STAR FORMATION AND GAS CONTENTS IN DISK GALAXIES: COMPLEX RELATIONSHIPS

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1. Introduction

Star formation activity is highly variable in galaxies. Can we relate it to the gas content of the galaxy? To the gas composition, the relative amounts of available molecular and atomic hydrogen? Or are these variations mainly due to the galaxy environment? To study this problem, we made a statistical study of the links between the star formation indicators and gas tracers in a sample of 469 disk galaxies. Since the molecular phase is the place of star formation, information about the H_2 content is crucial. Hence, the sample galaxies have all been observed in the ^{12}CO(1–0) line. We use a conversion factor $X = 2.3\ 10^{20}$. We studied the global properties of the sample objects: total gas content and global star formation indicators at various wavelengths from the optical colors to the radio continuum emission.

2. The Sample

One third of the C0(1–0) data comes from the FCRAO extragalactic survey and from Sage's survey of nearby galaxies (1993). The other CO data have been obtained by us in several surveys, in particular of the Coma region and of isolated galaxies from the Karachenseva catalog. These surveys have been conducted with the NRAO 12m and the SEST 15m telescopes, with some additional data from IRAM. The beamsizes are then respectively $55''$ and $45''$. All galaxies with $D_{25} > 4'$ have been mapped in order to get all the emission. 109 objects were not detected down to typical noise levels of 2–3 mK in 16 km s^{-1} channels and we take the upper limits into account using a survival analysis technique.

Figure 1.

The other available data are the blue magnitudes and diameters (467 galaxies), the 60 and 100 μm flux densities (425), the HI fluxes (421), the B-V and U-B colors (227), the H-band magnitudes (146), the 21 cm continuum fluxes (69 galaxies in the Coma region), and the Hα equivalent widths (68).

These are indicators and not true measurements of the star formation rate. For example, the colors are sensitive to the star formation history integrated over several 10^8 yr and to a limited range of stellar masses. As for the gas, the H_2 masses are derived from the CO line areas with the well-known uncertainty in the conversion factor, X. In addition, we have to normalize the observed quantities in order to get rid of the size effect. We have chosen to divide the luminosities and masses by the optical surface of the disk, D_{25}^2. We get essentially the same results if we scale by the blue luminosity, but not if we scale by the H-band luminosity.

3. Results and Interpretation

The average spiral in the sample has much more HI than H_2. For the 322 objects that are not strongly HI-deficient, we find $<\log(M(H_2))/M(HI))>$ $= \log(0.16) \pm 0.04$. We see a slight decrease (a factor 2–3) of $M(H_2)/M(HI)$ for later morphological types.

Figure 2.

Since stars are born in molecular clouds, we expect a tight relationship between the star formation tracers and the avaiblable H_2 link with HI. This is indeed what we see with the FIR and the radio-continuum emission (Figure 1). This also suggests that the CO line traces the available molecular gas well. Things are more complex, however, with the optical star formation tracers. There is little or no relation to the CO emission and only a fair relationship to the HI emission (Figure 2).

Can we explain these unexpected results if the CO emission is not a fair tracer of the H_2 mass? But this would explain neither the good CO-FIR and CO-radio relationships, nor the HI-optical relation. The optical data are likely affected by extinction, which could blur the relation with CO. But this cannot explain the correlation with the HI. A third explanation could be that the atomic phase has something to do with star formation: either directly, if for example the transformation of the HI into H_2 is a much slower process than the transformation of H_2 into stars; or indirectly, if most of the HI present in a galaxy is a by-product of star formation via photodissociation of molecular clouds.

In conclusion, it seems that the relationships between the star formation indicators and the gas tracers in disk galaxies are still poorly understood.