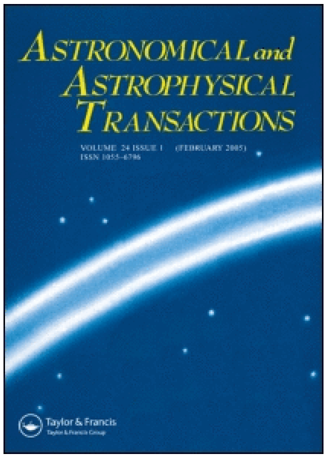

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

ON THE NATURE OF HI SUPERSHELLS AND STELLAR SUPERARCS

Yuri Efremov [a]
[a] Sternberg Astronomical Institute, Universiteskij pr. 13, Moscow, 119899, Russia.

Online Publication Date: 01 January 2002
To cite this Article: Efremov, Yuri (2002) 'ON THE NATURE OF HI SUPERSHELLS AND STELLAR SUPERARCS', Astronomical & Astrophysical Transactions, 21:4, 251 - 263
To link to this article: DOI: 10.1080/10556790215591
URL: http://dx.doi.org/10.1080/10556790215591

Astronomical and Astrophysical Transactions, 2002, Vol. 21(4–6), pp. 251–263 Taylor & Francis Taylor & Francis Group

ON THE NATURE OF HI SUPERSHELLS AND STELLAR SUPERARCS

YURI N. EFREMOV*

Sternberg Astronomical Institute, Universiteskij pr. 13, Moscow, 119899, Russia

(Received 16 April 2002)

The old and recent ideas on origin of HI supershells are discussed. The absence of supershells around most suitable clusters is even more enigmatic than the absence of paternal clusters inside most of supershells. The giant stellar arcs of regular shape were generally considered to have been originated from the swept-up gas shell. However their strictly circular shape suggest they were formed owing to the ram pressure to the surface of the infalling clouds. The examples of the star formation in the bow shock, arising due to the supersonic movement of galaxies through the IGM are given to demonstrate the similarity with the arc-shaped stellar complexes in the LMC and NGC 6946. The stellar superarc in NGC 300 was probably formed due to the action of the external blast wave to the HI supercloud in the spiral arm of the galaxy.

Keywords: Stellar complexes; Supershells; Star formation

1 THE ORIGIN OF THE SUPERSHELLS

The problem of an origin of HI supershells has an old history. The supershells have diameters 300–1500 pc and the issue is that the energy needed for their formation is equivalent to this of a few hundreds common Supernovae. Heiles (1979), first finding out a dozen of supershells in our Galaxy, noted, that though they could be made by the large number of Supernovae of type II flashing in the same OB-association, the supershells seem not to be connected with extreme objects of the population I, and it is the strong argument against such opportunity. He has assumed even, that the agent responsible for existence of supershells still never was observed, and even that this agent can in itself be new unknown kind of astronomical objects.

It is still possible, that Heiles was right. As such objects of new kind, delivering in interstellar medium energy, sufficient for formation of supershells, the Gamma-ray bursts were suggested, soon after they have been identified as extragalactic objects with energy output up to 10^{53} ergs (Efremov *et al.*, 1998; Loeb and Perna, 1998). Much earlier the origin from explosions of a Super-supernovae was suggested by Westerlund and Mathewson (1966) and then Hodge (1967) to explain the origin of the giant arcs of young stars and clusters which they found in the LMC and in NGC 6946.

* E-mail: efremov@sai.msu.ru

ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/1055679021000017583

Anyway, the common explanation of absence of the central cluster/association inside a supershell is that the supershell may be old enough for the parent cluster do not be noted. The supershells may preserve long in area of a galaxy within solid-body part of the rotation curve and/or the large thickness of a gas disk. Then its age can be so large that the central parental cluster is already old enough and consequently unseen (Efremov and Elmegreen, 1998; Stewart and Walter, 2000).

Starting with the age and sizes of a supershell it is possible to tell, what there should be parameters of a cluster, which could be its cause and by that check up this "standard model" origins of supershell. As it is strange, such check was conducted only recently. Rhode *et al.* (1999) have carried out careful searches of clusters inside numerous HI supershells in the irregular galaxy Ho II in M81 group. Only inside 6 of 44 supershells they did find clusters, for which quantity of stars and the age are compatible to the assumption, that they contained in the due time massive stars in quantity sufficient to cause these supershells. In Ho II there are no supershells even inside the greatest supershells, which, after all, (as well as the supershells in our Galaxy) are on periphery of the galaxy, where the young massive stars about absent.

It is possible, that only in rather massive (about 10^6 suns) clusters the explosions of Supernovae occur enough frequently for formation of superenshells. Efremov *et al.* (1998) noted that the average rate of output of energy even from 1000 Supernovae during 2×10^7 years means rate of heating of interstar medium close to rate of its cooling at normal pressure. So, it is quite possible that only the quite massive clusters may form supershells.

For a long time the problem of formation of arc-shaped stellar complexes seemed to be a derivative with respect to the problem of formation of HI supershells. The expanding supershell should under certain conditions (first of all the initial density of the ISM must be high enough) to fragment into clouds dense enough for formation of the star clusters, mostly due to the gravitational instability. The most recent development of theory of this process was given by Ehlerova and Palous (2001), Palous *et al.* (2002), and Elmegreen *et al.* (2002). Note that the Supernovae, apart from triggering the star formation via the gravitational instability in the swept-up shell, may induce star formation, compressing the pre-existing clouds by the shock waves (*i.e.* Dibai, 1958; Woodward, 1976; Boss, 1995). Both mechanisms of triggering may act simultaneously, leading to the high efficiency of the process (Chernin and Losinskaya, 2002).

The idea of the origin of the giant stellar arc from the HI supershell was first advanced by Westerlund and Mathewson (1964) to explain the supergiant arc of blue stars in the LMC (which they erroneously identified as Shapley's Constellation III – see Efremov and Elmegreen, 1998). These authors noted that this superarc (which we have named Quadrant) is inside the large HI supershell (which is now known as LMC4) near its southern rim, and concluded that this segment of HI rim have transformed already into stars.

