The AGB Population of NGC 6822: A Critical Assessment of the C/M Ratio

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1. Abstract

The spatial variation of metallicity in the Irregular dwarf galaxy NGC 6822 has been studied through the use of the C/M ratio. Using high quality near-infrared (J,H,K) photometry, carbon- and oxygen-rich AGB stars have been isolated and their ratio, has been used to derive the [Fe/H] abundance within the galaxy. The [Fe/H] abundance and the distribution of the AGB population has then been analysed as a function of galactic radius. During this study a critical assessment has also been made of the feasibility of using the C/M ratio as a method for the accurate determination of metallicity in resolved galaxies.

2. The C/M Ratio

During the final evolutionary phase of an asymptotic giant branch (AGB) star, the photospheric abundance of carbon can increase until it is greater than the abundance of oxygen, C/O>1, making it a carbon star.

The C/M ratio refers to the number ratio of carbon-rich (C-type) AGB stars to oxygen-rich (M-type) AGB stars. The C/M ratio is strongly affected by the metallicity of the environment where a high ratio implies a lower metallicity. It can therefore be used as an indirect indicator of metallicity and has the potential to provide information about the large scale distribution of metals across the surface of resolved galaxies.

Battinelli & Demers (2005) give a direct relation between [Fe/H] and the C/M ratio, this was modified Cioni et al. (2009) and is given below;

$$[Fe/H] = -1.39(\pm 0.06) - 0.47(\pm 0.10)\log(C/M)$$

We have used this relation to look at the spatial variation of metallicity in the Local Group galaxy NGC 6822.

3. NGC 6822

NGC 6822 is similar in size and structure to the Small Magellanic Cloud. Its close proximity (~490 kpc [3]) and apparent isolation provide a unique opportunity to study galactic evolution, possibly without the influence of other strong dynamical factors. As such it has been studied many times, and a number of metallicity estimates are available in the literature. It is therefore an ideal candidate for the application and assessment of the C/M ratio method to examine the metallicity and its spatial distribution.
NGC 6822 is made up of three principle structures; 1) a central stellar bar which is clearly visible at optical wavelengths, 2) a large elongated envelope of neutral hydrogen and 3) a proposed stellar spheroid of uncertain dimensions made up of old- and intermediate age stars.

We isolated the C- and M-type AGB star populations using colour magnitude diagrams (CMD's). Due to differences in the molecular opacity of the atmosphere, C- and M-type stars diverge in a (J-K,K) CMD of the galaxy, although there is some overlap at the colour boundary. The AGB sources were selected as having a K-band magnitude brighter than 17.41, and the C- and M-type AGB stars were separated using a J-K colour of 1.2 [4] – see Fig.1.

