TURBULENT AND ORDERED MOTIONS IN HII REGIONS

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Summary

The HII regions morphology have suggested, from the beginning of this century, the evidence of internal motions, very few gas radial velocities (RV) on the brightest "nebulae" had been obtained, because of obvious technical difficulties. The modern Fabry-Perot interferometers and the new Integral Field Spectrograph provide abundant RV fields at various scales in the interstellar gas. New ways in imagery, owing to these new instruments, lead to a better analyse of both, the velocities field and their precise morphology free of stellar, dusty, and non thermal continua. The richness and the quality of RV data, a better understanding of the expansion phenomena authorize again a rebirth of the turbulence observations of the ionized interstellar gas.

Key words : *HII regions - Ionized gas kinematics - turbulence - Imaging spectrography.*

Introduction

As soon as photographs of the galactic nebulae have been obtained hundred years ago, the chaotic morphology, as well as some frequent circular shapes of the gas was suggesting some evidence of various motions. However, it is at the beginning of the XXth Century that the first extended spectrographic radial velocities (RV) mapping permitted to confirm, at least for the brightest nebulae, (mainly the Orion Nebula), the reality of such a various RV.

The internal motions

Cambell and Moore (1918), using the radial velocities spectrograph of the Lick Observatory 36 inch refractor, after a laborious point by points work of 400 hours observing time, mapped 86 RV of the Orion Nebula, but earlier Fabry, Buisson and Bourget (1914) obtained, in once (45 min exposure time), owing to the first application of the Fabry-Perot "Etalon interférentiel" (F.P.) at the focus of the Foucault 80 cm telescope of Marseille Observatory (Courtès, 1986), a direct RV mapping on a field of 4' diameter. The "irregularities of speed which may amount to 1 about 10 km.s^{-1}" had been noted. The first interpretations were oriented :

1°) **To the kinematics** of the emission clouds ; their rotation ("Circulatory movements") (Fabry and Buisson, 1911) and more seriously (by analogy with the planetary nebulae) their expansion. The 1914 observations suggested "rotary movements" that have not been confirmed by Campbell and Moore (1918). In fact, Buisson et al. had prudently noted : "rotary movements but with numerous irregularities". They noted also, in the whole body of the nebula : "areas having uniform mean RV".

2°) **To the physics** of the ionised medium. The emission lines profiles giving the temperature : $\Delta\lambda = \lambda.0.78.10^{-6}\sqrt{T/M}$; the temperature estimate corresponding to the interference limit when one increases the interference order, was 15.000 K. Buisson and al. were perfectly conscious of the "too high" evaluation of this temperature caused by the difficulty of estimation of the vanishing fringes in the complete filling of the "free spectral range" of the etalon. In fact, this measure, before the invention of the microphotometer, was wrong, especially in the evaluation of M for the 3726-29 lines. The authors missed the right interpretation, the [OII] lines, given later by Bowen (1927) and Croze and Mihul (1927), Courtès (1986).

The HII regions morphology

Before any consideration on the turbulence and ordered motions, it is important to note that the modern HII region observations permit to select three main types having their morphology related to the gas kinematics.

Type 1) The condensed classical "Strömgren spheres", very similar to the ones of the Milky Way, the LMC-SMC, M33, M31, etc. (Courtès, 1977).

Type 2) The bubbles and super bubbles, especially detected since the work of Meaburn (1978) and Meaburn (1980) as well as the high contrast Fabry-Perot pictures and the first velocities fields of 43 shells in the LMC (Georgelin et al., 1983).

Type 3) The diffuse and filamentary large scale extended emission, similar to the ones recently detected in the Galaxy (Sivan, 1974), M33 (Courtès et al., 1987) and in M31 (Boulesteix et al. 1987), (Ciardullo et al., 1988).

Type 4) Gas "ejections", small scale, the Crab. neb. "jet". Large scale nuclei activities in galaxies NGC 253, NGC 4258, etc ...

The diffuse and filamentary large scale structures are the superimposition of many very extended bubbles at various evolution and deterioration stages (for example, the differential rotation in case of M33 and M31). From the first observations in the Galaxy (Courtès, 1960), it was obvious that the filaments were most of the time, bidimensional shells, seen tangent to the line of sight.

There is between types 1,2,3 many intermediate morphologies linked to the various formation origins, but often due to simple evolution steps. The selection between 2 and 3 is often very vague (Tenorio-Taglé and Bodenheimer, 1988) in spite of a relatively clear selection between 200 pc diameter bubble and 750 to 1144 pc, super bubbles (Goudis and Meaburn, 1978) and Meaburn (1978). The stellar content, the gas density and the dust, the radio and Xray content are also very important for interpreting different initial conditions.

