BURST GALAXIES

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ABSTRACT. Here we present observational evidences and theoretical approaches to the starburst phenomena in the different types of the galaxies. A starburst model for AGN, large-scale gas outflow of the central regions of galaxies, and ultimate fate of a matter venting out of a starforming regions are discussed.

Key words: galaxies: kinematics and dynamics; interstellar matter; shock waves.

Introduction

Starburst galaxies are among the most interesting and puzzling objects drown a great attention during the last decade. There are several reasons for a continuously rising interest to this objects which includes both of new observational programs and comprehensive theoretical models. They could be summarized as follows:

- an extreme energy release rate in the local space regions;
- a possible crucial role in the dynamic and chemical evolution of galaxies;
- the cosmological scenarios and mechanisms of galaxies formation itself;
- the galactic - intergalactic medium connection and X-ray background;
- a possible link with the basic properties of AGNs;
- starburst dwarf galaxies are the ideal laboratories for studying star formation itself.

Below in this paper we define starburst galaxies as the systems with a powerful cluster of young massive stars and highly ionized gas in the central kpc region with the characteristic time for a gas depletion

$$\tau_{dep} = \frac{M_{gas}}{SFR} \ll \tau_{gal} \qquad (1)$$

much smaller than a characteristic time-scale for a galaxy evolution. Here SFR is the star formation rate.

Starburst far-IR galaxies.

Stellar winds and SN explosions from a compact star cluster provide a powerful gas outflow and coherent shell formation around a central regions of starburst galaxies. There are three main observational evidences for a galactic-scale superwinds in these systems (Heckman et al. 1990).

- *Physical.* Strong shock wave formation and emission-line ratios inherent of material that has been shock heated;
- *Morphological.* Large-scale regions of optical, X-ray, and continuous radio emission with the main axis normal to the galaxy plane of symmetry, sometimes they are strong limb brightened;
- *Kinematic.* A double-peaked emission line profiles which cover a kpc-scale regions.

All these signatures are well defined in the edge-on far-infrared galaxies (FIRGs) that have been observed by Heckman et al. (1990). The sample of 14 galaxies includes the three nearest FIRGs M82, NGC253, NGC 4945, and the most luminous far-IR galaxy IRAS 001182-7112. The observed parameters of the starburst regions are summarized in the Table 1.

These values give an estimation for the total starburst energy $E_{burst} \approx P\Omega \approx 10^{56} - 10^{58}$

ergs, the average energy and mass input rates $L_{burst} = E_{burst}/\tau_{burst} \approx 3 \times(10^{41} - 10^{43})$ erg s^{-1}, $\dot{M} \approx 4L_{IR,11}\, M_{\odot}\, yr^{-1}$, and the rate of supernova explosions $\nu_{SN} \approx 0.2\ L_{IR,11}\, yr^{-1}$ (Heckman et al., 1990).

Table 1. Starburst parameters in the far-IR galaxies.

Star cluster size	< 1 kpc
Shell, X-ray region size	1-50 kpc
L_{H_α}	$10^{40} - 10^{42} erg\, s^{-1}$
L_{bol}	up to $10^{46} erg\, s^{-1}$
ΔV	200-600 $km\, s^{-1}$
n_e	$(0.5 - 1) \times 10^3 cm^{-3}$
P/k	(1-3) $\times 10^7\ K\, cm^{-3}$
τ_{burst}	$\approx 10^7$ yr

Seyfert galaxies.

It has long time been known that nuclei of Seyfert galaxies to be the sites of small-scale subkiloparsec radio emission. However the last years WSRT systematic study of the 13 Seyfert galaxies revealed also a diffuse large-scale radio components (Baum et al. 1993). The ratio of the extra-nuclear radio emission to the far-IR flux is in a good agreement with the empirical relationship found for the extragalactic star-forming regions. Regions of the large-scale radio emission are often not spherical, sometimes limb-brightened, with the main axis to be aligned with the minor axis of the galaxy. Thus the observed large-scale diffuse radio emission is not an extension of the nuclear radio jets like the radio lobes in the powerful radio galaxies. It's radio powers at 1.4 GHz is compared with the radio power of the prototype starburst galaxy M82 ($10^{22}\ W\, Hz^{-1}$), and starburst scenario is highly suggestive for explanation of high energy electrons and diffuse large-scale radio emission.

Dwarf galaxies.

Dwarf galaxies play a crucial role in the study of star formation, formation and evolution of galaxies. In the popular cosmological scenarios they were the first blocks for the current structure of the Universe. The most metal-poor dwarfs like I Zw18 probably undergo a fist burst of star formation, another ones are the ideal laboratories for studying star formation itself because they are free of the contamination influence of the outside star forming regions, fast galactic rotation etc. Star-forming dwarf galaxies fall primary into two morphological classes.

- *Dwarf amorphous galaxies* have centrally condensed light distribution. It is suspected they went through a powerful burst of star formation in their history.
- *Magellanic irregular galaxies* are more homogeneous in the light distribution, and are consistent with a steady rate of star formation.

Marlowe et al. (1995) have presented a detailed study of the 7 nearby amorphous dwarf galaxies with a clear evidence for a violent star formation activity. All the galaxies present evidence for a kiloparsec-scale hollow structures (superbubbles) which typically expand with a velocity 30-60 $km\, s^{-1}$. The major axes of the cavities are preferentially aligned with the minor optical axes of the galaxies. The observed H_α luminosities fall in the range $10^{39} - 10^{41}\, erg\, s^{-1}$, with the mean value of about an order of magnitude smaller, than in the far-IR galaxies. The estimated rate for a supernova explosions is then 1SN per 3 $\times 10^2$ - 10^3 yr.

Hydrodynamics of starburst galaxies.

