

10/10: corrections on slide 9, 10 & 37

Atoms and Stars IST 2420 and IST 1990

Class #7: October 19 and 24

Fall 2005 sections 001, 005, 010 and 981

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Tonight

- Handouts
 - Class 7 Notes
 - Revised Lab 3 Part II
- Initial the sign-in sheet
- Review of names
- Due:
 - Lab 8 Report
- Review for Midterm, last hour tonight
- Midterm next week, first hour in class

Disproving “nature abhors...”

- The definitive experiment disproving Aristotle’s “nature abhors a vacuum” was getting a vacuum in a tube of Mercury taller than 30 inches – now *there* is a vacuum
 - Pascal reserved this honor for tube on a mountain
- We did not disprove this here
 - Safety problems with Mercury

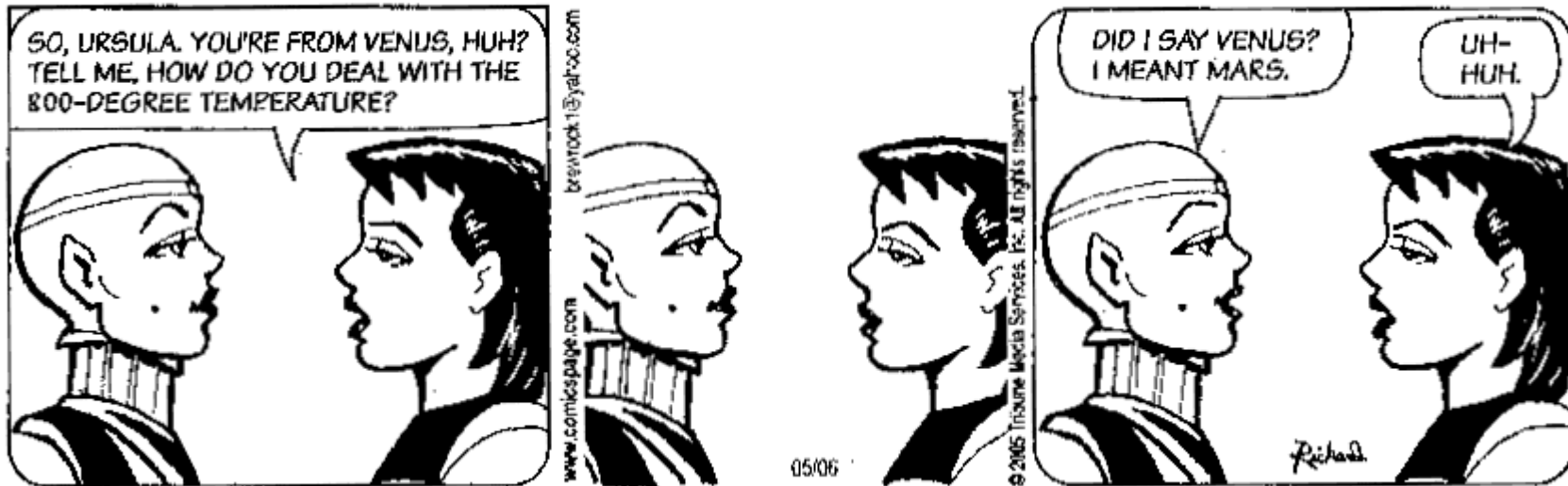
Life on Other Planets?

- Life like us?
 - May be alternate forms, but we haven't come up with any
- Deep space empty, cold, dark.
 - Life would need self-contained energy, light, materials
- Stars have energy, but temperatures are millions of degrees, much too hot

Life on Other Planets?

- So focus on planets
- In our solar system, no good candidates except Earth
 - Closer ones too hot

BREWSTER ROCKIT: SPACE GUY! By Tim Rickard



Life on Other Planets?

- So focus on planets
- In our solar system, no good candidates except Earth
 - Further ones too cold
 - Mars the best other possibility
 - Current search is for water on Mars
 - We may find microscopic life, or its remains
 - Moons too small to have atmospheres

Life on Other Planets?

- Planets around other stars?
- We are finding other stars with planets
 - Present techniques best for planets close to star
 - So far, too close to star, too hot
 - If planets around other stars are common, maybe there will be some planets with the right conditions, and maybe some of them will have life

Life on Other Planets?