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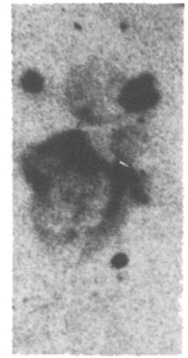

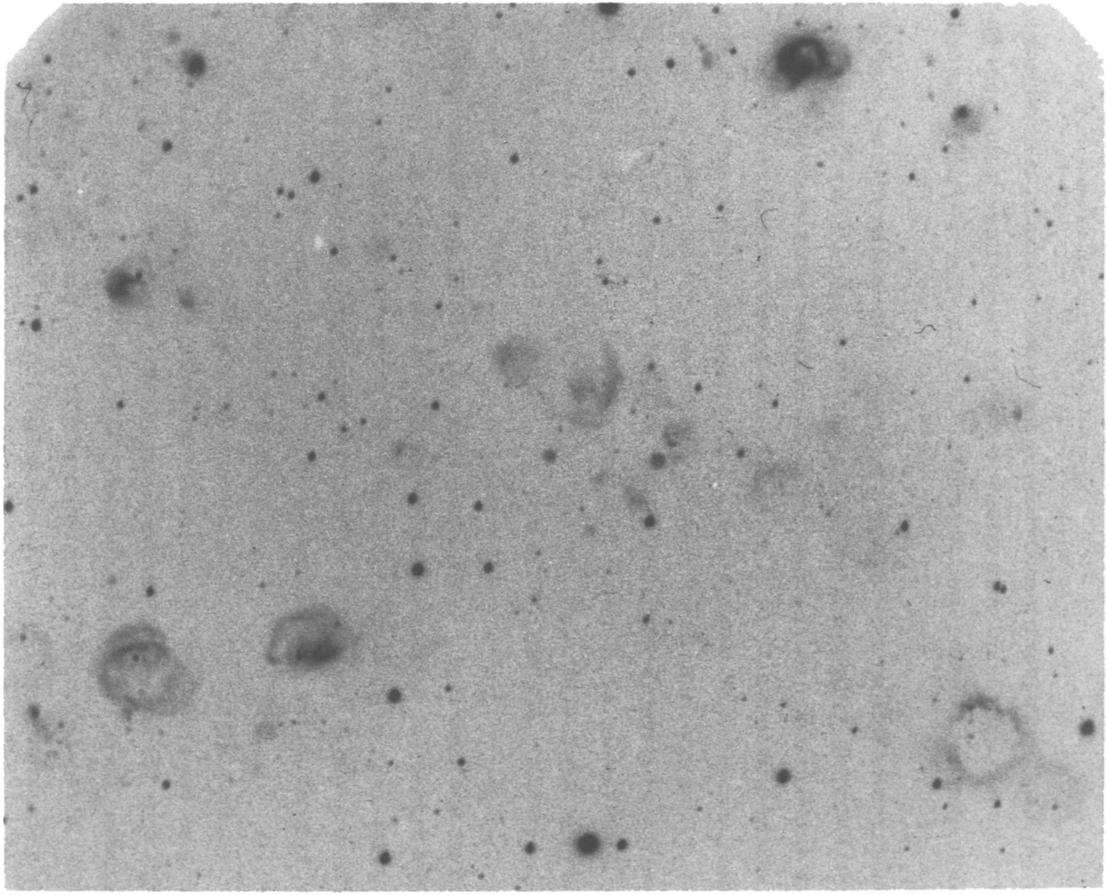

A peculiar example of large sized possible shock wave in Z 100 (top)

(Courtès et al., 1987)
(Gull and Sofia, 1979)

Picture obtained with the 6 m USSR Zelentchouk Telescope equipped of the french F/1 focal reducer.

Various expansion structures in M33 (Courtès et al., 1987)
One notes Tenorio-*Taglé HII regions* at the top (left and right)
Secant bubbles (bottom - left). Active and "fossile" bubble (bottom - right).

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The ionized gas motions

After numerous RV surveys of these phenomena, one could conclude that the morphologies are mainly dependant, among various kinematical phenomena, to expansions of different origins (see Plate 1) :

a) Classical symmetrical Strömgren sphere expansion, already found for type 1 (Deharveng, 1973), (Georgelin et al., 1983).

b) Interaction with stellar wind of more or less condensed star clusters in type 2 (Dyson, 1979), (Laval, 1989, this Colloquium).

c) Bow shocks generating, in composition with the velocity of the star, parabolic profiles layers (bubble p (N185) in the LMC (Georgelin et al., 1983), like in M33 (see N.N. 261-249 and Z100 in Courtès et al., 1987) ; see also Van Buren and MC.Cray (1988), Melnick, (1977), Gull and Sofia (1979).

d) Supernovae blast waves, conducting in their extreme cases to type 3.

e) "Champagne bottle effect" (Ténorio-Taglé, 1979) like in 88, 218, 632 and Z 112,115, 197 of M33 (COURTES et al., 1987) (6 case in M33),

f) Large scale galactic winds belonging to the extension of type 3.

If we want to clarify by some classification, we can, first, imagine only a morphology's coefficient of symmetry, starting from the almost perfect spherical (or ring) shape often at the outer parts of the galaxies (Courtès et al., 1987) to some degrees of segmentation and final complete dissipation in the interarm and central areas affected of the differential rotation. The relation with the diameter of the bubble in parsecs and, if possible, the nature of expansion energy would be considered (Meaburn, 1978). The best hope is in the most quantitative and accurate RV methods, given by the modern instruments.

