New Astronomy Reviews 52 (2008) 364–369

Contents lists available at ScienceDirect

New Astronomy Reviews

journal homepage: www.elsevier.com/locate/newastrev

Supernovae, their functioning, lightcurves, and remnants

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ARTICLE INFO

Article history:
Available online 25 June 2008

PACS:
97.60.Bw

Keywords:
Supernovae
Core collapse
Relativistic piston
Splinter bomb
Hubble flow

ABSTRACT

Ever since Shklovskii's influential 1962 paper, the literature tends to model supernovae (SNe) with strong shock waves (or blast waves), implying reverse shocks, Sedov stages, and the like. Here I repeat my conviction since 1988, that all SNe are of the core-collapse type, and are expelled by the collapsing core's wound-up magnetic field plus its decay product – an ultra-high-energy (UHE) relativistic cavity – which serves as the ultimate piston. The piston's Rayleigh–Taylor instability tears the ejected envelope into a huge number ($\gg 10^3$) of (magnetized, filamentary) fragments, or splinters. The critical stellar mass M_{crit} for core collapse to happen is closer to 5 $M_\odot$ than to 8 $M_\odot$. SN remnants are former stellar windzones, collisionally heated when traversed by the shell of ejected SN splinters and by its relativistic piston (which has strongly cooled, though, via adiabatic expansion).

1. The two (extreme) types of bomb

The supernovae we observe in the sky are known to be gigantic explosions of evolved stars, of masses M at or above some critical mass M_{crit} which is highly controversial, even though a straightforward estimate from the lightcurve's transition from optically thick (photospheric) to optically thin (nebular) yields ejected shell masses that cluster around $(3 \pm 1)\ M_\odot$ (Kundt, 1988, 1990, 1998). Such (high) shell masses are expected for $M_{crit} \approx 5\ M_\odot$, and are inconsistent with the exploding white-dwarf model for SNe of type Ia (more reasonings against the latter will be given in Section 4). A comparatively low M_{crit} (of 5 $M_\odot$) is independently implied by the large birthrate of neutron stars, 1 in $\lesssim 10$ yr in the Galaxy, obtained from pulsar statistics and the conviction that pulsars are the younger brothers, on average, in evolved massive binary (or multiple) systems (Blaauw, 1985; Van den Bergh and Tammann, 1991; Kundt, 1998).

Independently of their detailed structure, sudden, high-speed mass ejections from some compact source classify as bombs. In a bomb, a sudden transfer of potential (chemical or nuclear) energy to some ambient matter gives rise to its high-speed ejection. In a pressure bomb (or blast wave), such a transfer takes place (essentially) to some surrounding gaseous medium, whilst in a splinter (shrapnel) bomb, most of the energy is transferred to dense fragments of a container. Thin-walled bombs are of the blast-wave type, whereas thick-walled bombs are of the shrapnel type, whose ejecta realize a Hubble-flow velocity distribution: $\vec{v}(\vec{r}) \sim \vec{r}$. Of course, in reality, any combination of energy transfers can occur. Figs. 1 and 2 show examples of both types of bomb. In their seminal paper, Hoyle and Fowler (1960) assumed that SNe were powered by nuclear energy. Knowing the (thin-walled) morphology of nuclear explosions in the Earth's atmosphere, Shklovskii (1962) applied Sedov's (strong) shock-wave model to SNe. The impact of these two pioneering publications on the scientific community is still felt today. Instead, a consideration of the necessary energy transfer from the collapsing core to the extended envelope led me to explore the (thick-walled) splinter model (1976, 1988, 1990, 1998, 2003, 2005), variants of which have been independently pursued by Bisnovatyi-Kogan and collaborators ($\geqslant$1969), without convincing me in their details.

Most of the international research on SNe has taken numerical approaches, which tend to be careful as concerns the nuclear reactions (at high densities and temperatures!) but unrealistic by ignoring the huge (equi-partition) magnetic field strengths expected to be generated during core collapse, and by ignoring their subsequent reconnection and conversion to relativistic (matter–antimatter) particles, with energies as high as 10^{20} eV, see (3). They thus lack the UHE relativistic piston without which the heavy, extended envelope of the exploding star cannot be ejected, already because of insufficient radial-momentum (required to overcome gravity). When viewing the proceedings of the 5th workshop on 'Astronomy with Radioactivities' edited by Hartmann et al. (2006), I thus agree with the difficulty of "fallback in stellar collapse" highlighted by Fryer (p. 492): "Delayed ejections", as presented by Burrows et al. (p. 487; also: Burrows et al., 2007), forget the radial-momentum balance when claiming to have "dri-

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doi:10.1016/j.newar.2008.06.027