The formation of HI supershell paternal for the arcs of stars was considered later for a huge arc of clusters in NGC 1620 (Vader and Chaboyer, 1995), and for Quadrant and nearby smaller arc, Sextant, in the LMC (Efremov and Elmegreen, 1998). In NGC 1620 case the giant association is seen near the center of the arc, whereas in the arcs of the LMC the very existence of the central clusters is doubtful (Braun, 2001).

The issue of the origin of the 'Constellation III' (Quadrant) structure had deep, mostly unrecognized, influence to the problem of supershells. Most first researchers of supershells had in mind this superarc, not recognized it is a quite special object. It was this 'superring' to explain which Tenorio-Tagle (1980) was first to introduce the idea of the high velocity cloud impact with energy output equal to hundreds of Supernovae, capable to form the paternal supershell. However in many cases the absence of such clouds near the galaxy having HI supershells was noted, is some cases the galaxy was well isolated (see references in Efremov *et al.*, 1998).

At any rate, we have realised that the possibility of the origin of Quadrant and Sextant from the gaseous shells, swept up by the multiple Supernovae in clusters, suggested by Efremov and Elmegreen (1998), seems to be untenable, not only because there are only hints on the existence of the parent clusters. In the LMC4 region of the LMC within area around 1.5 kpc across there is altogether five giant stellar arcs, with radii 200–500 pc (Hodge, 1967; Efremov, 2001a), and one cannot explain why all clusters which were able to form such structures were confined within the same region of the galaxy (Fig. 1). Other arguments against the possibility these arcs have been formed from the gas shells swept up by central clusters were given by Braun (2001).

These arcs might be formed by the energetic events produced by objects originated in the massive cluster NGC 1978 which is in the same region, (Efremov, 2000; 2002), or might be result of impact of a few fast clouds – not necessarily from the swept-up shells. This possibility is considered below, and here we acclaim that problems of origin of supershells and superarcs may be well quite different.

Some other opportunities to explain the supershells were suggested. A supershell and then triggered star formation might arise around of a place of crossing of a gas galactic plane by a massive and fast cluster (Wallin *et al.*, 1996). The hypothesis of occurrence of huge cavities in the turbulent ISM owing to nonlinear development of the combined gravitational and thermal instabilities, without participation of energy supply from stars, plausibly does not pass (Sanchez-Salcedo, 2001).

More attractive is the possibility of the ram pressure action. If the galaxy moves in enough dense intergalactic medium, the originally small cavities in its gaseous disk could become larger under action of the ram pressure. This explanation was offered by Bureau and

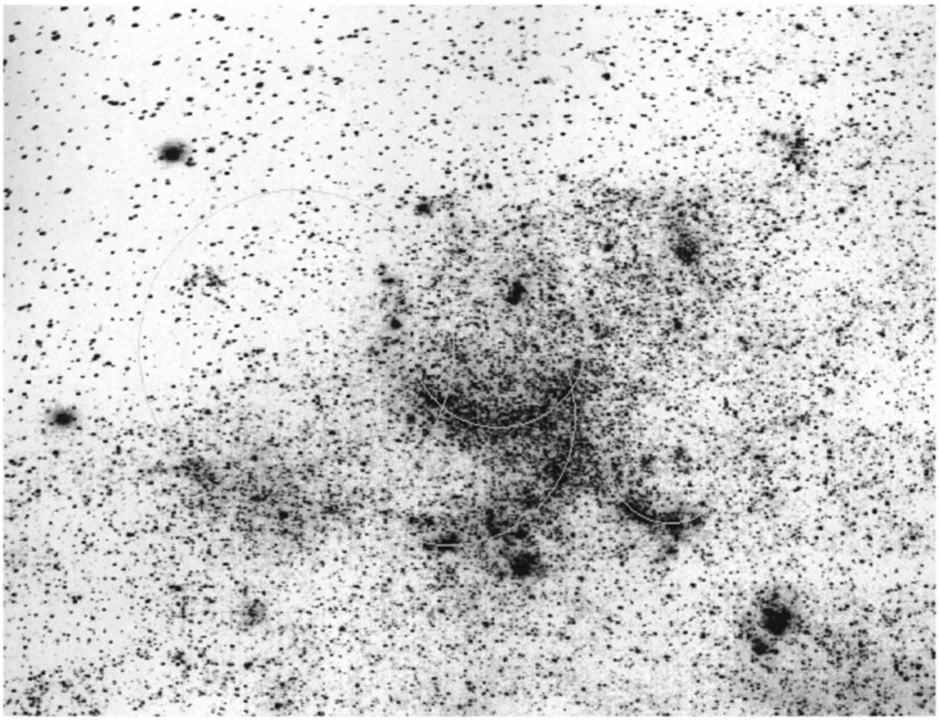

FIGURE 1 Giant stellar arcs in the region of the LMC4 of the LMC. Quadrant is in the center, Sextant to SW. North is up, East to the left.

Carignan (2001) for origin of the numerous holes in the Ho II galaxy, the evidence for the ram pressure being the bow-shock shape of its external isolines of HI.

After all, the question might be asked – if the supershells are formed under actions of the multiple Supernovae and hot stars on the ISM, why around of set of rich clusters, in which these objects undoubtedly have existed, no supershells are observed? The possible explanation could be, that around of such clusters the density of atomic and/or molecular hydrogen is very high. The morphological relations between hydrogen species around the clusters of the early stars are very complicated and sometimes a shell is surpisingly absent (see Oey *et al.*, 2002).

It seems that the clusters without surrounding supershells are too numerous if the standard model is true. It would be interesting to solve the inverse problem – to search not for clusters inside supershells, yet for supershells around of clusters, which are considered (from age and mass) to be able to form the formers.

There is opinion that many examples exist of triggering star formation by older clusters inside HI supershells (Elmegreen *et al.*, 2002). However only two certain case are known, where the central older cluster is inside the rings of the younger clusters, these are in galaxies NGC 1620 and IC 2574. The latter case is the only well studied – the younger clusters are within the elliptical hole of HI and its shape meets to a circle appearing as an ellipse because of an inclination of a plane of a galaxy to the line of sight (Stewart and Walter, 2000). Note that the younger clusters in this complex do not located along the rim of the HI supershell and therefore were plausibly formed form the preexisting clouds. The huge arc in NGC 1620 (Vader and Chaboyer, 1995) is rather irregular and may be in fact a fragment of a spiral arm; no HI data exists for this galaxy. These both structures are hardly similar to the regular arcs in the LMC or to the western border of the Hodge complex in NGC 6946, both being parts of an ideal circle (Fig. 1).

