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REVEALING THE NATURE OF THE NUCLEAR STARBURST IN M82

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RESUMEN

Se presentan nuevas imágenes IR de alta resolución del núcleo con brote de formación estelar de M82. La distribución de brillo en la banda K, de las líneas Brγ $\lambda 2.166\,\mu$m y He I $\lambda 2.058\,\mu$m así como el índice de CO, en combinación con modelos de síntesis de población, indican variaciones espaciales de la población estelar y gradientes de edades que son consistentes con un esquema de propagación de la formación estelar del centro hacia afuera.

ABSTRACT

New high resolution near-IR imaging spectroscopy of the nuclear starbursting regions of M82 are presented. The spatial distribution of the K-band emission, the Brγ $\lambda 2.166\,\mu$m and He I $\lambda 2.058\,\mu$m line emission and the CO spectroscopic index with population synthesis and cluster evolutionary models show spatial variations in the stellar population and age gradients, consistent with an inside-out propagation of the starburst.

Key words: **GALAXIES: STARBURST — GALAXIES: STELLAR CONTENT — GALAXIES: INDIVIDUAL: M82 — INFRARED: GALAXIES**

1. INTRODUCTION

M82 is considered the archetype starburst galaxy and at a distance of 3.3 Mpc it allows for detailed spatial studies, $1'' \approx 15$ pc. A global picture of its nuclear starburst emerges from a wealth of present data. A molecular ring, 500 pc in diameter, encloses the central starburst region. An inner molecular spiral arm is some 125 pc west of the nucleus, defined by the K-band peak. A group of supernova remnants extends over 600 pc along the plane of the galaxy. The $2.2\,\mu$m emission provides evidence for a stellar bar, possibly due to the interaction with M81, that could be responsible for the starburst activity. We have conducted high-resolution imaging spectroscopy in the near-IR (NIR), where extinction is low ($A_K \approx 1/10 A_V$) and the starburst activity is conspicuous, of a representative region of the core of M82, including the nucleus and extending to the west along the major axis up to the inner edge of the molecular ring. Our data allow to study in detail distinct star-forming sites and address questions concerning stellar population variations and relative ages of different starbursting regions which play an important role in understanding the origin and evolution of the starburst. For a review and previous NIR studies of M82, see Telesco (1988), Satyapal et al. (1995), and references therein.

2. OBSERVATIONS AND RESULTS

M82 was observed using the MPE NIR imaging spectrometer 3D at the 3.5-m telescope at Calar Alto, Spain, in January 1995. 3D (Weitzel et al. 1996) is the first of a new generation of NIR spectrometers and offers the opportunity to image an $8''\times 8''$ field of view at $0.5''$/pixel across the entire H- or K-band simultaneously at a spectral resolution of $R \sim 1000$. In order to cover the region selected for the observations, four fields were observed. The data were obtained in a *object-sky-sky-object* mode, with individual exposures of 80 s in the H-band and 100 s in the K-band, for total on-source integration times of 480 s and 600 s respectively. After dark current and background subtraction, flat-fielding, wavelength calibration, correction for bad pixels and atmospheric transmission, the data cubes for all fields were smoothed to a common seeing of $\approx 1.8''$ and mosaicked. Absolute flux calibration was performed using the broad-band photometry of Rieke et al. (1980).

Fig. 1*a* shows the K-band light distribution, to which the evolved stellar population contributes the most, with the prominent nucleus at the relative coordinates ($0''$, $0''$) and the so-called secondary peak at ($-8''$, $-2''$).

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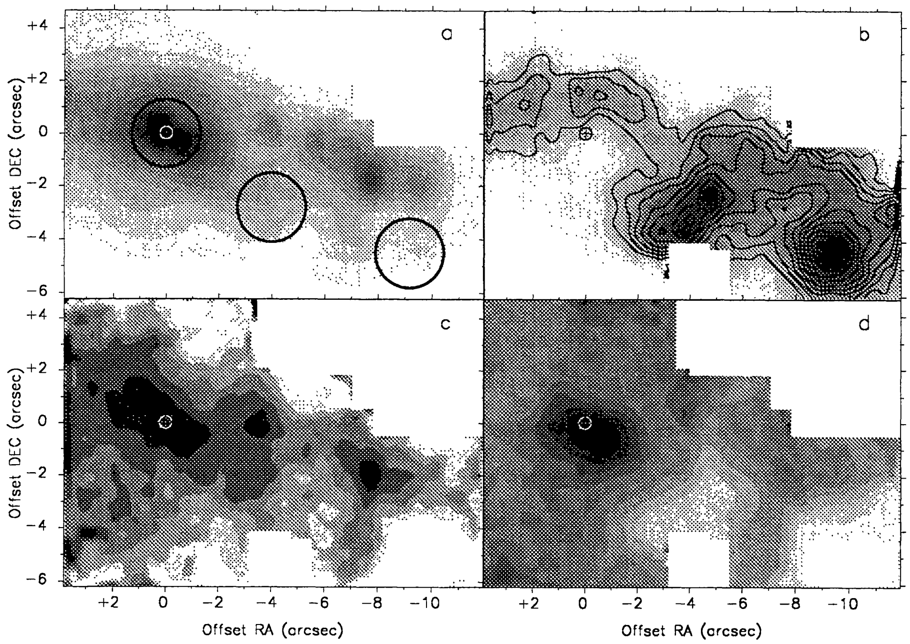

