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*Exploring local Starbursts with LBT/LUCIFER: the case of NGC 1569*

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We observed NGC 1569 during the commissioning run of LUCIFER, the NIR imager and spectrograph now available at the Large Binocular Telescope. The imaging was performed under good seeing conditions (0.4 arcsec on average) and with the highest angular resolution offered by LUCIFER (0.12 arcsec/pix). We obtained high-quality spatial maps of HeI 1.08, [FeII] 1.64 and Br-gamma emission across the galaxy, and used them together with HST/ACS images in Halpha and in the V band to derive the 2D map (1.6 x 0.9 kpc in size) of the dust extinction and surface star-formation rate density across NGC 1569. We show that dust extinction (as derived from the Br-gamma/Halpha flux ratio) is rather patchy and, on average, is higher in the NW portion of the galaxy [E(B-V) = 0.5 mag] than in the SE [E(B-V) = 0.4 mag]. Similarly, the surface star-formation rate density peaks in the NW region of NGC 1569, reaching a value of about 3 x 10-6 Mo/yr/kpc2. The total star-formation rate as estimated from the integrated, dereddened Halpha (Br-gamma) luminosity is about 0.4 Mo/yr, while the total SN rate from the integrated, dereddened [FeII] luminosityis about 0.005 yr-1 (assuming a distance of 3.36 Mpc). The azimuthally averaged [FeII]/Br-gamma flux ratio peaks at the edges ofthe central cavity (encompassing the super star clusters A and B) and atthe galaxy rim. If this line ratio were to compare an older star-formation history (as traced by supernovae) to an on-going activity (represented by OB stars able to ionize idrogen), it would then indicate that star formation has been quenched within the cavity and is presently occurring in a ring around the cavity.

# Exploring local Starbursts with LBT LUCIFER: the case of NGC 1569

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# Thanks to my Collaborators:

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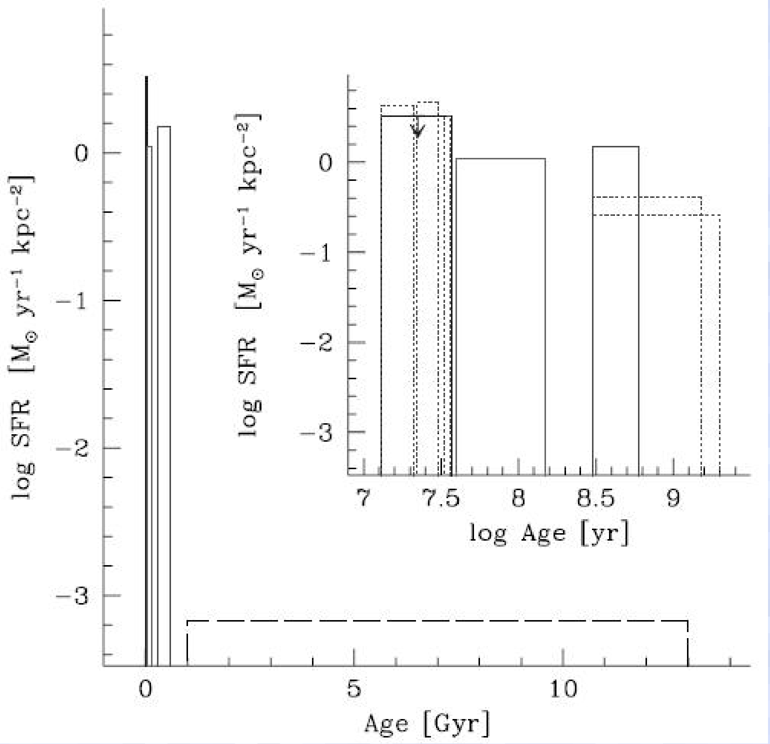
# A quick identikit of NGC 1569

- Host to two super star clusters, A & B, which likely underwent two episodes of star formation about ~9 Myr and ~3 Myr ago (Gonzalez Delgado et al. 1997, Origlia et al. 2001)

- Stellar winds and SN explosions from the older burst have likely evacuated gas and produced a cavity around SSC A & B

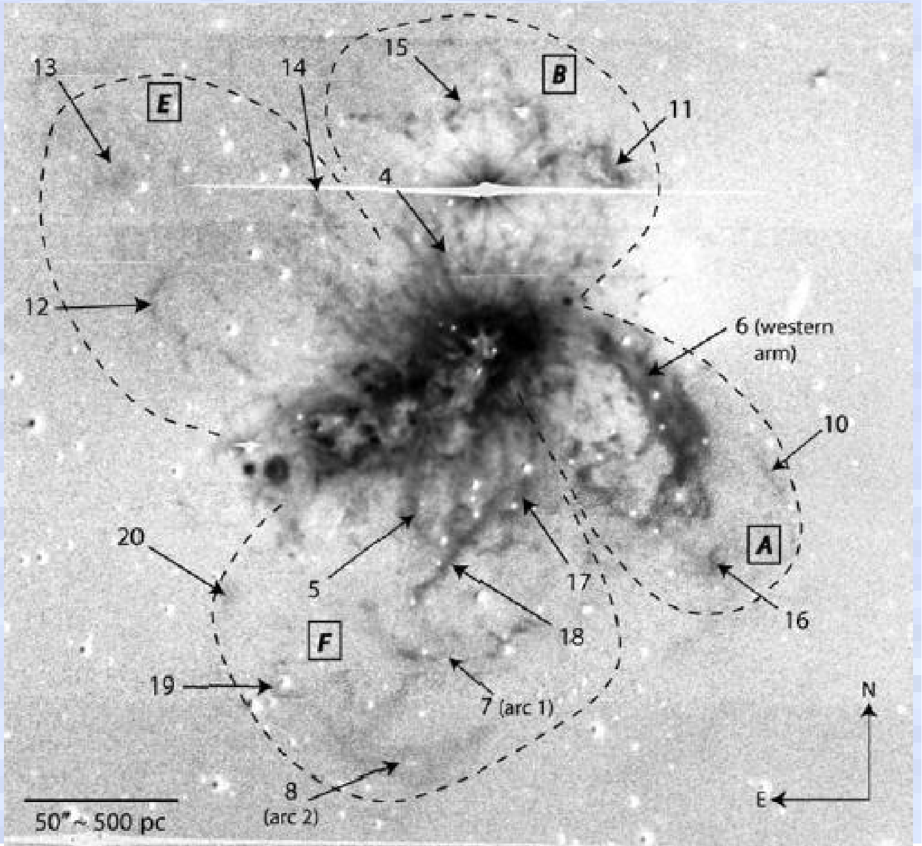
- Rather complex SFH (Angeretti et al. 2005):

