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THE ARP RING : GALACTIC OR EXTRAGALACTIC ?

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ABSTRACT

The Arp Ring is a faint, loop-like structure around the northern end of M81 which becomes apparent only on deep optical photographs of the galaxy. The nature of the Ring and its proximity to M81 are uncertain. Is it simply foreground structure - part of our own galaxy, or is it within the M81 system ? IRAS maps of the region show a far-infrared counterpart of the Ring. The new infrared data are compared with previous optical and radio observations to try to ascertain its physical nature. The poor correlation found between the common infrared/optical structure and the distribution of extragalactic neutral hydrogen, and the fact that its infrared properties are indistinguishable from those of nearby galactic cirrus, imply that the Arp Ring is simply a ring structure in the galactic cirrus.

INTRODUCTION

Deep optical pictures of M81 taken by Arp (1965) showed a faint and fascinating loop-like structure around the northern end of the galaxy. Arp originally considered the feature to be associated with M81, i.e. extra-galactic, and interpreted it as a manifestation of an electromagnetic interaction between electrons from M82 (then assumed to be exploding) and the magnetic field of M81. Gottesman and Weliachew (1975) considered the Ring to be the optical counterpart of the satellite neutral hydrogen they found around M81. However, more recent deep plates by Sandage (1976) revealed widespread, low-level diffuse optical emission throughout much of the region of sky about M81. IRAS extended emission maps (IRAS Explanatory Supplement) of the area show a good correlation between much of the diffuse optical emission and the infrared "cirrus" (Low et al, 1984) thought to be local to our galaxy. The Arp Ring could now be seen as simply a fortuitous alignment of a cirrus loop in the foreground of M81. Very recently Karachentsev et al (1985) have added a further twist in the tale with their reported detection, within the Ring, of young star clusters at recession velocities corresponding to the distance of the M81 group. So, is the Ring galactic or extragalactic ? Data obtained by IRAS show an infrared counterpart of the optical Ring; we compare the infrared and optical structure with the distribution of extragalactic neutral hydrogen to try to resolve the uncertainty.

OBSERVATION and RESULTS

Figures 1 and 2 show, respectively, the 100 and 60 micron maps of M81 made by coadding the data from IRAS pointed-mode observations (Young et al, 1985) of the area. The beam is 5 x 3 arcminutes at 100 microns and 4.7 x 1.5 arcminutes at 60 microns, with the long axis oriented perpendicular to the mean scan direction - indicated by the jagged line marking the edge of

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the area observed. The maps have been flatfielded using techniques described in Rice et al (1986). The infrared counterpart of the Arp Ring is the extensive low surface brightness structure outside the northern half of the disc of M81.

Figure 1

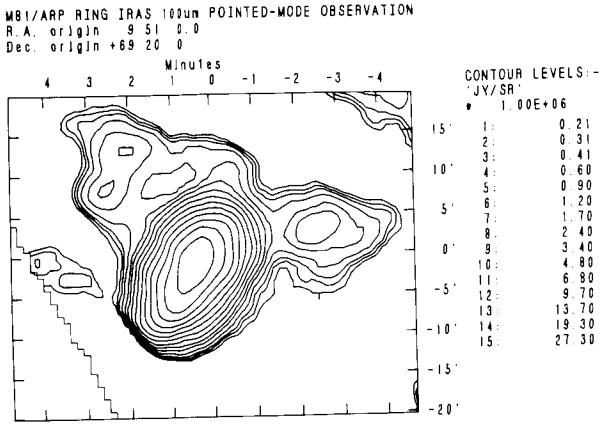
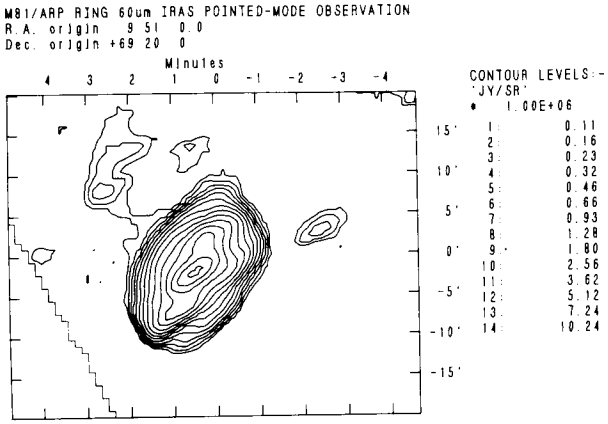


Figure 2



DISCUSSION

COMPARISON WITH SANDAGE'S DEEP OPTICAL PHOTOGRAPH

Inspection of Sandage's(1976) deep optical image reveals little to distinguish the Arp Ring from other cirrus/reflection nebulosity in the vicinity. Until recently only the relative sharpness of the Ring in the optical, and its curious orientation about M81, were compelling enough to suggest the Ring as a possible component of the M81 system; originating perhaps in the interaction between M81 and M82. However, Karachentsev et al now claim to have resolved "blue diffuse and star-like objects" on plates obtained with the Soviet 6 metre telescope (1986 and priv. comm.) Unfortunately details of where in the Ring this recent star-formation has taken place have yet to be disclosed.