- Our other approach is to look for radio signals
 - SETI: Search for Extraterrestrial Intelligence
 - Distances mean powerful signals, imply a much more advanced civilization than ours
 - Long distances imply radio waves started long ago if they reach us now, would be even more advanced
- Aliens visiting earth not supported in mainstream science

Solar System Examples

- ~~Helio~~^{Geo}centric example (Sun, other planets and our Moon revolve around central Earth):
 - Example: Ptolemy
 - Earth actually not thought of as a planet
- ~~Geo~~^{Helio}centric (Moon revolves around Earth, Earth and other planets revolved around central Sun)
 - Example: Copernicus

Why does sun rise and set?

Geo

- ~~Heliocentric~~:

- Sun carried on a sphere, rotates around earth

- ~~Geocentric~~ (more modern):

Helio

- Earth rotates under sun

- Night when we face away from sun

- Noon when we face towards sun

- Sunrise and sunset about halfway in between

Robert Boyle #1

- In “The Development of the Concept of Atmospheric Pressure”:
 - o Robert Boyle (1627 – 1691) in 1657 followed 1654 von Guericke, vacuum pump and Magdeburg spheres
 - o Put Torricellian barometer (column of Mercury) in a vacuum pump and pumped
 - o Level of mercury column fell

Robert Boyle #2

- (not in Readings) 1662 Boyle published what is now known as Boyle's Law:
 - At a constant temperature, the volume of a gas is inversely proportional to its pressure
 - Gas is “springy” – today used in gas struts in cars to hold up hatches
 - Easier version: Pressure \times Volume at one time = Pressure \times Volume at other times (earlier and later), if temperature does not change

Boyle's Law Examples #1

- Mathematically: $P_1 \times V_1 = P_2 \times V_2$
- Problem: given any three of P_1 , V_1 , P_2 , V_2 , find the fourth
- Method:
 1. Substitute given values into Boyle's Law
 2. Do multiplication of two on same side
 3. Use division to get unknown by itself
 4. Do division to yield answer

Boyle's Law Examples #2

- Example 1: A gas with pressure = 30” of Mercury and a volume of 20 cubic inches is expanded to 30 cubic inches at the same temperature. What is its new pressure?
 - $P_1 \times V_1 = P_2 \times V_2$ (insert numbers)
 - $30 \times 20 = P_2 \times 30$ (multiply out)
 - $600 = P_2 \times 30$ (now divide by 30)
 - $P_2 = 600 / 30 = 20$ (“ of Mercury)

Boyle's Law Examples #3

- Example 2: A gas with pressure = 15” of Mercury and a volume of 200 cubic feet is compressed to a pressure of 30” of Mercury. What is its new volume?
 - $P_1 \times V_1 = P_2 \times V_2$ (insert numbers)
 - ...
 - ...
 - ...

Boyle's Law

- Boyle's Law is an example of “the new Physics”
- Makes specific mathematical predictions
- Exhibits mathematical regularities in nature
- (Modern changes:
 - Correct when atoms in gas are far apart
 - Pressures higher than this when atoms close)

Review of Reading

“Copernicus Incites a Revolution”

- Scientific Revolution ~ 1700 not just a change in content
 - Change in methods (experiments)
 - Also new: idea of utility (usefulness)
 - Changes in social and institutional arrangements
- 15th & 16th centuries – a broad background in exploration, technology (including Gutenberg and printing), arts, the occult, new religions

“Copernicus Incites a Revolution”

- Europeans formerly knew Greeks from Arabic translations, translated again
 - Now, new direct translations
 - New sources, e.g. Archimedes
- Italian Renaissance –art, poetry
 - Medicine – William Harvey and circulation of the blood
- Also magic, occult or secret knowledge

“Copernicus Incites a Revolution”

- Protestant Reformation
 - Challenge to Catholic church
 - 1517 Luther’s Ninety-Five Theses nailed to door of cathedral in Wittenberg, to end of Thirty Years’ (religious) War in 1648
- Calendar reform: problem of Julian calendar (364 days plus leap years) – errors of ten minutes/year accumulated to 10 days

Copernicus

- Retrograde motion a problem for geocentrism
- Copernicus 1473 – 1543
- Current astronomical model of solar system was Ptolemaic (Ptolemy), geocentric (“geo” = earth), Aristotelian
 - Very cumbersome (slide 34 from Class 3 next)

Slide 34 from Class 3

- Hellenistic Period (after 323 BC)

