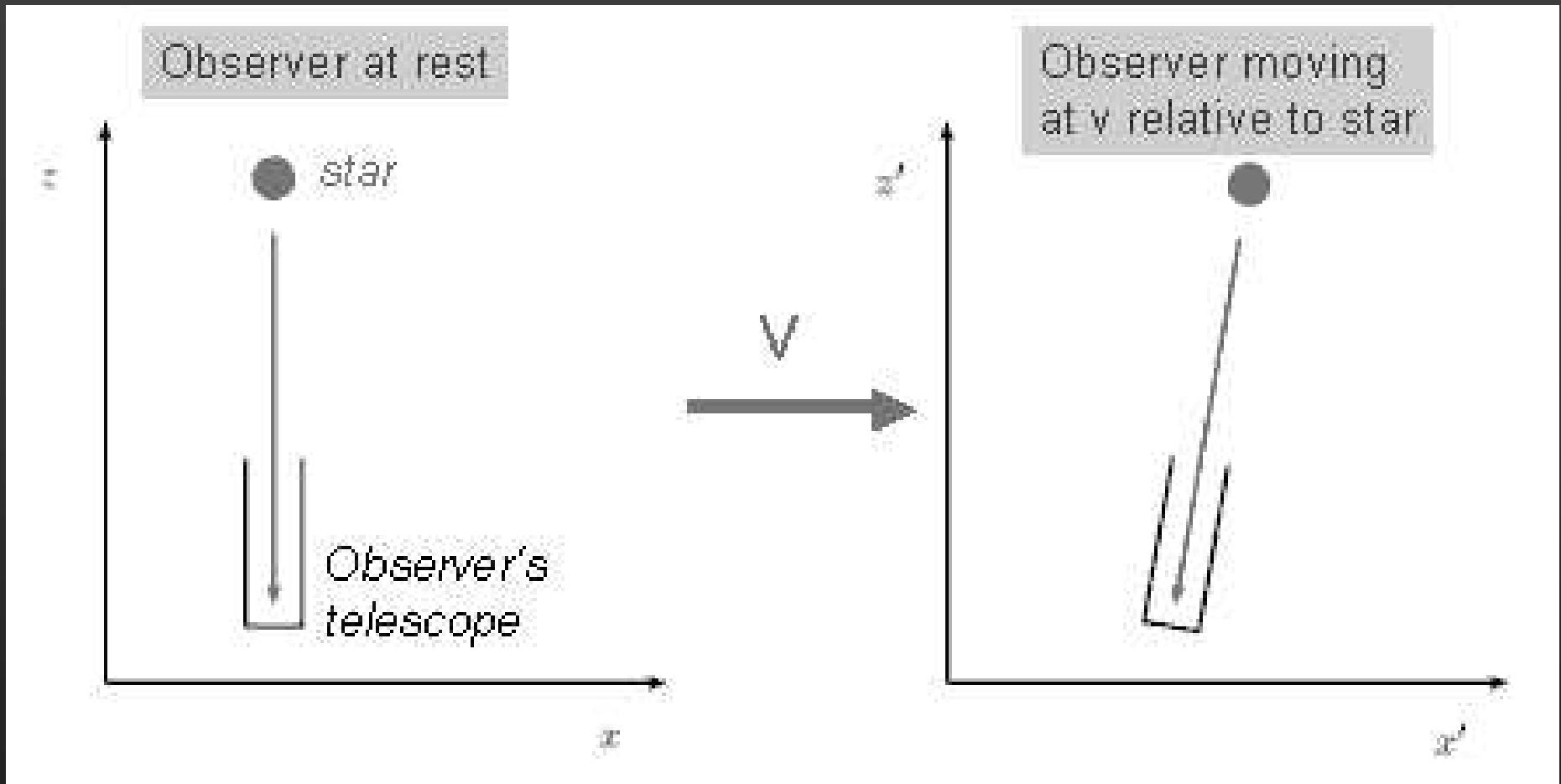
- Apparent stellar positions are shifted because of Earth's motion around Sun!

