Nearby Galaxies Observed with JWST

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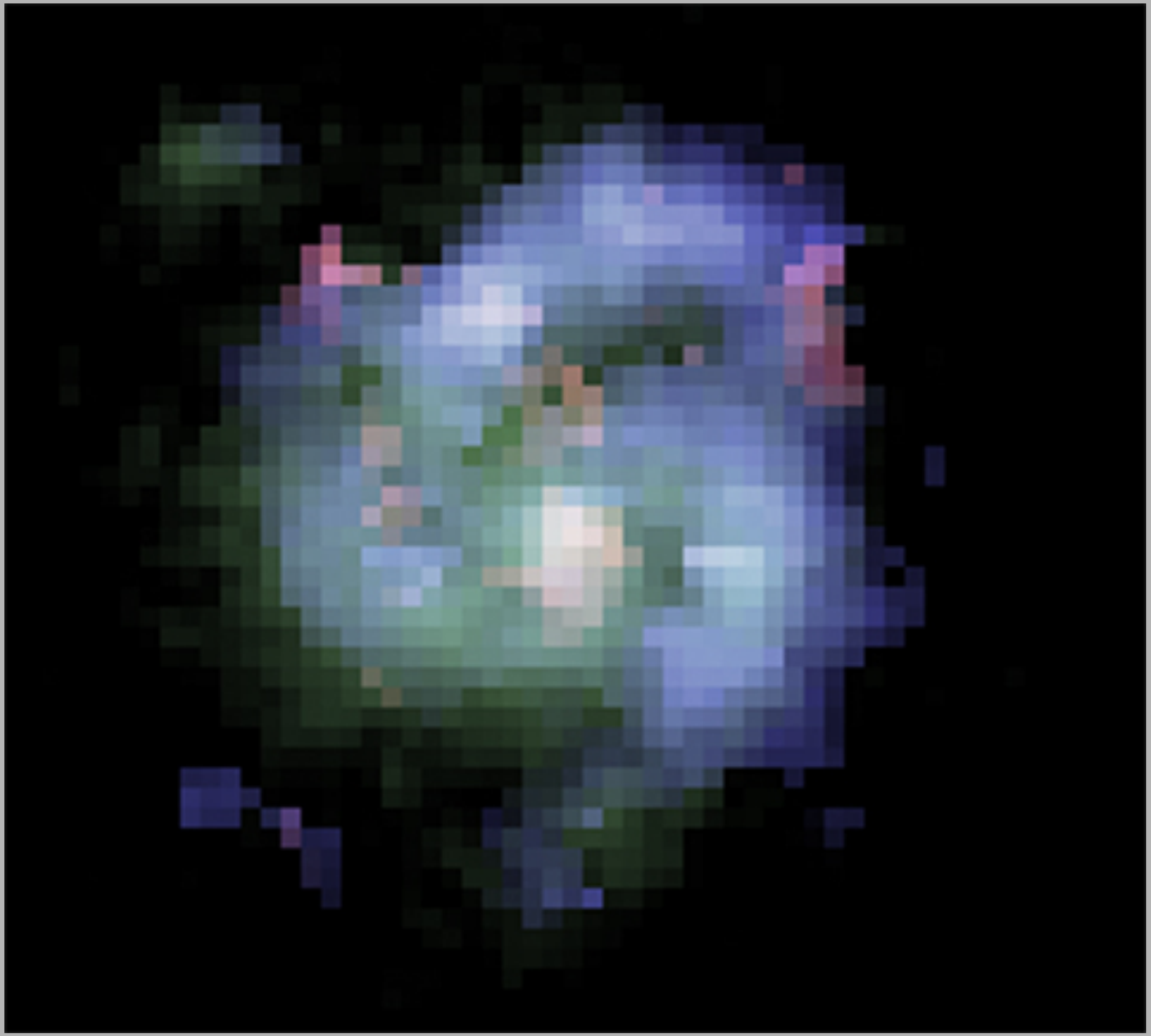
A spiral galaxy at around redshift 2.0



Thanks go to…

This talk is on behalf of the members of the European MIRI Science Team who are working on the topic of nearby galaxies.

With special acknowlegment to the following people who provided me with some material.

