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NEAR-IR IMAGING SPECTROSCOPY OF IC342: SPATIALLY RESOLVING A BAR-DRIVEN CENTRAL STARBURST

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RESUMEN

Para responder a algunas de las preguntas sobre los orígenes de los "starburst" nucleares en galaxias sin actividad nuclear, tomamos imágenes de alta resolución en las bandas H y K de los 12″ centrales de la espiral Scd cercana IC342. Las observaciones revelan una barra pequeña, que había sido supuesto para explicar la morfología del gas molecular. Tenemos mapas en líneas y espectros que muestran una estructura compleja en los 100 parsec centrales. Las supergigantes rojas en el cúmulo central indican la existencia de un brote de formación estelar de alrededor de 10 millones de años de edad. La formación estelar está centrada en un anillo de aproximadamente 4″ de diámetro.

ABSTRACT

To address some of the questions about the origins of nuclear starbursts in non-AGN galaxies and their importance in galaxy evolution, we have taken high resolution H- and K-band observations of the central 12″ of the near-by Scd spiral IC342. The data reveal a small scale stellar bar that has been assumed by several authors to explain the morphology of the molecular gas. We have taken line maps and spectra that both show a complex structure in the central 100 pc. We find strong evidence for a population of red supergiants in the central cluster, indicative of an instantaneous burst of star formation, approx. 10 million years ago. Star formation takes place in a ring with approx. 4″ diameter.

Key words: **GALAXIES: INDIVIDUAL: IC342 — INFRARED: GENERAL — STARS: FORMATION**

1. INTRODUCTION

Many galaxies that show enhanced IR luminosity in their central regions also show stellar bars and ring-like regions of star formation that are often explained as Inner Lindblad Resonances (ILR's). To investigate the details of the related dynamics, we have observed IC342, a giant Scd spiral at a distance of 1.8 Mpc. This proximity makes it an ideal test lab for the dynamical models that have recently developed, although due to its location close to the galactic plane, it suffers a somewhat higher galactic extinction. On the other hand, it is oriented almost face-on, therefore offers an almost unobscured view to its central region, with 1″ corresponding to 8.7 pc only. IC342 shows a prominent molecular bar on a 1′ scale, but neither a stellar bar nor a star formation ring has been observed previously.

2. OBSERVATIONS AND DATA REDUCTION

The data presented here were taken with the MPE field-imaging spectrometer 3D in January 1995 at the Calar Alto 3.5-m telescope. 3D represents a new generation of NIR instruments, since it allows simultaneous analysis both in spectral and spatial respect by cutting a squared 8″ field-of-view in 16 single 0.5″ slices, forming from them a single long slit and after dispersing that and imaging it on a 256x256 pixel NICMOS III array, reordering the data in a 16x16x300 element data cube. Each of the 600 wavelength channels (R = 900-1100) consists of a 16x16 pixel frame that offers a map with 8″ extension. The 3D instrument is described in detail by Weitzel et al. (1996). The complete data set, taken in five nights, consists of 45 frames in K-band with 100 sec integration time on-source, and 71 frames in H-band with 80s integration time on-source. The frames were taken in an ABBA chopping mode with 10′ chop throw. Since we had to mosaic the central 12″ of IC342 the total integration times and therefore the signal-to-noise ratios vary over the field of view. After subtracting the sky frames, all data were added and —after correction for non-linearities and bad pixels— corrected for atmospheric absorption. Flux calibration was done with the values given by Becklin (1980).

