Are CSO host-galaxies undergoing merging?

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The galaxy-type CSO (Compact Symmetric Objects) rate from the intermediate large sample PR+CJ1 is found to be consistent with the Sb-Sb merger rate of 4.6% at redshift $z < 1$. The CSO detection rate seems to decrease when the sample size is increasing, and can not reach the high merger rate at $z > 1$. However, to date there is no highly sensitive VLBI sample available for $z > 1$.

1. Introduction

The complete PR+CJ1 sample consists of 200 radio sources with flux > 0.7Jy at 5 GHz and declination > 35 degrees. 8/65 sources in the PR and 15/200 sources in the PR+CJ1 samples are identified as CSOs (Polatidis et al. 1999), so the CSO rate is 12% in the PR sample (flux > 1.3Jy at 5 GHz) and 7.5% in the PR+CJ1 sample. The CSO rate from the PR+CJ sample (including the flat-spectrum samples CJ2 and CJF, with flux > 0.35 Jy at 5 GHz) is 4.4% (18/411; Peck & Taylor 2000). The COINS sample (CSOs observed in the northern sky, based on VLBI continuum surveys of nearly 2000 compact radio sources, i.e. PR+CJ+VCS, VCS:VLBA Calibrator surveys, with flux > 100 mJy at 5 GHz, see Peck & Taylor 2000) gives a CSO rate of 2.1% (39/1900). From the JVAS and CLASS flat-spectrum sample (with flux > 100 mJy at 8.4 GHz) the CSO rate is 0.8% (14/1665; Augusto et al. 1999). The CSO detection rate appears to decrease when the sample size is increasing. However, both the uv-coverage and the sensitivity of the VCS are considerably worse than in the PR and CJ surveys, it is therefore possible that some CSOs have been missed in the VCS (Peck & Taylor 2000). The flat-spectrum samples could also miss some CSOs, since most of CSOs from PR+CJ1 sample show steep spectra (they are usually GPS sources).

2. Merger rate, CSO rate and discussion

Gravitional interaction and mergers affect the morphologies and dynamics of galaxies, from our Local Group out to the limits of the observable universe. Observations of interacting galaxies at low redshifts ($z < 0.2$) yield detailed information about many of the processes at work, these processes indicate that mergers play a major role in the delayed formation of elliptical and early-type disk galaxies both in the field and in clusters (Schweizer 1999). Merger ages from 65 E and S0 galaxies, based on UBV colors and a simple two-burst model of star formation, are spread over most of the age of the universe (Schweizer 1999). We measure the Sb-Sb merging (to E+S0, efficiency=0.10) rate from Schweizer & Seitzer (1992, hereafter SS) assuming that the epochs of 3, 6, 9, 12 and 15 Gyr ago correspond to the redshifts $z = 1, 2, 3, 4$ and 5. The result (i.e. the cumulative rate per z/3 range) is 3.1, 0, 1.5, 4.6, 12.3, 9.2, 15.4, 26.2, 16.9, 7.7, 1.5, 1.5, 0 % for redshifts from 0 to 4.33, as shown in Fig. 1. Using a Gaussian fitting formula: $y = 1.93 + 20.63exp(-2.16(z-2.45)^2)$, the fit is not good for the data in the range $z = 0-2$; we can see that the data slope is less steep than that for $z > 2.4$. We then fit the data between $z = 0-2$ with a power law $(1+z)^{2.28}$. The evolution of the merger (or pair) rate at $z < 2$ has been studied by several authors (see Gottlöber et al. and references therein), and follows a power law $(1+z)^{3\pm1}$. In

