K-Band Spectrophotometric Distance to W3

Felipe D. T. Navarete[1] (navarete@usp.br), Augusto Damineli[1], Elysandra Figuerêdo[1,2], Alessandro Moises[1], Robert D. Blum[3]

[1] Departamento de Astronomia, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo, São Paulo, Brazil.
[2] Open University, UK. [3] NOAO Gemini Science Center, Tucson, Arizona, USA.

Why W3?

The spiral structure of the Milky Way is difficult to trace from our position. Giant HII regions are the best targets for this job. However, different methods give discrepant results. The Galactic HII region W3, located in the **Perseus arm**, offers a golden opportunity to compare these methods. The values for the distance of W3, and the respective methodology, are below:

a) *Radio trigonometric parallax to W3OH* (Xu *et al*, 2006) → **1.95(4) kpc**;
b) *Spectrophotometry in the optical range* (Humphreys *et al*, 1978) → **2.18(1) kpc** and
c) *Kinematic model based on radio recombination lines* (Russeil, D. 2003) → **4.2(7) kpc**.

The kinemactic model disagrees from the other methods by a factor of 2. Since our K-band spectrophotometric measurements in other HII regions also are up to 50% smaller than the kinematic method (see Elysandra Figuerêdo poster for more about this work), we selected W3 for a critical test.

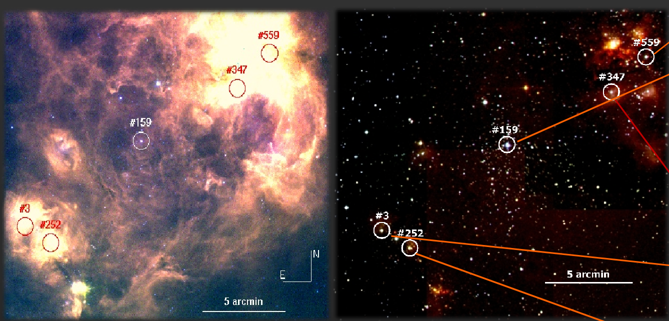

Fig 1. W3 Finding Chart. On the left, a composition of 3 images of W3 from **Spitzer** [8.0 μm (red); 5.8 μm (green); 3.6 μm (blue)] . On the right, a **2MASS** JHKs image of W3.

Object	m_{Ks} (mag)	Spec Type	M_{Ks1} (mag)	M_{Ks2} (mag)	A_{Ks1} (mag)	A_{Ks2} (mag)	D_1 (kpc)	D_2 (kpc)	D (kpc)
#159	7.61(2)	O6.5-O7	-4.24(67)	-4.12 (68)	0.28(5)	0.21(4)	1.90(30)	1.96(30)	1.93(30)
#559	8.49(1)	O7.5-O8	-4.01(67)	-3.90(67)	0.83(7)	0.62(5)	1.99(30)	2.20(31)	2.10(31)
#3	8.82(2)	O7-O9	-4.12(66)	-3.68(66)	1.11(5)	0.82(3)	1.37(43)	1.56(46)	1.47(44)
#252	9.99(5)	O9-B1	-3.68(66)	0.71(67)	1.20(9)	0.90(7)	2.25(58)	2.59(65)	2.42(62)
#347	8.90 (2)	O9-B1	-3.68(66)	0.71(67)	0.89(5)	0.66(4)	1.66(53)	1.48(57)	1.75(55)

Table 1. Object Characteristics. m_{Ks} were obtained from 2MASS catalog; M_{Ks1} and M_{Ks2} are the minimum and maximum absolute magnitudes, respectively, for each spectral type interval; stellar reddening A_{Ks1} and A_{Ks2} were calculated using Mathis's Law (Mathis, J.S., 1990) and Stead and Hoare's Law (Stead and Hoare *et al.* 2009), respectively; the spectral type and distances were obtained as described in Methodology; D_1 and D_2 are the distances obtained when considering each reddening law: Mathis as 1 and Stead and Hoare as 2, respectively; D is the mean distance.

The K-band Spectrophotometric Distance to W3

The derived **distance to W3** is **2.01 0.31 kpc**, given by the mean of the distances of #159 and #559.

The distances of supplementary stars are in accordance with these results, even their luminosity classification is not clear enough.

If all objects were considered, W3 distance goes to **1.95 0.43 kpc**.

Conclusions

We classified **five W3 stars** in O6.5 to B1 classes. Assuming luminosity class V, the **estimated distance is 2.01 0.31 kpc.**

This value is in good agreement with the method of trigonometric parallax and spectrophotometry in the optical band. The kinematic method disagrees with all other methods, giving distances 2X larger.

