Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
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Age indicators in starbursts before the Wolf-Rayet phase

Y. Divakara Mayya

INAOE, Luis Enrique Erro 1, Tonantzintla, Puebla, México

Abstract. Most of the commonly used tracers of age of starburst regions are based on the presence of massive O-type and Wolf Rayet stars, and hence are applicable only during the nebular and WR phases of starburst. The beginning of the WR phase coincides with the end of the RSG phase. The presence of RSGs in starburst regions can be directly inferred by the Calcium Triplet (CaT) and other characteristic absorption features. These features, accompanied by evolutionary population synthesis modeling, can be used for accurate age determinations of starburst regions. Spatially resolved CaT spectra of a sample of nearby starburst galaxies are being analyzed to determine the age of starbursts in them. Results for the starburst knots of M 82 are presented here.

1. Introduction

In an earlier work I had investigated the absorption strengths of CaT lines ($\lambda\lambda$ 8498, 8542, 8662 Å) (equivalent width EW(CaT)) and CO band (2.31–2.40 μm) (CO index) as a function of age and metallicity (Z), using a starburst evolutionary population synthesis technique, specifically with the aim of using them as age indicators in starbursts (Mayya 1997). It was shown in that study that diagnostic diagrams involving nebular line observations with RSG-sensitive spectral lines have the potential to trace stellar populations over a wide range of ages. In this work we demonstrate the utility of EW(Hα)-EW(CaT) diagram for age-diagnostics, taking the well-studied starburst region of M 82 as an example.

2. History of the starburst region of M 82

Long-slit spectra along the major axis of M 82 were taken with the Boller & Chivens spectrograph at the 2.1-m telescope of the *Observatorio Astrofisico de Guillermo Haro* at Cananea in Northern Mexico. A grating with 600 lines/mm was used with two separate settings to cover the Hα and CaT lines, at an effective spectral resolution of 3Å. The long-slit encloses six star forming knots over a region of 1 kpc in the center of M 82. The knot E is the presently active starburst center. The farthest knot A on the east is at $\sim$800 pc from the center. EW(CaT) and Hα for the six knots are obtained by integrating all the pixels in the spatial direction along the slit. The definition of Diaz *et al.* (1989) is used in computing EW(CaT).

The resulting values are plotted in Fig. 1 (solid dots marked A–F). The vertical bar represents the typical error in the measurement of EW(CaT). The curves are models which are explained on the right hand side of the plot. Numbers next to the model curves denote the age of the starburst in Myr. An initial

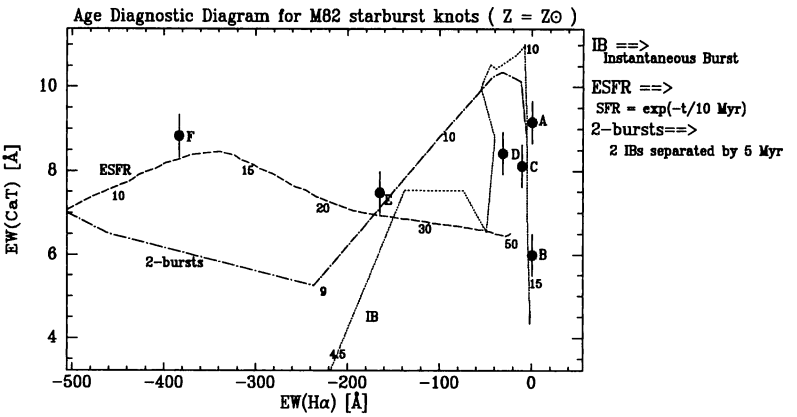

Figure 1. EW(CaT) *vs.* EW(Hα) plot for M 82 starburst knots

mass function with a Salpeter-slope and lower and upper cut-off masses of 1 and 100 $M_\odot$ are assumed for all the models.

Regions A, B, C and D are consistent with the IB model, with ages between 11–14 Myr for the first 3, and $\sim$ 7 Myr for D. The ESFR model with age 13 Myr is a good fit to Region F. For region E, the center, two IBs, 5 Myr apart in age, are able to explain the EWs with the age of the first burst being 9–10 Myr. The CO index of 0.22 mag (Satyapal *et al.* 1997) for this knot is also consistent with this age. Rieke *et al.* (1993) analyzed a variety of observational quantities and also required two bursts separated by 5 Myr for this region.

3. Conclusions

Using an age-diagnostic diagram involving EW(CaT) and EW(Hα), we obtain the following results on the history of star formation in the central region of M 82. The bright central starburst has two stellar populations of ages 5 and 10 Myr. This result is consistent with age estimation by Rieke *et al.* (1993) using multi-wavelength data. The knots on the east (A,B,C), 400–800 pc from the center, are around 11-14 Myr old. The knot 200 pc west (F) of the center seems to be forming stars continuously for around 13 Myr age. Hence in the central region of M 82, star formation activity had started around 14 Myr ago, with regions within 200 pc of the center forming additional generation of stars.

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