Name	z	ID	GPS	m_r	Comments for the optical hosts
0108+388 PR	0.669	G	Yes	21.8	very red color r-i=1.2 galaxy with an asymmetric morphology, the nucleus is more prominent in i band, suggesting a nuclear obscuration -[1]
0404+768 PR	0.5985	G	Y	20.7	has weak diffuse structure, possible companion, and very red color r-i=1.7 -[1]
0646+600 CJ1	0.455	Q	Y-[2]	19.9-[3]	a number of faint galaxies surrounded and a possible companion -[3]
0710+439 PR	0.518	G	Y	20.2	very irregular morphology with very red (r-i=1.9) color, there is evidence of strong interaction and presence of large amount of obscuring matter; many other resolved objects are present around the parent object suggesting it is the dominant galaxy in a cluster -[1]
1031+567 PR	0.45	G	Y	20.2	elliptical-like galaxy showing a possible asymmetric morphology, weak resolved objects are also present in the field suggest it is the domination in a cluster -[1]
1225+368 CJ1	1.974	Q	Y-[2]	21.6-[2]	
1242+410 CJ1	0.813	Q		19.6-[4]	very red compact object -[5]
1311+678 CJ1		EF			steep spectrum with $\alpha_{(11-6)cm}$=-0.73 -[6]
1358+624 PR	0.431	G	Y	19.8	a boxing morphology showing the obscuration by dust, more visible in r band and a resolved object is visible at 5" north, with r-i=0.3 -[1]
1437+624 CJ1	1.090	Q		19.0-[7]	
1843+356 CJ1	0.763	G	Y-[1]	21.7	faint galaxy -[1]
1943+546 CJ1	0.263	G		17.6-[8]	apparently in a faint cluster, faint objects surrounded -[8] and with $\alpha_{(11-6)cm}$=-0.55 -[6]
2021+614 PR	0.2266	G	Y-[9]	17.3	a low level extended halo around and the presence of at least two candidate companions within 12" of the galaxy -[2]
2342+821 PR	0.735	Q	Y-[1]	20.1-[1]	weak secondary emission with r-i=0.8 -[1]
2352+495 PR	0.2383	G	Y-[9]	18.5	an elliptical galaxy is located in a distant cluster, nearby faint objects are candidate companions -[2]

Notes: Source parameters if not referenced are from Polatidis et al. 1999 and Snellen et al. 1996 (for m_r). References: [1] Stanghellini et al. 1993, 1998. [2] O'Dea et al. 1990. [3] Stickel & Kühr 1993a. [4] Carballo et al. 1999. [5] Vigotti et al. 1989. [6] Stickel & Kühr 1994. [7] Aldcroft et al. 1994. [8] Stickel & Kühr 1993b. [9] Snellen et al. 1996

order to compare to the CSO rate (the CSO rate is indeed the cumulative rate in the corresponding z range, as shown in Fig. 1), we compute the cumulative merger rate in the ranges $z = 0-1, z = 1-2, z = 2-3, z = 3-4$, and draw this as the dashed line in Fig. 1. We find that the galaxy CSO rate of 4.5% in the PR+CJ1 sample is close to the cumulative Sb-Sb merger rate of 4.6% for $z < 1$. The CSO rate of 7.5% in the PR+CJ1 sample (line 2 in Fig. 1) for the redshift range $z = 0-2$, is probably not true for $z = 1-2$ since only 2 CSOs (quasars with $z = 1.09$ and 1.974) are detected between $z = 1-2$. The CSO rate of 12% in the PR sample is much higher than the cumulative merger rate for $z < 1$, this could be due to that the PR sample is still not a deep enough sample at $z < 1$. It suggests that in the intermediate deep sample PR+CJ1 (flux > 0.7 Jy), the cumulative galaxy CSO rate is consistent with the cumulative Sb-Sb merger rate for $z < 1$. This should be further investigated in a more deep and complete sample. On the other hand, we collect the properties of the CSO hosts from the literature (shown in the table above) and the CSO hosts seem to have the symptoms of merging or merging environment. However, this can not confirm that they actually are undergoing merging.

In the PR sample, 30/65 sources are identified as quasars, 29/65 as galaxies and 6/65 as BL Lac sources. The sources in the PR+CJ1 sample are not completely identified. From a large optical galaxy sample, 41% of the ellipticals, 65% of the galaxies and 75% of the peculiars are detected in the NVSS with fluxes > 2.5 mJy (Cotton & Condon 1998). The ellipticals and peculiars mainly display AGN activity, while the spiral galaxies detected in the NVSS usually are starbursts. At flux densities greater than 10 mJy, more than 95% of the optical identifications of radio sources are red ellipticals, Seyferts and quasars, but this fraction drops to 30% at 5 mJy; the majority of the sources with 200 μJy< S_{20cm}< 5 mJy have optically blue, disk-galaxy counterparts (Richards 1998). So for a CSO rate detection, VLBI samples can go as deep as > 10 mJy without considering the starburst galaxies.

