# CORRECTIONS FOR VELOCITY DISPERSION IN THE TULLY-FISHER RELATION

L.BOTTINELLI[+], L.GOUGUENHEIM[+], G.PATUREL[°], G. de VAUCOULEURS*

[+]Observatoire de Paris et Université Paris XI
[°]Observatoire de Lyon
*University of Texas at Austin

The 21-cm line width is a good indication of the maximum rotational velocity in a galaxy. However, the turbulent motions affect the observed line width and must be corrected. Not taking them into account introduces both accidental and systematic errors.
A first example of this effect is the dependence of the slope $a$ of the Tully-Fisher relation:

$$- M = a \log \Delta V_{obs} + b$$

on the level at which the line width $\Delta V_{obs}$ is measured. In their 1977 paper, Tully and Fisher find the following values:

| level | slope |
|---|---|
| 20% | 6.25 |
| 50% | 5.4 |

A second example is the departure from linearity in the H-band Tully-Fisher relation obtained by Aaronson et al. (1982) (their figure 2): the narrow lines are more strongly affected by these turbulent motions.

In order to take this effect into account, we have adopted the following model (Bottinelli et al. 1980, 1982):

$$\Delta V_{obs} = 2 (V_m \sin i + V_t)$$

where $V_m$ is the maximum rotational velocity, i the inclination of the plane of the galaxy upon the plane of the sky and $V_t$ the turbulent component, calculated from an ellipsoidal gaussian model with:

$$\sigma_z = 10 \text{ km s}^{-1}$$
$$\sigma_y = \sigma_x = 1.5 \ \sigma_z \quad \text{(x and y in the plane of the disk)}$$

Our optimized corrections $V_t$, in km $s^{-1}$ are the following:



*Richard M. West (ed.), Highlights of Astronomy, Vol. 6, 283–285.*

| i | level 20% | 50% |
|---|---|---|
| 0° | 38 | 14 |
| 90° | 57 | 21 |

These corrections agree with detailed model calculations from Roberts (1978) and independent empirical determination by Fisher and Tully (1981) who give an estimate of 50 km $s^{-1}$ at the 20% level. They are far from negligeable.

Results.

Our main results are the following:

1 - The corrected line widths $W_l^c$ are independent of the level l at which the observed ones have been measured

2 - They are in close agreement with the amplitude of the mean rotation curves data from Bosma (1978). The mean value of

$$\delta_l = \log V_m - \log (W_l^c / 2 \sin i)$$

for the 22 galaxies in common are the following:

| level | $\delta_l$ | stand. deviation |
|---|---|---|
| 20% | 0.003 | 0.054 |
| 40% | -0.008 | 0.043 |
| 50% | -0.008 | 0.046 |

3 - The slope $a$ is *reduced* when corrected line widths are used. When starting from a value $a = 5$ and adding these turbulent components, the slope becomes equal to 6 (at the 20% level). Analizing Aaronson et al.'s data (1982) both in H-band and B-band, the following slopes have been obtained:

| | H-band | B-band |
|---|---|---|
| uncorrected widths | 11.2 | 7.6 |
| corrected widths | 9.2 | 6.3 |

https://doi.org/10.1017/S1539299600005244 Published online by Cambridge University Press

4 - The curvature in the Tully-Fisher relation seams to disappear when using the corrected widths.

5 - We have shown that the slope is a continuous function of the isophotal wavelength of the magnitude system varying from $\alpha$ (B) = 5 to $\alpha$ (H) = 10. Aaronson and Mould (1982) confirm that the slope is larger in the IR withs values in the range:

$$\alpha(H) = 10 - 13$$
$$\alpha(B) = 7 - 10$$

It must be also noted that Tully et al. (1982) give:

$$\alpha(H) - \alpha(B) = 4.53$$

This has an important effect on the errors in the derived distance moduli $\mu = m - M$:

$$\sigma(\mu) = [\sigma^2(m) + \alpha^2 \sigma^2(\log W_c)]^{\frac{1}{2}}$$

Adopting $\sigma(m) = 0.1$, the second term of this relation will remain dominant as long as $\sigma(\log W_c) > 0.01$
If the slopes are respectively 10 and 5 in the H and B-band, the error ratios would be:

$$\sigma[\mu(B)]/\sigma[\mu(H)] = 0.18 / 0.32 = 0.56$$

This last ratio becomes equal to 0.7 or 0.8 if the ratio of the slopes were 1.4 or 1.3 as recently quoted by Aaronson and Mould (1982).

The actual errors are in fact slightly larger in both cases when taking into account errors in sin i and in the slope $\alpha$ . The mean errors in distance moduli for our sample are in the range 0.3 - 0.5.

It can thus be concluded that the B-band Tully-Fisher relation, when using correction for turbulent motions, gives accurate distance moduli determinations.

REFERENCES

Aaronson,M.,Huchra,J.,Mould,J.R.,Tully,R.B.,Fisher,J.R.,van Woerden,H., Goss,W.M.,Chamaraux,P.,mebold,U.,Siegman,B.,Berriman,G.,Persson, S.E.,1982,preprint Steward Obs. n°383

Aaronson,M.,Mould,J.R.,1982, preprint of the Steward Obs. n°404

Bosma,A.,1978,Thesis,University of Groningen

Bottinelli,L.,Gouguenheil,L.,Paturel,G.,Vaucouleurs,G.de,1980 Ap.J. 242 L153

Bottinelli,L.,Gouguenheim,L.,Paturel,G.,Vaucouleurs,G.de,1982 Astron. Astrophys. in press

Fisher,J.R.,Tully,R.B.,1981,Ap.J. Suppl.47,139

Roberts,M.S.,1978,A.J. 83,1026

Tully,R.B.,Aaronson,M.,Mould,J.R.,1982,Ap.J.257,527

Tully,R.B.,Fisher,J.R.,1977,Astron.Astrophys.54,661