

THE UNIVERSE

A 20 MINUTE REVIEW

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ASTRONOMY 1010-03, FALL 2008

STUFF IN THE UNIVERSE

- **OUR VIEW FROM EARTH:**
 - **CONSTELLATIONS:** RANDOM GROUPING OF STARS FROM OUR VANTAGE POINT IN THE GALAXY.
 - **ECLIPSES:** SOLAR (MOON BLOCKS SUN FROM REACHING PART OF EARTH) AND LUNAR (EARTH BLOCKS SUN FROM REACHING MOON).

STUFF IN THE UNIVERSE

- **OUR VIEW FROM EARTH:**

- **METEORS:** OR SHOOTING STARS. CHUNKS OF ASTEROIDS, PLANETS, OR COMETS WHICH ARE CAPTURED BY EARTH AND BURN UP IN OUR ATMOSPHERE.

- **METEORITES:** CHUNKS THAT MAKE IT TO THE GROUND, TELLING US ABOUT THE COMPOSITION OF THE SOLAR SYSTEM, AND MUCH MORE.

STUFF IN THE UNIVERSE

■ OUR SOLAR SYSTEM:

- 8 PLANETS, 4 TERRESTRIAL (ROCKY, SMALL: MERCURY, VENUS, EARTH, MARS), 4 JOVIAN (GIANT, GAS RICH: JUPITER – THE LARGEST, SATURN, URANUS, NEPTUNE).
- GAS PLANETS: SAME METAL-RICH CORE SIZE, DIFFERENT AMOUNTS OF H AND HE.
- MOON SYSTEMS (JUPITER, SATURN IMPRESSIVELY RICH, GEOLOGICALLY ACTIVE, TIDAL HEATING).
- ASTEROIDS: ROCKY, UP TO 100KM, MOST IN A BELT BETWEEN MARS AND JUPITER - FAILED PLANET.

STUFF IN THE UNIVERSE

■ OUR SOLAR SYSTEM:

- **COMETS:** ICY DENIZENS OF THE OUTER SOLAR SYSTEM. WE SEE THEM WHEN THEY VISIT THE INNER SOLAR SYSTEM. “DIRTY ICEBALLS.”
- **KUIPER-BELT 30-50 AU:** SOME COMETS, AND “**KUIPER BELT OBJECTS**”, DWARF PLANETS (PLUTO BEING THE MOST FAMOUS, BUT NOT THE BIGGEST!).
- **OORT CLOUD:** DISTANT ROUND CLOUD OUT TO 50,000 AU, MANY, MANY COMETS.
- **THE SUN:** PRODUCER OF SOLAR WIND, AND **CORONAL MASS EJECTIONS.**

STUFF IN THE UNIVERSE

- **THE SUN:**

- **PHOTOSPHERE IS WHAT WE SEE AT 5800K, BUT CORE IS MUCH HOTTER: 10 MILLION K TO BURN HYDROGEN!**
- **SUN-SPOTS OCCUR IN CYCLES, PEAKING AT THE SOLAR MAXIMUM.**

STUFF IN THE UNIVERSE

- **EXTRA-SOLAR PLANETS:**

- **PRIMARILY DETECTED BY DOPPLER “WOBBLE” OF HOST STAR. SO FAR MOSTLY JUPITER-MASS, CLOSE ORBIT PLANETS (STRONGEST WOBBLE!).**

- **OVER 300 FOUND, MORE EVERY WEEK.**

- **FIRST REAL IMAGES OF AN EXTRA-SOLAR PLANET: THIS YEAR!**

STUFF IN THE UNIVERSE

■ STARS:

- BALLS OF GAS SUPPORTED AGAINST THE CRUSH OF GRAVITY BY NUCLEAR FUSION.
- MOSTLY STARS LESS MASSIVE THAN THE SUN.
- MAIN SEQUENCE STARS BURNING HYDROGEN STABLY IN THEIR CORES.
- PROTO-STARS: EARLIEST STAGES OF STAR.
- EVOLVED STARS: THE END OF A STAR'S LIFE, DEPENDS ON MASS. GIANT AND SUPERGIANT PHASE.
- CEPHEID VARIABLES AND OTHER VARIABLE STARS ARE BRIGHT AND IMPORTANT STANDARD CANDLES.