Bradley's Proof for Earth's Motion



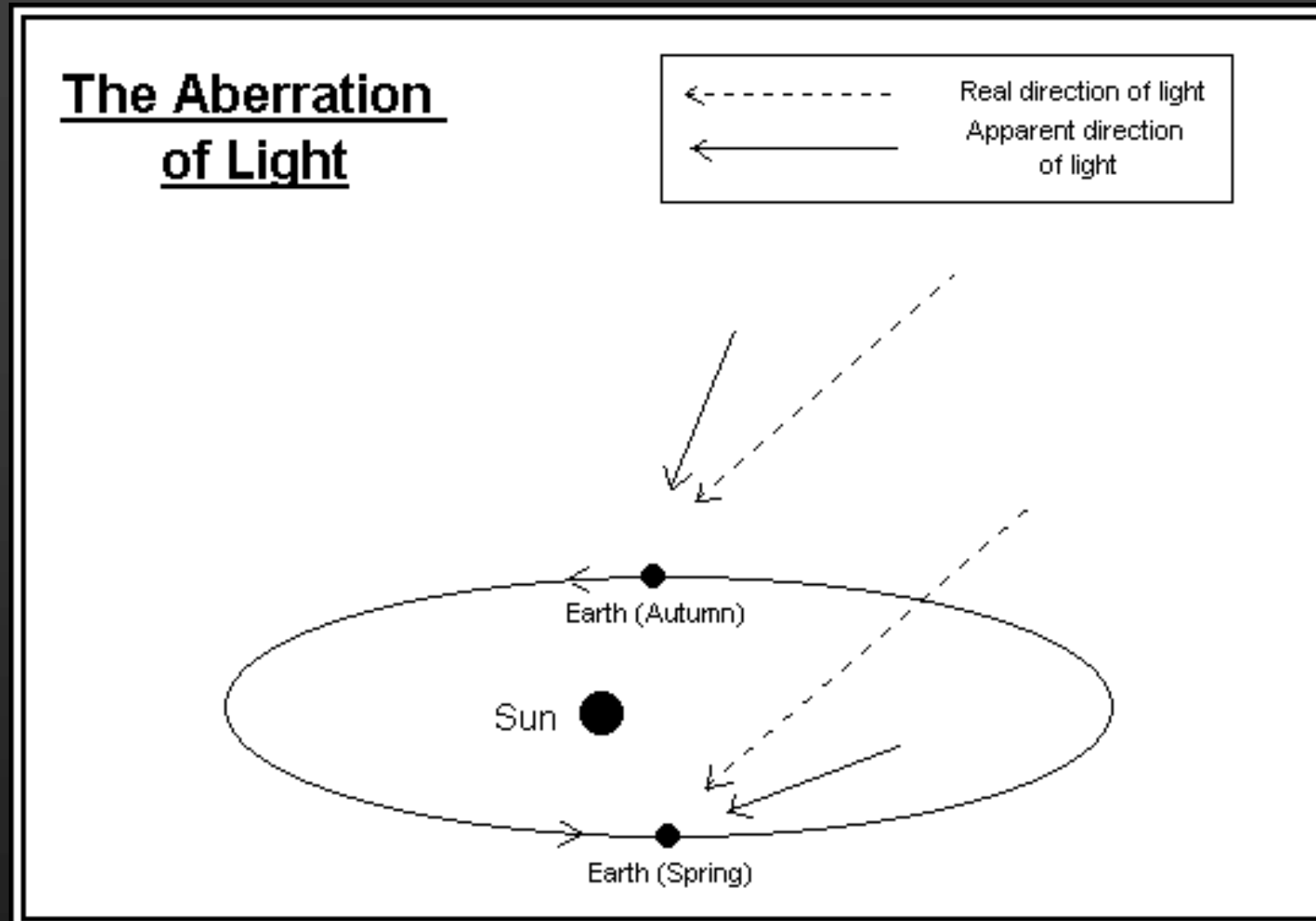
- James Bradley (Astronomer Royal, 1693-1762)
- 1728: 'Aberration of Light'
- Incontrovertible proof for Earth's revolution around Sun (Copernicus was right!)

Serendipity: Bradley's Discovery of Aberration



- Apparent stellar positions are shifted because of Earth's motion around Sun!

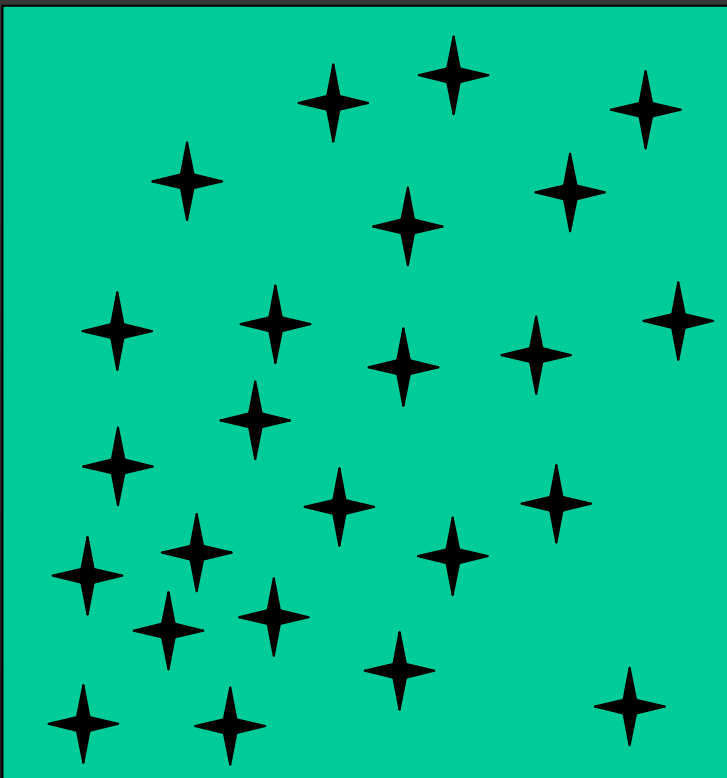
Serendipity: Bradley's Discovery of Aberration



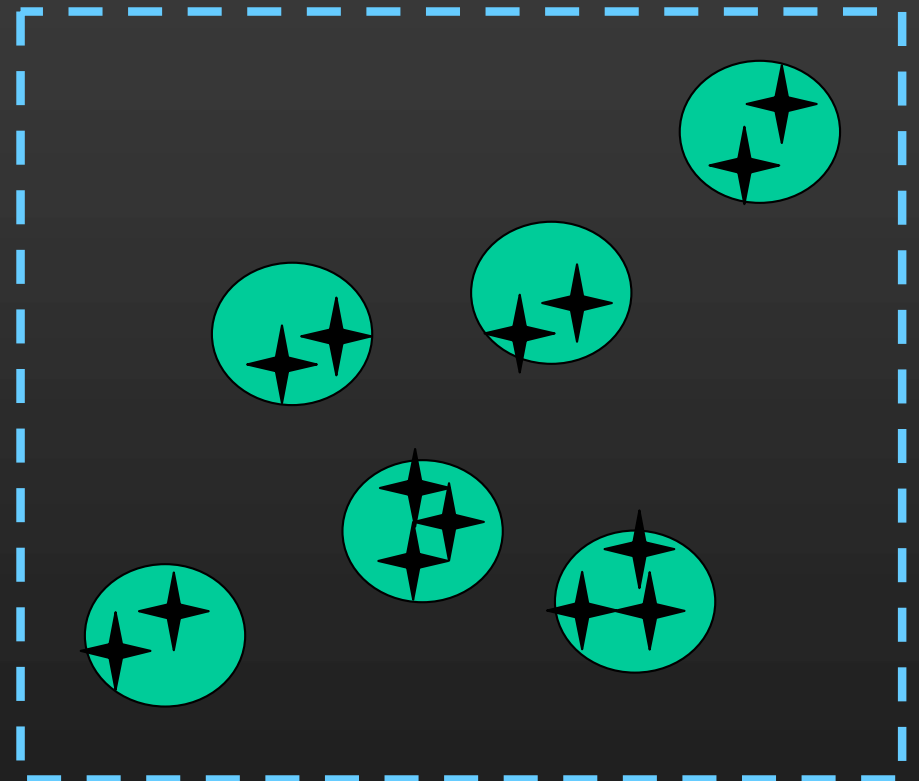
- Apparent stellar positions are shifted because of Earth's motion around Sun!

