Interaction of Fanaroff-Riley class II radio jets with a randomly magnetised intra-cluster medium

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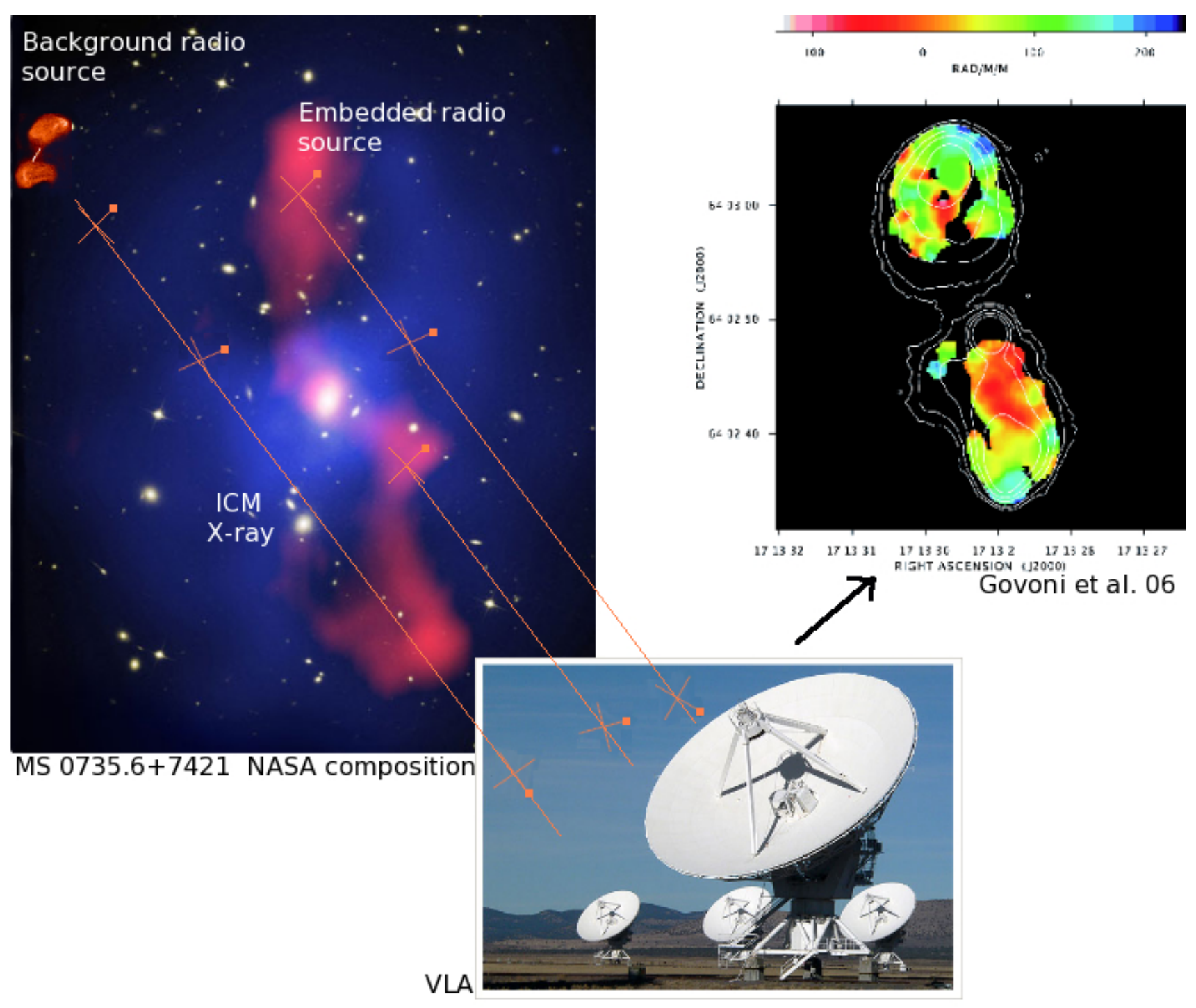
Introduction

The Faraday rotation effect is observed on the AGN polarised radio emission traveling through the ICM, revealing magnetic fields of ~100 kpc scale threading this media. RM maps are consistent with the following facts about the cluster magnetic fields [1] (CMFs):