  SFR ~ 0.13 $M_{\odot}$/yr    10 Myr ago
  
  0.04 $M_{\odot}$/yr    100 Myr ago
  
  < 0.06 $M_{\odot}$/yr    >300 Myr ago



- The presence of HII regions (Waller 1991) and extended Hα emission indicates on-going star formation.
From the integrated Hα luminosity Hunter & Elmegreen (2004) derive SFR ~ 0.3 $M_o$/yr.

- The ISM exhibits bubbles, arcs and filaments (Hunter et al. 1993, Heckman et al. 1995).
The Hα kinematics indicates the occurrence of a galactic wind (~100 km/s) along and away from the galaxy disk, likely due to the expansion of several super-bubbles. Much of the hot gas seems to be confined, hence the galactic wind may not imply mass loss (Heckman et al. 1995, Westmoquette et al. 2008).



# Our Goals

- **To obtain the first 2D spatial map of dust extinction of NGC 1569**

  **HOW:** from Hα and Brγ imaging

  **WHY:** Previous studies, based on longslit spectroscopy and stellar CMDs, show that dust extinction varies across the galaxy, from E(B-V) ~ 0.5 (foreground) to ~0.8 (foreground+intrinsic, Israel 1988, Gonzalez Delgado et al. 1997, Kobulnicky & Skillman 1997, Origlia et al. 2001).

- **To derive the first 2D spatial map of SFR rate from Hα and Brγ**

- **To compute the first 2D spatial map of [FeII]1.64/Brγ, i.e. number ratio between SN and OB stars**

