Dependence of the magnetic field on the explosion of core-collapse supernovae

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Numerical method

- 2D (axisymmetry)
- progenitor: non-rotating 27Msun (Woosley et al. 2002)
- grid: $0 < r < 5000$km, $N_r=480$ (logarithmically),
  $0 < \theta < \pi$, $N_\theta=120$ (uniformly)
- hydro: based on Takiwaki et al. 2016
- neutrino: isotropic diffusion source approximation (IDSA) scheme
  (Kotake et al. 2018)
- ideal MHD, HLLD, divergence cleaning (Dedner et al. 2002)
- B-field: pure poloidal: $A^\phi = \frac{B_0}{2}\frac{r_0^3}{r^3+r_0^3} r \sin\theta,\ r_0 = 1000\ \mathrm{km},\ B_0 = 10^{10-12}\ \mathrm{G}$
  (Obergaulinger & Janka 2018)
- special treatment of the calculation of induction equations

Treatment of induction equations

$$\frac{\partial B_r}{\partial t} + \frac{1}{r^2}\frac{\partial}{\partial r}(r^2\psi) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\left[\sin\theta(B_r v_\theta - v_r B_\theta)\right] = \frac{2\psi}{r}$$

finite volume   finite area   finite volume

$$\frac{\partial B_\theta}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}\left[r(B_\theta v_r - v_\theta B_r)\right] + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\sin\theta\psi) = \frac{\cot\theta\psi}{r}$$

finite area   finite volume   finite volume

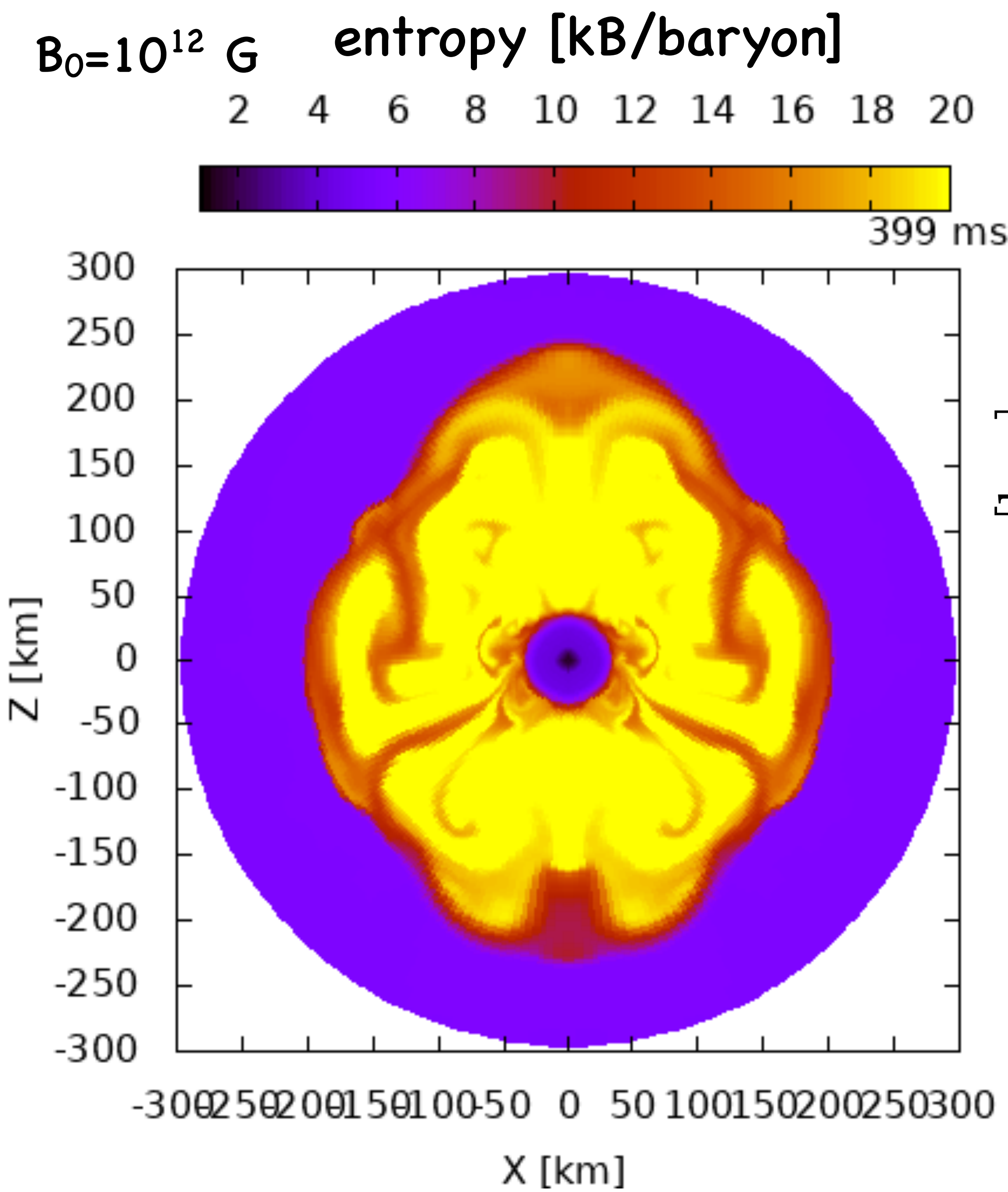
$$\frac{\partial B_\phi}{\partial t} + \frac{1}{r}\frac{\partial}{\partial r}\left[r(B_\phi v_r - v_\phi B_r)\right] + \frac{1}{r}\frac{\partial}{\partial\theta}\left[B_\phi v_\theta - v_\phi B_\theta\right] = 0$$

