Lect3: EVERYTHING ELSE...

October 10, 2007

"There are Type Ia Supernovae and there is everything else."

Plan of the lecture

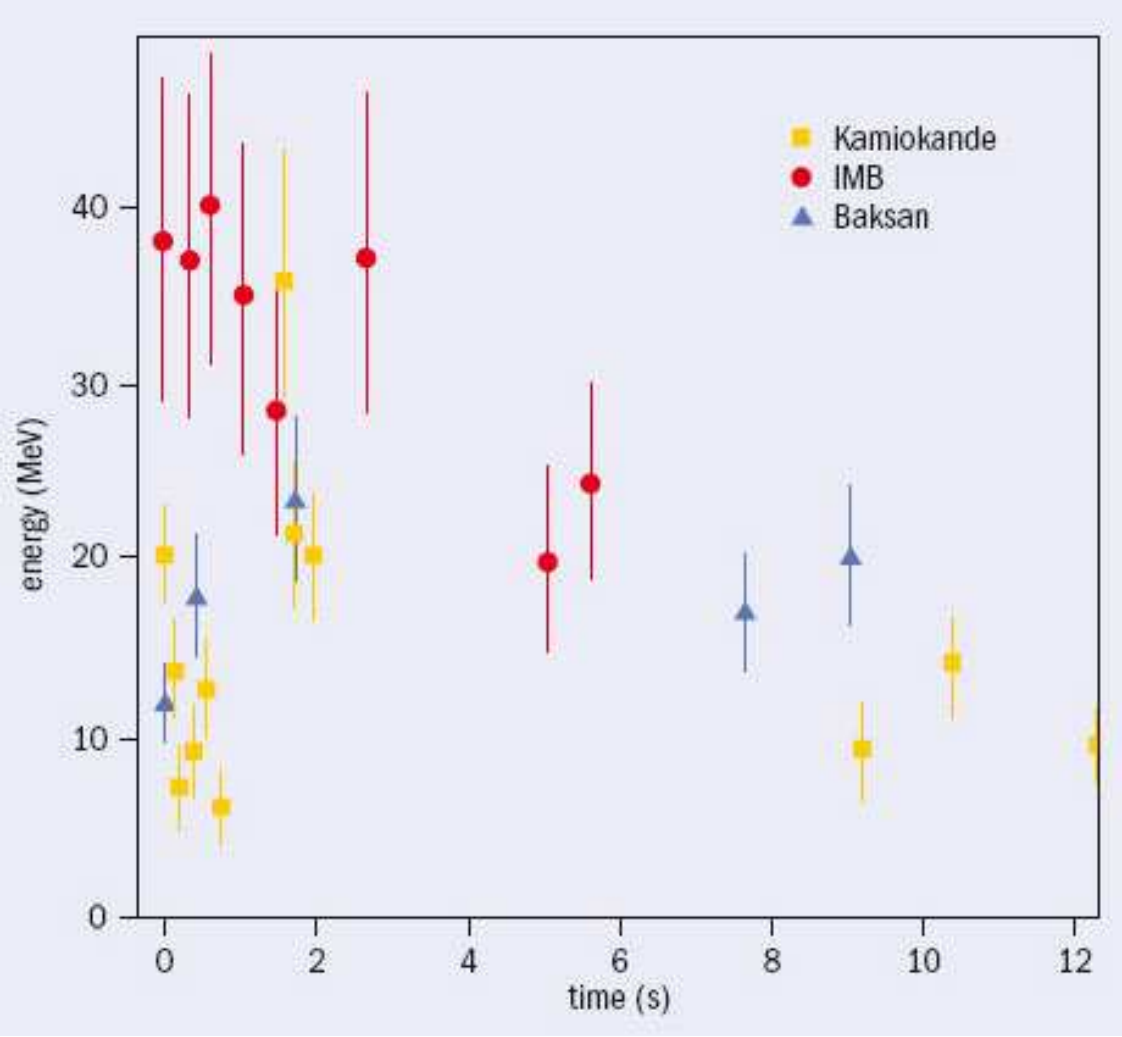
- Core Collapse
- Outer Problem
- Remnants

CORE COLLAPSE

Sources of energy:

- Gravitational: $E_g \sim GM_{NS}^2/R_{NS} \sim$ few $\times 10^{53}$ergs.
- Nuclear: $E_n \sim 10^{51}$ergs.

(1) Most of the grav. energy is radiated away by neutrino.



Observed neutrino signal from SN1987A agreed with theoretical predictions (both spectrum and duration) that were made before the light from SN1987A reached the Earth.

