Magnetic field properties derived from radio relics

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Rajpurohit et al. 2017 submitted

Kierdorf et al. 2017

Ridge is surprisingly narrow!

- select a downstream profile for modelling

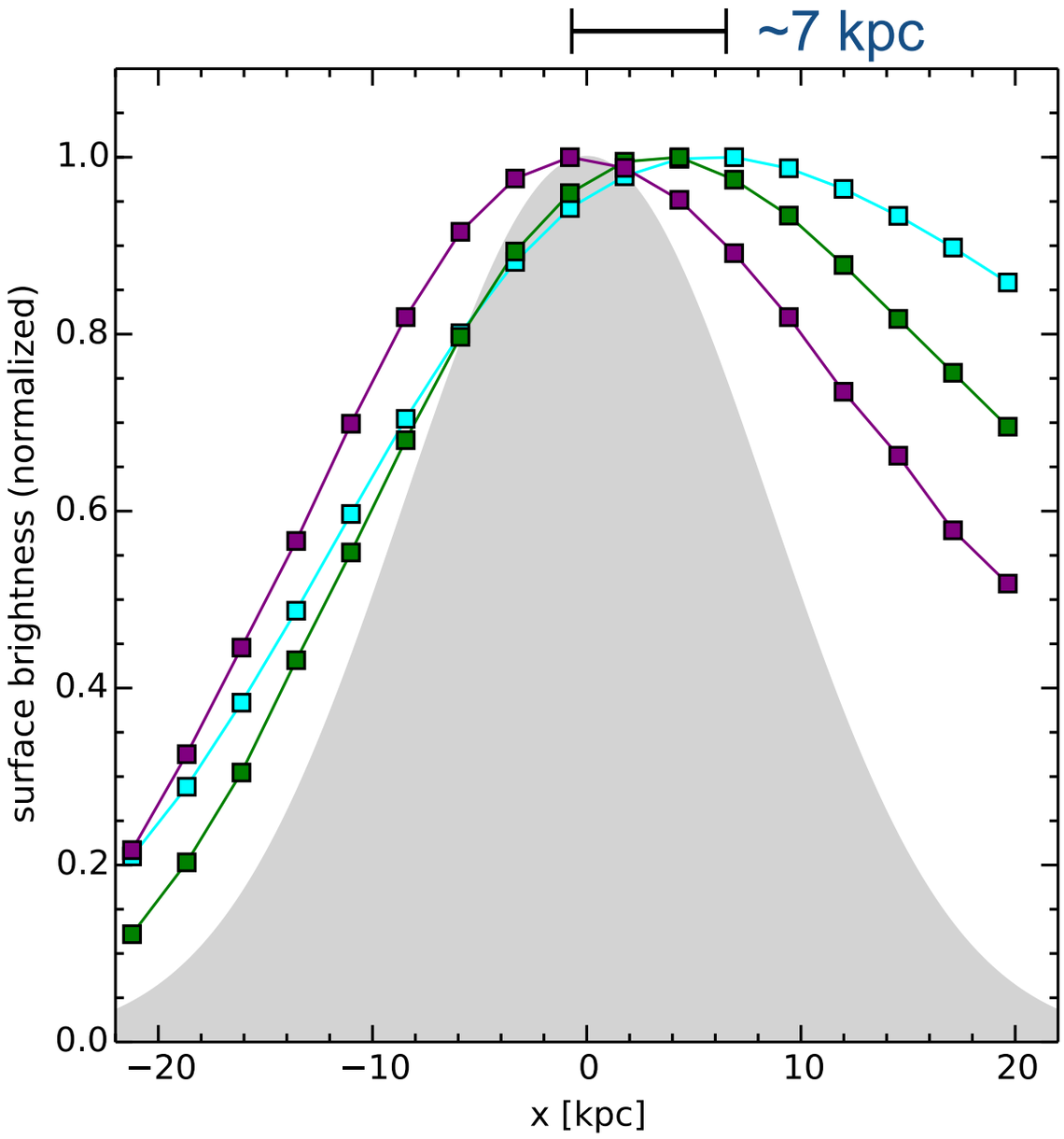
‘ridge’

profile region

Rajpurohit et al. subm.

Shift and asymmetry of ridge

- downstream profile changes with frequency
- consistent with shock+downstream cooling scenario
- watch the distance!



LOFAR - 150 MHz

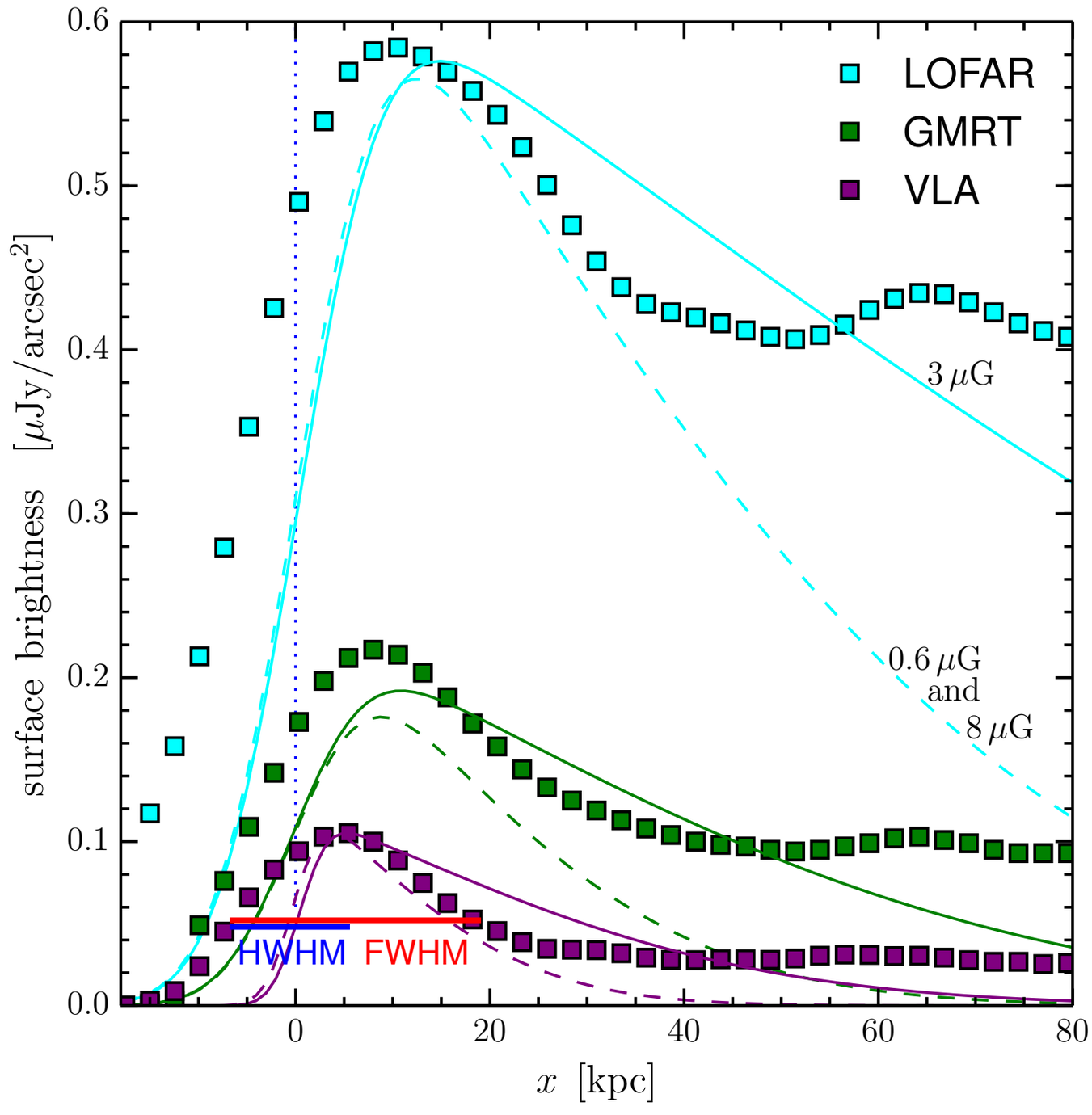
GMRT - 610 MHz

JVLA - 1.5 GHz

beam 5.5 arcsec

Narrowness of ridge

- disfavours $B \sim 0.8 \ldots 5 \mu\mathrm{G}$
- impossible to match width and downstream slope

