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SHOCK-SHOCK COLLISIONS AND STARBURSTS

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RESUMEN

Las grandes regiones de formación estelar violenta (las superasociaciones) muestran una estructura espacio-temporal binaria. Un sistema típico consta de dos componentes separadas con dos generaciones de estrellas en cada una de ellas. En nuestro modelo suponemos que el mecanismo físico que da origen a estos sistemas es la colisión de grandes ondas de choque en el medio interestelar. Estos procesos han sido estudiados con simulaciones numéricas.

ABSTRACT

The large-scale regions of violent star formation —the superassociations— reveal a binary space-time structure. A typical system consists of two separated components with two generations of stars in each of them. In our model, a key physical mechanism which is assumed to be responsible for the origin of these systems is the collision of large-scale shocks in the interstellar medium. This process has been studied with computer simulations.

Key words: **GALAXIES: STARBURST — ISM: STRUCTURE — SHOCK WAVES**

1. SUPERASSOCIATIONS: THE LARGEST STARBURSTS

Superassociations are known as huge agglomeration of young stars, stellar clusters and 'ordinary' associations of OB stars with a total mass which is typically around a million solar masses and a mean diameter of about 1 kpc. These are the largest starburst regions in galaxies. Geometrically, they usually consist of two separate components of more or less equal size.

The well-studied systems of this type (OB 78 = NGC 206 in M31, Region IV = 30 Dor E + 30 Dor W in LMC, NGC 604 in M33, etc.) contain two populations of stars: the relatively old stars with an age about 30 – 50 Myr (the Cepheids), and the youngest stars with an age less than 10 Myr (OB stars). This may mean that there were two major bursts of star formation in the history of the systems separated in time by the interval of some 20 – 40 Myr. The second of them which seems to be more effective produces the superassociation and giving its identity as the region of violent ongoing massive star formation.

Which physical process can provide the extreme nature of the superassociations and their binary space-time structure? Why do they have the highest rate and, probably, the highest efficiency of massive star formation on the largest scales observed in the galaxies?

2. A SCENARIO

We search for an answer to these questions in supersonic gas dynamics of the interstellar medium. The key process which is assumed to be responsible for the origin of the superassociations is the collisions of large-scale shock fronts involving gas masses of a million solar masses or more.

This approach to the nature of the superassociations can be presented in the form of an evolutionary scenario (Chernin & Efremov 1994). There may be considered four basic subsequent stages of the evolution of the violent star formation region:

1. 'Ordinary' star formation bursts occur more or less simultaneously in two separate, but neighboring areas of ISM. The rapid evolution of the massive stars formed in these processes produces an energy and momentum release which leads to the formation of expanding shock fronts around these areas;

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2. The shock fronts meet each other in the area located between the initial star formation regions and then undergo contact collision with subsequent formation of two reflected shocks;

3. The reflected shocks move back to the areas of the initial output of energy and drag the shocked material to these areas;

4. The evolution of the reflected shocks is affected by hydrodynamic and thermal instabilities which give rise to the formation of dense gas flows with a high velocity dispersion within them. Because of the high gas density and high velocity dispersion in the material, the extremely intensive star formation proceeds in the areas from which the process started.

The first stage of the scenario relates to the large-scale shocks in ISM around regions of star formation which have been studied in a number of works; the stages 2–4 address the physics of shock-shock collision which has not been exploited in this context.

3. STARBURSTS DRIVEN BY SHOCK-SHOCK COLLISIONS

Almost a half-century ago, Courant & Friedrichs studied a dynamic structure that is produced when two shock fronts came into collision. The fronts were assumed to be spherical with the equal radii. The structure includes the ring of the Mach front, two surfaces of tangential discontinuities and two reflected shocks that propagated backward in the opposite directions.

We have developed a set of 3-d models which reproduce this picture and show the further nonlinear dynamic behaviour of Courant-Fridrichs structure, which is not described by existing theories. Two major dynamic elements that form at advanced stages of this evolution are the outflows behind the reflected shocks and the toroidal large-scale eddy structure in the central region. More about the models see in the work by Chernin et al. (1995).

The scenario, together with the computer simulations provide grounds to expect that:

1) A high rate of massive star formation and high efficiency of gas consumption for star formation in the secondary starburst are due to high density and high velocity dispersion in the gas behind the reflected shocks;

2) Two populations of stars in each component of the binary star-forming systems have an age difference of about 20 – 30 Myr that is related to the time interval between initial star bursts and the secondary star bursts;

3) Different space distribution and different kinematics of the stars of the two populations reflect the 'initial conditions' in the gas from which they form in each of the two subsystems: more or less isotropic distribution of the first generation stars and a stream-like distribution of the second generation stars;

4) High velocity dispersion of young stars and the gas from which they form in the system is produced by the energy of the outflows behind the reflected shocks; the energy of these motions is of not gravitational, but nuclear origin and is released via stellar winds and supernova explosions;

Features rather similar to 1, 2, and 4 are probably observed in some superassociations. Features like 3 and some others may provide an observational test for the scenario. It is important that the superassociations at different stages of their evolution can, in principle, be observed, and so the scenario seems to be tested by observations of not only the final state of the systems, but also the earlier stages described by the scenario.

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