Q: How are Stars distributed in infinite Space?

- Stars are in motion, but what is architecture of stellar system?



OR



Explaining the Milky Way!



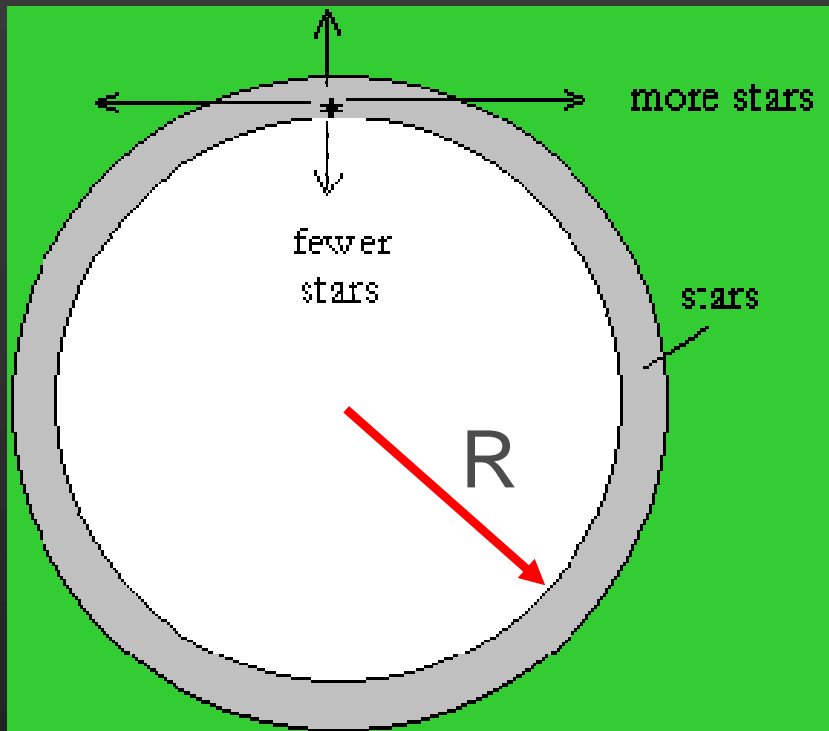
- Thomas Wright of Durham (1711-86)
- *An Original Theory of the Universe* (1750)
- Concept of Milky Way as a 'Galaxy' (distinct system of countless stars)

Wright Explains the Milky Way!

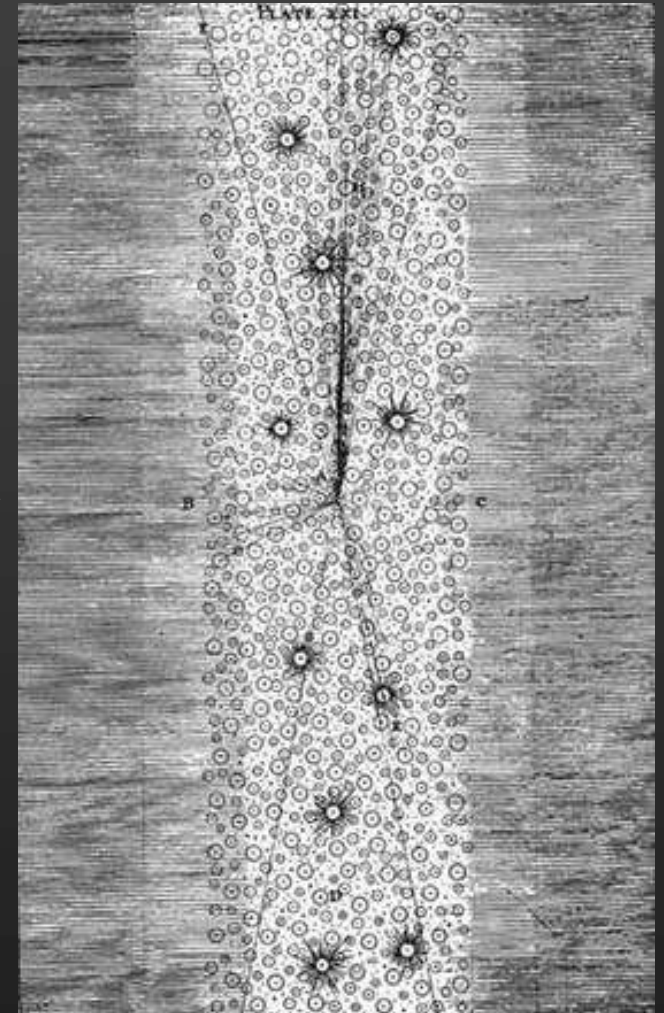


Outer Darkness

Wright Explains the Milky Way!



