The continuous star formation history of a giant HII region in M101

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We present results about the star formation process in the giant HII region NGC 5471 in the outskirts of M101. From resolved HST/WPFC2 photometry we find that star formation has been going for the last 70 Ma. We further compare previous results from integrated infrared-optical photometry with the stellar resolved CMD and we discuss the star formation properties of this region and its individual knots, as well as characterizing the different stellar content. This result has very important consequences in our understanding of the burst versus continuous star formation activity in spiral galaxies.

IMAGES & REDUCTION

The WFPC2 data was retrieved from the HST archive. The images (see Fig. 1) were taken through two emission-line filters, F656N (Ha) and F673N ([SII]), and two continuum filters, F547M (Strömgren *y*) and F675W (WFPC2 R). NGC 5471 is centered in the WF3 camera in all images. The presence of a hypernova is clearly seen as an intense [SII] (F673N) emission source (Fig. 2).

The pipeline processed HST images were subjected to the usual processing using the IRAF and STSDAS software, following the procedures in the *HST Data Handbook*.

We used the multiple exposures to account for cosmic rays, and we eliminated hotpixels and other defects. We finally co-added the images to produce deep mosaics.

Since NGC 5471 is very luminous, its Hα emission contributes significantly to the broad band (F675W) image. Therefore, we have subtracted scaled Ha and [SII] images from the continuum F675W image obtining a new almost emission line free image (F675W').

We obteined JHK CCD images (Fig. 3) with the TNG 3.58 m at la Palma with the ARNICA camera on April 28 (2002), with a seeing of 0.8 arcsec.

In order to compare the two set of images, we aligned the HST and TNG images. We degraded the WFPC2 images to the spatial scale and seeing of the JHKs ones (Fig. 4), and then we identified several objects in both sets and used them to align the images.

