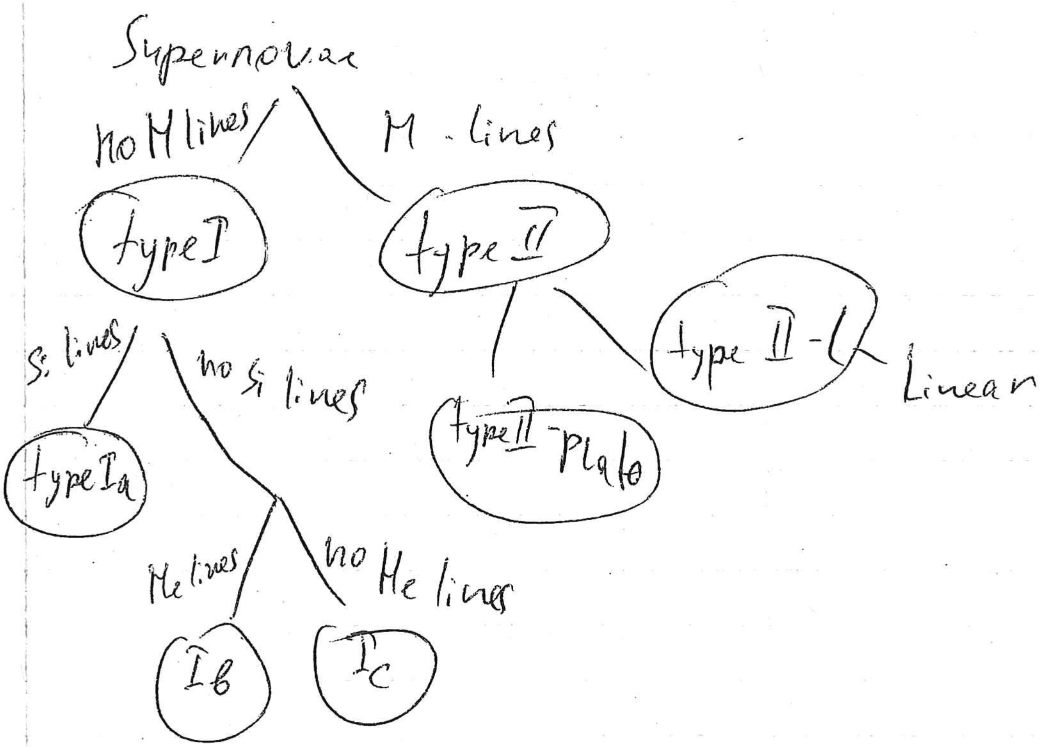
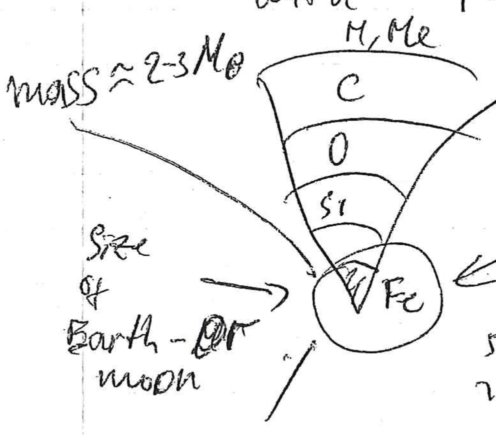
Lecture 29 on time

* Supernovae
* Gamma ray bursts
* Cosmic rays (charged particle flux)



Observed change from type II to type Ib in SN 1993J

Onion like composition with Fe at the core



collapses → neutron star / black hole

$^{56}_{26}Fe + \gamma \rightarrow 13\,^{4}_{2}He + 4n$

$^{4}_{2}He + \gamma \rightarrow 2p^{+} + 2n$

↑ takes energy

P ↓ drops

$p^{+} + e^{-} \rightarrow n + \nu_e$

↑ carry away energy

Gravitational collapse releases HUGE amount energy → 10^{46} J

1% kinetic energy of material

0.01% photons

of the rest neutrinos

let's estimate collapse time of the core

$$t_{ff} = \left(\frac{3\pi}{32}\frac{1}{G\rho_0}\right)^{1/2} = \left(\frac{2M_\odot}{R_E} \Rightarrow \rho = 1.8\cdot 10^9\right)$$

$R_E \approx 6.4\cdot 10^6\,m$

$$= \sqrt{\frac{3\pi}{32}\frac{1}{G\frac{2M_\odot}{\frac{4\pi}{3}R_E^3}}} =$$

$$= \sqrt{\frac{\pi^2}{8}\frac{1}{G\frac{2M_\odot}{R_E^3}}} = \sqrt{\frac{\pi^2}{8}\frac{1}{G}\frac{(6.4\cdot 10^6)^3}{2\cdot 2\cdot 10^{30}}}$$

$$\approx 1.56 \text{ sec}!$$

$$U = -\frac{3}{10}\frac{GM_{core}^2}{R}$$

$$\Delta E = -\frac{3}{10}GM_{core}^2\left(\frac{1}{R_{start}} - \frac{1}{R_{End}}\right)$$

$R_{start} \uparrow R_E$, $R_{End} \uparrow 50\,km$

$$= \frac{3}{10}G\frac{M_{core}^2}{R_{End}} = \frac{3}{10}\,6.67\cdot 10^{-11}\frac{(2.2\cdot 10^{30})^2}{50\cdot 10^3} =$$

$$\approx 6.4\cdot 10^{45}\,J$$

Recall sun luminocity $4\cdot 10^{26}\,J/s$!

SN 1987A — distance 51.4 kpc

Neutrino burst detecteted 3 hours before! photons, it lasted ~12.5 sec

with total ν count of <u>24</u>

Most energy carried away by neutrino

Gamma rays

seems to be distributed uniformly across sky.

fluence $S = \frac{E}{A} = \frac{E}{4\pi r^2}$

$r = \sqrt{\frac{E}{4\pi S}}$ Assume $E = const$

Then N of events with fluence $> S_0$

$\approx$ Volume contained in r

$N \sim \frac{4\pi}{3}\left(\frac{E}{4\pi S_0}\right)^{3/2} \cdot n$

n ← density of sources

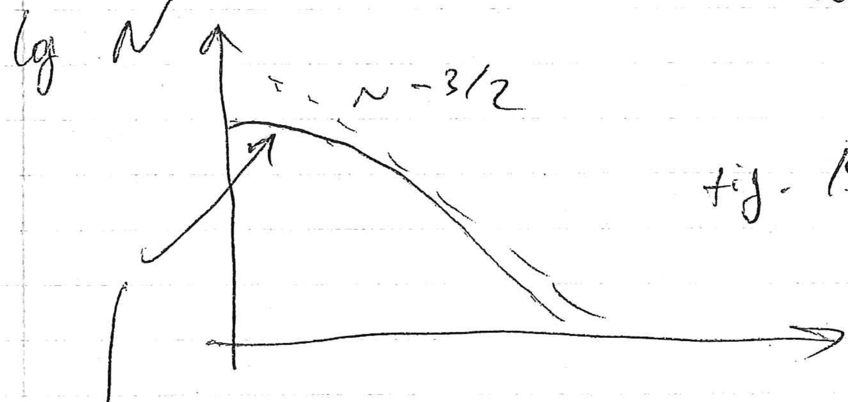


fig. 15.19

looks like for large r or small detected fluence we are missing sources

Q: So what? A: is universe finite?