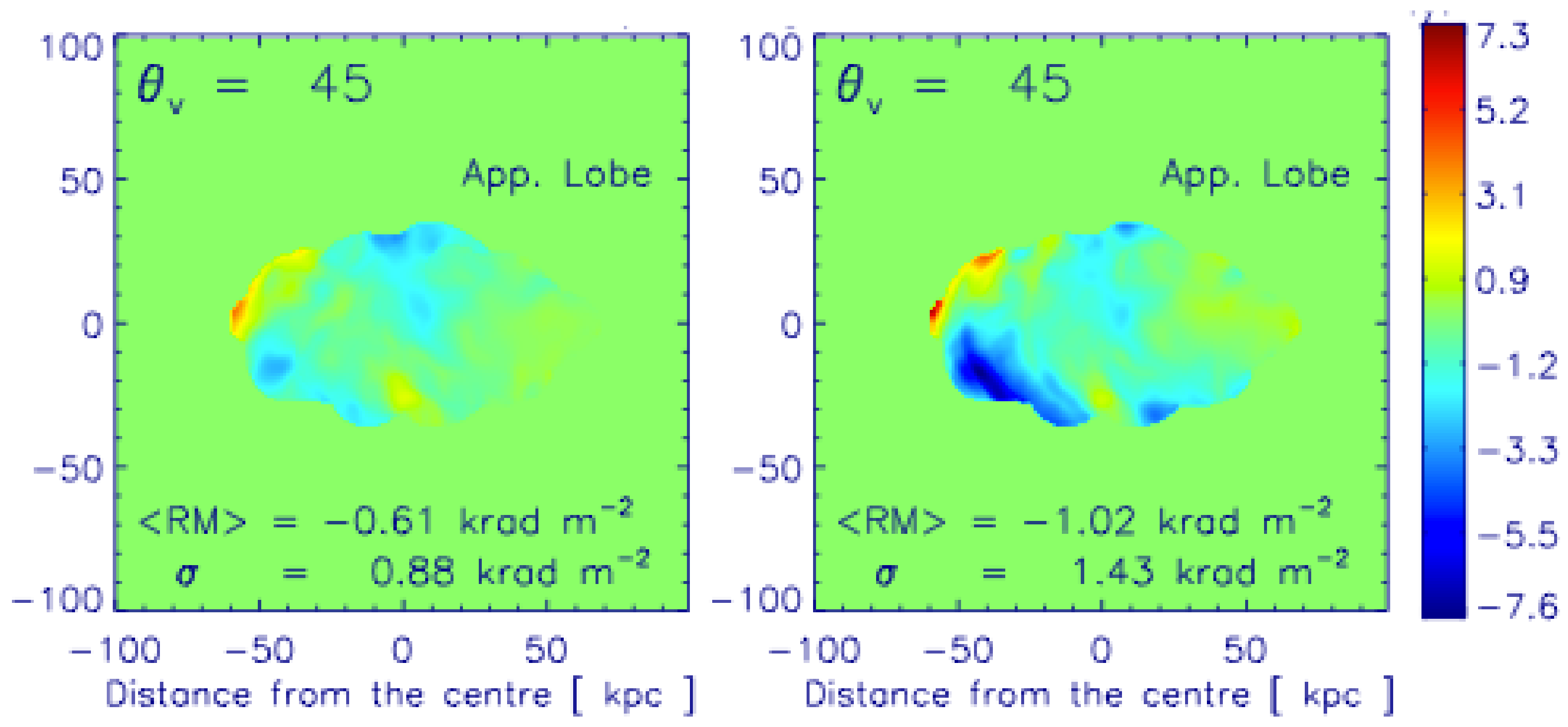
- $|\mathbf{B}| \sim \mu$G,
- $|\mathbf{B}(r)| \propto \rho_{\rm ICM}(r)$,
- $|\mathbf{B}| \propto \dot{M}_{\rm cooling\ flow}$,
- Turbulent structure.

Open questions: The origin, evolution and role of the CMFs in the ICM stability. Since AGN jets have strong effects on the ICM, it is not clear to what extent, and how, they affect both the CMFs and their RM characterisation. We investigate this in [2].