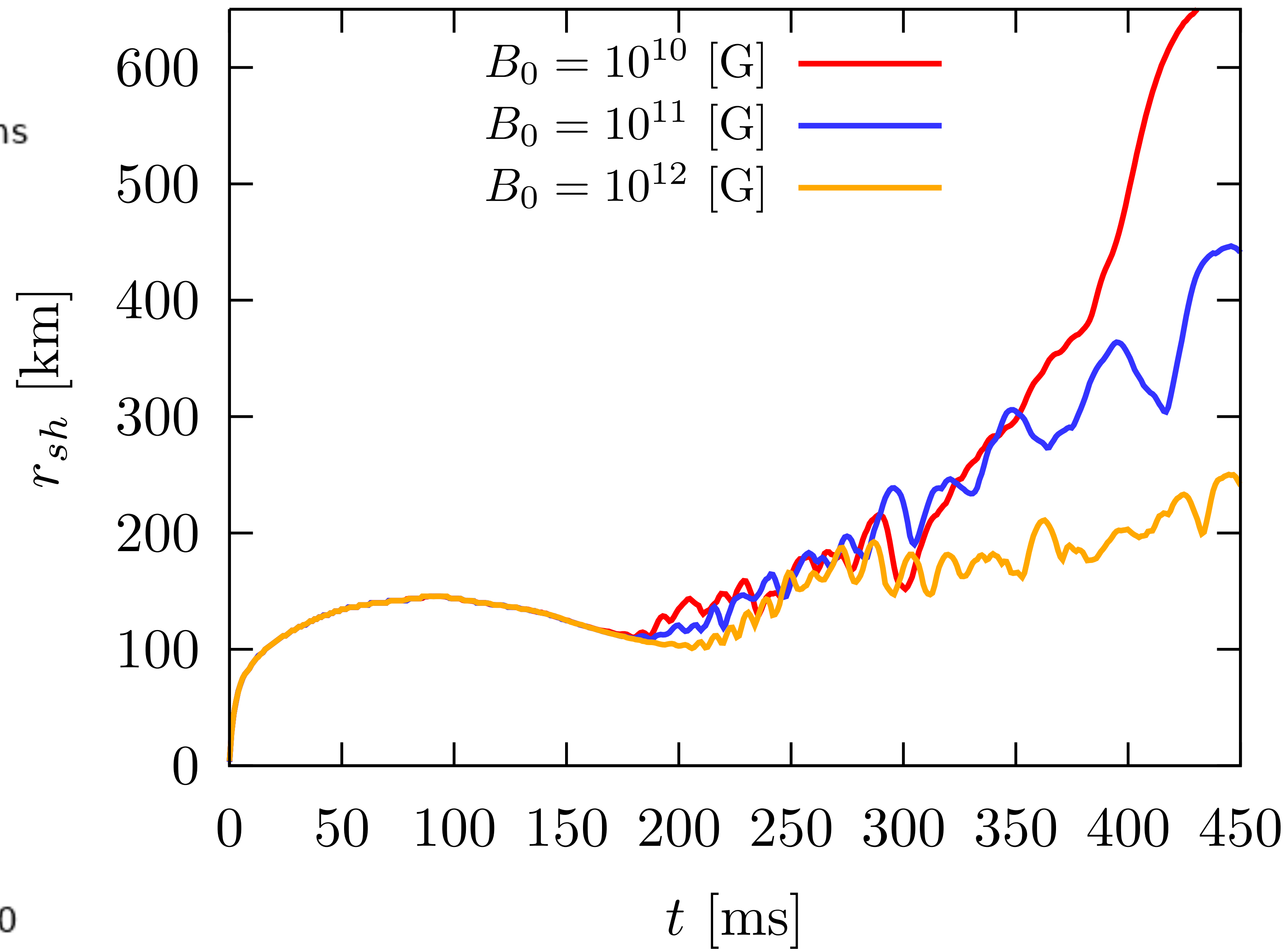
finite area   finite area

$$\frac{\partial\psi}{\partial t} + \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 C_h^2 B_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}\left[\sin\theta C_h^2 B_\theta\right] = -\frac{C_h^2}{C_p^2}\psi$$

finite volume   finite volume   finite volume

Results





The larger the initial magnetic field strength,
the smaller the spherical (angle-)averaged shock radius.