- o Ptolemy (2nd cent AD) used new tools to simplify geocentric model of heavens

- Epicycle (small sphere moved on larger sphere, planet on small sphere)
 - Eccentrics (circle displaced from earth)
 - Equant – point from which planet appeared to move at constant speed

- Almagest – manual of Astronomy

Copernicus

- 1514 privately circulated idea of heliocentrism (“helio” = sun)
- 1543 full theory just before death in De revolutionibus orbium coelestium
(Concerning the revolutions of the heavenly spheres)
- His intent was to preserve Greek ideas of perfection and circular motion

Copernicus

- Retrograde motion was natural in heliocentrism – relative motion of planets
- Earth rotated on axis once per day, circled sun once per year
- But earth carried on solid crystalline sphere, axis would move with it, so he introduced a third motion to keep axis pointed towards north star

Copernicus

- Objects fall to center of earth, not center of universe
- We do not spin off of earth because we share its motion
- No equants but epicycles and eccentrics

Copernicus

- Objections
 - Not a big simplification over Ptolemy
 - Said stars far away, to explain lack of observed parallax of stars: unsatisfactory
 - Falling bodies have no observed falling behind as earth turns under them
 - Religious objections surfaced after Galileo
- 1582 led to Gregorian calendar – no leap years for centuries unless divisible by 4

Tycho Brahe

- 1546 – 1601 Tycho Brahe
- Danish nobleman and astronomer
- Built great observatories on his island
- Fights, duels, possibly died from being drunk, but also careful astronomical measurements
- Convinced astronomy needed good measurements

Tycho Brahe

- Naked-eye instruments shielded from wind, kept temperature stable, studied and corrected for errors including atmosphere
- Accurate to 5 – 10 seconds of arc, sometimes, never worse than 4 minutes
- Also systematic, over years

Tycho Brahe

- November 11, 1572: saw extremely bright new object, parallax measurements showed it to be outside of solar system. Lasted for three months.
 - Heavens not unchanging
- Comet of 1577, parallax measurements showed comet cut through crystalline spheres. They were not real.

Tycho Brahe

- Rejected Copernicus because no observed stellar parallax
- Also rejected rotation of earth because cannon fired west should travel further
- Tycho's system: geocentric but sun revolves around earth, other planets rotate around sun
 - o Simpler, accurate, no spheres

Johannes Kepler

- 1571 – 1630 Johannes Kepler
- Obsessed with numerology, mysticism, astrology
- At first convinced planets fell in orbits determined by five regular solids
- During counter-Reformation, refused Catholicism, became Brahe's assistant

Johannes Kepler

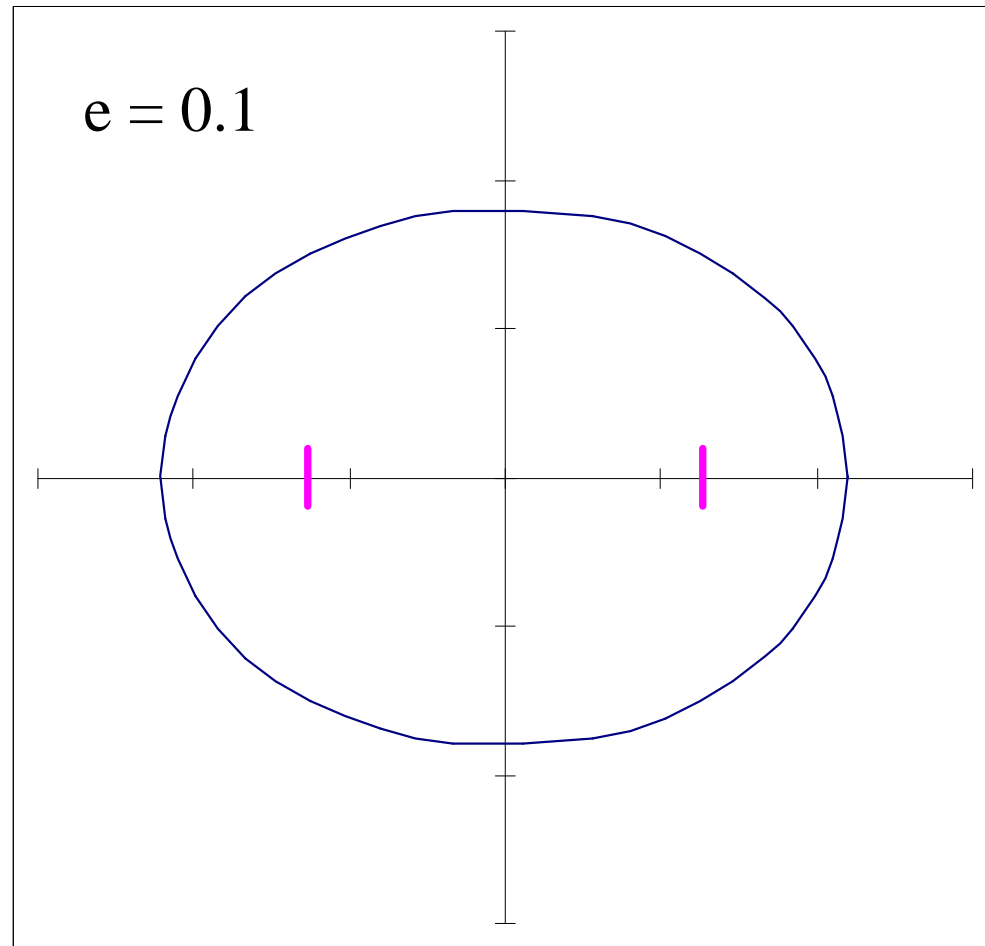
- Assigned eccentric orbit of Mars
- Six-year heroic effort, errors on top of errors, restarting, blind alleys
- Achieved accuracy within 8 minutes of arc, but Brahe's observations good to 4
- Became convinced Mars traveled in ellipse, not circle

