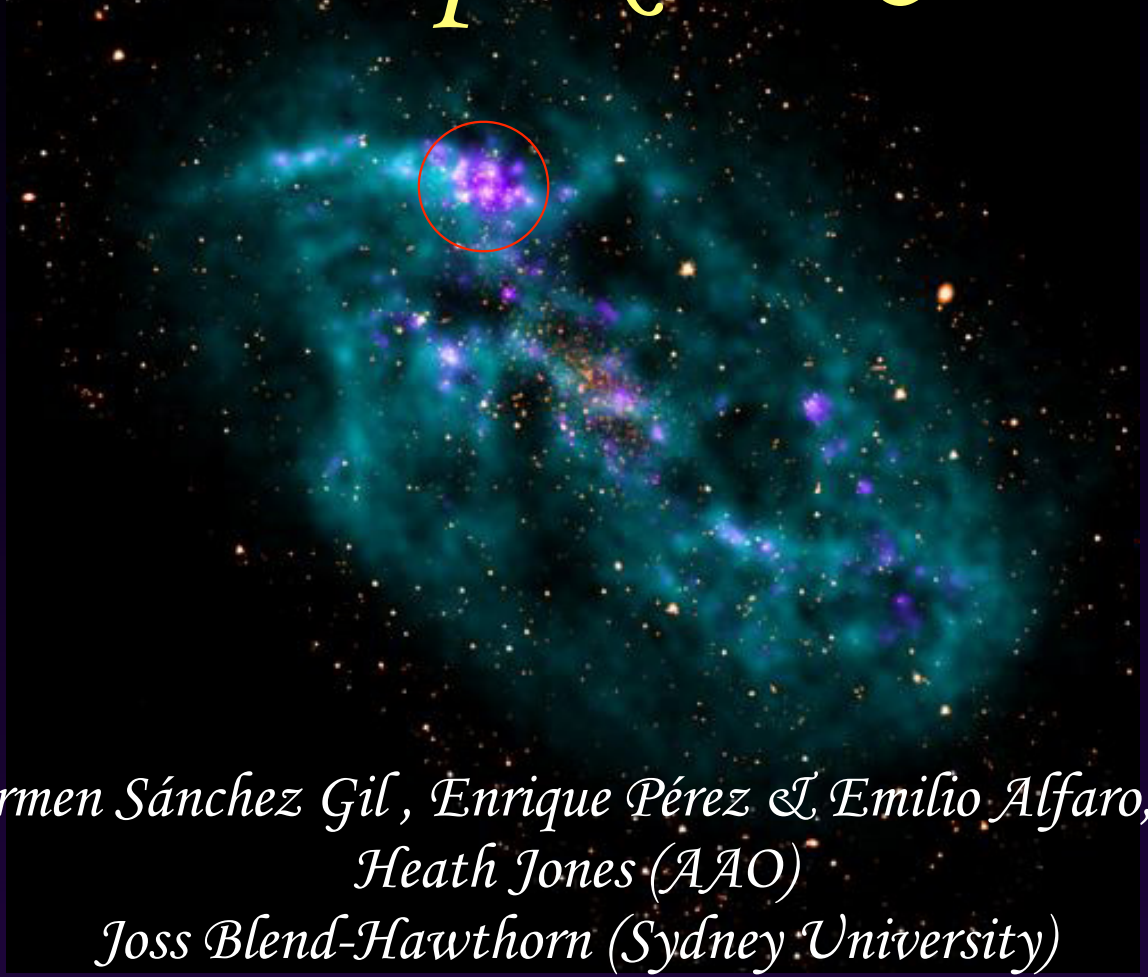
Age mapping a super giant star complex in IC 2574



Mª Carmen Sánchez Gil , Enrique Pérez & Emilio Alfaro, (IAA)
Heath Jones (AAO)
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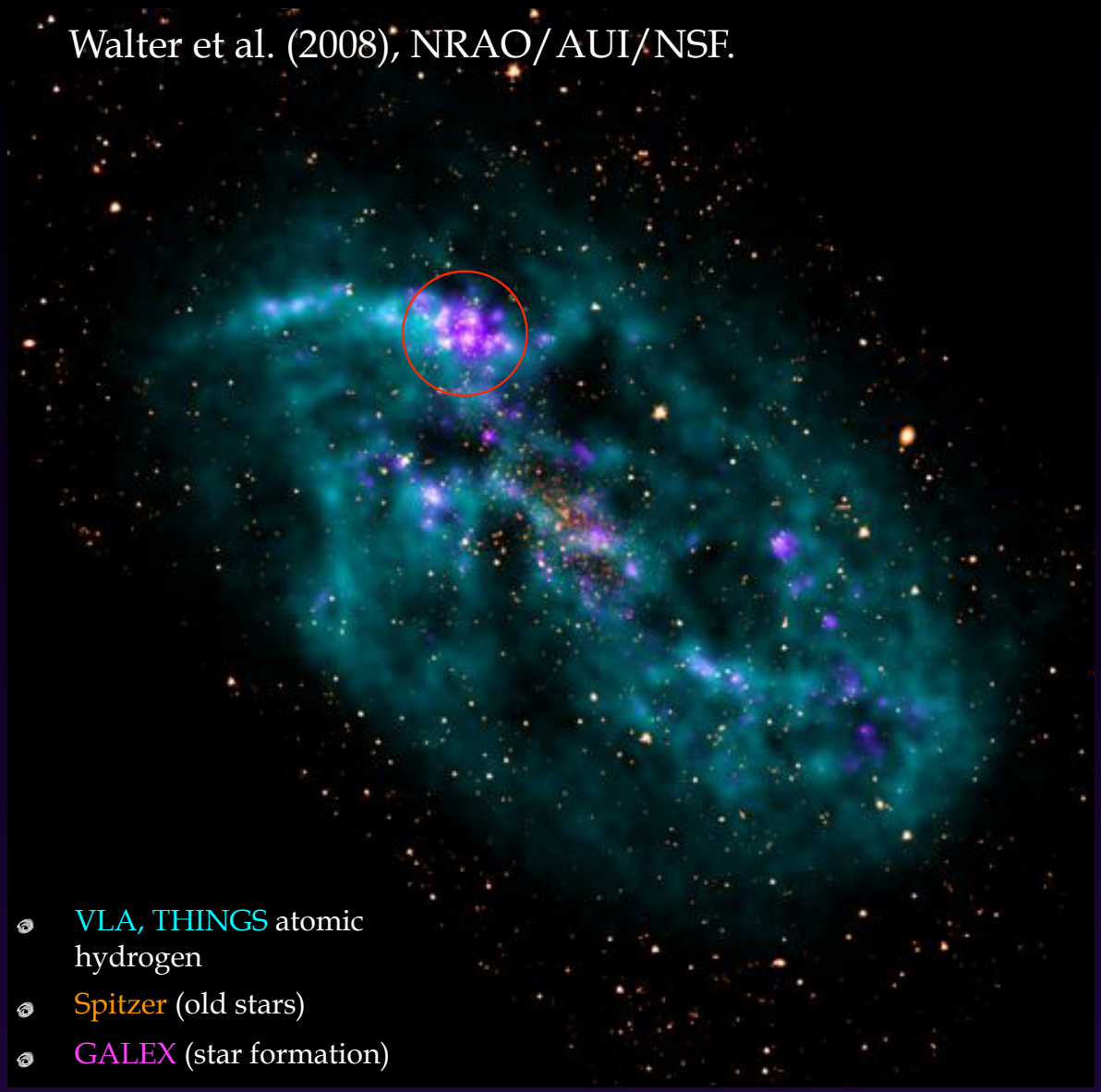
VIII ESTALLIDOS WORKSHOP: "Challenges for the new decade" March 8-10 2010, Salobreña