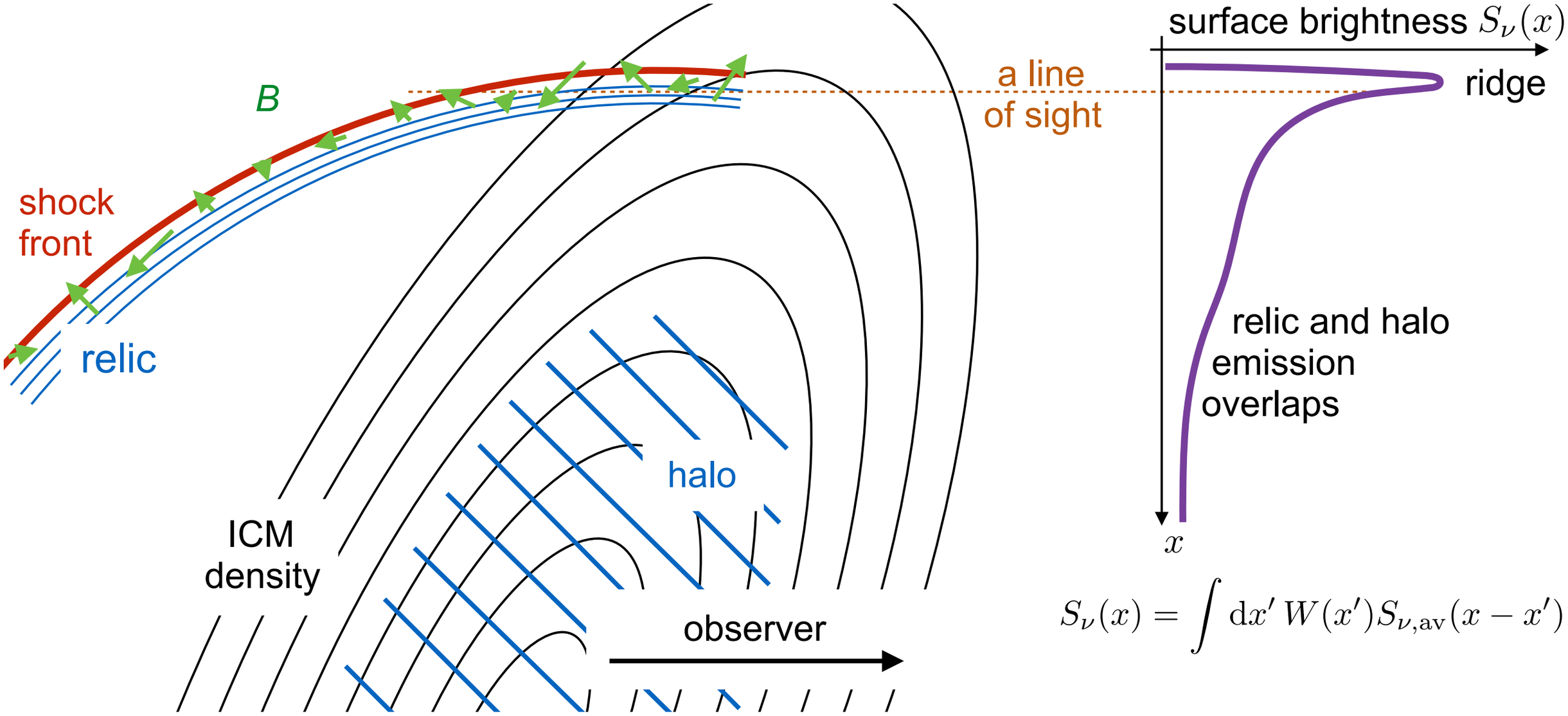


Mach number of model

$\mathcal{M} = 3.1$

“Theorists have always some parameters to vary”

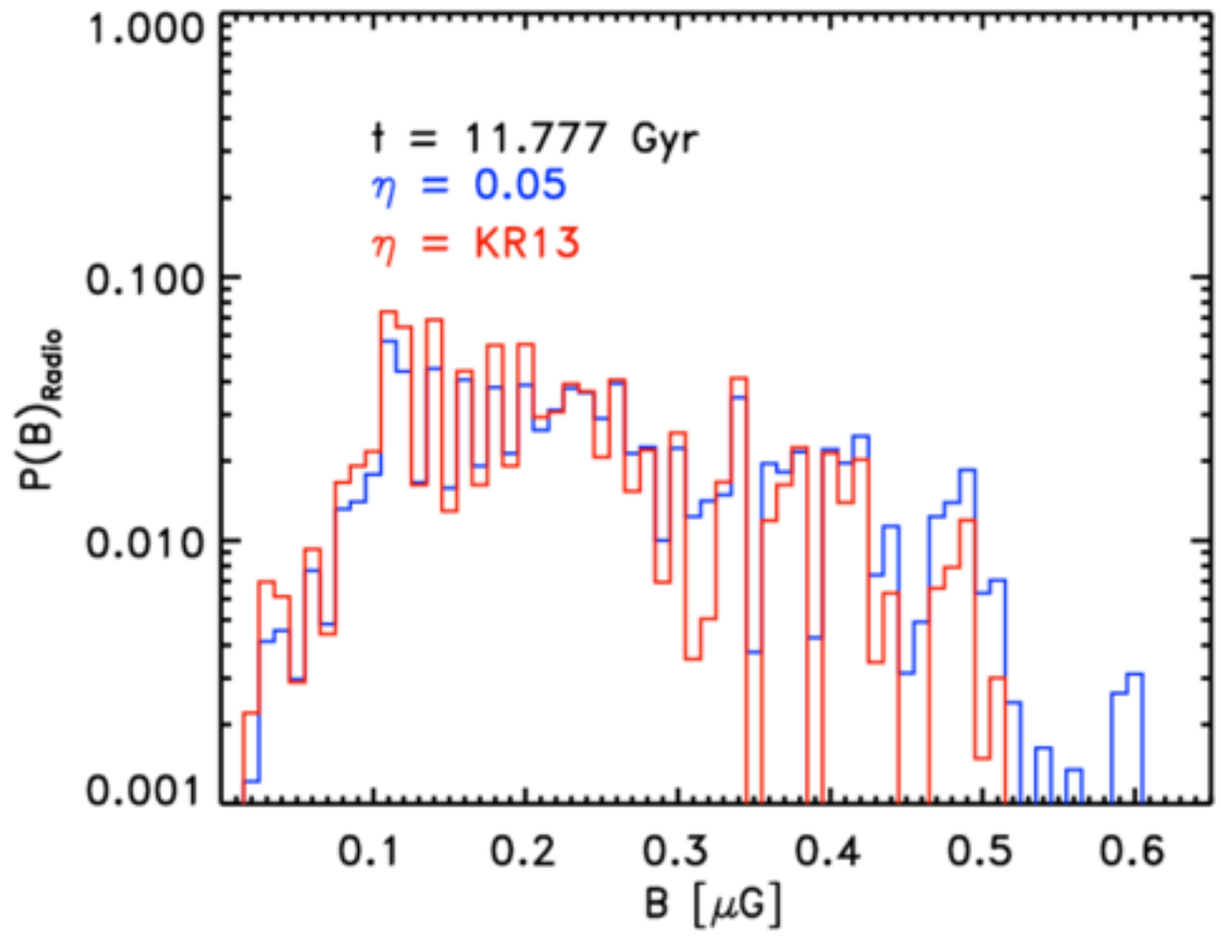
- Part 1: projection of shock front



$$S_\nu(x) = \int \mathrm{d}x'\, W(x') S_{\nu,\mathrm{av}}(x - x')$$

“Theorists have always some parameters to vary”