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3. RESULTS

Figure 1 shows a contour map of the K-band continuum of the central 12″ of IC342. Like in all other maps, the spatial resolution is $\approx 1''$. The emission can be separated in 2 components, a strong and symmetric

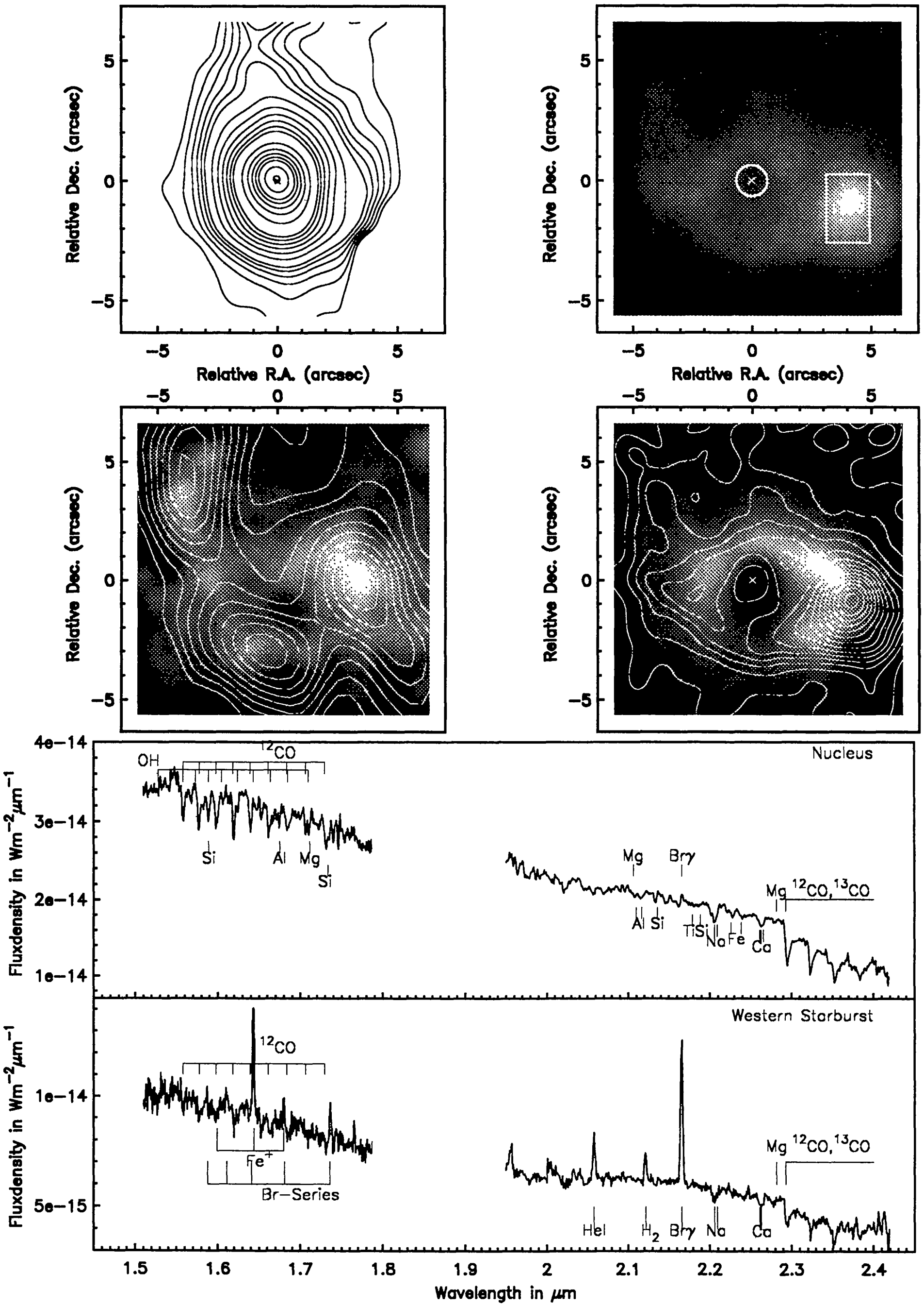

Fig. 1. Top left: contour plot of the continuum flux at 1.65 μm. Top right: Line map of Brγ at 2.166 μm. Middle left: Line map of $H_2$1-0 S(1) at 2.12 μm (grayscale) vs. HCN-emission (contours) from Downes et al. (1992). Middle right: Line map of [Fe II] at 1.644 μm (grayscale) vs. Brγ emission from Fig. 1a) (contours). Resolution of all maps is $\approx 1''$. Bottom: H and K spectra of the central 1.25″ (12 pc) and the western starburst region.