Age mapping a super giant star complex in IC 2574

Walter et al. (2008), NRAO/AUI/NSF.

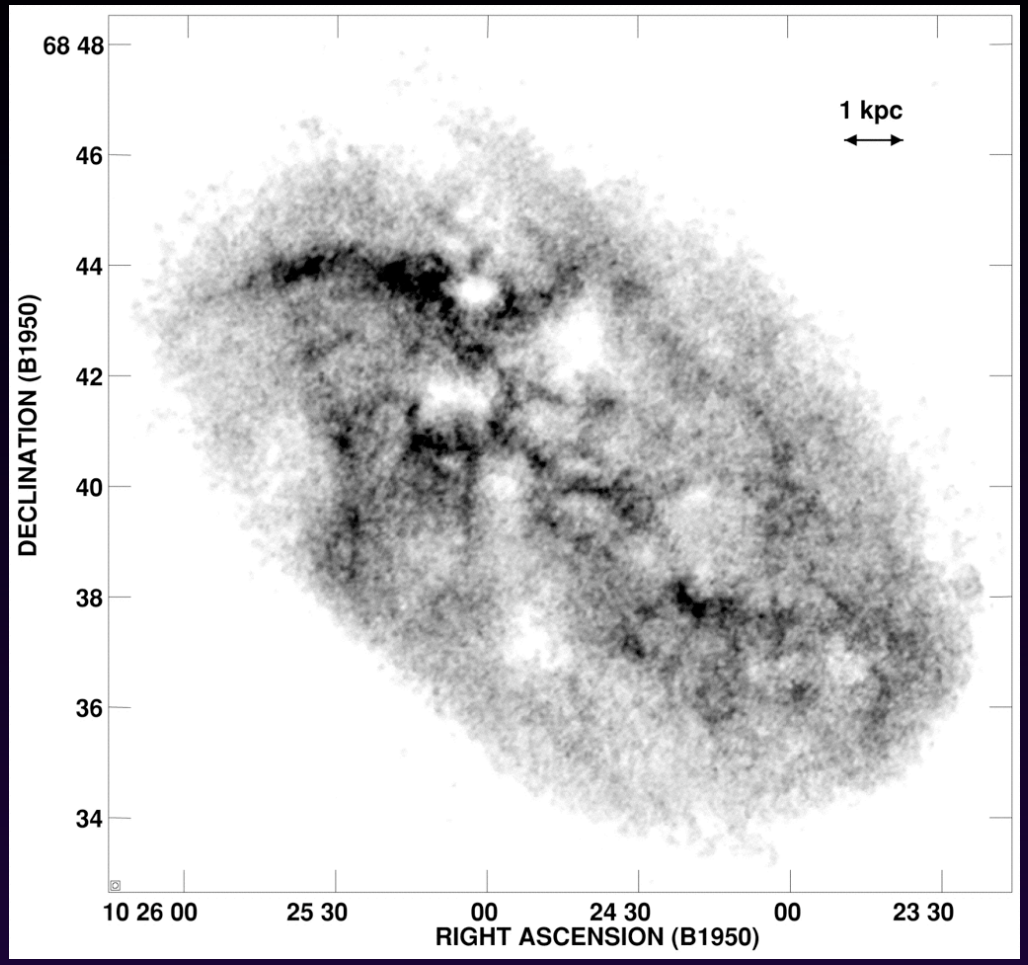


- VLA, THINGS atomic hydrogen
- Spitzer (old stars)
- GALEX (star formation)

- IC 2574 is a gas-rich dwarf irregular galaxy, member of the M81 group of galaxies.
- D=4 Mpc (Gil de Paz et al. 2007).
  1″ ~ 19.4 pc.
- Hα emission is stronger and more concentrated at the northeast of the galactic centre, where this outstanding giant Hα complex (~ 1 kpc in diameter) is located.

Age mapping a super giant star complex in IC 2574

Walter & Brinks (1999)

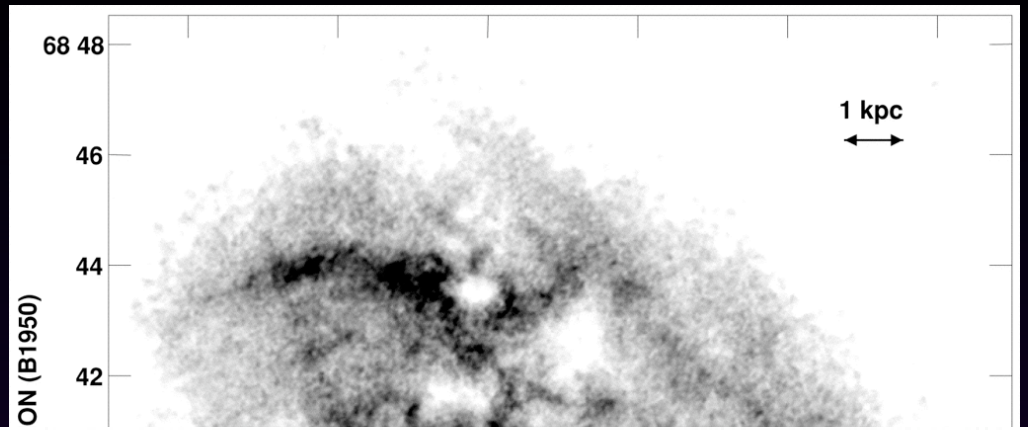


HI surface brightness map of IC 2574

- Numerous HI expanding shells and holes in its interstellar medium (Walter & Brinks 1999)
- The star complex is in the location of one prominent expanding supergiant HI shell (Walter et al. 1998; Walter & Brinks 1999; Weisz et al. 2009)
- Associated as well with the locus of highest HI density emission (Martimbeau et al. 1994; Walter & Brinks 1999).