- Part 2: distribution of magnetic field strengths



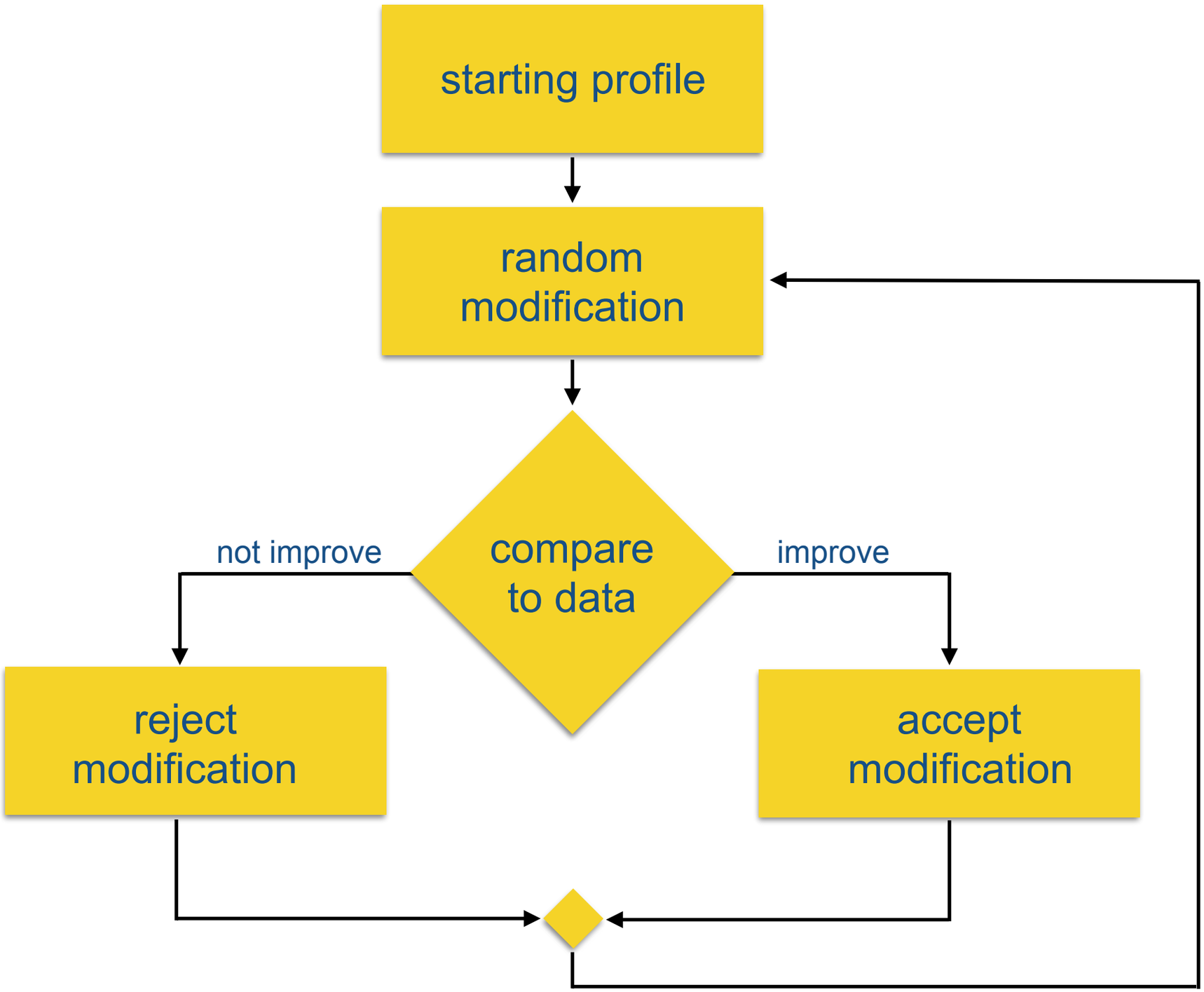
credit: D. Wittor

- Toy model: lognormal distribution

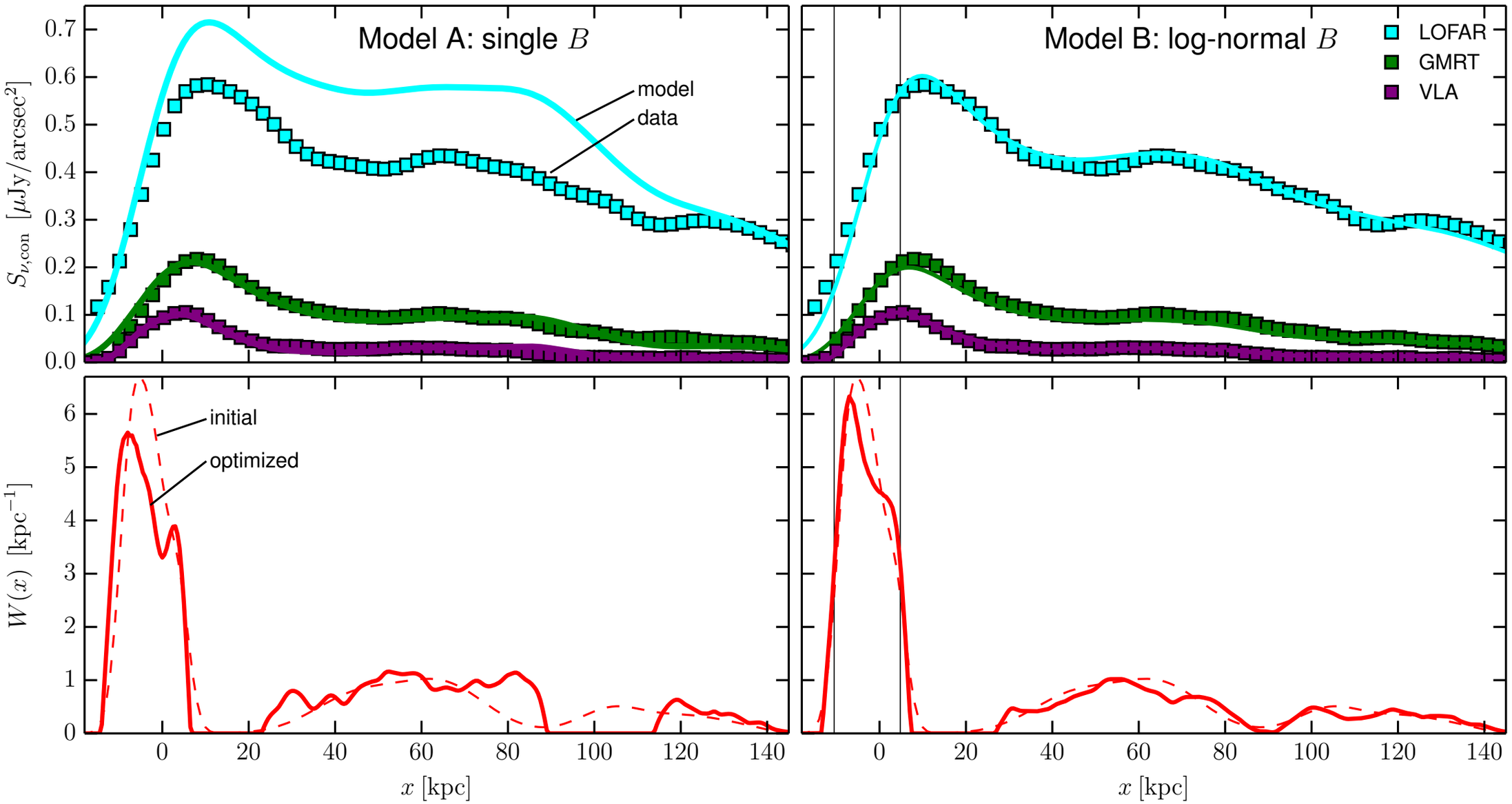
$$h(B; B_0, \sigma)\,\mathrm{d}B = \frac{1}{\sqrt{2\pi}\sigma B} \exp\left\{-\frac{\ln(B/B_0)}{2\sigma^2}\right\}\,\mathrm{d}B$$

Shock geometry, W(x) is not known!

- estimate W(x) with an optimisation scheme
- via best match to observed profiles



