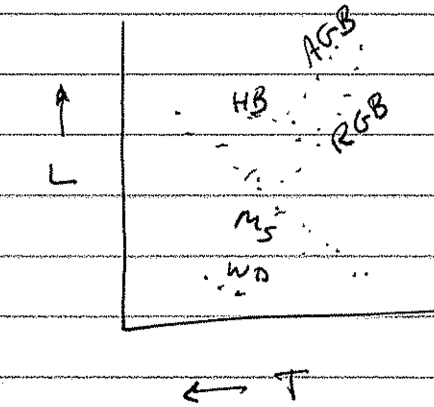
Final Review

Stars!

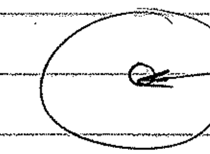
IMF $\xi(m)$

LF $\Phi(M)$



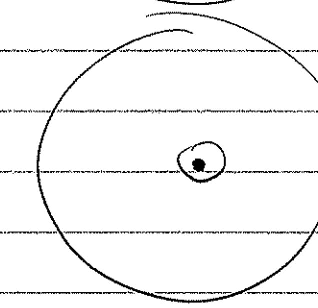
Stellar evolution ($\sim 1\ M_{\odot}$)

Main Sequence
longest lived phase



H burning in core

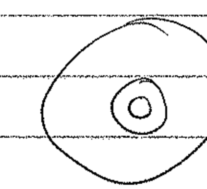
Red Giant



H burning in shell around inert He core

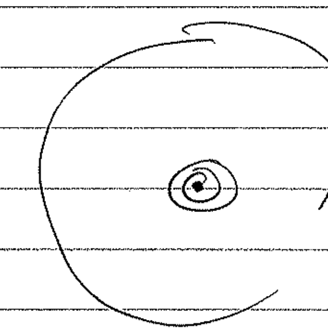
→ Helium flash ⇐ ignites He burning in core; some mass loss

Horizontal Branch



H burning in shell
He burning in core

Asymptotic Giant
(or "double shell burning" giant)



H burn in outer shell
He " " inner shell
inert C core

... death ... outer envelope lost to space

White dwarf

inert remnant of

Local Group

M31 & MW big spirals
then M33 then lesser galaxies (LMC, M110 ... etc)
fall in 3 "dwarf categories":

- dwarf irregulars — lots of gas, SF ... miniature spirals (or at least disks)
- dwarf ellipticals
- dwarf spheroidals (tiny satellites, hardly more than GCs)

LSS: Most galaxies in Groups like the LG
Also larger (richer) clusters with 100's, even 1000's of galaxies (like Virgo, Coma).
These systems considerably more rare.

Density – morphology relation: Es in cores of big clusters [mostly]
Ss mostly in groups; cluster outskirts

On still larger scales, galaxies organize into large filaments & walls surrounding very empty voids.

Surface photometry

Spirals: $\Sigma(r) = \Sigma_0 e^{-r/R_d}$
"exponential disk"

Ellipticals (+ some bulges)

$$I(r) = I_e \, 10^{-3.33\left[\left(\frac{r}{R_e}\right)^{1/4} - 1\right]} = I_e \, e^{-7.67\left[\left(\frac{r}{R_e}\right)^{1/4} - 1\right]}$$

"de Vaucouleurs" or $r^{1/4}$ profile

$$\ldots^{-b_n\left[\left(\frac{r}{R}\right)^{\frac{1}{n}} - 1\right]}$$

AGN: driven by SMBH.

Already suspected because

- $L \gtrsim L^*$ from a tiny volume; what else can have that energy density
- time variation of order days to weeks; again requires source to be smaller than $\lesssim c t_\Delta$

SMBHs now detected by motions of tracers nearby (stars & gas). Best case our own MW ($M \sim 3\times10^6 M_\odot$) directly from stellar orbits.

TIDES: $r_t = D\left(\frac{m}{2M}\right)^{1/3}$

Virial Thm

$$2\langle KE\rangle + \langle PE\rangle = 0$$

gives virial mass estimator $M = \frac{2\sigma^2 R_{hms}}{G}$

with $R_{hms} \approx 1.25 R_{eff}$

Of course, for circular motion around a point mass (or spherical mass distr.)

$$V^2_{(r)} = \frac{GM(r)}{r}$$

More generally, one has potential-density pairs

$$\nabla^2 \Phi = 4\pi G\rho$$ so knowing ρ gives Φ & vice-versa.

Must be solved numerically in general.

For spherical mass distributions $M(r) = \frac{4\pi}{3}\rho(r)\, r^3$

$$V^2(r) = \frac{GM(r)}{r} = \frac{4\pi G}{3} r^2 \rho(r)$$

Evidence for Dark Matter

flat Rotation curves ; MW satellites ($M_{MW} \sim 2\times10^{12} M_\odot$) ; LG timing argument
local Oort discrepancy ; disk stability
Clusters of galaxies – velocity dispersions, X-ray gas, gravitational lensing

Types of DM :

baryonic DM	e.g. brown dwarfs	
Hot DM	e.g. neutrinos	$v \approx c$
Cold DM	WIMPs	$v \approx 0$

CDM favored because of
1. $\Omega_m \gg \Omega_b$
2. LSS

Efforts to detect WIMPs include
- direct detection experiments (e.g. CDMS, XENON100)
- indirect detection (γ-ray ; cosmic rays) e.g. Fermi
- create them with the LHC

Dynamical Systematics

- RCs flatten at large R
- Inner RC well fit by maximum disk
- Disk Halo "conspiracy"
- Tully-Fisher $L \sim v^4$
- RC shape depends on light distribution
- MDacc / acceleration scale
  ↳ Mass Discrepancy – Acceleration Relation