that the magnetic field (MF) from the synchrotron emitting shell evolved as: $B = (2.5 \times 10^{-7} \text{G}) (\rho/100 \text{M}_{\odot})^{0.5}$. This can be compared with the equipartition MF in the progenitor wind, $B_e = (2.5 \times 10^{-9} \text{G}) M_e^{-0.5}$. Thus it appears that the magnetic field is amplified about a 1000 times. Since the shock itself is not substantially modified in the model of T09, the compression ratio (left) is close to 4. We conclude that a strong MF amplification (MFA) process, driven by Diffusive Shock Amplification (DSA) of hadrons, is at work at the forward shock front. The efficiency of particle acceleration, defined as ratio of energy in accelerated particles to the total incoming flux, increases with time to almost 25%.

**Procedure**: Proton particle spectrum is a power-law $s=2$, with exponential cutoff at $E_{max}$. One zone energy equation to calculate evolution of secondary electrons and protons. Radiative losses (synchrotron, Inverse Compton) included for primary and secondary electrons. Gamma- rays can be absorbed by soft photon fields to produce electron-positron pairs (gamma-gamma absorption). Photon source - SN photosphere. Full calculation of $\gamma$ opacity including geometrical effects due to anisotropic interaction.

**Radio Evolution of SN 1993J (above, from N. Bartel & M. Bietenholz)**: SN 1993J is a Type Ibb SN, with a possible Red Supergiant (RGB) progenitor (Chevalier & Oishi 2003, ApJ, 593, 123). Using a synchrotron self-absorption model to explain the multi-frequency radio lightcurves, Tatsheck 2009 (A&A 493, 191; “T09”) showed that the magnetic field (MF) from the synchrotron emitting shell evolved as: $B = (2.5 \times 10^{-7} \text{G}) (\rho/100 \text{M}_{\odot})^{0.5}$. This can be compared with the equipartition MF in the progenitor wind, $B_e = (2.5 \times 10^{-9} \text{G}) M_e^{-0.5}$. Thus it appears that the magnetic field is amplified about a 1000 times. Since the shock itself is not substantially modified in the model of T09, the compression ratio (left) is close to 4. We conclude that a strong MF amplification (MFA) process, driven by Diffusive Shock Amplification (DSA) of hadrons, is at work at the forward shock front. The efficiency of particle acceleration, defined as ratio of energy in accelerated particles to the total incoming flux, increases with time to almost 25%.

**Streaming Instabilities**: Streaming of shock waves ahead of the shock front produces magnetic fluctuations. The streaming modes can be in resonance (R) with the energetic particles (wavenumber $k_r = r$), or they can be non-resonant (NR) ($k_r \gg r$). NR modes grow fastest, which are prevalent in young SNe.

**Maximum Energies**: At early times, maximum energy is limited by the SN age, and is obtained by equating the acceleration timescale with the age: $t_{acc} = \frac{t_{age}}{r_c} = \frac{g(r) t_{age}}{f_{1.17}}$, where $g(r) = 3c (\lambda r^3 k_{r_0} k_{r_0}^2)$. If the NR streaming instability is active, then we have: $E_{max, NR, PeV} \approx 1 \times 10^{-17}$, and if longer wavelength fluctuations are produced due to ponderomotive instability, then, following Maund et al 2004, Nature, 427, 129:

$$E_{max, LW, PeV} \approx 55 \frac{n_{tot}}{0.1} \times 10^{-14}$$

This value is however optimistic, since magnetic field experienced by the highest energy particles is less than $B_{init}$. The maximum cosmic ray proton energy is the minimum of the above. In all cases, it appears that PeV energies can be reached. These can be probed with a gamma-ray telescope sensitive above a few hundred TeV.

**Conclusions**: A high velocity shock and a high density medium are both key ingredients to initiate fast particle acceleration, aided by fast growing instabilities driven by the acceleration process. Other important parameters are: the shock velocity, the ionization fraction of the ambient medium, the background stellar wind MF and the SN peak luminosity. Plasma instabilities driven by the energetic particles accelerated at the shock front grow over inradar timescales. Along with the interplay of non-linear processes, this permits a fast amplification of the MF at the shock, that can explain the MF strengths deduced from radio monitoring. The maximum particle energy is 1-10 PeV depending on the dominant instability. CTA should easily detect objects like SN 1993J, particularly above 1 TeV, which are marginally detectable by current telescopes. The gamma-ray signal is heavily absorbed by pair production process during the first week after outburst. We predict a low neutrino flux above 10 TeV, implying a detectability horizon with a KM3Net-type telescope of 1 Mpc only. Among SNe, the rare Type IIn events would presumably be promising targets for $\gamma$-ray telescopes because of the high density. The most common type IIP should theoretically have high mass-loss rates, but observationally are less luminous in X-rays (Dwarkadas 2014, MNRAS, 440, 1917), which may indicate that they arise from lower mass stars (Smartt 2009, ARAA, 47, 63). Type Ib/c SNe have the fastest shock waves, but arise from Wolf-Rayet stars which have a high wind velocity (~2000 km s$^{-1}$) and thus lower wind density, delaying the peak of gamma-ray emission.

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