EXPLOSION MECHANISM(S) OF CORE-COLLAPSE SUPERNOVAE

So far, survival time of a "successful" explosion mechanism of a core-collapse supernova has been less than five years.

Neutrino-driven explosions:

- Core of a massive star looses pressure support due to electron capture, dissociation of nuclei, or pair production.

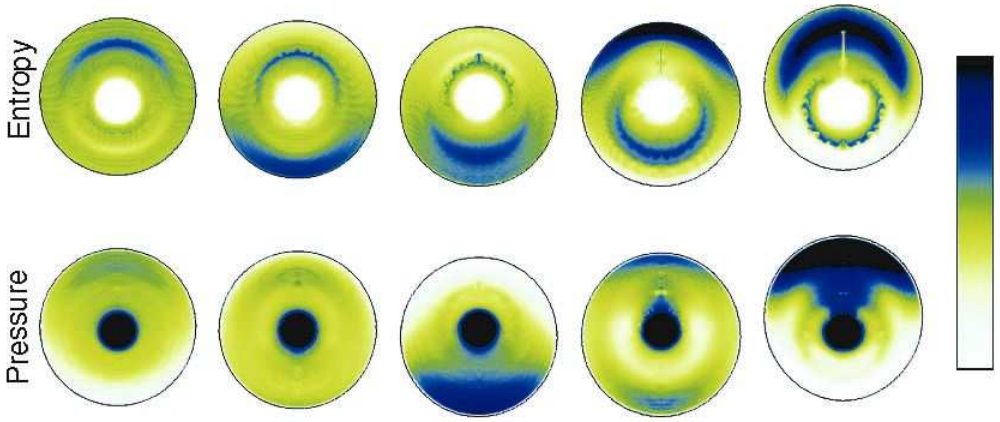
- Central part of a core collapses homologously, coillapse stops at ∼nuclear density, and an outgoing shock is formed.

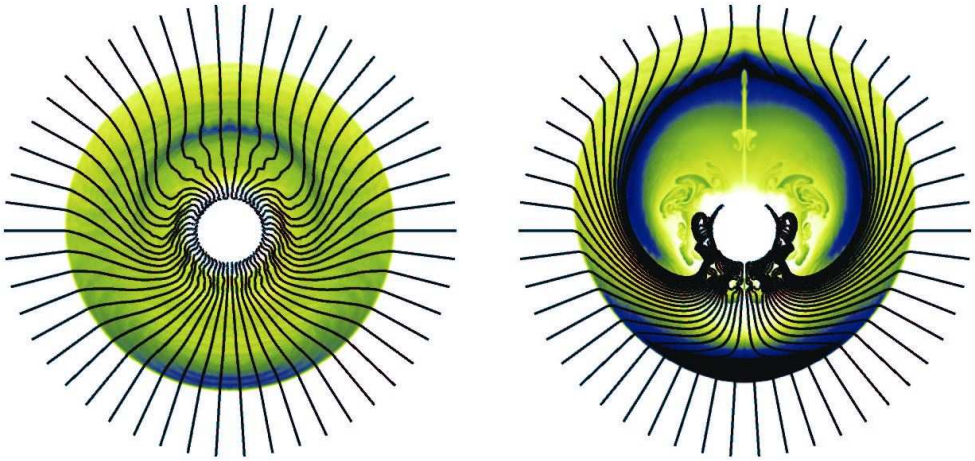
- Rest of the core material continues to fall onto the formed proto-neutron star. Shock stalls. Most of the energy is radiated away by neutrino.

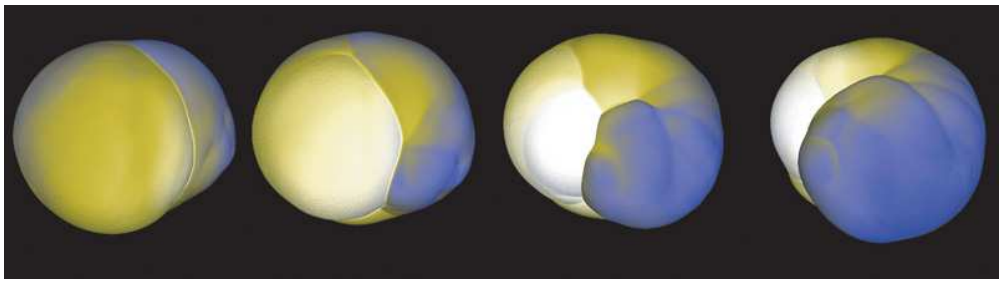
- The region behind the shock is unstable to convective, acoustic, etc. instabilities. Flow becomes 3D and very complex.