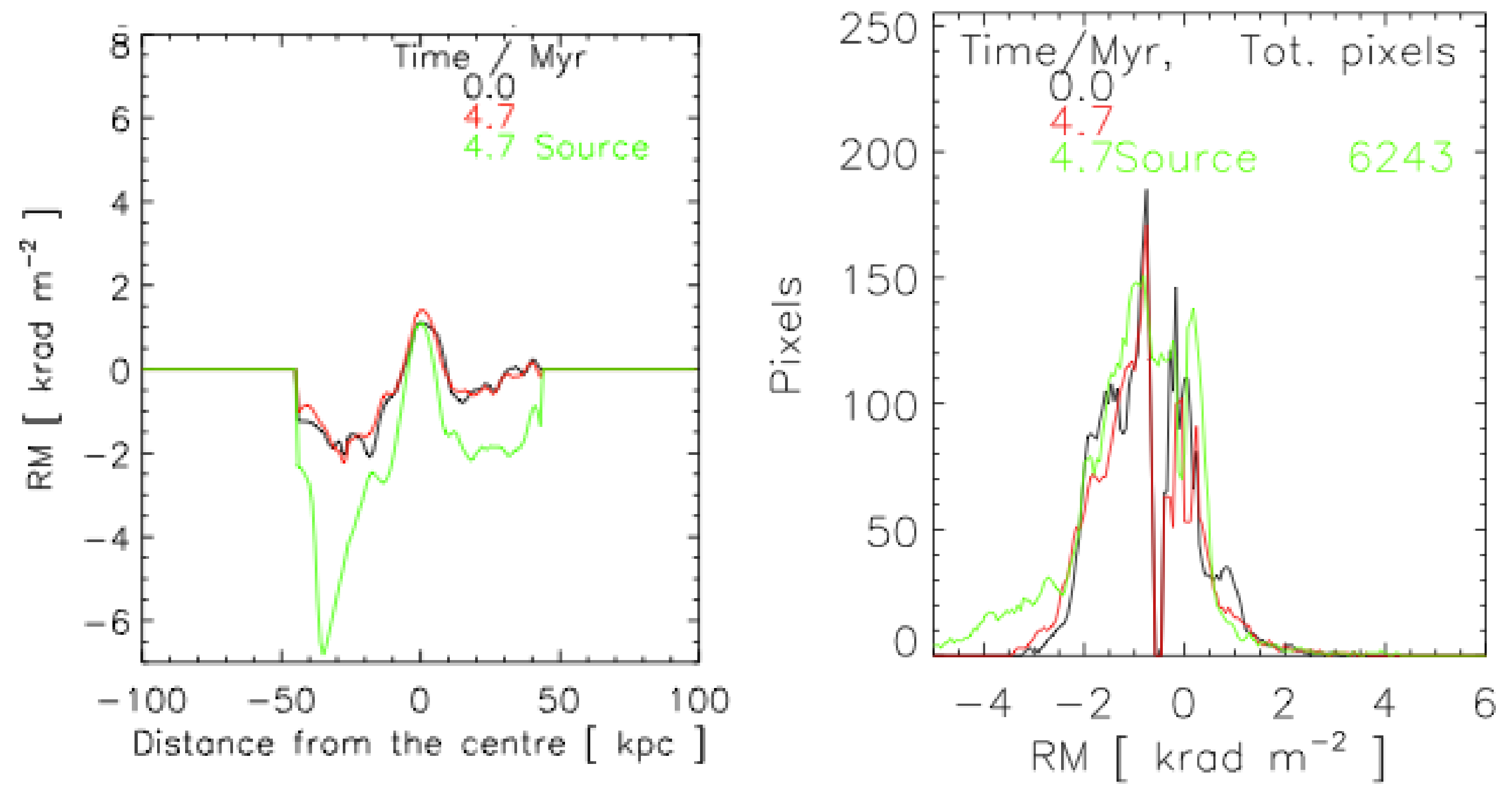


Effect of radio jets on the rotation measure

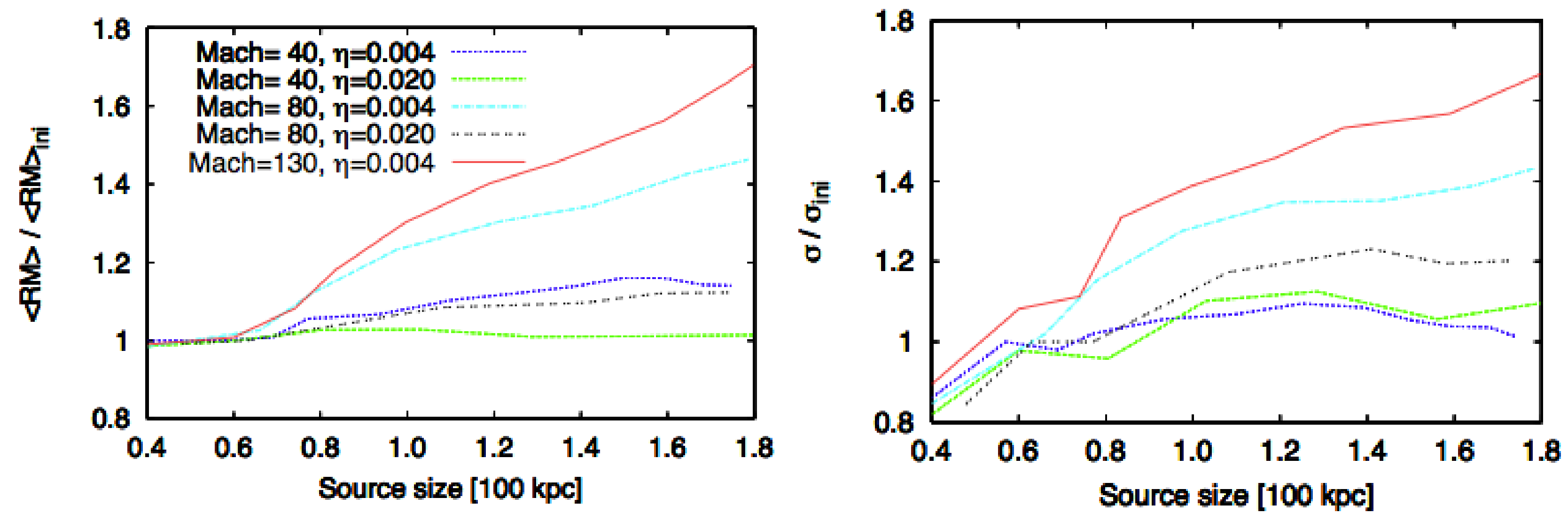
We calculate RM= $812\int_0^{D/\mathrm{kpc}}\left(\frac{n_e}{\mathrm{cm}^{-3}}\right)\left(\frac{B_\parallel}{\mu\mathrm{G}}\right)dl$ rad m^{-2} from the jets' cavity contact discontinuity to the end of the domain, along different viewing angles. We do this at different times, with and without the jets to assess their effects on the CMFs. The fields in the region between the cocoon and the bow shock are compressed, stretched and amplified. e.g. below we show the case of jets' velocity and density of 130 Mach and $0.004\rho_0$, respectively, at a viewing angle of 45°.



