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# High-Resolution Imaging of Stars, Dust, and Star Formation in Nuclear Rings in Galaxies

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**Abstract.** Nuclear rings in barred spiral galaxies offer an opportunity to study starburst properties, as well as the evolution of star formation in the central regions of galaxies. To further our understanding in these areas, a large imaging survey of over 80 galaxies with previous evidence for the existence of nuclear ring structure has been performed in the H$\alpha$ emission line and the $B$ and $I$ broad bands using the William Herschel Telescope. Here, we present images of a subset of these galaxies, which reveal well-resolved nuclear rings in H$\alpha$. The rings consist of numerous "hotspots" (i.e., H$\alpha$-bright star-forming regions). For each hotspot we calculate H$\alpha$ equivalent widths and compare the results to population synthesis models to obtain age estimates. Typical cluster ages are no more than 10 Myr.

## 1. Introduction

Nuclear rings in spirals are the most numerous class of nearby starburst regions and often dominate the overall star formation in the central regions of their host galaxies (Sérsic & Pastoriza 1967). While many galaxies with nuclear star-forming rings are known (e.g., Buta & Combes 1996), it is hard to make general statements on the physical mechanisms behind the triggering and propagation of star formation in clusters due to the inconsistent and incomplete nature of the existing data. A systematic study of the structure of nuclear star-forming rings is therefore critical for an understanding of the evolution of star formation in galaxies.

To allow for a more statistical approach to answering some of the mysteries of nuclear rings, we performed a large survey of over 80 galaxies suspected of containing nuclear rings (Knapen et al., in preparation). Each galaxy was imaged in the $B$ and $I$ broad bands and in the H$\alpha$ line. Analysis of a subset of these galaxies reveals well-resolved rings in H$\alpha$. This paper presents a preliminary analysis of such rings in four galaxies.

## 2. Observations

The data described here were taken with the 4.2 m William Herschel Telescope AuxPort camera under photometric conditions and at sub-arcsecond resolution. The camera's field of view is 1.5′ by 1.5′, which nicely suits the angular size of between 5″ and 50″ of the nuclear rings in our sample. The subset sample of four galaxies selected for the current paper consists of spiral galaxies with redshifts less than 0.005. Table 1 is a summary of the galaxies' properties.

Table 1. Summary of observations

| Galaxy | RA (J2000) (hh:mm:ss) | Dec. (J2000) (dd:mm:ss) | $v$ (km s$^{-1}$) | Type |
|---|---|---|---|---|
| NGC 473 | 01:19:55.07 | +16:32:41.4 | 2134 | SAB(r)0/a |
| NGC 1343 | 03:37:49.80 | +72:34:16.0 | 2215 | SAB(s)b: pec |
| NGC 7716 | 23:36:31.56 | +00:17:50.4 | 2571 | SAB(r)b |
| NGC 7742 | 23:44:15.80 | +10:46:01.0 | 1663 | SA(r)b; LINER H II |

## 3. Analysis and Results

### 3.1. Individual Hotspot Fitting

After producing H$\alpha$ continuum-subtracted images for the four galaxies, we identified the individual hotspots forming the nuclear ring. We used the program SExtractor[1] (Bertin & Arnouts 1996), which builds a catalog of objects and their fluxes from an astronomical image.

Although SExtractor is optimized for analysis of large extragalactic surveys, we were able to adjust the parameters for detection of the clusters. We selected the detection threshold to be $2\sigma$ above the standard deviation of the background. The catalog file recorded the magnitude, area, and flux of each object detected. The program also produced an image of the objects detected (Fig. 1).

### 3.2. Fluxes and Equivalent Widths

After we obtained the H$\alpha$ fluxes, we were able to compute the H$\alpha$ equivalent width for each identified object by dividing the H$\alpha$ flux by the respective $I$-band continuum flux across the bandwidth. In order to obtain proper alignment of the objects between the H$\alpha$ line and $I$-band images, the software package SExtractor was used in a two-image mode. The H$\alpha$ image was used for detection of the

[1] Created at the Institut d'Astrophysique de Paris.