TABLE 1

RV Expansions from Georgelin et al., 1983

Moderate expansions			Strong expansions		
N 30	35 km.s^{-1}		N 70	60 km.s^{-1}	
N 44 BC	30	Xray	N 103 B	20	
N 51 D	40	WR		75	SNR
N 75 ADE	30		N 185	70	
N 62 A	20		N 135	220	SNR
N 79	30		DEM 316		
N 84	20				
N 100	20				
N 144	25				
N 186	30	SNR			
N 204	20				
N 221	25				
DEM 89	20				

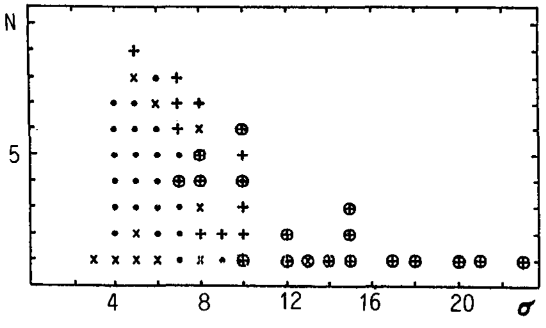

Fig. 1 : Histogram of the velocity dispersion σ The symbols are surronded by a circle when Georgelin and al. (1983) have indicated a shock velocity.

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Interference radial velocities : The very deep and extended radial velocities mappings owing to the wide field Fabry-Perot methods (Georgelin et al., 1983), (Caulet et al., 1982) (Laval et al., 1987), show that the largest expansion RV are related to the HII regions close to a general circular shape, unique or complex.

Kinematics of the optical emission lines - Need of resolution and accuracy : interference methods have given for the first time the precise profile of the emission lines because of the fact that their resolution is independant of the brightness and can reach beyond the expected width of the line without lost of sensitivity. This is not the case in the conventional nebular spectrograph in which the line profile, for high resolution, is much broader than the geometrical width of the slit image (Courtès, 1972). Most of the recent observations have been obtained owing to the Hα and [NII] lines, some remarks have to be made on the Hα emission.

The quality of the Hα emission : The width of the Hα line is affected by :

a) The fine structure of H atomes ($\Delta\lambda = 0{,}14$ A),

b) The temperature : $\Delta\lambda = \lambda\, 0.78.10^{-6}\ \sqrt{T/M}$, with, $M_H = 1{,}008$

c) The turbulence (often complicated by superposition along the line of sight of emissions completely independant of the observed structure. In this case, mean radial velocities, profiles, and other lines, [OII], [OIII], [SII], etc.. can help the discrimination). See, for example, the Münch (1958) observation of [OII] compared to [OIII] in the Orion Nebula.

d) The general internal motions at the scale of the space resolution of the instruments.

Fabry and al. (1914) noted first that the effects b) and c) can be disconnected in comparing profiles of Hα with heavier atomes like O, N or S. Münch remarked the same gain of resolution in using [OII] lines instead of Hγ in his first high resolution survey of the 3 x 3' trapezium field in the Orion Nebula with the 200" telescope coudé 4,5 $A.mm^{-1}$ spectrograph (Münch, 1958). For example, the temperature broadning being function of the square root of the atomic weight, the [NII] 6584 A line is about 3.7 times narrower than Hα (Courtès et al., 1968), (Courtès, 1988). When [NII] is bright enough it constitutes the best way to detect and measure with a great accuracy the expansion splitting of the bubbles (L. Deharveng, 1973). One notes, in this case in the Orion Nebula, and with a spectral resolution of 7.10^4, the remarkable continuity of the expansion and all the considerations of Campbell and Moore as well as those of Fabry et al., and Münch (1958) or Wilson et al. (1959), found a very simple interpretation, the wide fields reveals the general expansion structure, independant of the small scale motions. Anyway, Hα is sometimes, narrow enough, to discriminate for example several components with expansion of 30 km.s^{-1} in the LMC, spectacular case of the shell situated at α_{1975} = 5 h 41 min 5 sec ; δ = - 69° 25'. The radius of the sphere is ρ = 475 pc (Caulet et al., 1982). The famous complex shell of 30 Dor Nebula shows some places of empty shells (Cox and L. Deharveng, 1983) or at least, the evidence of a larger density at the inner surface of the spheres as it was noted since the beginning of the Fabry-Perot observations (Courtès, 1960 ; Courtès et al., 1968). The LMC bubble observations of Georgelin et al. (1983) show clearly : i) a generalization of the expansion, ii) a relation between the velocity dispersion and the presence of shocks (Fig. 1).

New methods of observations

The static Fabry-Perot equipped with a focal reducer (Courtès, 1952) (Courtès, 1972) was used extensively but, an important improvement has been the Fabry-Perot Field Scanning Interferometer method designed first by B. Tully (1974) and generalized by the TAURUS instrument (Atherton et al., 1982) and by the CIGALE instrument using photon-counting detector (Boulesteix et al., 1983). A stellar wind bubble N62B was observed with this new instrument providing imagery in any choosen radial velocity (Laval et al., 1987). The authors fund a semi-spherical expanding cavity (Ve = 35 km.s^{-1}) around a 08 I star, open towards the observer. The mean diameter is 50 pc. The main advantage of CIGALE as any Fabry-Perot (Courtès, 1977) designs is to provide, in fact a very selective filter (few tenths of one Angström $\Delta\lambda = (\lambda_2 - \lambda_1)/F_{(\lambda_2 - \lambda_1)}$, the FWHM of the interference filter being $\lambda_2 - \lambda_1$ and F the finesse of the etalon) with consequently a perfect elimination of the stellar continuum. (See for example the complete elimination of the stars in Laval et al., 1987 or in Courtès (1988).

The field scanning interferometer could detect, in any field, for example 15°, by adaptation to small or large telescopes and different resolution (Caplan et al., 1985) in survey mode, all various emission features owing to their different radial velocities and their line broadning. This is a new other way of selection of the different physical natures of the HII regions.

