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STAR FORMATION RATES AS A FUNCTION OF GALAXY MASS

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ABSTRACT

Several groups have found correlations between the colors and absolute magnitudes of spiral galaxies. Using optical and/or near IR (1.6 micron) colors, they find that lower luminosity spirals are systematically bluer than higher luminosity spirals. I have used IRAS far IR luminosities to investigate the suggestion that one prime cause of these color- absolute magnitude correlations is a systematic variation with galaxy mass of the current star formation rate (SFR) per unit mass. To the extent that the IRAS fluxes actually measure disk SFR, I find NO correlation of SFR/ unit mass and galaxy mass. Other possible explanations of the color- absolute mag. correlations are discussed, as well as caveats on the use of IRAS fluxes as a means of comparing SFRs in galaxies of differing mass.

INTRODUCTION

Several groups (Tully, Mould, and Aaronson 1982; hereafter TMA; Wyse 1982, and Visvanathan 1981) have reported finding color- absolute magnitude correlations for spiral galaxies. All find that lower luminosity galaxies are bluer than higher luminosity galaxies. The most striking relation is shown by TMA, who plot the optical minus infrared color BT(b,i)- H(-0.5) versus the HI line width. Their B magnitude is a total magnitude corrected for Galactic absorption and internal galaxy absorption (galaxy tilt). Their H (1.6 micron) magnitude encompasses a diameter corresponding to about 1/3 the B=25 mag/sq. arcsec isophotal diameter. This B-H color changes by almost 2 magnitudes as W, the HI line width corrected for galaxy inclination, ranges from 200 to 600 km/sec. TMA postulate that much of this effect is caused by a higher star formation rate (SFR) per unit mass in lower mass galaxies.

I am studying the role of SFR in explaining the B-H relation for spirals using IRAS far infrared fluxes. The rationale, of course, is that the far IR flux might be a good measure of the current SFR for massive stars, as the massive stars are presumably the heating source for the dust radiating at 60-100 microns.

SAMPLE AND ANALYSIS

My sample is similar to that in TMA. The TMA sample was drawn from "A Catalog of Infrared Magnitudes and HI Velocity Widths for Nearby Galaxies" (Aaronson et al 1982, hereafter the "HI CATALOG").

The primary sample consists of all galaxies in the HI CATALOG meeting the following criteria:

1) Only galaxies smaller than 3.5 arcmin diameter were included , as the fluxes in the Cataloged Galaxies in the IRAS Survey (Lonsdale et al 1985) for larger galaxies may be seriously underestimated.

2) Galaxies with inclinations larger than 80^{o} were ignored, to avoid the worst of the possible inclination dependent detection problems (Burstein and Lebofsky 1986).

Approximately 120 galaxies from the HI CATALOG meet these 2 criteria. Of these, about 80% had positive detections at 60 and 100 microns listed in Cataloged Galaxies in the IRAS Survey (Lonsdale et al,1985).

A more restricted sample was also chosen, for which good B magnitudes could be determined. These were chosen from the galaxies meeting 1) and 2) which also:

3) Had BT magnitudes listed in the Second Reference Catalog (RC2) or had Zwicky magnitudes which were converted to BT estimates using the procedure in Auman, Hickson, and Fahlman (1982).

4) Had Galactic latitude greater than 30^{o}, following TMA.

Of this restricted sample of 88 galaxies, 76% had positive IRAS 60 and 100 micron detctions.

Far IR luminosities (LFIR) were found using LOG(FIR) listed in Cataloged Galaxies in the IRAS Survey (Lonsdale et al 1985) and galaxy distances from the HI CATALOG. These distances are based on a Virgocentric infall model. I assumed a value of 15.7 MPC for the distance to Virgo.

Galaxy masses (Mgal) were derived from the simple relation (Faber and Gallagher 1979)

$$Mgal = R\,(\Delta V)^2\;/\;G$$

where R is the galaxy radius (derived from the diameters in the HI CATALOG) and Δ V is an estimate of the rotational velocity (derived from the HI line width).

RESULTS AND DISCUSSION

In Figure 1 I have plotted Log(LFIR/Mgal) , which should be a measure of the SFR per unit mass, against the galaxy mass. This figure shows NO OBVIOUS CORRELATION OF SFR/UNIT MASS WITH MASS. Notice that the scatter is large. If there is any trend, it is actually for lower mass galaxies to have a lower Log(LFIR/Mgal) than higher mass galaxies. However, this is not statistically significant with the present sample.

The LFIR/ blue luminosity ratios for this sample are similar to the lower to middle range found for Shapley- Ames spirals (de Jong et al 1984, ApJ 278, L67). This implies that galaxies in the present sample are not unusually active.

