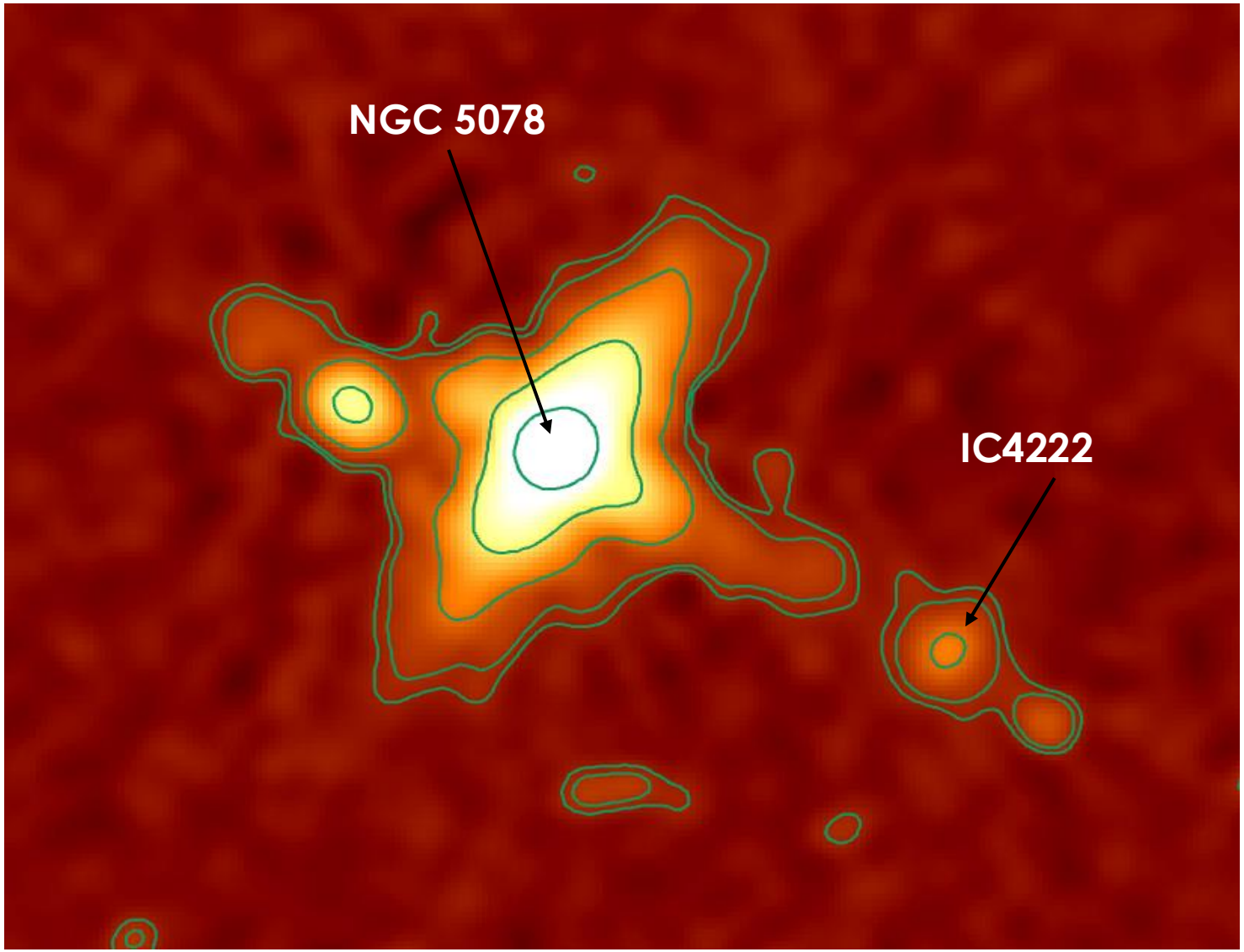

Figure: ASKAP radio image of galaxy pair at 944.5 MHz with NGC 5078 and IC4222 annotated. Log scaling and contours are at 3, 5, 20, 100, and 1000 σ.

