

Patterns of Super Star Cluster Formation in ‘Clumpy’ Starburst Galaxies

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Abstract.

We present preliminary results from a Hubble Space Telescope (HST) WFPC2 investigation of spatial and temporal distributions of star clusters in the clumpy irregular galaxy NGC 7673 and the starburst spirals NGC 3310 and Haro 1. We compare the spectral energy distributions of star clusters in the large clumps in NGC 7673 to model calculations of stellar clusters of various ages. We also propose that the presence of super star clusters in clumps seems to be a feature of intense starbursts.

1. Introduction

The optical morphologies of active star forming galaxies are often dominated by kpc-scale star-forming regions, which appear as luminous ‘clumps’ or ‘islands’. These clumps can have very high optical and UV surface brightnesses, making them visible signatures of intense star formation over cosmological distances. High angular resolution imaging with the *Hubble Space Telescope* (HST) and ground-based telescopes, reveals that clumps consist of associations of dense star clusters. These are usually superimposed on a more diffuse background, probably made up of massive stars.

The presence of numerous star clusters influences the evolution of clumps through their interactions with the surrounding ISM, that must respond to photoionization, as well as mechanical energy and momentum inputs from the evolving star clusters. These processes can trigger star formation and simultaneously remove ISM from the clump. Since star clusters can be age-dated from their spectra, their presence also offers the possibility of measuring the history of star-forming activity in starburst galaxies.

Starbursts are well-known producers of dense, massive star clusters and thus are an excellence place to study these interactions. In this paper we explore the spatial and temporal patterns of massive star cluster formation in a small sample of relatively nearby starburst galaxies.

The primary objects in this study are NGC 2415 (Haro 1), NGC 3310 and NGC 7673. The Haro 1 and NGC 7673 data are HST WFPC2 ultraviolet (UV) and optical images, while we use ground-based optical images from the WIYN 3.5-m telescope for NGC 3310. Details are presented in Gallagher et al. (2000).

Properties of Studied Starbursts			
Galaxy	Distance	Magnitude	Size
NGC 2415	D=50 Mpc	$M_B=-20.8$	A=13 kpc
NGC 3310	D=19 Mpc	$M_B=-19.9$	A=17 kpc
NGC 7673	D=46 Mpc	$M_B=-20$	A=17 kpc

Figure 1. WFPC2 image of NGC 7673 (left) showing the clumpy star formation appearance that is occurring in distinct star clusters. A WIYN image of the center of NGC 3310 (right) displays a more normal circumnuclear ring of star formation.

2. Star Clusters in Starbursts

We begin with NGC 3310, the least intense example in our sample (Figure 1). WIYN optical images reveal compact star clusters in the ring and along the arms of this galaxy, with a wider distribution of fainter cluster candidates outside of these regions. While clusters are numerous, their spatial distribution in this non-clumpy starburst resembles that of a normal spiral galaxy.

Haro 1 is an intense starburst with high optical brightness, producing a luminous galaxy with a diameter of only about 13 kpc. The spectrum shows strong Balmer absorption lines indicating that this is a relatively evolved starburst. High quality ground-based images with the WIYN Telescope suggest a transition to a clumpy structure. Our WFPC2 image in the emission line-free F547M filter displays a moderate degree of clustering of dense, luminous star clusters, and high surface brightness regions usually containing more than one compact star cluster.

NGC 7673 is a star bursting clumpy irregular galaxy. Colors and magnitudes derived for star cluster candidates in the F255W, F555W, and F814W WFPC2 bands indicate that young clusters are mixed through the optically prominent clumps; their colors appear to be driven at least as much by locally variable extinction as by ages. A low level of organization may be present, with clusters near the galaxy’s center possibly being made in a linear structure by

Figure 2. Spectral Energy distributions for super star clusters within two clumps in NGC 7673.

Figure 3. Model calculation for an aging cluster from 4 Myr to 100 Myr (right y-axis) vs. wavelength. Fluxes from Starburst99, and magnitudes from models by A. Watson.

bar-induced gas flows. Some clumps are roughly circular, and so propagating star formation could be present. Figure 2 shows the spectral energy distribution (SED) of two clumps in NGC 7673, while Figure 3 shows model calculation SEDs for star clusters at various ages. Probably more than one mechanism structures the distribution of star clusters within clumps, but in most cases populations of star clusters are formed over relatively short time scales of < 100 Myr.

3. Discussion

Clumps seem to be features of active star bursts with high intensities. This fits with theoretical models (Elmegreen & Efremov 1997; Noguchi 1999) where stellar clumps form in gas-rich galactic disks with higher than average internal velocity dispersions, leading to large Jeans masses and lengths. Such conditions could be natural consequences of collisional perturbations of gassy disk galaxies. They would be more common in less evolved galaxies with higher gas contents and lower degrees of organization, providing a possible explanation for the clumpy appearances of high redshift galaxies (Noguchi 1997). Although super star clusters can form in a range of conditions, clumps may be particularly important in unevolved galaxies; observations of nearby clumps then may provide insight into the formation of globular clusters.

Once star formation begins in a clump, the subsequent evolution must be complex. Energy and momentum inputs from massive stars and star clusters produce obvious observational signatures in emission line profiles (Homeier & Gallagher 1999) will disturb the ISM, and likely lead to compressed regions which are excellent sites for further cluster formation (eg., Scalo & Chappell 1999). The close spacing between clusters and high densities of gas clouds may also lead to cluster-cluster mergers or cluster rejuvenations due to gas cloud captures. These possibilities reinforce the capabilities for massive star forming clumps to be prime producers of massive super star clusters. Once made these clusters will be the most likely to survive and observed at later times.

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