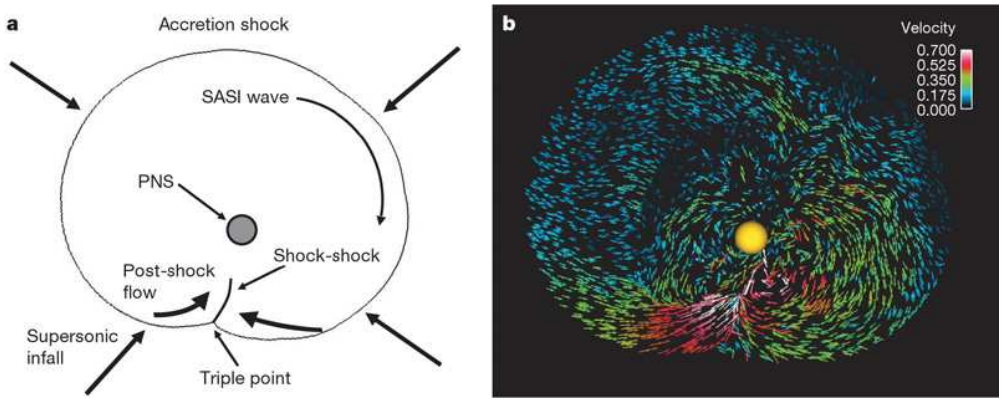
- Most recent development is the discovery (Blondin etal. 2003) and study of a spherical accretion shock instability (SASI). The existence of SASI is confirmed by several groups (Mezzacappa etal., Burrows etal., Janka etal.). Current debate is about the exact effect the SASI may have on the explosion.

SASI









Blondin & Mezzacappa (2003,2006,2007)

MAGNETO-ROTATIONAL MECHANISM

LeBlanc & Wilson (1960?), Bisnovatyi-Kogan etal. 1971, finally Burrows etal. 2007.

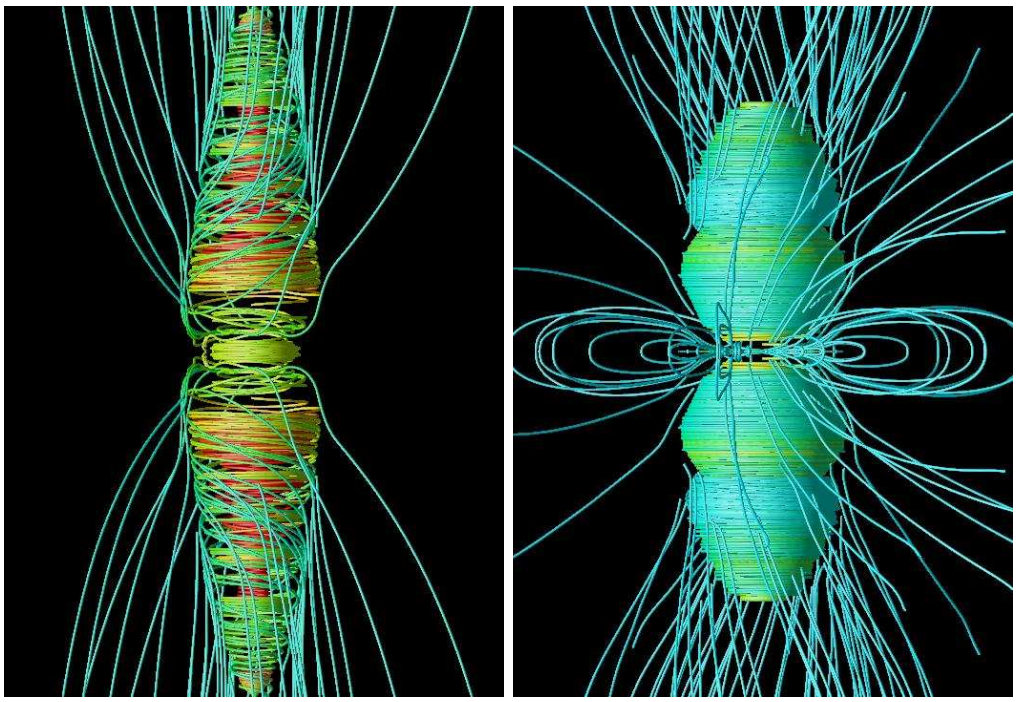
- Rotation energy increases when core collapses. There could be up to $E_{rot} \sim M_{NS}U_{rot}^2 \sim$ few $\times 10^5$2ergs available after bounce.

