Star-formation Modes in Dwarf Irregular Galaxies

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Abstract

Various processes, that act as a consequence of newly formed stars and reduce the star-formation (SF) capacity of molecular clouds themselves, lead to SF self-regulation, like e.g. stellar heating (Franco & Cox 1983; Köppen, Theis, & Hensler 1995), supernova type II explosions (Burkert & Hensler 1989), as well as gas-phase transitions through interfaces between the embedded cool clouds and their surrounding hot supernova gas (Köppen, Theis, & Hensler 1998). On the other hand, the formation of dwarf elliptical and dwarf spheroidal galaxies with their old to intermediate-age stellar populations, in some objects clearly separated by epochs of SF quiescence, as well as the present occurrence of starbursts (SBs) in several dwarf irregular galaxies (dIrrs) require the stimulation of SF by some action that overcomes self-regulation because it works on a shorter timescale. Since low-mass galaxies are very sensitively influenced by energetical events, present-day dIrrs show a large variety of SF rates from very low to extraordinarily high values in SB galaxies. Their brightnesses range from low and diffuse over irregular and patchy to very high, blue and compact. Hunter et al. (1998) therefore stated that "dIrrs are a unique test .... for the physical laws regulating star formation".

Models with external perturbations (see e.g. Scalo & Struck-Marcell 1986) have already demonstrated that cyclic SF enhancements can occur in low-mass galaxies. With the discovery of intergalactic H I clouds in the present universe (Blitz et al. 1999; Braun & Butler 2000; Kilborn et al. 2000), and because observations become more and more sensitive, it is not surprising that also growing evidence exists from observations that SBs in dIrrs are often connected with large H I envelopes around the luminous galactic body with slightly decoupled dynamics, like e.g. in NGC 4449 (Hunter et al. 1998) and in I Zw 18 (van Zee et al. 1998). Or SBs are obviously triggered by collisions of dIrrs with large intergalactic H I clouds as it happens e.g. in He 2-10 (Kobulnicki et al. 1995) and in II Zw 40 (van Zee et al. 1998). Even smoothly infalling gas can fuel a new episode of SF in dwarf ellipticals (NGC 205: Welch et al. 1998) and by this leads – in analogy to human superstition – to their "reincarnation".

Therefore we have addressed the question under which circumstances the different observed modes of SF occur: SBs, self-regulated SF and suppressed SF (like in low-surface brightness galaxies). For this we refer to chemo-dynamical models of dIrrs that trace their evolution while implying gas infall from a surrounding gas reservoir. Only models that take the multiple phases of the interstellar medium into account and their mutual energetical, materialistic and dynamical interaction processes (and only those should be denoted as chemo-dynamical because also the enhancement and mixture of particular elements depend on these processes) can properly allow for SF self-regulation by the various mentioned feedback mechanisms. These simulations of dIrrs reproduce self-consistently different modes of SF, from SBs to SF quiescence, that can be attributed to specific evolutionary epochs, and can provide a first insight into the energetical balance and the dynamical influence of the SF in dIrrs.

"Dwarf Galaxies and their Environment"; Bad Honnef, Germany, 23-27 January 2001; Eds. K.S. de Boer, R.-J.Dettmar, U. Klein; Shaker Verlag

We can show (Hensler & Rieschick 2001a,b) e.g. that gaseous disks at low density accumulate smoothly infalling gas but remain at low SF rates because the infall excites turbulence whose energy cannot be dissipated and radiated off rapidly enough. The SF rate increases indeed moderately as a result of the growth of gas mass, while the energy release according to the SF rate rises more rapidly until it balances the gas infall. This happens in the sense that material is expelled again from the disk with a net rate, i.e. the amount of infalling gas reduced by the SF rate minus the almost 12% (for a Salpeter IMF between 0.1and 100 $M_{\odot}$) of massive-star ejecta (for 10 to 100 $M_{\odot}$ stars), so that the disk's gas mass does not grow anymore. Only if the infall is vehemently enough, preferably with increasing mass flux and for a long duration, gas compression overcomes the gas heating so that the SF cannot balance the infall and is triggered and enhanced. Under particular circumstances then the SF can explode as a SB.

These models are already presented in part by Hensler & Rieschick (2001a) and will be fully demonstrated in a further comprehensive paper (Hensler & Rieschick 2001b).

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