Very large R



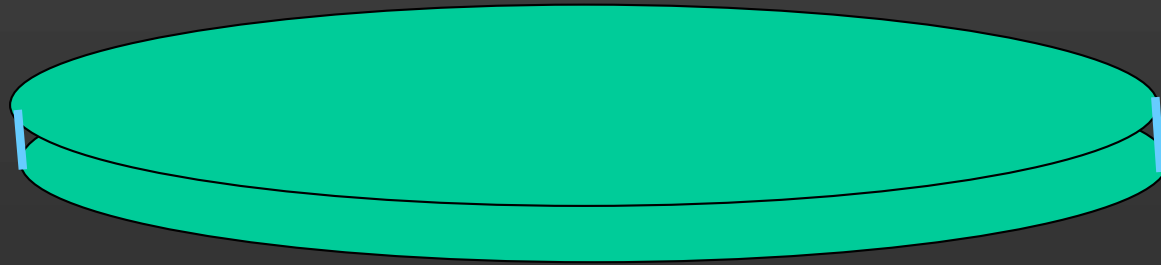
- a disc-like appearance (like observed band of MW)!

Enlightenment Philosophy

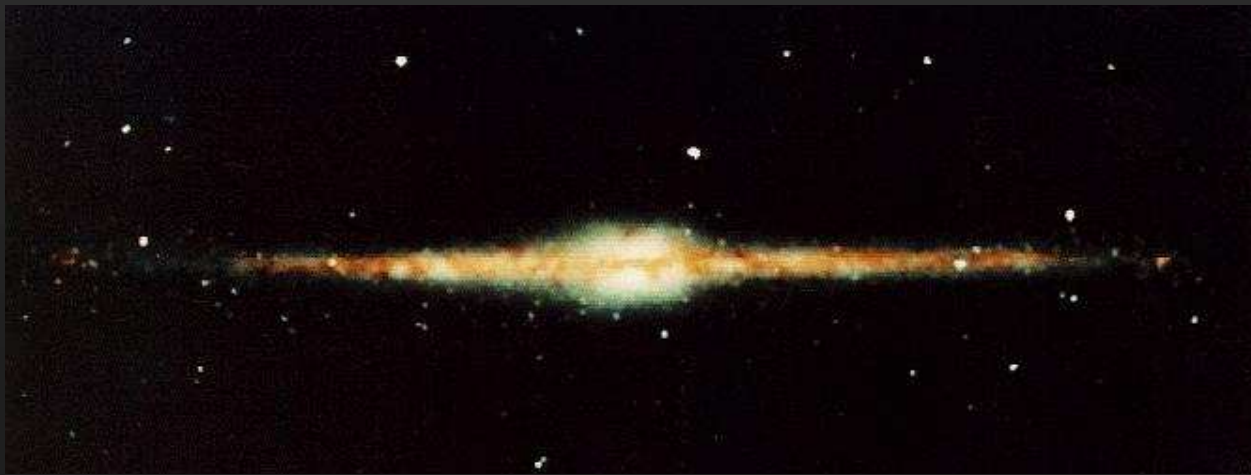


- Immanuel Kant (1724-1804)
- *Critique of Pure Reason* (1781):
 - Big Q: What can we know?
- *Theory of the Heavens* (1755):
 - “Island Universes” (galaxies)

Kant Postulates Disc-like Milky Way!



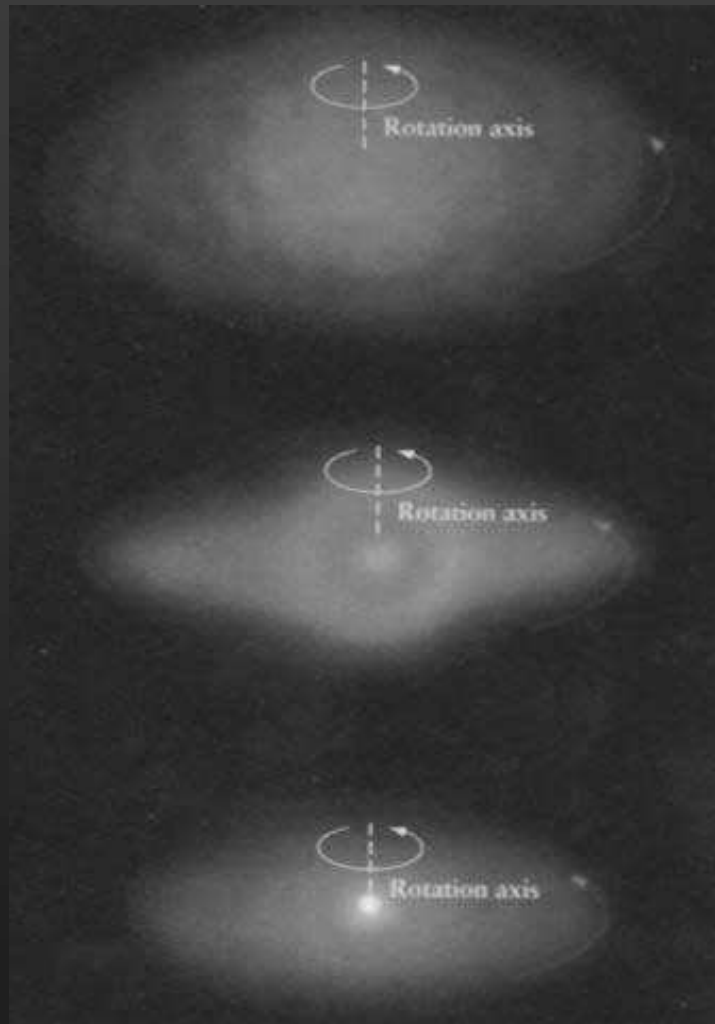
- basically correct picture for our Milky Way!