How an AGN jet can impact the habitability of a neighbouring galaxy:

A case study of NGC 5078 and IC4222

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Main question:

• How can AGN radio jets from galaxy impact the habitability of its neighbour?

Sub questions:

- How could the AGN jets affect star formation?
- Is there a way to model the cosmic ray flux from radio AGN jets?
- How could this cosmic ray flux affect neighbouring galaxies?
- How could the neighbouring galaxies magnetic field protect it?

NGC 5078

Larger galaxy, Radio loud AGN

Ordinary non-barred S-shaped galaxy, edge-on[1]

Redshift: 0.007232 ± 0.00002[2]

Hubble Distance: 36.38 ± 2.57 Mpc

IC4222

- Smaller galaxy
- Peculiar barred S-shaped galaxy[1]
- Redshift: 0.007965 ± 0.00004[3]
- Hubble Distance: 39.62 ± 2.80 Mpc

[1] de Vaucouleurs et al. 1991, *Third Reference Catalogue of Bright Galaxies*

[2] Lauberts & Valentijn 1989, *The surface photometry catalogue of the ESO-Uppsala galaxies*

[3] Theureau et al. 2007, A&A, 465, 71

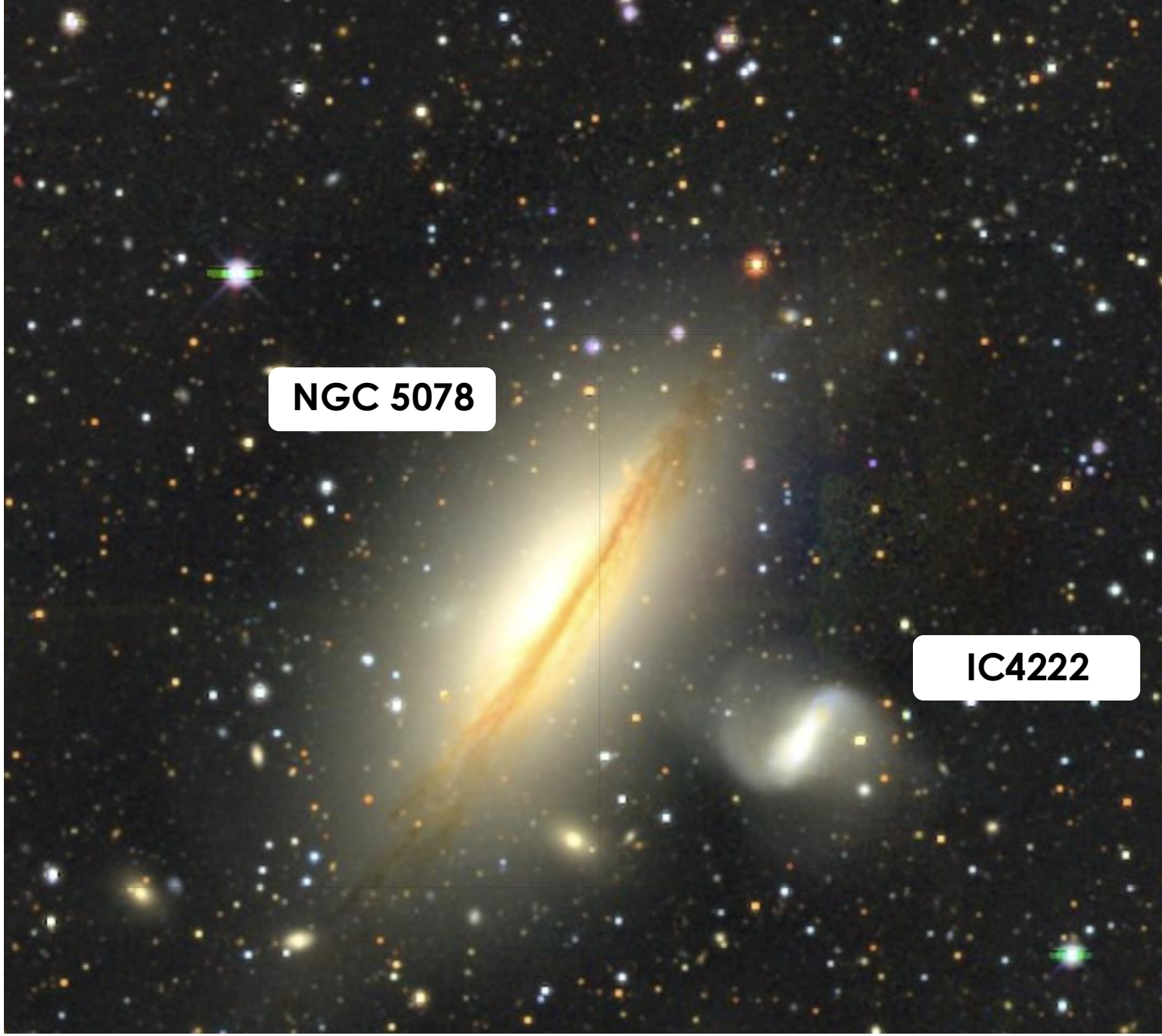


Figure: DESI DR10 optical image from Legacy Survey Sky Browser (https://www.legacysurvey.org/viewer) with NGC 5078 and IC4222 annotated

