Miras in Nearby Galaxies

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Abstract: We describe current optical imaging with the ESO NTT, and future observations with the ESO VLT looking for Mira variables in nearby and more distant galaxies. We consider the possibility of using these variables as independent distance indicators, and compare their performance with the planetary nebulae. It is argued that under optimum conditions, we would be able to measure accurate distances with the VLT as far as 10 Mpc using Miras.

1 Introduction

Miras are long period, red pulsating variables, which show a characteristic light curve. Miras exist in two groups: the long-period high-mass-loss stars (OH/IR stars and related objects; $P > 400$days) and short-period variables ($P < 400$days). The latter trace an older galactic population. In our own Galaxy, the properties of Miras are starting to be well understood thanks mostly to the efforts of the SAAO (e.g. Whitelock et al. 1994).

Miras have been detected on 4m-class telescopes in nearby galaxies beyond the Magellanic Clouds (e.g. Freedman 1994). However, all such studies were aimed at finding the most luminous objects. A few long-period Miras have so far been discovered outside the Local Group, but detecting the less luminous short-period objects should also be feasible with modern instruments.

A study of extragalactic Miras has two scientific objectives: Firstly, to use Miras as distance indicators, and secondly, to establish a PL relation for Miras. In this report, we discuss these two points in turn. Then we describe NTT observations, and finally we propose observations with VLT.

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2 Miras as distance indicators

The luminosity function of planetary nebulae has been used to find distances to galaxies up to the distance of Virgo. The method uses the well-defined cut-off on the bright end of the luminosity function. However, the method has the drawback that it depends on the [OIII] line which makes it metallicity dependent to an unknown degree. Also, the luminosity function requires a large sample size (Tamman 1993).

Miras populate the tip of the AGB, immediately preceding the planetary nebula phase. The stellar luminosity will not change significantly between the two phases of stellar evolution. Miras should therefore show a similar luminosity cut-off as planetary nebulae. We do in fact find this for LMC Miras (see Figure 1), suggesting they can be used as distance indicators just as planetary nebulae can. In fact, better distances could be achieved for three reasons:

• Miras emit their luminosity in the stellar continuum making it much easier to find the bolometric magnitude.

• the period–luminosity (PL) relation gives the absolute magnitude for individual objects, which is not available for individual planetary nebulae.

• Miras outnumber the planetaries by a factor of 10-20, providing much better statistics, and allowing the study of smaller galaxies.

There is also a drawback when we compare the performance of Miras as distance indicators with respect to planetary nebulae:

◦ Miras emit their luminosity in the red stellar continuum making detection more difficult. They cannot be identified to as large distances as planetary nebulae.

We conclude that Miras would be excellent candidates to map out the three-dimensional structure of the vicinity of the Local Group.

3 The PL relation

A relation between the period and bolometric luminosity is known for the short-period variables from studies in the LMC. The brighter, long-period (P>400 days) stars deviate from this relation (Feast et al. 1989). There may also be a slight difference between oxygen and carbon Miras. The PL relation is sensitive to the mass of the degenerate C/O core at the moment in stellar evolution when mass loss becomes dominant.

We expect that the PL relation will depend on the metallicity history and the star-formation history. To determine these dependencies, it will be necessary to find Miras in nearby galaxies and to determine their periods and luminosities. Determination of the luminosity requires infrared JHK observations. From the known metallicity of the host galaxy, a PL–Z relation can be defined. Such a relation would also greatly improve our knowledge on the effect of metallicity on the AGB evolution, specifically whether the onset of mass loss is delayed for low metallicities.

Complementary to the PL relation, a complete distribution of periods would also give valuable information on the nature of Miras and their parent population. As an example, the work of Whitelock et al. (1994) on the Miras in the Galactic cap show large differences between the period distributions at different Galactic latitudes. These differences can be interpreted in terms of a large metallicity gradient, in terms of the interplay of different Galactic components (bulge *vs* disk *vs* halo), or in terms of age differences. These data can add to our knowledge of how the Galaxy itself formed.

4 The NTT / VLT

NTT: To study the PL–Z relation, we are currently observing galaxies with metallicities different from the MW and LMC. We identify Mira variables in the nearby galaxies WLM, NGC300, and NGC7793, at distances of 0.9, 1.8, and 2.2 Mpc, respectively, using NTT + EMMI. Deep V and I images will be used to detect the expected variations and to determine periods.

From the total luminosity of NGC 300, and an adopted Mira lifetime of $\tau = 2 \times 10^5$ yr, we estimate a total population of 10^4 Miras in this galaxy. The expected number of Miras in NGC7793 is similar, while in WLM we estimate about 100 in total. Confusion especially in the inner regions of these galaxies will reduce the detected numbers, but we aim to obtain an unbiased sample down to the periods of 200 days.