Fig. 1. (a) K-band image from 2.0 (white) to 15.0 (black) ($\times 10^{-15}$Wm$^{-2}\mu$m^{-1}arcsec^{-2}). The nucleus is indicated by the crossed circle and the large circles locate the three regions of interest (see text): the nucleus at (0″, 0″), B1 at (−4″, −3″) and B2 at (−9″, −4.5″). (b) Grayscale image of the Brγ line emission, from 5.0 (white) to 25.0 (black) ($\times 10^{-18}$Wm^{-2}arcsec^{-2}) with superposed contours of the He I λ2.058 μm emission, starting at 5.0 in steps of 1.0 ($\times 10^{-18}$Wm^{-2}arcsec^{-2}). (c) Map of the CO$_{sp}$ index, from 0.15 mag (white) to 0.33 mag (black). (d) Map of log(L_K/L_{Lyc}), from 0.0 (white) to 1.1 (black).

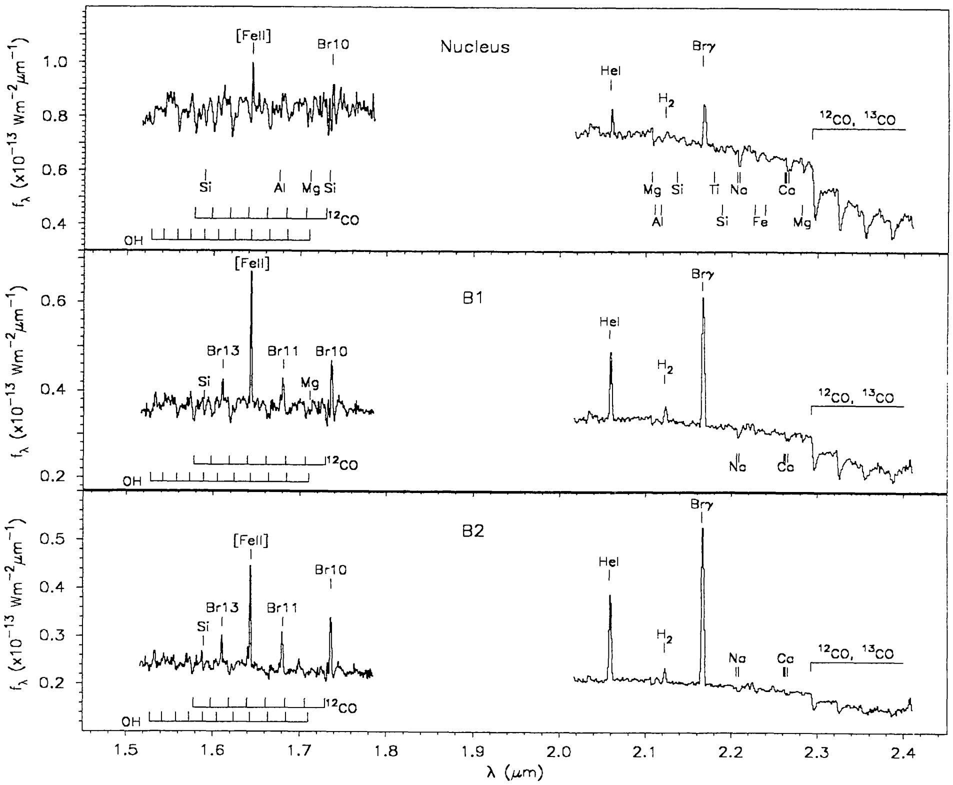

Fig. 2. Spectra taken in 2.5″ apertures at the positions indicated in Fig. 1a.

