NEARBY GALAXIES AS LABORATORIES FOR HIGH RESOLUTION STUDIES OF MOLECULAR GAS PHYSICS

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This project aims to develop a detailed study of physical conditions of molecular gas in nearby galaxies with the use of observations at different wavelengths.
In the last years the composition of the gas and dust present in galaxies has been studied, discussing the relation between different ISM tracers (60 and 100 micron fluxes, CO and 21 cm lines, X ray emission) and the connection between anomalous abundance of a tracer and the dynamical phenomena of gas accretion from the environment. The molecular gas content is anomalous, for instance, in merging galaxies and it depends from galaxy metallicity also..

1 - Until now, most part of optical observations were performed with high resolution instruments (1" or less) while infrared and radio data were based on telescopes with large beams (some tens of arcsecond). Now the first observations of molecular gas at high resolution (from 0.5 to 6 arcsec FWHM) start to be available and radiotelescopes, as the IRAM ones, are improving their performances for this kind of study. In addition ESO makes available instruments at high resolution to observe from Earth the H2 roto-vibrational transition at 17 micron with resolution of 0.13 arcsec. This line was previously observable from space only at poor resolution. This is now the right moment to start a study on the content of molecular hydrogen made observing its lines at different wavelengths, coming from regions at different temperatures. We shall have a complete picture of the state of hydrogen molecules across the galaxy. The presence of instruments at high resolution will allow also to distinguish in nearby galaxies single regions, such as giant molecular clouds, restricting the range of studied physical conditions. Then, the first aim of this project will be to perform detailed observations of the hydrogen in the same galaxies separating the different components.

2 - The second goal will be to measure the hydrogen column density from lines emitted by regions at different temperatures: for instance the cold hydrogen from CO lines, the warm one at ~100 K from the 17 micron line, that at thousand degrees from the ~2 micron lines and the ionised one from Balmer lines. This should help us to clarify the problem of the determination of the X (greek Chi) conversion factor between H2 and CO because we shall have independent measurements of the lines generated by the two molecules. In fact this point is still controversial because of the difficulty to understand the mechanism of emission of the CO induced by collision with H2 molecules. Then, to reach this goal will allow to define more strict limits to the values of the X factor in the different regions of nearby galaxies.

3 - The results of these observations are expected from a set of proposals presented in collaboration with Italian and foreign astronomers at the following telescopes: IRAM radiotelescopes for CO lines, ESO-VISIR for the H2 line at 17 micron, TNG for the H2 lines around 2 micron and Asiago-AFOSC for optical lines. The same galaxies, chosen among spiral galaxies seen almost face-on and visible both at ESO and from the northern hemisphere, will be observed with different telescopes,. A exception is M81, visible in the northern hemisphere only, that appears interesting for several aspects. With the Asiago 182 cm telescope we will be able to study the stellar and gas kinematics also inside the galaxies. To link the different physical conditions with the global gas and stellar dynamics will be the third goal of this project.

Project 1: I Are truncated stellar disks linked to the molecular gas density?
This project has been presented to the TAC of IRAM radiotelescopes to use the Pico Veleta (SP) di 30m instrument.

We want to map the molecular hydrogen distribution in two disk galaxies, one with and one without a truncation in their stellar light distribution, to test the theories connecting this break to a density fall of molecular gas. Previous studies suggest a correspondence between star formation and a threshold value in the local molecular mass, sometimes coupled with dynamical constraints. If such a threshold persists for sufficient time, it should introduce the visible turnover or truncation of the observed stellar luminosity profile. In this project we shall observe two galaxies carefully selected with known luminosity profiles comparing their molecular gas density by means of observations of CO(1-0)line at 2,6 mm.
Project status: accepted in priority B (observations subject to the observability conditions).

Project 2: The M81 puzzle: a CO(2-1) map of the center.
M81 is the prototype of giant spiral galaxies which are very CO-poor, in which the derived molecular to atomic gas ratio is of the order of 10%. Recent observations with infrared (SPITZER) and UV (GALEX) satellites show the absence of recent stellar formation in a wide central region where CO lines are faint, while the disk possess star formation and a strong density wave is triggered by a tidal interaction with the close galaxies M82 and NGC 3077. The CO to H2 conversion ratio X is suspected to depart significantly from the mean producing this effect, and M81 is thus an interesting laboratory chosen among the nearby galaxies where to explore the parameters controlling the X-ratio. Since the metallicity is normal in these giant galaxies (contrary to dwarfs), the main parameter governing the X-ratio is likely to be the physical conditions of the gas, and the CO excitation. Mapping with the multi-beam spectrometer HERA the CO(2-1) line and comparing it with the intensity values of CO(1-0) one may quantify these excitation ratio and deduce important phenomena controlling the conversion ratio.
This project has been approved in B priority (observations conditioned by the observability conditions) by the international committee of IRAM radiotelescopes.