2 PECULIAR STELLAR COMPLEX IN NGC 6946

The absence of the HI superbubble around the isolated and very luminous stellar complex in NGC 6946 is one more problem in studies of supershells. The complex discovered by Hodge (1967) is unique with its semicircular western rim and the high density of the rich young clusters and the high luminosity stars. The photometric data obtained with the HST permitted to identify about 20 rich young clusters (Larsen *et al.*, 2002), besides known earlier the supergiant cluster with age about 15 Myr and mass about 10^6 suns; this cluster should be bound providing the mass function there is normal (Larsen *et al.*, 2001). The NGC 6946 galaxy hosts a lot of high velocity clouds and HI holes; there are they also near the Hodge complex, but none coincides with the latter. This is really strange.

Around NGC 6946 the group from 8 dwarf galaxies of late types is found out, almost all from which are registered in a line HI (Karachentsev *et al.*, 2000), so they could be a source of gas clouds at having flown interaction with the main galaxy. It already allows to consider infall of a gas cloud on a plane of a galaxy as the probable reason of formation of a complex. The sharp arc-like western rim of the complex is then indication of the motion of the parent cloud from East to West (Efremov, 2002). There are certain morphological evidences for this scenario (Fig. 2).

Investigation of the complex in the H_alpha line on telescopes BTA and Keck-I has shown, that the radial velocity of the main cluster of a complex is 150 kms, that on 20–30 km/s exceeds a local rotation rate of a galaxy on HII (Efremov *et al.*, 2002). This small difference probably specifies that if the complex was formed in result of infall of a high velocity cloud,

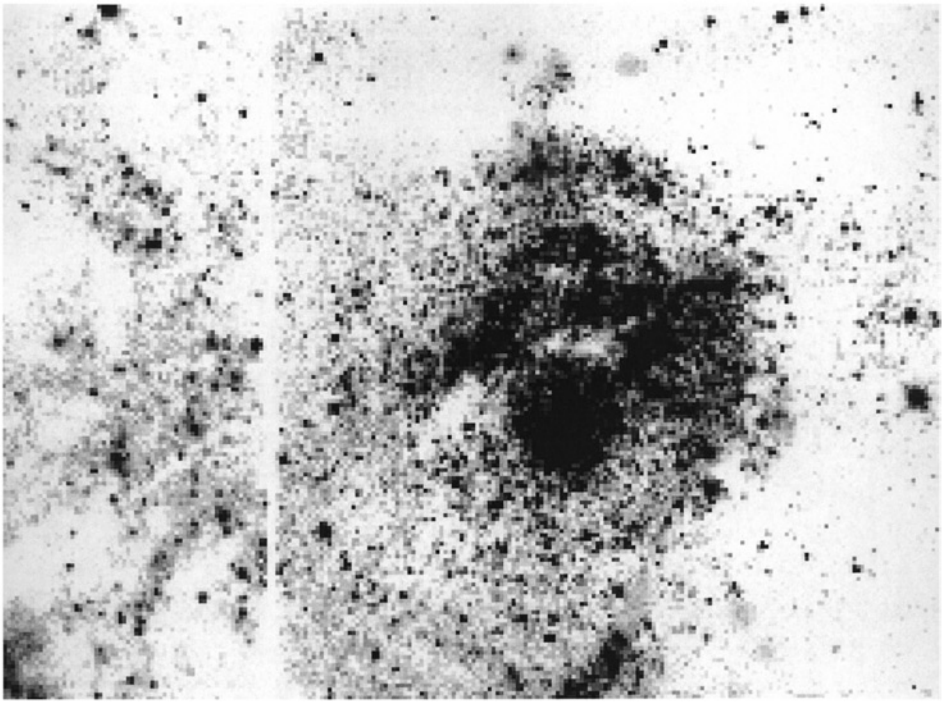

FIGURE 2 The peculiar stellar complex in NGC 6946. The detail of the HST WF image, from Larsen *et al.* (2002). The gas vortices in the tail of impacted cloud are probably imprinted at the East as arcs of dust and stars.

its trajectory was strongly inclined to a plane of a galaxy. The significant distortion of the HII velocity field were found, especially to east from the supergiant cluster; one of this looks like the semishell of 200 pc in diameter expanding with velocity of 120 km/s. There is also indication of the velocity gradient which may be interpreted as the overall rotation of HII gas around the axis lying in the plane of the galaxy along NS direction. This rotation, if confirmed, might be indication of vortice originated in result of the motion of the invased cloud trough the galactic gas.

The galaxy NGC 6946 is known as having a strong magnetic field which is regular outside of limits of optical spiral arms (Fendt *et al.*, 1998 and references there). Collision of a high-velocity cloud with a galaxy, having such field, was modeled by Santillana *et al.*, (1999) at various assumptions about a trajectory of the cloud. According to this work, at some angles of the cloud trajectory to the galaxy plane and magnetic fields lines, the field interferes with penetrating cloud and it is possible to assume, that this causes absence of the large HI cavity around the complex. At some orientation of trajectory the complicated picture of magneto-hydro-dynamical waves arises, and it is possible to assume, that the collision of shock waves results in occurrence of the peculiar structure of the complex.

This process, being probably the most effective trigger of star formation (Chernin *et al.*, 1995), may lead also to the formation of the bound massive cluster. The complex has certain footprints of the collision of the shock fronts, outlined by these authors. Two elongated dust clouds cross the complex, there are two generations of stars distinguished on age on 20–30 Myr. They are divided spatially – older stars are near the super-massive cluster, and younger – in a wide arc to west from it, and the dust clouds are between these two generations of stars. The age of the oldest stars in the complex is about 30 Myr, but in some areas star formation still goes. About 10–20 Myr ago the region looked as a bright superassociation, and its contemporary high brightness is explained in high density of the high luminosity stars. The complex is far from the centre of a galaxy and the thickness of a gas disk here can be enough large, what is good for the effective collisions of the shock waves. The star formation rate in the complex was non-uniform, with maxima about 30 and 5 Myr ago, and in an interval between these epoches of formation of isolated stars and usual star clusters the supergiant cluster formed (Larsen *et al.*, 2002).

