Age Patterns in a sample of Spiral Galaxies

M101

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Talk Outline

**Aim**: Determine the temporal pattern of star formation in spiral galaxies (different morphological types)

**Data**:
- TTF (WHT&AAT), GALEX & SINGS images

**Work**:
- Image processing
- Extinction correction
- Calibration from Starburst99 model

**Results**: Age maps
I. Aim

- To map the ages of star forming regions across spatially-resolved spiral arms
- Use a pixel-by-pixel mapping technique
- Hα emission line (6563Å) from HII gas ionized by young massive O-type stars ≥10M* with lifetimes ≤20Myrs
- UV emission dominated by O-B stars with lifetimes ≤100Myrs
- As star forming region evolves, Hα emission drops off earlier than UV, so the flux ratio is sensitive to age (F_{Hα}/F_{FUV})
- The flux ratio is independent of the total stellar mass and the distance to the galaxy. So it is not affected by uncertainties in these parameters

SAMPLE: (Cianci 2003)
- Nearby and face-on spirals galaxies have enough spatial resolution to see detail in the HII structures of spiral arms (i < 30°)
- Images available in GALEX NGS
## II. Data: The sample

<table>
<thead>
<tr>
<th>GALAXY</th>
<th>RA J2000</th>
<th>DEC J2000</th>
<th>TYPE</th>
<th>REDSHIFT</th>
<th>HELIO RADIAL VELOCITY (km/s)</th>
<th>DIAMETER</th>
<th>MAGNITUDE</th>
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</thead>
<tbody>
<tr>
<td>M74</td>
<td>01 36 41.70</td>
<td>+15 46 59.4</td>
<td>SA(s)c</td>
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<td>-00 00 47.8</td>
<td>(R)SA(rs)b</td>
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<td>7.1 x 6.0’</td>
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<td>+78 21 21.6</td>
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<td>+41 07 13.7</td>
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<td>8.31</td>
</tr>
</tbody>
</table>

*NASA Extragalactic Database*
II. Data: The Taurus Tunable Filter (TTF)

- The TTF forms a FP interferometer with highly polished plates.
- Used in 3.9m AAT (TAURUS-2 focal reducer at Cassegrain focus) from 13-16 February 2000 & 4.2m WHT from 4-6 March 1999 (Sonia Cianci 2000)
- Piezo-electric stacks alter plate separation and were used to center bandpass at Hα emission line (6563Å).
- Extremely narrowband imaging: bandwidth 10-14Å able to avoid the nearby [NII] lines at 6583Å
  - AAT images: 0.37” per pixel, 10’ field of view
  - WHT images: 0.56” per pixel, 15’ field of view
- Frequency switching could be used to obtain Hβ images but these were not available.
GALEX was launched on April 28, 2003

50cm diameter, modified Ritchey-Chrétien telescope with 1.2° circular field of view

Data includes imaging and spectroscopy in two wavebands:
- FUV ($\lambda_{\text{eff}} = 1528\text{Å}, \Delta \lambda=268\text{Å}$), NUV ($\lambda_{\text{eff}} = 2271\text{Å}, \Delta \lambda=732\text{Å}$)

Resolution: 4″(FUV), 5.6″(NUV)
1.5″ per pixel

Undertook a number of surveys: One of these, the Nearby Galaxies Survey (NGS) targeted 200 well-resolved nearby galaxies

Newest data release was in May 2006.
II. Data: Galaxy Evolution Explorer (GALEX)

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NUV 3840x3840 1.5′/px   FUV
The Spitzer Infrared Nearby Galaxies Survey (SINGS) is a comprehensive imaging and spectroscopic study of 75 nearby galaxies (D < 30 Mpc). (Spitzer Space Telescope launched by a Delta rocket from the Kennedy Space Center on August 25, 2003).

