Atoms and Stars
IST 2420
and IST 1990

Class 5

Winter 2006

Instructor: David Bowen

Course web site: www.is.wayne.edu/drbowen/aasw06
IST 1990 Moodle: techtools.culma.wayne.edu/moodle

Handouts & Announcements

- Class 5 Notes
- Initial the sign in sheet

Due tonight

- Essay 1, on a 3½” diskette
- Report for Lab 3 Part 2

Online Grade Reports (repeat)

- See your line in my grade book
- Disabled by default – turn in form if you want this (you should want this)
  - Check to enable and write a password
- Demo
- Later
  - Will have averages, projected grade
  - How to make up each assignment
- www.is.wayne.edu/drbowen/aasw06

Overview

- Typical sequence of advance (“focus” comes first and is assumed here) Q28:
  - Observation / Measurement
  - Description
  - Understanding (theory)
    - Often this is first association (statistical) then causal
  - Control or technology (especially last 50 years)
- Science is progressive: Q20
  - Start in small area, expand

EAA Grades:

- -H: deficient in homework
- -L: deficient in lab work
- -E: deficient in exams and/or quizzes
- -T: deficient in attendance
- Can be doubled up, e.g. –LT
- ---: three or more problems
- These are the online grades, but they get spelled out in letter (email?)

Overview

- Science is progressive (cont'd)
  - Later theory / experiment can change earlier theory
    - Example: Einstein's 1915 General Theory of Relativity changed ideas about his 1905 Theory of Special Relativity
    - However, old results still correct but range extended
  - Scientific knowledge provisional – subject to change

Overview

- Science is progressive (cont'd)
  - Scientific knowledge can change rapidly at the frontier
    - Later experiments can show errors in the first ones
    - Extending theory beyond data can introduce errors
  - Science is sometimes called aggressive
    - Keeps pushing into new areas
  - Science always has a boundary, but it keeps expanding
    - Not a complete basis for your life (so far)

Overview

- Science is not:
  - Fair – theories do not have a right to be considered – someone must want to do this
  - Democratic – no votes, nor formal consensus, theories can come “back to life” (string theory)
  - Not based on authority – Newton and Einstein can be (were) wrong

Overview

- Most scientists follow these rules but (with many scientists) there are many individual exceptions (continued)
  - Science is social – scientists help & check each other Q23
  - Scientific arguments can be fierce
    - Issue about women and aggressive argument
    - Our heroes – the people who overthrew the established order
    - Instant success: prove someone else wrong
  - Scientists often become advocates of a theory
    - Social interaction corrects this

Science and Industry

- Scientific method not followed in recent drug-company controversies (e.g. Vioxx)
- Conditions in industry are indeed different
  - Data and internal theories are proprietary (trade secrets)
  - Executives have authority
  - Decisions are made, and are to be followed
  - Executives often do not get bad news
- So yes, scientific method often not strictly followed in business and industry

Overview

- Scientists are skeptical about truth claims
  - Many strongly-held beliefs have been shown to be wrong, e.g. common ideas about space
  - Many purely rational arguments have been shown to be wrong – e.g. Aristotle
  - Experiments keep science correct and reliable

Why do scientists change their minds?

- While focus is being studied, new facts arise, hypotheses must be changed
  - At the boundary, experiments and theories are changing
- At some point, tests are made, focus moves on
  - For example, no change in Kinetic Theory of Heat for about 200 years

Readings: “Motions in the Solar System”

- Motions in sky known to all civilizations
- Constellation: groups of stars, pattern invariant over human lifetime
  - 88 total constellations, Zodiac is 12 of these
- Angular measurement
  - Degrees: 360° = circle (horizon), 90º horizon to pole. Fist at arm’s length ~ 10°, finger ~ 1º
  - Minute ('): 60' = 1°
  - Second ("): 60" = 60'

“Motions in the Solar System”

- Stars circle around pole (Pg 97)
  - All rotate together (seemingly) as if on a sphere
  - (Really, earth is turning underneath stars)
  - 360º in 24 hrs = 15º/hr
- Also move annually relative to sun
- Five visible planets Mercury, Venus, Mars, Jupiter, Saturn move with respect to stars
  - Uranus, Neptune, Pluto require telescope

“Motions in the Solar System”

- Planets move through stars west to east like sun and moon, but periodically reverse or retrograde motion
  - Mercury, Venus stay close to sun (morning & evening stars)
    - Retrograde when close to but farthest east of sun, reappear west of sun
  - Mars, Jupiter, Saturn roam with respect to sun
    - Retrograde when opposite sun

