X-Ray Continuum Variability in Cassiopeia A

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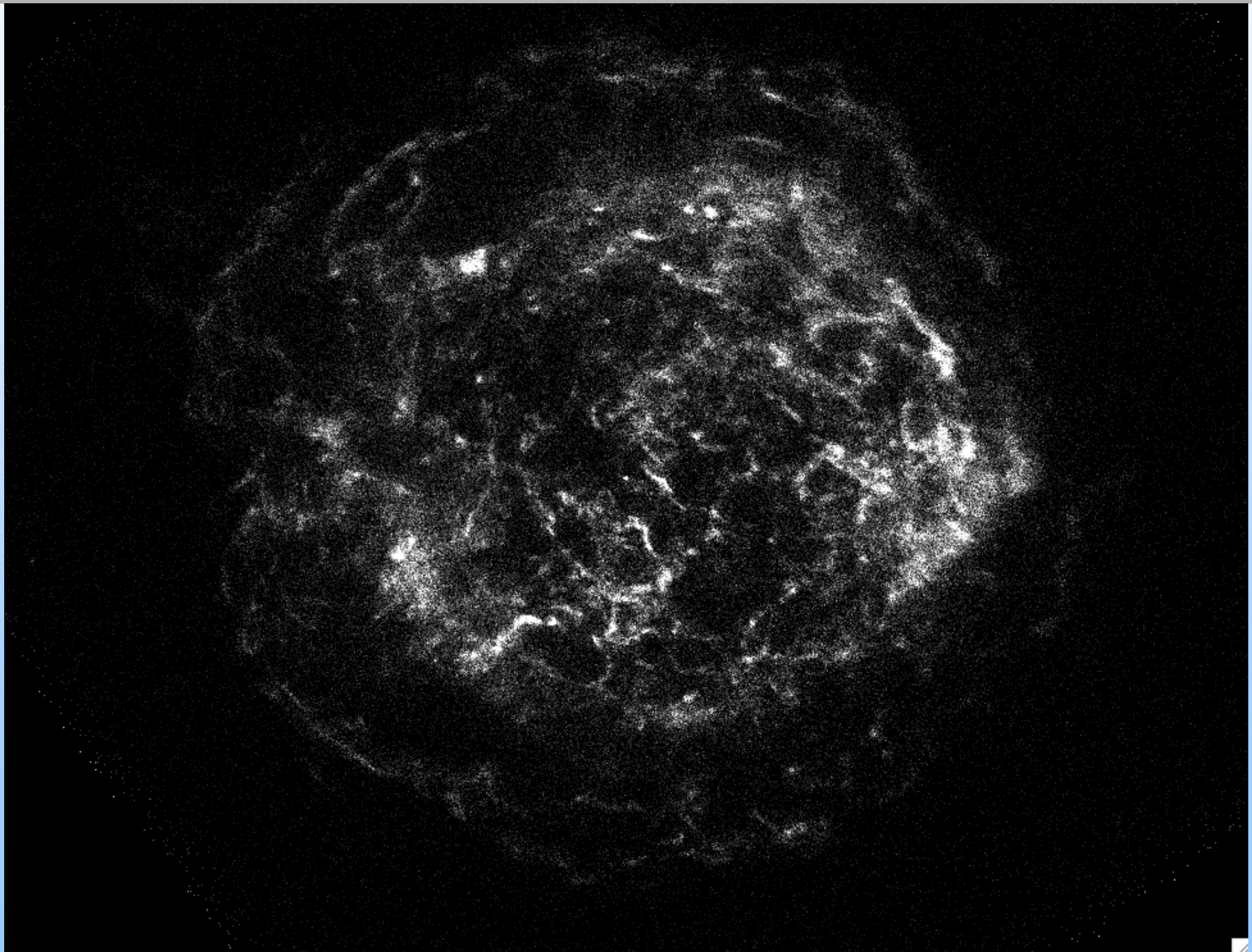
4.2-6.0 keV continuum, from 2000, 2002, 2004, 2007 (courtesy Dan Patnaude)



Acceleration, Cooling Times

$\tau_{acc} = \int_{p_0}^{p_1}(D_1/pU_1 + D_2/pU_2)dp \;\; 3/(U_1-U_2)$

$\approx 8D_1/U_1^2$

≈ 1.7 / B(mG) years,

for $D_1=4D_2 = r_gc/3$, $U_1=4U_2= v_{for}=5000$ km/s,

electron energy = 50 TeV, ($\gamma = 10^8$).