Above: RM maps. Without the source (left) with the source (right).



Above: cut though the RM maps at $y = -25$ kpc (left), RM histograms (right). The green, the red and the black profiles correspond to RM maps produced with the source, without the source and before the source, respectively. See [5] for details.



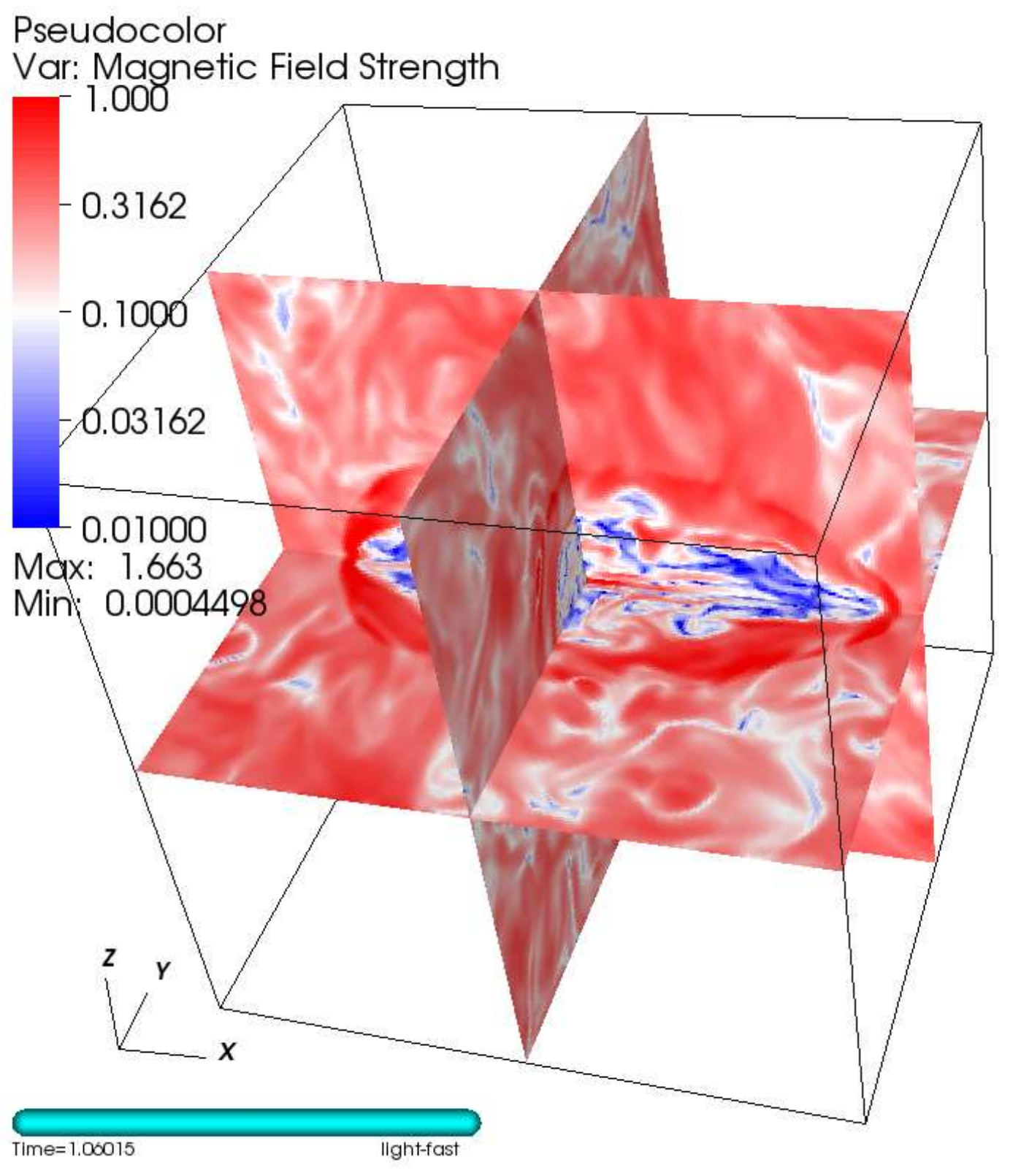
Above: RM evolution as the model radio jets affect the magnetized ICM. Mean RM (left) and RM standard deviation (right).

