

Our view of the sky (2):

The celestial sphere as a model for appearances (only!)

Sizes and distance from naked-eye observations

Constellations

Daily motions from Earth's rotation

Annual motions from Earth's orbit; seasons

Eclipses: solar (partial/annular/total), lunar

Gravity and orbits (3)

Geocentric versus heliocentric solar system schemes

The Copernican revolution

Galileo and early telescopic discoveries

Kepler's laws, Newton's laws and gravity

Gravity, orbits and tides

General relativity - gravity as curvature of spacetime

Formation of the solar system (4)

Clues: layout of orbits and rotations

kinds of planets at different distances from Sun

comet, meteorite composition

dusty disks around young stars

Accretion of planets, accumulation of remaining material

The Earth (5)

Atmosphere: troposphere, stratosphere, thermosphere

Impacts, tectonism, vulcanism, erosion on surfaces

Greenhouse effect, ozone layer

Magnetic field, radiation belts, aurorae

Crust: plate tectonics, vulcanism, erosion

Mantle, dense core known from seismic studies

The Moon (5): Tidally locked rotation; one side always faces Earth

Size, mass; giant-impact theory for lunar origin

Features: maria, highlands, craters

Maria = lava flows, craters dominated by meteor impacts

Lunar exploration: probe flyby/landings, Apollo landings

Mercury (5): Lunar-like surface with impact craters

High density, temperature

Polar ice caps?

Venus (5): near-twin of Earth in size and mass

Atmosphere: cloud layers, runaway greenhouse effect

Radar mapping: volcanic features, some not yet understood

Mars (5): Seen from Earth: light/dark markings, polar caps

Thin atmosphere, cold surface

Craters, huge volcanos, canyons, ancient riverbeds

History: strong evidence for water-rich periods

The search for life

Giant planets (6): Jupiter, Saturn, Uranus, Neptune

H/He composition

Visible weather: cloud belts, winds, storms (Great Red Spot)

Interior inferred: no solid surface. Rocky core?

Strong magnetic field, radiation belts

Uranus: tipped rotation, off-center magnetic field - impact?

Neptune: violent winds and storms despite distance from Sun

Rings and moons (6)

Ring locations - tidal forces, collisional flattening

Tides and their influences, the Roche limit

Some ring matter has been knocked off moons

Shepherd moons

Large active moons of outer planets (some volcanic now)

Many small inactive ones

Small bodies (6):

Minor planets: most in so-called asteroid belt

formation theories

potential for catastrophe from Earth impacts

Comets: nucleus/coma/tail (always points away from Sun)

elongated orbits; spend most time far from Sun

Icy "primitive" makeup; fossils of early Solar System

Oort and Kuiper clouds; put there by planet encounters

cometary debris can make meteor showers

Pluto/Charon, Eris - parts of Kuiper Belt beyond Neptune

"Dwarf planets", small and icy

Meteors: debris seen entering the atmosphere

Comet tails eventually produce meteor showers

Other planetary systems (7)

Detection - Doppler shifts, transits

Variety - hot Jupiters, super-Earths

The Sun (8): a typical star

Energy-producing core, transport of this energy outward

Atmosphere: photosphere, chromosphere, hot corona

Sunspots, flares, solar cycle: symptoms of magnetic field

H->He fusion in the core; solar neutrino detection

Introduction to stars (9)

Distances: parallax, star-matching techniques

Color and temperatures: blackbody radiation

Hertzsprung-Russell diagram:

main sequence/red giants/white dwarfs

Masses of stars: binaries and Kepler's laws

Low-mass stars (9)

Main sequence: H-> He in core producing energy;

lifetime is mass-dependent

H exhaustion in core: evolve to red giant, helium fusion

Production of a planetary nebula, leaving a white dwarf

High-mass stars (9)

Faster lifetime, complex red giant phase, He core reactions

Elements up to iron, core collapses, supernova explosion

Star clusters as laboratories to see these things happen

Compact remnants of stars (10)

Neutron stars, pulsars

neutron-degenerate matter; size 10-20 km

pulsar magnetic fields, spin. Some have planets!

Black holes: from stars too massive for neutron stars

escape velocity faster than light

singularity, event horizon

detection in interacting binary systems

The Milky Way galaxy (11)

Observed guise: band of starlight around sky

Disk, bulge like external spiral galaxies

Spiral structure from young stars and gas clouds

Stars of populations I and II

Spiral arms as wave phenomena

Energetic events in the galactic center - massive black hole

Galaxies (11):

Recognition; distances via Cepheid variable stars

Hubble classes:

elliptical, S0, ordinary/barred spirals, irregular

Distances and the Hubble law; an expanding Universe

Motions in galaxies: the riddle of dark matter

Galaxy collisions and mergers; transforming galaxies in time

Galaxy evolution: galaxies look different at high redshift

Active galaxies (11):

Seyfert galaxies: bright nucleus, broad emission lines

strong central gravity to hold gas in place

Radio galaxies: twin lobes of radio emission, jets

directional memory for central object

Quasars: bright, high redshifts

variability implies small volume for energy source

Standard model: accretion disk, jets around massive black hole

Using quasars as probes of the universe: absorption lines,

gravitational lensing, quasar evolution with redshift

Cosmology (12, 13)

Olbers' paradox, Hubble expansion, microwave background

Expanding universe: uniform expansion, age of Universe

Cosmological principle; the "Big Bang" picture

Acceleration of the expansion rate

Early Universe: inflation, nucleosynthesis

Dark matter and dark energy (14)

Dark matter in galaxies and clusters

Motions, gravitational lensing evidence

Dark energy inferred from cosmic distance data

Implications in cosmic history

Cosmic history (13)

Nucleosynthesis: H,He, other light elements

Atoms form, Universe transparent - microwave background

Gravity + dark matter: structures form

Galaxy formation, first stars and quasars

Galaxy clusters/superclusters

environmental effects on galaxies (change with time)

hot gas in clusters, some must have come from stars

Life in the Universe (15)

The Drake equation and unknowns in the search

Looking for planetary systems: Doppler shifts pay off

Communicating: signalling/using probes