The real geometry of the expanding shells : the high spectral resolution of the Fabry-Perot method shows that the thickness of the HII layer is very small in comparison of the mean radius of the spherical or pseudo-spherical shells. This is detected by the clear separation of the emission lines in two radial velocities components. Others arguments went for the early observations of the "rim effect" and the RV deviations in front of the "elephant truncks" (Courtès et al., 1962). A very peculiar, small scale case, the Crab neb. "jet", was discovered by van den Bergh (1970), it is, in fact, an unique cylindrical expansion case (Shull et al., 1984) and CIGALE RV mapping (Marcelin et al., 1989).

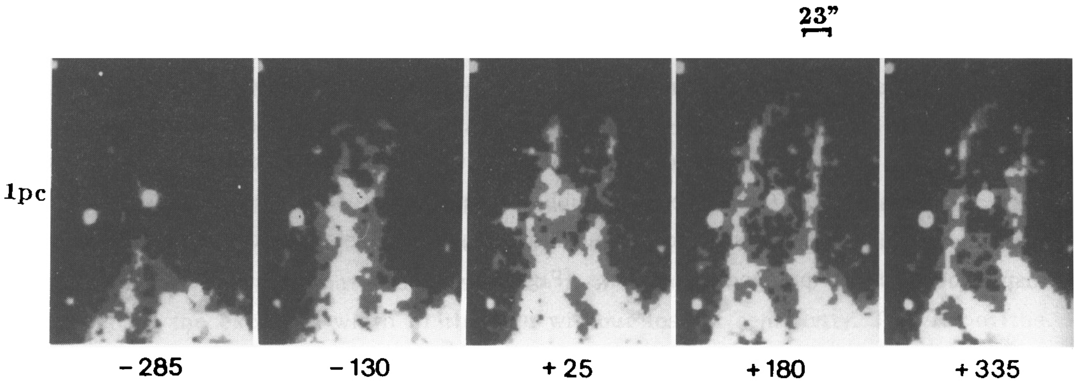

Fig. 2 : A case of cylindrical expansion : Ve = 260 km.s^{-1} [OIII], RV imagery of the Crab.neb.jet. Fabry-Perot field scanner CIGALE. (Marcelin et al., 1989)

The turbulence

The dispersion of the RV could be due to others reasons than expansions, internal group motions or ever rotations. But it was not possible to be envisaged before the turbulence concepts had been developped (Kolmogoroff, 1941, Chandrasekhar, 1949, von Karman, 1951). In the years 1950, the velocities mapping had not been developped since the 1918 last Fabry observations. Then, the first test of turbulence of the interstellar gas was made by L.H. Aller (1951), not from RV data (non existing at this time) but from the brightness fluctuations of the Hα emission on a relatively homogeneous field of filamentary and loop structures. The key idea of this method, suggested also by Pikelner (in Münch, 1958), concerns the relation between the Hα brightness $I(x)$ and its fluctuations point to point. $I' = I(x) - Io$, the density repartition of the gas supposed to be produced by the turbulence. Aller used this expression : $g(r) = \Sigma I'(x). I'(x + r)/ \Sigma I'(x)^2$ with r taking successives values in a field of 4° wide in Cygnus. Aller found a diameter of 10 pc for the largest eddies in good agreement with the mean diameters of the loops of the ionized gas.

The turbulence theory considers a "hierarchy" of eddies, large to small with, at the end, the dissipation of energy in very small eddies in form of heat. This mechanism leads to a relation between the relative velocity of two points v and their distance l ; $v = k\, l^{1/3}$ the Kolmogoroff law. At the same period, von Weizsäcker (1951) was suggesting a direct approach from the statistics of one component of the gas velocity, the RV, in various points of the medium and their corresponding distances. He demonstrated that the observed fluctuations of velocities can be related to the Kolmogoroff theory, valid for sufficiently high Reynolds numbers and an isotropic medium. Applied with success as a first verification on the Campbell and Moore data (von Hoerner, 1951), the 86 RV of the

ORI nebula verified the v = k $l^{1/3}$ law (with possibility to reach 0,4 exponent instead of 0.33, may be due to a compressibility effect, von Weizsäcker, 1951).

The generalization of the Fabry-Perot interference method provided abundant RV mappings up to 20' from the "Trapezium". The von Hoerner results were confirmed (Fig. 3) (Courtès, 1953, 1955) and extended to several others HII regions (Courtès, 1960). The large HII region around λ ORI (12° app. diam), classical pure Strömgren sphere, was giving $l^{1/3}$ with a break of the correlation about 10 pc, close to the Aller evaluation (Fig. 4).