Fig. 1*b* displays the spatial distribution of the Brγ $\lambda 2.166\,\mu$m (grayscale) and He I $\lambda 2.058\,\mu$m (contours) line emission, both tracing the sites of star formation. Two bright sources can be identified: B1 at ($-4''$, $-3''$) and B2 at ($-9''$, $-4.5''$). Our Brγ image compares well with previously published images (e.g., Satyapal et al. 1995) and its clumpy morphology contrasting with the smoother K-band emission shows distinct bursting regions. The CO spectroscopic index map (CO_{sp}) is shown in Fig. 1*c*. The CO_{sp} (Doyon, Joseph, & Wright 1994) measures the depth of the CO absorption bands longwards of $2.3\,\mu$m produced in the atmosphere of red giants and supergiants. A normal population typical of ellipticals and bulges of spirals has $CO_{sp} = 0.20$ mag; the abnormally high CO_{sp} values is indicative of an important population of late-type giants and supergiants. Fig. 1*d* shows the $\log(L_K/L_{Lyc})$ map; L_K/L_{Lyc} is proportional to the ratio of the K-band and Brγ fluxes. H- and K-band spectra of the nucleus, B1 and B2 are displayed in Fig. 2. The continuum is dominated by the wealth of absorption features characteristic of an evolved stellar population such as the CO bandheads and lines of Si I, Na I, Ca I, Mg I, Al I and Fe I. Hydrogen recombination lines (Brackett series) and the He I line at $2.058\,\mu$m emitted by ionized gas around OB stars, the H_2 1-0 $S(1)$ line at $2.122\,\mu$m and the [Fe II] line at $1.644\,\mu$m are seen in emission and are particularly strong for B1 and B2.

3. INTERPRETATION

The stellar populations contributing to the NIR continuum provide important constraints to the starburst history and to the relative ages of different bursting regions. We examine in detail the nucleus, B1 and B2 which, on the basis of the images and the spectra in Fig. 1 and 2, sample three representative regions of the starburst in M82. The quality of the spectra allows direct comparison with the stellar data of Kleinmann & Hall 1986 (KH86) and Origlia, Moorwood, & Oliva 1993. A quantitative analysis of the equivalent widths of absorption features shows the dominant spectral type for the nucleus, B1 and B2 to be M2I or M5III, K5I or M4III and K4I or K5III, respectively. A population synthesis with a χ^2-fit of template spectra from the KH86 atlas with the K-band data gives similar results. However, this analysis does not allow to discriminate between giants and supergiants. We have run the evolutionary synthesis model for the clusters described in Krabbe et al. (1994), assuming a Salpeter IMF and an exponentially decaying SFR with a timescale of 20 Myr for the nucleus, and delta bursts for B1 and B2. The L_K/L_{Lyc} and M/L_K ratios can be interpreted as global age indicators. According to our results and a mass estimate for the nucleus from Shen & Lo (1995), the age of the nucleus is 60–90 Myr, ~ 15 Myr for B1 and ~ 10 Myr for B2. The $\log(L_K/L_{Lyc})$ map in Fig. 3*a* illustrates well the "age gradient" from older to younger when going to larger radii along the major axis. Disentangling between the giant and supergiant solutions from our population synthesis is not straightforward. Considering only the nucleus, the 60–90 Myr derived from the global age indicators is larger than the lifetime of the M2I stars and rules out this option. On the other hand, there is no possible scenario in which late M giants can dominate the K-band continuum with available evolutionary models. The He I/Brγ ratio and the CO_{sp} map provide further evidence for spatial variations in the stellar population. The He I/Brγ ratio varies over the observed region (map not shown here), indicating variations in the effective temperature of the exiting stars to which this ratio is sensitive. The spatial variations of the CO_{sp} could be due to real gradients in the stellar population but also to dilution by hot dust. However, the value of 0.15 mag measured at B2 would imply a hot dust contribution of 85% to the K-band if the intrinsic CO_{sp} is as high as the 0.30 mag measured at the nucleus. This is unreasonably large for starbursts and is indicative of gradients in the composition of the stellar population. Summarizing, our data provide evidence for spatial variations in the stellar population and for a time sequence in the triggering of star formation within the starbursting core of M82. The age gradients are consistent with an inside-out scenario for the propagation of the starburst activity. Constraining the composition of the stellar population proves not to be straightforward. A more thorough analysis and modeling will be presented in a forthcoming paper (Förster-Schreiber et al. 1996).

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