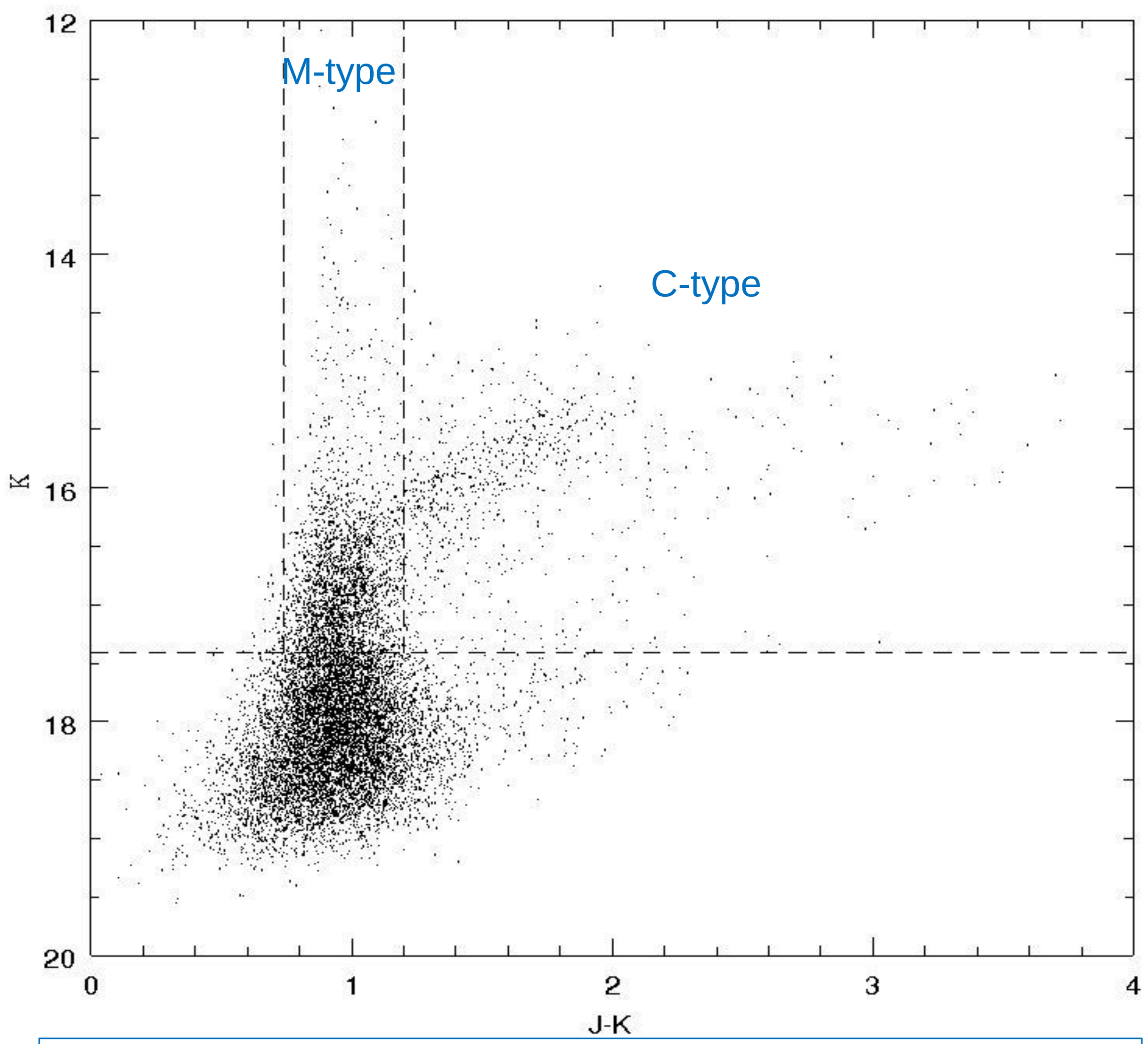

Fig. 1 Colour magnitude diagram showing the division of C- and M-type stars in the near-infrared.

4. Results

The distribution of the C- and M-type AGB stars has been examined as a function of distance from the galactic centre, and the [Fe/H] abundance derived from the C/M ratio has been investigated as a function of galactic radial distance and azimuthal angle. The primary results of our analysis are as follows;

- The AGB population of NGC 6822 extends out to at least a distance of 4kpc from the galactic centre. This is the approximately the limit of the stellar spheroid. Beyond this limit the stellar density is too low to reliably detect C- and M-type AGB stars belonging to NGC 6822 – see Fig.2 – due to residual foreground Milky Way contamination of the sample.
- Inside 4kpc the overall C/M ratio is 0.61 ± 0.03. Using the above relation this indicates an iron abundance of -1.29 ± 0.06 dex. Outside 4kpc we cannot reliably measure the C/M ratio.
- There is no significant radial gradient in [Fe/H] in the AGB population of NGC 6822 – as a function of distance from the galactic centre (see Fig.3), or as a function of angle.

