RevMexAA (Serie de Conferencias), **12**, 236–237 (2002)

ON THE KINEMATICS OF H II REGIONS: YESTERDAY, TODAY, AND TOMORROW

H. O. Castañeda and Maite Rozas

UNAM, Ensenada, México

RESUMEN

El estudio de la cinemática y dinámica de las regiones H II nos provee de información sobre las condiciones físicas del gas, la interpretación de su espectro de emisión y el intercambio de energía mecánica entre las estrellas masivas y el gas ionizado. Discutimos en nuestra presentación el pasado, presente y futuro de la investigación en este campo. Cubrimos brevemente los avances teóricos y observacionales realizados durante las últimas décadas, incluyendo el estudio de los efectos del medio circundante en la cinemática, el llamado modelo de champagne, los movimientos supersónicos observados en regions H II gigantes, y los efectos de la turbulencia y virialización del gas. Finalmente discutimos como observaciones con espectrógrafos Fabry-Perot, tanto en regiones individuales como en muestras completas de regiones en galaxias, puede llevarnos a una mejor comprensión del estado físico del gas.

ABSTRACT

The study of the kinematics and dynamics of H II regions provides us with clues about the physical conditions of the gas, the interpretation of their emission spectra, and the exchange of mechanical energy between the ionizing stars and the ionized gas. We discuss in our presentation the past, present and future research in this field. We briefly review the theoretical and observational advances performed during the last decades, including the study of the effects of the environment in the kinematics, the champagne model, the supersonic motions observed in Giant Extragalactic H II Regions, and the effects of turbulence and virialization of the gas. Then, we discuss in detail how Fabry-Perot observations, both at single regions and sampling complete galaxies, could lead us to a better understanding of the physical state of the gas.

Key Words: **HYDRODYNAMICS — ISM: H II REGIONS**

1. INTRODUCTION

The velocity structure of H II regions, both Galactic and extragalactic, is extremely complex. The simple idea of the Strömgren sphere, i.e., the single ionizing source creating an ionized volume in a uniform density medium, has been replaced by more realistic models for the evolution of H II regions, taking into account that most of the normal H II regions are located at the edge of molecular clouds. In the observational arena, the emission-line spectra show clearly the evidence of high velocity gas and chaotic motions described by the generic word of turbulence. In the case of the extragalactic H II regions, a surprising result was the detection of supersonic motions in the integrated line widths of the emission lines, a phenomenon that would require a continuous resupply of energy to the ionized medium. The different models studied since the eighties to resolve this problem have been extensively discussed. The possible sources of turbulence can be traced to the effect of virialized motion of the ionized gas in the potential well of the combined star/gas system, the effect of the stellar winds of the ionizing stars on the gas, or the effect of the winds of low mass stars in the ionized medium, moving in the gravitational potential of the region (Melnick, Tenorio-Tagle, & Terlevich 2000)

2. FABRY-PEROT STUDIES

The most promising observational technique for the study of these extended objects is three-dimensional spectroscopy, in particular with the use of Fabry-Perot spectrographs. Two options are available for these studies, either looking at individual regions or at a complete sample of H II regions in a single galaxy, limited only by the observational constraints of flux-restricted samples and seeing-limited images. Here we summarize some of the highlights of the work done during the last decade by our research groups at the Instituto de Astrofísica de Canarias, with the aim of understanding the kinematics and dynamics of giant H II regions in external galaxies. Our work it was based on the extensive use of the TAURUS Fabry-Perot spectrograph on the 4.2-m

William Herschel Telescope at the Observatorio del Roque de los Muchachos, La Palma.