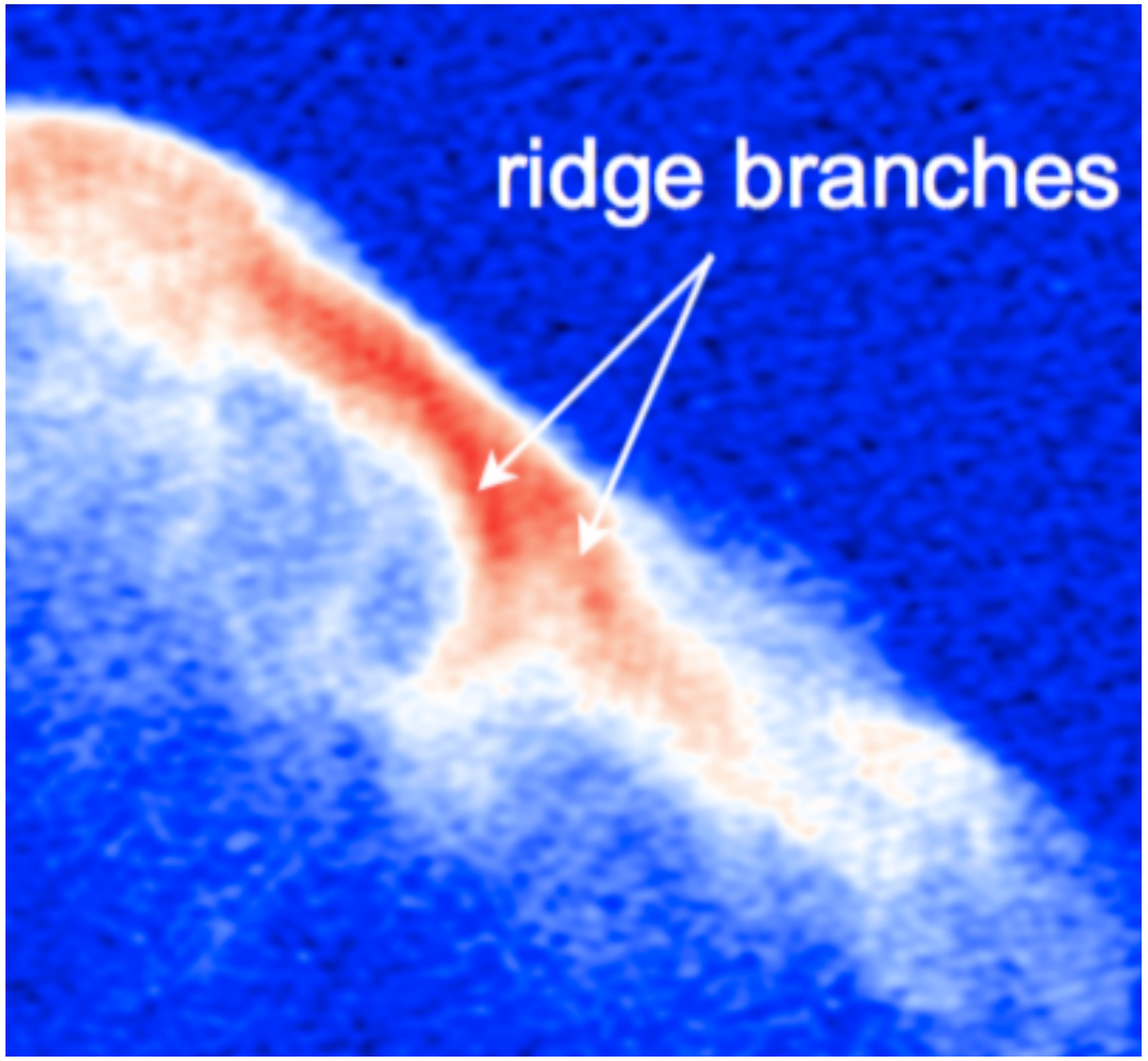
A non-matching and a matching profile

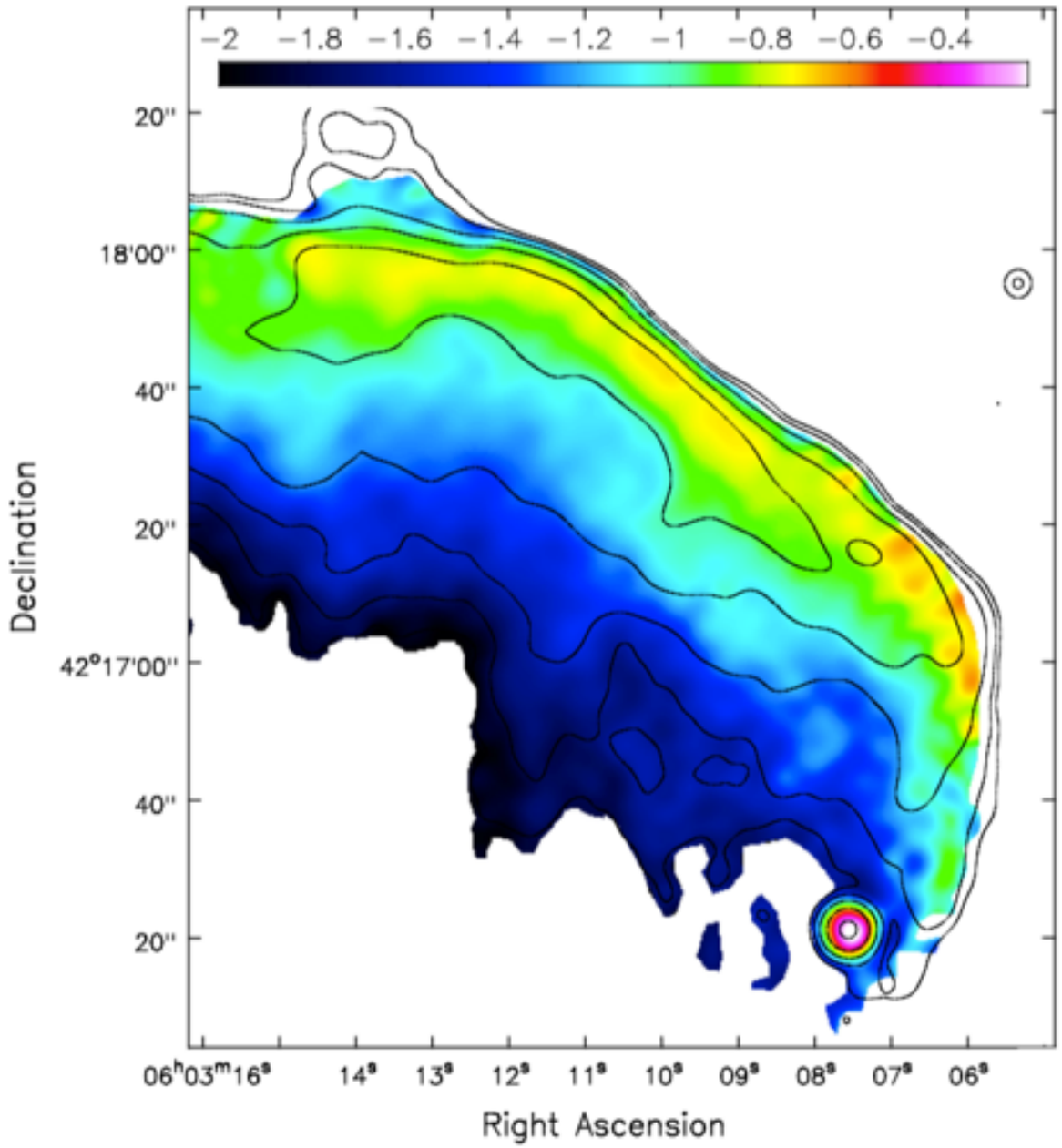


$\mathcal{M} = 3.0, \;\; B_0 = 6.81\,\mu\mathrm{G}, \;\; \sigma = 0.001$

$\mathcal{M} = 3.75, \;\; B_0 = 0.46\,\mu\mathrm{G}, \;\; \sigma = 1.3$