Model

Using Flash 3.1 [3] we solve the equations of MHD with a constrained transport scheme [4] in a cubic Cartesian domain with 200^3 cells. The ICM is implemented as:

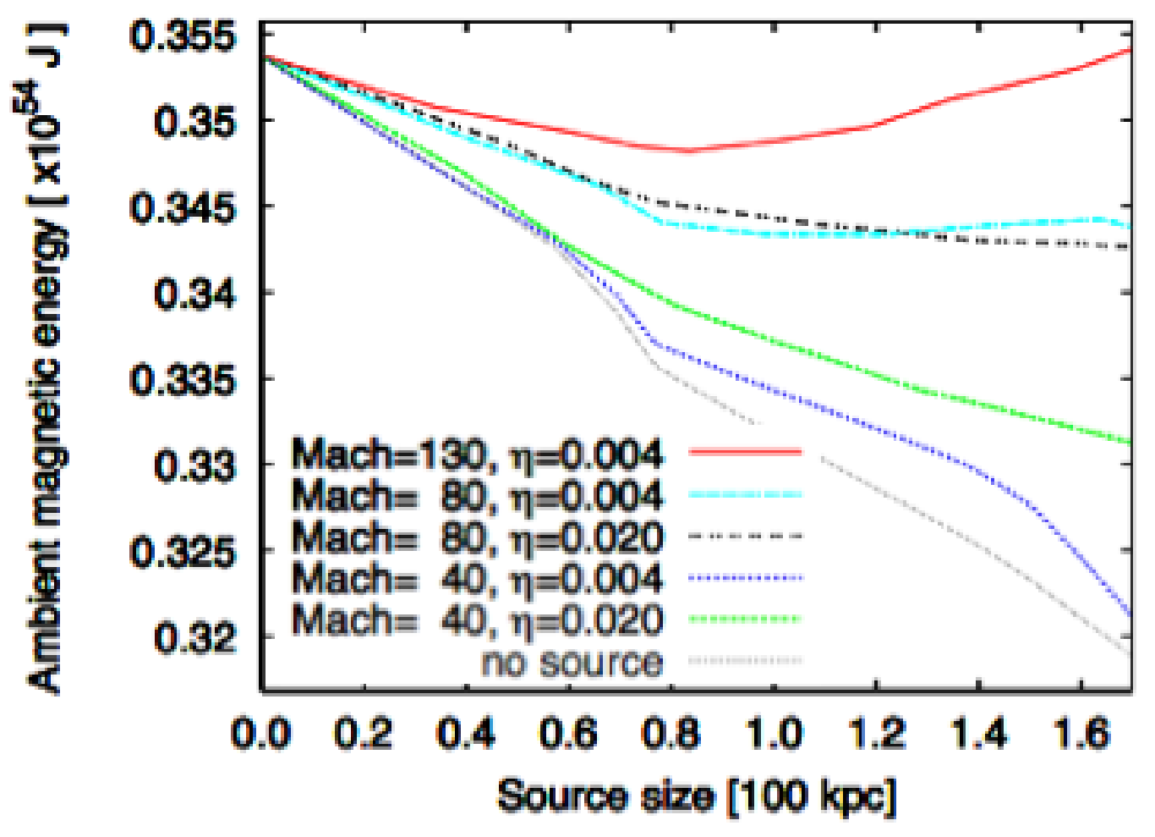
- Monoatomic ideal gas ($\gamma = 5/3$),
- King density profile $\rho_{\rm ICM} = \frac{\rho_0}{(1+(r/a_0)^2)}$,
- Magnetohydrostatic equilibrium with central gravity,
- Magnetic fields with a Kolmogorov-like structure (following [5]),
- $\beta_m \gtrsim 10$.