# The Large Binocular Telescope

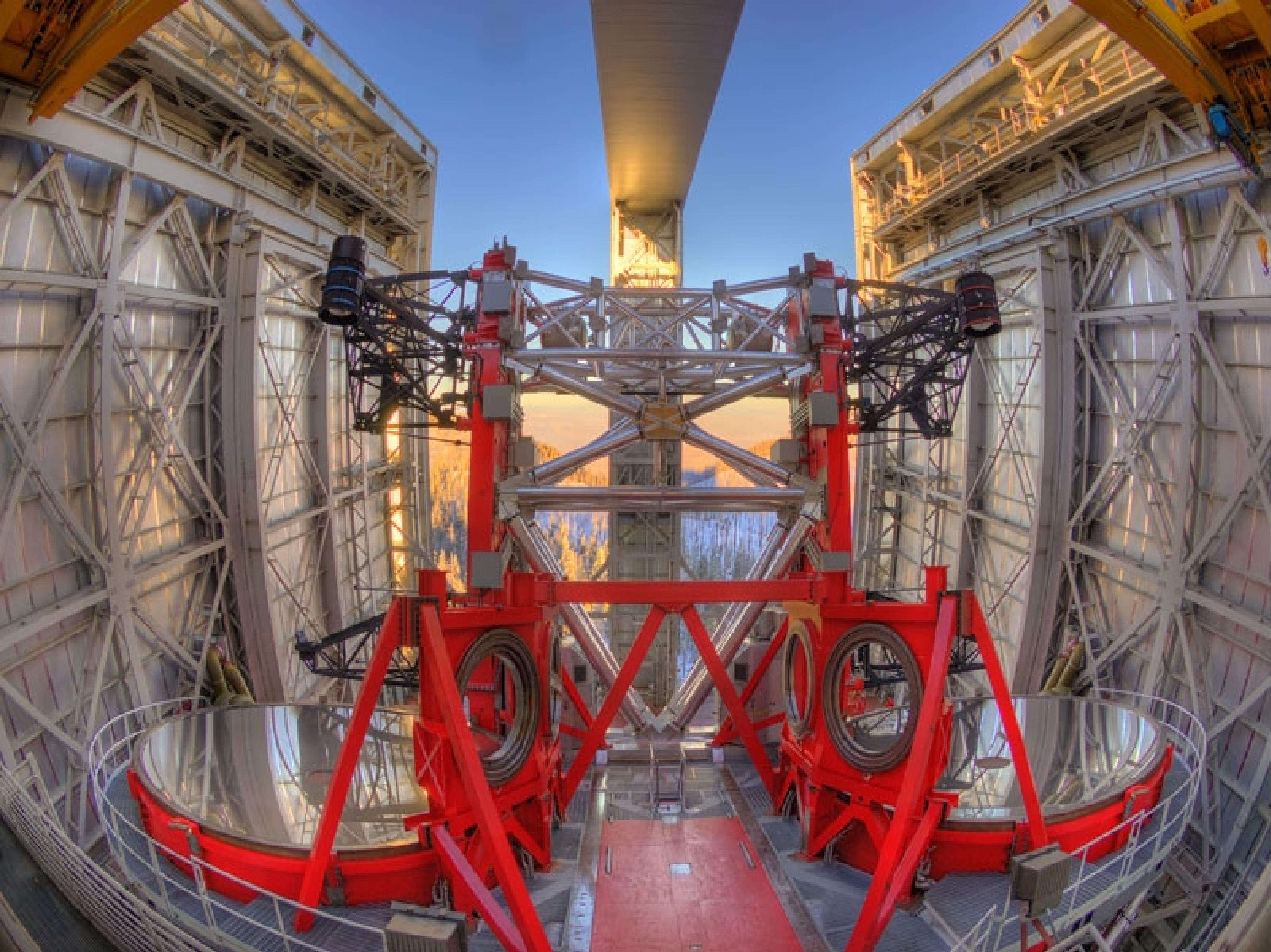
On Mt. Graham, Arizona, at 3221 m

Two 8.4m primary mirrors, at a distance of 14.4 m, and with a focal length F/1.142

Elevation over an azimuth mounting

Swing arms can replace secondary mirrors with prime-focus cameras

Two prime-focus cameras (U to z imaging) and one near-IR imager-spectrograph



# LUCIFER

**L**BT NIR spectroscopic **U**nit with **C**amera and **I**ntegral-**F**ield Unit for **E**xtragalactic **R**esearch

- **IMAGING:** J,H,K,Ks and HeI1.08, Paγ, Paβ, [FeII]1.64, $H_2$, Brγ

  **N1.8:** 4' x 4' with 0.25 arcsec/pix
  **N3.75:** 4' x 4' with 0.12 arcsec/pix

- **SPECTROSCOPY:** longslit and up-to-33 masks in FOV = 4' x 2'

  **G210:** 0.6 to 1.6 Å/pix from z to K
  **G200:** 4.4 Å/pix in H and K
  **G150:** 2.7 Å/pix in K

- **Seeing limited** at the moment; AO first light on May 2010, available to users in 2011

**(Seifert et al. 2002)**

# Observing Log

- **Average seeing:** 0.4 arcsec

- **N3.75 Camera**: FOV = 4' x 4' and scale = 0.12 arcsec/pix

  **J band:** 20 min on source
  **H band:** 55 min on source
  **K band:** 121 min on source

  **HeI1.08:** 30 min on source
  **[FeII]1.64:** 67 min on source
  **Brγ2.16:** 111 min on source

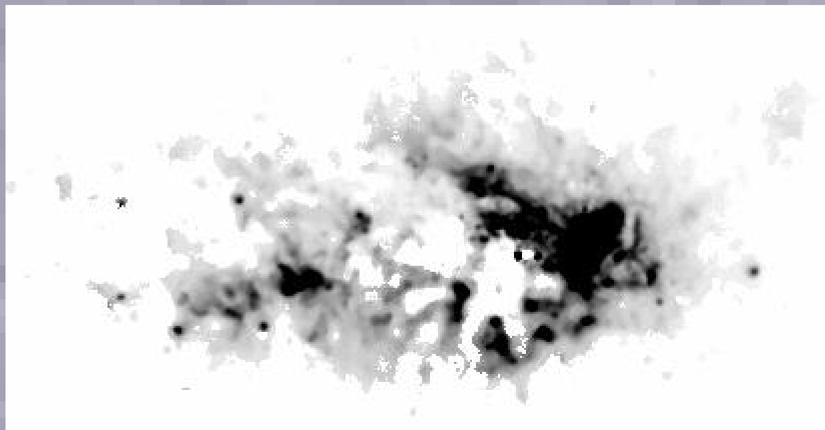
- ***HST*/ACS imaging (PI Aloisi, Prop. ID 10885):**

