CENTRAL STAR FORMATION IN EARLY-TYPE GALAXIES: IMAGES AND IMPLICATIONS

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INTRODUCTION

We are reporting on an on-going study of strong central star-bursts in early-type galaxies. These galaxies are brighter than m(pg) = 14.5 and are classified as type S0, S0/a, or Sa in the Uppsala General Catalog (UGC, Nilson 1973). All of them have unusually warm, bright far infrared sources for early-type galaxies, with F(100 microns)/F(60 microns) < 2.0 and F(60 microns) > 2.5 Jy (Dressel 1988, Ap. J. 329, L69). Much of the infrared emission comes from the central few arcsec (Telesco, Dressel, and Wolstencroft, in prep). Most of the galaxies were detected at 2380 MHz at Arecibo (Dressel and Condon 1978, Ap. J. Suppl. 36, 53), with flux densities between 15 and 33 mJy. They have diffuse radio sources with a variety of morphologies, typically a few kpc in extent (Dressel, in prep). Long slit spectra through the nucleus show that all have Balmer absorption lines, signifying a large B or A star population, and [OII] 3727 and Balmer emission lines, consistent with ionization by hot young stars (Dressel and Gallagher, in prep). We have made optical continuum and emission line images of the galaxies to use in combination with the above data to study the causes and evolution of strong central star-bursts in early-type disk systems.

DATA

We have used the CCD direct imaging camera on the 2.1 m telescope at Kitt Peak with the TI2 CCD to take images with U, B, R, I, and H alpha + [NII] filters. The CCD has 800 x 800 pixels with a scale of 0.19 arcsec per pixel. The observations were made in October 1991 on three photometric nights with seeing typically 0.9 arcsec. H alpha + [NII], U, I, and composite continuum images of seven galaxies were presented in the poster, to show the distribution of the young and old stellar populations and the overall structure of the galaxies. Descriptions of the individual galaxies are given here:

UGC 00861, NGC 471: type = S0, brightest in multiple system (UGC). The three small UGC companions are within 0.6 diameters. The U isophotes are noticeably asymmetric. The composite continuum image shows a dust lane a few arcsec from the nucleus. The line emission forms a clumpy central ring.

UGC 01157, NGC 632, Mkn 1002: type = S0, pair with UGC 01153 (UGC). The UGC companion, a 15.0 mag E galaxy, is 5 diameters away. The continuum images show a possible bar, inner arms, and irregular outer isophotes. The line emission is centrally concentrated and trefoil-shaped.

UGC 01385, Mkn 2: type = SBa, brightest of 3 (UGC). Two large UGC companion galaxies are 2 and 4 diameters away. The bar and arms are apparent in the continuum images. The line emission is slightly asymmetrically peaked and elongated.

UGC 03201, NGC 1691, Mkn 1088: type = SB0/SBa (UGC). This is a strongly barred galaxy. Most of the line emission is in the center, with an elongated double-peaked morphology suggestive of a clumpy ring. Knots along the arms are also clearly visible.

UGC 03265, NGC 1819, Mkn 1194: type = SB0 (UGC). This is a strongly barred galaxy with classic bar-driven structure. The line emission and the radio continuum emission lie in a clumpy elongated ring.

UGC 12575, NGC 7648, Mkn 531: type = S0 (UGC). The "diamond ring" galaxy. A large off-center clump of star-formation causes strong asymmetry even in the I image. Much structure is visible in the composite continuum image. The composite image and

U image suggest that the clump may be part of an otherwise faint ring.

UGC12618, NGC 7679, Mkn 534, Arp 216: type = S0, pair with UGC 12622, disturbed (UGC); SB0 peculiar: (deVaucouleurs et al. 1976, Second Reference Catalog of Bright Galaxies); Sc/Sa (tides?) (Sandage and Tammann 1981, A Revised Shapley-Ames Catalog of Bright Galaxies). This galaxy is clearly difficult to classify because its properties do not fit neatly into any one Hubble type bin. It has fairly obviously been tidally disturbed by its companion, a disturbed SBa Seyfert galaxy, 3 diameters away. Most of the line emission comes from the complex central region, some from tidal loops.

We have used published IRAS far infrared fluxes and CO fluxes to determine the far infrared luminosities and molecular hydrogen masses of the galaxies. For the three galaxies with no CO observation, the average L(FIR)/M(molecular H) ratio for the CO-detected galaxies was used to estimate the molecular hydrogen mass: < 4, 12, 17 > = 11 (L solar/M solar). Young et al. (1989, Ap. J. Suppl. 70, 699) have found that these parameters are well correlated. For Ho = 50 km/sec/Mpc and a conversion factor of N(cm**-2) = 3.5x10**20 I(CO) (K km/sec), the molecular hydrogen masses of the galaxies range from 3x10**9 to 3x10**10 solar masses, with one upper limit of 8x10**9. We have calculated the star formation rate for a Salpeter IMF from 0.1 to 100 solar masses from the far infrared luminosity using the relation developed by Thronson and Telesco (1986, Ap. J. 311, 98): dM/dt = 6.5x10**-10 L(FIR) solar masses per year. The molecular hydrogen mass has been divided by the deduced star formation rate to see how long the molecular hydrogen would last if it continued to be consumed at the current rate. The hydrogen lifetimes are all less than 4x10**8 years. Even for much lower gas consumption rates or substantial additions to the molecular gas supply, all seven galaxies would meet the defining characteristic of a star "burst": there is not enough gas to support the current star formation rate for a Hubble time.

CONCLUSIONS

The H alpha line images clearly confirm that star formation is occurring in the centers of these early-type galaxies at a high rate. The far infrared luminosities and molecular hydrogen masses imply that the star formation is occurring in a burst that cannot be sustained at the current rate for longer than several hundred million years, if a full Salpeter IMF is formed.

The line emission region is ring-like in morphology in the two most strongly barred galaxies, UGC 03265 and UGC 03201. Several theoretical studies have shown that a barred galaxy can form a ring of molecular gas at an inner Lindblad resonance (e.g., Combes and Gerin 1985, A. and A. 150, 327). This gas presumably forms stars when compression produces sufficient densities.

UGC 12618, the Arp galaxy visibly interacting with a Seyfert galaxy, appears to be a classic case of a tidally induced central star-burst. Many studies have shown that such interactions can channel gas towards the nucleus.

Although the remaining galaxies have comparably strong central star-bursts, judging from their far infrared luminosities and "warm" F(100 micron)/F(60 micron) colors, the causes of the bursts in these galaxies are not as obvious. Some of them have irregular outer isophotes and (apparent) companions, but the companions are generally relatively more distant in projection or smaller than the companion of UGC 12618. Some of the galaxies have bars that are less prominent than that in UGC 03265, and some may have oval distortions or bars that could only be seen in the near infrared.

The burst in UGC 12575, the "diamond ring" galaxy, may require a theory other than tidal disturbance or bar-driven dynamics. The galaxy is fairly isolated and not apparently barred, and the burst is distinctly off-center.

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