“Motions in the Solar System”

- Sun
  - Highest in sky at Summer Solstice (~June 21, most daylight)
  - Lowest at Winter Solstice (~December 21, longest night)
  - In between Spring and Vernal (Fall) Equinoxes – equal day and night
  - Reversed in Southern Hemisphere
  - Also moves east with respect to stars

“Motions in the Solar System”

- Sun
  - As sun moves through stars, traces plane called “ecliptic”
  - Moves through 12 constellations of Zodiac

“Motions in the Solar System”

- Moon
  - Rises in east, sets in west like sun
  - Also moves to the east with respect to stars
  - New moon – moon between earth and sun
  - Full moon – earth between sun and moon
- Eclipses
  - Moon eclipses sun, orbit tilted so rare
  - Lunar eclipse when earth’s shadow hides full moon

Retrograde Motion #1

- Retrograde: moving or directed backwards
  - Backwards motions of planets – a problem for Aristotelian astronomy.
    - Celestial (heavenly) domain is perfect
    - Perfectly circular motion, but retrograde motion didn't fit in
    - Normally counter-clockwise from above north pole
    - All planets exhibited this sometimes
    - Plato's theory had extra spheres and features to handle retrograde motion

Retrograde Motion #2

- Retrograde: moving or directed backwards
  - o “Fixed” stars – most celestial objects (stars) rotate together, today called fixed
    - Now we see they really do move, just very slowly
  - o Planet: Greek for “wanderer” – wandered among fixed stars
  - o Motion actually very regular
  - o Wander through astrological constellations

Retrograde Motion #3

- Objects and orbits in solar system close to the same plane
  - Also close to the plane of our galaxy
  - Milky Way is looking out into the plane of our galaxy – we are in it so we see Milky Way 360º
- Computer demo: Retrograde Motion
  - Click "Model," stop at "COPERNICUS"
  - Click on "Months,"
  - See "Notes" at bottom of screen to explain what you see
  - Top strip is view from earth to object (e.g. Sun)
    - Imagine strip wrapped around in back of your head
    - Background is astrological constellations (e.g. Pisces)
  - Right-to-left normal, reverse/pause is **retrograde**

New “planets”

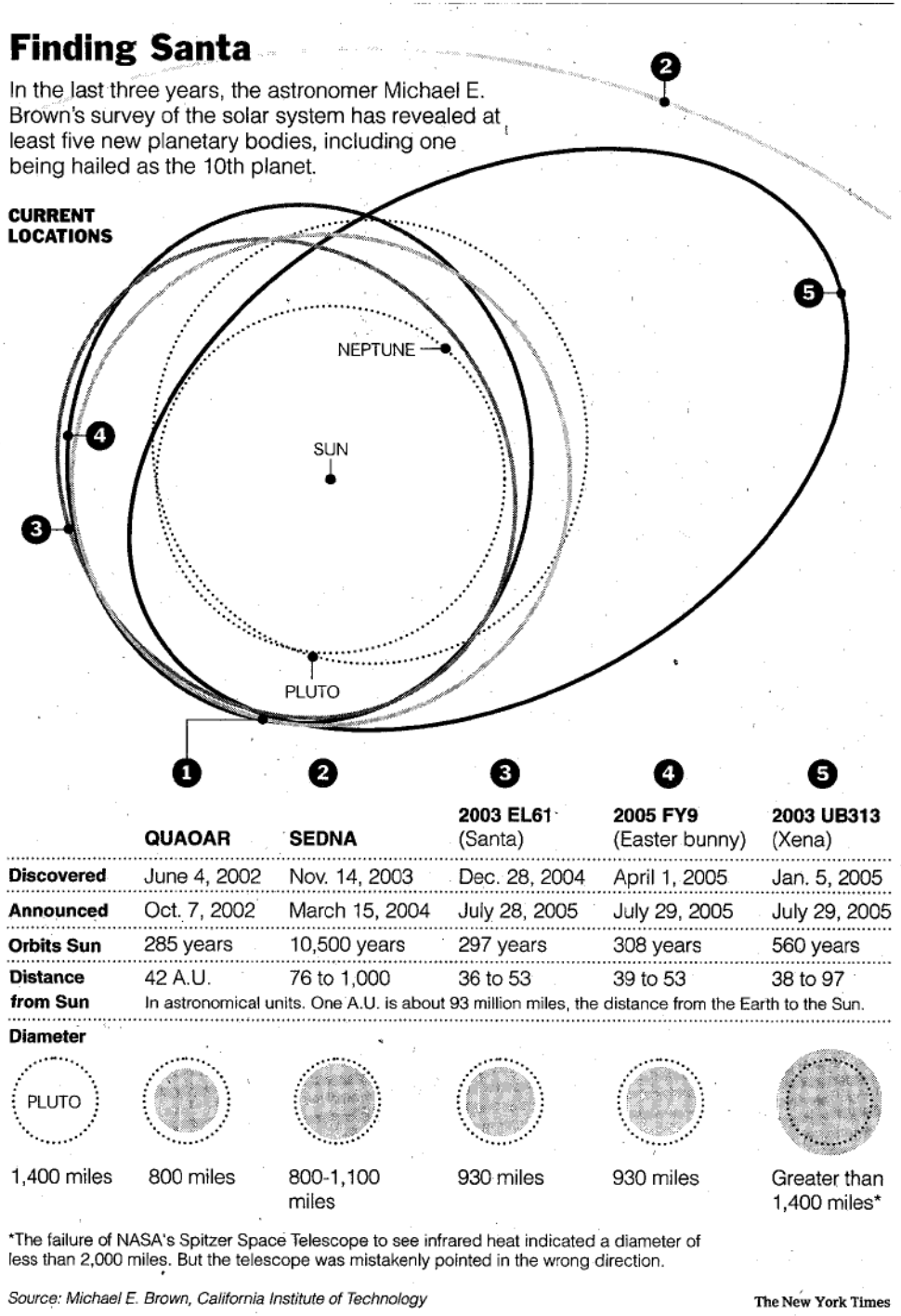
- Pluto discovered 1930, orbit radius ~30 AU
- Quaoar discovered 2002, ~1/8 size of Pluto
  - 42 AU from sun (42 × radius of earth’s orbit)
    - Radius of earth’s orbit = 93 million miles
- 2003 VB12 (“Sedna”) ~ size of Pluto
  - Orbit radius ~ 39 AU
- 2004 DW ~½ size of Pluto
  - Orbit radius ~45 AU
- 2005 “Xena” with moon “Gabrielle”
  - ~ 20% larger than Pluto, 39 to 97 AU (very flattened)
  - Plane ~ 43° to ecliptic