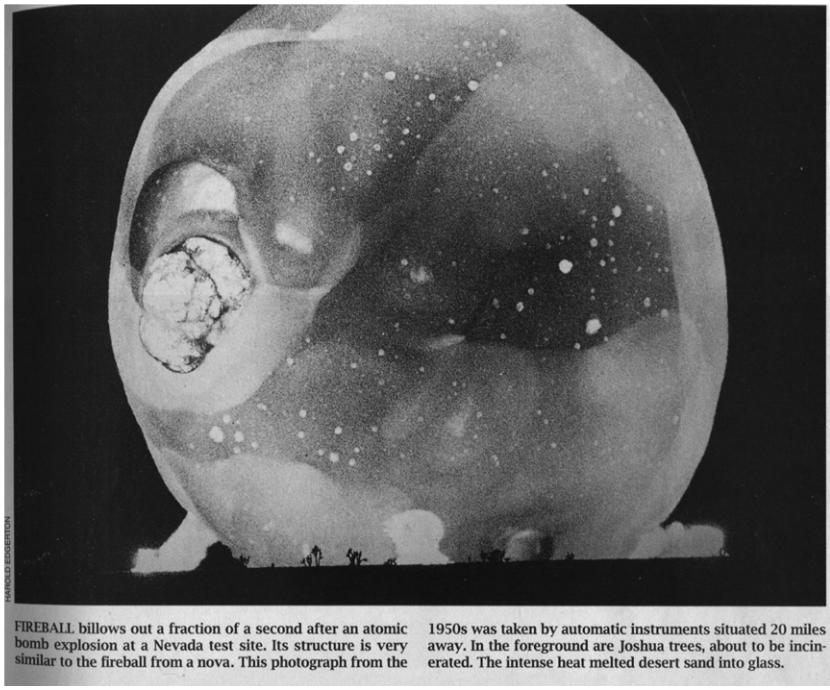

Fig. 1. Hydrogen-bomb explosion in air at a Nevada test site, photographed within a fraction of a second after ignition by automatic instruments situated 20 miles away, in ⩾1952; from Starrfield and Shore (1995). The Joshua trees in the foreground will soon be incinerated. Desert sand was melted into glass. This event was a close approximation to a Sedov–Taylor wave.

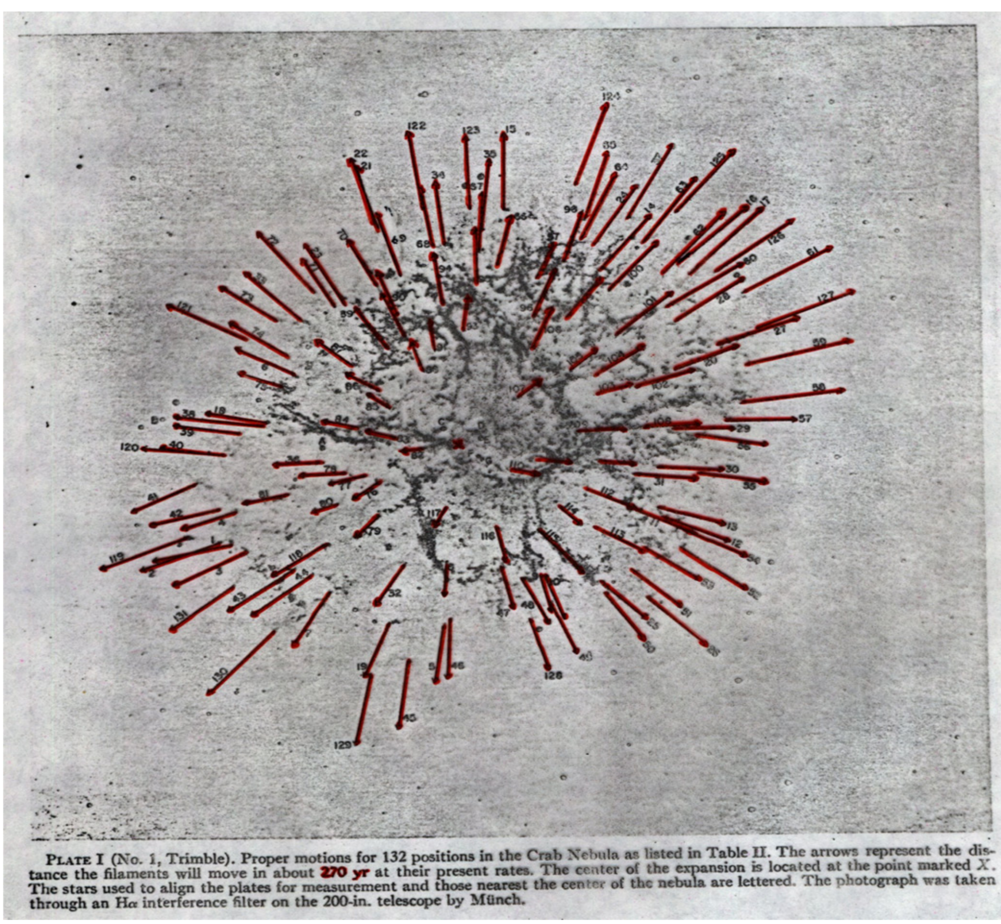

Fig. 2. Proper motions for 132 positions in the Crab Nebula, drawn by Virginia Trimble (1968) into a photograph taken through an Hα interference filter on the 22-in. telescope by Münch. The (numbered) arrows represent the distances the filaments will move in about 270 yr at their present rates. The center of the expansion is marked X. The stars used to align the plates for measurement and those nearest the center of the nebula are lettered. Clearly, we deal with a close approximation to a splinter bomb. For corroborative, improved recent data see Rudie et al. (2007).