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DIFFERENCES IN THE SIZE-INTERNAL VELOCITY RELATION OF GALACTIC AND EXTRAGALACTIC HII REGIONS

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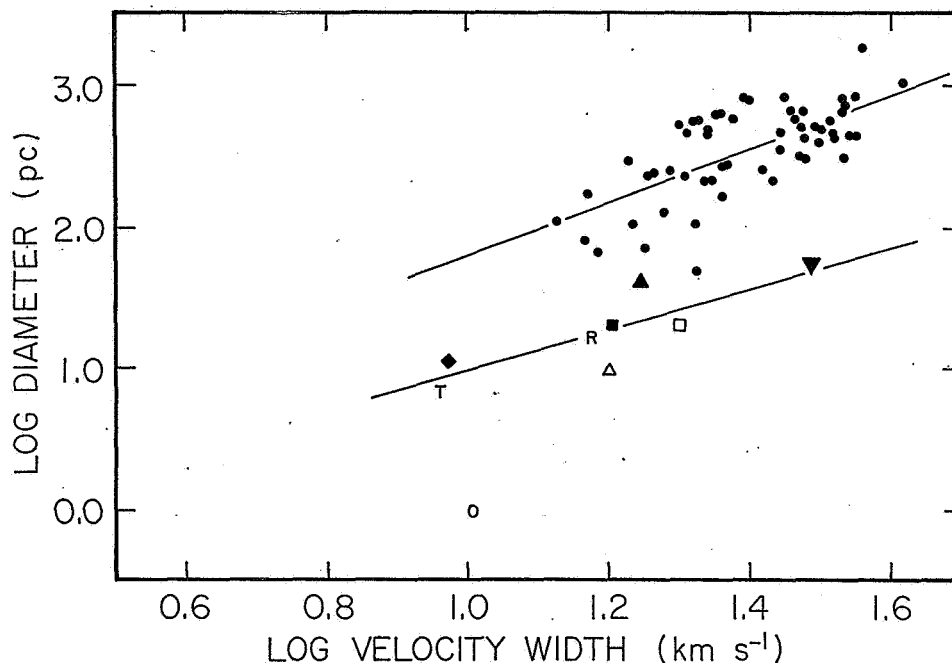
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SUMMARY: This study examines the nature of the size-internal velocity relation in extragalactic HII regions in order to improve their use as distance determinants. I have compared the relation between the linear size and the internal velocity for HII regions in the Galaxy and in external galaxies. Data for the former are from my own studies at high spatial resolution while the latter have been the subject of spectroscopy that includes almost the entire objects. The Galactic HII regions are corrected to values of the internal velocity that would be observed if they were at extragalactic distances. I find a very different size-internal velocity relation for the two types of objects in the sense that the extragalactic objects are some ten times larger at the same internal velocity. This is interpreted to mean that the extragalactic HII regions are actually complexes of small HII regions comparable in size to their Galactic counterparts.

EXTRAGALACTIC. The potential application of Giant Extragalactic HII Regions (GEHR) as distance determinants for galaxies is very great because of the ability to resolve them at large distances. The early studies that assumed limiting sizes for the largest objects have given way to methods that seek to determine the linear size from an observable quantity such as the emission line broadening. A linear relation between GEHR size and line width was first quantitatively advocated by Melnick (1977) and has since been refined (Roy, Arsenault, and Joncas 1986, Melnick et al. 1987, Arsenault and Roy 1988, Melnick 1988, Arsenault et al. 1988). The line width is usually expressed as the half width at which the intensity has dropped to a value $1/e$ that of the line peak. The line widths (β) are usually expressed in values corrected for the appropriate electron temperature, which allows the variable quantities to be more visible. The small angle of the GEHR means that values of β are usually determined from spectroscopic apertures that include most of a single object. The results of the study of Arsenault and Roy (1988) are shown in the figure, where we have used their sizes for the limiting $H\alpha$ isophotes. One finds a general relation of the form $\log D = -0.077 + 1.878 \log \beta$.