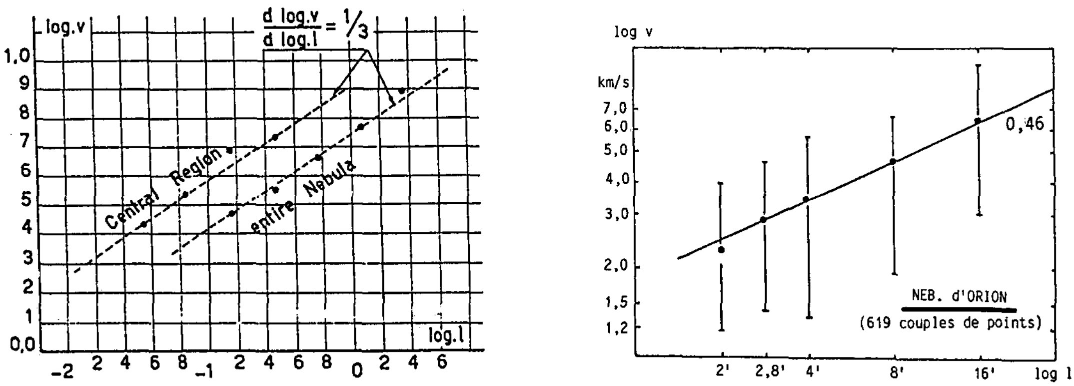

Fig. 3 : First verification of the Kolmogoroff law on the ORION nebula (from S. von Hoerner, 1951 (left) and from G. Courtès, 1953)

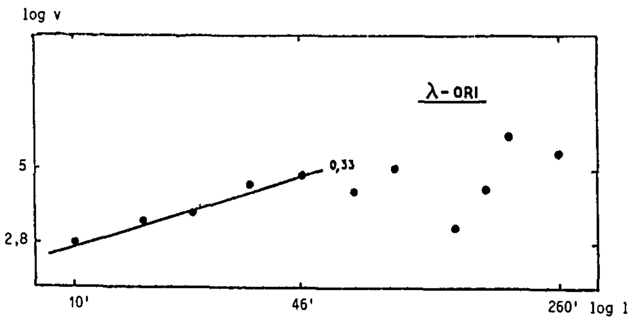

Fig. 4 : The Kolmorogoff law in λ ORI, HII regions (G. Courtès, 1953).

Former observations (Courtès, 1960) on the Horse Head NGC 434 nebula near ζ ORI having a more chaotic morphology were giving several values of the exponent n, n = 0.44, n = 0.33, n = 0.0 ± 0.1 ; n is relatively consistent with the von Hoerner results (n = 0 corresponds to the most confuse morphology of the field) (Fig. 5).

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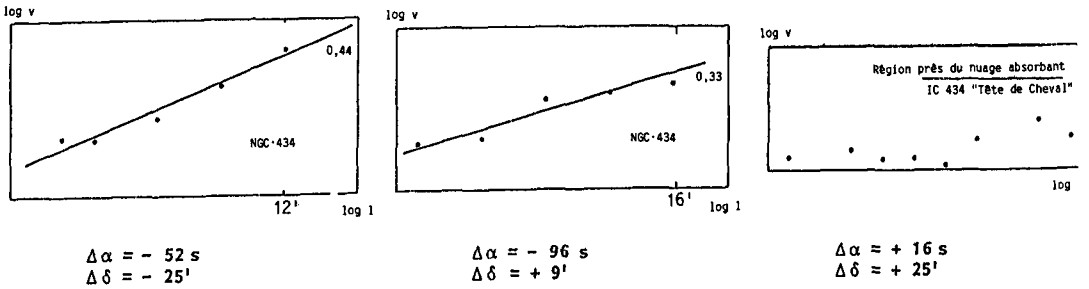
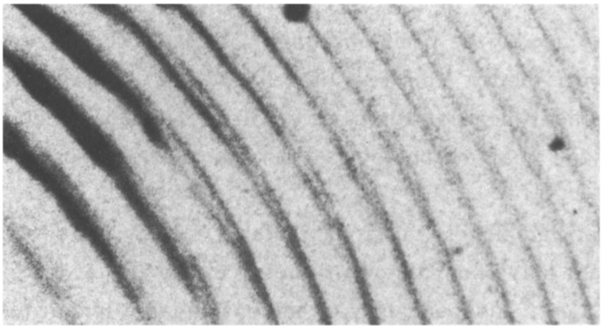
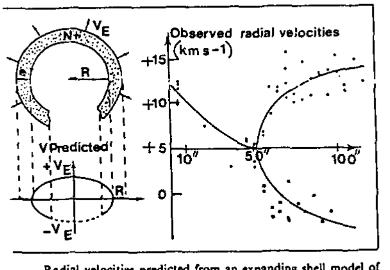


Fig. 5 : Differential coordinate are from ζ ORI.