MEASURED PROPERTIES

- **NGC 5078**
- Disk: 24 X 16 kpc
- NE jet: 16 kpc
- SW jet: 14 kpc

- **IC4222**
- 7 kpc diameter

- **Core to core distance**
- 23 –25 kpc

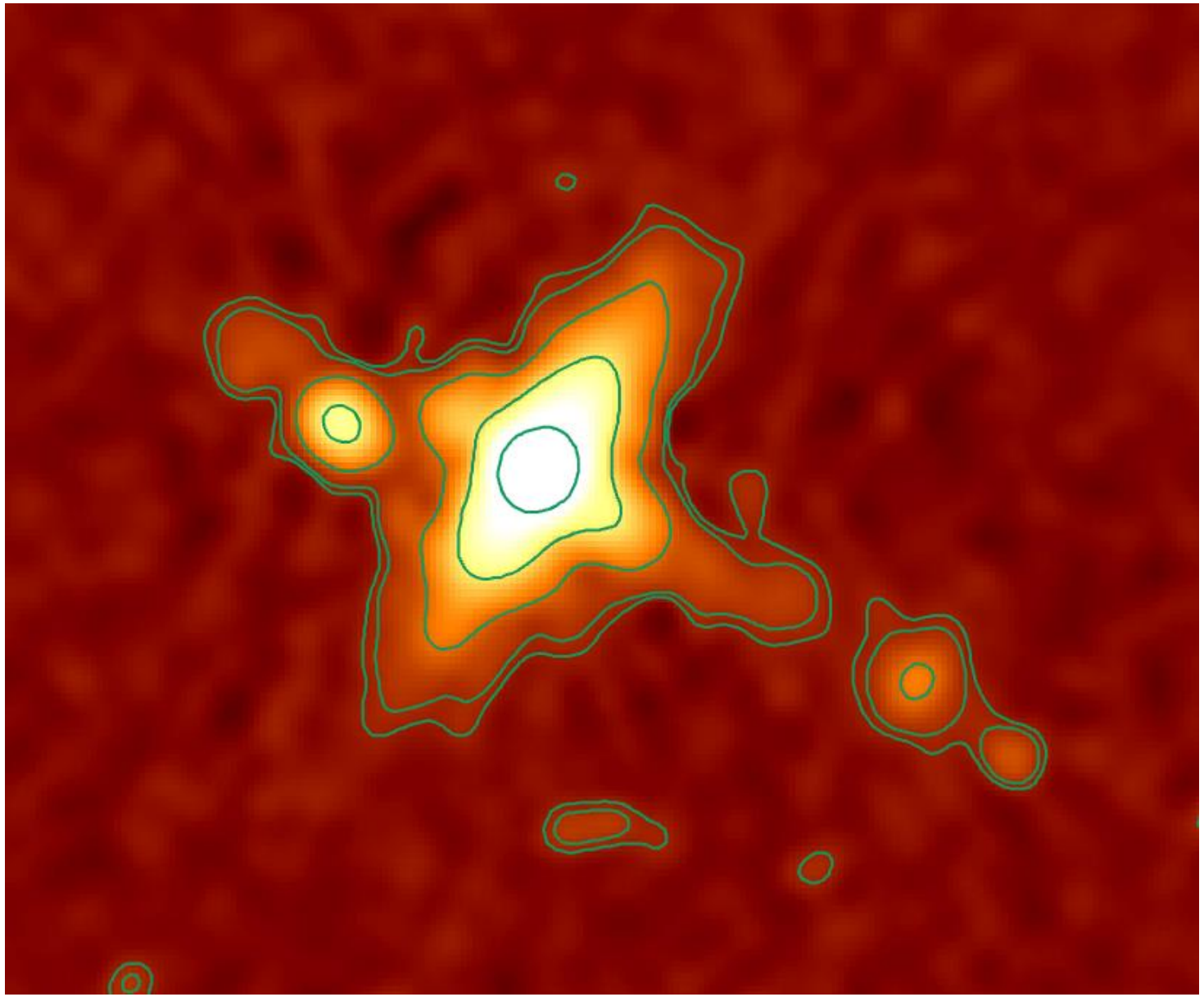
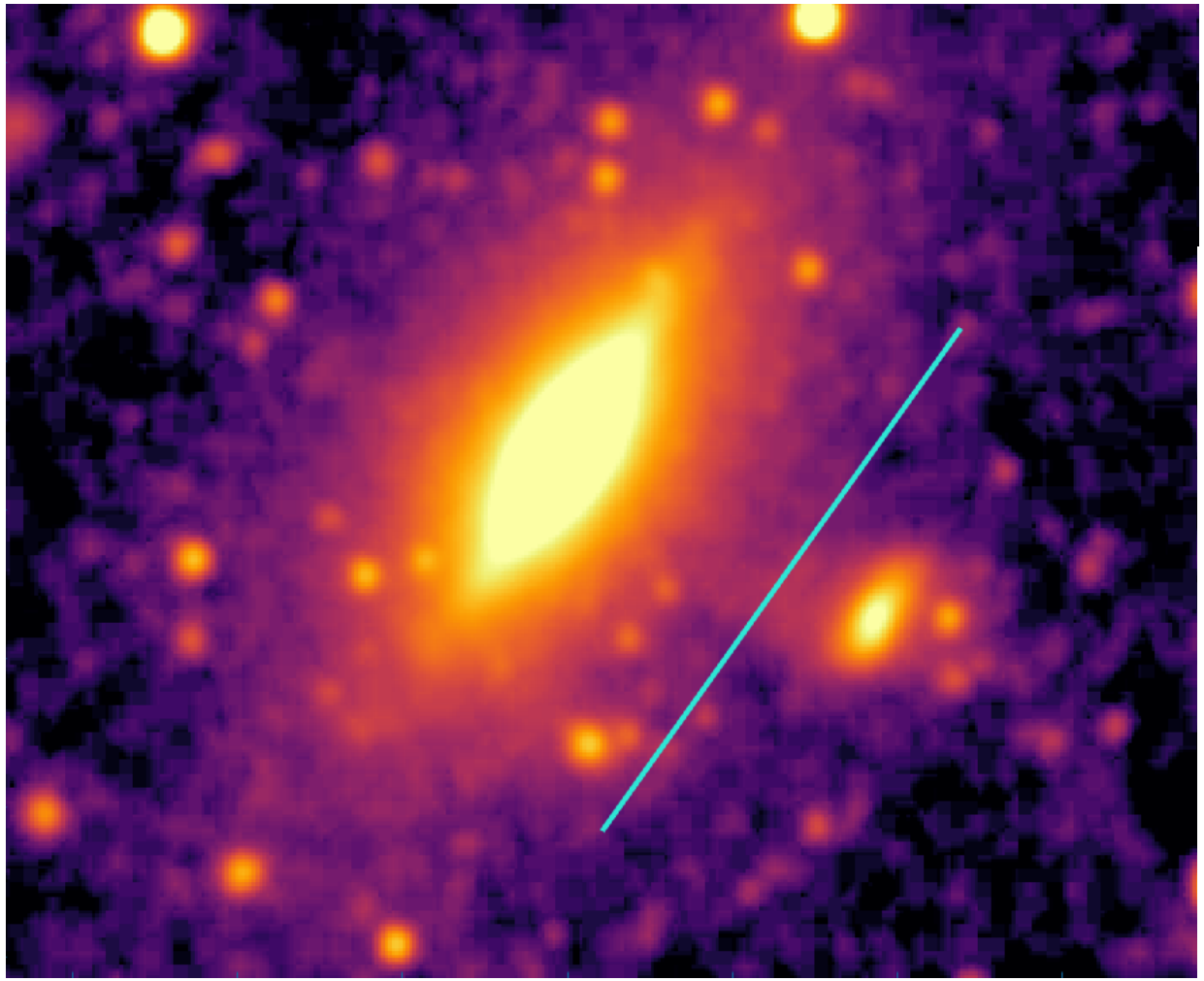