New “planets” (cont’d)

- Pluto discovered 1930, orbit radius ~30 AU
- Five new candidate planets since 2002 (see next slide)
- Definition of a planet is in dispute. Also casts doubt on whether or not Pluto is a planet
- Newest (Xena) may have the best claim – size, moon
- These are in or near the “Kuiper Belt” (asteroids)

New “planets” (cont’d)

- Neptune outermost “real” planet
- “Reals” formed from dust cloud, forced orbits to circular
- Term “planet” may be abandoned



Finding Santa

In the last three years, the astronomer Michael E. Brown's survey of the solar system has revealed at least five new planetary bodies, including one being hailed as the 10th planet.

CURRENT LOCATIONS

	QUAOAR	SEDNA	2003 EL61 (Santa)	2005 FY9 (Easter bunny)	2003 UB313 (Xena)
Discovered	June 4, 2002	Nov. 14, 2003	Dec. 28, 2004	April 1, 2005	Jan. 5, 2005
Announced	Oct. 7, 2002	March 15, 2004	July 28, 2005	July 29, 2005	July 29, 2005
Orbits Sun	285 years	10,500 years	297 years	308 years	560 years
Distance from Sun	42 A.U.	76 to 1,000	36 to 53	39 to 53	38 to 97

In astronomical units. One A.U. is about 93 million miles, the distance from the Earth to the Sun.