It is proposed that all elliptical galaxies originates from spiral-spiral galaxy mergers (Schweizer 1997). We searched in the NVSS for 32 ellipticals of the SS sample, 15/32 (47%) of these ellipticals show radio fluxes > 2.5 mJy. The fact that more than 50% of the ellipticals have not been detected in the radio regime, indicates that the radio phase of mergers (which eventually will form ellipticals) is very short compared to the lifetime of the ellipticals. For example, the radio lobes of Cygnus A is 0.01 Gyr (Kaiser 2000), while the ages of young ellipticals in the SS sample are greater than 0.9 Gyr. Indeed, 2 merger remnants (0.3-0.6 Gyr) in the SS sample are point-like radio sources in the NVSS. The CSO lifetime is less than 10^{3-4}years (Owsianik et al. 1999 and references therein; Xiang et al. 2000). CSOs may be triggered by the merging of spiral nuclei. Since strongly merging pairs we known have not shown jet-like radio emission, their nuclei might not yet have merged. So the CSOs could occur at a late merging stage (say at the elliptical-forming stage; in that time the nuclei of spirals is merging and the arms of spirals have already merged).

Quasar-type CSOs in the PR+CJ1 sample show a large deviation from galaxy-type CSOs in the Hubble diagram (Fig. 2). Radio selected QSOs are usually hosted by giant elliptical galaxies (Benn et al. 1998), so they may be the mergers from giant spirals. We think that their unusual luminosities and relatively few data points in Fig. 2 result in a flatter slope than what is obtained for the galaxy CSOs. The scattering of the QSOs in Fig. 2 suggests that the QSOs are not good standard candles, they may be more bright with increasing redshift.

It is expected that radio AGNs will live a longer period in the MSO phase. Because the MSOs are defined to have a broad range of linear scales (1-15 kpc), we should detect more MSOs in a complete sample, e.g. in the PR+CJ1. However, the MSO detection rate is 2% in the PR sample (one quasar) and 5% in the PR+CJ1 sample (Polatidis et al. 1999). One reason may be that the symmetric two-side jets are very disturbed by the remnant of the spiral arms - we assumed that the merging of spiral arms is finished when a CSO is triggered. At this point, most of the CSS and some of the GPS sources might actually be MSOs.

Liu Xiang wish to acknowledge P.N. Wilkinson for illuminating discussions, and to thank Zhang Haiyan for help with the figures.

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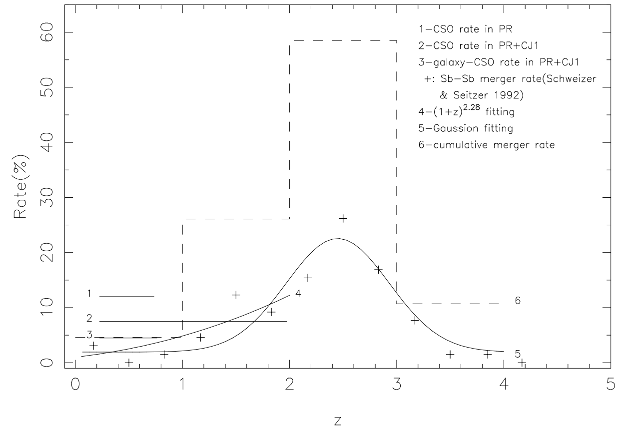

FIGURE 1. The cumulative CSO rate and the Sb-Sb spiral merging (into E or S0) rate

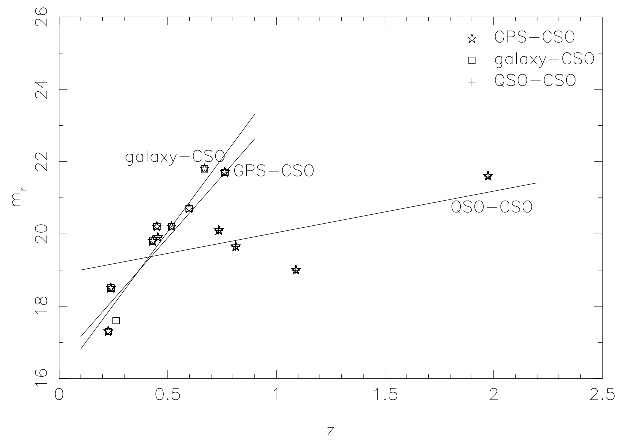

FIGURE 2. Hubble diagram for CSOs in PR+CJ1 sample

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