In variants of inclined infall of a cloud modelled by Santillana *et al.* (1994) occurrence of the bow shock, oscillating tail with vortices and then origin of the Parker instability is predicted. The sharp circular western rim of the complex might be the result of star formation in the most dense part of the bow shock arised from the supersonic movement of the parent cloud.

3 THE RAM PRESSURE AND ORIGIN OF THE ARC-SHAPED STELLAR COMPLEXES

Amazing feature of the arc-shaped stellar complexes in the LMC and in NGC 6946 is that the large part of their borders are very close to the arc of a perfect circle (Fig. 1). This geometry we consider to be the clue to the origin of these complexes. The planes of both the LMC and NGC 6946 being inclined to the sky plane (at angle of about 30–40 degrees), the arcs of circles laying in a plane of a galaxy would look ellipses notably distinguished from an observable picture. The most natural explanation of the circular shape seen even in projection is the assumption, that these structures are segments of spherical layers (in case of arcs of Quadrant and Sextant in the LMC) or segment of the filled sphere (in case of the Hodge complex in NGC 6946), seen sideways (Efremov, 2001a).

The swept-up gaseous supershell is a circle in a plane of a galaxy and should remain a circle only in the event that we look at a galaxy precisely pole-on. Apart from the assumption that the intrinsic shape is a segment of a sphere, only a quite special orientation of the plane of complex may compensate for the inclination of the galaxy disk to the line of sight, what seems to be rather improbable (anyway, the plane of the Gould Belt complex is indeed inclined to the Galaxy plane). Also, the swept-up gas shell plausibly formed rather irregular complex, as it is the case for the complex in IC 2574.

In the world of galaxies, however, almost perfect hemispheres are known. These are the central parts of the Mach cones arising in result of the supersonic movement across the intergalactic medium in a cluster. The galaxy moving through the IGM under influence of the ram pressure gets characteristic comet-like shape, with the sharp semicircular edge which is leading in the galaxy movement.

There is known a number of galaxies in clusters or groups, whose shapes suggest the strong influence of the ram pressure. Recently the characteristic shape of the Mach cone was found for the outer isolines of HI for the irregular galaxy Ho II (Fig. 3) in M81 group (Bureau and Carignan, 2000) and the same shape is long known for NGC 7421 (Fig. 4), moving to West (Ryder *et al.*, 1997). Less striking examples are numerous and well known, especially for the galaxies in the Virgo cluster.

Under certain conditions the ram pressure may trigger star formation at the whole galaxy scale. The sharp bow shock appearance of a segment of a galaxy edge is the signature of this phenomenon. It is the only possible explanation for the sharp arc of a circle which is the southern rim of resolved stellar disk in the dwarf galaxy DDO 165 (Fig. 3) in M81 group, as it is seen at 6 m telescope plate (Efremov, 2001; 2002). The same origin was suggested

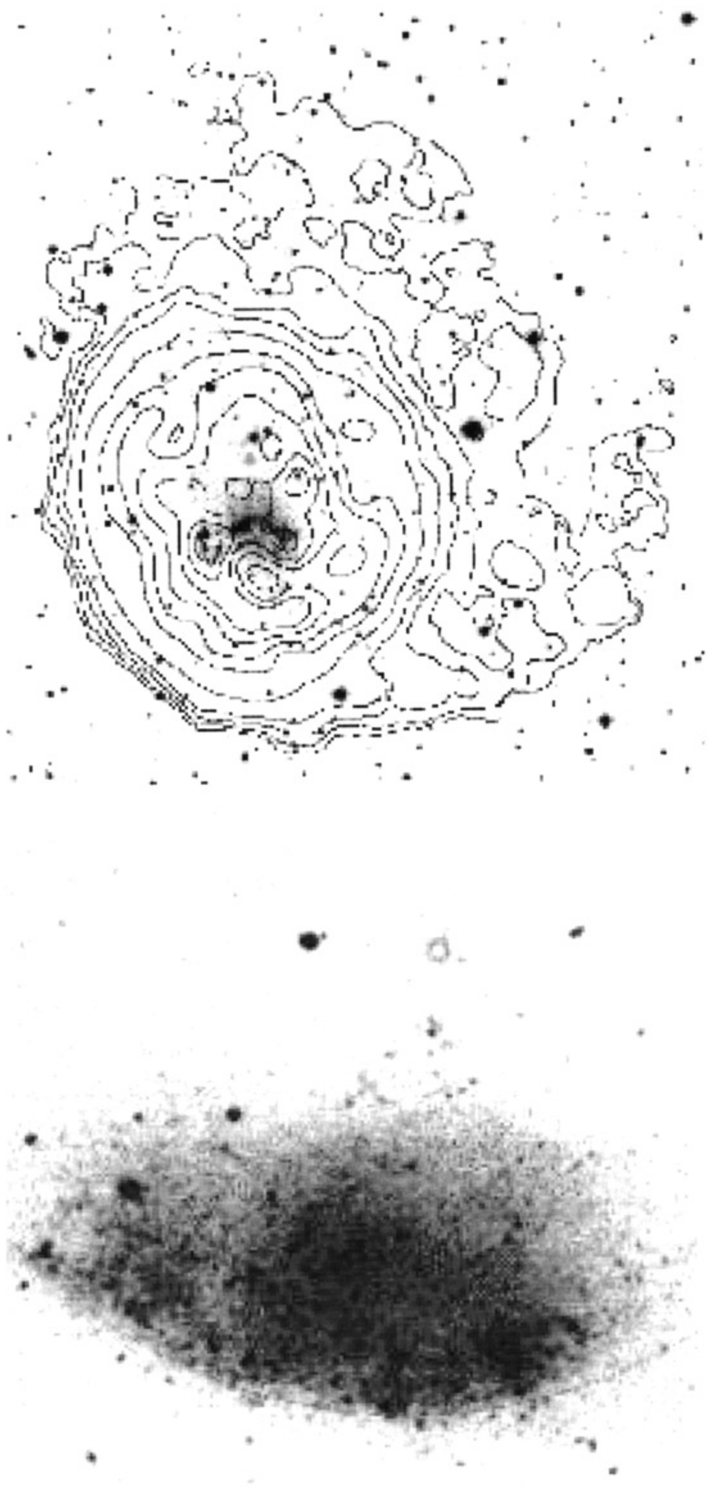

FIGURE 3 Two galaxies in M81 group shaped by the ram pressure. The Mach cone formed by the outer isolines of the Ho II galaxy (top) and the sharp arc-like edge of the stellar disk of DDO 165 galaxy (bottom).