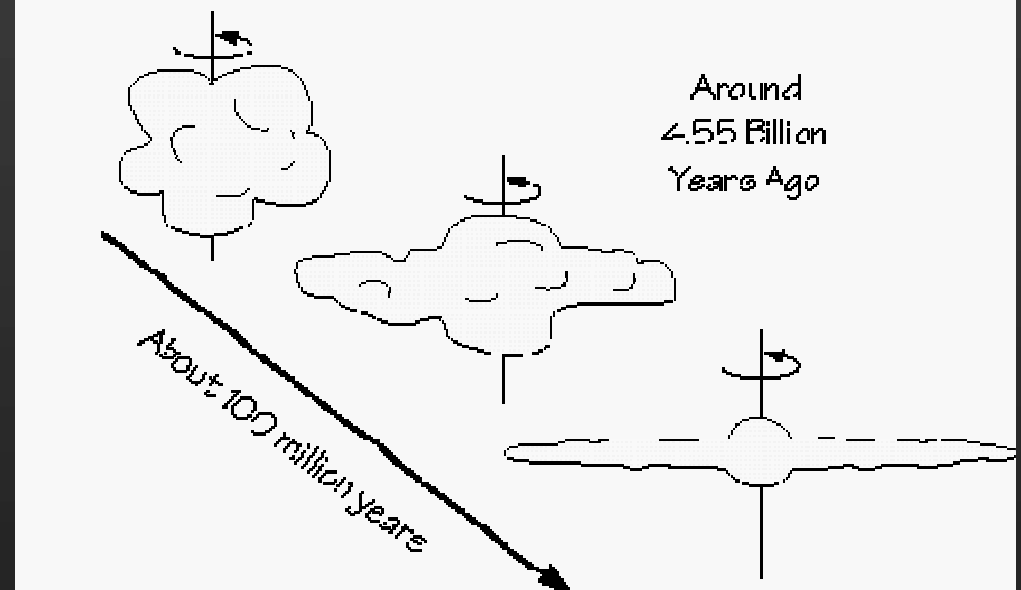
- direct proof:
COBE, 1993
(infrared
picture)

Kant's Cosmogony:

Formation of disc-like systems!

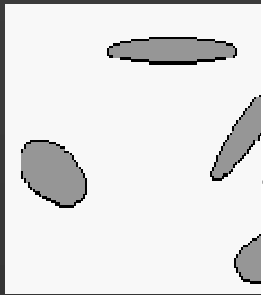


■ The Solar System coalesced from a rotating gas cloud formed during a supernova.

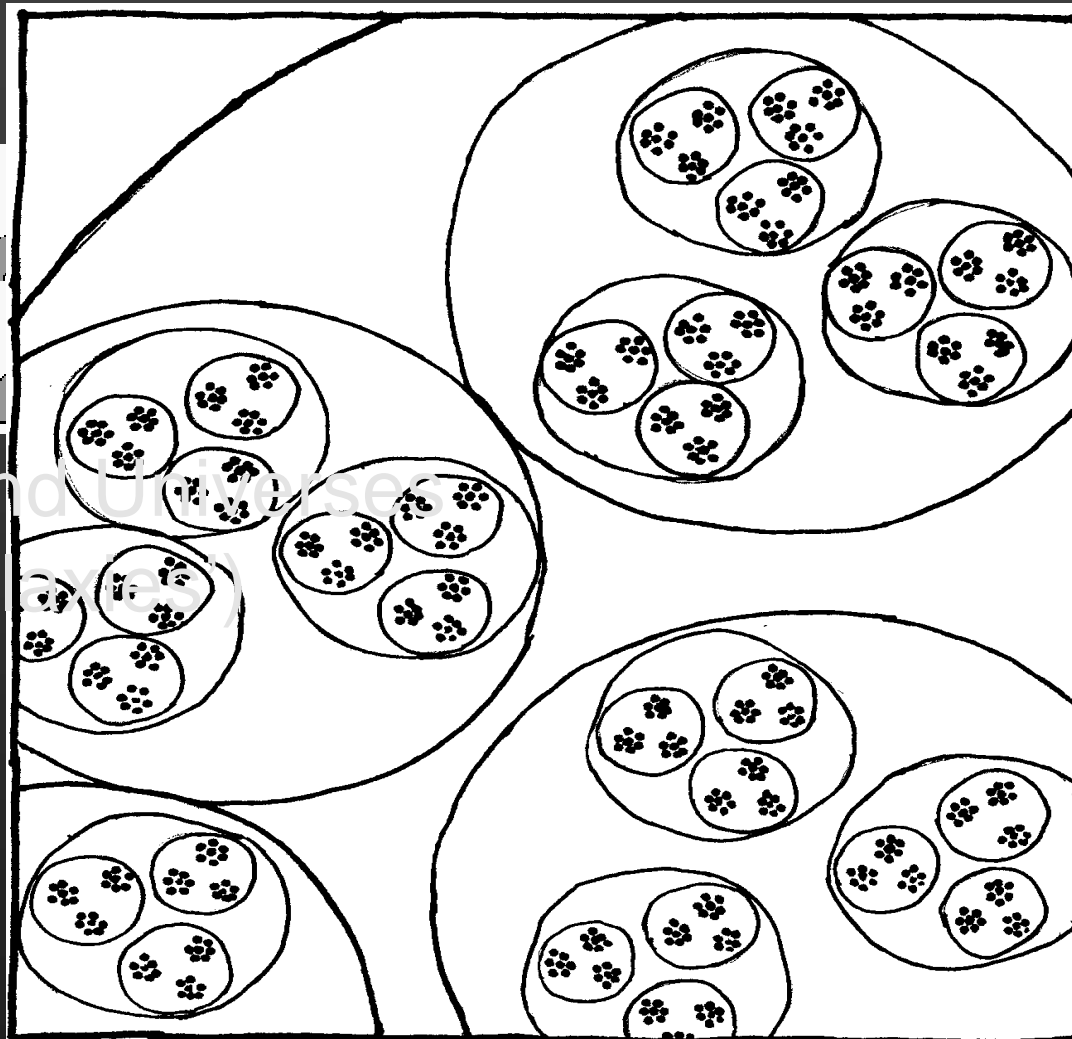


- Kant-Laplace hypothesis!

