Decay of OB associations and evolution of dwarf galaxies

Evgeny Kurbatov

Institute of astronomy, Russian Acad. Sci.

Nearby Dwarf Galaxies
SAO 2009

The exchange of the matter between galaxy and IGM (ICM) can affect the chemical composition of IGM, the chemical composition of galactic gas and stars, and even the morphology of galaxy.

Possible mechanisms of exchange are:

- galactic wind driven by multiple explosions of SNae
- ram pressure of intergalactic gas
- tidal action from nearby galaxies
- evaporation of gas by hot IGM
- blow out of dust by star radiation pressure
- accretion from IGM
- escape of stars with velocities large enough achieved in:
  - scatter of stars on the stars
  - decay of closed binaries
  - **decay of OB associations**

Some mechanisms of gas exchange

Galactic wind

The efficiency of wind strongly depends on gas distribution, i.e. whether the gas stratified or not (Cooper et al. 2008ApJ...674..157C), and on the details of the distribution for continuous one (Mac Low et al. 1989ApJ...337..141M).
De Young & Gallagher 1990ApJ...356L..15D showed that the galaxies with mass $1.4 \times 10^9~M_\odot$ eject gas of mass fraction 0.6 but observations can't find yet the gas ejection from galaxies with masses $\sim 10^9~M_\odot$ (van Eymeren et al. 2009A&A...493..511V).
So the question on quantitative reliability of the theoretical models of galactic wind is still open.

Some mechanisms of gas exchange

Tidal action

Every galaxy in cluster undergo a collision at least once in a lifetime (Tutukov `2006ARep...50..439T`). Two galaxies can merge, lose one or both of their gaseous components, or totally disintegrate as a result of a collision; ultimately, a new galaxy may form from the gas lost by the colliding galaxies.

Ram pressure, evaporation, and dust ejection

Thought to be less effective than noted above

Star ejection by decaying OB association

The common opinion is that majority of stars form in stellar associations (but see Elmegreen & Efremov `1996ApJ...466..802E`). OB associations has short life time till their decay, about few million years. In decay time stars gain the velocities with mean values from 2 to 8 km/s (Brown et al. `1997MNRAS.285..479B`).

The value of virial velocities in dwarf galaxies may be as low as few km/s (Karachentsev et al. `2004AJ....127.2031K`) and the escape velocity may not exceed $10\ldots20$ km/s (Bovill & Ricotti `2009ApJ...693.1859B`, Dijkstra et al. `2004ApJ...601..666D`). If the galaxy has disk morphology the ordered motion of matter can help to stars to escape.

The aim of this work is to estimate this effect and clear its observational consequences.

The mechanism of star ejection

The condition for star to escape:

$$\frac{(\mathbf{v}+\mathbf{u})^2}{2} \geqslant -\Phi \tag{1}$$

The probability of escape:

$$\chi(\mathbf{v}, -\Phi) = \int\limits_{\frac{(\mathbf{v}+\mathbf{u})^2}{2} \geqslant -\Phi} \frac{d^3u}{(2\pi\sigma_{\rm OB}^2)^{3/2}} \exp\left[-\frac{u^2}{2\sigma_{\rm OB}^2}\right] \tag{2}$$

I.e.

$$\chi = \chi(\eta, \psi) \tag{3}$$

where

$$\eta = \frac{v}{\sigma_{\rm OB}} = \sqrt{\frac{r}{\sigma_{\rm OB}^2}\frac{\partial\Phi}{\partial r}} \qquad \psi = -\frac{2\Phi}{\sigma_{\rm OB}^2} \tag{4}$$

The mechanism of star ejection

$$\overline{\chi} = \frac{\int_V dV\, \Psi_V\, \chi}{\int_V dV\, \Psi_V} \tag{5}$$

Plummer sphere

$$\psi = \frac{2\beta^2}{(1 + r^2/a^2)^{1/2}} \qquad \beta = \sqrt{\frac{GM}{\sigma_{\mathrm{OB}}^2 a}} \tag{6}$$

SFR law of Firmani & Tutukov `1992A&A...264...37F`:

$$\Psi_V \propto \rho^2 \tag{7}$$

The mechanism of star ejection

$$\overline{\chi} = \frac{\int_S dS\, \Psi_S\, \chi}{\int_S dS\, \Psi_S} \tag{8}$$

Exponential disk

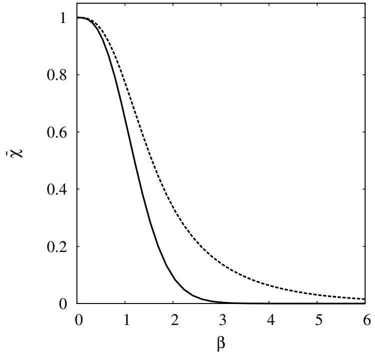
$$\eta = \beta \sqrt{\frac{1-(1+r/a)\, e^{-r/a}}{r/a}} \qquad \psi = 2\beta^2\, \frac{1-e^{-r/a}}{r/a} \tag{9}$$

SFR law of Kennicutt `1998ApJ...498..541K`:

$$\Psi_S \propto \Sigma^{3/2} \tag{10}$$

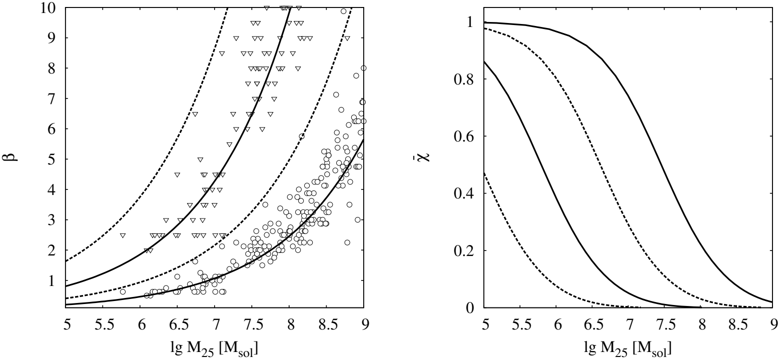
The mechanism of star ejection

The mean probability of ejection for plummer sphere (solid line) and exponential disk (dashed line) as a function of dimensionless virial velocity.