Several points must be kept in mind:

1) If lower mass, lower metallicity galaxies have a lower dust mass/ total mass ratio, LFIR might not be a good measure of current SFR. Arguing against the importance of this effect is the fact that LFIR does seem to measure SFR in small

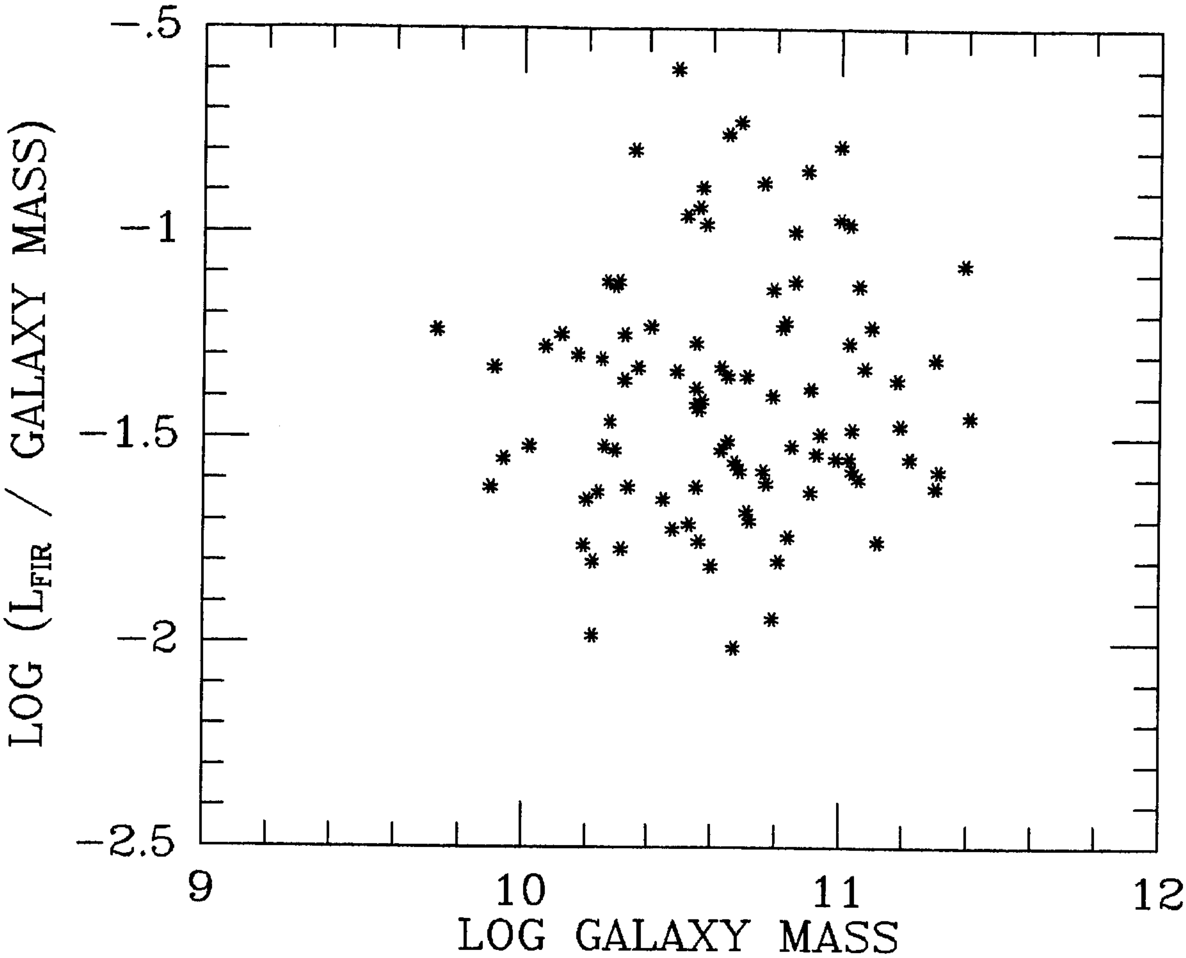

FIGURE 1. Plot of Log(Far IR Luminosity / Galaxy Mass) vs. Log (Galaxy Mass). Luminosity and mass are measured in Solar units.

blue irregular galaxies (Hunter, Gillett, Gallagher, Rice and Low 1986).

2) There may be strong contamination of the disk emission by nuclear sources (Burstein and Lebofsky 1986). I hope that analysis of IRAS pointed observations of nearby galaxies will settle this question.

3) Possible problems with overestimation of the flux for sources near the survey limits have not been dealt with yet.

4) Galaxies with upper limits to LOG(FIR) have not been included. There is a slight trend for the lower mass galaxies to have a lower detection rate. Thus, proper inclusion of upper limit data might actually accentuate any tendency for lower mass galaxies to have lower SFR/ unit mass.

What are some other possible explanations for the (B-H)- absolute magnitude relation? Some possibilities include:

1) GALAXY AGE- Lower luminosity galaxies might well be younger (in some sense) than higher mass galaxies. If this is true, they might have far less of the old "Population II" component which is red in (B-H). (see discussion in Bothun, Romanishin, Strom and Strom 1984).

2) IMPORTANCE OF BULGE POPULATION TO H(−0.5) − The manner in which the H magnitude is measured (to a fraction of the standard isophotal diameter) emphasizes the contribution from the center of a galaxy. This accentuates the importance of any old (red) bulge population. If bulge/ total galaxy population increases with galaxy mass (on average) this could help explain the correlation. (Note however that TMA find little type dependence of the correlation, arguing against the importance of this poiunt.)

3) SYSTEMATIC METAL ABUNDANCE VARIATIONS− TMA do point out the possibility of a contribution of a change in stellar metal abundance with galaxy luminosity to the (B−H)−W correlation. Perhaps this is more important than previously thought (see Bothun et al 1984 for a discussion of systematic metal abundances in spirals).

4) EXTINCTION VARIATIONS − If lower luminosity spirals have less dust, they will tend to be bluer optically simply because they have lower internal extinction.

Possibly all these factors play some role in the color− absolute magnitude relation.

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