STUFF IN THE UNIVERSE

- **INTERSTELLAR MEDIUM OF GAS AND DUST.**
- **STELLAR GRAVEYARD:**
 - **LOW-MASS STARS LOSE THEIR OUTER MATERIAL FORMING A PLANETARY NEBULA, AND LEAVING BEHIND A WHITE DWARF, THE HOT BUT DIM REMNANT OF THE CORE.**
 - **HIGH-MASS STARS CAN EXPLODE AS A CORE-COLLAPSE SUPERNOVA, OFTEN LEAVING BEHIND SUPERNOVA REMNANTS.**

STUFF IN THE UNIVERSE

- **STELLAR GRAVEYARD:**

- **NEUTRON STARS:** REMNANT OF A SUPERNOVA, OR WHITE DWARF WHICH GOT TOO BIG TO HOLD ITSELF UP. ROTATING ONES CAN BEAM RADIO BEACONS, AND ARE CALLED **PULSARS**.

- **BLACK HOLES:** WHEN DEGENERACY PRESSURE CAN'T HOLD A NEUTRON STAR UP, IT COLLAPSES TO A SINGULARITY. **SMALL, BUT DEADLY:** NO LIGHT CAN ESCAPE. AT A DISTANCE, GRAVITY ACTS NORMALLY. A FEW SUN MASSES IN A BALL THE SIZE OF CAMPUS!

STUFF IN THE UNIVERSE

- **STELLAR GRAVEYARD:**

- **NOVA ARE FORMED IN BINARY STAR SYSTEMS: ONE STAR DONATES MATERIAL TO THE OTHER (USUALLY WHITE DWARF OR NEUTRON STAR).**

- **WHITE DWARF SUPERNOVAE ARE SIMILAR: BINARY TRANSFERS TOO MUCH MASS, AND WHITE DWARF COMPANION CAN'T HOLD UP, EXPLODES AS SUPERNOVA. EXCELLENT STANDARD CANDLE (USED TO DISCOVER THE ACCELERATING EXPANSION OF THE UNIVERSE).**

STUFF IN THE UNIVERSE

- **GAMMA RAY BURSTS ARE THE MOST LUMINOUS EXPLOSIONS IN THE UNIVERSE: BRIEFLY OUTSHINE A MILLION MILKY WAY GALAXIES! MASSIVE STAR COLLAPSE (HYPERNOVA) AND/OR BLACK-HOLE VS. NEUTRON STAR COLLISION!**

STUFF IN THE UNIVERSE

- **STAR-FORMING MOLECULAR CLOUDS:** THESE COLLAPSE BY GRAVITY TO FORM STARS.
- **GLOBULAR CLUSTERS** ARE GIANT SPHERICAL CLUSTERS OF THOUSANDS TO MILLIONS OF OLD STARS, HOLDING AMONG THE OLDEST STARS IN THE GALAXY (OR ANY GALAXY).
- **OPEN CLUSTERS:** YOUNGER, SMALLER CLUSTERS OF HUNDREDS TO THOUSANDS OF STARS FOUND PRIMARILY IN THE DISK OF THE GALAXY.