Observations and Methodology

Data Acquisition: The data were taken on 2008B at the **Gemini North 8 m class** telescope using the instrument **NIFS** (*Near-Infrared Integral Field Spectrometer*). **Seven O-type stars were observed** with a S/N ~ 164 and R~5200 in the K-Band and **5 of them were classified as mid to late O-type and early-B stars**.

Data Reduction: data were reduced and processed with the IRAF software and specific Gemini/NIFS scripts.

K-band Spectroscopy: Hanson *et al*, 1996 & Hanson *et al*, 2005 → Spectral Type → Luminosity Class → Distance Modulus

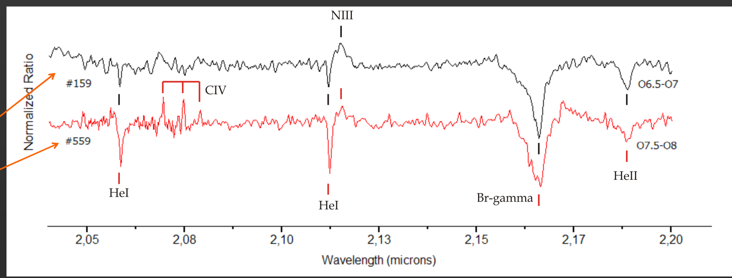

Fig. 2. Spectra of mid to late-O stars. The stellar spectra were obtained as described in Methodology.

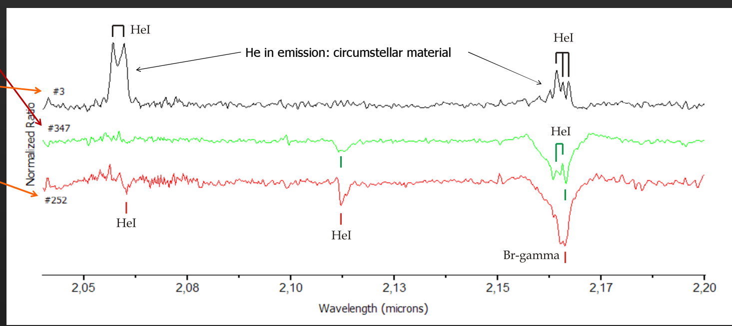

Fig. 3. Spectra of late-O to early-B stars. The stellar spectra were obtained as described in Methodology. These stars were considered as supplementary data by their doubtful classification.

Discussion

Spectral types: 2 O-type stars with firm spectral type ↔ presence of **photospheric features on the spectra.**
3 later stars → HeI and **Hydrogen** (Brγ) lines → spectral type uncertain → *supplementary data* for W3 distance determination.

Luminosity Class: stars are most seen on V luminosity class (Garmany et al., 1982)

Reddening Law: Mathis→$\mathbf{A_k}$=1.8(H-K)   Stead & Hoare→$\mathbf{A_k}$=1.3(H-K)

Possible source of errors in the kinematic method:
- Radial velocities suffer degeneration toward the GC line-of-sight.
- Distance ambiguity for directions inward of the solar circle;
- Non-rotational components: Outflow of gases from HII regions; Density-wave attractive force (up to 10 Km/s) and collisions between GMC.
- A single measurement for the entire HII gas.

The K-band spectrophotometry method:
Advantages: based on stellar photospheres, multiple targets;
The **major source of uncertainty** of the method is associated to **the flux calibration of the absolute magnitudes** (0.65 mag for O-type stars) (Vacca *et al.*, 1996), which dominates the instrumental error. The lack of luminosity class in the K-band catalogue also is a source of uncertainty.

References
Blum, R. D., Conti, P. S. & Damineli, A. 2000, AJ, 119, 1860
Garmany, C. D., Conti, P. S. & Chiosi, C. 1982, ApJ, 263, 777
Hanson, M. M., Conti, P. S. & Rieke, M. J. 1996, AJ, 107, 281
Hanson, M. M. *et al.* 2005, AJ, 161, 154
Humphreys, R. M. 1978, AJ, 38, 309
Koornneef, J. 1983, A&A, 128, 84
Mathis, J.S. 1990, ASPC, 12, 63
Martins, F., Schaerer, D., Hillier, D.J. 2005, A&A, 436, 1029
Russeil, D. 2003, A&A, 397, 133
Stead, J. J. & Hoare, M. G. 2009, MNRAS 400, 731
Vacca, W. D., Garmany, C. D., Shull, J. M. 1996, ApJ, 460, 914
Xu, Y., Reid, M. J., Zheng, X. W. & Menten, K. M. 2006, Science, 311, 54