Figure: ASKAP radio image of galaxy pair at 944.5 MHz. Log scaling and contours are at 3, 5, 20, 100, and 1000σ.

IR BRIDGE



- Weak emission, only possible detection, weakly visible in all IR and optical images
- Could be matter exchange / tidal interaction between the galaxies

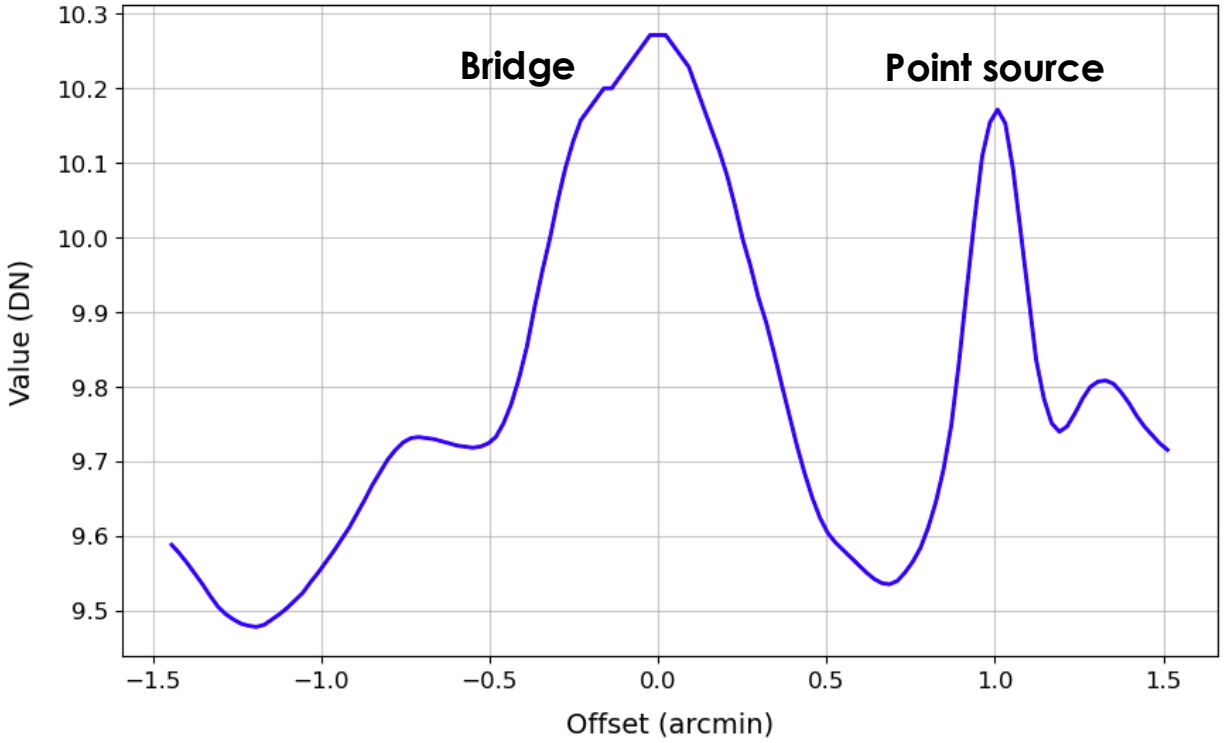


Figure: WISE IR image of galaxy pair at 4.6 µm (W2 band). Subsection from possible