STUFF IN THE UNIVERSE

■ **MILKY WAY GALAXY:**

- **OUR OWN GALAXY, ABOUT 100,000 LY ACROSS, AND 1000 LY THICK. A SPIRAL DISK GALAXY. WE ORBIT IT EVERY 230 MILLION YEARS.**
- **200 BILLION STARS, GIVE OR TAKE.**
- **HARBORS A SUPERMASSIVE BLACK HOLE IN ITS CENTER OF ABOUT 3 MILLION SOLAR MASSES.**
- **NOTHING SPECIAL: ONE OF 100 BILLION GALAXIES IN THE OBSERVABLE UNIVERSE.**

STUFF IN THE UNIVERSE

■ **LOCAL GROUP:**

- **THE IMMEDIATE ENVIRONS, INCLUDING THE SMALL AND LARGE MAGELLANIC CLOUDS (DWARF GALAXIES ORBITING US), MANY OTHER SMALL GALAXIES WE'VE ALREADY CANNIBALIZED, AND JUST A COUPLE LARGE GALAXIES, ANDROMEDA FOREMOST AMONG THEM.**

■ **GALAXIES:**

- **LARGE COLLECTIONS OF STARS, GAS AND DUST, LIKE THE MILKY WAY.**
- **VARIETY OF SHAPES: ELLIPTICAL (OLD STARS ON RANDOM ORBITS, NO DISK), SPIRAL (PINWHEEL ARMS), BARRED (SPIRAL WITH A BAR), IRREGULAR (EVERYTHING ELSE).**

STUFF IN THE UNIVERSE

■ GALAXIES:

- **BULGE AND HALO** ARE SPHEROIDAL COMPONENTS (MOSTLY OLD RED STARS), **DISK** IS FLAT COMPONENT (WITH GAS, DUST AND FORMING STARS).
- **STARBURST GALAXIES** ARE OFTEN THE RESULT OF GALAXY COLLISIONS. STARS FORM VERY FAST (100x MW).
- **MERGERS:** GALAXY COLLISIONS, GAS AND STARS MERGE. MORE COMMON IN EARLY UNIVERSE (SMALLER UNIVERSE = CLOSER GALAXIES).

STUFF IN THE UNIVERSE

■ **ACTIVE GALACTIC NUCLEI**

- **POWERED BY THE SUPER-MASSIVE BLACK HOLES IN THE CENTER OF GALAXIES.**
- **BEING FED MATERIAL, CONVERT POTENTIAL ENERGY TO HEAT GRAVITY: MORE EFFICIENT THAN FUSION IN STARS!**
- **SHOOT OUT JETS AND RADIO LOBES: RADIO GALAXIES.**
- **QUASARS ARE MOST LUMINOUS AGN: 1000x MW!**

STUFF IN THE UNIVERSE

- **LARGE SCALE STRUCTURE:** THE ARRANGEMENT OF GALAXIES IN THE UNIVERSE INTO SHEETS, VOIDS, AND FILAMENTS.
- **DARK MATTER:** THE MATTER WE INFER TO EXIST FROM THE ORBIT OF STARS IN THE GALAXIES, THE ORBITS OF GALAXIES IN CLUSTERS, THE HOT GAS IN CLUSTERS, AND GRAVITATIONAL LENS MODELS OF CLUSTERS. MASS DOES NOT FOLLOW LIGHT IN THE UNIVERSE.
- **GRAVITATIONAL LENS:** AN OBJECT (LIKE A CLUSTER) WHICH BENDS THE LIGHT OF A BACKGROUND OBJECT (LIKE A GALAXY) DISTORTING IT, MAKING MULTIPLE IMAGES, ETC. A BASIC PROPERTY OF GRAVITY: IT BENDS LIGHT!

STUFF IN THE UNIVERSE

- **DARK ENERGY:** AN UNKNOWN FORCE CAUSING THE EXPANSION OF THE UNIVERSE TO ACCELERATE (COSMOLOGICAL CONSTANT, QUINTESSENCE). MAKES UP 72% OF THE ENERGY DENSITY OF THE UNIVERSE. MATTER (ATOMS) MAKES UP ONLY 5%, DARK MATTER, 23%.
- **COSMIC MICROWAVE BACKGROUND:** REMNANT PURE HEAT OF THE BIG-BANG. SLOWLY COOLING AS THE UNIVERSE EXPANDS. CURRENTLY 2.73K (A PERFECT THERMAL EMITTER). TINY FLUCTUATIONS: REGIONS OF ENHANCED DENSITY FROM WHICH GALAXIES FORMED!