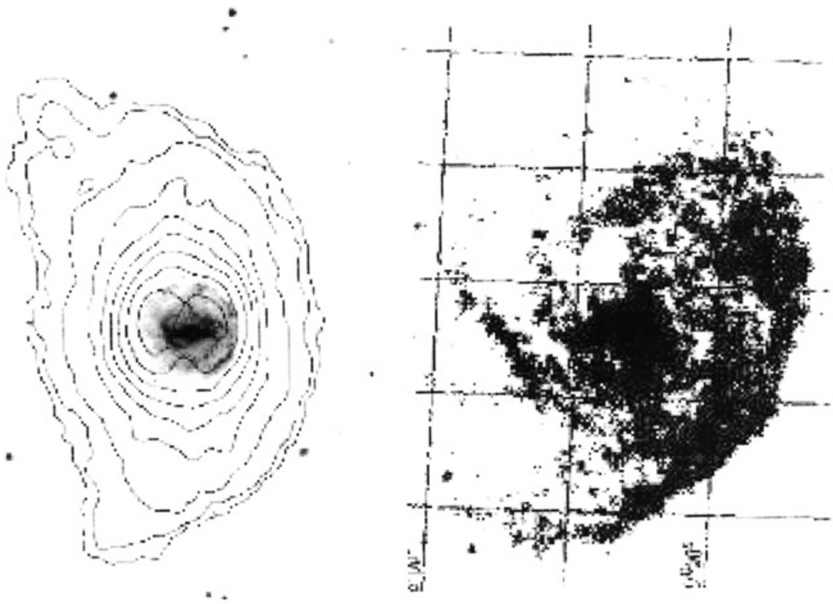

FIGURE 4 The HI Mach cone of NGC 7421 (left) and shaped by the ram pressure 20 cm emission of NGC 2276 (right).

for the arcs of HII regions at borders of galaxies 97-079 and 97-073 in A1367 cluster, the ram pressure action being confirmed by the 75 kpc long HII tails at directions opposite to arc-like edges (Gavazzi *et al.*, 2001). The ram pressure is plausibly responsible for the concentration of HII regions and the stars (Fig. 5) along the sharp and circular SW rim of NGC 2276 (Gruendl *et al.*, 1993) and the motion in this direction is indicated by the appearance of the 20-cm emission (Fig. 4, Davis *et al.*, 1997).

The influence of the galactic dynamical interactions is often suggested to explain the appearance of galaxies in clusters, which we believe is due to the ram pressure, but the absence of counter-tidal tails in all cases considered above is the strong argument for the ram pressure action.

There is one more observational argument for the ability of the ram pressure to trigger the large-scale star formation in the bow shock. The mentioned above galaxy NGC 7421 is outstanding not only with the comet-like shape of its hydrogen halo. The Western border of stellar disk is bright and sharp; it as a first approximation has the semicircular shape. By more detailed consideration of the galaxy image in DSS (Fig. 5) it was found out, that this border is depicted by three rectilinear segments with angles between them about 130 degrees (Efremov and Chernin, 2002). These segments are brighter than the region inside and all the picture is unmistakable evidence for the bow shock which has triggered star formation. The straight lines delineated the leading side of the stellar disk of NGC 7412 amazingly reminds polygonal structure of spiral arms of many galaxies found out and described by Chernin (1999), who argued that this shape is indication of the shock waves, which have always the tendency to transform their shape to the linear one.

Now it worth noting that the western border of the peculiar complex in NGC 6946 looks as semicircular only as a first approximation. The images received with the HST allow to note, that the western rim is more exactly described by three pieces of direct lines, reminding the western border NGC 7421 (Fig. 2). We consider this as strong argument for the assumption, that this complex too has undergone to influence of the ram pressure and its western rim preserved