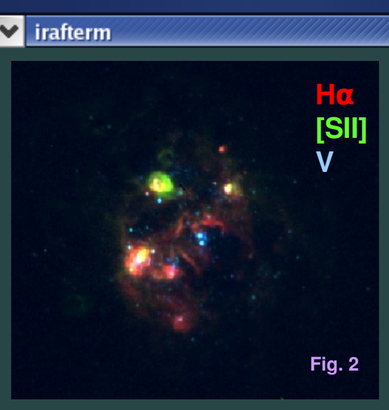


Fig. 2

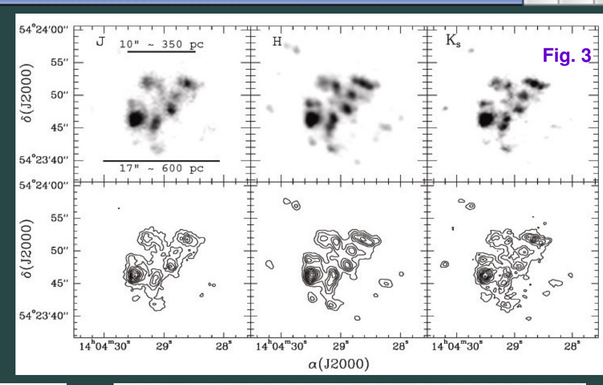


Fig. 3

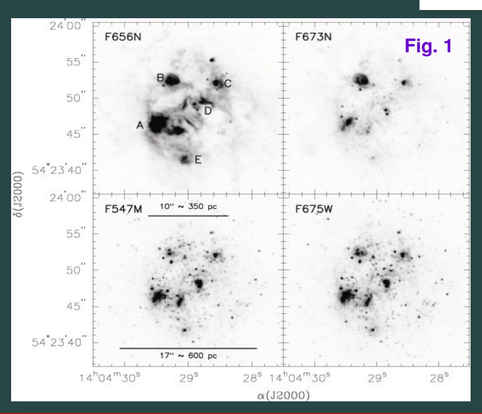


Fig. 1

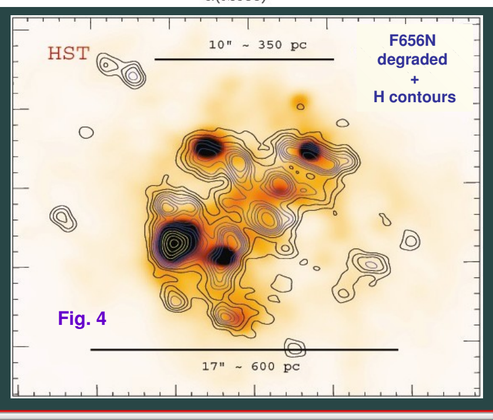


Fig. 4

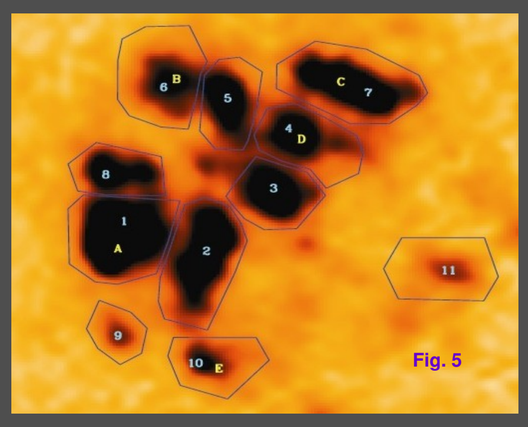


Fig. 5

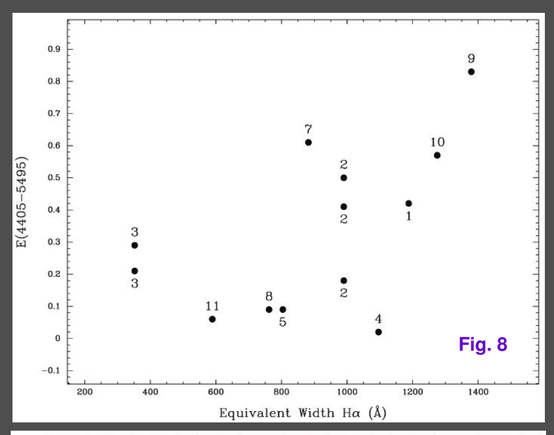


Fig. 8

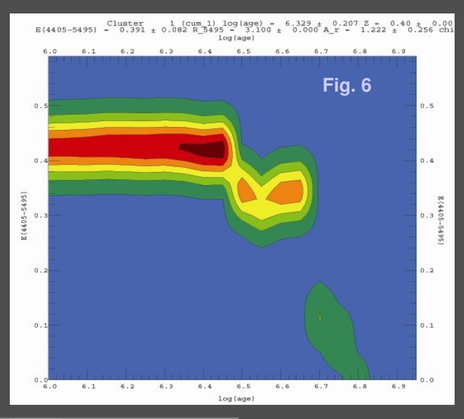


Fig. 6

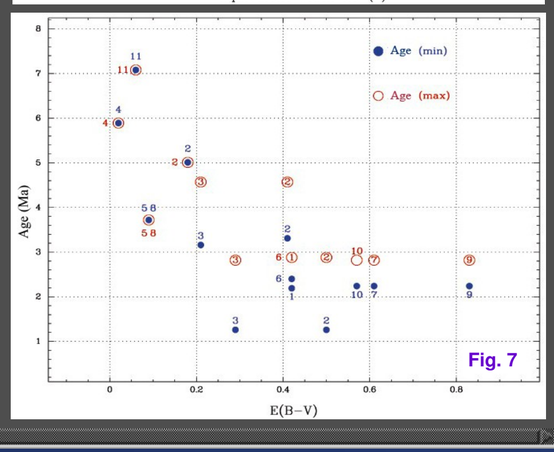


Fig. 7

INTEGRATED STUDY

In order to perform an analysis of the stellar population content of the main components in NGC 5471 we derived the integrated magnitudes (JHK + F547M + F675W') and colors in eleven different apertures. They were chosen and defined in the H contour plot (Fig. 5), maximizing the area in order to include the features of all images, since there were some small offsets in the position and intensity of the knots in the optical and infrared images.

We have identified the A-E main knots defined by Skillman (1985, ApJ) (Fig. 5 & 1). We have applied the PHOLYPHOT task (IRAF) to obtain the integrated photometry. The hypernova is located in knot 6 (models are not able to reproduce supernova data, so this knot cannot be taken into account).

To find the correspondence between the observed photometric properties and the models, we have used CHORIZOS, a code written in IDL by Maíz-Apellániz (2004, PASP). The code uses χ^2 minimization to find all models (Starburst99) compatible with the observed data in the 4-dimensional parameter space. We have fixed two of these parameters: the known metallicity of NGC 5471 and the type of dust R_v = 3.1, leaving unconstrained the amount of extinction and the age (Fig. 6: output of de code).