Longer at reverse shock by $(v_{for}/v_{rev})^2$.

B(mG) is upstream magnetic field.

$\tau_{cool}= 0.3/B(mG)^2$ years @ energy = 50 TeV, requires B=0.4 mG.

B is average magnetic field seen by cr electrons.

Magnetic Field Saturation

Luo & Melrose (2009)

$\delta B^2/B^2 \approx 10\sqrt{\eta}\,(v_s/c)^{3/2}(k_0 r_{g0})^{3/2}\ln(v_s/v'_{cr}) \approx 39$

My estimates for Cas A; with $n_{cr}/n_i=10^{-3}$, $B=10^{-5}$-10^{-6}G,
$\delta B^2/B^2=10$-10^4 ($\delta B=0.03 – 0.1$ mG)

Gargaté et al. (2009 in prep)

run B1 rescaled to $v_s=5000$ km/s, $V_A=32$ km/s, $B=2.1\mathrm{x}10^{-5}$G, $n_{cr}/n_i=10^{-3}$, $\delta B^2/B^2\sim 10$

run B2, $V_A=3.2$ km/s, $B=2.1\mathrm{x}10^{-6}$G, $n_{cr}/n_i=10^{-4}$, $\delta B^2/B^2\sim 30$

Magnetic Field Amplification versus Electron Heating

Linear theory:

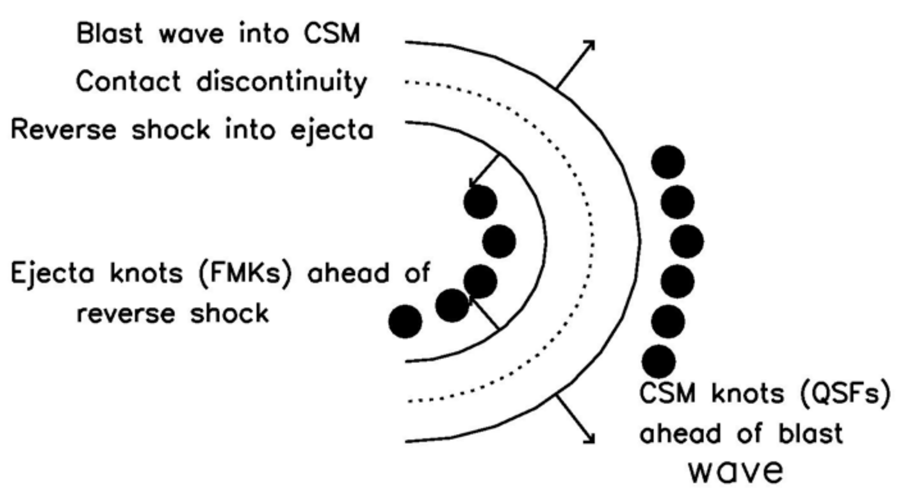
B-field growth $\gamma_B = n_{CR} M_A v_s / 2 n_i r_{g,inj}$, parallel shock
$= 0$, perpendicular (Bell 2004, MNRAS, **353**,550)

LH-wave growth $\gamma_{LH} = 32 n_{CR} \omega_{LH} / 225 n_i$, perpendicular shock
$= 0$, parallel (Rakowski, Laming, & Ghavamian 2008, ApJ, **684**, 348)

High M_A, cosmic rays amplify B, low M_A, cosmic rays grow LH waves, heat electrons. Equality at $M_A \sim 6 v_{inj}/v_s \sim$ 12-60? (depending on geometry) M_A=12 gives B=0.27 mG.

Measurements at Cas A forward shock, 0.1 – 0.4 mG ***postshock*** (i.e. compressed) magnetic field.

Another Possibility: Reflected Shocks from Blast Wave Carry CR Electrons back to Contact Discontinuity



Reflected shocks; max. speed = $9v_s/8$, max. compression ratio =2.5, → softer cr and synchrotron spectra

- Magnetic field at CD ~ 1mG from RT instability
- Synchrotron observations: forward shock Γ=2.1-2.24, interior Γ~3.14 (harder on west limb)
- Need reflected shock compression ratios > 2, velocities > $0.9v_s$, QSF density contrast > 30
- Same thing as reverse shock hits ejecta knots?

Conclusions

- Reverse shock magnetic field of 1 mG appears unlikely, but possibly enough "wiggle room" for forward shock.
- Faster observed variability would favor reflected shock scenario.
- Chandra Cycle 11 observations (P.I. Dan Patnaude) will look for just that!
- RXJ1713.7-3946?