The plasma relaxes for one crossing time and then we inject mass and x-momentum to a central control cylinder. We experiment with the jets' power using velocities of 40, 80 and 130 Mach, and densities of $0.02\rho_0$ and $0.004\rho_0$.

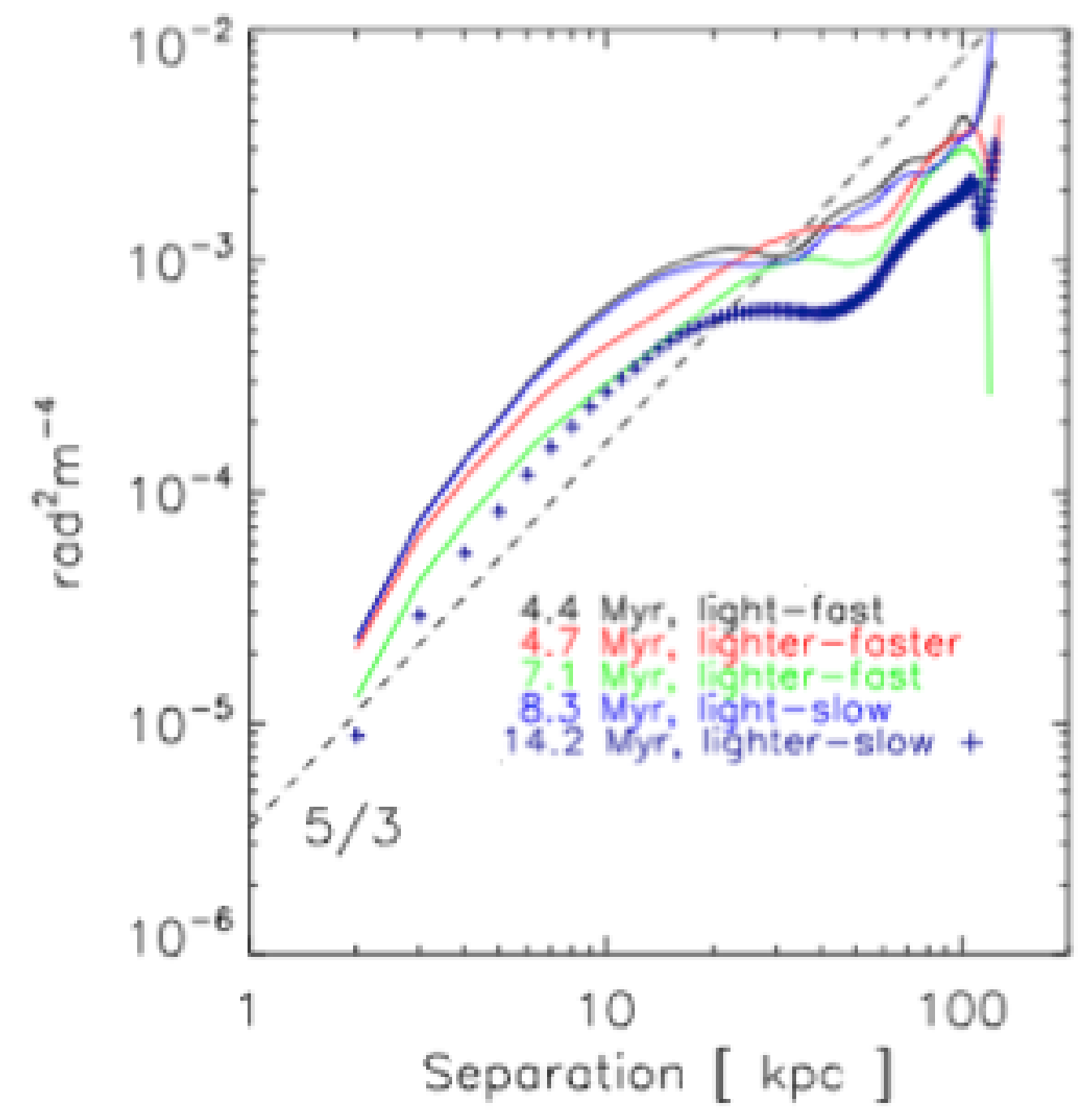