Johannes Kepler

- Three laws of planetary motion
 - o First two 1609 Astronomia Nova (New Astronomy), third buried in Harmonice mundi (Harmonies of the world) 1619
 1. Planetary orbits are ellipses with sun at one focus
 2. Equal areas in equal times
 3. $t^2 \propto r^3$ (period squared proportional to radius cubed)
 - o Unsatisfactory explanations for these laws
 - o Not well received, rejected for the most part

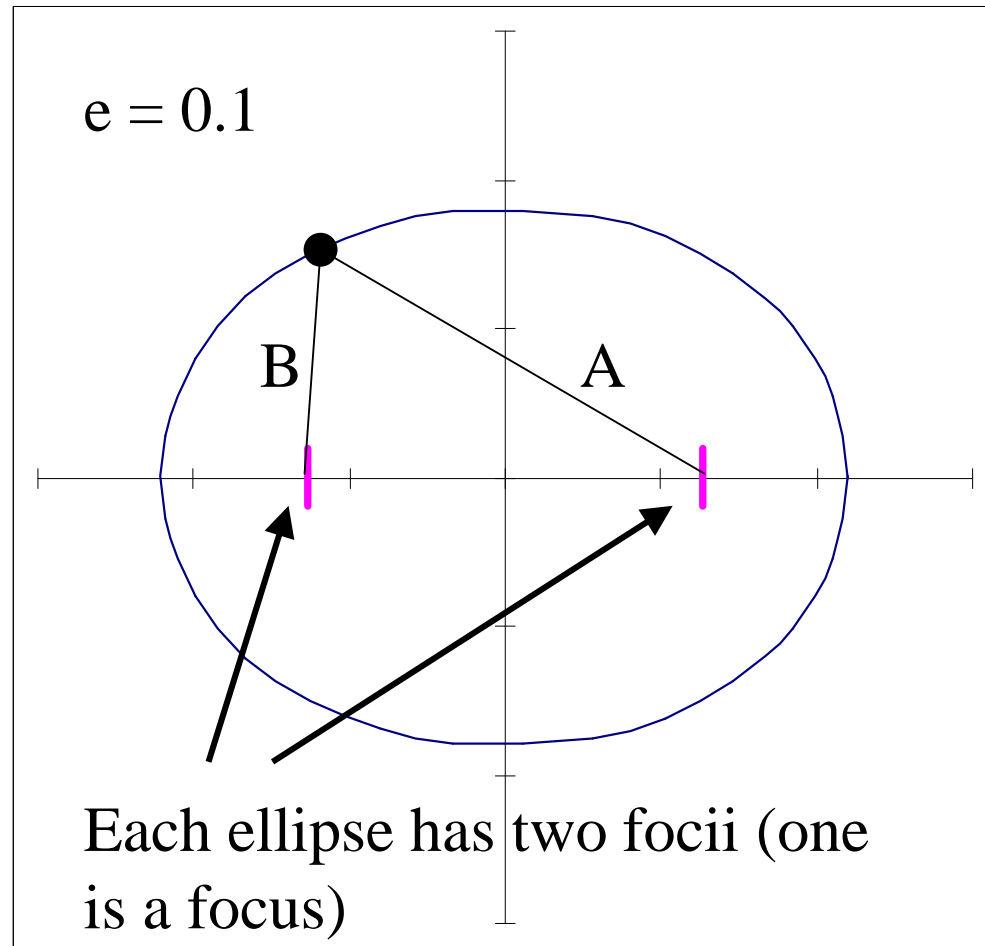
Ellipse

- Eccentricity (e)
 - how much different than a circle?
 - $e = 0$, perfect circle
 - Circle more flattened as e larger than 1



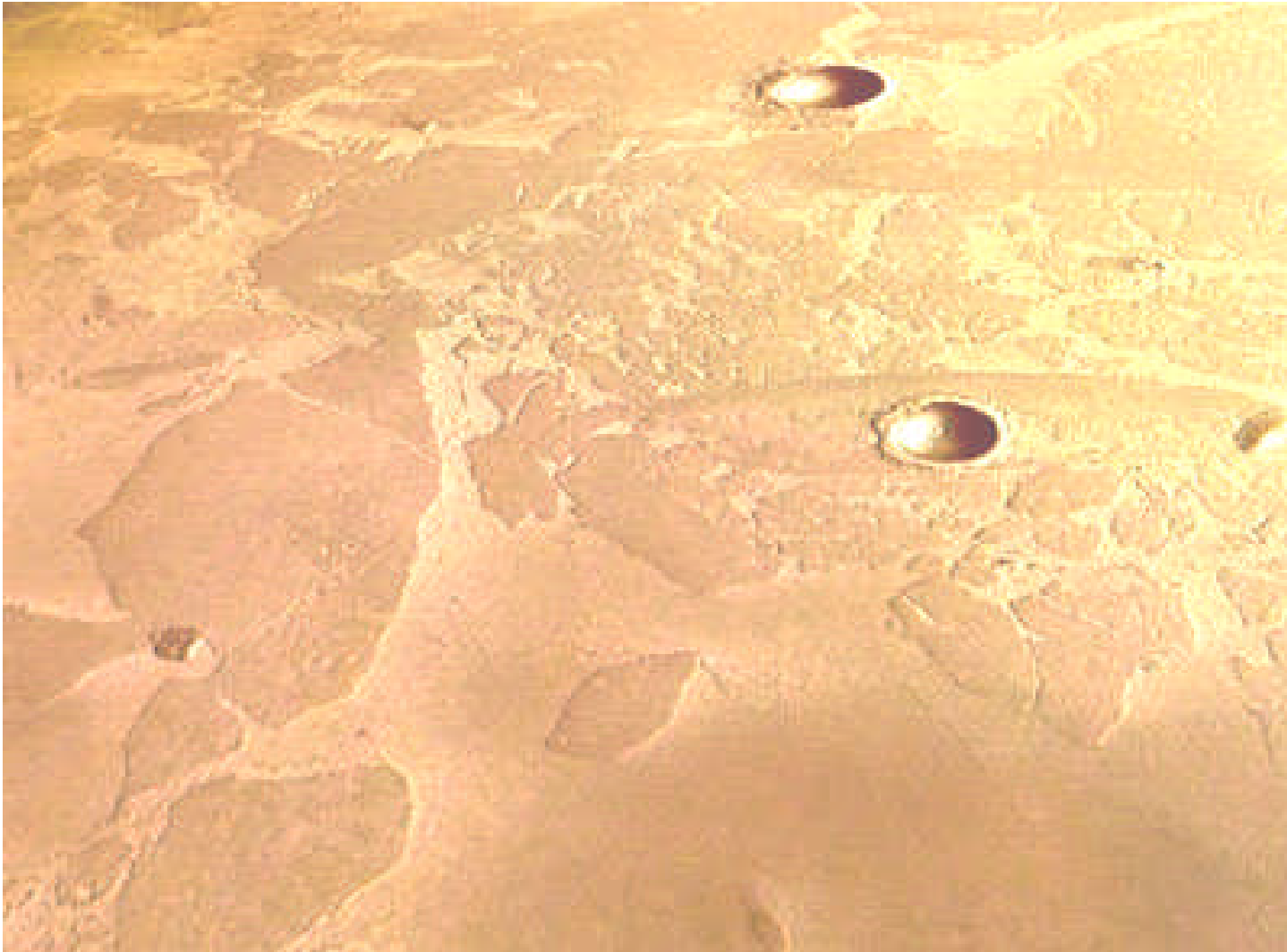
Ellipse

- Focus
 - $A + B =$
same for
each point on
ellipse
 - Circle: the
two foci
coincide,
distance is
radius