Macarena Garcia Marin — See her poster “Observing nearby galaxies with MIRI”

Torsten Boker

Almudena Alonso

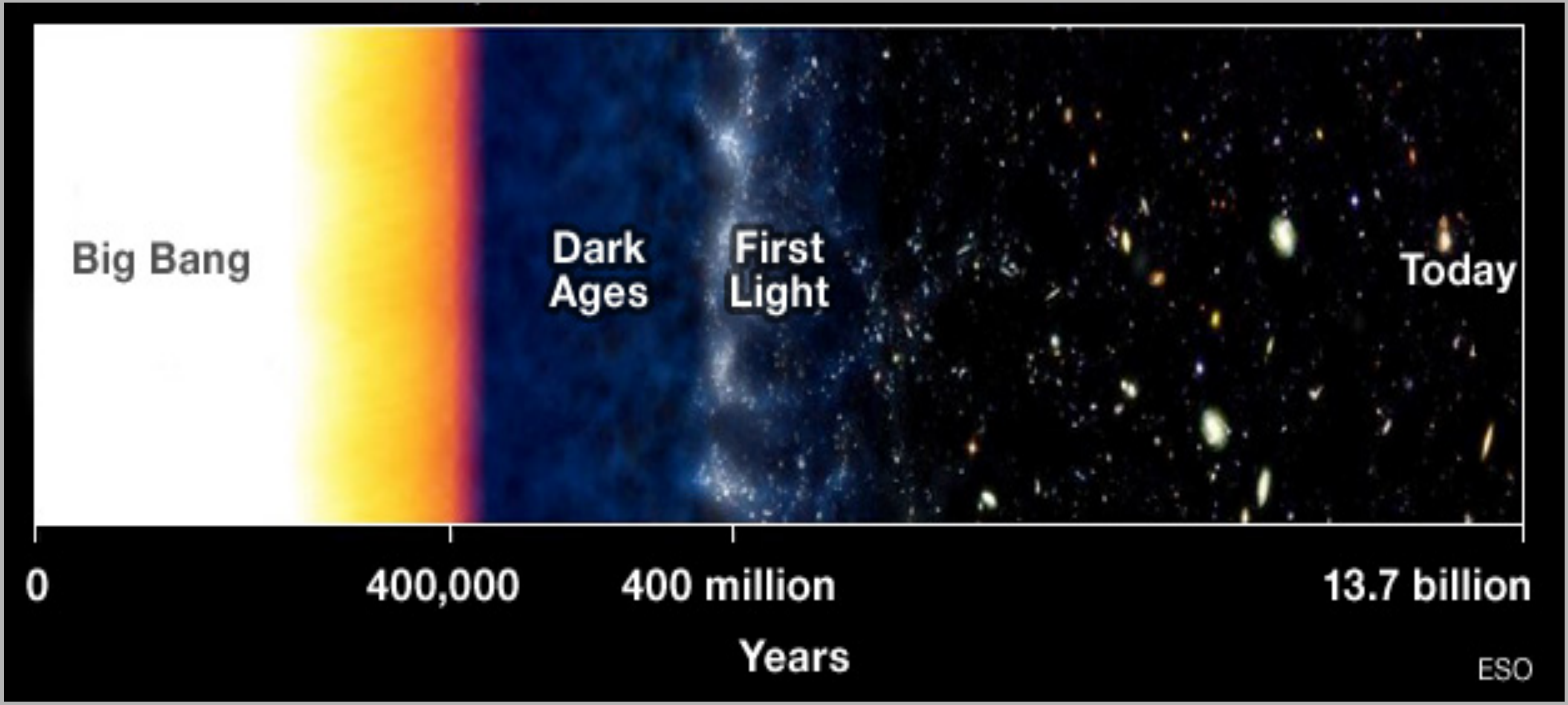
Ruyman Azzollini

The BIG picture

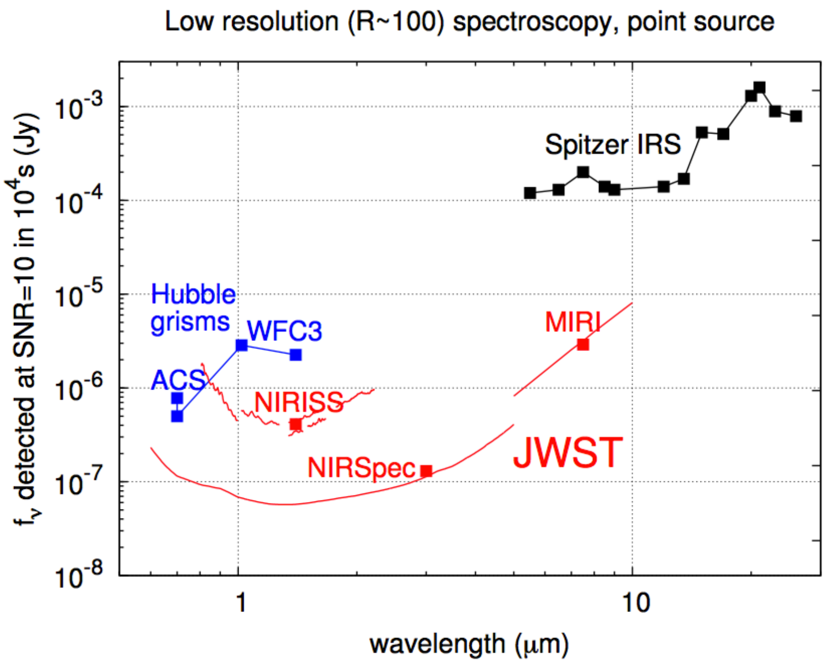
Also need to study individuals,"warts and all"