The IRAS maps of M81 can be used to compare the infrared and deep optical appearance of the region immediately surrounding the galaxy. Despite the lower spatial resolution of the infrared maps, superimposing them on the deep optical image shows a one-to-one correspondence between the infrared and optical bright spots of the Ring. This is particularly clear at 60 microns where the spatial resolution is better and there is less confusion from nearby cirrus.The glaring difference between the infrared and optical views is the absence of the dwarf Magellanic irregular companion of M81, DDO 66, from both the 60 and 100 micron images. DDO 66 is of considerably higher optical surface-brightness than any part of the Ring, and, unlike the Ring, can even be seen on the blue sky-survey print. If the Ring was to be considered extragalactic, it would be unique as the only extended infrared feature, in any nearby galaxy observed by IRAS, to have no optical counterpart on sky-survey prints. (See "Atlas of IRAS Extended Galaxies" Rice et al, this conference.)

FAR-INFRARED COLOURS

Can the Arp Ring be distinguished from nearby cirrus on the basis of far-infrared colour ? The answer appears to be no ! The 100-over-60 micron flux ratio has been determined for many cirrus features within two degrees of M81 (Abolins and Rice, 1986). The values obtained are all greater than 5.5, ranging mainly between 6 and 8, corresponding to dust grains with colour temperature $T \leq 25$ K assuming emissivity proportional to ν^{+1}, or $T \leq 22$ K assuming emissivity proportional to ν^{+2}. The value for the Ring as a whole is 6 ± 1. This value does not change appreciably if smaller regions about the peaks are sampled, i.e. when possible contamination from cirrus not associated with the Ring is minimised.

21cm LINE DATA

Having established a close correspondence between the optical and infrared structure, we now compare both with the distribution of extragalactic neutral hydrogen from the published 21cm line data. The entire M81 group has been extensively observed : Gottesman and Weliachew (1975) showed the existence of clumps of satellite neutral hydrogen around M81, Cottrell (1977) and Gottesman and Weliachew(1977) showed the neutral hydrogen bridge connecting M81 with M82, van der Hulst (1979) described the bridge connecting M81 with NGC 3077 and Roberts(1972) and Davies(1974) showed that M81,M82 and NGC 3077 are enveloped in a giant cloud of neutral hydrogen. Is there then any close similarity between the optical/infrared structure and neutral hydrogen distribution, from which an extragalactic distance to the Ring could be inferred ? There is no detected counterpart of either the giant enveloping cloud or the connecting bridges (Abolins and Rice,1986). Gottesman and Weliachew(1975) interpreted the Ring as the optical counterpart of the satellite neutral hydrogen close to M81, but remarked that the radio emission was "very patchy" by comparison. In fact only the eastern parts of the Ring show any coincidence with the radio emission. Cottrell (1977) noticed this and pointed out that the bright portion of the Ring due north of M81 is coincident with a minimum in the HI distribution. The brightest of the satellite HI features is that associated with DDO 66, also the brightest optical feature outside M81, but undetected in the infrared. A cloud due north of DDO 66 is the only HI feature to overlap with the infrared structure. Its total mass and surface density are similar to, but rather lower than, those of DDO 66 (Gottesman and Weliachew, 1975), and therefore, if the Ring is extragalactic and its infrared emission is from heated dust grains, the gas-to-dust ratio must be quite unlike that of DDO 66.

INFRARED COUNTERPARTS OF EXTRAGALACTIC HI CLOUDS ?

Searches for infrared [dust] counterparts of extragalactic clouds of neutral hydrogen, using IRAS data, are underway in the USA and Europe (eg this work and priv. comms.). It is now clear that the task is likely to be severely hampered by confusion from galactic cirrus if dust grains present attain temperatures $T \sim 20K$ (Pierce and Tully, 1985). Extragalactic HI clouds in cirrus-free areas are clearly the most promising candidates in this respect.

CONCLUSIONS

The far infrared maps and colour temperature of the Arp Ring are entirely consistent with the Ring being composed of galactic cirrus. The app-

arent conflict between this conclusion and the report of recent [extragalactic] star-formation within the Ring is resolved if there is a faint dwarf Im galaxy behind the [cirrus] Ring. This is not an unlikely event in a group known to be rich in dwarf systems.

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