The large H II complexes of relatively nearby galaxies have been studied in detail. For example, in NGC 5471, the outermost and brightest complex in M 101, the study of the line widths showed that all the emission profiles for the sample were supersonic (Muñoz-Tuñón, Gavryusev, & Castañeda 1995). The most detailed study carried out to date was done in the giant complex NGC 604 in M 33 (Sabalisck et al. 1995). In this region, shells, filaments, and loops are distributed over the region, while two main knots dominate the emission, showing well-defined Gaussian profiles with a supersonic velocity dispersion of 16.5 km s^{-1}, which agrees with the global integrated line profile of the region. The large values of velocity dispersion are found in zones of low intensity, which present line profiles with strong asymmetries of splitting. Studies of individual giant H II regions show that there is evidence of large-scale mass motion (deduced from the asymmetry of the velocity histograms), that the brightest zones of the regions seem to define the integrated velocity dispersion of the region, and, at least in one case (NGC 604), correlations have been observed between the velocity field in different regions that could be explained as two-dimensional turbulence.

The alternative approach it is developed in Rozas et al. 2000, who observed spiral galaxies in order to look for the global kinematics of the galaxies, and to examine the dynamical behavior of the circumnuclear regions. With these goals in view, they planned observations of the ionized gas in a sample of spiral galaxies via Hα emission, using Fabry-Perot interferometry. This technique permits us to obtain kinematic information across the whole face of a galaxy at once; it offers a three-dimensional "data cube" of intensity versus position in each of a set of discretized wavelength channels, from which moment maps of integrated intensity, radial velocity, and velocity dispersion along the line of sight can be extracted.

From this data set we can use the ionized hydrogen as a tracer of star formation, and of velocity fields within and perpendicular to the plane of the galaxy, as well as dynamical processes within individual star forming zones. The types of velocity fields anticipated include "streaming motions" across spiral arms, or gas flows in the direction of the major bar axis; measurements of these fields allow us to infer the response of the gas to the underlying potentials involved (cf. Knapen et al. 2000; Rozas et al. 2000). In the case of individual H II regions, it is possible, using FP measurements, to look simultaneously at flux, velocity dispersion, and size of the regions. Typical observations can yield up to $> 10^2$ regions with all the properties measured. Statistical studies show that after fitting Gaussian profiles to well-defined regions the relationship ($\log \mathrm{L}\alpha$-$\log \sigma$) indicates that the systems could be virialized, but only in the regions that are density-bounded. Similar results are obtained in a different approach by studying the irregular galaxy NGC 4449, where a clear correlation is observed with the regions of highest surface brightness, with symmetric line profiles and good S/N in the spectra (Fuentes-Masip et al. 2000).

3. FUTURE WORK

Whereas these new data provide us with insights into the physics of the ionized gas, a good deal of work remains to be done. Our aim is to study the kinematics of H II regions in other emission lines, and also to continue the two-dimensional mapping of irregular and spiral galaxies, with the use of PUMA, a Fabry-Perot spectrograph available at the Observatorio Astronómico Nacional de Mexico. In other areas of research, infrared imaging is needed to study the population of low mass stars in GEHRs, in relation with the cometary-stirring model. Also, deep photometry of the regions can give us information about the content of the stellar population. Finally, the observation of the calcium triplet could give us information about the velocity dispersion of the stars, and how it compares with the observed σ of the ionized gas.

REFERENCES

Fuentes-Masip, O., Muñoz-Tuñón, C., Castañeda, H.O., & Tenorio-Tagle, G. 2000, AJ, 120, 752
Knapen, J. H., et al. 2000, ApJ, 528, 219
Melnick, J., Tenorio-Tagle, G., & Terlevich, R. 2000, MNRAS, 302, 677
Muñoz-Tuñón, C., Gavryusev, V., & Castañeda, H. O. 1995, AJ, 110, 1630
Rozas, M., Zurita, A., Beckman, J. E., & Pérez, D. 2000, A&AS, 142, 259
Sabalisck, N. S. P., Tenorio-Tagle, G., Castañeda, H. O., & Muñoz-Tuñón, C. 1995, ApJ, 444, 200

Héctor O. Castañeda and Maite Rozas: Instituto de Astronomía, UNAM, Observatorio Astronómico Nacional, Carretera Tijuana-Ensenda km. 103, 28830 Ensenda, Baja California, México (hcastane, maite@astrosen.unam.mx).

Ionized Gaseous Nebulae (Mexico City, 21-24 November 2000)
Editors: William Henney, José Franco, Marco Martos, & Miriam Peña