Astro Review: Ch 13-17.

Chapt 13:

a) n-star

size of city $r \sim 10km$
supported by n degeneracy pressure
$m \leq 3m_\odot$
rapid rot^n, high mag^c fields
lighthouse emission model (pulsars)
all pulsars are n-star / not all n-stars are pulsars.

b) n-star in mass transfer binary systems

i) X-ray bursters
(analog to novas "on" white dwarf stars)

ii) milli second pulsar
"spun up" by transfer of angular momentum

c) γ ray bursts

uniform over sky, ∴ at large distance from us
two models:
i) n-star n-star merger
ii) hyper nova
} ⇒ jets (beam emission) ⊕ black hole?

d) Black holes

$m \gtrsim 3 m_\odot$
$"r" \sim 3km \left(\frac{m}{m_\odot}\right)$ ← { mathematical: ① event horizon ② Schwarzschild radius

e) skip 13.6, 13.7

f) observational evidence for BH:

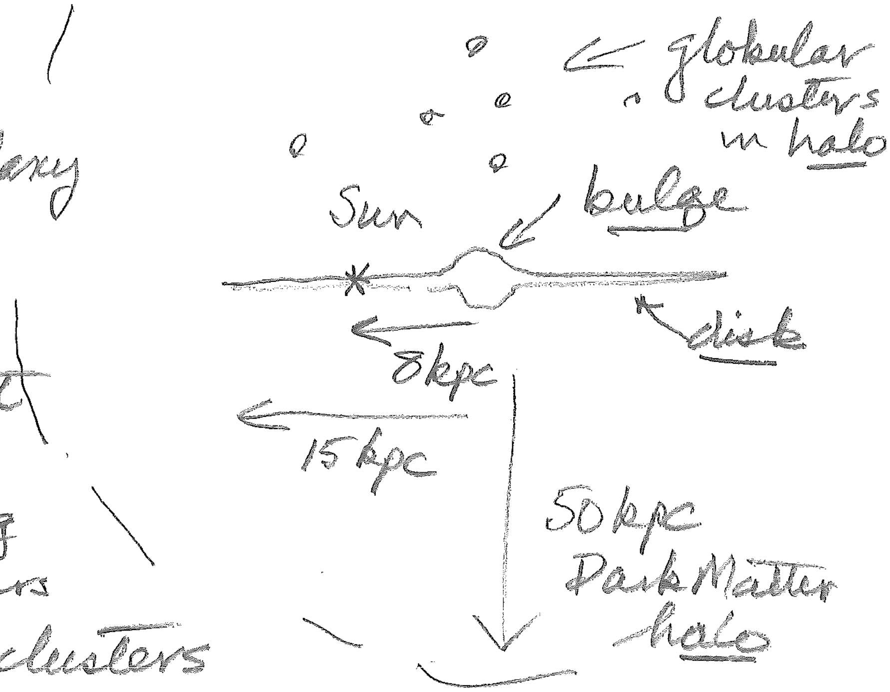
i) stellar mass

BH in mass transfer binary system
eg Cygnus X-1

ii) supermassive BH at centers of most (all) large galaxies

Chapt 14:

a) Milkey Way Galaxy
Barred spiral
1^{st} reliable measurement by Harlow Shapley using RR Lyrae stars in globular clusters



b) Intrinsic variable stars

RR Lyrae type, period ≤ 1 day, $\mathcal{L}/\mathcal{L}_{\odot} \sim 100$

Cepheid variable type, period luminosity rel^{n}, period > 1 day, $\mathcal{L}/\mathcal{L}_{\odot} \gg 100$ & related to period

c) Stellar populations
young (newly formed) stars in disk ← significant gas and dust
old stars in globular clusters in halo ← little gas and dust

d) Spiral arms
"orderly" motion about center of galaxy
arm structure likely "density waves"
↳ promotes new star formation

e) Galaxy mass
star (and hydrogen gas) "rotation curve"
requires a large (50kpc radius)
dark matter halo

not brown dwarfs, small black holes.
most likely some new form of matter

f) Sgr A*
probably ~4 million $M_\odot$ black hole
"visible" in radio and IR telescopes (other wavelengths blocked by intervening dust!)

Chapt 15:

a) Galaxy classification (visual appearance)

Spiral / Barred Spirals ↔ ongoing star formation

Elliptical

Irregular

also: lenticular ← No ongoing star formation

peculiar (probably colliding galaxies)

b) new standard candles

Tully Fisher

Type I super nova ⟸ brightest "standard candle"

c) Galaxy clusters

groups of gravitationally bound galaxies

Local group (includes Milky Way) ~55 galaxies

Virgo cluster ~2500 galaxies

d) Hubble Law

$v_{recession} = H_0 \times distance$

↑ from "redshift"

↑ fractional change in wavelength of light due to recessional motion (or cosmological expansion)

c) Active Galactic Nuclei (AGNs)

characterize by unusually luminous galaxies with <u>non</u> black body spectra

3 major types (probably just different view of "same" object)

i) Seyfert galaxies (also blazar if jet pointed at Earth)

ii) Radio galaxies

iii) Quasars ← only in early universe

Model: central super massive black hole, infalling matter onto <u>accretion disk</u> with magnetic field confined emission along 2 <u>jets</u>

New emission of "light" via <u>synchrotron radiation</u>

Spacial extent of "light" source small (compact) because of short time variations in brightness

Chapt 16:

a) Dark Matter (DM):

Rotation curves of spiral galaxies "need" DM.