emission bridge. Emission graph (right) given in values of arbitrary digital numbers (DN). Middle peak is bridge, right peak is likely background point source.

UV properties (GALEX)

Far UV (154 nm)

Near UV (232 nm)

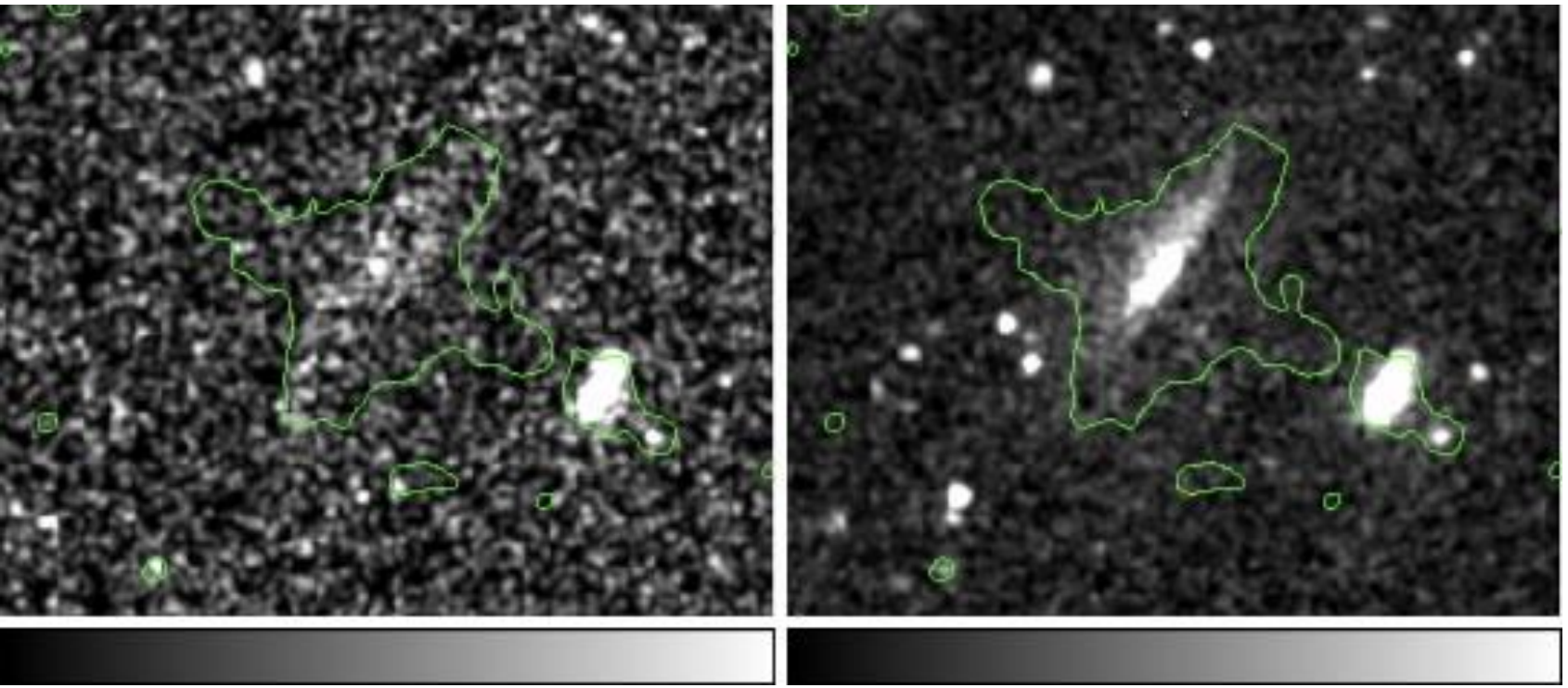


Figure: GALEX UV image of galaxy pair. FUV (left) at 154 nm and NUV (right) at 232 nm. Contours are 3σ from ASKAP radio image (944.5 MHz).