Age mapping a super giant star complex in IC 2574

Walter & Brinks (1999)



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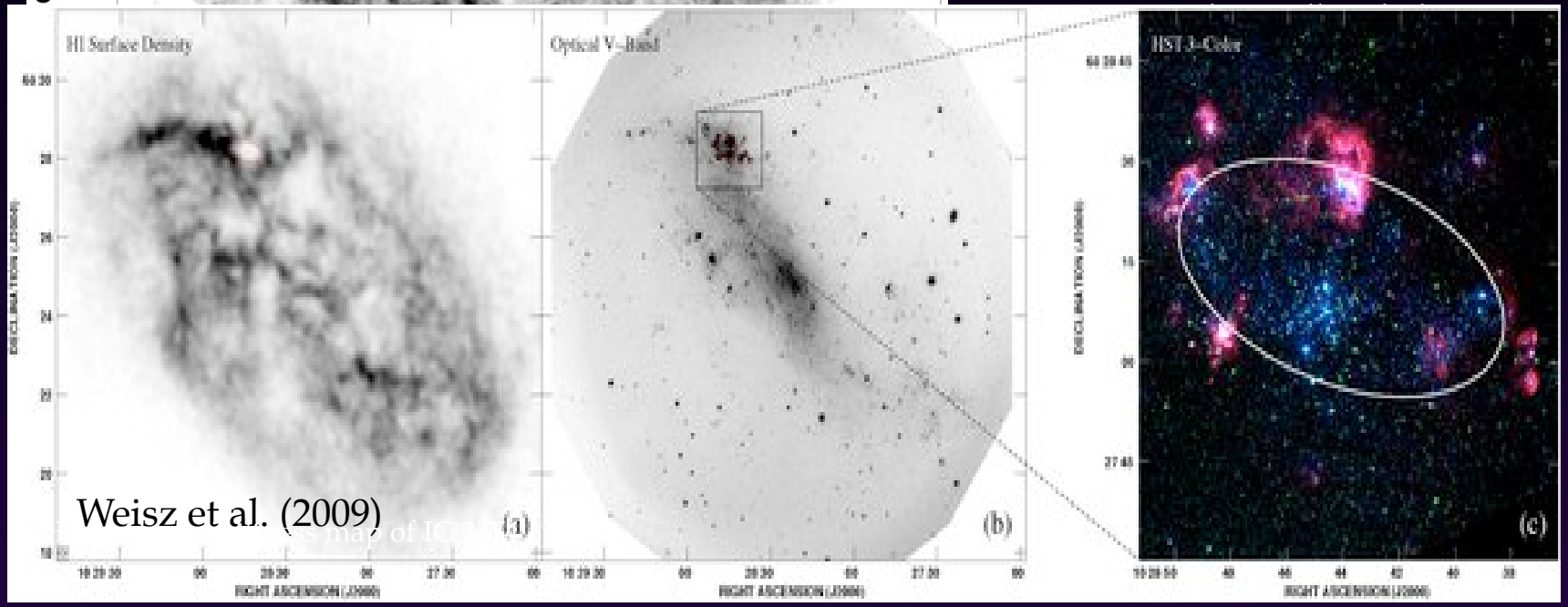
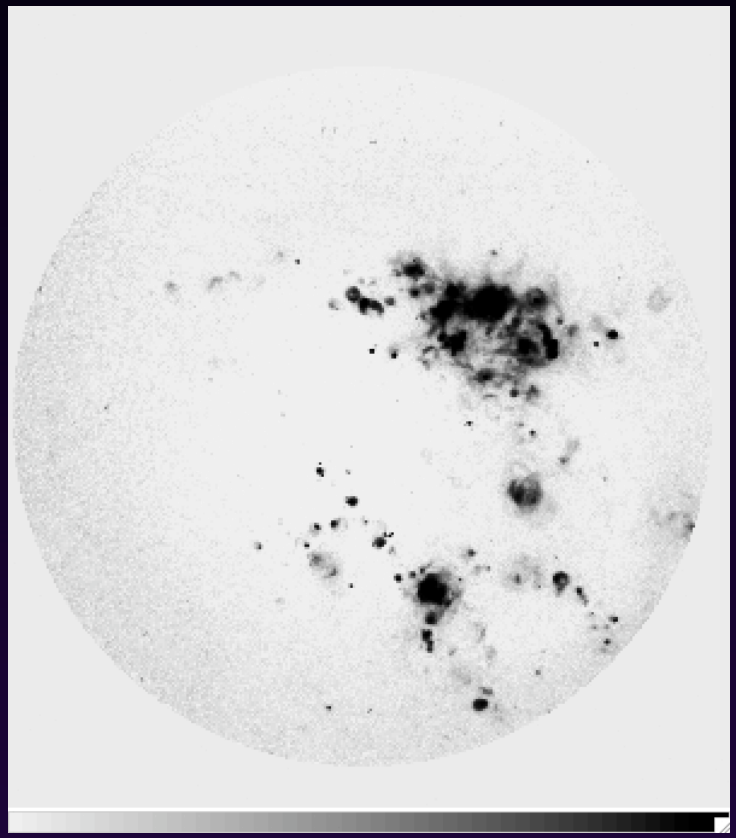


Weisz et al. (2009)

Data:

- Hα image taken with the Taurus Tunable Filter (TTF) at the William Herschel Telescope on 1999 March 4-6; Tunable bandpass of width $\Delta\lambda$ = 20 Å and centre λ = 6570 Å. Pixel scale of 0.56 arcsec/pixel and a field of view of 15 arcmin; seeing 1.0 arcsec



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- The ultraviolet image was retrieved from the GALEX public database (http://galex.stsci.edu/GR2 and GR4). The far-ultraviolet band image, FUV, has a λ_{eff} = 1516 Å, Δ λ=268Å, and a pixel scale of 1.5 arcsec.

- Infrared images [MIPS24, MIPS70 & MIPS160] from The Spitzer Infrared Nearby Galaxies Survey, SINGS (http://irsa.ipac.caltech.edu/data/SPITZER/SINGS). The pixel scale of the MIPS mosaics is wavelength-dependent: 1.5 arcsec at 24 μ, 4.5 arcsec at 70 μ, and 9.00 arcsec at 160 μ. The flux scale is MJy sr-1. The orientation is North up, East left.