An evolutionary trend for a powerful star cluster evolved in a dense gas condensation is highly depend on the ambient gas density and the rate of supernova explosions. It is easy to catch this dependence from the McKee and Ostriker (1977) relation for a tenuous hot gas volume filling factor:

$$f_V = 1 - \exp\left(-Q_{SN}\right), \qquad (2)$$

where $Q_{SN} = 53 E_{51}^{1.28} S_{-11} n_0^{-0.14} P_4^{-1.3}$, E_{51} is the explosion energy per supernova in 10^{51} ergs units, S_{-11} is the supernova rate in the units

10^{-11} supernovae per year in pc^3, P_4 is the ambient gas pressure in $10^4 k$ units. Analysis of this criterion leads immediately to two possible evolutionary trends, which are shown schematically in the figure 1. For a high density medium which may be suspected for a prestarburst region, and low rate of supernova explosions any SNR may be considered as an isolated system and one gets a starburst model for AGN which has been firstly proposed by Shklovskii (1960) and then revived and fully developed by Terlevich and Melnick (1985), Terlevich et al. (1992), (figure 1a).

However, starburst parameters found in the discussed above FIRGs and dwarf galaxies lead to another regime with a coherent shell formation and large-scale gas outflow of the central starburst region (figure 1b). There is a common believe that in the dwarf galaxies shell distortion due to Rayleigh-Taylor instabilities allows the processed matter to flow away of the galaxy, and in extreme cases bubble expansion may result in a full loss of the ISM throughout the galaxy (De Young and Heckman, 1994). However, this conclusion is based on the numerical calculations for a shock propagation in the plane-stratified, disk-like gas distribution. In fact several well studied dwarfs exhibit an extending low density HI envelopes, which highly exceed an optical size of the galaxies. Thus, in the real systems at least two different gaseous components may be assumed. There are a dense galaxy disk and a low-density halo. Therefore a natural next step in modelling starburst hydrodynamics is the incorporation of the two-component gaseous structure with a dense disk and extended halo. A secondary shell forms in the halo after a primary shell distortion and hot gas blow-out of the galaxy disk. A careful analysis (Silich and Tenorio-Tagle, 1997) shows that under a wide range of parameters the hydrodynamical action of the gaseous halo could preserve mass venting from the galaxy into IGM and leave a total system bound.

Conclusion.

Comprehensive studies of the starburst galaxies in visible, IR, X-ray and radio wave bands and numerical simulations undertaken during the last decade made a great progress in our understanding these intrigue puzzling objects. We understand now a current phase of the burst evolution, however can only guess of the principal mechanisms that initiate starburst activity and still cannot predict with a great degree of confidence the ultimate fate of the matter processed in a powerful starburst explosion.

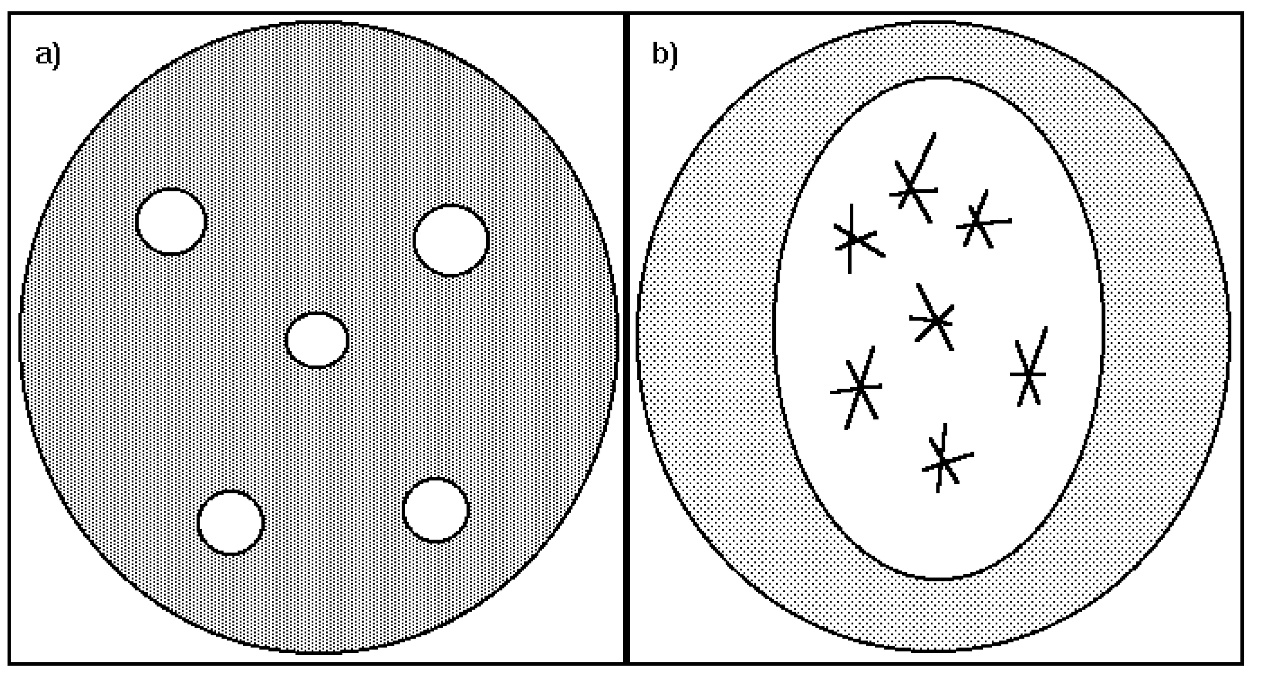

Figure 1: Two regimes for multiple SN explosions. a) Isolated remnants. b) Coherent shell.

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