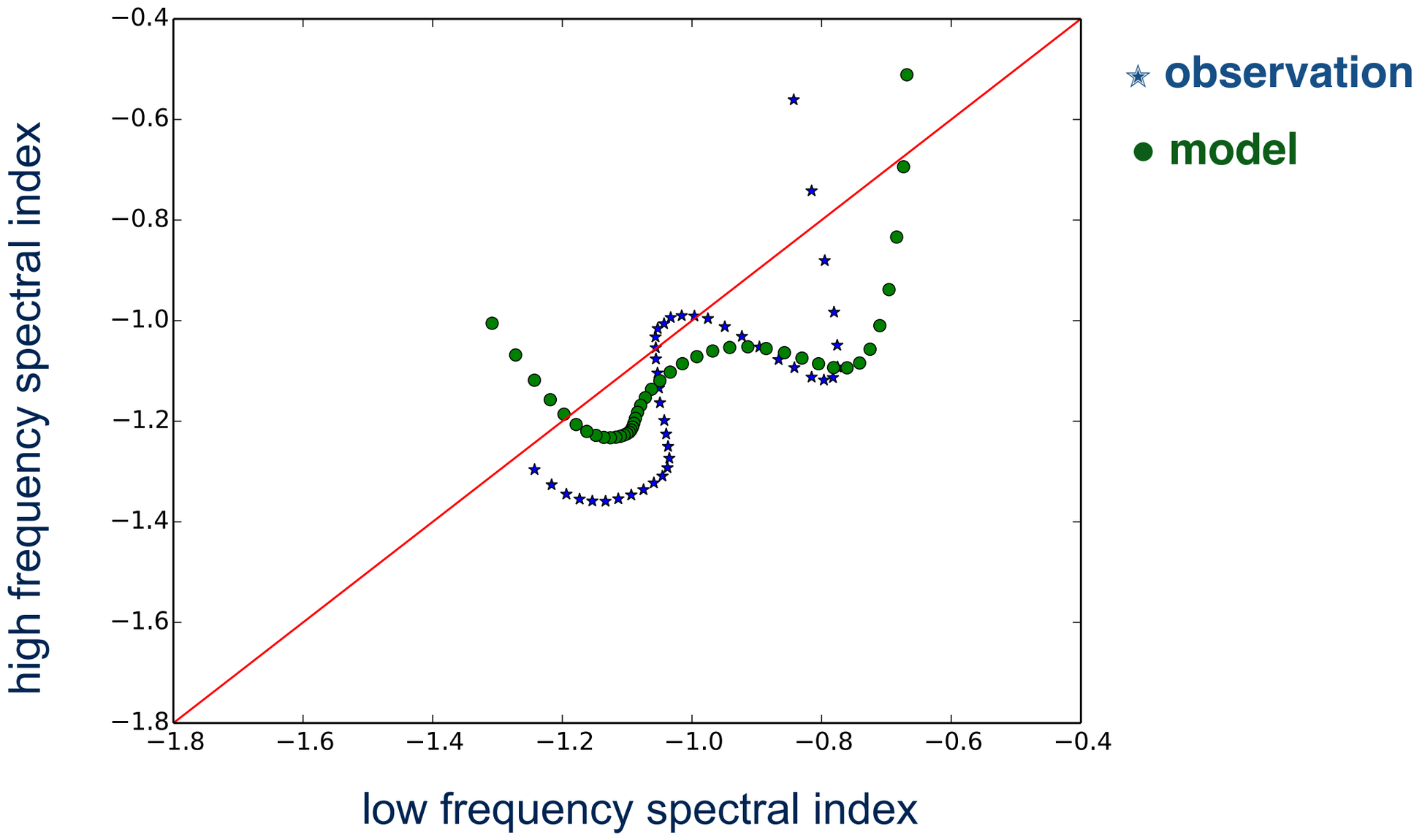
W(x) Detail 1: Double peak in accord with ridge branching





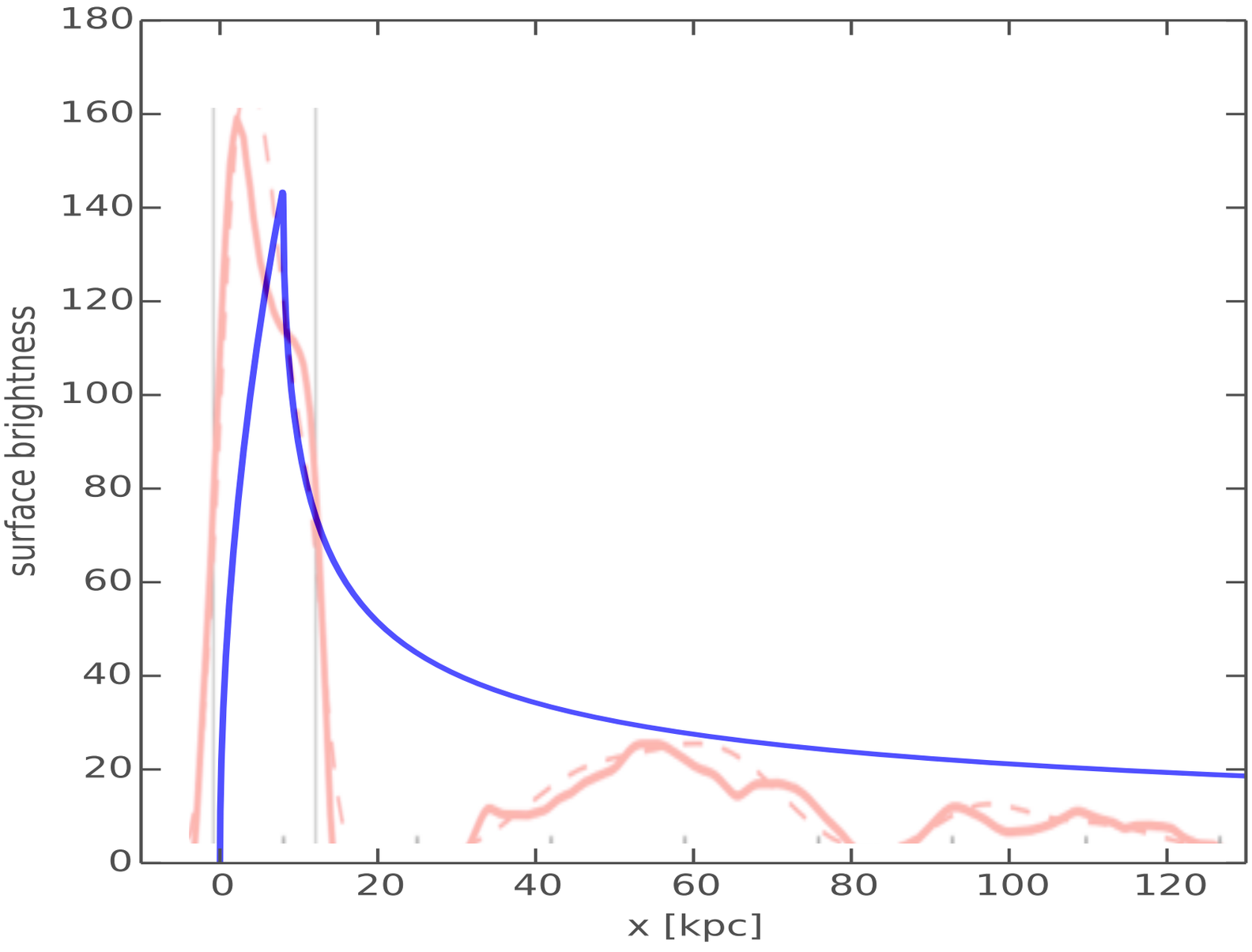
Attention when measuring X-ray shock properties!

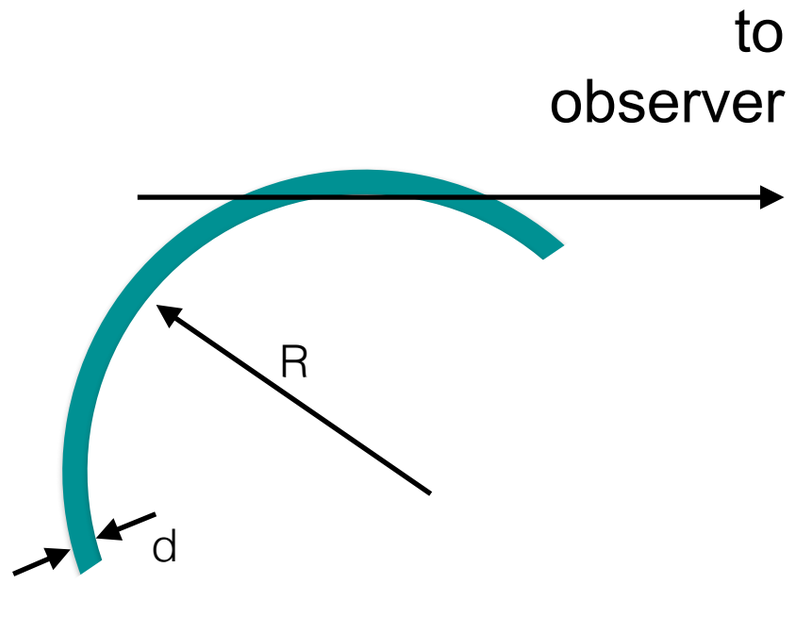
W(x) Detail 2: A color-color diagram comparison



