Mem. S.A.It. Vol. 84, 725

Memorie della

Mass loading and knot formation in AGN jets by stellar winds

M. Huarte-Espinosa[1], E. G. Blackman[1], A. Hubbard[2], and A. Frank[1]

[1] Department of Physics and Astronomy, University of Rochester, Rochester NY, USA
e-mail: `martinhe@pas.rochester.edu`
[2] Department of Astrophysics, American Museum of Natural History, New York NY, USA

Abstract. Jets from active galaxies propagate from the central black hole out to the radio lobes on scales of hundreds of kiloparsecs. The jets may encounter giant stars with strong stellar winds and produce observable signatures. For strong winds and weak jets, the interaction may truncate the jet flow during its transit via the mass loading. For weaker jets, the interaction can produce knots in the jet. We present recent 3DMHD numerical simulations to model the evolution of this jet-wind interaction and its observational consequences. We explore (i) the relative mechanical luminosity of the radio jets and the stellar winds (ii) the impact parameter between the jets' axis and the stellar orbital path (iii) the relative magnetic field strength of the jets and the stellar winds.

Key words. Stars: mass-loss – stars: winds, outflows – ISM: bubbles – ISM: jets and outflows – galaxies: active – galaxies: jets

1. Introduction

Powerful radio jets are often observed emerging from Active Galactic Nuclei (AGN). Given the stellar density at the center of these galaxies, interactions between jets and stars may occur. The stellar wind will mass-load the jets, potentially temporarily truncating them (Hubbard & Blackman 2006). We are carrying out numerical simulations to follow AGN jet mass loading by stellar winds for a range of jet mechanical powers, L_j, and magnetic field strengths. The following questions remain open: what are the observational consequences of the jet/wind interaction? Does the jet/wind interaction cause radio knots as in Cen A (Hardcastle et al. 2003)? Do radio jet magnetic fields affect the interaction?

Send offprint requests to: M. Huarte-Espinosa et al.

2. Model

We use *AstroBEAR2.0* (Cunningham et al. 2009) to solve the equations of MHD, with domain: $|x|, |y| \leq 2$ kpc; $0 \leq z \leq 6$ kpc; $40\times40\times120$ cells plus 5 AMR levels; max resolution of 1.5 pc. *The star:* moves across the AGN jet beam at $600\,\mathrm{km\,s^{-1}}$ and injects a spherical wind with $\dot{M} = 10^{-4}\,\mathrm{M_\odot\,yr^{-1}}$ and $v = 200\,\mathrm{km\,s^{-1}}$, for 10 kyr, based on Maeder & Meynet (1987). We explore AGN jet mechanical luminosities, L_{AGN}, of 1.5 and $0.024\times10^{45}\,\mathrm{erg\,s^{-1}}$ (based on Falcke & Biermann 1995; Biretta, Stern & Harris 1991, respectively).

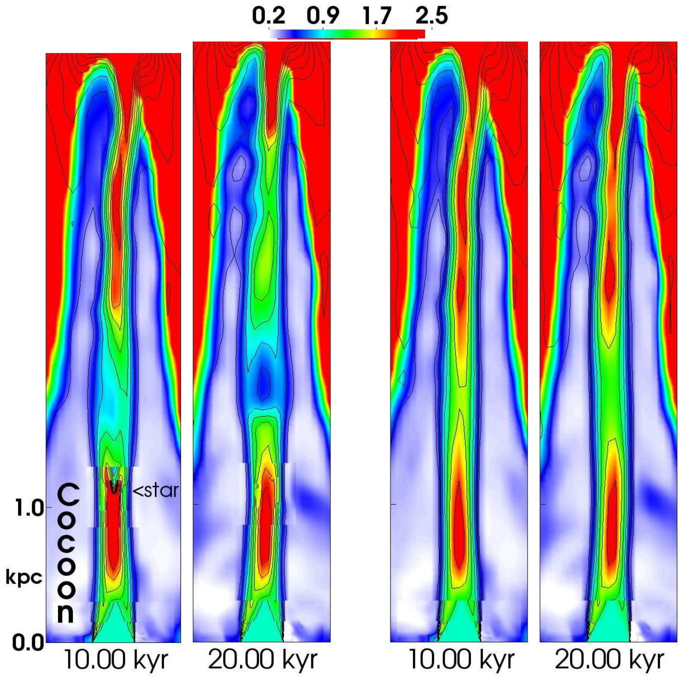

Fig. 1. Density [$\times 10^{-4}$ part cm^{-3}] of models with and without a wind-injecting star (left and right panels, respectively) for $L_{AGN} = 24 \times 10^{42}$ erg s^{-1}.

3. Results

The initial jet structure in Fig. 1 is caused by fluting instabilities. The star injects a wind for 10 kyr (left panel, 10 kyr). Mass-loading onto the AGN jet causes a density dip in the beam and mixing of jet and stellar wind material (contours). We see a knot in the jet's beam, which lasts for about 30 kyr and should have observational consequences. Synthetic synchrotron emission maps will show whether the mass loading formed knot may be distinguished from jet intrinsic structure.

4. Conclusions

Preliminary studies show: A star with $\dot{M}_{wind} = 10^{-4}\,M_{\odot}\,yr^{-1}$ which lasts 10 kyr is able to cause a significant density dip by about 65% on an AGN jet with $L_j = 2.4\times10^{43}$ erg s^{-1}. • Mass loading causes mixing of jet and star material. • Knots formed by stars entering the jet will propagate along the path of the stellar orbit. This path need not be parallel to the jet flow, thereby distinguishing such knots from those produced by instabilities propagating along the jet. • For models in which the entire jet volume emits, not just the edge, the effect of mass-loading could be a dark spot.

Acknowledgements. Financial support for this project was provided by the Space Telescope Science Institute grants HST-AR-11251.01-A and HST-AR-12128.01-A; by the NSF under award AST-0807363; by the Department of Energy under award DE-SC0001063; and by Cornell University grant 41843-7012.

References

Biretta J. A., Stern C. P., Harris D. E., 1991, AJ, 101, 1632
Cunningham, A. et al., 2009, ApJS, 182, 519
Falcke, H., Biermann, P. L., 1995, AAP, 293, 665
Hardcastle, M. et al., 2003, ApJ, 593, 169
Hubbard, A. Blackman, E. G., 2006, MNRAS, 371, 1717
Maeder, A., Meynet, G. 1987, A&A, 182, 243