ICM magnetic energy and RM gradients

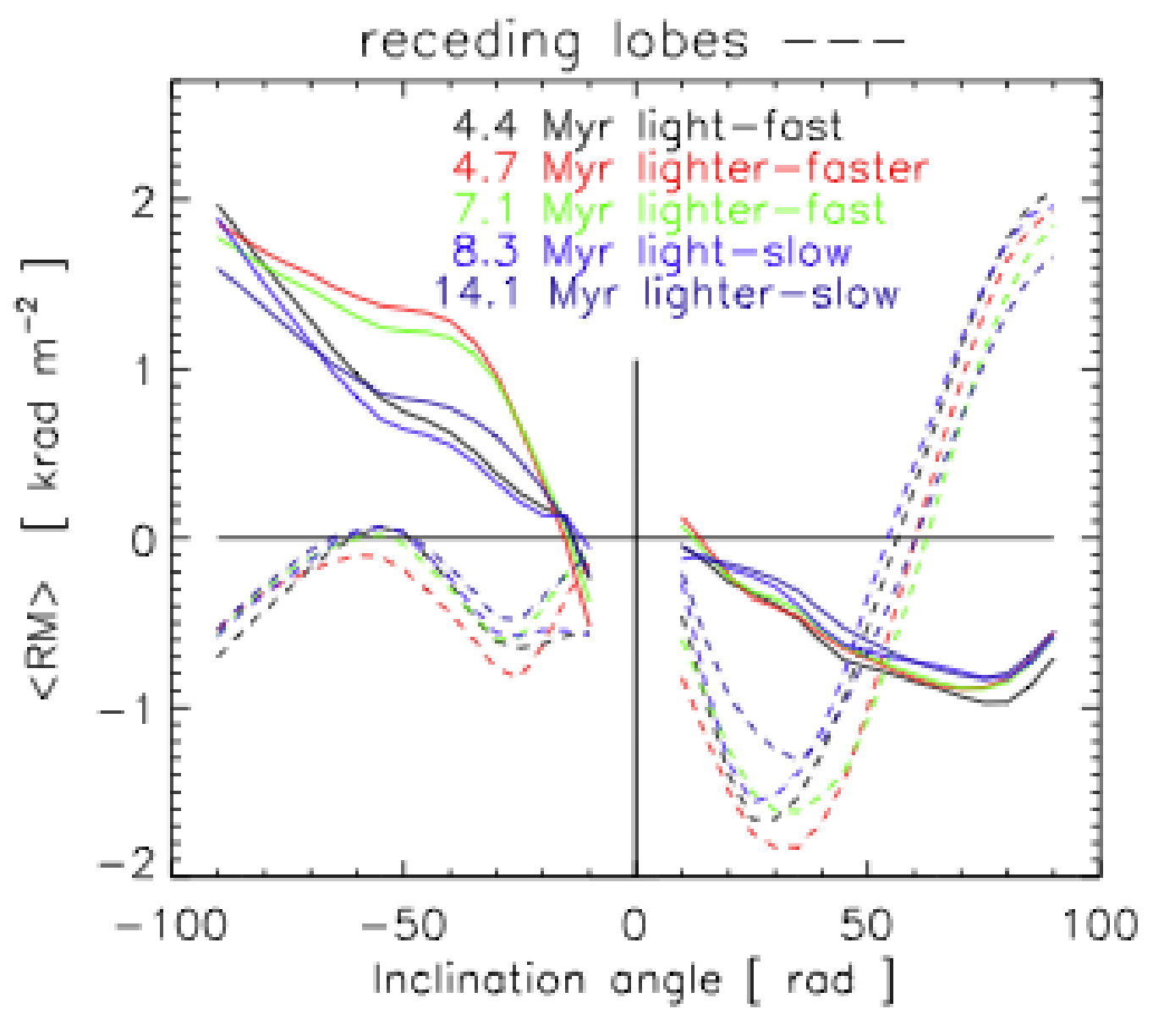
The energy decays due to numerical diffusion, but the jets with Mach= {80, 130} are able to impede this and to increase the energy in proportion to the jet velocity (image below).

