

RADIO BRIGHTNESS TEMPERATURES AND ANGULAR DIMENSIONS OF RECENTLY PREDICTED VLBI SMALL-SCALE STRUCTURES

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RESUMEN. Muestro que análisis recientes publicados de fuentes de radio galácticas y extragalácticas predicen estructuras en pequeña escala en fuentes de radio extendidas, remanentes de supernova, vientos protoestelares, nubes moleculares, distorsiones del fondo de 3 K, enanas blancas magnetizadas, estrellas de tipo tardío y el Sol. Discuto las temperaturas de brillo de radio de estas estructuras y sus dimensiones. Muestro que estas estructuras son detectables con las sensibilidades actuales de VLBI (o en el futuro cercano).

ABSTRACT. I show that recently published analysis of galactic and extragalactic radio sources make predictions of small-scale structures in extended radio sources, supernovae remnants, protostellar winds, molecular clouds, distortions of the 3 K background, magnetized white dwarf binaries, late-type stars and the sun. I discuss the radio brightness temperatures of these structures and their dimensions. I show that these structures are detectable with present (or near future) VLBI sensitivities.

Key words: RADIO SOURCES-EXTENDED

I. INTRODUCTION

Radio structures have recently been discussed in: 1) extragalactic jets (Jafelice and Opher 1987, 1989; Jafelice, Opher, Assis, and Busnardo-Neto 1990; Gouveia Dal Pino and Opher 1989a,b; Medina-Tanco and Opher 1989); 2) protostellar winds (Jatenco-Pereira and Opher 1989a; Gouveia Dal Pino and Opher 1989c); 3) supernova remnants (Gouveia Dal Pino and Opher 1989d); 4) molecular clouds (Opher and Valio 1989); 5) distortions of the 3 K background (de Araujo and Opher 1988, 1989); 6) magnetized white dwarf binaries (Canalle and Opher 1988, 1989); 7) late-type stars (Jatenco-Pereira and Opher 1989b); and 8) the sun (Jatenco-Pereira and Opher 1989c). I show that these analysis predict small-scale structures that are observable by VLBI.

II. SMALL-SCALE RADIO STRUCTURES

In relation to extragalactic jets, Gouveia Dal Pino and Opher (1989a) showed for a wide range of possible jet parameters that the plasma of the jet is thermally unstable. In the region of the perturbation the electronic pressure is less than the ambient electronic pressure causing a compression of the perturbed region and an increase of its magnetic field to over twice the ambient value. This "bending-in" and change in direction of the magnetic field in filaments and knots can be traced by the polarization of the synchrotron radiation.

Gouveia Dal Pino and Opher (1989b), in another investigation, showed that apparent superluminal motion can be due to a thermal instability, rather than due to relativistic beaming. We have the resultant predictions that: a) there is a high probability for random oriented jet sources to have superluminal motion; and b) the size of superluminal knots is greater than $\tau_V c$, where τ_V is the characteristic time variation of the radiation flux and c is the velocity of light.

Jafelice, Opher, Assis and Busnardo-Neto (1990) studied the damping of magnetosonic and surface waves in extragalactic jets and obtain a high current density at the border of the jet sufficient to confine the jet. We have the resultant prediction that surrounding the border of the jet there is a poloidal magnetic field whose pressure is sufficient to balance the internal pressure.

Jafelice and Opher (1987, 1989) showed that kinetic Alfvén waves can be important in reaccelerating electrons and produce an electric current in extragalactic jets. Jets should have bright spots where electrons are accelerated by the kinetic Alfvén waves.

Medina-Tanco and Opher (1989) studied the general nonlinear case of oblique shock acceleration of particles in extragalactic jets and other sources. Smooth shocks are predicted to exist and in the region of these smooth shocks we should observe a change in direction of the ambient magnetic field and a brightening due to the accelerated electrons.

In relation to young and old stars, Jatenco-Pereira and Opher (1989a,b) suggested that Alfvén waves create the observed galactic molecular and ionized outflows in young stellar objects (YSO) and the strong winds in old giant stars (OGS). They predict a strong diverging magnetic field near the surface of YSO and OGS where mass loss occurs. Transverse velocity fluctuations to the outgoing flow ~ 20 km/s at a radius $r \sim 2 r_0$ (where r_0 is the radius of the stellar "surface"), with periods $0.2 - 1 \times 10^7$ sec in YSO and $10^5 - 10^6$ sec in OGS are predicted.

Gouveia Dal Pino and Opher (1989c) show that the physical conditions in the ionized jets in YSO are favorable for the formation of condensations by the thermal instability. We have the prediction that ionized jets in YSO are highly inhomogeneous and lumpy.

Jatenco-Pereira and Opher (1989c), studying the flow geometry of coronal holes in the sun, found that in order to satisfy the existing observational data, slow divergence up to height $\sim 0.01 - 0.1 R_\odot$ is required, followed by a rapid divergence up to a height $\sim 1 R_\odot$.