IC4222

FUV = 17.31±0.04 mag[1]
NUV = 16.65±0.02 mag [1]

FUV – NUV = 0.66±0.06 mag

Recent study gives typical values: 0 – 0.4 mag [2]

Higher ratio indicates older stellar population

[1] Brianchi et al. 2014, *GALEX-GR6/7 data release*
[2] Amrutha et al. 2024, MNRAS, 530, 2199

SED Modeling

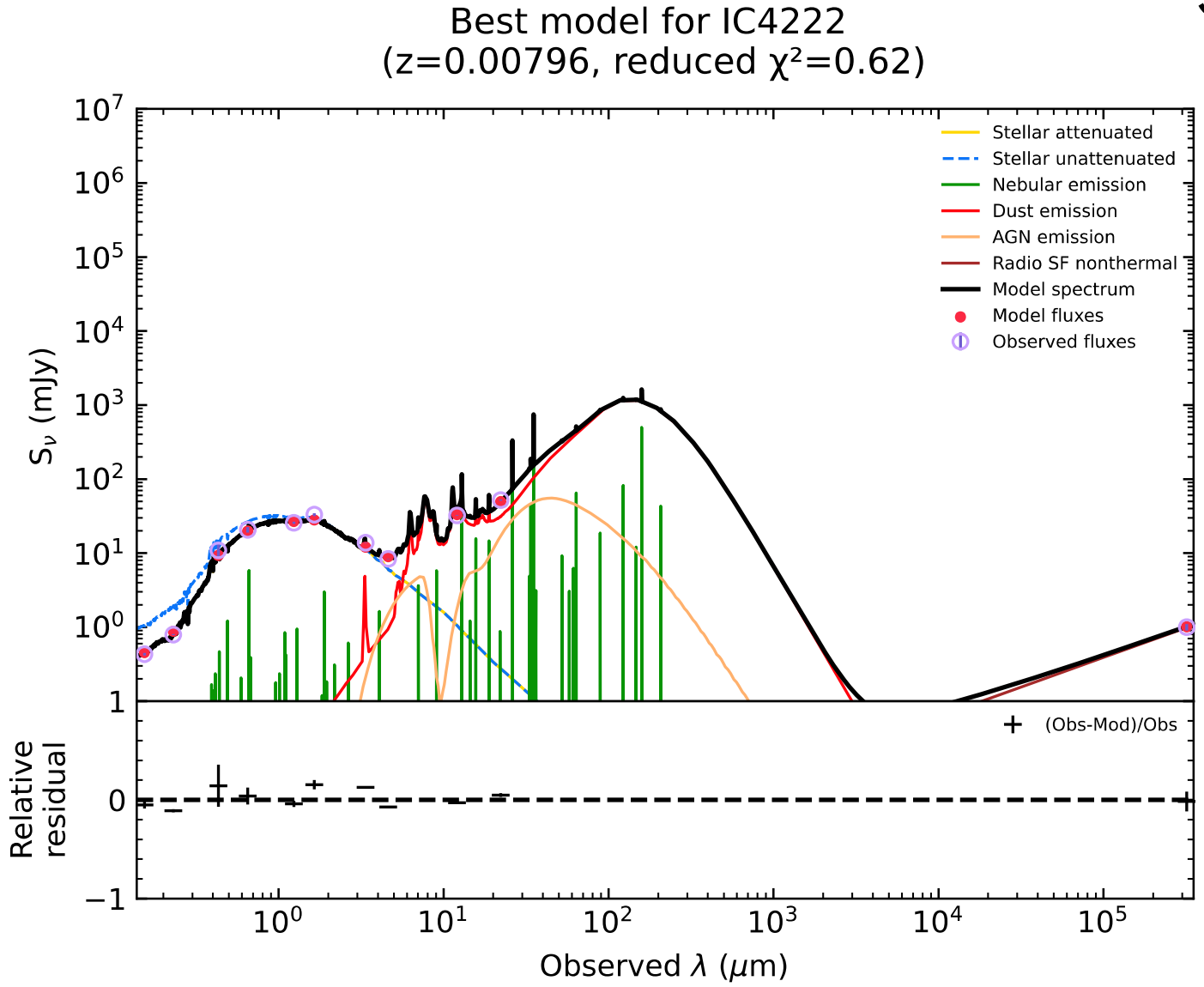


Figure: SED modelling output with best fit model from CIGALE. Different coloured lines show different physical processes. Relative residuals at bottom show relative difference between observed and model fluxes.

- Code Investigating GALaxy Emission (CIGALE)[1]
- Has parameters to model specifically for AGN contribution[2]

Results

- SFR: 0.025±0.017 $M_{\odot}$ / year
- Stellar population age: 3 Gyr
- Quench episode occurring 300 Myr ago
- SFR dropped by 40% during episode

[1] Burgarella et al. 2005, MNRAS, 360, 1413
[2] Boquien et al. 2019, A&A, 622, A103

HOW CAN STAR FORMATION RATE AFFECT HABITABILITY?

Effect on galactic UV flux

- Young, hot stars are one of the main sources of UV flux in a galaxy
- A drop in SFR means drop in galactic UV flux
- Excess UV flux can be harmful to biological life[1]
- It can also strip planetary atmospheres[2]
  - Recent evidence suggests this might have played a role in Mars's atmosphere loss[3]
- UV can act as a catalyst for prebiotic chemistry that forms life[4]
  - Lab experiments have shown that UV light can catalyse RNA synthesis[5]

[1] Roy 2017, Ultraviolet light in human health, diseases and environment, pp 207-219
[2] Lammer et al. 2003, ApJ, 598, L121
[3] Lillis et al. 2015, Space Sci. Rev., 195, 357
[4] Buccino et al. 2007, Icarus, 192, 582
