# INTERACTING GALAXIES(Proceedings of Japan-France Seminar on Chemical Evolution of Galaxies with Active Star Formation)

*Proceedings of Japan-France Seminar on Chemical Evolution of Galaxies*

# INTERACTING GALAXIES

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Three topics on interacting galaxies are presented. The first is on ring galaxies and bead instability, the second on Seyfert 1 nucelus of a new ring galaxy in Sextans, and the third on dual emission line clouds in the interacting pair Arp 90.
Keywords: Ring galaxies, Seyfert Nuclei, Infrared Sources

## §1. Ring Galaxies in the Hercules Supercluster of Galaxies

Four ring galaxies and two candidates have been discovered in the Hercules supercluster of galaxies by applying the photographic contrast enhancement technique to deep IIIa-J or IIIa-F Schmidt plates. They appear to belong either to cluster halos or to a field population. IC 1194 has been found to have the largest linear diameter ($\sim$ 133 kpc: on the scale of H = 55 km $s^{-1}$ $Mpc^{-1}$) and the brightest magnitude ($M_V$ = -22.2) so far found. It shows no patchy structure on its ring, and hence no prominent HII regions. This is probably an SO-ring galaxy, i.e., a ring galaxy whose progenitor might have been a gas-free SO galaxy. Dressler # 36 of Abell 2151 cluster has six bright knots which are surrounded by a faint diffuse ring. This is quite reminiscent of the structure of a self-gravitating ring undergoing "bead instability". As this instability could be suppressed by the presence of a massive halo, it will be interesting to make further observations to study its kinematical and spectroscopic properties.

The full paper has been appeared in A. J., 92, 700, 1986.

## §2. A Seyfert 1 Nucleus of a New Ring Galaxy in Sextans

A new ring galaxy has been found in Sextans. Its nucleus shows broad Balmer lines with width at least 7000 km $s^{-1}$ (FWZI) and narrow forbidden lines, which are characteristic of a Seyfert 1 nucleus. The ring galaxy was identified as an optical counterpart of the IRAS source 09595 - 0755, and found to be one of the most luminous infrared sources among ring galaxies. It is suggested that such galaxy collisions as result in ring galaxy formation

may activate nuclei into Seyfert activity.

We would like to examine nuclear activity of ring galaxies of RN type. These galaxies have prominent nuclear regions interior to their rings, and so their progenitors are believed mostly to be galaxies earlier than Sb type. If so, their nuclei are expected to be gas free, in general. Indeed, no emission lines are detected in the nuclei of the Cartwheel galaxy (Fosbury and Hawarden 1977), the Vela galaxy (Taylor and Atherton 1984), IC 1194 (Wakamatsu et al 1986), NGC 414 (van den Bergh and Schommer 1981; Wakamatsu and Nishida, in preparation), and a pair of ring galaxies II Hz 4 (Lynds and Toomre 1976). Weak emission lines are observed in AM 064 - 741 (Few, Madore, and Arp 1982), Arp 10 (Dahari 1985), and VV 256 (Dahari 1985). However, there are several ring galaxies with active nuclei. The present ring galaxy in Sextans and NGC 985 are classified as Seyfert 1 galaxies, Arp 118 = NGC 1144 has been suggested as a Seyfert 2 galaxy (Huchra, Wyatt, and Davis 1982; Dahari 1985), and Arp 143 = NGC 2245 is found to have a HII region type nucleus (Keel et al. 1985). Several other ring galaxies are known as RN type (e.g., the ring galaxies in Canes Venatici Brosch 1982 and in Bootis Hartl et al. 1979 ), but no spectroscopic observation has been made of them. Arp 107A, a Seyfert 2 galaxy (Keel et al. 1985), appears a RN type ring galaxy on Arp's (1966) Atlas, but has not yet been confirmed due to luck of recession velocity of its probable intruder.

Among the above thirteen or fourteen (if Arp 107A is included) well-studied ring galaxies, the fraction 2/13 (2/14) of Seyfert 1 or the fraction 3/13 (4/14) of all types of Seyferts are high, when compared with the respective values 2/162 or 16/162 among interacting spiral galaxies (Table 10 of Dahari 1985). The fraction 3/13 (4/14) is about 2.5 times higher than that among field Sa galaxies, but comparable to that among interacting Sa galaxies (Figure 13 of Keel et al. 1985). (Out of nine interacting Sa Seyferts listed in Table VII of Keel et al. 1985 , six are type 2 or 1.9, and three are type 1.5.) Our present statistics on ring galaxies support the presumption that galaxy-galaxy collisions may activate galactic nuclei by fueling gas into their nuclear region (Byrd, Saarinen, and Valtonen 1986).