The most probable extinction in each knot is plotted against its age (Fig. 7) and Hα equivalent width (Fig. 8). For some knots more than one solution is found. The general behaviour is as expected: an old knot shows a small amount of extinction.

STELLAR STUDY

The stellar photometric analysis was performed with the HSTphot package (Dolphin 2000, PASP).

We obtained the completeness limit by adding artificial stars to the images and subject them to the same analysis as the real ones. The ratio between the number of simulated stars recovered and the total number of artificial stars added provides the estimate of the completeness factor. The 50% completeness of the F547M filter derived on the basis of the CMD data is 25.2 mag, while that for the F657W' filter is 50% at 24.7 mag.

Our CMD consist of the sum of the intrinsic population IP and the contaminating field population FS, and therefore the CMD shows both populations (IP+FS).

The field star contribution has been estimated using the CMD of adjacent fields FS' cotaining only foreground and background stars. FS contribution may be removed statistically (Bellazzini et al. 1999, MNRAS) by comparing the local density of stars in the two diagrams (Fig. 9). See procedure below figure 9.

We assume a distance modulus of (m−M) = 29.3 for M101 (Stetson et al. 1998, ApJ). In Figure 10 is plotted the final CMD with isochrones provided by Miguel Cerviño, showing a mixture of different age populations ranged from 4 to 70 Ma: the star formation in NGC 5471 has been going for at least that period. Figure 11 compares the stars laying inside each polygon and its position in the CMD.

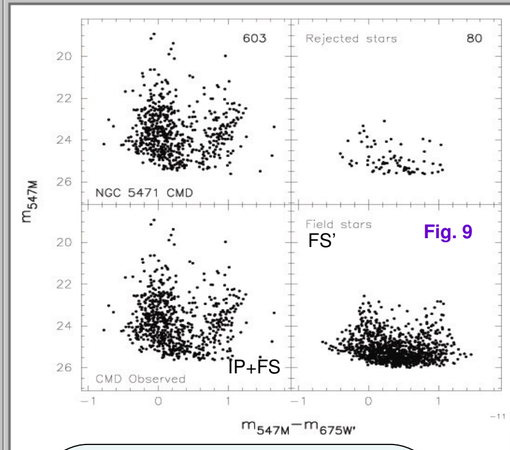


Fig. 9

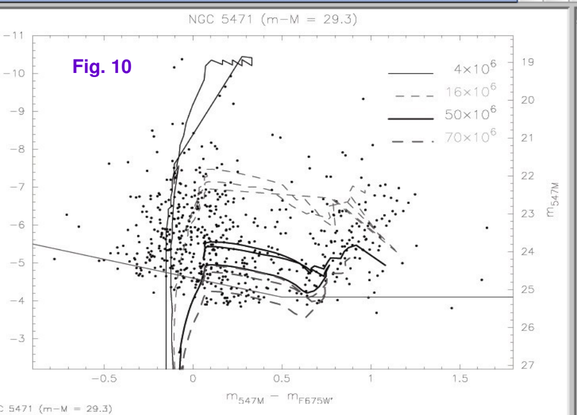


Fig. 10

$$P = 1 - min\left(\frac{\alpha N_{FS'}}{N_{IP+FS}}, 1.0\right)$$

N_{IP+FS} = number of stars inside an ellipse (axis = errors of mag & colour) centered on a CMD(IP+FS) star

$N_{FS'}$ = number of stars inside the same ellipse in the Field CMD(FS')

α = ratio area of IP+FS field to the area of the FS' field

0 ≤ P' ≤ 1 → Random number

If P' ≤ P → star accepted as member of NGC 5471.

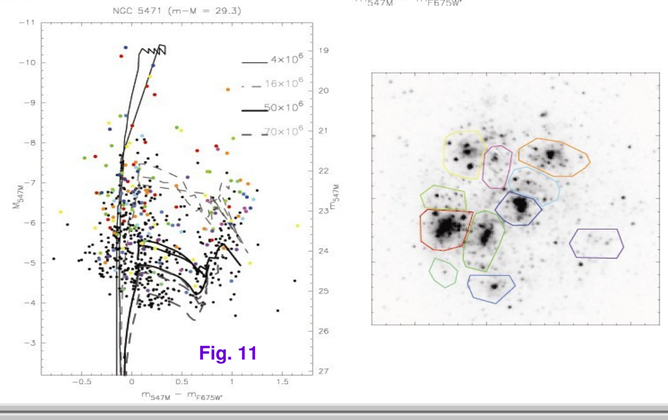


Fig. 11