STUFF IN THE UNIVERSE

- **THE OBSERVABLE UNIVERSE:** TIME LIGHT HAS TRAVELED SINCE THE **BIG BANG** SETS THE REGION INSIDE OF WHICH WE CAN EVER HOPE TO OBSERVE ANYTHING. UNIVERSE IS 13.7 BILLION YEARS OLD.
- **THE UNIVERSE: ???** PERHAPS MUCH LARGER THAN THE OBSERVABLE UNIVERSE; CAN'T DIRECTLY OBSERVE ANYTHING THERE.

STUFF THAT HAPPENS

- **THE BIG BANG:** AN INITIAL MOMENT IN WHICH THE SPACE AND TIME OF THE UNIVERSE WAS CREATED.
- **LAWS OF PHYSICS VERY STRANGE IN EARLY, VERY HIGH TEMPERATURE UNIVERSE. MATTER AND ANTI-MATTER CONVERTED BACK AND FORTH INTO RADIATION.**
- **INFLATION:** THE VERY SHORT-LIVED INCREDIBLY RAPID EXPANSION OF THE UNIVERSE.

STUFF THAT HAPPENS

- **UNIVERSE COOLS, SMALL AMOUNT OF MATTER LEFT OVER. COMBINED IN THE ERA OF NUCLEOSYNTHESIS IN HYDROGEN, HELIUM, AND TRACE OF LITHIUM, BERYLLIUM, BORON. EVERYTHING ELSE MADE IN A STAR, AND MOST THINGS ARE PRIMARILY HYDROGEN, SECONDARILY HELIUM (SUN INCLUDED).**
- **NUCLEI RECOMBINE WITH ELECTRONS, THE HOT RADIATION STREAMS FREELY TO BECOME THE CMB WE SEE TODAY.**

STUFF THAT HAPPENS

- **REGIONS WITH SLIGHTLY MORE DENSITY, CREATED BY INFLATION, BEGIN TO ATTRACT DARK MATTER BY GRAVITY. THE H AND HE GAS FOLLOWS IT.**
- **FIRST STARS: FORM WHEN THE GAS HAS COLLAPSED. PROTO-GALAXIES BORN.**
- **GALAXY EVOLUTION: GALAXIES USE THEIR GAS TO FORM STARS, GALAXIES MERGE AND EAT SMALLER GALAXIES, MATERIAL FROM STARS (SUPERNOVAE, SUPER-GIANT STARS, ETC.) IS RECYCLED INTO THE GAS, AND MAKES NEWS STARS. PROCESS KEEPS HAPPENING.**

STUFF THAT HAPPENS

- **EXPANSION: UNIVERSE CONTINUES TO EXPAND. GRAVITY AT FIRST SLOWS EXPANSION, BUT SEVERAL BILLION YEARS AGO, DARK ENERGY TAKES OVER AND EXPANSION ACCELERATES.**
- **SUPER-MASSIVE BLACK HOLES FORM AT THE CENTERS OF GALAXIES. GO ON TO BECOME QUASARS, AGN.**

STUFF THAT HAPPENS

- **STARS FORM, AND THEIR SOLAR NEBULAE – DISKS OF THEIR BIRTH MATERIAL – FORM INTO PLANETS, ALL SHARING THE SAME ANGULAR MOMENTUM OF THE ORIGINAL CLOUD.**
- **SOME STARS FORM PLANETS IN THE HABITABLE ZONE WHERE WATER CAN REMAIN LIQUID. EARTH IS FORMED SOME 4.5 BILLION YEARS AGO.**
- **PLANETS PROCESSED AND SCULPTED BY EROSION, TECTONICS (E.G. SHRINKING LITHOSPHERE), ETC.**