  **F658N (Hα):** 77 min
  **F606W (~V):** 326 min

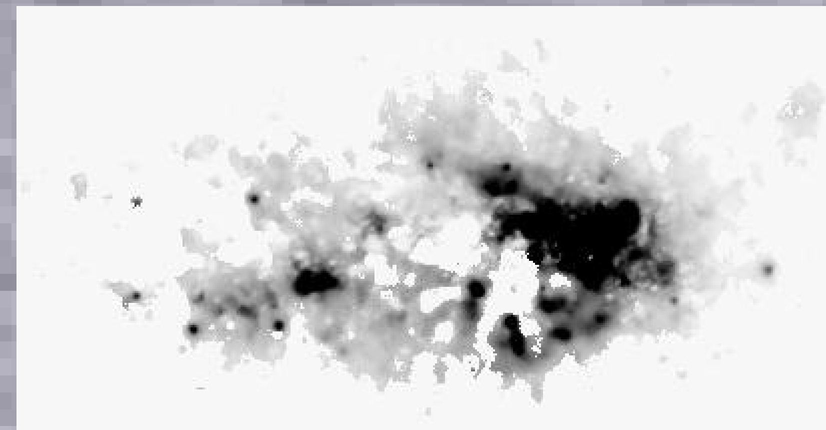

[FeII]
K
Brγ

Hα

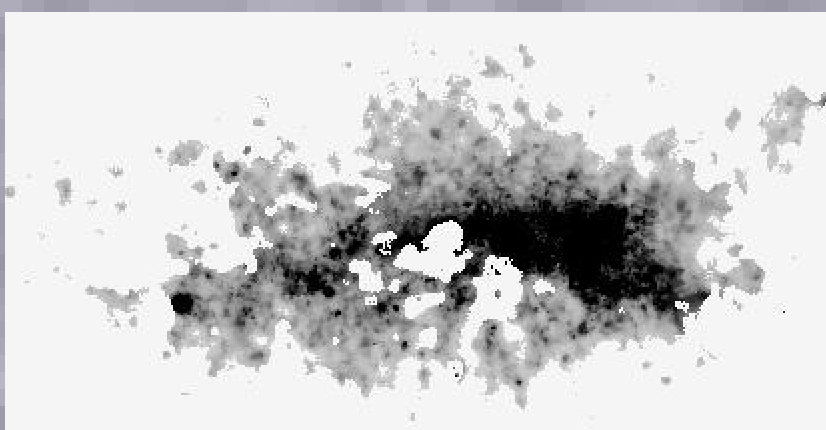
# The Line Emission Maps



**Hα:** $10^{-17}$ to $10^{-15}$ erg cm$^{-2}$ s$^{-1}$



**HeI1.08**: $10^{-18}$ to $10^{-16}$ erg cm$^{-2}$ s$^{-1}$



**[FeII]1.64**: $10^{-18}$ to $10^{-17}$ erg cm$^{-2}$ s$^{-1}$

**Brγ2.16:** $10^{-18}$ to $10^{-17}$ erg cm$^{-2}$ s$^{-1}$

Image size: 1.6 kpc x 0.85 kpc (at 3.36 Mpc, Grocholski et al. 2008)

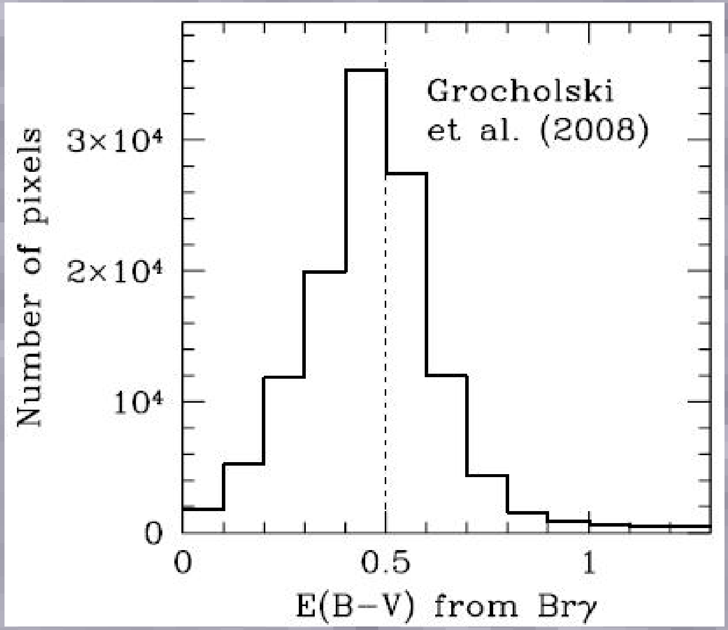
Zibetti (2009, arXiv:0911.4956)
http://www.mpia.de/homes/zibetti/software/adaptsmooth.html