Are there any particular morphological difference between ring galaxies with or without active nuclei? Colliding intruders are found always within distances several times of the ring diameters for both groups of ring galaxies. Since the separation between ring galaxy and its colliding intruder represents the time elapsed after galaxy collision, it is difficult to interpret ring galaxies without active nuclei as galaxies whose active nuclei have been burning out by aging. All four ring galaxies with active nuclei have rings with plenty of HII regions, whereas ring galaxies showing no nuclear emission lines have rings either with plenty of HII regions (Cartwheel galaxy, Vela

galaxy, and the southern component of II Hz 4), or with no HII regions (IC 1194, NGC 414, and the northern component of II Hz 4). We found no clear morphological difference between these two groups of ring galaxies. Collisions leading to ring galaxy formation could not always activate their nuclei. However, ring galaxies with Seyfert 1 nuclei may provide an unique opportunity to clarify mechanisms for nuclear activity or for fueling gas into nuclei, because their collision processes are elucidated by theoretical models (Lynds and Toomre 1976; Theys and Spiegel 1976; Chatterjee 1984).

The full paper will be appeared in March or April issue of Ap. J. Letters.

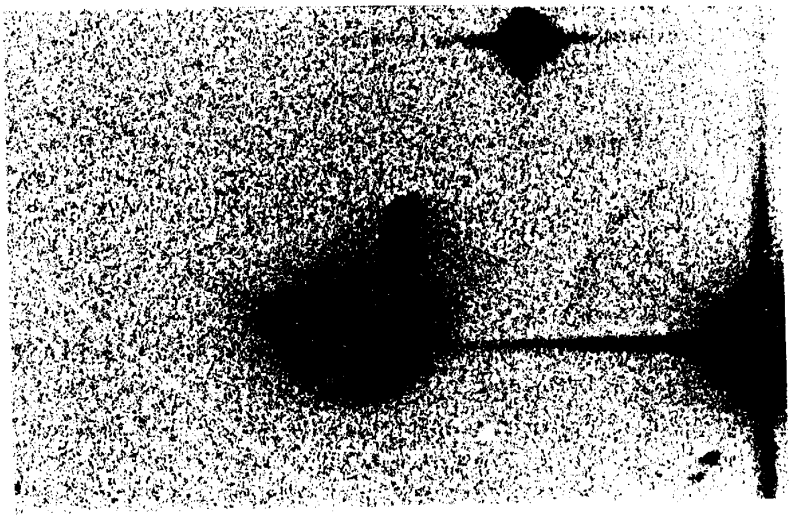

Fig. 1 - A ring galaxy in Sextans. (a) Ten or more knots delineate a ring, and off-center in the ring there is a bright Seyfert 1 nucleus. A physical companion located 17" NW of the nucleus is connected to the NW edge of the ring by a fairly bright bridge. The bright star in the west is SAO 137302 ($m_V$ = 9.2). Reproduced from a 2.5-m duPont telescope plate.

## § 3. Dual Emission Line Clouds in the Nuclei of the Interacting Pair Arp-90

On optical spectra, dual peak emission line clouds have been discovered in both nuclei of an interacting pair Arp 90 (NGC 5929 + NGC 5930). The clouds in each galaxy have diameters of about 3.6 arcsec = 860 pc and are separated by 1.5 arcsec = 360 pc or 1.3 arcsec = 310 pc on the opposite directions of the nuclei with velocity differences of 197 $\pm$ 10 and 282 $\pm$ 10 km $s^{-1}$ for NGC 5930 and NGC 5929, respectively. Their spatial structures are reminiscent of the 6-cm radio maps, double lobes of equal fluxes separated by 1.5 - 2.0 arcsec (Ulvestad and Wilson 1984). The clouds in each galaxy are quite similar in their spatial, kinematical, and radio properties, but quite different in the excitation levels of the ionized gas, i.e, classified as HII region type or Seyfert 2 type for NGC 5930 or NGC 5929, respectively. NGC 5930 was detected as an IRAS source with the luminosity $L_{IR} = 2.0 \times 10^{10} L_{\odot}$, while NGC 5929 was not. The pair of Arp 90 may provide a unique opportunity to study the relationship or evolutional sequence between Seyfert 2 nuclei and HII region type or star burst nuclei.

The Full paper has been submitted to Ap. J.

The spectra of NGC 5930 and NGC 5929 in the region of Hα, [NII] λλ6548, 6583, and [SII] λ6717, 6731. Each emission line splits into two components spatially and spectrally with velocity differences of 197 km $s^{-1}$ and 282 km $s^{-1}$ for NGC 5930 and NGC 5929, respectively. The spatial separation between the two components of NGC 5929 chages with position angle.