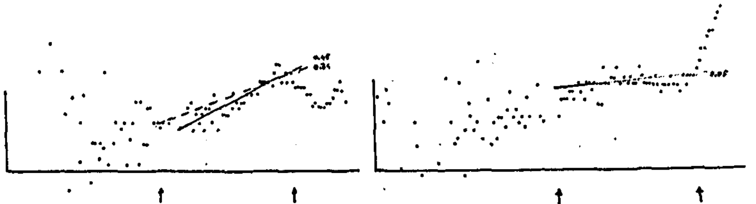
Another important approach was discussed (Münch, 1958) with a rich and completely different material provided by the multislit 200" "coudé" spectrograph of Wilson et al., 1959 (600 RV on a 40x40" field). The whole survey comprised 50.000 RV. Münch clarified the turbulence problem owing to an exceptional space and spectral resolution. The splitting of the lines appears from place to place at the scale of a few arc seconds, the RV were obtained with an accuracy of 0.5 km.s^{-1}, the thermal and turbulent components were disentangled owing to the atomic weight dependance of the profile (see above). Münch found again the $l^{0,33}$ relation but remarks that the turbulent component of the line width is comparable to the variations of velocities across the gas in emission. This remark concerning the geometrical depth along the line of sight that could be of the same order than the distances of the measured points, has not any more the same meaning since the recent observations of, for example, the ORI nebula. The emitting gas is concentrated in well defined expanding layers (Courtès, 1960), (L. Deharveng, 1973). When one observes couples of RV points across the nebula, each value is the average of a relatively short depth along the line of sight and the integrated RV of each point corresponds to a relatively very small volume of the gas. The projected distance of the points is of one or two order larger and the statistics Δv versus Δl finds again a real meaning. Louise and Monnet (1970) obtened also, from about 10.000 couples of RV points, the $l^{1/3}$ Kolmogoroff law on M8. If we except the Louise and Monnet work, and Courtès et al. (1976), the turbulence has been the sleeping Lady during 27 years, because of the dissuasive effect of the outstanding Münch work. Roy and Joncas (1985) reinitiated the turbulence statistics owing to 40983 RV of S.142. Recently, Roy et al. (1986) were doing an important observation of 47 extragalactic HII regions, after similar work of Dyson (1979) and Melnick (1977). They found a $D = f\,(W^n)$ with $n < 1.6$ between the linear diameter D and the velocity width W, confirming Melnick (1977). The canadian authors are suggesting the turbulence as a possible interpretation of the velocities dispersion, function of the linear size. However, L. Deharveng (1973) and Georgelin et al. (1983) have shown that the expansion of the HII regions (classics and SNR) can play (in the case of integration of the whole HII region), a considerable part of the velocities dispersion. In fact, it is necessary, to disentangle expansion, temperature (often very different from point to point and from various HII regions (Louise et Monnet, 1970), peculiar motions, especially in the case of secant HII regions or superimposition of SNR (Laval et al., 1989), before giving any interpretation of a global turbulence.

Turbulence of the ORION expanding layers : Courtès et al. (1976) were using for the first time, this well defined geometry of the expansion sheets of the ORI nebula (L. Deharveng, 1973), clearly splitted on large areas of several arc minutes, these sheets have a very small thickness in respect to their mean diameter (Fig. 6) ; they are giving, owing to the large field of the F.P., a completely different appreciation of the same kind of splitting observed at a much smaller scale by Münch. We found $l^{0.46}$ for the receding layer, may be affected by compressibility and $l^{0.06}$ for the approaching one, certainly more chaotic. The receding layer is much brighter than the approaching one, confirming the L. Deharveng (1973) model of a cavity open towards the observer. If the F.P. had been unable to select the two expanding components, we would have obtained a relation around $l^{1/3}$. One sees that the space and spectral resolution are necessary for a clear understanding of the turbulence. On the contrary, the wide aperture F.P. etalon method integrates all this broadening effects without any possibility to disentangle them. It is better, when the apparent diameter permits it, to use Fields Scanning F.P. (TAURUS or CIGALE) or the Integral Field Spectrograph I.F.S. TIGER (Courtès et al., 1987).





Radial velocities predicted from an expanding shell model of : Orion Nebula; radial velocities observed in region A; the ıscissa is the distance from the outline of the Nebula in a direction rpendicular to this outline



Break of linear relation log v/log I
Receding layer + Ve
(higher brightness)

Break of linear relation log v/log I
Approaching layer - Ve
(fainter brightness)

Fig. 6 : ORI NEB Statistics on 10730 RV
(G. Courtès, L. Deharveng, M. Joubert and F. Genova, 1976), (L. Deharveng, 1973)

These last months, we exploited, with Boulesteix and Lecoarer, the fantastics number of RV given by CIGALE through an automatics $\overline{Va} - \overline{Vb} = k\ (\overline{La} - \overline{Lb})^n$ computations of several hundred RV couples. It is then possible to select several areas in various parts of an HII regions, center (where expansions splitting are expected), rims (free of this effect) superimpositions of different morphological features, filaments, etc.., one obtains, in a few minutes time for each area, the RV statistics in function of the distances. We found convenient to graph in log. directly the power law. This method was applied to N 62 (Laval et al., 1987) and to Sh 305 (Y. Georgelin, 1989) (Fig. 7). The $l^{1/3}$ law appears again in some clear limited structures. Gull et al. (1974), using an echelle spectrograph and the structure function $B(r) = [v(r') - v(r'')]^2$ (Kolmogoroff, 1941), (Scalo, 1984), (O'Dell, 1986) have found extension at the $l^{1/3}$ law from 0,3 to 30 pc in NGC 7000, S252 and NGC 1499.

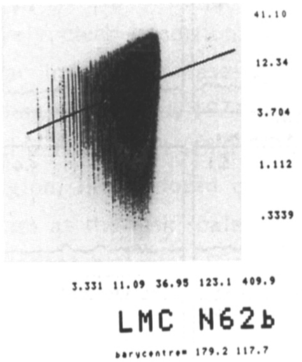
The NGC 434 results (Courtès, 1960) were a first attempt to see how the l^n can change in one specific HII region. One sees that n = 0 appears often in the brightest area where several emission layers or clouds are superimposed on the line of seight, but is is not a general rule because some bright areas are often at the bright front surface of dense absorbing clouds with an effective depth, in fact very short, this is likely the case of NGC 434 ($\Delta\alpha$ = 96 s ; $\Delta\delta$ = + 9' from ζ ORI as well as λ ORI, where the HII material is "coating" a concave cavity in the HI medium. The other case of NGC 434 with n = 0.44 is being interpreted as a compressibility effect n = 0.33 + ε (von Weizsäcker, 1951). Recently Roy and al. (1986) found again $l^{1/3}$ law in M17. We agree with Roy et al. and O'Dell (1985) that the l^n law is certainly due to the turbulence, but can not be considered as a pure verification of the Kolmogoroff theory. This test of a l^n law has anyway the main advantage to provide a very convenient mean of appreciation of the RV repartitions and then, to understand much better the real morphology in surface and in depth.