  - $F_{TIR} = \zeta_1 \nu_1 F(24\mu) + \zeta_2 \nu_2 F(70\mu) + \zeta_3 \nu_3 F(160\mu)$, (Dale&Helou 2002)

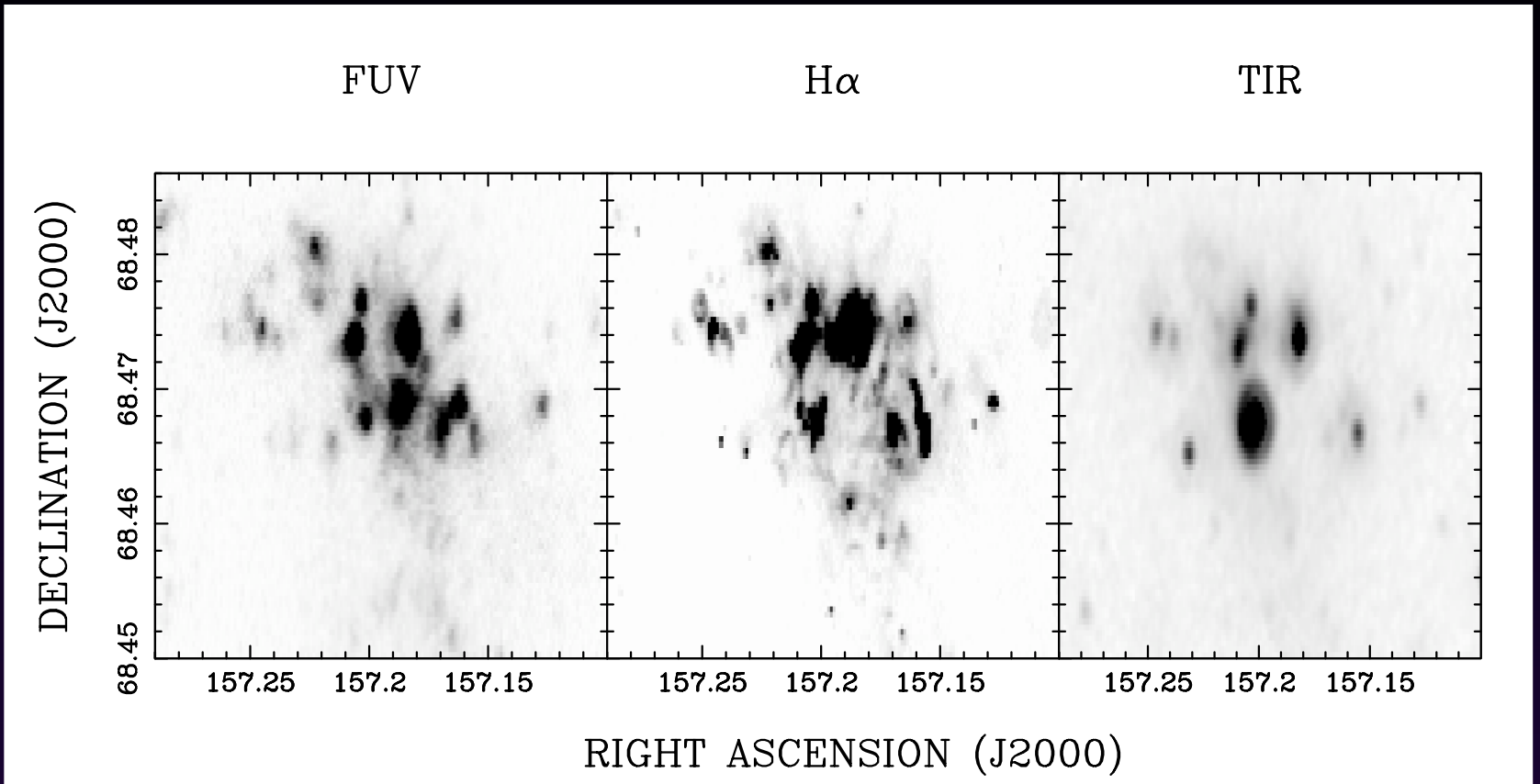
    ($\zeta_1 = 1.559$, $\zeta_2 = 0.7686$, $\zeta_3 = 1.347$)

Pixel - by - pixel technique

- To map the ages of star forming regions across spatially–resolved spiral arms. Resolved galaxies allow us to look at star formation locally by using a pixel-by-pixel technique.
- Abraham et al. (1999), Eskridge et al. (2003).
- Rather than measuring radial variations or disk-average quantities, this technique compares various properties, in particular the Hα line emission to UV flux , corresponding to a small region of the disk defined by a single pixel in an image.
- Comparisons between star forming distributions have concentrated on identifying HII regions and gas clouds (e.g. Zurita et al. 2001; Battinelli et al. 2000; Rozas et al. 2000; Knapen 1998; Kennicutt 1998). Such studies rely on subjective identification techniques, even with the use of region-finding codes (e.g. REGION, developed by C. Heller).
- An alternative is to consider SF objectively, where there is no difficulty or bias in object selection. Galaxy images are differentially compared pixel by pixel.
- Instead of considering individual HII regions, this technique provides information on the global SF properties of a galaxy.

Age mapping a super giant star complex in IC 2574

Pixel - by - pixel technique



Hα/FUV
age estimation

TIR/FUV
extinction correction

Correcting for dust

- The extinction within our galaxy is corrected using the Cardelli et al. (1989) extinction curve and the Schlegel et al. (1998) dust maps for the colour excess E (B-V) (www.irsa.ipac.caltech.edu/applications/DUST)

- Internal extinction was calculated from equation 2 of Buat et al. (2005), relating A_{FUV} extinction to the TIR-to-FUV flux ratio:

  $A(FUV) = -0.0333\ y^3 + 0.3522\ y^2 + 1.1960\ y + 0.4967$, where $y=\log(F_{TIR}/F_{FUV})$

  - This ratio appears to be much more robust and universal to trace the dust extinction.
  - As a quantitative dust estimator, it is found to be almost independent of dust and stellar geometry, provided that the galaxies are forming stars actively (Buat & Xu 1996; Buat et al. 1999; Gordon et al. 2000).

- With no available Hβ data, the A(Hα) extinction was calculated using the relation A(FUV) = 1.4 A(Hα), from Boissier et al. (2005).