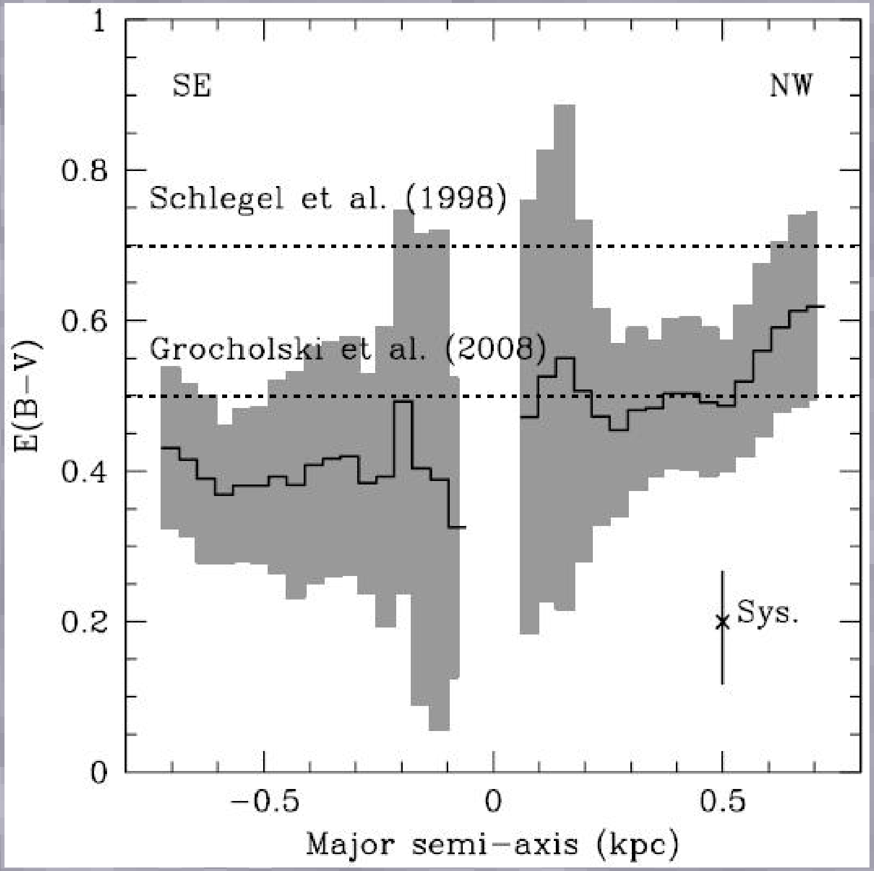
# The 2D map of dust extinction

1.6 kpc x 0.85 kpc

E(B-V): 0 to 1 mag

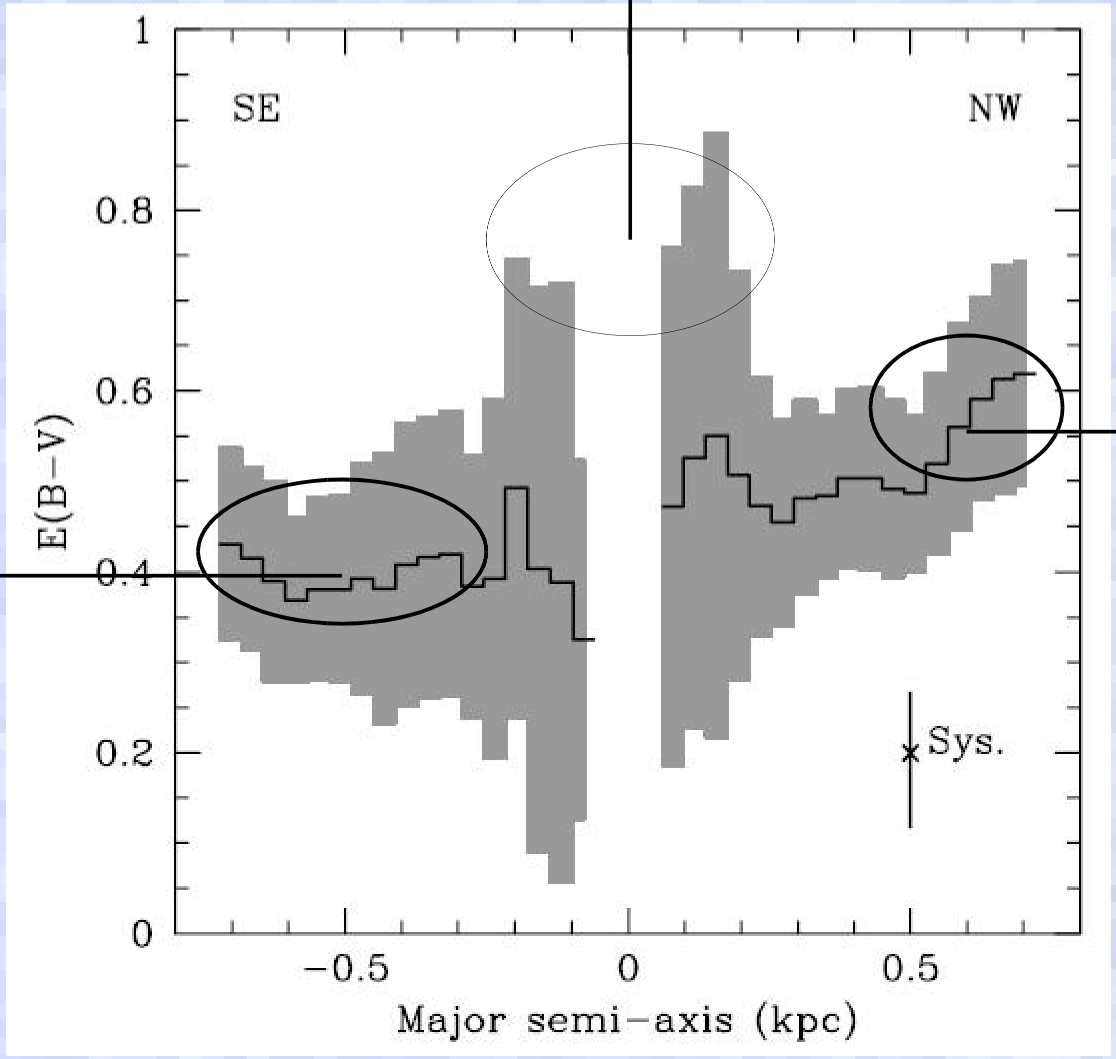
E(B-V) from Brγ/Hα, Case B (T=$10^4$ K), and Calzetti et al.'s (2000) extinction law