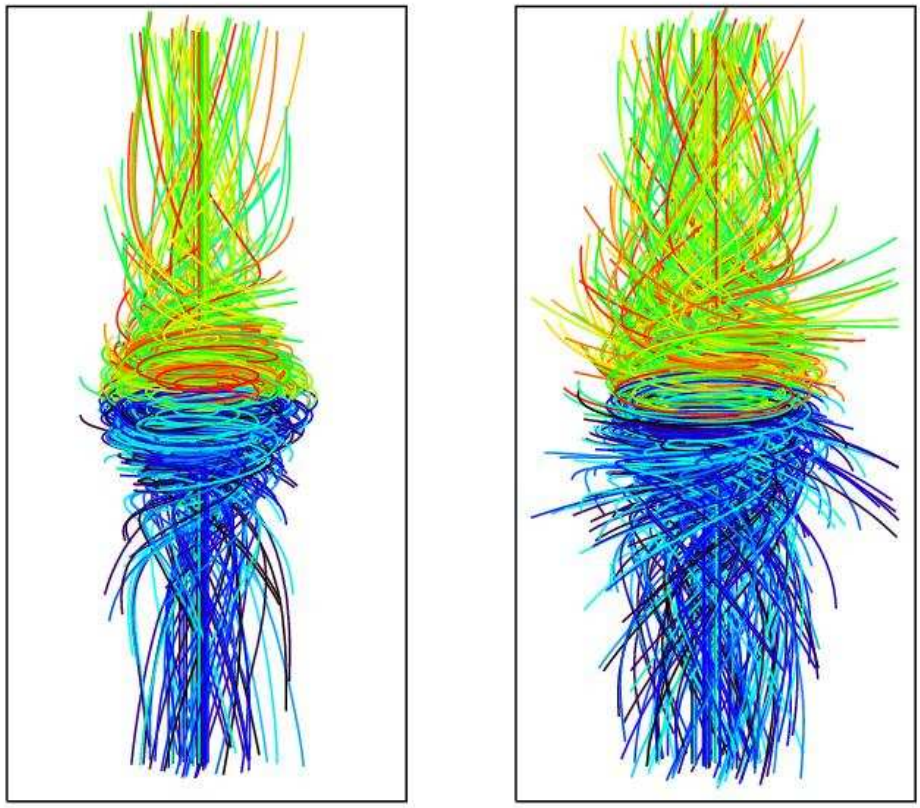
- magnetic field may be amplified/generated by rotation.

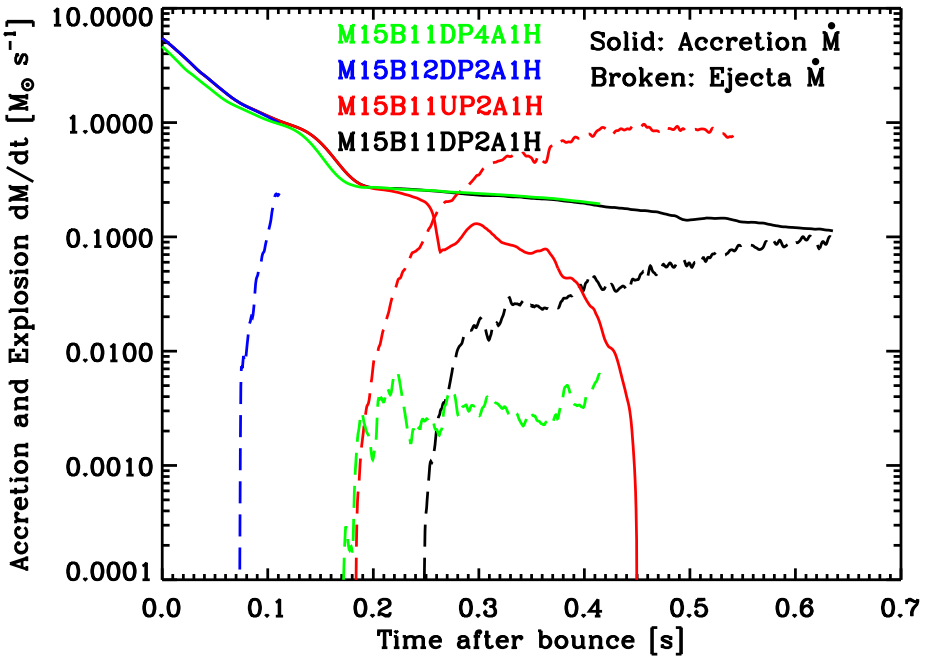
- Result - a collimated outflow of mass and energy.