[5] Rimmer et al. 2018, Science Advances, 4, eaar3302

HOW CAN STAR FORMATION RATE AFFECT HABITABILITY?

Effect on supernova rate

- A lower SFR means a drop in SN explosions
- As SN produce cosmic rays, this results in a drop in galactic CR flux
- Similar to UV, CRs are damaging to biological life[1]
- A close SN event (< 10 - 50 pc[2,3]) could devastate a nearby planet
- SN are responsible for generating and dispersing heavy elements
  - These elements are required for next generations of stars, terrestrial planets, and life[3]

[1] Cucinotta & Durante, 2006, Lancet Oncol, 7, 431
[2] Gehrels et al. 2003, ApJ, 585, 2
[3] Melott et al. 2017, ApJ, 840, 2
[4] Johnson et al. 2020, Philosophical Transactions of the Royal Society of London Series A, 378, 20190301

HOW CAN STAR FORMATION RATE AFFECT HABITABILITY?

Overall effect

- Most likely make a more stable current galactic environment
  - Lower UV flux, SN rate, CR flux
  - More stable for any currently existing life
- Less likely to provide opportunities for life to form
  - Less catalysts that might be needed to form life
  - Less heavy element synthesis
  - Less stars for planets to form around
  - Could have negative implications for longer term habitability

OTHER POTENTIAL EFFECTS

- Direct impact of jet on galaxy
  - AGN jets are composed of high energy particles and CRs
  - Will interact with IC4222's magnetic field
    - Could be deflected (such as in the case of 3C 321[1])
    - Could disrupt magnetic field
  - Could pass through and directly inject CRs into galactic environment, creating pockets of habitability

- More data would be needed (γ-ray, X-ray, radio, polarization)

[1] Evans et al. 2008, ApJ, 675, 1057