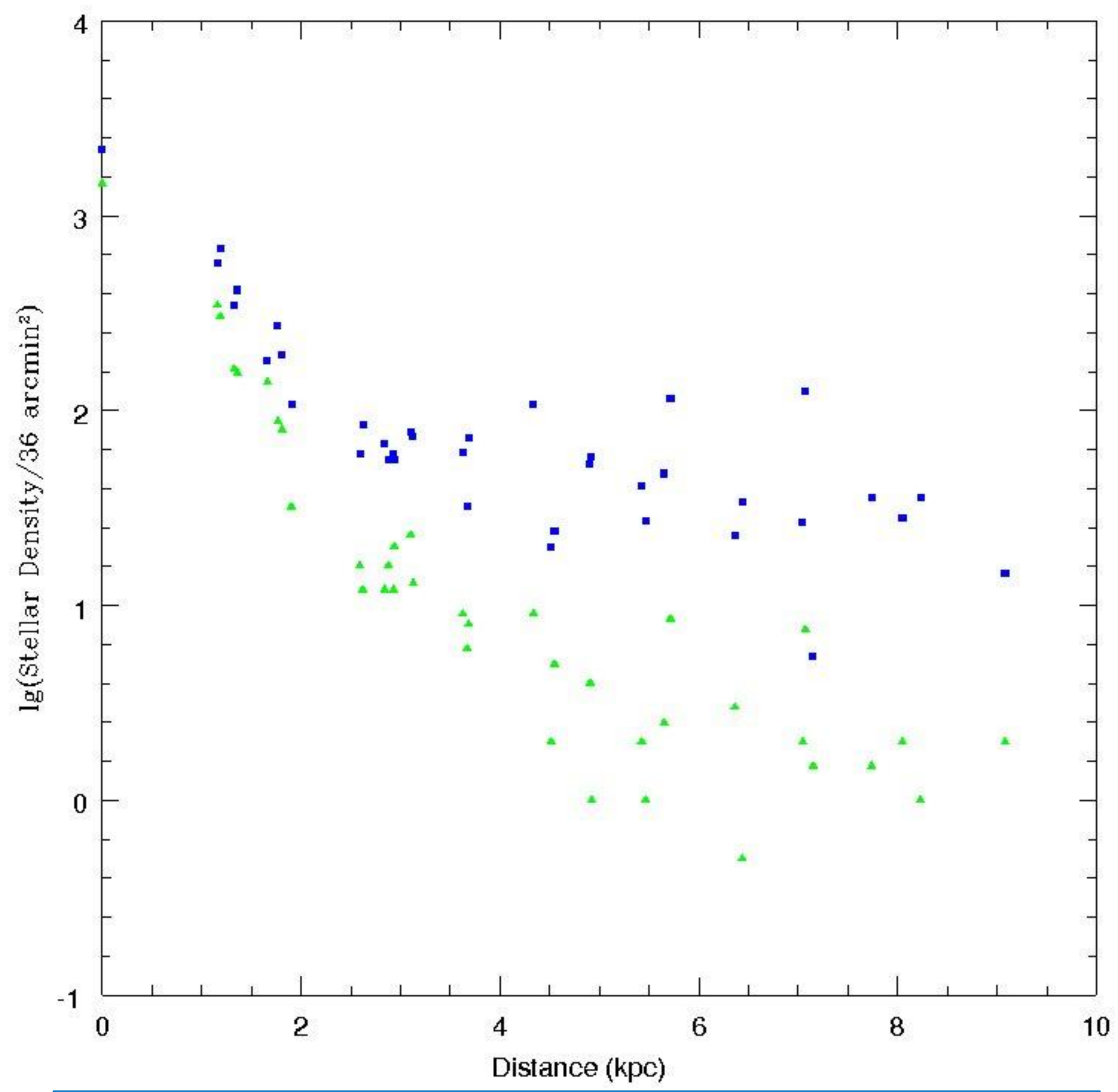

Fig. 2 Stellar density profiles of the C- (green triangles) and M-type (blue squares) identified from the near-infrared photometry of NGC 6822.

5. Conclusions

The C/M ratio and [Fe/H] abundance presented here are the mean values calculated from the C- and M-type stars identified within 4 kpc of the galactic centre. This marks the 'edge' of the stellar halo surrounding NGC 6822.