It is not well known if the PL relation holds tight for the C–type Miras also. Thus, is is essential to be able to discriminate C from M type Miras. Fortunately, Cook et al. (1986) designed two narrow–band filters that make the distinction straightforward. The 77–81 filters are located at both sides of a strong C_2 Swan band in C stars, and at both sides of a strong TiO band in M stars, in such a way that the 77-81 color in combination with V–I or J–K separates efficiently the different types. Then, the 77–81 filters can be used to classify the Miras as carbon or oxygen type,.

To summarize, the present long term NTT study will:

- yield information on the AGB evolution as function of Z,
- show how accurate distance indicators Miras are.

VLT: If the outcome of the NTT study on Miras as distance indicators is positive, future VLT observations can extend the possible distances to > 10Mpc. This project is designed around the predicted capabilities of the ESO VLT + FORS. From the VLT Instruments Booklet, FORS would reach a limiting magnitude $V = 29$ in 1 hour (for 0.5" seeing, $S/N = 5$).

- Consider that the distance modulus to the Virgo cluster is $(m - M)_0 = 31.1 \pm 0.4$. A typical LMC Mira has $m_I = 14.3$, the distance modulus to the LMC being $m - M = 18.5 \pm 0.15$. Then, typical short-period Miras in the Virgo cluster will have $m_I = 26.9$ (the faintest Miras in Virgo will have $m_I = 28.5$). Thus, Miras could be detected as far as Virgo, and beyond. An OH suppressor could significantly improve the limiting magnitudes in the I-band and would be very useful for teh present program.

• The bolometric corrections are better in the near-IR wavelengths. Then, once the Miras are found and their periods determined, observations with the VLT + CONICA in the J, H and K bands will allow the measurement of accurate bolometric magnitudes for the variables. According to the instrument specifications, CONICA at the VLT would reach a 3-σ limiting magnitude of $H = 26.3$ in 1 hour of exposure time. A typical Mira in Virgo will be around $H = 26$. This limit would allow to obtain accurate bolometric magnitudes for Miras in Virgo. Alternatively, observations with the VLT + ISAAC would reach brighter magnitudes, but would allow a larger sky coverage, very useful in more nearby galaxies.

This project could thus be done using the foreseen intrumentation of the VLT, although I-band observations would benefit from an (unforeseen) OH suppressor. A large field of view is an important requirement for the infrared observations. For determining the periods, it is important that exposures can be taken at fixed time intervals and one would apply for a certain number of exposures of one field rather than a number of full nights. The monitoring would thus be done as service observing.

References

Cook, K., Aaronson, M, & Norris, J. 1986, ApJ, 305, 634
Feast, M., et al. 1989, MNRAS, 241, 373
Freedman, W. 1994, in ESO/CTIO, Workshop on The Local Group Galaxies, eds. A. Layden, J. Storm, & C. Smith (in press)
Tamman, G. 1993, in IAU Symp 155, Planetary Nebulae, p. 515
Whitelock, P., et al. 1994, MNRAS, 267, 711
Hughes S.M.G., Wood, P.R., 1989, AJ, 99, 784

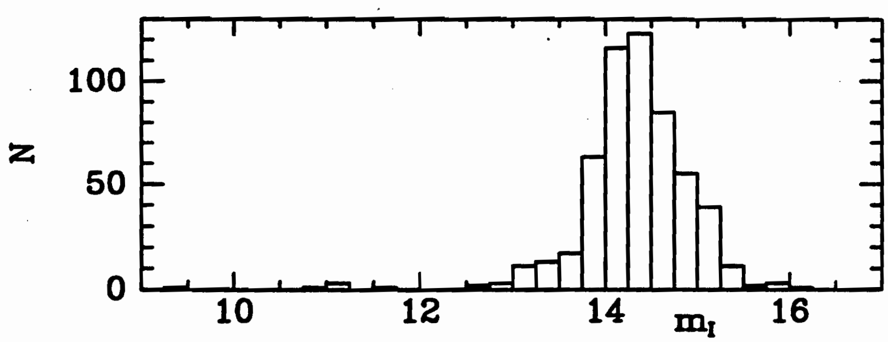

Figure 1: Distribution of I magnitudes for Miras in the LMC. The data have been taken from Hughes and Wood (1990)

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The images released to date are especially suited to the studyof star formation in the Magellanic Clouds, the stellar population inthe halo of nearby galaxies, and the properties of star-forming galaxiesat z~3.Â Near-infrared integral-field spectroscopy of violent starburst environments Near-infrared (NIR) integral-field spectroscopy (IFS) of violentstarburst environments at high spatial (and spectral) resolution has thepotential to revolutionise our ideas regarding the local interactionsbetween the newly formed massive stars and the interstellar medium (ISM)of their host galaxies.Â Carbon-rich Mira variables: kinematics and absolute magnitudes The kinematics of Galactic C-Miras are discussed on the basis of thebolometric magnitudes and radial velocities of Papers I and II of thisseries.