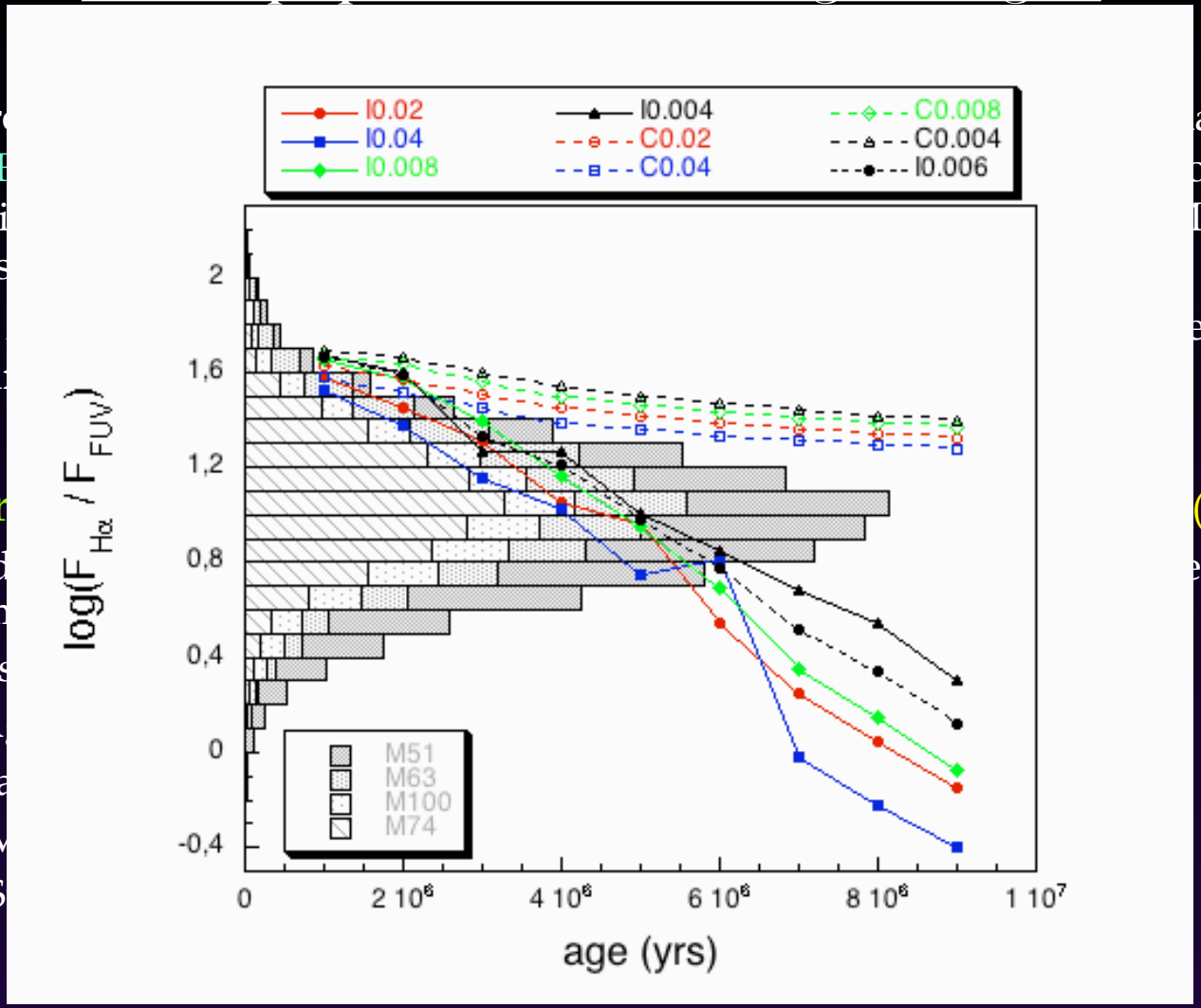
Stellar population modelling and ages:

- As recent star forming region evolves, Hα emission drops off earlier than UV, so the $F_{H\alpha}$ / F_{FUV} flux ratio is sensitive to age. Hα emission line (6563Å) from HII gas ionized by young massive O-type stars ≥10$M_\odot$ with lifetimes ≤20Myrs. UV emission dominated by O-B stars with lifetimes ≤100Myrs
- 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

- Starburst99, evolutionary synthesis model created by Leitherer et al. (1999).
- Modelled flux density ratio $F_{H\alpha}$ / F_{FUV} is compared to the measured ones for age estimation.
- Physical constraints (Leitherer et al. 1999; Vázquez & Leitherer 2005):
  - Age range 10^6 - 10^9 yr, steps of 1 Myr.
  - Salpeter IMF α=2.35, M_{up} = 100$M_\odot$, 30$M_\odot$
  - Metallicity: Z=0.02 ($Z_\odot$), 0.04 ($2Z_\odot$), 0.008 ($2/5Z_\odot$), 0.004 ($1/5Z_\odot$)
  - Star formation history: Instantaneous or Continuous

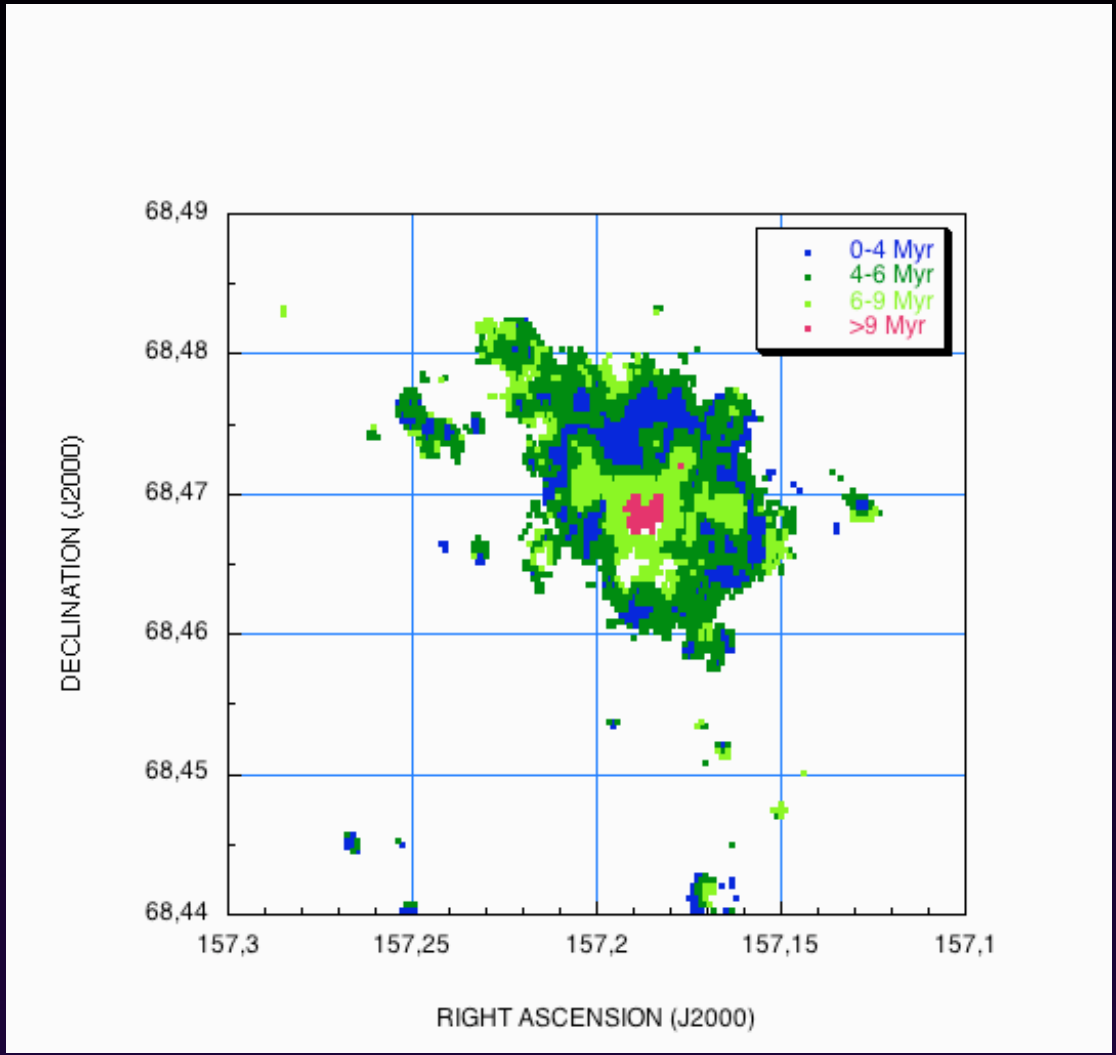
Stellar population modelling and ages:

- As r… an UV, so the H… om HII gas i… lyrs. UV emis…
- The … e to the gala…
- Star… (1999).
- Mod… es for age estin…
- Phys…
  - A…
  - Sa…
  - M…
  - S…



Age mapping a super giant star complex in IC 2574

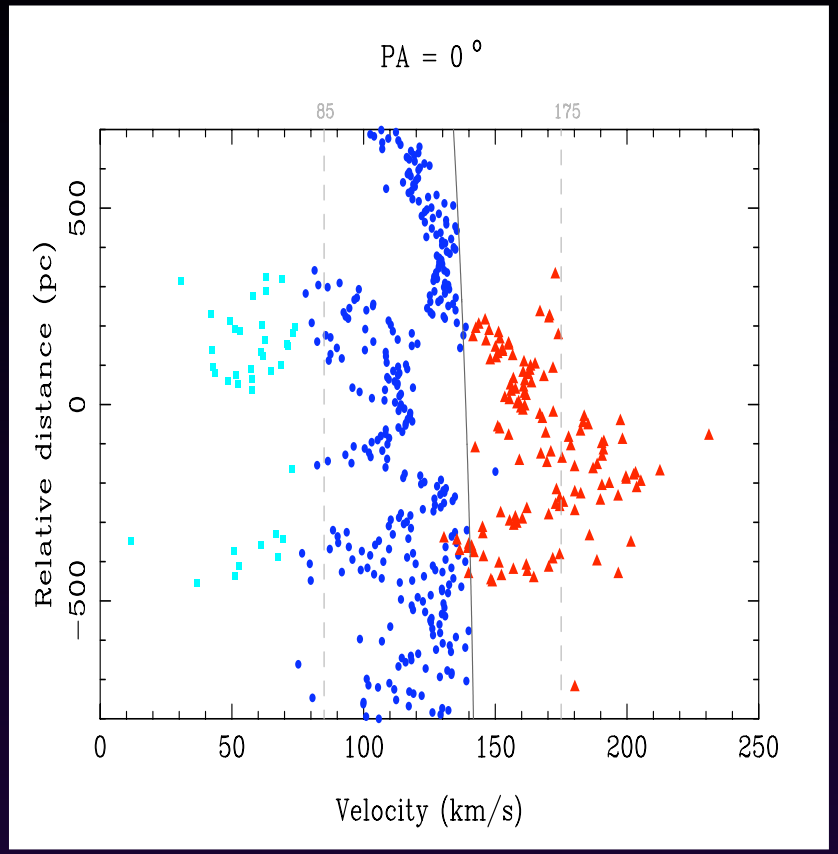
Result: The Age map



- Global vision of the current SF processes, the maximum scale of coherent SF, and it s correlation with other large scale processes (as density waves).
- Clear age gradient that gets younger radially outwards ⇒

  Shell in expansion with secondary SF at its rim triggered by stellar winds and supernova explosions from the older central stars.
- Current star formation along the rims of the larger HI holes and indicating propagating star formation also found in Martimbeau et al. (1994), Walter et al. (1998), Walter & Brinks (1999), Cannon et al. (2005) & Weisz et al. (2009).
- Similar giant star forming complex process found in Sánchez Gil et al. (2009).