STUFF THAT HAPPENS

- **LIFE EVOLVES ON THOSE HABITABLE PLANETS. APPARENTLY DOESN'T COLONIZE THE GALAXY (UNLESS IT'S HIDING — FRACTION OF HABITABLE PLANETS WITH LIFE COMPLETELY UNKNOWN).**
- **LIFE BECOMES INTELLIGENT (AT LEAST ON EARTH), STARTS WATCHING THE SKY. OBSERVES THE PATTERN OF STARS, RISING AND SETTING, DAY AND NIGHT, ALL DUE TO THE EARTH'S ROTATION EVERY 24HRS.**
- **SEES CHANGING SEASONS, CAUSED BY THE TILT OF THE EARTH'S AXIS AS IT ORBITS THE SUN.**

STUFF THAT HAPPENS

- SEES MOON MOVE AND CHANGE PHASE. MOON ORBITS EARTH, GIVING IT PHASES AS ONLY A PORTION OF THE ILLUMINATED HALF OF THE LUNAR SPHERE IS VISIBLE.
- EARTH ORBITS THE SUN, GIVING THE YEAR, AND CAUSING DIFFERENT CONSTELLATIONS TO BE VISIBLE (OPPOSITE SUN) AT NIGHT.
- SEES THE POLE STAR POLARIS, WHICH DOES NOT RISE OR SET, AND THE CIRCUMPOLAR STARS AROUND IT, WHICH NEVER DIP BELOW THE HORIZON.

STUFF THAT HAPPENS

- **EVOLVES INTO ANCIENT GREEKS, WHO FOUND ASTRONOMY AND MAKE MODELS OF SOLAR SYSTEM. VERY COMPLEX TO KEEP THE EARTH AT THE CENTER OF THE UNIVERSE. SEE “WANDERERS”.**
- **COPERNICUS PUTS SUN AT THE CENTER, KEEPS CIRCLES.**
- **KEPLER (WITH THE OBSERVATIONS OF BRAHE) DISCOVERS ALL WORKS WELL WITH ELLIPSES INSTEAD, STATES 3 LAWS: EQUAL AREAS, SWEEPED OUT, $P^2=A^3$.**
- **GALILEO USES TELESCOPE TO FINALIZE THE SUN-CENTERED SOLAR SYSTEM REVOLUTION.**

STUFF THAT HAPPENS

- **EVENTUALLY DISCOVER THE ULTIMATE FATE OF THE UNIVERSE, WHICH IS VERY LIKELY TO EXPAND FOREVER.**
- **CREATE TECHNOLOGY THAT EMITS COPIOUS GREENHOUSE GASES, WHICH ABSORB THE INFRARED (HEAT) RADIATION FROM THE EARTH, CAUSING IT TO WARM.**
- **COMES TO TAKE ASTRONOMY 1010 AND THE UNIVERSITY OF TOLEDO. COMES IN FOR AN EXAM REVIEW, LEARNS THE HISTORY OF THE UNIVERSE.**

HOW THE UNIVERSE WORKS

- **GRAVITY: GETS WEAKER AS $1/\text{DISTANCE}^2$. KEEPS OBJECT IN ORBIT. DOESN'T MATTER WHAT IT'S MADE OF (BLACK HOLE, STAR, GIANT BALL OF WAX).**
- **RADIATION: LIKE LIGHT, IN THE FORM OF PHOTONS, SPANNING A BROAD RANGE OF WAVELENGTH, FROM HIGH-ENERGY, HIGH-FREQUENCY, SHORT-WAVELENGTH GAMMA RAYS TO LOW-ENERGY, LOW-FREQUENCY, LONG-WAVELENGTH RADIO.**

HOW THE UNIVERSE WORKS

- **MOTION: NEWTON'S LAWS. BODY AT REST/IN MOTION STAYS THAT WAY UNLESS ACTED ON. EQUAL AND OPPOSITE REACTION (WHY A ROCKET FLIES). $F=MA$.**