Canalle and Opher (1988, 1989) examined the structure of the optical emission region of the accretion column of magnetized white dwarfs, in particular, AM Herculis binaries. Studying the optical emission region, they took into account the variation with height of the magnetic field. A strong diverging magnetic field near the optical emitting region is predicted.

When the energy source region is situated above the base of a rapidly diverging magnetic field, an inverse energy population of electrons occurs producing electron cyclotron maser radiation at $\sim 75 - 80^\circ$ with respect to the magnetic field. We have the prediction that the rapidly diverging magnetic fields in YSO, OGS, the sun and near the optical emitting region in AM Herculis binaries can produce strong electron cyclotron maser radiation at $75 - 80^\circ$ with respect to the magnetic field. The brightness temperatures can reach $\sim 10^{15}$ K.

Gouveia Dal Pino and Opher (1989d) studied the thermal synchrotron instability in supernova remnants. They found that an expanding shell with a radial magnetic field can efficiently form filaments in supernova remnants such as the Crab nebula. A compressed magnetic field in these filaments is predicted.

Opher and Valio (1989) showed that gravitationally unbound condensations in molecular clouds can be due to thermal instability aiding gravity. These small clumps can become visible by compression-heating when collapsing or by masering if there is a nearby HII shocked region.

de Araujo and Opher (1988, 1989) studied the evolution of Population III objects from the recombination era as a function of redshift. For a $\Omega h^2 = 0.1$ universe, for example, the recombination redshift is 1481, where Ω is the ratio of the present to the critical density of the universe and h is the Hubble constant in units of 100 km/s-Mpc. Using previously suggested isothermal density perturbation spectra, they evaluated the density and temperature of the evolving perturbation as a function of the redshift taking into account photon drag, photon cooling, photoionization by the background radiation, and the formation and destruction of the hydrogen molecule.

The formation of Population III objects come from nonlinear fluctuations of mass $10^6 M_\odot$. A fluctuation of mass $\sim 10^6 M_\odot$ produces a $T_B \sim 3$ K on an angular scale $\Delta\phi \sim 600 \Omega^{2/3}$ milliarcsecond (mas). We expect greater $T_B (\Delta\phi)^2$ for the Population III objects of smaller mass; they collapse. We thus expect, in general, temperatures $T_B \sim 10^6 \text{ K} (\Delta\phi)^{-2} \Omega^{4/3}$ on angular scales $\Delta\phi \lesssim 600 \Omega^{2/3}$.

The above are new predictions which can be detected with present (or near future) VLBI sensitivities.

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REFERENCES

- Canalle, J.B.G. and Opher, R., 1988, *Astr. and Ap.*, 189, 325
 Canalle, J.B.G. and Opher, R. 1989, *Astr. and Ap.*, 219, 334
 de Araujo, J.C.N. and Opher, R. 1988, *M.N.R.A.S.*, 231, 923
 de Araujo, J.C.N. and Opher, R. 1989, *M.N.R.A.S.*, 239, 371
 Gouveia Dal Pino, E.M. and Opher, R. 1989a, *Ap. J.*, 342, 689
 Gouveia Dal Pino, E.M. and Opher, R. 1989b, *Proceedings of the IAU VI Latin American Regional Meeting of Astronomy*, *Rev. Mex. Astr. Astrof.* (in press)
 Gouveia Dal Pino, E.M. and Opher, R. 1989c, *Astr. and Ap.* (in press)
 Gouveia Dal Pino, E.M. and Opher, R. 1989d, *M.N.R.A.S.* (in press)
 Jafelice, L.C. and Opher, R. 1987, *Astrophys. and Space Sci.*, 137, 303; *Astrophys. and Space Sci.*, 137, 23
 Jafelice, L.C. and Opher, R. 1989, *Proceedings of the IAU VI Latin-American Regional Meeting of Astronomy*, *Rev. Mex. Astr. Astrof.* (in press)
 Jafelice, L.C., Opher, R., Assis, A.S., and Busnardo-Neto, J. 1990, *Ap. J.* (January)
 Jatenco-Pereira, V. and Opher, R. 1989a, *M.N.R.A.S.*, 236, 1
 Jatenco-Pereira, V. and Opher, R. 1989b, *Astr. and Ap.*, 209, 327
 Jatenco-Pereira, V. and Opher, R. 1989c, *Ap. J.* (September)
 Medina-Tanco, G. and Opher, R. 1989, *Proceedings of the IAU VI Latin-American Regional Meeting of Astronomy*, *Rev. Mex. Astr. Astrof.* (in press)
 Opher, R. and Valio, A. 1989, *Proceedings of the IAU VI Latin-American Regional Meeting of Astronomy*, *Rev. Mex. Astr. Astrof.* (in press)

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