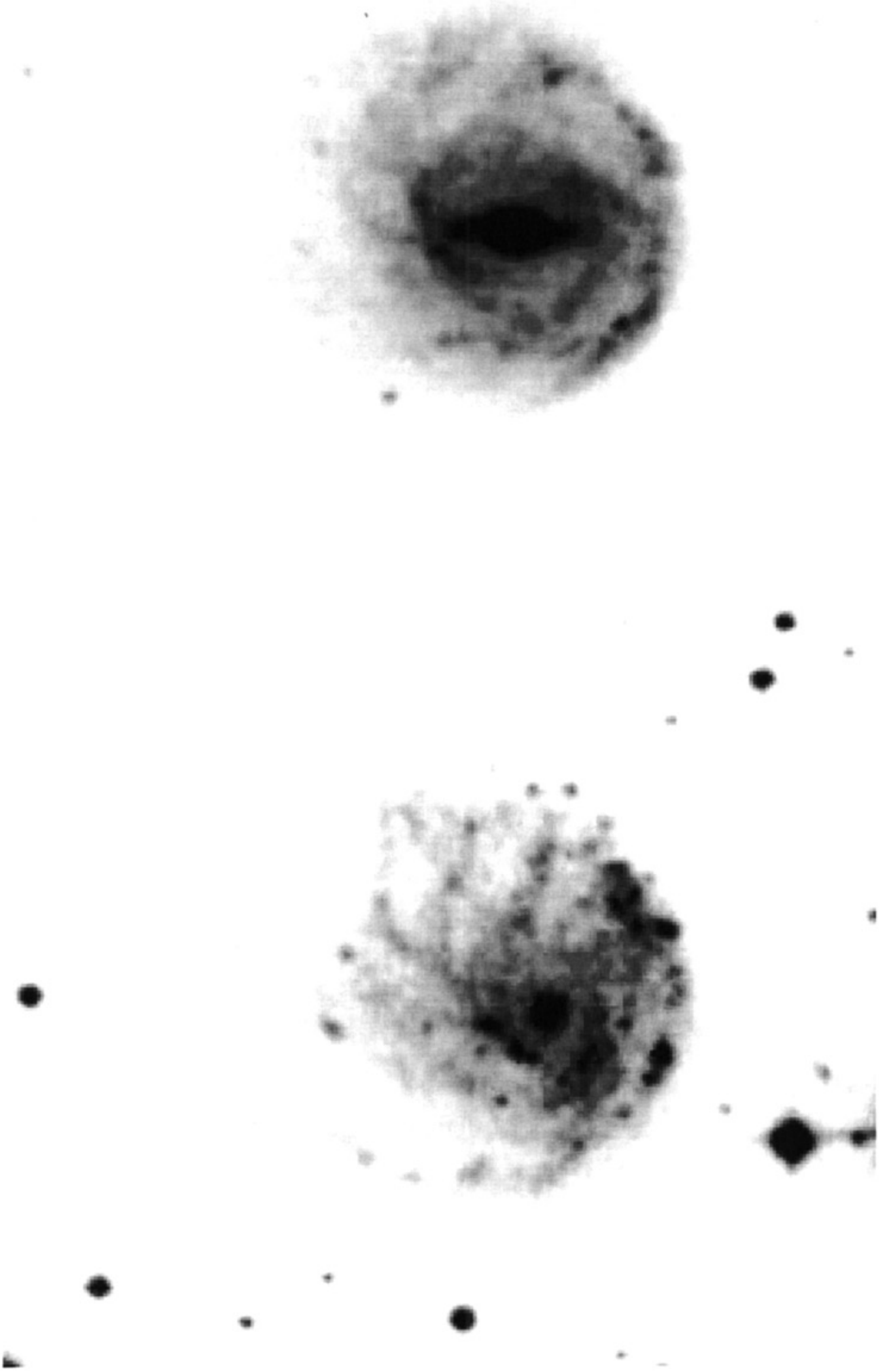

FIGURE 5 The ram pressure shaped stellar disks of NGC 7421 (top) and NGC 2276 (bottom).

the shape of the most dense part of bow shock. The whole complex has somewhat comet-like shape, and the same might be said on the Quadrant arc (Fig. 1). Thus we have the confirmation of hypothesis that the shape of segment of sphere for these complexes could arise as a result of inclined fall of a fast dense cloud, long enough moving through a gaseous disk of a galaxy.

The hypothesis of the oblique infall of the high-velocity clouds may also explain the shape of the superarcs in the LMC. Their concentration on NE outskirt of the LMC might be explained with noting that this edge is plausibly leading in the motion of the LMC through the gas of the Galactic halo (Efremov, 2001b). However the recent data confirm the older result – the Eastward direction of the LMC proper motion (Pedreros *et al.*, 2002), whereas its NE edge points to the Galaxy center (Marel, 2001). These circumstances may help to explain why all the arcs in the LMC are in the same NE region of the galaxy. This might be connected somehow with the orbital motion of the LMC through the gas of the galactic halo. The formation of the LMC4 supershell and triggering of the star formation in this region was attributed by de Boer *et al.* (1998) to the ram pressure connected with this movement. However, the general appearance of the galaxy stellar edge shaped by the ram pressure, described above, is completely non-similar to what is observed in the LMC. Anyway, the borders of HI distribution in the LMC in East and North-East are sharp and made by the direct lines, like the NGC 7421 case. This is in agreement with the supersonic movement of the LMC through the gas halo of the Galaxy.

It worth noting that the HI distribution in the region of LMC4 have no evident signs of the possible impact of the high velocity clouds, both in morphology and kinematics, as was note by Domgorgen *et al.* (1995). There are anyway the disturbations of HI velocities which were noted in the region of SNR N49, at distance of about 1.5 kpc North the Sextant arc, ascribed to a few SNRs near SNR N49 (Dopita *et al.*, 1985). Might this be the footprint of the impacting cloud first contact with the LMC gas? At any rate, it is strange that nothing else might be connected with the suggested impact in HI data for the LMC.

Nevertheless, the dark rings surrounded by arcs of clusters, which we have noted in a few galaxies (Efremov, 2001a) may deal something with the star formation triggered by the ram pressure. The Eastern complex in M83 is the arc of five clusters (one of those being triple) around the dark semiring. It might be an example of the cluster formation under the gravitational instability in the swept-up shell, yet in this case there should not be the diffuse matter inside the arc! The similar feature we have found in the *N* corner of the irregular galaxy NGC 4449 – the circle of clusters around the dark ring. The reality of the lower surface brightness inside the ring is confirmed by the isophotes, and what is significant, the outer isophotes of the galaxy indicate that just this *N* corner of this rectangular galaxy is the most sharp (Hitchcock and Hodge, 1968). May this indicate the north-ward motion of the galaxy? Then the arc may be triggered by the ram pressure and the dark ring is the relict of the paternal cloud. This explanation is not so good for the M83 ring, the clusters there being at the inner side. There the source of the external pressure might be the near-by superexplosion (see below).

It looks like that only an assumption of an origin as a result of the ram pressure can explain, why all arc-shaped complexes have similar (about 100–150 degrees) opening angle, the same as seen in bow-shock-like stellar edges of galaxies. The available theoretical data show, that the range of conditions conducting to the triggered star formation at collision of clouds is quite limited (Klein *et al.*, 2001) and the more so if the requirement of preservation of the resulting star complex of the form of a bow shock is necessary. This obviously explains the rarity of the arc-shaped star complexes. One of such conditions can be presence of a magnetic field (MacLow *et al.*, 1994), that is obviously applicable at least to the case of a complex in NGC 6946.

All in all, it looks like the superarcs in the LMC and the Hodge complex in NGC 6946 might be the late stage of evolution of greatly scaled-up versions of those high velocity clouds in our Galaxy, which have the head-tail morphology. The Mach cones sometimes are seen, indicating the supersonic movement through the ISM, and sometimes signs of star formation in their nuclei are observed (Odenwald, 1988). Recently Bruns *et al.* (2000) found the correlation between fraction of HVCs with cometary appearance in HVC complexes and their densities and velocities, so their shape is really explained by interaction with the ISM. The origin of the HVCs is long disputed unsettled issue, as well as their distribution in sizes.

4 THE ORIGIN OF THE ARC-SHAPED STELLAR COMPLEX IN NGC 300

The physically similar situation arises after interaction of the dense enough cloud with the blast wave from the powerful external explosion. The large increase in pressure lead to the compression of the cloud, most rapid at the face, exposed to the blast wave, and the bow shock may appear along this side (McKee and Cowie, 1975). The observational data discussed above demonstrate, that the triggered star formation may result, the bow shock appearance preserving in the distribution of the young stars.