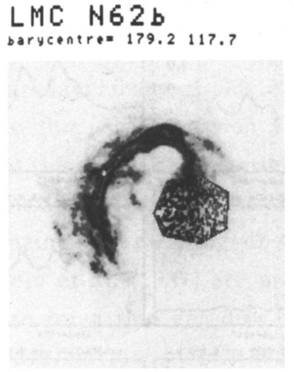
In the case of well identified molecular clouds, this thin HII layer closely linked to the surface of this cloud could inform, not only about its own turbulence, but also at some other frequency of the molecular cloud itself, independantly of the unavoidable lenght of integration (due to the radio detection) along the line of sight in the molecular cloud.

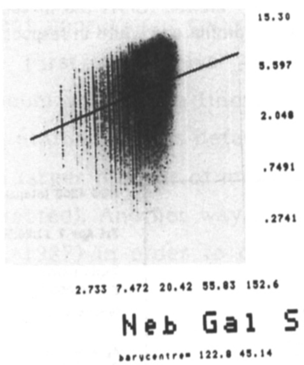
Generalization at the galaxies scale

a) <u>The largest eddies of the turbulence :</u>

Since the first applications of the turbulence, it was suggested (von Weizsäcker, 1951) that the gas in its most extended scale, in the rotation plane of the galaxies (Courtès, 1977 ; Courtès et al., 1987), could verify some constant distorsion of the interstellar gas by the differential rotation of the galaxies. Consequently, the turbulence would create and also, destroy gas clouds in a hierarchy from large eddies to smaller







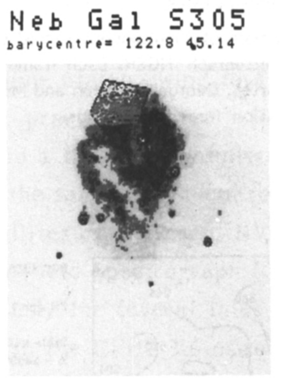
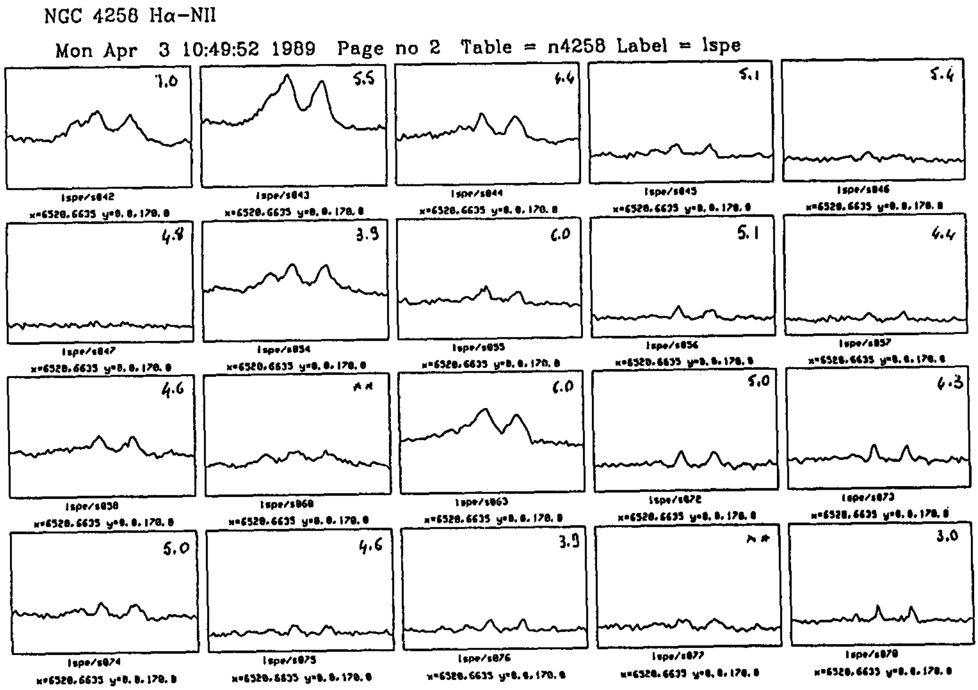


Fig. 7 :

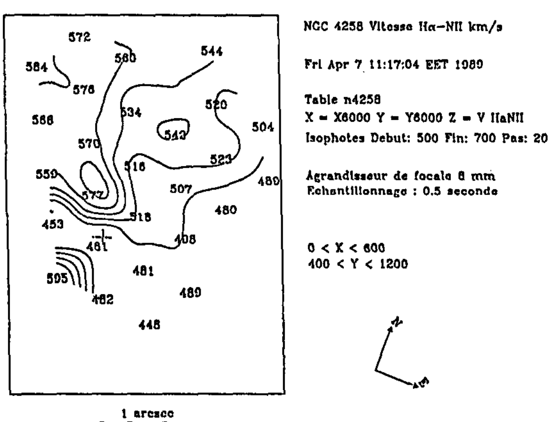
Modern automatic evaluation of the Kolmogoroff law from CIGALE Field Scanning Fabry-Perot (see text).
The contour on the Hα picture corresponds to the RV statistics on the right. Other positions in the same nebulae are giving other slopes. The ones close to 1/3 are always in the places where the morphology suggest dissipation and eddies.