Kant's Hierarchy of Worlds



Island Universes
(galaxies)



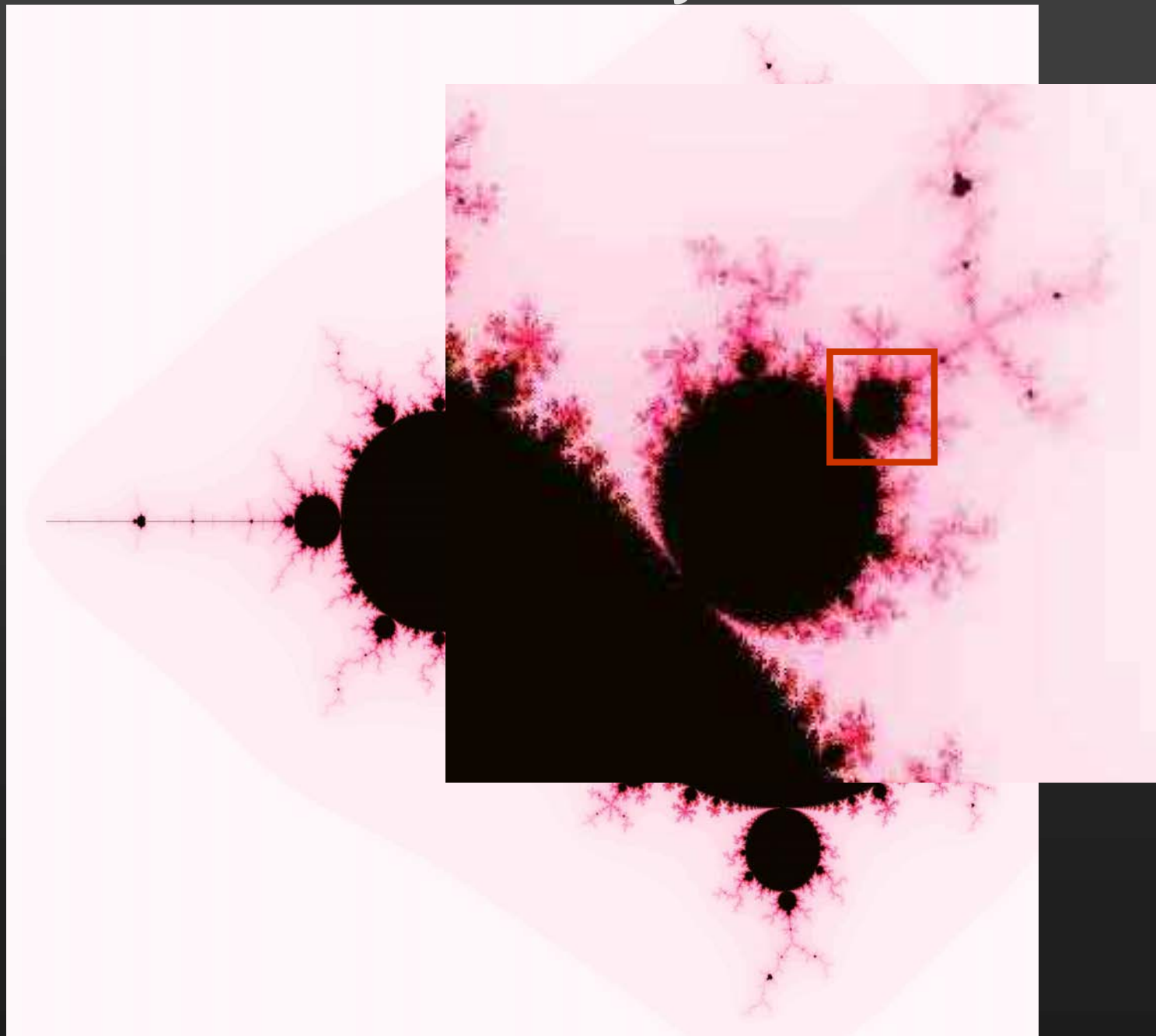
- Systems of systems
- a fractal universe!

The Fractal Geometry of Nature



- Benoit Mandelbrot
- Fractal: self-similarity

The Fractal Geometry of Nature



Enlightenment Philosophy



- Pierre-Simon de Laplace
(1749-1827)
- *Exposition de System du Monde*
(1796)
- **Laplace Demon:**
 - a being endowed with unlimited capability to compute
 - would be able to predict everything in past, present, and future
 - a completely deterministic universe!