Motion of galaxies in galaxy clusters "need" DM.

↳ suggest DM ~ 5 to 10 × "luminous" matter.

b) Galaxy collisions:

common (even more so in past)

gas/dust clouds are what actually collides

↳ leads to "star burst" phase

c) Galaxy evolution:

Galaxies in early universe smaller & more irregular (vs galaxies "today")

Galaxies appear to evolve through mergers (galactic cannibalism) and also near misses:

i) spirals unlikely in regions of a high density of galaxies

ii) spirals may result from near collision of small and large galaxy.

d) Galaxy central black hole:

Central black holes "grow" with time from galaxy galaxy collisions

Probably all large galaxies have central black holes

Qusar "epoch" only in early universe

Brightest quasars must consume 100s to 1000s of $M_{\odot}$/year. Based on most massive central black holes (today), quasars only "binge feed" for perhaps 10^6 years.

e) Large scale structure of (galaxies in the) universe:

"Redshift" surveys map galaxies (and galaxy clusters) in 3D showing a network of:

i) strings (or filaments) ← overdense regions of galaxies

ii) voids ← under dense regions of galaxies

Confirmed by "quasar absorption line" maps and "pencil beam" surveys

f) Gravitational lensing:

Because light is "bent" (deflected) as it passes large concentrations of mass, analysis of images of very distant galaxies allow maps to be made of the distribution of dark + normal matter

Chapt 17:

a) Cosmological principle
Universe is homogeneous (same everywhere) → scale ~ 300 Mpc
and isotropic (same in all directions)

b) Olbers' paradox (why is night sky dark)?
↳ because it is of finite age.

c) age of the universe ~ $\frac{1}{H_0}$ ⇒ ~ 14×10^9 years

d) start of universe is called the big bang.
ie time = 0
(vs time today ~ 14×10^9 years)

e) in expanding universe the redshift of distant galaxies is caused by the expansion of space, called cosmological redshift

f) expansion of universe, as modelled by general relativity, depends on on "mass energy" density in the universe.

IF this is < "critical density" universe is "open"

= " " is "flat"

> " " is "closed"

Light in the universe (even in the absense of overdense regions that cause gravitational lensing) travels differently depending on the "curvature" of the universe:

1. "negative" curvature (saddle-like) ≡ "open"
2. flat (no curvature) (like piece of paper) ≡ "flat"
3. "positive" curvature (sphere like) ≡ "closed"

g) So is the universe: open, flat or closed? These make different predictions for the future & also for the past

New "Hubble" plots (distance vs redshift) using Type I SN standard candles disagreed with all predictions and require a new term, called <u>Dark Energy</u> or <u>Cosmological Constant</u>, to be included in the general relativity models!

<u>Dark Energy</u> is now causing the expansion of the universe to <u>accelerate</u>: ie H_0 is increasing with time!

This also adds a new component to the "mass energy density" making the observed <u>mass energy density</u> = <u>critical density</u>!

In this model the predicted age of the universe very close to the $1/H_0 = 14 \times 10^9$ year value in agreement w/

i) 1st quasars: ~ 13×10^9 years ago

ii) globular clusters: $10 - 12 \times 10^9$ years ago

h) Cosmic MIcro Wave Radiation Background aka CMB:

The big bang initiated an insanely small, hot universe.

Light from that early universe is now redshifted to a Black Body spectrum w/ temperature 2.725K w/ typical wavelength ~ 1mm!

(cold today)

This has been observed, a major conformation of the big bang!!

i) Premordial nuclear synthesis:

A few minutes after the big bang, "free" n and p combined to produce the light nuclei, primarily the nuclei of H and He.

j) Formation of neutral atoms:

When the radiation from the big bang cooled to $\lesssim 3000\,K$, then free e^- and p became bound as atomic H

Species were then all neutral, allowing light to travel in straight lines to us today [ie without scattering on charged e^- & p!]

This was at a redshift ~ 1100 = $\frac{3000\,K}{2.7\,K}$

k) "Horizon" & "Flatness" problems:

"Horizon": CMB "identical" in every direction — how/why?

"Flatness": mass energy density observed = critical density — how/why?

Proposed solution is "<u>epoch of inflation</u>" lasting 10^{-32} seconds & causing the universe to grow by a factor of 10^{50} × ...

e) Formation of large scale structure:

Images of the CMB show tiny temperature fluctuations across the "photosphere at $z=1100$)

These can not come from non-uniformities in the distribution of e^- and p (kept ultra homogeneous by light scattering) rather they reflect some clumping in dark matter (that isn't kept homogeneous by light scattering)

Normal matter then "fell" into these DM clumps, allowing the structure formation seen since! Simulations of large scale structure provide some additional insights into the properties of dark matter.