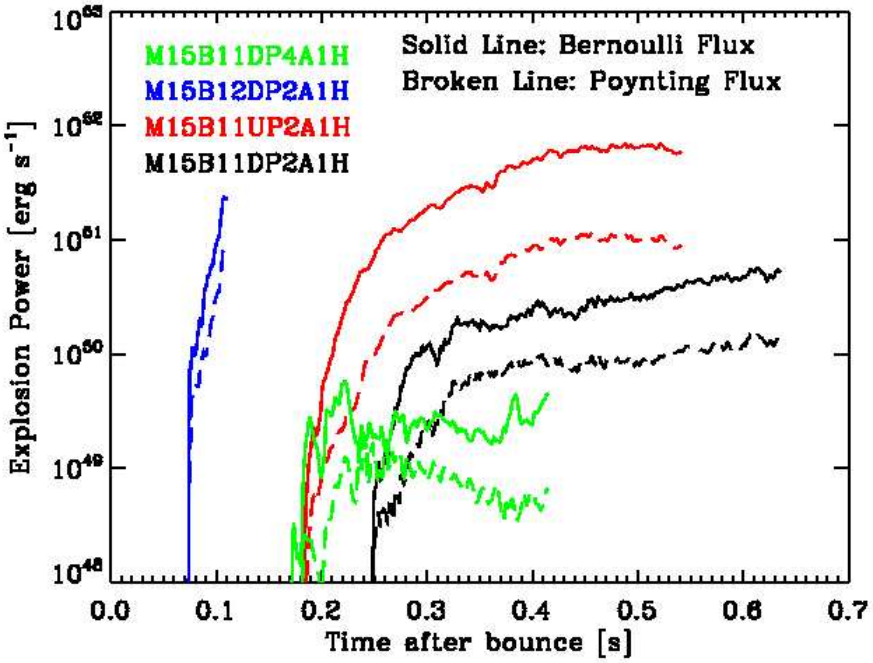
Both L&W and B calculations predict a non-realtivistic, high-density, matter-dominated jet-like outflow that may last a few seconds.

Some of the results of Burrows etal. are shown below:



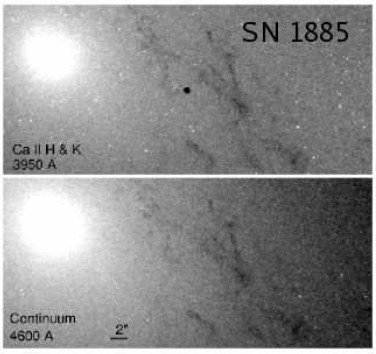



M15B11DP4A1H
M15B12DP2A1H
M15B11UP2A1H
M15B11DP2A1H
Solid: Accretion Ṁ
Broken: Ejecta Ṁ
Accretion and Explosion dM/dt [M⊙ s⁻¹]
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time after bounce [s]

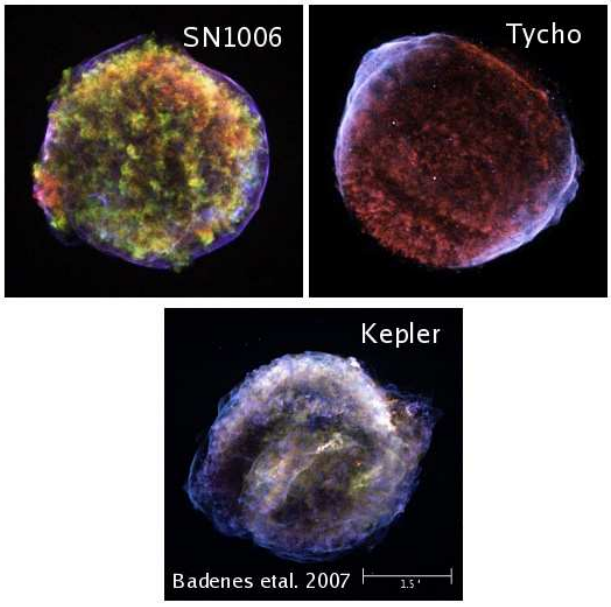

M15B11DP4A1H
M15B12DP2A1H
M15B11UP2A1H
M15B11DP2A1H
Solid Line: Bernoulli Flux
Broken Line: Poynting Flux
Explosion Power [erg s⁻¹]
10⁵²
10⁵¹
10⁵⁰
10⁴⁹
10⁴⁸
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time after bounce [s]

Remnants of Type Ia Supernovae

"The long sought-after remnant of the celebrated 1885 supernova, commonly known as S Andromedae, has been discovered!" R. Fesen etal. 1998,2007



X-ray Images of Galactic Type Ia Supernova Remnants



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