# Comparison with the Literature

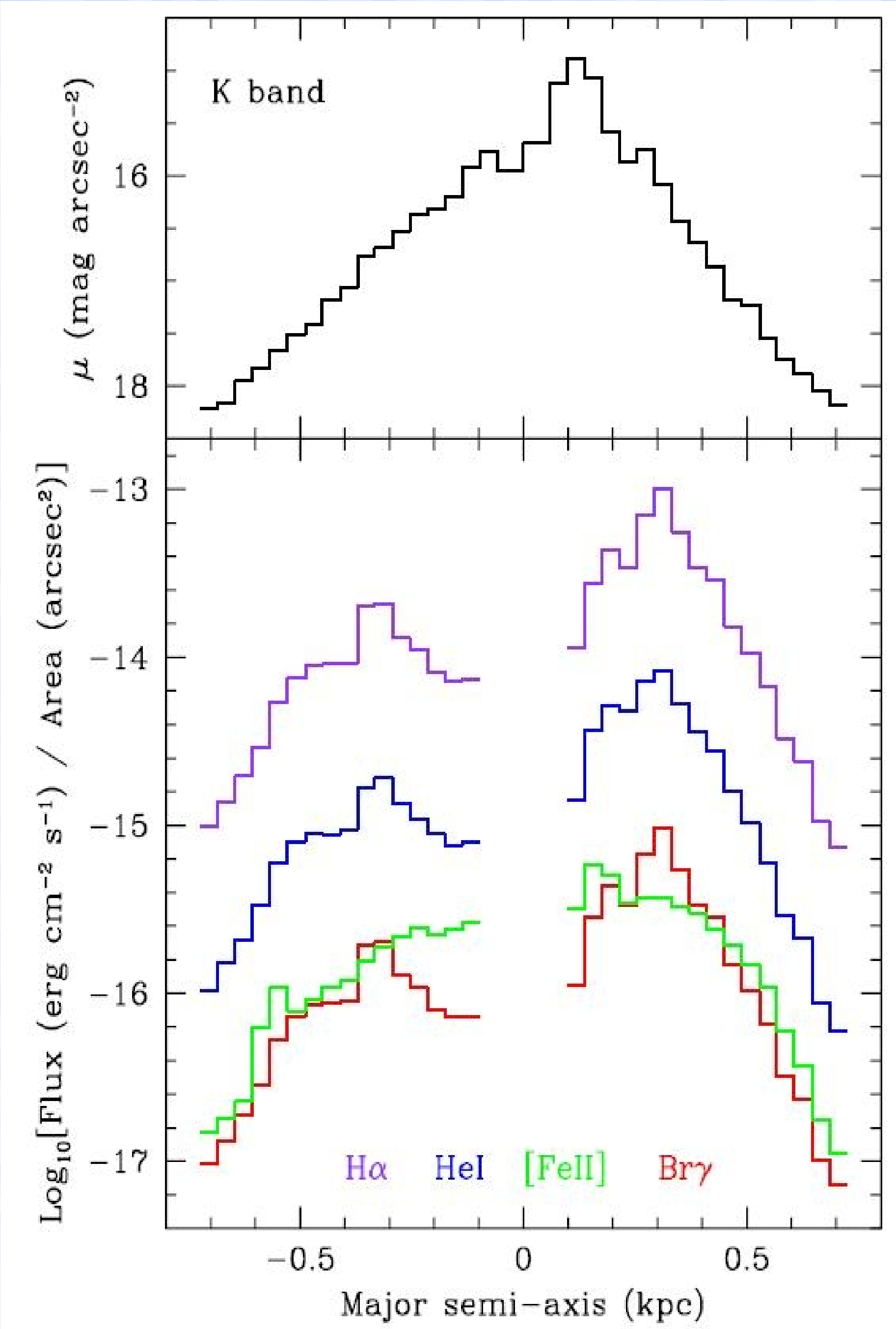
in agreement with Gonzalez Delgado et al. (1997)




in qualitative agreement with Kobulnicky and Skillman (1997)

in agreement with Kobulnicky and Skillman (1997)