W(x) Detail 3: Peak roughly consistent with projection of shell

- R = 1 Mpc, d = 10 kpc

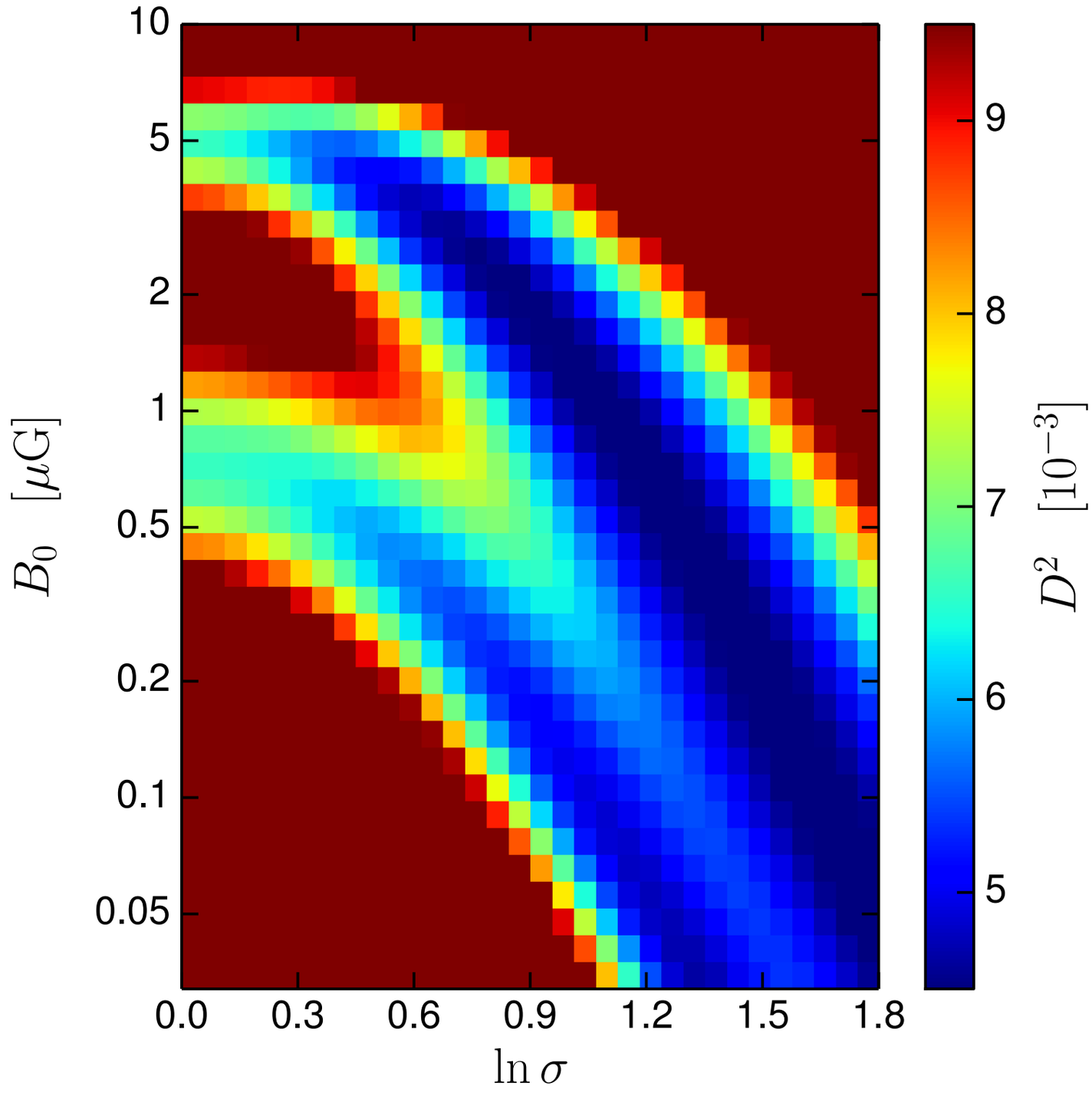




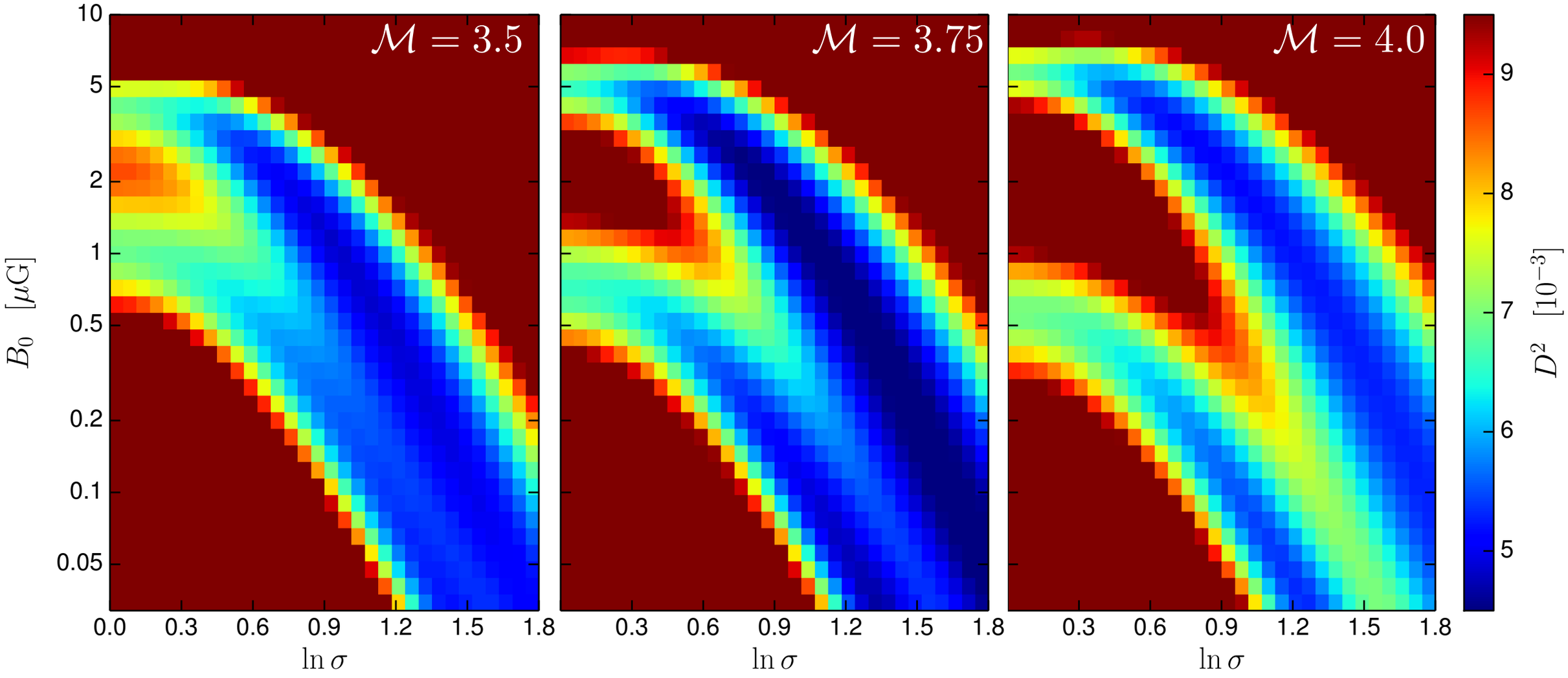
- shock front only roughly a sphere
  there holes, kinks, …