Diameter

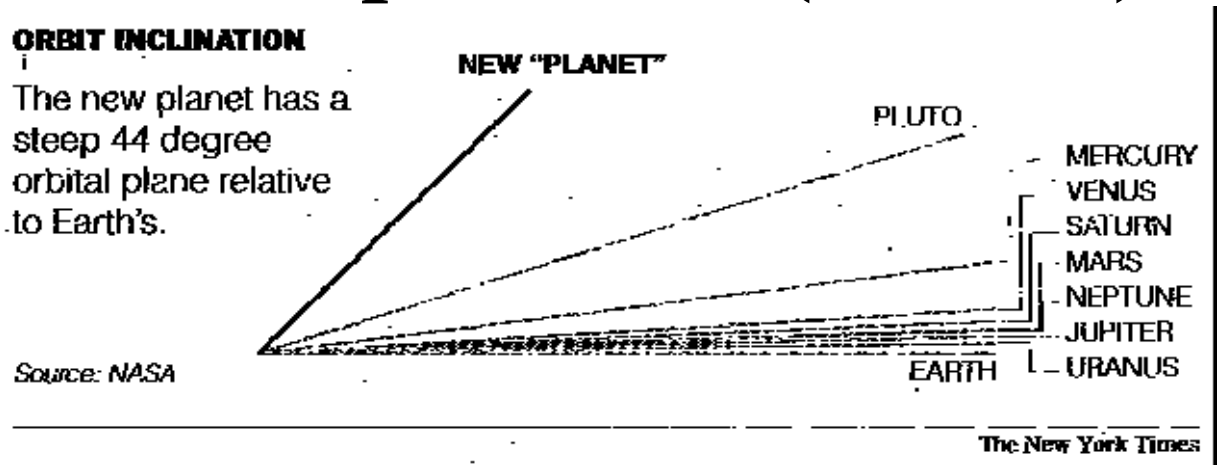
1,400 miles	800 miles	800-1,100 miles	930 miles	930 miles	Greater than 1,400 miles*

*The failure of NASA's Spitzer Space Telescope to see infrared heat indicated a diameter of less than 2,000 miles. But the telescope was mistakenly pointed in the wrong direction.

Source: Michael E. Brown, California Institute of Technology

The New York Times

New “planets” (cont’d)



- “Classification” - what is a planet?
  - Follows “description” in development of science
  - What are the real differences?
  - Interesting to see it going on here

What are these things? (modern)

- Star – source of light (gravity has crushed atoms to start nuclear reactions)
- Planet – large, opaque, nonluminous, circles a star (Pluto is on the smallish side)
- Moon – a natural satellite of a planet
- Asteroid – Small planet, size from 1 km (.6 mi) to 1,000 km (620 mi)
- Comet – Few km, frozen ice & rock, elongated orbit, vaporizes when near sun, makes tail

“In Between” Greece and Europe…

- Why “In Between” in quotes? Earlier view: these civilizations merely caretakers, conduits for Greek civilization, Now viewed more for themselves.
- First period: Eastern Roman Empire, Persia, Byzantine Empire & Barbarians
  - Western Roman Empire fell first
- Then: Islamic empire

Locations


Byzantine Emp.
"Barbarians"
Persian Empire
Islamic Empire
Asia
EUROPE
AFRICA
Arabian Sea
INDIAN OCEAN
Bay of Bengal
Philippine Sea
OCEAN
AUSTRALIA
Georgia
Armenia
Cyprus
Lebanon
Israel
Jordan
Saudi Arabia
Yemen
Oman
U.A.E.
Pakistan
Nepal
India
Bangladesh
Myanmar
Maldives
Sri Lanka
Mongolia
China
South Korea
Bhutan
Hong Kong (China)
Macao (China)
Philippines
Laos
Vietnam
Cambodia
Brunei
Malaysia
Indonesia
Singapore
East Timor
Russia
Uzbek.
Kyrgyzstan
Tajikistan
Bering Sea
1,000 Miles
1,000 Kilometers

In between…

- Barbarians
  - Had their own technology e.g. textiles
  - Brought Chinese technology further west
- Byzantine
  - Inherited Greek culture
  - John Philoponos questioned Aristotle
    - Spear-throwing – said thrower imparted power to spear to move itself

In between (cont'd)

- Persian
  - Cultural center Jundishapur (NE today's Basra)
  - Translated most Greek writing
  - Hospital and medical school
  - Astronomy and astrology
  - Also developed Greek science

In between (cont'd)

- Islamic Empire
  - Mohammad 632 A.D.
  - After 642, started conquering the area in Northern Africa to Spain and Portugal, in East towards China
  - Medicine, astronomy, astrology
    - Needed to know where Mecca was for praying
  - Agricultural science, irrigation
  - Largest cities in the world (Baghdad)

In between (cont'd)

- Islamic Empire (cont'd)
  - Respected other traditions, treated them well
  - Principal heir to Greek science
  - Medicine, astronomy, math and geometry
    - Arabic numerals from India
  - Sometime after 1,000 A.D., peak and decline
    - Became fixated on Koran and past?
    - Success led to homogenization?