GALACTIC. My colleagues and I have studied the internal velocity in Galactic HII regions for over a decade, compiling observations at spatial resolutions that varied from about 1 to 10 percent of the size of the nebulae (Castañeda and O'Dell 1987, Castañeda 1988, Fountain, Gary and O'Dell 1979, 1983a, 1983b, Mufson et al. 1981, O'Dell, Townsley, and Castañeda 1988). In these studies we have found that there are velocities due to thermal gas motion, large scale flow of gas, and fine scale random motions usually referred to as turbulence. Since these observations were made at high spatial resolution, the data for each nebula must be corrected to what would have been observed had the entire nebula been observed, as was the case for the GEHR. The results are shown in the table and in the figure. One sees that the Galactic HII regions also fall into a linear relation with the exception of the Orion Nebula, which is substantially smaller than the other nebulae studied. Excluding the Orion Nebula from the set gives a relation $\log D = -0.46 + 1.43 \log \beta$ with a correlation similar to the GEHR. The slope in this relation is much less than the

value of three that would be expected for a Kolmogorov model of turbulence for HII regions having similar energy densities. This more rapid increase in turbulence with size is probably due to the large scale motions of the HII regions, which for the optically bright objects selectively includes objects in the champagne phase of their evolution.



The relation between size and $1/e$ velocity for GEHR (filled circles), and Galactic HII regions NGC 1499 (open triangle), NGC 7000 (filled triangle), S252 (open square), NGC 6611 (filled square), NGC 6514 (T), IC 1318B/C (inverted filled triangle), NGC 6523 (filled diamond), the Rosette Nebulae (R) and NGC 1976 (O).

Comparison of the results for the two data sets shows that the GEHR are all larger than the Galactic HII Regions, the GEHR being about ten times larger at the same value of β , and that the slope of the relation is slightly different. Had we used the core diameters where available, the GEHR would have been only about three times smaller. The most straightforward interpretation of the difference is that the GEHR are actually complexes of HII regions like the Galactic objects. In this case the size would be determined by the “packaging” of the nebulae and the inferred velocities would be the addition of the values of the individual regions together with any random motions. A detailed numerical model with the number of HII regions decreasing in number with increasing sizes shows that the slope in the figure should vary between GEHR and HII regions in the same sense as shown. This interpretation could be tested by observing GEHR down to sizes that overlap the Galactic sample, in which case one would expect to see a wider spread of velocities in a given size range since individual large regions would begin to be observed in addition to the complexes.

In summary, we see that the size-internal velocity relation for GEHR that is used for extragalactic distance determination is based on the same physics that govern this relation for Galactic HII

regions, which makes this method much less *ad hoc* than first appears; however, the GEHR seem to be complexes of multiple HII Regions, which gives them a different zero point in their calibration.

TABLE 1
Expected Velocity Widths of Galactic HII Regions

Object	Diameter (pc)		Log D (total)	β_{OBS} (km s ⁻¹)	Standard Deviation*	$\sqrt{\beta_{\text{OBS}}^2 + \text{SD}^2}$	References ⁺
	studied	total					
NGC2237-46	15.0	15.0	1.176	16.4	0.0	16.4	1
NGC1499	9.55	9.55	0.980	15.8	2.34	15.97	2
NGC7000	40.7	40.7	1.610	16.9	5.13	17.66	2
IC1318B/C	52.4	52.4	1.719	31.2	--	31.2	2
S252	19.5	19.5	1.290	19.3	4.79	19.89	3
NGC6611	20.1	20.1	1.303	16.5	4.62	17.13	4
NGC6514	0.71	7.0	0.845	8.8	2.48	9.11	5
NGC6523	1.0	11.6	1.064	7.42	5.65	9.33	5
NGC1976 A+B	0.3	1.0	0.0	7.05	7.29	10.14	6

*Calculated standard deviation in all radial velocities, scaled to the full size of the nebula.

⁺(1) Fountain, Gary and O'Dell 1979, (2) Fountain, Gary and O'Dell 1983a, (3) Fountain, Gary and O'Dell 1983b, (4) Mufson et al., 1981, (5) O'Dell, Townsley & Castañeda 1987, (6) Castañeda 1988

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