Find best matching average downstream profile

- optimise W(x) for every parameter pair $B_0,\ \sigma$



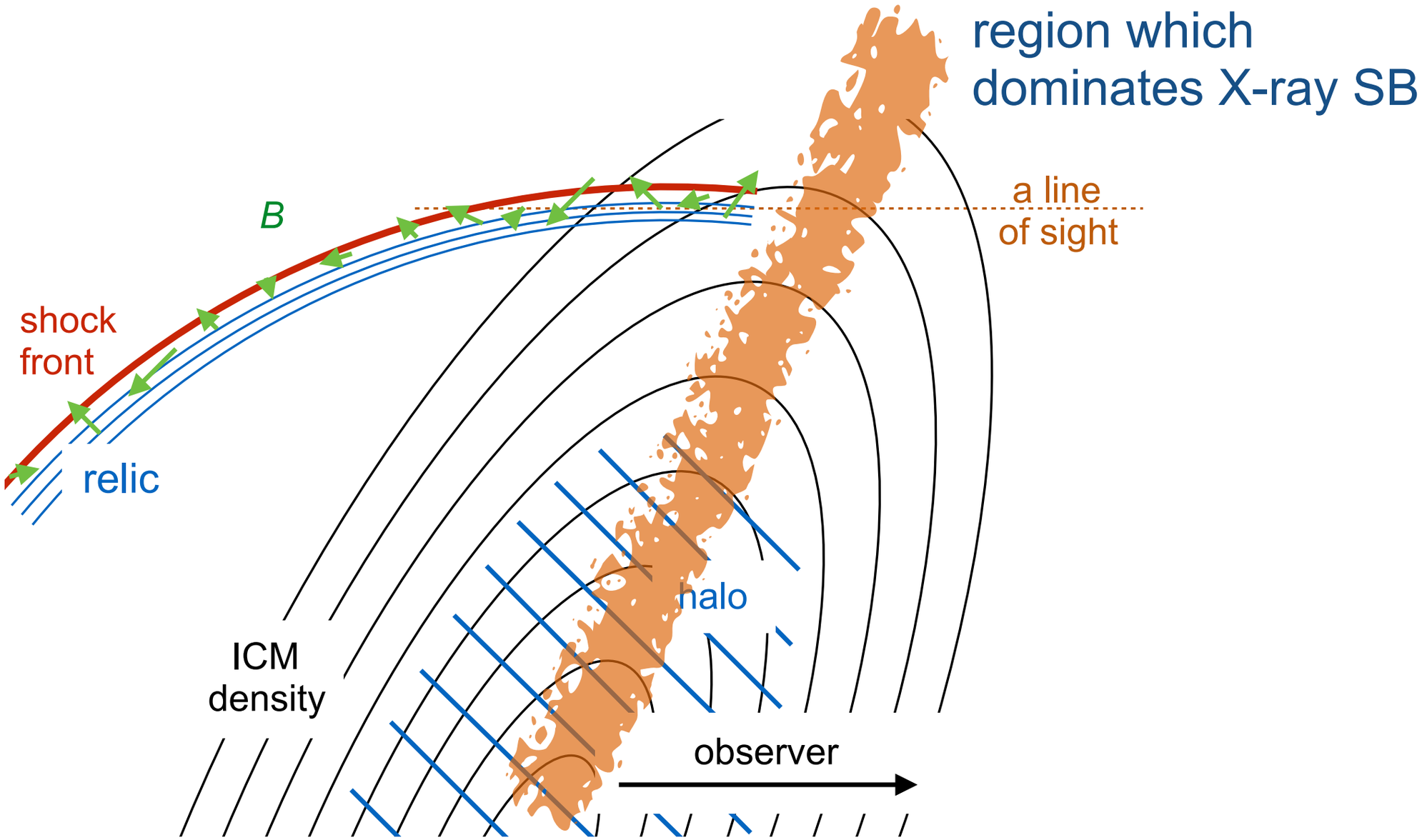
Vary also Mach number



- best match for *M* ~ 3.75

Why different X-ray Mach number ?

- complex merger, shock front rather behind dense ICM



Toothbrush: Depolarisation

RM variations depolarise emission

$$\frac{p_2}{p_1} = \exp\{-2\sigma_{\rm RM}(\lambda_2^4 - \lambda_1^4)\}$$

B1 : $11 \pm 2\,\mathrm{rad\,m^{-2}}$

B2 : $25 \pm 2\,\mathrm{rad\,m^{-2}}$

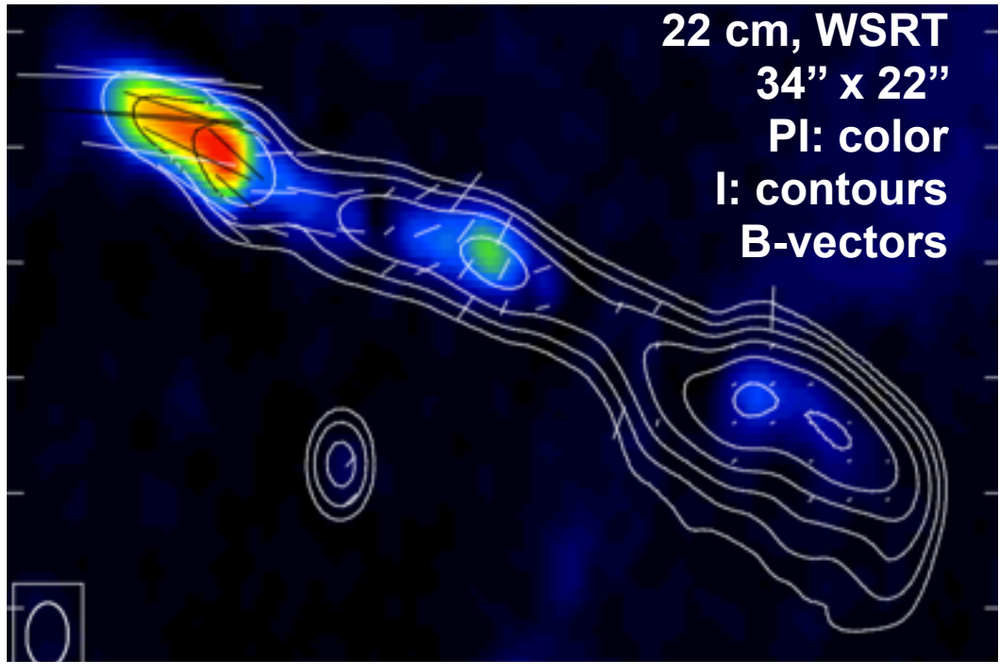
B3 : $134 \pm 35\,\mathrm{rad\,m^{-2}}$

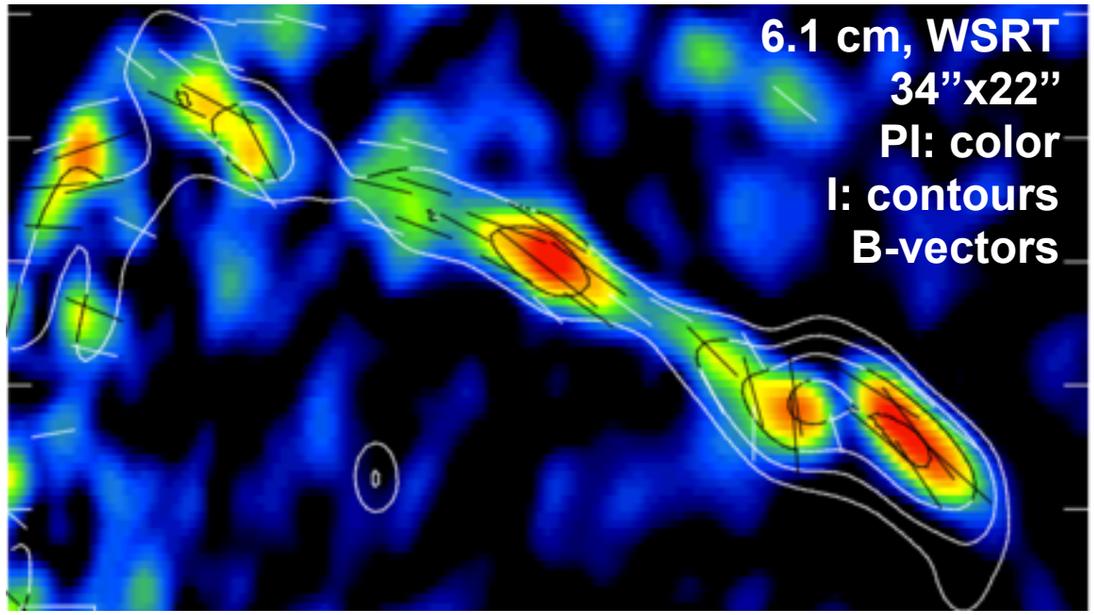
Constraints on ICM physics for B1

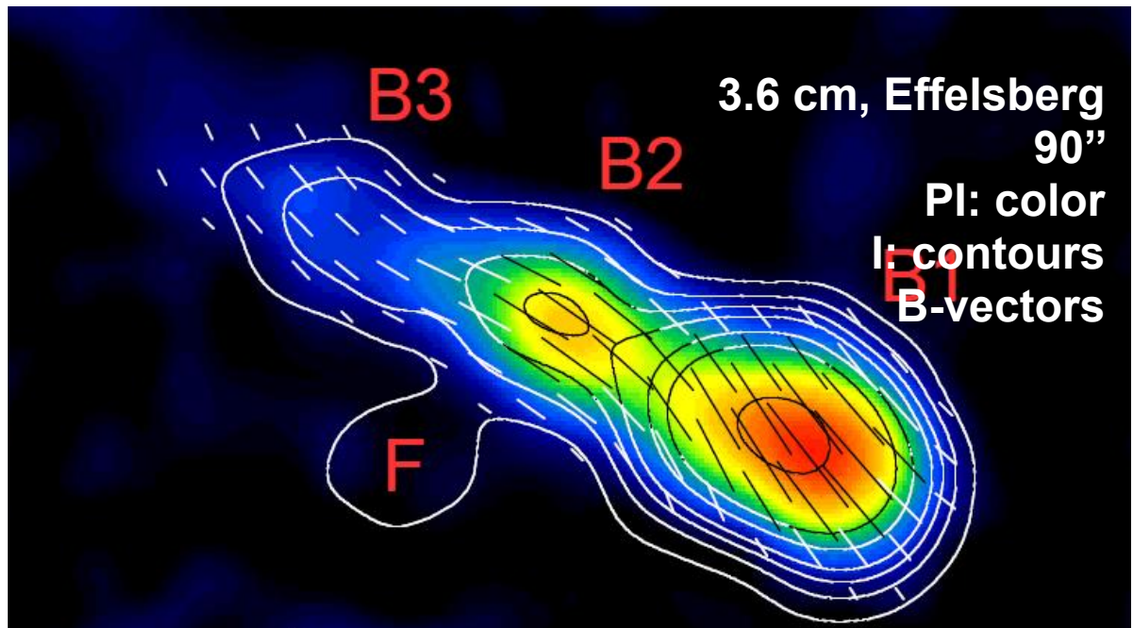
$$\sigma_{\rm RM} \sim n_{\rm e} B_{\rm turb} (Ll)^{0.5}$$