Beyond this (>4 kpc) the density of old- and intermediate-mass stars is too low for the techniques available to cleanly pick out M-type stars belonging to NGC 6822 (Fig.1). C-type stars are not seen in the Milky Way foreground and therefore do not substantially pollute our sample and final C/M ratio. The C/M ratio is distorted by heavy foreground pollution beyond 4 kpc.
The selection of C- and M-type stars in the near-infrared is also imperfect and influenced by a number of complex physical factors. This leads to some misclassification of C- and M-type stars and a consequent distortion of the ratio.

We therefore conclude that the C/M ratio has the potential to be a powerful tool for the studying metallicity gradients in resolved galaxies, specially with forthcoming facilities like the E-ELT. However, further calibration and a better understanding of the sensitivities of the C/M ratio and its relationship with [Fe/H] relation is needed.

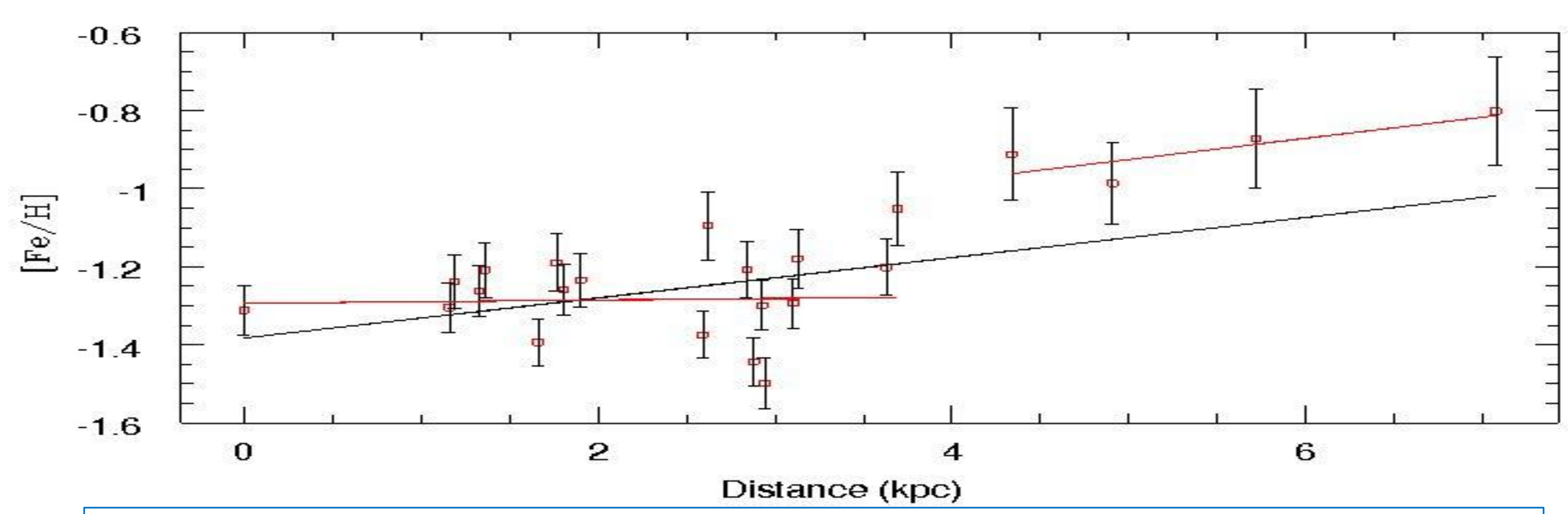

Fig. 3 [Fe/H] derived from the C/M ratio, plotted as a function of distance from the galactic centre of NGC 6822.

6. References

[1] Battinelli et al. (2005), A&A, 434
[2] Cioni (2009), A&A, 506
[3] Mateo (1998), ARA&A, 36
[4] Sibbons et al. (2010) 2010arXiv1011.4464S