We have found the case when the stellar superarc was probably formed in the result of interaction of the blast wave with the surface of HI supercloud (Efremov, 2002). Within the spiral arm of the NGC 300 galaxy the arc of the bright stars, having the size about 45” ($\sim$400 pc), is near to the most intensive point X-ray source in this galaxy, which is at the convex side of the arc (Fig. 6). It is object P42 = H13, which is classified as X-ray binary system containing a black hole (with mass about $5\,M_{\odot}$).

The superarc in the question was included in the list of OB-associations and complexes in NGC 300 as AS 102 (Pietrzynski *et al.*, 2001). These authors determined its size in 360 pc and classified as a star complex, consisted of four subgroups. Recently the estimations of ages of associations in NGC 300 from the colour – luminosity diagrams were obtained by Kim *et al.* (2002); for AS 102 these authors gave about 5 Myr.

The young age of the complex is demonstrated also by the bright HII regions, enveloping the arc. For a few Myr age, the gaseous SNR, seen either in optics or radio disappears, but may the high mass X-ray binary P42 be the stellar remnant of a Supernovae? It is probable that such a binary, one of components of which is the accreting black hole, may still be bright in X-rays at age of a few Myr (Lipunov *et al.*, 1996).

Figure 6 constructed by overlapping of the image (kindly provided by S. Larsen) and the map of X-ray sources and HII regions (from Pannutti *et al.*, 2000) shows that unique for NGC 300 X-ray source is near to the complex (at the distance of 0.8’ = $\sim$700 pc), and, moreover, is exactly on the axis of symmetry of the arc. Considering the area of the galaxy populated by HII regions is about 200 square minutes, the chance for the unique X-ray source be within the same 1 square minute area with another unique object, the AS 102 arc, is only 1/200, and this probability is getting about 1/5000 considering the accuracy of positioning of the X-ray source at the arc symmetry axis.

The size of complex implies the parental cloud was even larger, yet the size of $\sim$1 kpc is usual for the HI/H_2 superclouds within the spiral arm, where the AS 102 arc is. The size of the arc and its distance from P42 imply, that the energy of explosion was evidently much higher than that of the common Supernovae. We have to conclude that the X-ray binary P42 in NGC 300 is the first known stellar remnant of the Hypernova. Considering the suggested mass of the black hole component of the binary, this finding confirms the progenitors of Hypernovae are massive stars. Anyway, no stellar clustering is seen immediately near the P42 source.

The similar explanation may explain the cases of the star formation around dark rings in M83 and NGC 4449, though we cannot point the possible sources of the external pressure.

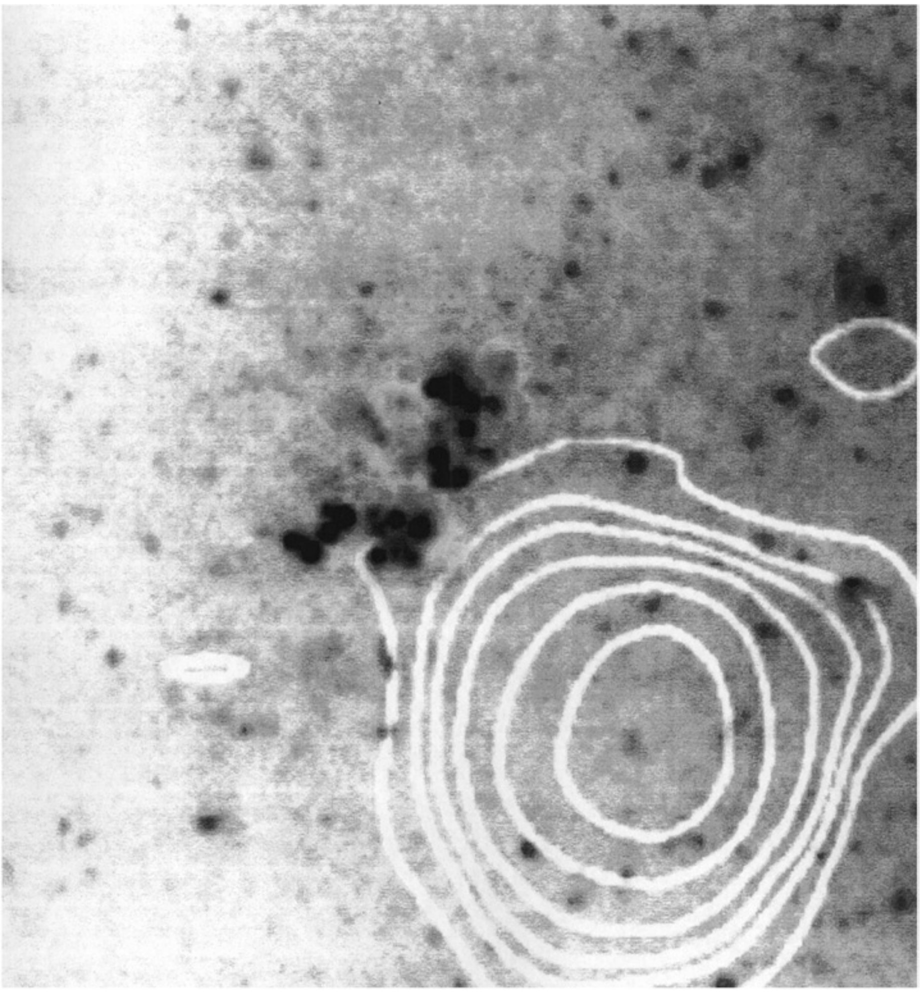

FIGURE 6 The giant stellar arc and the position of X-ray source P42 in the NGC 300 galaxy.

This is the case also for the LMC arcs; the concentration of these arcs in the same region is also difficulty for such an explanation.

Unfortunately, the existing data on HI or H_2 for NGC 300 have the resolution unsufficient to find out possible features in this region. In case of validity of the above hypothesis, between the AS 101 complex and the X-ray source P42 there should be about no HI–CO gas. Providing this is the case, there will be all bases to consider our exotic hypothesis to be true. The high resolution optical, X-ray and radio observations are clearly needed.