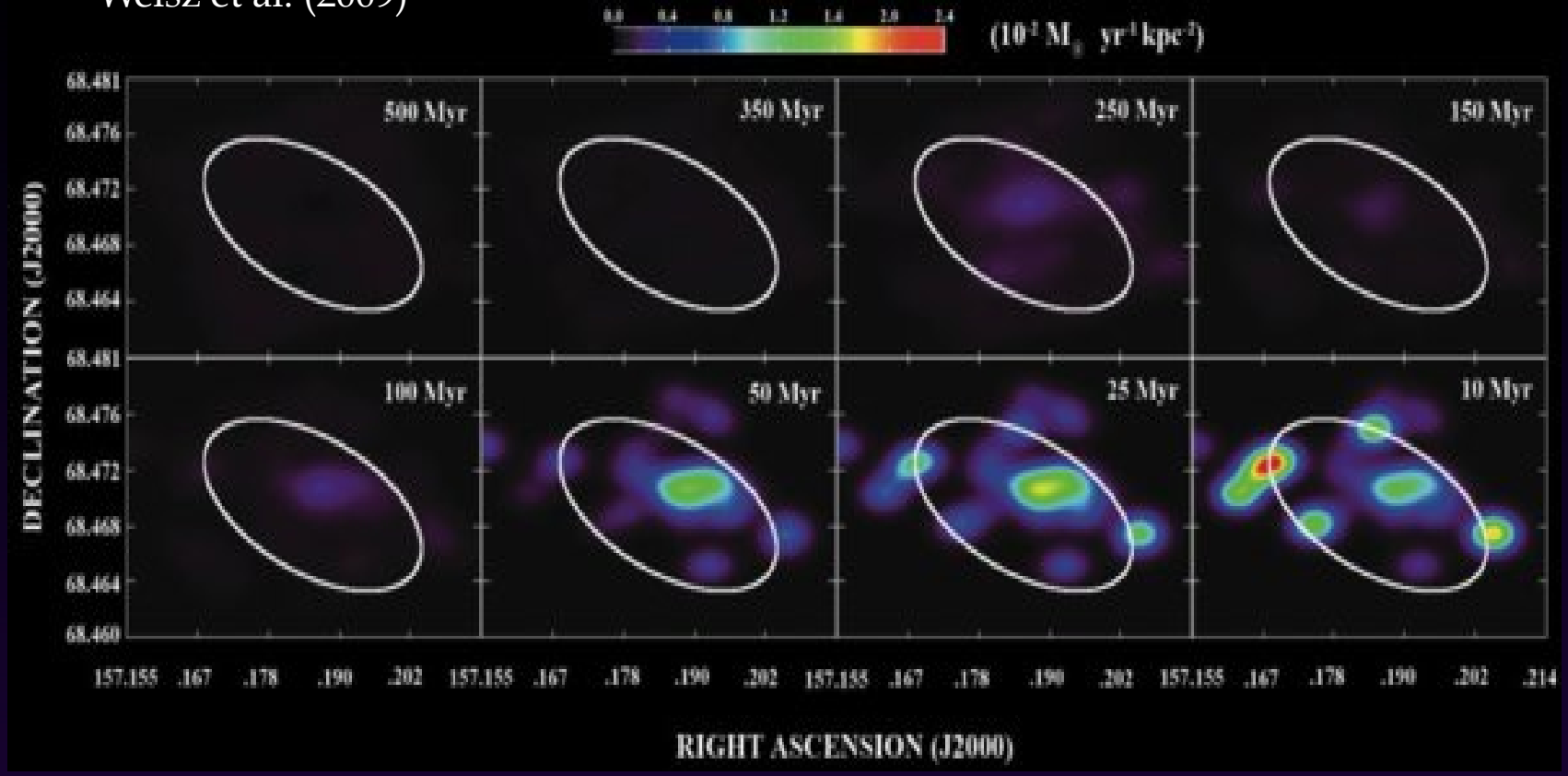
Age mapping a super giant star complex in IC 2574



NGC 6946, Sánchez Gil et al. (2009)

Age mapping a super giant star complex in IC 2574

Weisz et al. (2009)



Age mapping a super giant star complex in IC 2574

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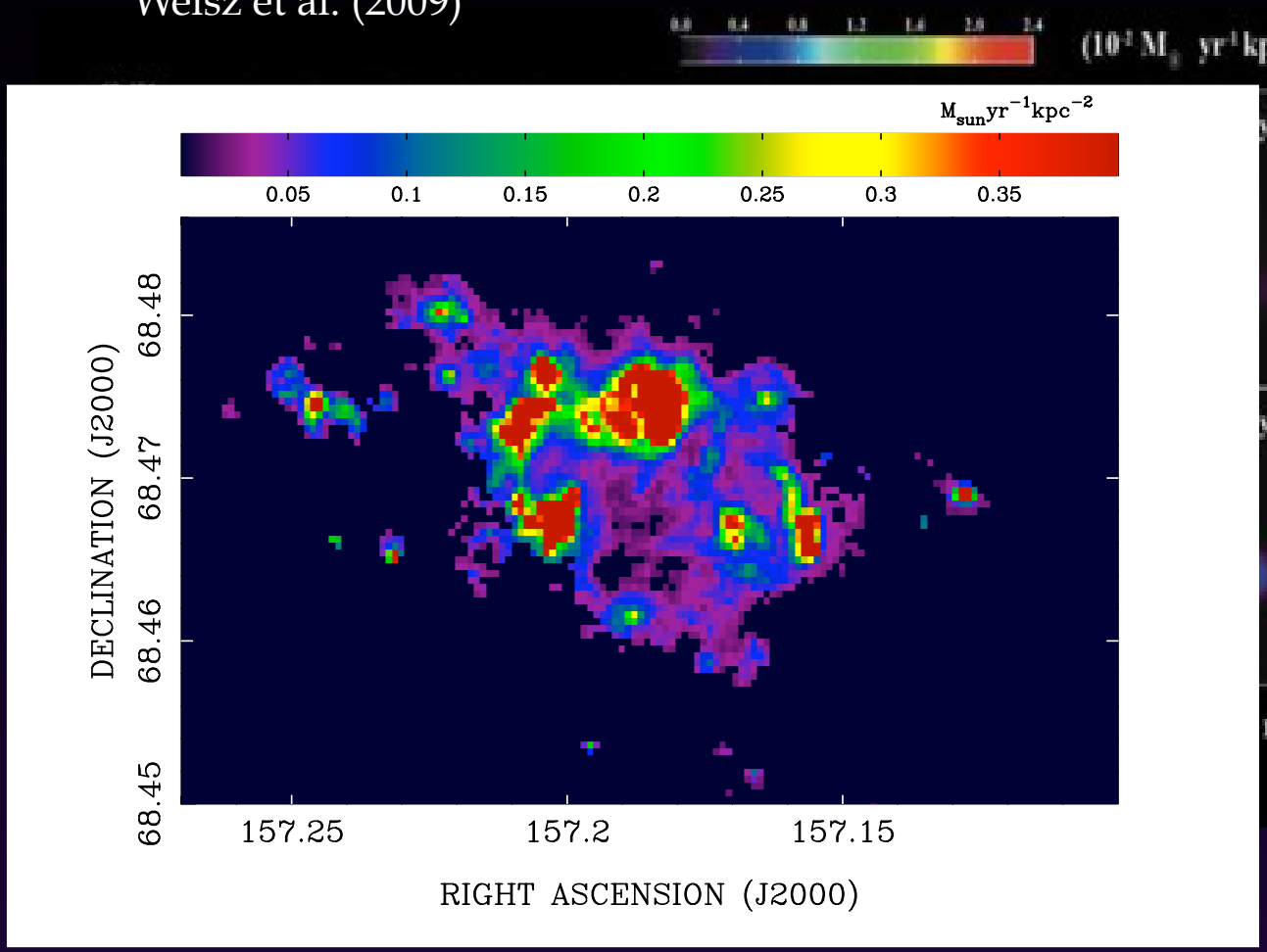