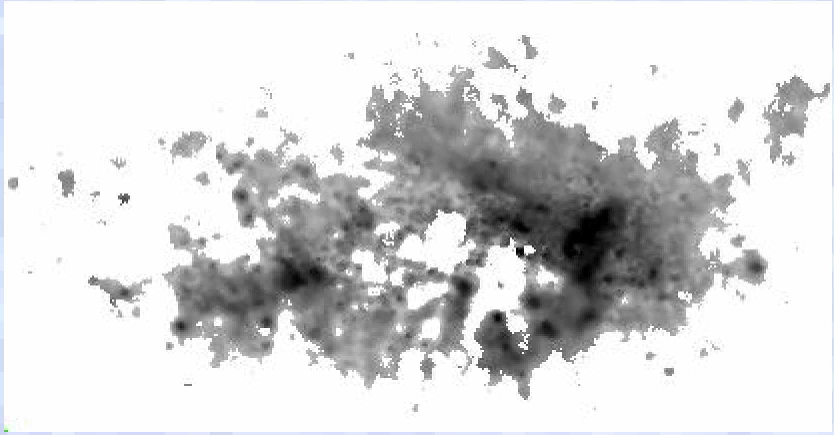
# Surface Brightness Profiles




All corrected for reddening

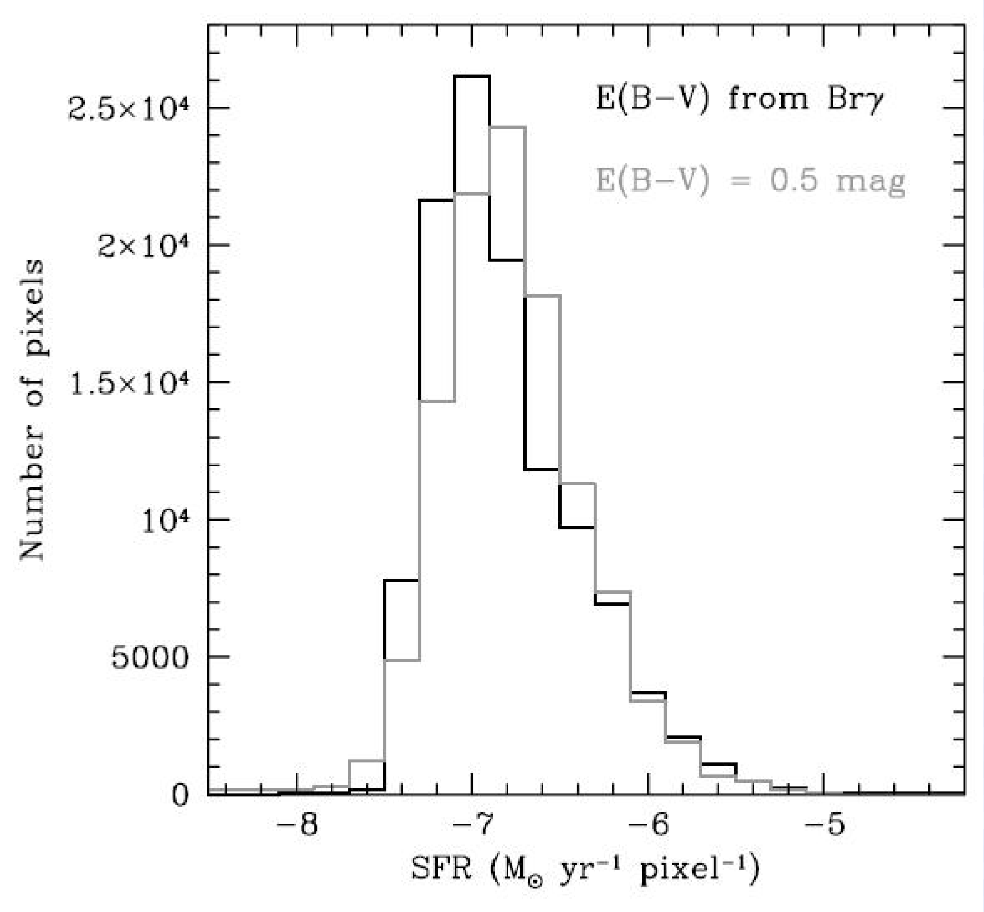
# Star Formation Rate and Density

- Integrated SFR from Hα and Brγ: 0.39 $M_o$/yr (from Kennicutt 1998)
- Distribution of SFR density:

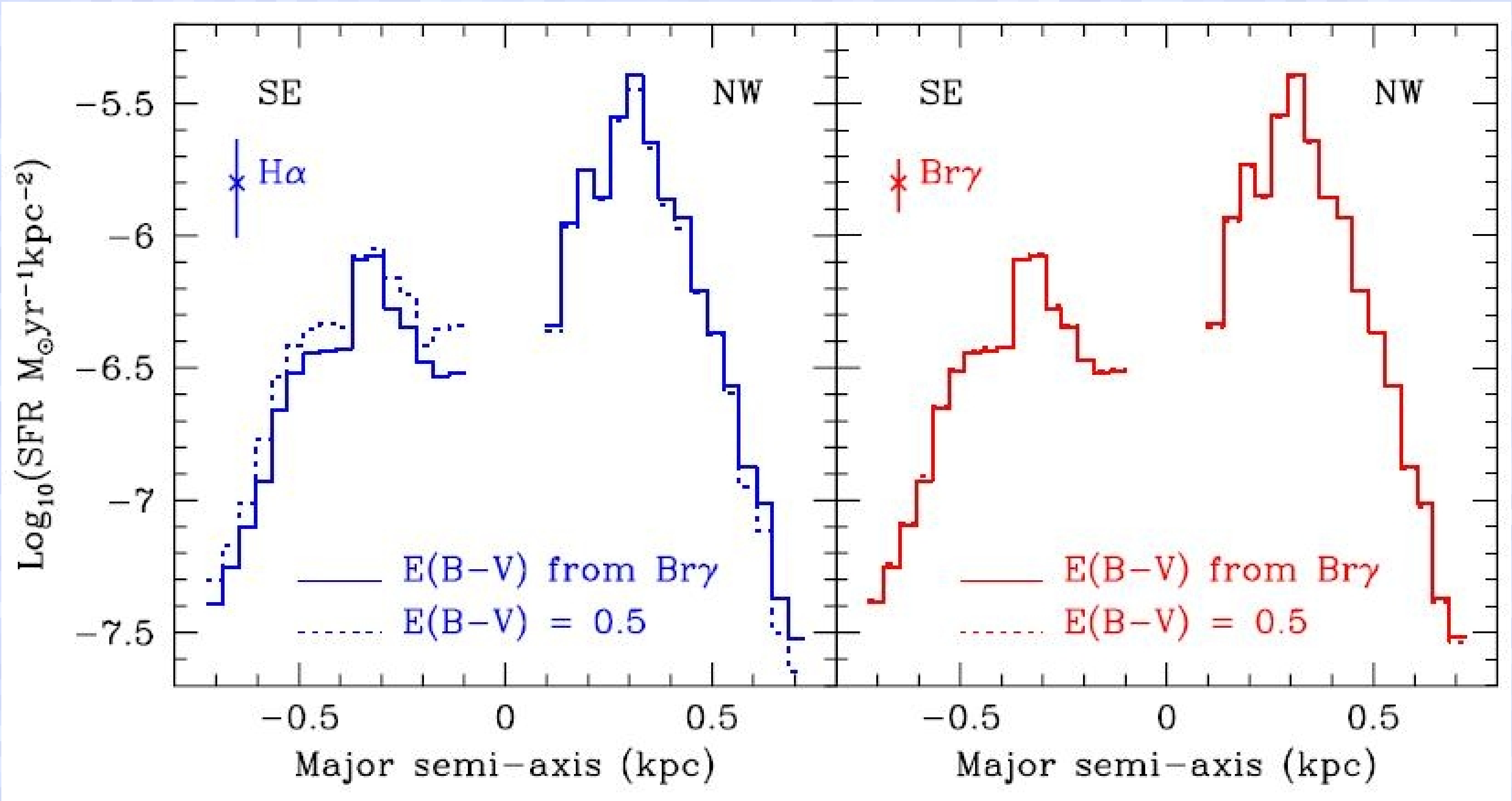


**1.6 kpc x 0.85 kpc**

SFR density: $10^{-7}$ to $10^{-5}$ $M_o$/yr/pix



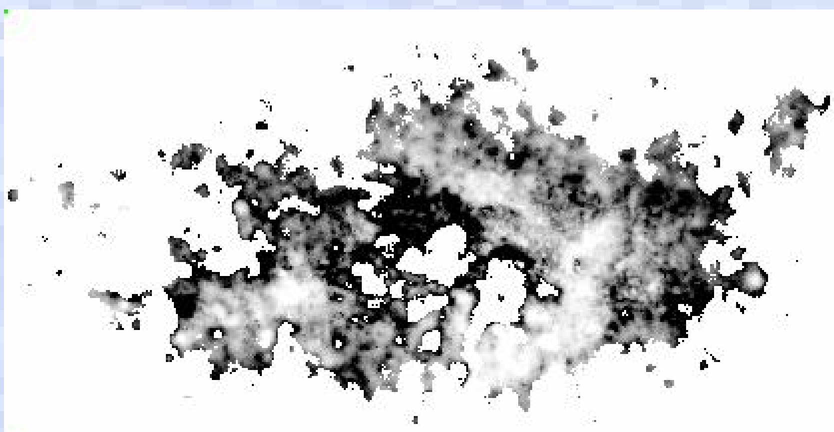
# Azimuthal Distribution of SFR density



# The [FeII] emission

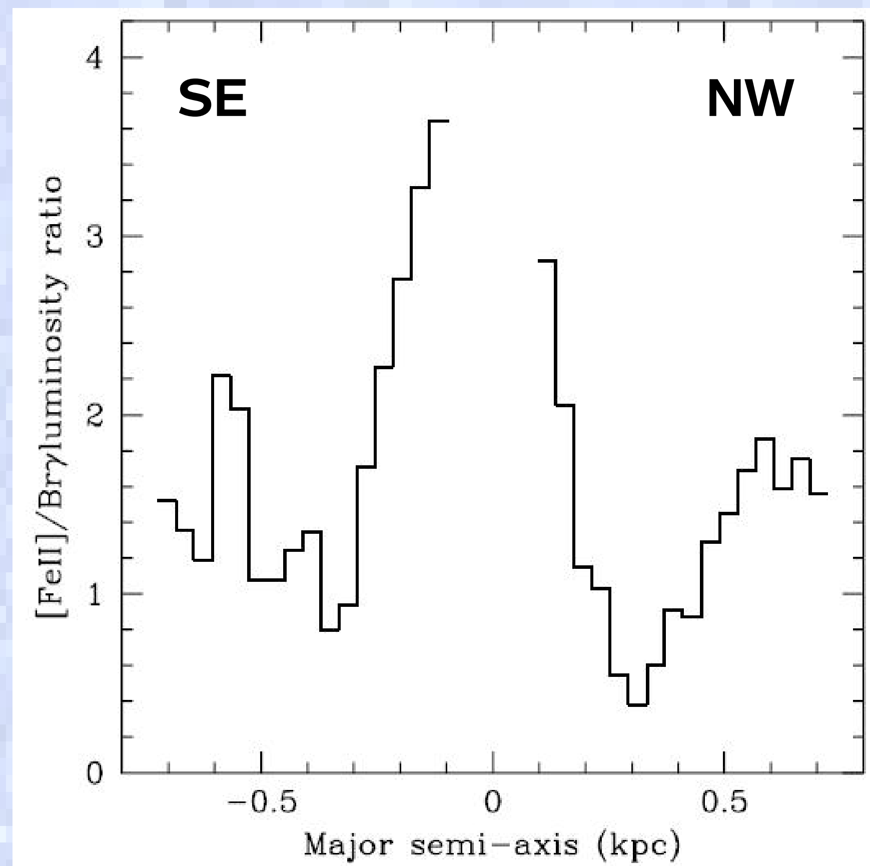
- Integrated [FeII]1.64 luminosity: ~5 x $10^{39}$ erg $s^{-1}$
  Integrated Supernova rate: ~0.005 $yr^{-1}$
  (assuming 1 SN = $10^{37}$ erg $s^{-1}$ and age = $10^4$ yr, from Lumsden & Puxley 1995)

- The spatial distribution of [FeII]1.64/Brγ:



**1.6 kpc x 0.85 kpc**

Ratio from 0 to 5



# SUMMARY

Dust extinction is patchy across the galaxy, with a scatter of about 0.5 mag.
High extinction is seen to occur also around SCC A & B.
The SE portion of NGC 1569 been on average less extinguished than the NW, where the SFR is higher.

The SFR density peaks on both sides of the central cavity and is highest in the NW portion of NGC 1569.
The SFR density varies a factor of ~10 across the galaxy.

The [FeII]/Brγ flux ratio peaks at the edges of the central cavity and at the edges of NGC 1569, indicating that OB stars are mostly located in a ring around the central cavity.