HOW THE UNIVERSE WORKS

- **RADIATION CAN BE ABSORBED, TRANSMITTED, REFLECTED, OR EMITTED.**
- **RADIATION: LIKE LIGHT, IN THE FORM OF PHOTONS, SPANNING A BROAD RANGE OF WAVELENGTH, FROM HIGH-ENERGY, HIGH-FREQUENCY, SHORT-WAVELENGTH GAMMA RAYS TO LOW-ENERGY, LOW-FREQUENCY, LONG-WAVELENGTH RADIO.**
- **ASTRONOMERS USE MAGNITUDES, BOTH APPARENT (HOW BRIGHT IT LOOKS, LOWER=BRIGHTER), AND ABSOLUTE (MEASURE OF LUMINOSITY: APPARENT AT 10PC).**

HOW THE UNIVERSE WORKS

- **ANYTHING WARM EMITS THERMAL RADIATION (ALSO CALLED BLACKBODY RADIATION): HIGHER TEMPERATURE, SHORTER WAVELENGTH. EVEN STARS OPERATE THIS WAY (HOTTER STAR=MORE ULTRAVIOLET). MOST DENSE THINGS ARE THERMAL EMITTERS.**
- **INTENSITY OF LIGHT AT VARIOUS WAVELENGTHS IS ITS SPECTRUM: POWER TOOL TO ANALYZE MOTION, COMPOSITION, ETC. ATOMS HAVE UNIQUE SPECTRUM.**
- **LINE EMISSION SPECTRUM FROM HOT GAS. STAR SEEN THROUGH GAS, LINE ABSORPTION SPECTRUM.**

HOW THE UNIVERSE WORKS

- **LIGHT FROM MOVING OBJECTS IS SHIFTED IN WAVELENGTH: REDSHIFT FOR MOVING AWAY, BLUESHIFT FOR MOVING TOWARDS.**
- **TELESCOPES COLLECT FAR MORE LIGHT THAN THE EYE, AND HAVE BETTER ANGULAR RESOLUTION (1 ARCSEC). GOING TO SPACE OR USING ADAPTIVE OPTICS, IMPROVES BY A FACTOR OF 10 OR MORE! NOT JUST VISIBLE LIGHT, BUT THE ENTIRE ELECTROMAGNETIC SPECTRUM.**

HOW THE UNIVERSE WORKS

- **MATTER COMPOSED OF ATOMS WITH DIFFERING NUMBER OF PROTONS, AND NEUTRONS, GIVING IT ALL ITS PROPERTIES. LARGE ATOMS CAN UNDERGO NUCLEAR FISSION, AND, IF HOT ENOUGH (MILLION OF K — NOT ON EARTH THUS FAR) SMALL ATOMS CAN UNDERGO NUCLEAR FUSION (E.G. IN THE SUN).**
- **STARS FALL IN THE MAIN SEQUENCE OF STABLE HYDROGEN BURNING IN THE HERTZSPRUNG-RUSSEL DIAGRAM OF THE UNIVERSE. DEPART TO COOLER (RIGHT) AND MORE LUMINOUS (UP) WHEN THEY BURN IN SHELLS.**

HOW THE UNIVERSE WORKS

- **HUBBLE'S LAW: THE FURTHER A GALAXY IS, THE FASTER IT'S RECEDING. RAISIN BREAD ANALOGY.**
- **UNIVERSE EXPANDS UNLESS DENSITY IS ABOVE THE CRITICAL DENSITY NEEDED TO HALT EXPANSION. BEST (ONLY) WAY TO FIND THE DISTANCE TO MOST DISTANT GALAXIES.**
- **UNIVERSE IS NEAR THE CRITICAL DENSITY, BUT 73% DARK ENERGY, WHICH ACTS LIKE ANTI-GRAVITY! EXPANSION CONTINUES EVER FASTER.**

YOUR QUESTIONS

TOMORROW AT 2:45 IN
MH 1005, BRING YOUR
BRAIN AND YOUR #2
PENCIL!