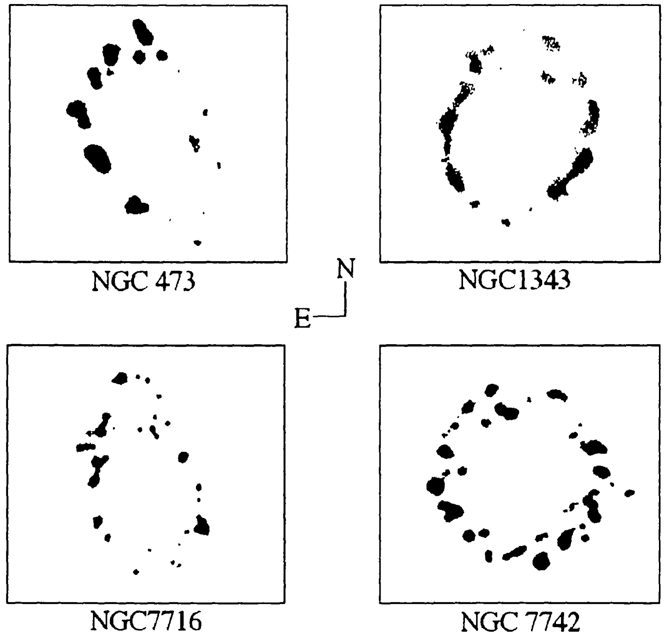


Figure 1. Objects detected for the H$\alpha$ continuum-subtracted images. Scale sizes of the rings are as follows: NGC 473—48″, NGC 1343—44″, NGC 7716—13″, NGC 7742—50″.

hotspots and the $I$-band image was used for photometry based on the objects detected in the H$\alpha$ image. Using this method, we were able to attain the fluxes for each object in both the emission line and the continuum band. However, since SExtractor was not designed for finding clusters on top of a galaxy, we had to adjust the resulting background values to include the galaxy background. With the adjusted fluxes, we could then compute the equivalent widths of each object.

### 3.3. Age Dating

We finally compare the equivalent widths for each object with an evolutionary model from Leitherer et al. (1999), as seen in Figure 2. The model presents the time evolution of the H$\alpha$ equivalent width for varying initial mass functions (IMFs). We adopted an instantaneous starburst with a Salpeter (1955) IMF between $M_{\rm low} = 1\ M_\odot$ and $M_{\rm up} = 100\ M_\odot$. A solar metallicity is assumed. The box indicates the range of measured EWs for all of the objects. The crossing point of the box and the model shows an age of no more than $\approx 10$ Myr.

## 4. Discussion and Conclusions

Although the results presented here have identified an age for each hotspot, the uncertainties introduced during the reduction process, combined with the H$\alpha$ equivalent width model, lead to inconclusive results regarding definitive ages of the stellar clusters forming the rings. For example, we assumed that each galaxy was constant in color; therefore, the nucleus of the galaxies was slightly

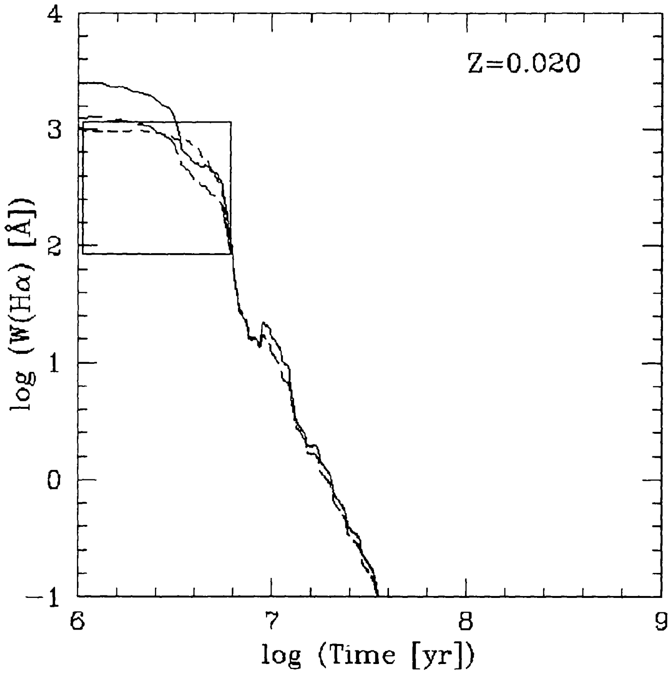


Figure 2. Hα EW vs. time evolutionary model for an instantaneous burst with a Salpeter IMF. A solar metallicity of $Z = 0.02$ is assumed.

oversubtracted in some cases. This introduces an uncertainty that is propagated through the computation of the fluxes and luminosities, which is currently unquantified. With these known uncertainties, our preliminary results are not definitive enough to indicate if a relative age difference between the clusters exists. However, what is clear and not subject to these uncertainties is our result of relatively young ages for the "hot spots", of less than 10 Myr. This conclusion is in agreement with results on nuclear rings in other galaxies by, for example, Ryder, Knapen, & Takamiya (2001) and Alonso-Herrero, Ryder, & Knapen (2001). In future work, we will enhance our currently described technique and apply it to all our sample galaxies.

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