J. Astrophys. Astr. (1997) **18**, 321–322

Epoch of Galaxy Formation

Arati Chokshi, *Indian Institute of Astrophysics, Bangalore, India*

Abstract. A preferred epoch for forming galaxies argues strongly in favour of a standard Big Bang cosmology with a single epoch of creation. In this paper I present a model in which there is a causal connection between AGN activity and galaxy formation with its epoch closely linked to the observed epoch of peak AGN activity.

Key words. Galaxies—AGNs—black holes.

1. Introduction

There are two distinct phases related to the formation epoch of galaxies. In an expanding universe, a galaxy's birth would mark the time when a system turned around under its own self gravity and acquired a separate dynamical status. A second stage more amenable to searches for young galaxies marks the epoch when such a system undergoes its first primary episode of star formation. On the basis of cooling arguments and dynamical timescales, it is usual to assume that the former phase precedes the latter i.e. majority of stars form within a self-gravitating gaseous 'protogalaxy'. In this paper I illustrate how the pre-existence of a central black hole and its activity influences the protogalactic environment to initiate large scale star formation.

2. The cocoon model

Models for radio jet induced star formation were proposed (Begelman & Cioffi 1989; Daly 1990; de Young 1989) to explain the alignment of the optical and radio axes in the high redshift radio galaxies (HZRGs). While other mechanisms are also proposed for the origin of this 'alignment effect' star formation in overpressured environments of radio sources is inevitable at some level based on the availability of sufficient gaseous material and Jeans mass arguments in their simplest form.

I use Begelman & Cioffi's (1989, BC89) analytical model for the evolution of the radio cocoons expanding into the protogalactic environment. For any source age, the length of the cocoon is governed by the balance of the thrust of the jet against the ram pressure of the ambient medium. The sideways expansion of the cocoon is driven by the static pressure that builds up within the cocoon over the lifetime of the source. For the higher ambient densities under consideration in the protogalactic environment, the radio cocoons envelop, and via overpressuring trigger stars in the two phase medium over size scales relevant to elliptical galaxies for the most powerful radio jets ($L_j$et $= 10^{47}$ erg/s) while the lower powered jets (10^{43} ergs/s) induce stars over 1–3 kpc scales corresponding to typical bulge sizes in galaxy disks.

3. A few implications

1. If radio brightness is a phase in the total activity cycle of AGNs, as might be expected from lifetime considerations and from unification models (Rawlings 1994) then one expects the entire AGN population to have participated in the radio cocoon phase. Under this assumption, one finds that the typical number densities of qsos in the local universe times their observed increase in the number density at the peak activity is consistent with the number densities of normal galaxies seen today. In other words, there were enough qsos at peak activity to have produced most galaxies seen today.
2. Galaxy morphologies find a natural explanation within this framework, with smaller central blackholes making milder jets, which build smaller cocoons which go on to become central bulges. The remaining gas dissipatively settles with time to make disks of these systems. On the other hand, more massive blackholes are capable of converting the entire protogalactic baryons into stars and become giant ellipticals. Such a scenario explains the strong correlation between the central blackhole mass and the bulge luminosity found by Kormendy (1996) from studies of central dynamics in nearby galaxies.
3. Ostriker & Rees (1977) showed that there is a maximum galaxy mass ($\sim 10^{12} M_{\odot}$) derived from a comparison of the cooling versus free fall time in protogalaxy, with typical scales of ≤ 75 Kpc. Since the most powerul AGNs are able to convert the entire baryonic mass of this system into stars, they automatically yield a standard candle required to explain the tight K-Hubble sequence between the first rank cluster ellipticals at low z and the highest redshift powerful radio galaxies.
4. Since the AGN and star formation activity go hand-in-hand within this framework, one expects that signatures of both should be detected from high redshift galaxy population, as is indeed the case in the case of the powerful IRAS10214, (Kroker *et al.* 1996) the high redshift radio galaxy 4c41.7 (Miley *et al.* 1992) and the starforming complexes discovered in radio galaxy fields by Pascerelle *et al.* (1996) activity.

References

Begelman, M. C., Cioffi, D. F. 1989, *Astrophys. J.*, **345**, 21.
Daly, R. 1990, *Astrophys. J.*, **355**, 416.
de Young, D. 1989, Astrophys. J., **342**, L59.
Kroker, H., Genzel, R., Krabbe, A., Tacconi-Garman, L. E., Tecza, M., Thatte, N., Beckwith, S. V. W. 1996, *Astrophys. J.*, **463**, L55.
Pascarelle, S. M. *et al.* 1996, *Astrophys. J.*, **456**, L96.
Rees, M. J., Ostriker, J. 1977, *Mon. Not. R. Astr. Soc.*, **179**, 541.