One finds n = 0.30 for LMC N62b (Y.M. Georgelin, 1989)
and n = 0.31 for Galactic S305 (A. Laval et al., 1987)

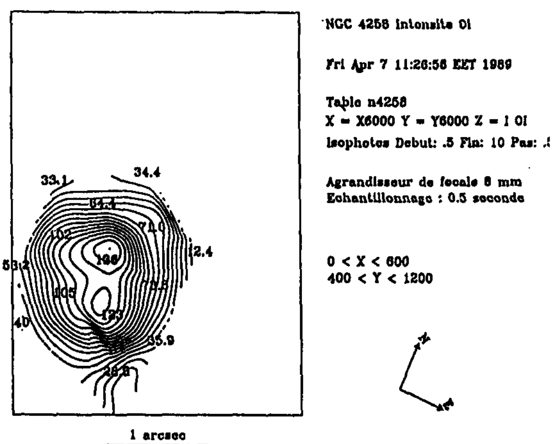
(Courtès, Boulesteix, Le Coarer, 1989)



Example of simultaneous record on CCD of Hα [NII] spectra of NGC 4258 nucleus owing to the Integral Field Spectrograph TIGER. Each frame corresponds to focal image elements of 0.5 arc.sec (CFHT 3.6 m telescope, Courtès, Georgelin, Bacon and Monnet, 1989). One sees the variations of line profile and width in respect to the position from the nucleus.



Radial velocities map (Hα, [NII])



Detection owing to OI line reconstructed imagery of a maximum 0.45 arc.sec from the nucleus on the direction of the anormalous arms. This emission is likely due to the interaction of the "jet" on the ISM.

Fig. 8 : Detection of large RV phenomena and shock excited emission at the galaxies scale.

sized eddies. We saw, from the observational point of view, how the quasi-bidimensional nature of the gas repartition is playing a fundamental role in the simplification of a relatively clear conditions for a turbulence detection (thin layer/large field, etc..). A peculiar interesting case is given by the diffuse galactic thin disk emission (340 pc according to Monnet, 1971) in some nearest galaxies like M31 and M33. The case of the central parts of M31 (Ciardullo et al., 1988) is interesting because of the lack of classical HII region, likely doted of their own expansion, compromizing the meaning of the RV statistics at the disk scale. The RV observations of Boulesteix et al. (1987) are providing an abundant material. Ciardullo et al. (1988) concluded also for a thin gas disk (80 pc), possibly more tilted than the equatorial plane of M31. We have, in spite of this difference of tilt (in fact in the good sense), a minimum of good conditions to extract from the RV CIGALE mapping the turbulence and the hope to obtain the size of the eddies along the spiral structures. The splitting of the [NII] 6584 A line found by Boulesteix et al. will reveal, may be another interpretation of the geometry and dymamic of the ionized gas in the M31 central regions.

b) The large scale motions and shocks

The galaxy nuclei and their surroundings are needing other observational approaches. The excess of continuum of their light recommands the Fabry-Perot methods, but a very efficient improvment could consist in a double pass of the same étalon owing to a corner prism. First tests give 0.8 monochromatic transmission, practically free (10^{-4}) of continuum and with a finesse F' = 1.55 F low enough to avoid a too low transmission due to the étalon flatness defacts (main risk when one looks for the same continuum rejection with a larger number of multilayers (faint emission line satellites of diffferent RV should be detected). Another way is to use an lenses array Integral Field Spectrograph (Courtès et al., 1987) in order to obtain velocities field, simultaneously for several lines and to detect shock spectrographic criteria. Recent OI detection with the CFHT 3,6 m telescope at 0,45" of the nucleus of NGC 4258 are especially encouraging for this new methodology (Fig. 8).

Conclusion

The turbulence and in general the analysis of the motions of the ionized gas can be studied now much more carefully owing to the modern interference and spectro-imagery methods. The reduction of the data owing the structure function or the simple Kolmogoroff correlation are needing more experience, but the last published results are showing that these reductions are more dependant of the instrumentation and observational conditions than of some excessive computation sophistication.

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Discussion:

ROY: I would like to point out to the superb work of Castañeda (1988, Ap. J. Suppl.) recently published on the [OIII]λ5007 velocity field and structure functions of a large sections of the Orion Nebula. This work was done with an echelle spectrograph. How do echelle spectrographs and Fabry-Perot spectrometers compare and differ?

COURTES: The answer is simple. If you need large spectral range, spectrographs may be needed, but not absolutely true for echelle spectrograph used with long slit (needed for RV statistics along it). In this method I would recomend the Integral Field Spectrograph (IFS TIGRE) that extends to 2D the spectrographic nebular field. Anyway the obvious and unavoidable advantage of the Fabry-Perot is to have no slits. With high resolution spectrograph the line profile is larger than the geometric width of the slites image in pure monocromatic light. The loss of sensitibity is in the ratio of these two values. Low path FP with high "Finesse" can be a good compromise for these problems. The F.P field is always much larger than one or 2D Spectrographs but the scanning time is observational time consuming!

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