Enlightenment Astronomy



- William Herschel (1738-1822)
- **Discovery of Uranus (1781):**
 - First planet not known in Antiquity
- **Greatest telescope-builder of the age**
- ***On the Construction of the Heavens* (1785):**
 - star counts à Map of the Milky Way

Herschel: From Musician to Astronomer



Section of the New Octagon Chappel at Bath

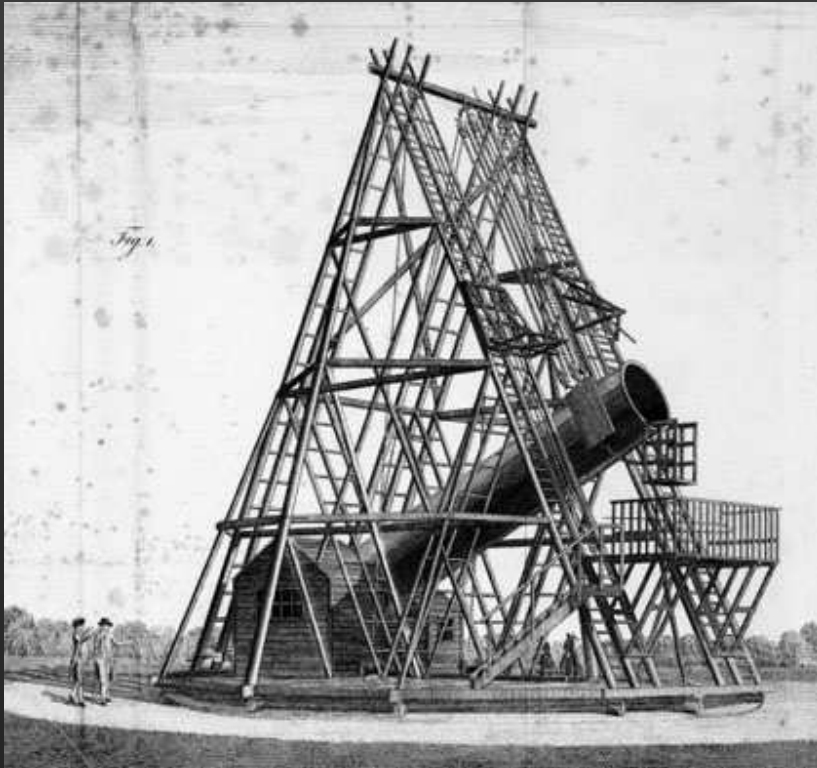
Organist in Bath (1766-82)



- Composer, conductor, oboist, organist

→ At age 35, Herschel turns to astronomy!

Herschel: Greatest Telescope-builder of the Age



40-foot reflector



Card (1750-1848)

Herschel: Discovery of Uranus (1781)



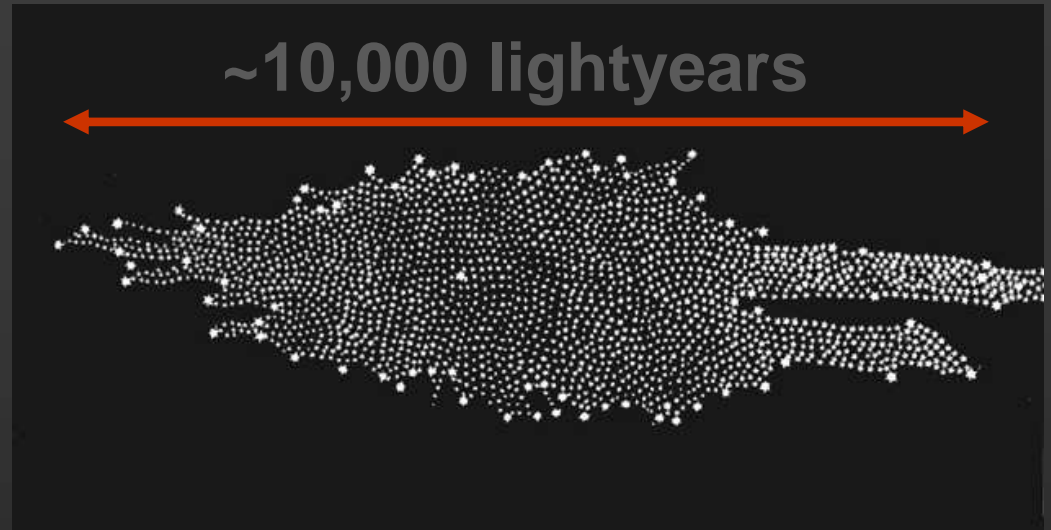
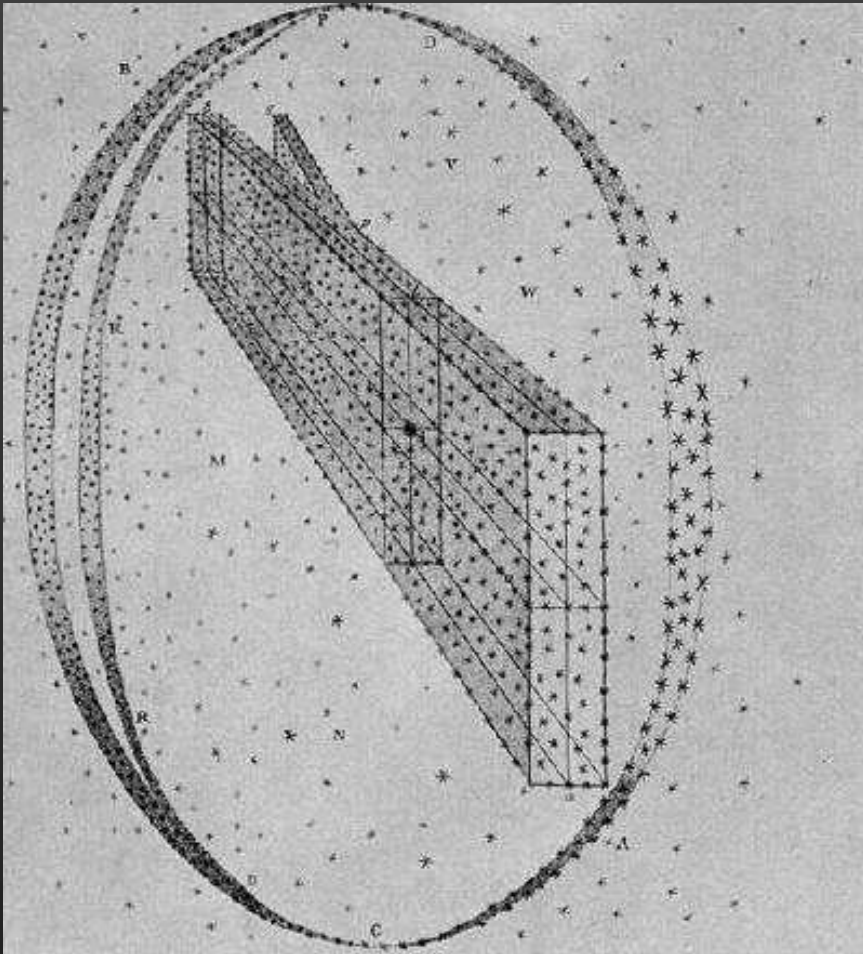
7-foot reflector