Project 3: The X affair in nearby galaxies.
At the 8-m telescope VLT Melipal it has been recently mounted VISIR, an instrument able to do photometry and spectroscopy of the roto-vibrational hydrogen line at 17 microns, coming from regions at temperatures of ~100 K and observable until now only from satellites but at low resolution. In this project we asked to use VISIR to study the X conversion factor, whose direct determination is impossible because CO and H2 lines come from regions with different densities and temperatures. Three nearby galaxies seen almost face-on, were the single components such as arms, nucleus, regions with ongoing stellar formation are clearly visible, will be observed, in the line at 17 microns, pointing the telescope in regions where the CO(1-0) line at 2.6 mm has been observed at resolution better than ~6 ". It will be a unique opportunity to compare the different components of nearby galaxies with similar spatial and spectral resolution.
At the same time it has been asked to observe at the TNG telescope of Canarian Islands the same galaxies but in the H2 roto-vibrational lines around 2 microns. They come from gas at higher temperature, beyond 1000 K, and the intensity of these lines will allow to evaluate the temperature and ionisation conditions of the gas.
In addition to these infrared lines it has been asked to observe the hydrogen line at 656.2 nm with the 182 cm telescope of Cima Ekar to study his intensity and the gas kinematics. They will give data on the ionisation state of hydrogen in the same regions where it will be observed at 2 and 17 microns and will improve our knowledge of the relation between the gas dynamics and molecule excitation.
This project has been presented for evaluation to the ESO, TNG ed Asiago Committees. We are waiting the evaluation of the first two, while the first observations have been performed at Asiago and the relative data reduction is in progress

Project 4: Insight about induced star formation: what is going on in the shell system of elliptical galaxies ?

Current views consider shell structures as a debris of recent minor/major merging event though also weak interaction models (WIM) could produce long lasting shells on host galaxies possessing a stellar thick disc. Recent observations suggests an external acquisition of the gas, as predicted by merging models. At the same time, a set of observations showing a clear association between cold (HI/CO) gas and stars challenges present merging models which do not foresee it unless cold gas behaves differently from ionized gas. The GALEX satellite has the capability in detecting low UV fluxes in a wide field of view and it will map faint shell up to the galaxies outskirts. In this framework one has planned to observe a well selected sample of shell galaxies chosen among those with detected HI and/or CO both in the main body of the galaxy and interleaved with shells. These data will allow us to verify whether the cold gas-rich shells host ongoing star formation processes thus giving an independent indication about
the age of the last burst of star formation and the possible companion/accreted galaxy that originate this kind of systems.
This project has been presented to the GALEX Committee and it has been approved. The first of the requested galaxies has already been observed and the reduction of these data is in progress.

Personnel:

Prof. Cesare Chiosi, Ordinario, Dip. Astronomia (Project 4)
Prof. Giuseppe Galletta, Associato, Dip. Astronomia (Projects from 1 to 4)
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Researchers external to the University:
Dr.ssa Daniela Bettoni, INAF – Osservatorio Astronomico - (Projects 1, 3 and 4)
Dr. Roberto Rampazzo INAF – Osservatorio Astronomico (Project 4)
Other researcher of italian and foreign institutions

Collaborations:

Research activity by means of an agreement for a shared doctorate with the LERMA (Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique) and with the Université Pierre et Marie Curie - Paris 6, signed the 25 febbraio 2005 by the Rettori of Padova e Pierre et Marie Curie Universities.

Francoise Combes, LERMA – Observatoire de Paris (Francia)
Santiago Garcia-Burillo, Observatorio Astronomico Nacional – Madrid (Spagna)
Michael Pohlen, Kapteyn Institute – Groningen (Olanda)
Michael Rich, Univ. California (USA)

Research products:

2004: 2 papers on international journal, 2 international proceedings, 1 other;
2003: 2 papers on international journal, 1 international proceedings, 1 other;
2002: 1 papers on international journal, 1 other;
2001: 3 papers on international journal, 5 international proceedings;
2000: 2 international proceedings, 2 other.

List of 5 most relevant publications:

V. CASASOLA, D. BETTONI, GALLETTA G. (2004). The gas content of peculiar galaxies: strongly interacting systems. ASTRONOMY & ASTROPHYSICS. vol. 422, pp. 941-950 ISSN: 0004-6361;

BETTONI D, GALLETTA G., GARCIA BURILLO S. (2003). A new catalogue of ISM content of normal galaxies. ASTRONOMY & ASTROPHYSICS. vol. 405, pp. 5-14 ISSN: 0004-6361;

MARQUEZ I., MASEGOSA J., MOLES M., VARELA J., BETTONI D., GALLETTA G. (2003). Isolated and mildly interacting spiral galaxies: rotation curves and metallicity. ASTROPHYSICS AND SPACE SCIENCE. vol. 284, pp. 711-714 ISSN: 0004-640X;

MARQUEZ I., MASEGOSA J., MOLES M., VARELA J., BETTONI D., GALLETTA G. (2002). Rotation curves and metallicity gradients from HII regions in spiral galaxies. ASTRONOMY & ASTROPHYSICS. Vol. 392, pp. 389-407 ISSN: 0004-6361;

BETTONI D., GALLETTA G., GARCIA BURILLO S., RODRIGUEZ FRANCO A. (2001). The gas content of peculiar galaxies: counterrotators and polar rings. ASTRONOMY & ASTROPHYSICS. Vol. 374, pp. 421-434 ISSN: 0004-6361