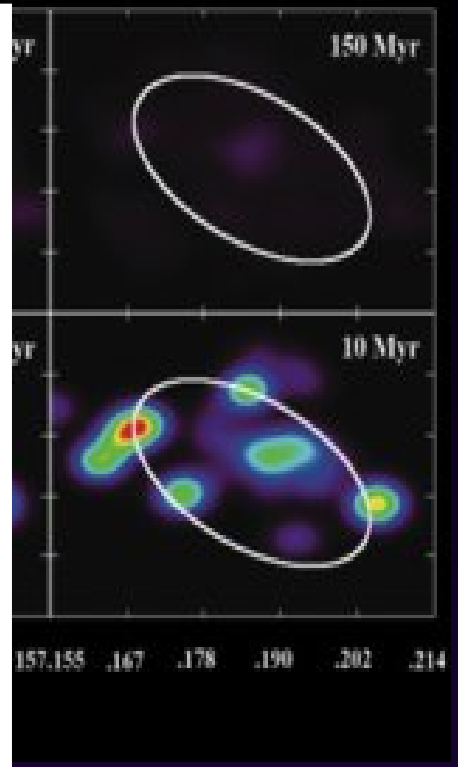

SFR_{total} ($M_\odot$ yr^{-1}) = $L_{H\alpha}$ / (1.12×10^{41} erg s^{-1}) , Kennicutt (1983)

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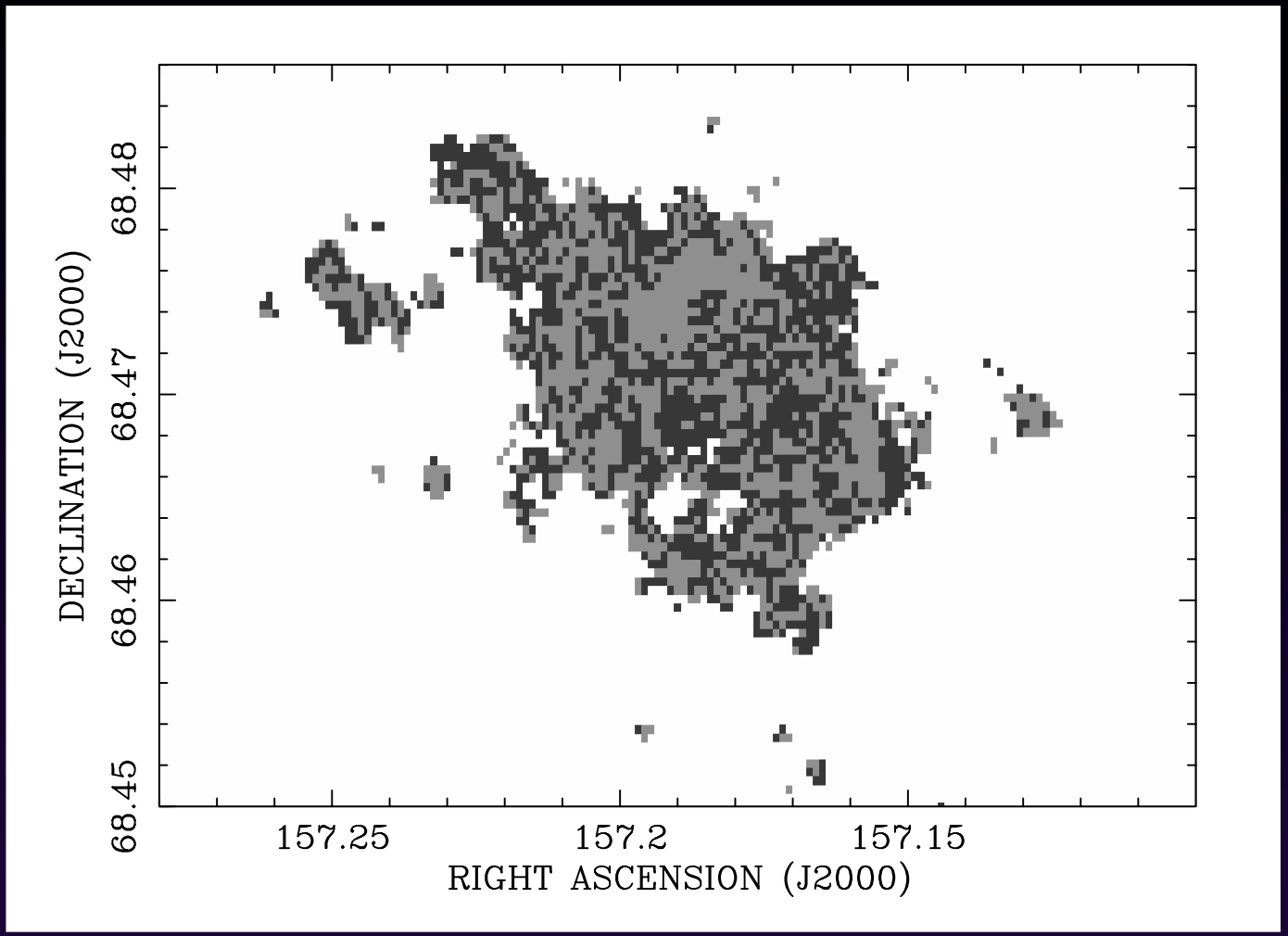

Age mapping a super giant star complex in IC 2574

Summary:

- We present the spatial age pattern and the recent SFH of a supergiant (~1 kpc in diameter) Hα complex in the nearby dwarf galaxy IC 2574, located at ~5 kpc northeast of the galactic centre, coinciding with one of the prominent expanding supergiant HI shells in IC 2574 (Walter et al. 1998; Walter & Brinks 1999; Weisz et al. 2009).
- The analysis is done by combining narrow band Hα imaging, taken with the TTF in the WHT, with GALEX ultraviolet and SPITZER infrared archival images.
- The differential comparison of images at these wavelengths is used to derive spatially resolved burst ages for young stellar populations by comparing with population synthesis models from Starburst99.
- The comparison of the total infrared and the far-ultraviolet fluxes, TIR/FUV, gives a robust estimation for dust extinction correction.
- We use a pixel by pixel technique for objective comparison of star forming regions between the Hα and UV galaxy images.
- The resulting age map of this region shows a star forming complex with a clear center to outer rim age gradient.
- The older population (>9 Myr) is located at the complex center, with successively younger population of stars in rings at increasing radial distances out to ≥500 pc. This age pattern indicates that star formation propagates at velocities of ~50 kms^{-1}, suggesting a mechanism of induced star formation by the massive stellar winds and supernova explosions from the older to the younger generations.

Summary:

- We present a method based on the interaction of stars and gas as probe of star formation mechanism, that helps to understand the star formation processes and its propagation.
- The age map shows the age pattern across the spatially resolved galaxies, remarking as well their morphology and in many cases finding interesting age gradients.
- The pixel to pixel technique allows the spatial characterization of the age distribution for HII regions within a range of distance in the Local Volume provide enough spatial resolution to infer the internal history of the star formation procesees.
- Finally, we remark the ability and interest of the proposed methodology for determining the largest scale of coherent star formation in galaxies, a quantity intimately connected with the internal dynamics and the arrangement of gas clouds, in the disks.