In between (cont'd)

- Islamic Empire (cont'd)
  - Enormous libraries, many works only in original manuscript today
  - Well-known scientists, court appointments (here I use their Western names)
    - Averroës (1126-1198) – Physician, "The Commentator" (Aristotle)
    - Avicenna (980 – 1037) – earned living as physician to pursue philosophy and science
    - Moses Maimonides (1135 – 1204) – Physician to King of Egypt

“Copernicus Incites a Revolution”

- Protestant Reformation
  - o Challenge to Catholic church
  - o 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 36 from Class 3

- Hellenistic Period (after 323 BC)
  - 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 Ptolemey
  - 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
  - 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

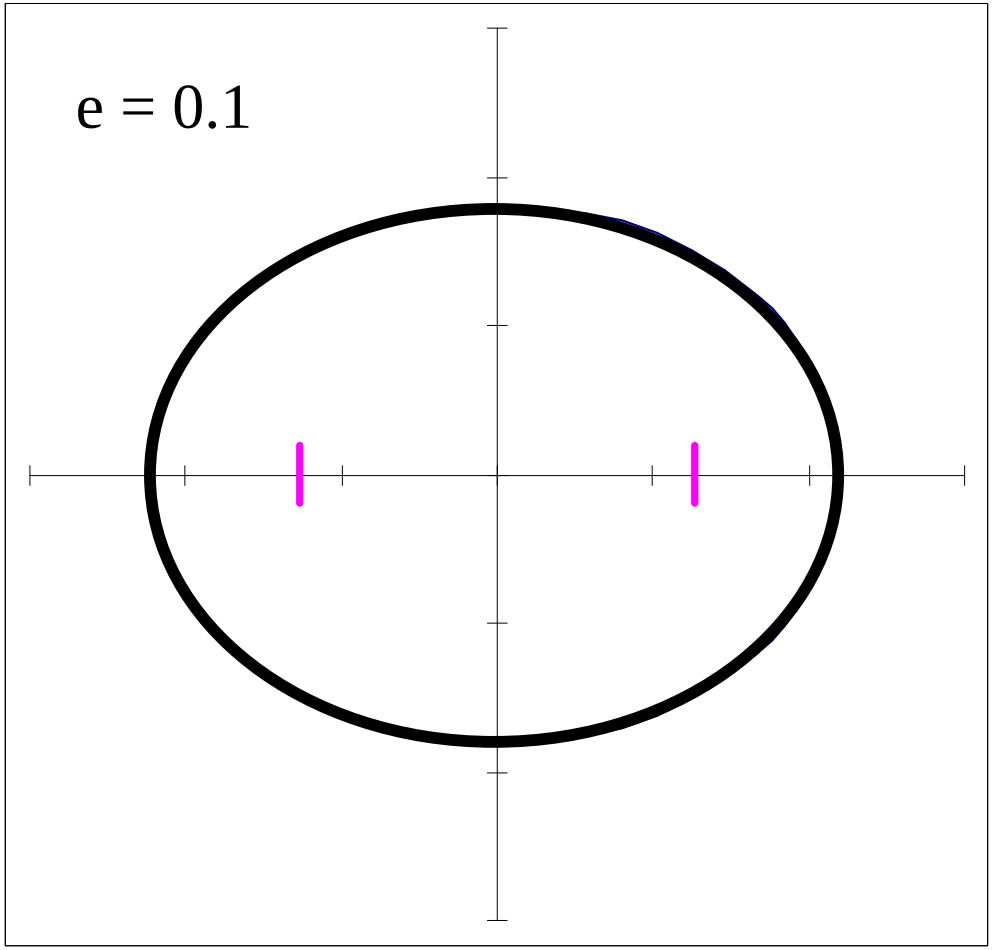
- Assigned eccentric orbit of Mars
- Six-year heroic effort, errors on top of errors, restarting, blind alleys
- Achieved accuracy within 8 minutes of arc, but Brahe's observations good to 4
- Became convinced Mars traveled in ellipse, not circle

Johannes Kepler

- Three laws of planetary motion
  - 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)
  - Unsatisfactory explanations for these laws
  - Not well received, rejected for the most part