Voyager 2 (1986)

- First planet not known to the Ancients already!

Herschel: Mapping the Milky Way



Shape of Milky Way Galaxy

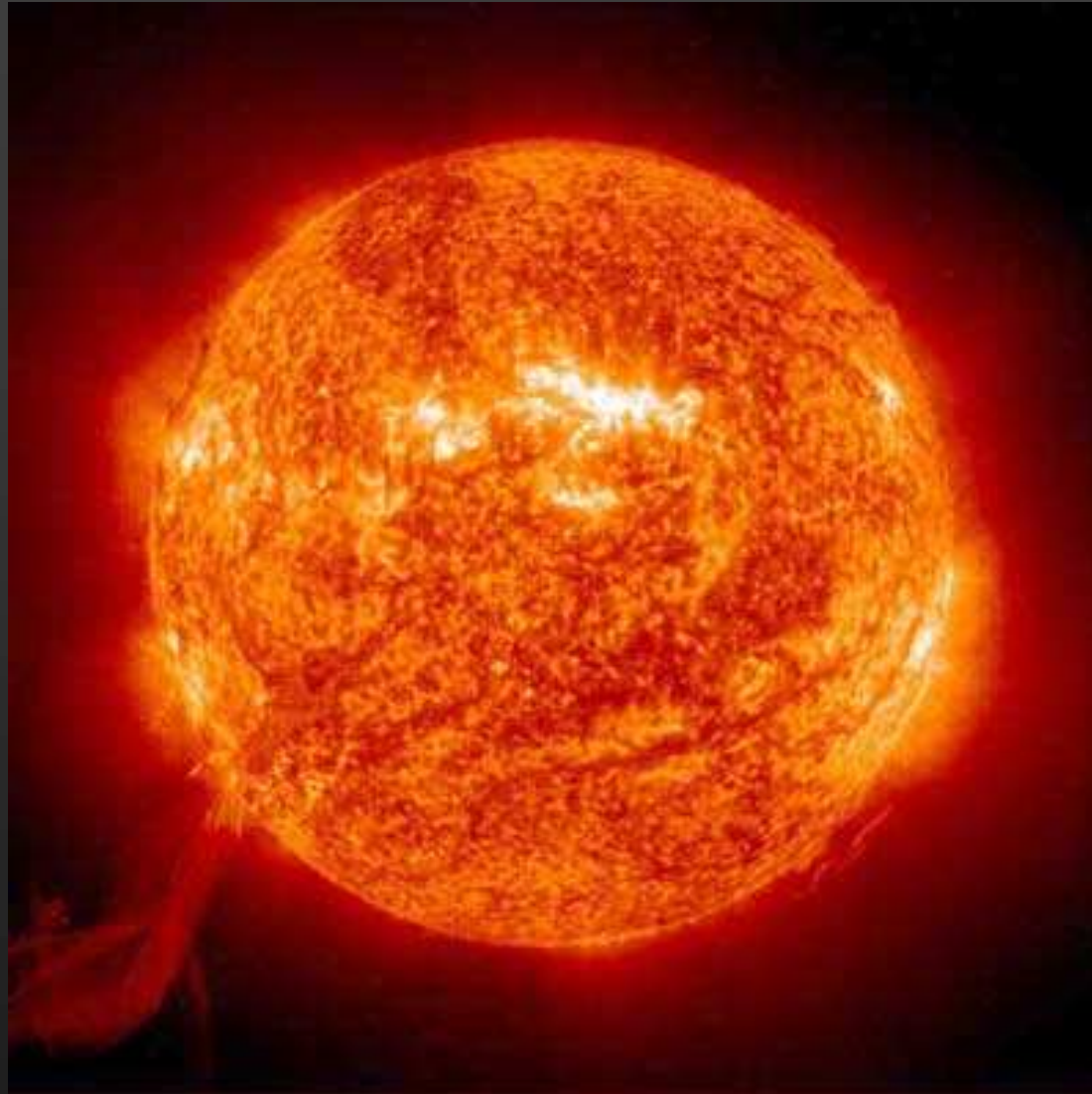
- Using star counts to estimate distance to the edge of Milky Way

Herschel: Discovery of Infrared Radiation (1800)



- Use prism to disperse sunlight into spectrum (blue-green-yellow-red)
- Place thermometer at “empty” place beyond red
- Detect heat there
 - à there must exist energy (radiation) beyond red
 - = Infrared

Great Task Ahead: What *are* the Stars?



- still unsolved: Need better physics and chemistry!

Enlightenment Astronomy (Kant/Herschel)

- First promising explanations for stellar architecture:
 - Milky Way
 - an infinite system of 'island universes' (galaxies)
 - maybe universe is a fractal (infinite regression of worlds)?
 - no incontrovertible proof yet: need stellar distances!
- Proof Earth's motion around Sun:
 - Bradley's 'aberration of starlight'
- A mechanistic (clockwork) universe
 - Laplace's Demon
 - a fully deterministic universe