Gas and Molecular Dynamics in Galaxies

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A brief message from our sponsor

1. Authors: Proofread!

2. Editors: Edit!
Introduction

1. What’s the point?
2. Correlation between CO and H$_2$
3. It’s dusty in here
4. Molecular content vs. galaxy type
5. Effect on galaxy structure
What is the point?

- Most abundant element: $\text{H}_2$
- $\text{H}_2$ content determines star formation rate
- How do we determine gas content of galaxies?
  - $\text{H}_2$ is hard to see
  - CO traces $\text{H}_2$
- Spirals vs Ellipticals
CO and H$_2$ lines

- Carbon Monoxide
  - Molecular rotation: $\sim 1.3 \text{mm}$

- Hydrogen
  - 21cm spin flip transition
CO, dust and H$_2$

- Empirical fit
- CO and H$_2$ column densities similar
  - CO transition “strength”
  - H$_2$ density
- Dust lanes and CO arms
  - star forming shells and chaotic motion
Dust and CO

Figure 2. Dust emission radial profile in NGC 4565, compared to the CO and HI profiles, from Neininger et al (1996).
NGC891: dust and CO emission

Fig. 2. a) The λ 1.3 mm continuum emission and the $^{12}\text{CO}$ (2-1) integrated line intensity along the major axis, observed with a 12'' angular resolution. Abscissa, the apparent distance from the center of the galaxy.
Galaxy type

Figure 1. \( \frac{H_2}{HI} \) mass ratio in galaxies as a function of morphological type; full squares: mean values with upper limits treated as detections; empty squares: mean values with upper limits taken into account using the survival analysis (SA), from Casoli et al (1998).
Importance of bar

- Drives of gas and dust
  - Molecular gas and dust to center
  - Feeder of AGN and/or starburst

- Linblad resonance
  - Nuclear, Inner, Outer
  - Pattern speed
  - Orbital frequency
  - Oscillation frequency of the potential
Linblad resonance

Fig. 2. Velocity and frequency curves for a potential with 3 ILRs. The circular velocity ($v_{\text{circ}}$) is drawn with dotted line, the frequency curve is solid. The constant pattern speed $\Omega_p$ is marked with the horizontal dashed line. Positions of the three ILRs: nuclear (nILR), inner (iILR), and outer (oILR) are marked with squares. A close-up of the inner region is shown in the insert, where the sphere of influence of the $10^7 M_\odot$ MBH has roughly the radius $r_{\text{BH}}$. 
Spirals

Fig. 1. A representative snapshot of the gas density and velocity field in a barred galaxy, taken after 6 rotation periods of the bar, once the main flow patterns have been established. The gas, treated as a non-selfgravitating, isothermal fluid with a sound speed of 5 km/s, responds to a fixed gravitational potential of a bar, disc and spheroid, and is modeled with an Eulerian code on a fixed grid. The density is shown in grayscale, and arrows mark gas velocity in the reference frame rotating with the bar. Dotted circles mark corotation and the ILR. Examples of $x_1$ and $x_2$ orbits are drawn with solid and dashed lines, respectively. PS marks the principal shock in the bar, NR is the nuclear ring. Units on axes are in kpc. From the model S05 by Maciejewski et al. (2002).
Clusters

Cluster spirals
- deficient in HI
- Still contain CO - $\text{H}_2$?

Starburst outside of galaxies?
- Xu & Tuffs (1998)
- 25kpc from neighbouring galaxies
- Young stars - $\sim 0.7M_\odot$/year
Redshift dependence

- High z observations
  - > 10 objects with z > 2.2
- Gravitational amplification
- Gas excitation uncertainty
- Infrared background
- Early starbursts?