Acknowledgement

I am grateful to A. Chernin, M. Prokhorov and Yu. Shchekinov for the useful discussions. I am indebted also to S. Larsen for the beautiful image of NGC 300, obtained by him with the 1.5 m telescope at ESO.

This paper have widely used the NASA Astrophysics Data System. The work was supported by the grants RFBR 00-02-17804 and 00-15-96627.

References

Braun, J. M. (2001). astro-ph/0108056.
de Boer, K. S., Braun, J. M. Vallenari, A. and Mebold, U. (1998). *AAp*, **328**, 167.
Bruns, C., Kerp, J., Kalberla, P. M. W. and Mebold, U. (2000). *AAp*, **357**, 120.
Bureau, M. and Carignan, C. (2001). Preprint astro-ph/0104117.
Boss, A. P. (1995). *ApJ*, **439**, 224.
Chernin, A. D. (1999). *MNRAS*, **308**, 321.
Chernin, A. D., Efremov, Yu. N. and Voinovich, P. A. (1995). *Mon. Not. RAS*, **275**, 313.
Chernin, A. D. and Losinskaya, T. A. (2002). this volume?
Davis, D. S., Kell, W. C., Mulchaev, J. S. and Heking, P. A. (1997). *AJ*, **114**, 613.
Dibai, E. A. (1958). *Soviet Astr.*, **2**, 429.
Dopita, M. A., Matheson, D. S. and Ford, V. L. (1985). *APJ*, **297**, 599.
Domgorgen, H., Bomans, D. J. and de Boer, K. S. (1995). *AAp*, **296**, 523.
Efremov, Yu. N. (2000). *Astron. Lett.*, **26**, 558.
Efremov, Yu. N. (2001a). *Astron. Zh.*, **78**, 887; *Astron. Rep.*, **45**, 769.
Efremov, Yu. N. (2001b). In: Grebel, E. K., Geisler, D. and Minniti, D. (Eds.), Extragalactic star clusters. *IAU Symp*, 207 p. (in press).
Efremov, Yu. N. (2002). *Astron. Zh.*, **79**, 879; *Astron. Rep.*, **46**, 791.
Efremov, Yu. N. and Elmegreen, B. G. (1998). *Mon. Not. RAS*, **299**, 643.
Efremov, Yu. N., Elmegreen, B. G. and Hodge, P. W. (1998). *ApJ*, **501**, L163.
Efremov, Yu. N. and Chernin, A. D. (2002). Submitted to UFN.
Efremov, Yu. N., Pustilnik, S. A., Kniazev, A. Y., *et al.*, (2002). *Astron. Astrophys*, **389**, 855.
Ehlerova, S. and Palous, J. (2001). *Mon. Not. RAS*, **330**, 1022.
Elmegreen, B. G., Palous, J. and Ehlerova, S. (2002). astro-ph/0204143.
Fendt, Ch., Beck, R. and Neininger, N. (1998). *AAp*, **335**, 123.
Gavazzi, G., Boselli, A., Mayer, L., *et al.* (2001). *ApJ*, **563**, L23.
Gruendl, R. A., Vogel, S. N., Davis, D. S. and Mulchaev, J. S. (1993). *ApJ*, **413**, L81.
Heyles, C. (1979). *ApJ*, **229**, 533.
Hitchock, J. C. and Hodge, P. W. (1968). *ApJ*, **152**, 1067.
Hodge, P. W. (1967). *Publ. ASP*, **79**, 297.
Karachentsev, I. D., Sharina, M. E. and Hutchtmeier, W. K. (2000). *AAp*, **362**, 544.
Kim, S. C., Sung, H. and Lee, M. G. (2002). astro-ph/0203032.
Klein, R. I., Woods, T. and Mckee, C. F. (2001). *Bull. AAS*, **198**, 87.04.
Larsen, S. S., Brodie, J. P., Elmegreen, B. G., *et al.* (2001). *ApJ*, **556**, 801.
Larsen, S. S., Efremov, Yu. N., Elmegreen, B. G., *et al.* (2002). *ApJ*, **567**, 896.
Lipunov, V. M., Postnov, K. A. and Prokhorov, M. E. (1996). *AAp*, **310**, 489.
Loeb, A. and Perna, R. (1998). *ApJ*, **503**, L35.
Marel R. van den (2001). astro-ph/0105340.
MacLow, M.-M., McKee, C. F., Klein, R. I., Stone, J. M. and Norman, M. L. (1994). *ApJ*, **433**, 757.
McKee, C. F. and Cowie, L. L. (1975). *ApJ*, **195**, 715.
Odenwald, S. F. (1988). *Astroph. J.*, **325**, 320.
Oey, M. S., Groves, B., Staveley-Smith, L. and Smith, R. L. (2002). *AJ*, **123**, 255.
Palous, J., Ehlerova, S. and Elmegreen, B. G. (2002). astro-ph/0203436.
Pannuti, T., Duric, N., Lacey, C. K., *et al.* (2000). *ApJ*, **544**, 780.
Pedreros, M. H., Anguita, C. and Maza, J. (2002). *AJ*, **123**, 1971.
Pietrzynski, G., Gieren, W., Fouque, P. and Pont, F. (2001). astro-ph/0103374.
Read, A. M. and Pietsch, W. (2001). *AAp*, **373**, 473.
Rhode, K., Salzer, J. J., Westphal, D. J. and Radice, L. A. (1999). *AJ*, **118**, 323.
Ryder, S. D., Purcell, G., Davis, D. and Andersen, V. (1997). *Publ. AS Austr.*, **14**, 81.
Santillan, A., Franco, J., Martos, M. and Kim, J. (1999). *ApJ*, **515**, 657.
Sanchez-Salcedo, F. J. (2001). *ApJ*, **563**, 867.
Stewart, S. G. and Walter, F. (2000). *AJ*, **120**, 1794.
Tenorio-Tagle, G. (1980). *AAp*, **88**, 61.
Vader, P. and Chaboyer, B. (1995). *ApJ*, **445**, 691.
Wallin, J. F., Higdon, J. L. and Staveley-Smith, L. (1996). *ApJ*, **459**, 555.
Westerlund, B. E. and Mathewson, D. S. (1966). *Mon. Not.*, **131**, 371.
Woodward, P. R. (1976). *ApJ*, **207**, 484.