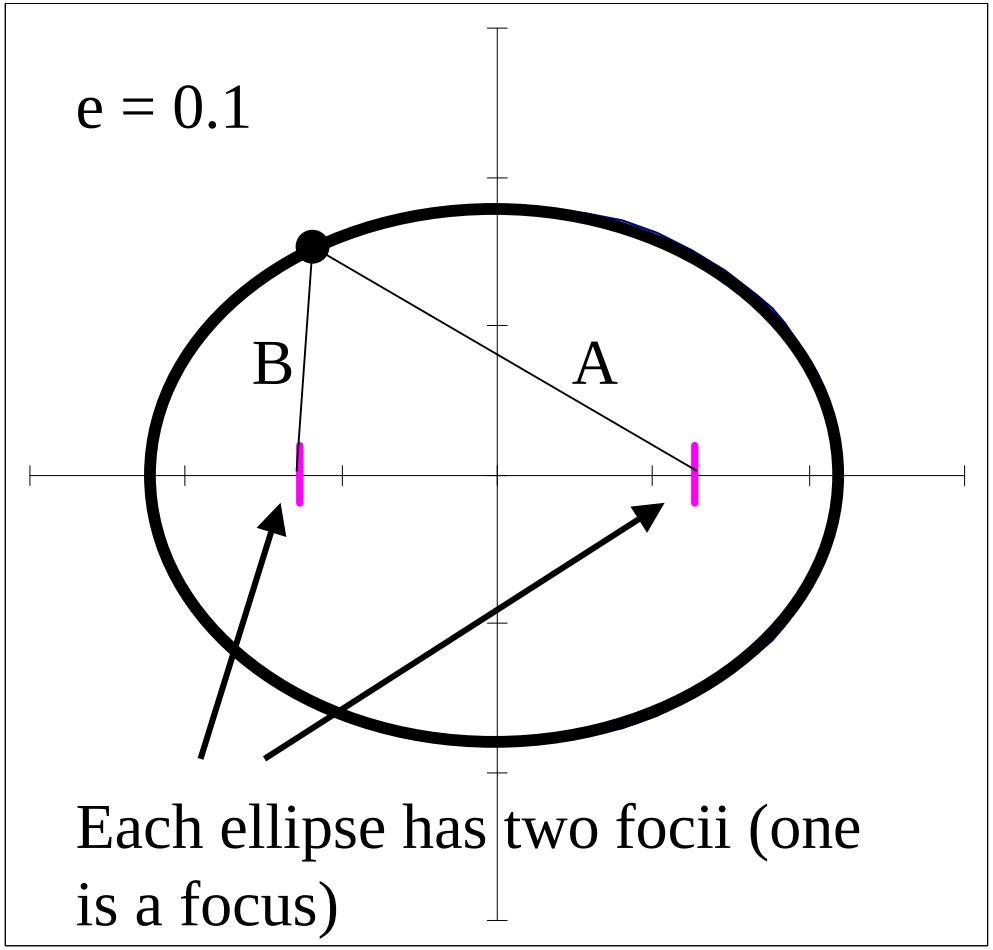
Ellipse

- 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 focii coincide, distance is radius

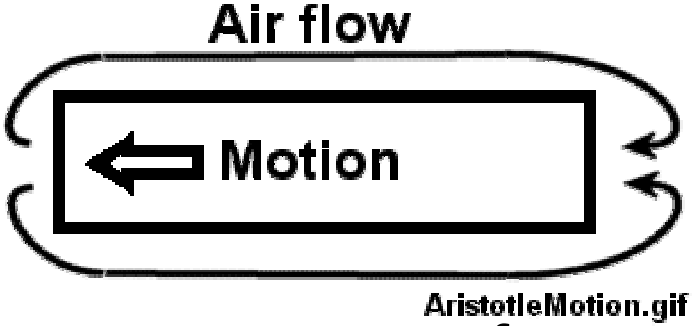


For Lab 8 Part 1

- Motion – Aristotle (terrestrial) and Newton
  - In many ways, Aristotle and Newton are opposites here
  - Aristotle: without a continuing force (a push), nothing moves
    - Motion stops as soon as push stops
    - Coasting is a problem (see next slide)
  - Newton: a force causes a change in motion
    - Force necessary to start and to stop
    - No force, no change – if at rest (not moving), stay at rest, but if moving with no change in speed, direction

Terrestrial Motion: Aristotle

- Object only moves if force applied
  - Object stops immediately if force stops
- Universe is full
  - Air moves out at front, comes in at back



AristotleMotion.gif

  - Explanation for coasting: air coming in from back pushes object to keep it moving
  - (Today: air actually streams *away*, vacuum in back, creates drag)

…and Newton (1687 A.D.)

- Newton's Second Law: F = ma
  - **F**orce = **m**ass × **a**cceleration
  - Acceleration = rate of change in velocity (speed and/or direction)
  - Constant speed in a straight line: no acceleration, no force
  - Inverse also true: no force means no acceleration, result is no change in velocity = no change in speed and no change in direction
    - "An object in motion tends to stay in motion. An object at rest tends to stay at rest."