The mechanism of star ejection

Dimensionless virial velocity of galaxies for limiting values of σ_{OB}: 2 km/s (triangles) and 8 km/s (circles).



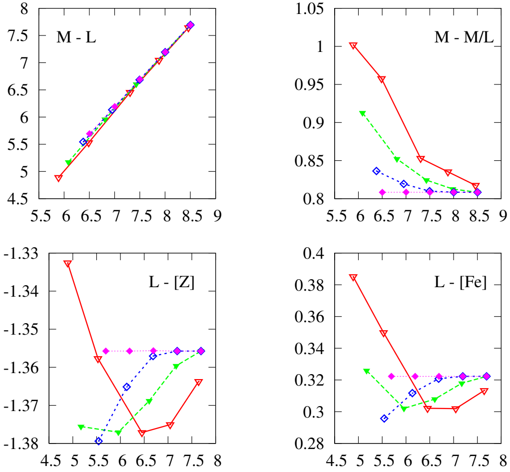
The model series

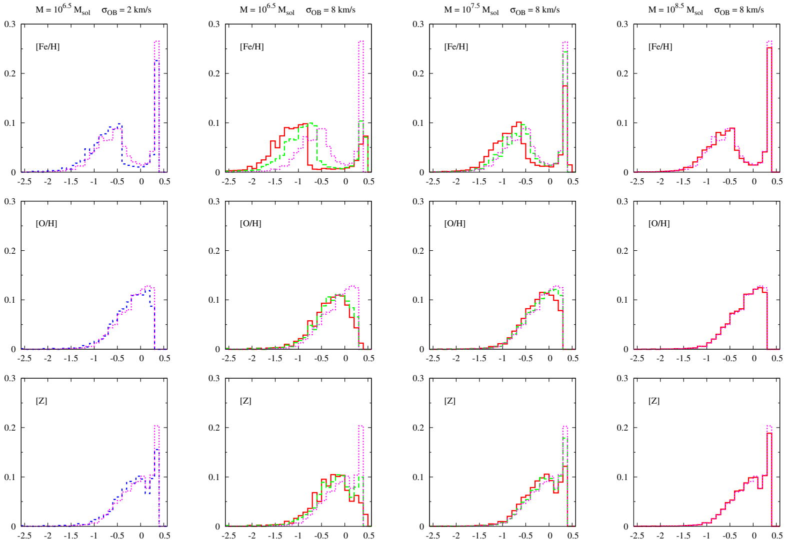
The one-zone model of galaxy evolution of Tutukov & Firmani 1992A&A...264...37F (see also Shustov et al. 1997A&A...317..397S and Wiebe et al. 1998AZh...75.....3W) was the basis of the series of modelling of galaxies with barionic masses from $10^{6.5}\ M_\odot$ to $10^{8.5}\ M_\odot$:

- series of closed models with the same M/L and $[\mathrm{Z}]$
- models with ejection of stars for $\sigma_{\mathrm{OB}} = 2$ km/s
- $\ldots\sigma_{\mathrm{OB}} = 8$ km/s
- $\ldots\sigma_{\mathrm{OB}} = 8$ km/s + Dark halo

		$\sigma_{\mathrm{OB}} = 2$ km/s		$\sigma_{\mathrm{OB}} = 8$ km/s		$\sigma_{\mathrm{OB}} = 8$ km/s +Dark halo	
$\lg M/M_\odot$	R, pc	β	$\overline{\chi}$	β	$\overline{\chi}$	β	$\overline{\chi}$
6.5	79.5	2.73	0.21	0.70	0.92	1.38	0.6
7	141.4	4.14	0.09	1.07	0.743	2.08	0.32
7.5	251.5	6.26	0.012	1.62	0.481	3.16	0.13
8	447	9.48	0	2.45	0.21	4.78	0.035
8.5	795	14.25	0	3.72	0.075	7.23	0

- magenta (filled diamonds) — closed models
- blue (open diamonds) — $\sigma_{OB} = 2$ km/s
- green (filled triangles) — $\sigma_{OB} = 8$ km/s + Dark halo
- red (open triangles) — $\sigma_{OB} = 8$ km/s





M = $10^{6.5}$ M_{sol} σ_{OB} = 2 km/s
M = $10^{6.5}$ M_{sol} σ_{OB} = 8 km/s
M = $10^{7.5}$ M_{sol} σ_{OB} = 8 km/s
M = $10^{8.5}$ M_{sol} σ_{OB} = 8 km/s
[Fe/H]
[O/H]
[Z]
0.3
0.2
0.1
0
-2.5
-2
-1.5
-1
-0.5
0
0.5

Conclusions

- Stars with life time greater than 10^7 yrs can leave the galaxies of lowest mass contributing to IGM abundance as SNIa and SNII (less significant)
- The "mass–luminosity" rate increases just slightly
- Metallicity can vary about 0.05 dex
- Iron abundance can vary about 0.1 dex
- Disk galaxies of the lowest mass can effectively turn to spheroidal type
- The galaxies of lowest mass can eject nearly all of stars becoming too faint to observe