central "bulge" and a small "bar" with an average axis ratio of 1.25 elongated in N-S-direction. The elongation indicates a non-axisymmetric potential which might be responsible for the molecular bar-like structure (e.g., Ishizuki 1990). Also shown are three line maps; Brγ (2.166 μm), $H_2$1-0 S(1) (2.122 μm), and [Fe II] at 1.644 μm. They reveal a ring-like morphology with a diameter of approx. 4″ (35pc). Note also the good agreement between the molecular H_2 and the HCN-emission from Downes et al. (1992), indicating a common source of energy for the excitation of the two molecules. Figure 1 also shows 2 spectra, taken from the apertures marked in the Brγ map. The spectrum from the central cluster is stellar, without signs of gas emission, as demonstrated by the comparison with the K-band spectra of two supergiants, taken from the Kleinmann & Hall (1986) atlas and convolved to 3D's resolution. In contrast, the region in the ring shows ongoing star formation and a prominent [Fe II] line, probably due to supernova shocks.

4. INTERPRETATION

The ring-like gas morphology, as traced by the line maps, and the non-axisymmetric shape of the continuum emission strongly suggests the presence of an ILR at about 35 pc from the dynamical center. This is in agreement with the rotation curve (Turner & Hurt 1992), provided the pattern speed is around 40 km s^{-1} kpc. We have applied various methods for determining the dominant spectral type and, more importantly, the luminosity class of the central stellar cluster. For example, the quantitative analysis of the equivalent widths of the stellar absorption features as used by Origlia et al. (1993) as well as a least square fit to the template stellar spectra from the Kleinmann & Hall atlas gives a twofold solution, either giants around M6 or supergiants around M0. To solve this ambiguity, we have run cluster evolution models described in Krabbe et al. (1994). The results show that the first solution can be excluded since with currently available models, there is no possible scenario in which M6III is the dominant type of stars. In addition, the M/L_K ratio for a Salpeter IMF and a burst decay time of 10^6yr give an age of $\approx 15 \cdot 10^6$yr for the central cluster, also in agreement with a supergiant population. It is likely that the onset of supernovae in the central cluster has depleted the central region from the gas and thus stopped the star formation, explaining why do not see any gaseous emission from inside the ring, neither in NIR, nor in sub-mm or radio-wavelengths. The spectra give no evidence for a variation of stellar spectral type within the bar, it is possible that we witness the first burst of star formation. This is another evidence for the recent suggestion of galaxy evolution along the Hubble-sequence, going from Sd to Sa (e.g., Martinet 1995). In fact, the observed proximity of an ILR to the dynamical center of IC342 might be understood, if the stellar bar is still in its early phase, while its growth would push the ILR further outside due to its increasing mass. The current star formation in the ring and especially the western starburst region is $\approx 5 \cdot 10^6$yr old, as indicated by the evolution of the L_K/L_{bol}-ratio in our models. The morphology of the [Fe II]-map, which is smoother than e.g., the H_2-map, suggests that the massive newly formed stars explode as supernova as they orbit around the center. The fast supernova shocks destroy the dust grains in the ISM and enrich the ring region with Fe II-ions. This scenario requires a supernova-rate of $\approx 2 \cdot 10^{-4}$yr^{-1} to account for the [Fe II]-flux from the western region, well in agreement with the rate derived from the H_2-line fluxes or the 6 cm radio-continuum. It is likely that the H_2 emission is also due to shocks, in agreement with the absence of the 2-1 S(1)-line at 2.248 μm.

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