“The Planet Mars and Kepler’s Three Laws of Planetary Motion”

- “My Very Excellent Mother Just Sent Us Nine Pizzas” – planets and their order out from the sun
- Mars a special case for Kepler, for mankind too – life on Mars?
- Illusory “canals” on Mars, “War of the Worlds”
- Recent indications of water, “Mars Express” (next slide). Life there?



A dust-covered frozen sea?

10/16/05

Atoms & Stars #7 (10/19 & 10/24)

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“The Planet Mars and Kepler’s Three Laws of Planetary Motion”

- Mars (and other planets) get brighter and dimmer
 - In ~~heliocentric~~ ^{geo} theory, hard to explain this
 - Natural in ~~geocentric~~ – closer and further to us
- Kepler’s three laws: ^{helio}
 1. Planetary orbits are ellipses, sun at one focus
 2. Planet sweeps out equal areas in equal times
 3. $T^2 \propto R^3$ (\propto means “is proportional to”)
 - Period T (length of year), mean radius R

A Common Sequence

- Brahe → Kepler → Newton
- Accurate measurements → “empirical” theory (little explanatory power, descriptive only) → explanatory theory

A Common Sequence

- Reader says Physics has no explanation for gravity
 - Modern Physics does have explanations

“The Watershed”

Arthur Koestler, from The Watershed (1959)
biography of Johannes Kepler

- As noted in Introduction, an unvarnished view of how science comes into being, from Kepler’s own writings

The Watershed

Chapter 1: “The Young Kepler”

- K always precise (time of own conception)
- Born 1571 in Weil, Germany, still a hero
- Grandfather was the mayor, but family in decline
 - Age 26, K described them as bad or dead
- Father and mother ran off, father exiled

The Watershed

- Mother not much better
- Six siblings, three lived, two normal, brother Heinrich sickly, fired, died at home
- K himself put out to work, delayed in school, sickly, accidents
- Saw comet 1577, moon's eclipse at nine yrs
- Excellent educational system, clerical track

The Watershed

- Miserable and lonely in school, quarrels
- Extreme self-criticism at 26, but productive
- Often defended Copernicus, “first motion”
- Became “mathematicus” at Gratz before graduation
- In teaching, always off in new directions
- Lucky astrological table made him popular
 - o Love-hate relationship with astrology

The Watershed

Chapter 2: The “Cosmic Mystery”

- 1595 in class felt orbits of planets determined by geometrical shapes – five regular solids
 - False, but motivated him throughout life
- Pp 91& 182: pictures of Brahe’s instruments and observatories

The Watershed

Chapter 3: Tycho and Kepler

- Brahe old, needed Kepler to make sense of observations
- Kepler's draft of a contract with Brahe
 - o Stormy relationship, leaving and returning, Brahe magnanimous, Kepler mean-spirited
 - o Kepler could be forced back to Styria where Protestants were being persecuted

The Watershed

- Kepler had to drag data out of Brahe
- Exiled as Protestant from Gratz, returned to Brahe
- 1601 Brahe died, wanting Kepler to prove Brahe's model of solar system
- Emperor appointed Kepler as his successor "imperial mathematicus"

Assignments 2420

- Next week:
 - Midterm (first hour)
 - No assignment in Reader – prepare for Midterm
 - Lab
 - Experiment 3 Part II (new handout tonight)
 - Experiment 8 Part II

Moodlers (POL & 1990)

- See “SUCCESS” on course web site

2420 POL

- Summaries
- Average two postings per week
 - Try answering the Exam questions!!!
 - Get me on record in writing
 - Rehearsal – the best way to study

IST 1990

- Essay 1 due on Moodle (see “19 October - 25 October” , “Science and Religion: Essay 1”)
- Reading – see Syllabus
- On the course web site:
 - Essay topics for all three essays
 - Notes on IST 1990 books
- Postings every week
 - Two credits: average one per week
 - Four credits: average two per week
- Four credit: extra readings online: PW = “apple”

Review for Midterm