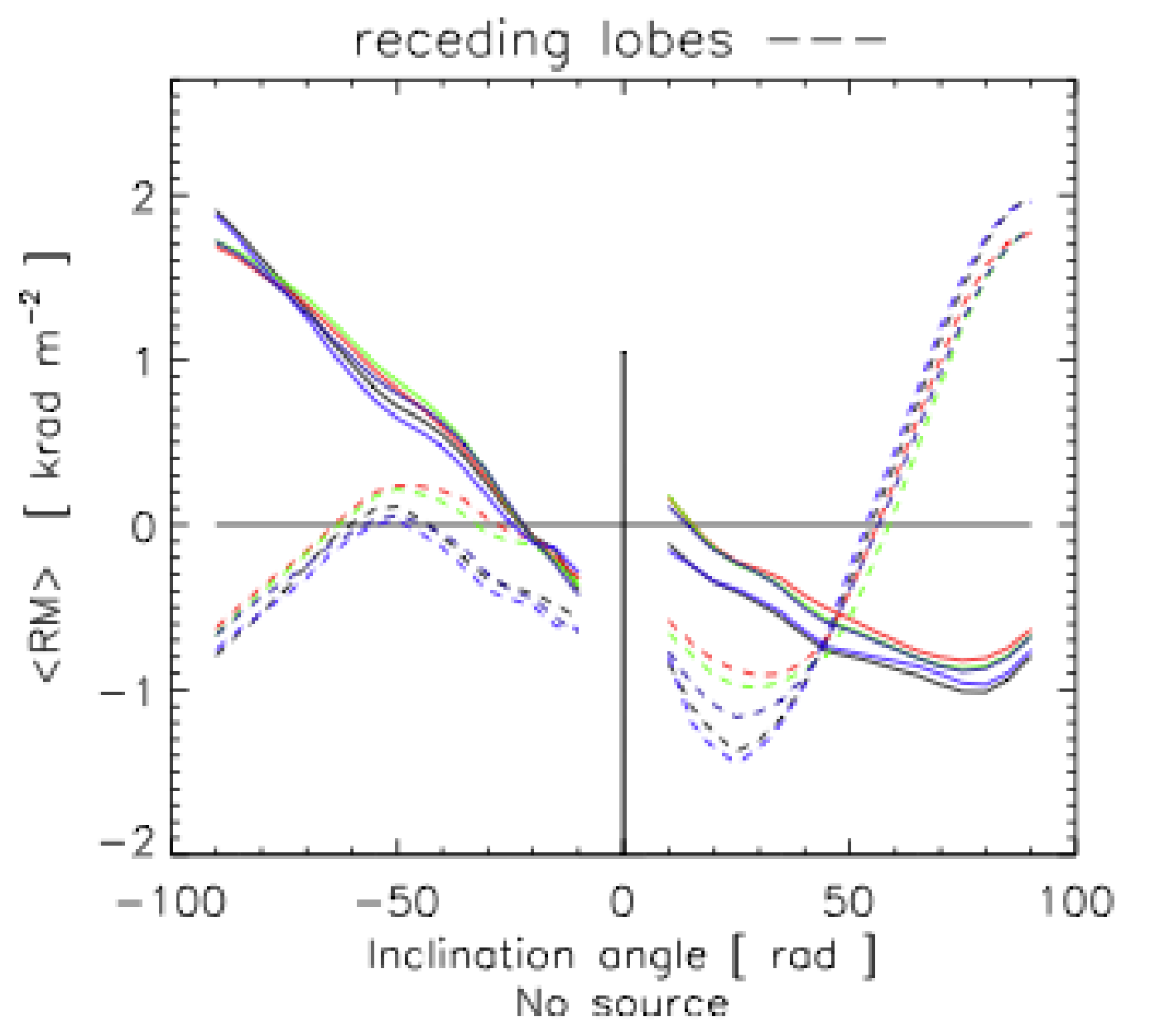


Though the RM structure functions show and preserve the CMFs initial condition (see section Model), they are flattened by the jets, at scales of order tens of kpc. This scale is larger for sources with fat cocoons (image below).



We calculate the mean RM for the approaching and the receding radio lobes vs. the viewing angle. Below, the jets are on the plane of the sky at an inclination of ±90°. Intrinsically, the depolarisation is always higher for the receding lobe; i.e. the Laing-Garrington effect [6]. This however is only moderately affected by the radio source expansion, in such a way that the associated trends tend to be amplified.





Conclusions

- The jets distort and amplify the CMFs, especially near the edges of the lobes and the jets' heads,
- $\langle$RM$\rangle$ and σ_{RM} increase in proportion to the jets' power. The effect may lead to overestimations of the CMFs' strength by about 70%,
- A flattening of the RM structure functions is produced by the jets, at scales comparable to the source size,
- Jet-produced RM enhancements are more apparent in quasars than in radio galaxies.

References

[1] Carilli C. L., Taylor G. B., 2002, ARA&A, 40, 319; [2] Huarte-Espinosa, Krause & Alexander, 2011, accepted in the MNRAS, arXiv:1108.0430; [3] Fryxell B. et al., 2000, ApJS, 131, 273; [4] Lee D., Deaane A. E., 2008, Journal of Computational Physics, doi:10.1016/j.jcp.2008.08.026; [5] Murgia et al. 2004, AAP, 424, 429; [6] Laing, R. A., 1988, Nature, 331, 149.

Acknowledgements

The software used in these investigations was in part developed by the DOE-supported ASC / Alliance Center for Astrophysical Thermonuclear Flashes at the University of Chicago. MHE acknowledges financial support from The Mexican National Council of Science and Technology, 196898/217314; Dongwook Lee for the 3D-USM-MHD solver of Flash 3.1.