**MIPS Data:**

- The image (FITS) MIPS data available for download are listed based on bands of the observation [MIPS24, MIPS70 and MIPS160].
- The pixel scale of the MIPS mosaics is wavelength-dependent: 1.5 arcsec at 24 mm, 4.5 arcsec at 70 mm, and 9.00 arcsec at 160 mm. The flux scale is MJy sr-1. The orientation is North up, East left.

\[
F_{\text{TIR}} = \zeta_1 v_1 F(24\mu) + \zeta_2 v_2 F(70\mu) + \zeta_3 v_3 F(160\mu) \quad \text{(Dale\&Helou 2002)}
\]

\[
\zeta_1 = 1.559, \quad \zeta_2 = 0.7686, \quad \zeta_3 = 1.347
\]
II. Data: Spitzer Infrared Nearby Galaxies Survey (SINGS)

M94

720x600 240x200 120x100
1.5''/px 3''/px 9''/px
III. Work: Image Processing

Images had already been partially processed: Hα images had been bias subtracted, flat-fielded, sky background and continuum subtracted as part of Cianci (2003). Gradient in the background was not subtracted out of some images properly (ex. M51)

I have done:

- Astrometrical solution and rotation (North up, East left)
- Background subtracted and calibration in flux of Galex images and calibration in flux of Hα images.
- Masking (bulge, foreground stars and field)
- Cutting out the noise
- Reescaling and alignment of Galex, Hα and IR images.
III. Work: Image Processing

M74
Schlegel et al. 1998 used diffuse IR emission as a measure of dust column density.

- Removed contribution from dust within bright galaxies.
- Mapped galactic extinction by colour excess E(B-V) in all directions.

The GALEX team have interpreted the Cardelli et al. (1989) extinction curve to find the conversion factor in the two GALEX wavebands:

- $A(\text{FUV}) = 8.24 \ E(B-V)$
- $A(\text{NUV}) = 8.20 \ E(B-V)$
- $A(\text{H\alpha}) = 2.6 \ E(B-V)$
III. Work: Correcting for dust

Internal Reddening

- Face on spirals have little depth, but more dust in HII regions
- SINGS data not available for all galaxies (M83, M101, NGC1068 and NGC2146)
- H\text{\textbeta} images not available, so use UV spectral slope instead:

\[ \beta = \frac{\log(f_{\text{FUV}}) - \log(f_{\text{NUV}})}{\log(\lambda_{\text{FUV}}) - \log(\lambda_{\text{NUV}})} \]

\[ \log(L_{\text{TIR}}/L_{\text{FUV}}) = (0.70 \pm 0.06)\beta + (1.30 \pm 0.06) \]

Kong et al. (2004)

Empirical expression for normal galaxies:

\[ \beta = (0.37 \pm 0.07)A(H\alpha) - (1.15 \pm 0.08) \]

Cortese et al. 2006

\[ A(\text{FUV}) = 1.4 \ A(H\alpha) \]

Boissier et al. 2005
Evolutionary synthesis model created by Leitherer et al. 1999
Simulates evolution of stellar spectra
Simulates flux through particular filters: GALEX imaging response profiles were integrated with the synthetic spectra
Modelled flux ratio using output: $L_{H\alpha}$ and $L_{FUV}$

$$\log \left( \frac{F_{H\alpha}}{F_{FUV}} \right) = \log \left( \frac{L_{H\alpha}}{L_{FUV}} \right)$$

Physical constraints:

- Salpeter IMF $\alpha=2.35$, $M_{up} = 100M_\odot$, $30M_\odot$
- Metallicity: $Z=0.02$, 0.04, 0.008, 0.004
- Star formation history: Instantaneous or Continuous
III. Work: Starburst99

![Graph showing models vs M74 with various age (yrs) and log(F_ν/F_λ) on the y-axis and age on the x-axis. The graph includes multiple models denoted by different colors and line styles.](image)
III. Results: Age maps

M51

β₁
III. Results: Age maps

M51

\[ \beta_2 \]
III. Results: Age maps

M74

\[ \beta_1 \]
III. Results: Age maps

\[ \beta_1 \]
IV. Summary:

- Work in progress: Analysis
- Determine the better redenning correction among several methods and the better parameters for the model
- Calculate the pattern velocity of the wave front and the corotation radius
- ...

Thank you!