

### Everything

How does critical density relate to universe?  
- Basically how much matter is there per cubic cm  
- If not, enough gravity to recollapse  
- If not, Universe could go on expanding forever  
- Dark energy - seals the fate of the universe and an expansive body  
Accretion  
- Binary star: material could fall of companion onto pair star  
- doesn't fall straight in, spirals in and forms disk around the star  
- accretion disk ... holding pattern until it falls into star  
Milky Way size  
- 100k light year across  
How do we detect exosolar planets?  
- same as binary stars  
- direct detection: take a picture, hard because light gets swamped

### Everything (cont)

- transit method: if things are lined up, exoplanet will cross in front of star and block a portion of light (very tiny)  
- spectroscopic method: cross star, but doesn't block light  
- star wobbles a little bit due to the gravity of the star (doppler shift)  
Cosmic module principal  
- the universe is the same every and in all direction (does not differ greatly anywhere)  
- helps explain the structure of the universe  
Brahe  
- made telescope obsvs to measure positions of planets  
Copernicus  
- first to say heliocentric  
Keplar  
- mathematical laws for the orbits  
- used bra he's precise measurements  
- ellipses and speed change as they changed distant

### Everything (cont)

Galileo  
- telescopic discoveries for keplar support  
- TONS OF TELESCOPE OBSERVATION  
Spiral structure  
- spiral galaxies  
- waves of higher and lower density that travel through disk  
- higher density = spiral arms light up as stars form  
Finding mass of a star  
- in binary = easy  
- in not binary = not easy  
- infer in comparison to other stars  
Doppler effect  
- change in frequency or wavelength due to the relative motion of the source and observer  
xray binary  
- exist and due to transfer of energy from of one star to next, X-ray flares

### Still Everything

- baryonic and non baryonic WIMPS
- baryonic suggestions are incomplete
- baryons are what we are made of (all atoms)
- non baryonic: things that are not made out of what we are made of (dark matter)
- cepheids
- stage of the stars life after the main sequence
- variable stars
- They have very particular patterns of change and variability
- luminosity is related to the period
- pulsars and neutron stars
- pulsars are neutron stars
- connected by very strong magnetic fields
- rotate very quickly
- if you tried to take normal stars and spin them that fast, they would pull apart
- radio waves are most common, optical light too and xray



### Still Everything (cont)

- nova explosions and xray binary explosions
- very similar
- dump material onto surface of star = surface explosion
- young medium and old clusters when they turn off main sequence
- for the sun, 10 billion years it turns on to main sequence
- Low mass
- eject nebula, end up in white dwarf
- Galileo's experiment with velocity and acceleration
- rolled balls down a plain (demonstration in class)
- Hubble relation explain age of universe
- Several ways to think about it
- universe is expansion, hubble relation tells rate of expansion
- calculate how long ago expansion started which tells us distant
- Equilibrium in stars
- Gravitational and Hydrostatic equilibrium

### Still Everything (cont)

- acts like a gas or a fluid
- Gravity tries to make the star contract
- Pressure is center is trying to slow down contraction
- Era's of the Universe
- First less than a second, particle era
- particles are being created or destroyed
- five minutes
- nucleosynthesis
- first 400k years, when universe becomes transparent
- radiation can flow freely throughout universe
- after that, stars begin to form
- cosmic microwave background
- Hubble relationship in graph form
- Velocity x Distant
- Straight line = hubble constant

### Moar

- 1000 exoplanets
- Standard candle
- object who's luminosity before you measure the distant
- Greenhouse effect
- CO2 concentration in atmosphere increase, plants grow larger
- Plant grows larger, removes CO2, puts out O2 = NEGATIVE FEEDBACK
- Ice is a good reflector of sunlight, water is good absorber
- Temperature of earth rises, ice melts, less reflected and more absorbed
- warm the earth, melt more ice, make warmer = POSITIVE FEEDBACK
- Bootstrapping
- process of starting with one set of distance measurements and using it to progress
- measuring parallax using radar inside solar system by using size of earth's orbit
- once measured parallax, measure stars and clusters

### Moar (cont)

- What is hubble constant?
- 70 km/sec/Mpc
- velocity for every km away from us, moving 70x that fast away from us
- Interactions of light and matter in respect to radiation
- light can scatter off of matter (blue sky)
- absorb light (photons disappear)
- produce light and photons (excite atoms in a gas)
- bend light (refraction)
- Equilibrium of stars
- amount of energy created = energy flowing out of star
- have to stay in balance or star will heat up or cool down and mess up star
- Filaments (cluster of galaxies)
- 3d spider web = filaments are lines and thread of web
- basically where galaxies and stars are heavily concentrated



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### Moar (cont)

- Wiens law / Greenhouse
- wavelength at which most of the radiation comes out = temperature
- our atmosphere absorbs infrared, radiation gets trapped but sun's radiation (sunlight) reaches the earth
- earth heats up because infrared is being trapped
- Dark matter evidence
- measured velocity of objects orbiting milky way
- how much mass do you need/gravity to keep object in orbit
- not enough present, has to be something else that has mass
- gravitational lensing
- light bends under influence of gravity
- gravity distorts images more than there is present, must have dark matter
- clusters of galaxies are filled with hot gas

### Moar (cont)

- why doesn't it escape? moving very fast
- more gravity than should be present

### Moarrr

- Dark energy existence
- universe is accelerating
- shouldn't be accelerating unless acted on by separate force
- Energy sources
- Certain labs will help explain
- Release gravitational energy to create heat
- waterfall, gravity pulls water down which creates electrical energy
- Chemical energy --> heat
- burning
- nuclear energy
- nuclear reactions to create heat or kinetic
- kinetic energy
- motion energy
- potential energy
- springs
- Motions of spiral galaxy
- motions in disk are orderly

### Moarrr (cont)

- motions in bulge are random and spontaneous
- Measuring composition
- spectral lines
- Black holes and time
- all clocks slow down when nearing a black hole
- distorts time
- Black hole at the center of a galaxy
- orbit of stars
- something dark with TONS of mass at center
- no light being emitted at center
- schwarzschild radius
- radius from which light cannot escape
- Olber's paradox
- if universe is infinite in space and time, if i go out in a direction, i will eventually hit a bright star
- sky should be bright, then
- the universe is finite in time, i.e. BIG BANG
- matter vs antimatter
- antimatter exists, we see it during nuclear reaction

### Moarrr (cont)

- counterpart to matter with opposite charges
- very limited in nature
- weird because in physics b/c antimatter and matter should be equal
- andromeda nebula?
- didn't know it was a galaxy, classified as nebulae
- hubble discovered that it was far away and as big as our Milky Way
- High Mass vs Low Mass
- High mass ends in supernovae explosions
- Low Mass turn into white dwarf
- Binary stars can gain matter from other stars
- CDMS lab searches
- One of the ways we look for dark matter
- Telescopes
- size goes up, collecting area goes up<sup>2</sup>
- bigger telescope = better resolution