Sokoloff+ 98

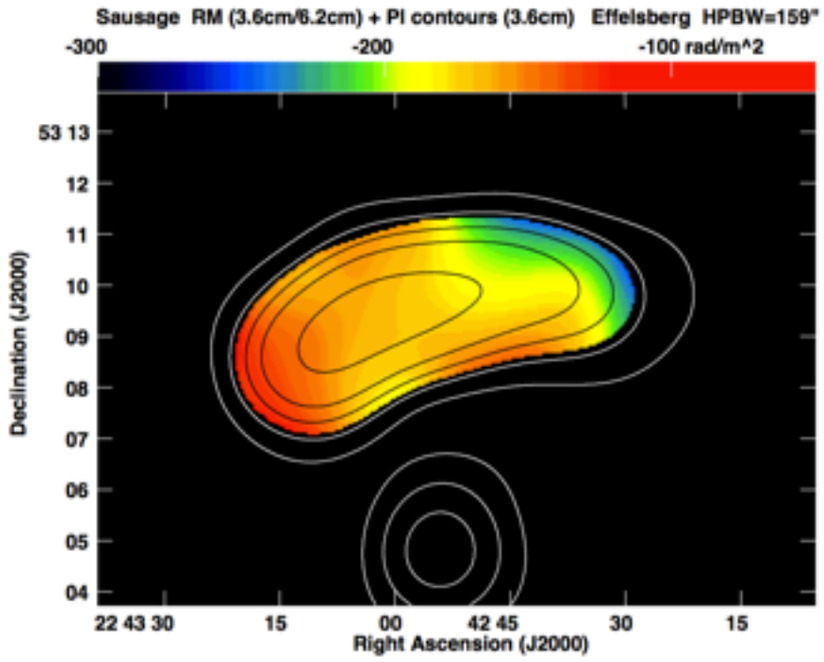
10^{-3} cm^{-3}, 1.5 μG, 2.5 Mpc, 10 kpc

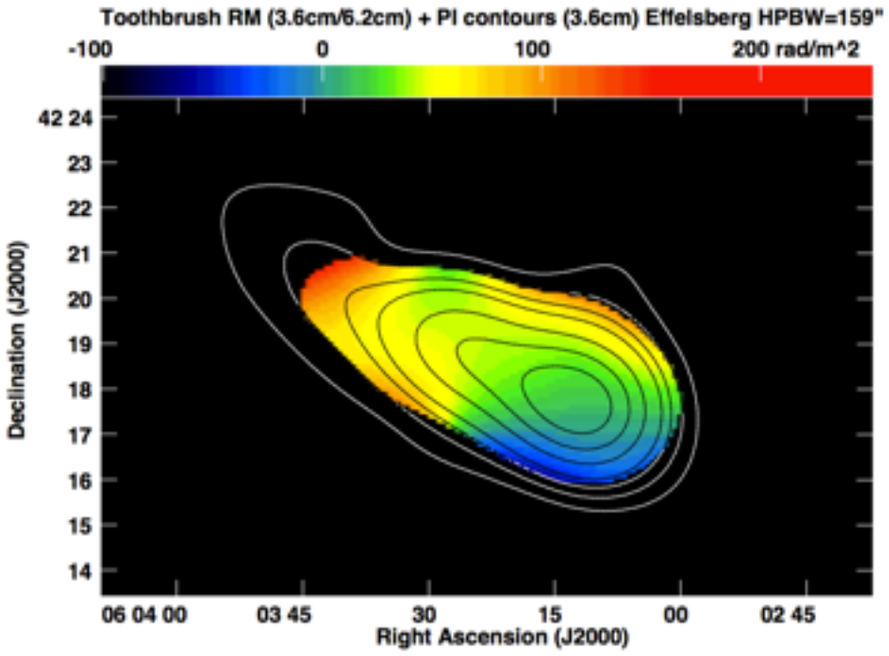


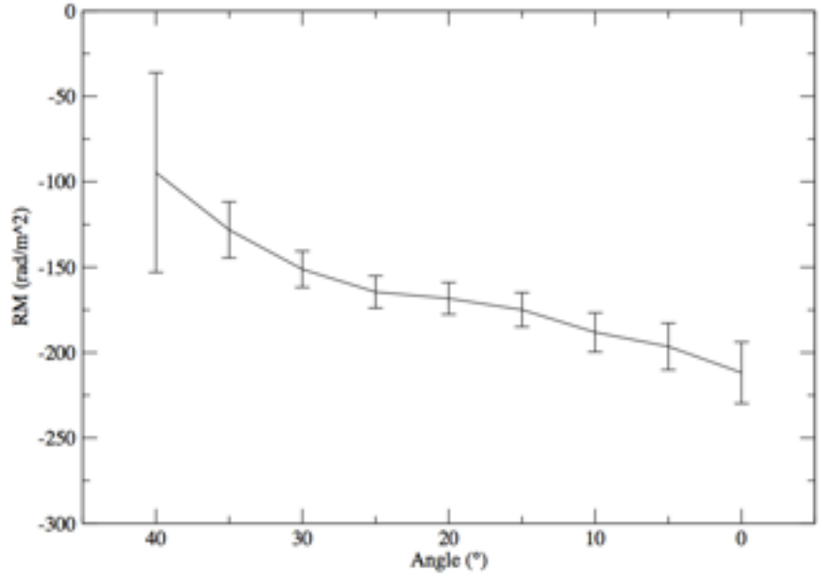


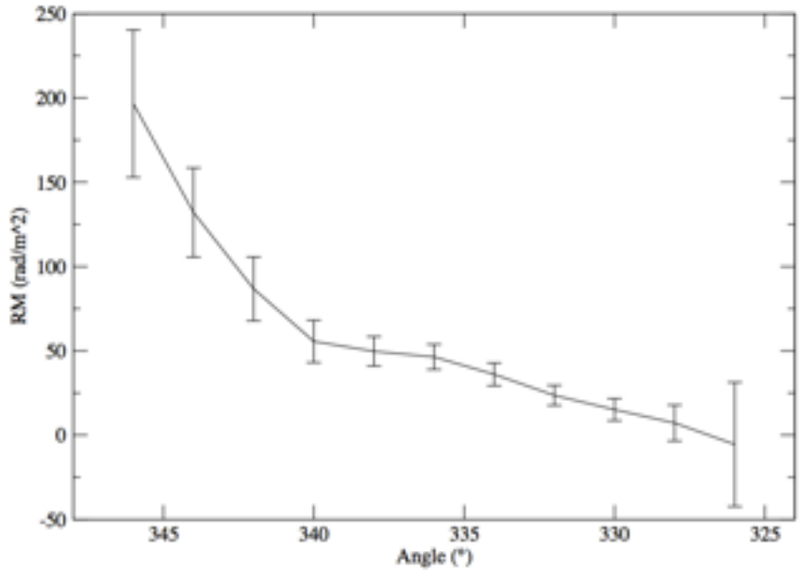


Faraday rotation: RM gradients, foreground fields ?









Caution: $$P = \int \mathrm{d}V\, \epsilon(\mathbf{r}, \lambda)\, p\, e^{2i(\alpha(\mathbf{r}) + \phi\lambda^2)}$$

Conclusions

- ridge: peak shift shows frequency dependent downstream width
  (order of 10 - 20 kpc)

- log normal B distribution allows to match observed profiles
  significantly better

- best fit: Mach ~ 3.75, $B_0 < 5$ μG, $\sigma > 0.5$

- suggestion: ridge caused by projection