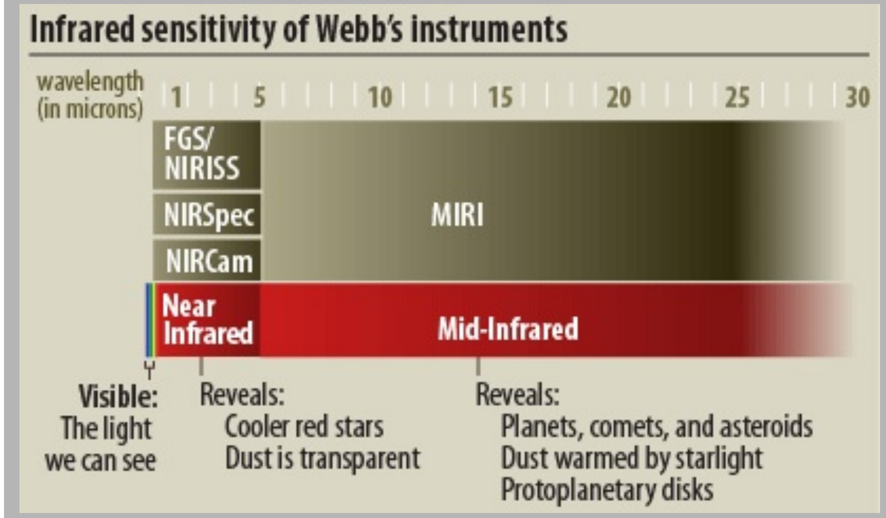
A snapshot in cosmic time

We are now here

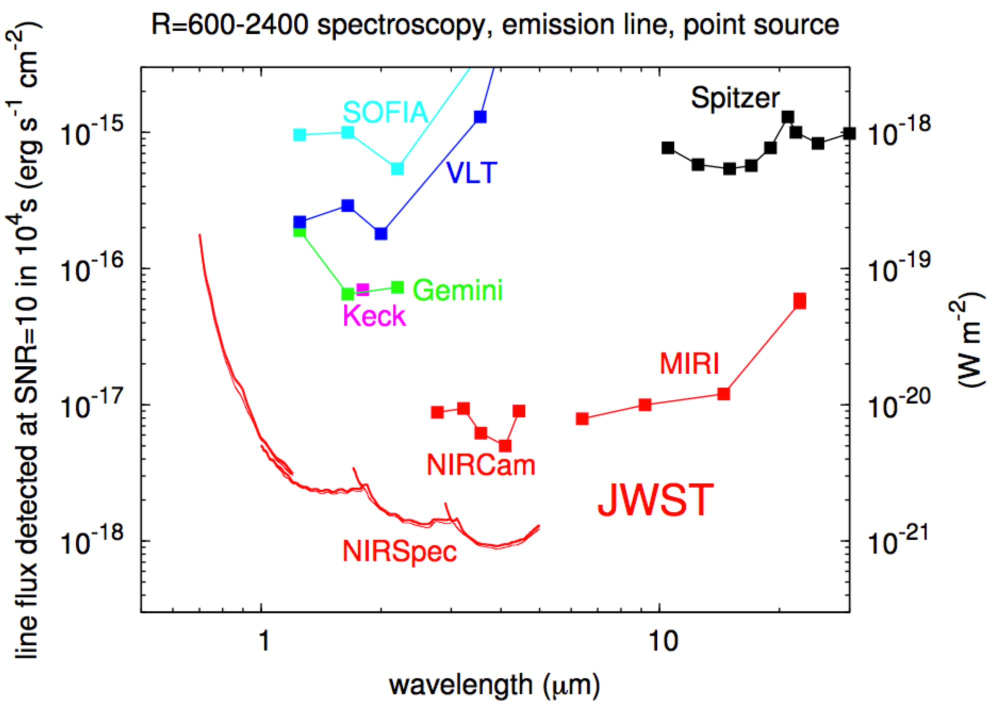


Jane Rigby, STScI JWST Office





JWST in context…



Nearby galaxies are great objects to study in detail, but remember their projected size is big….

really BIG

The binary nucleus of NGC 6240
Image Credit: NASA, ESA, the Hubble Heritage Collaboration, and A. Evans (University of Virginia)

Previous work eg. ground-based IR interferometry

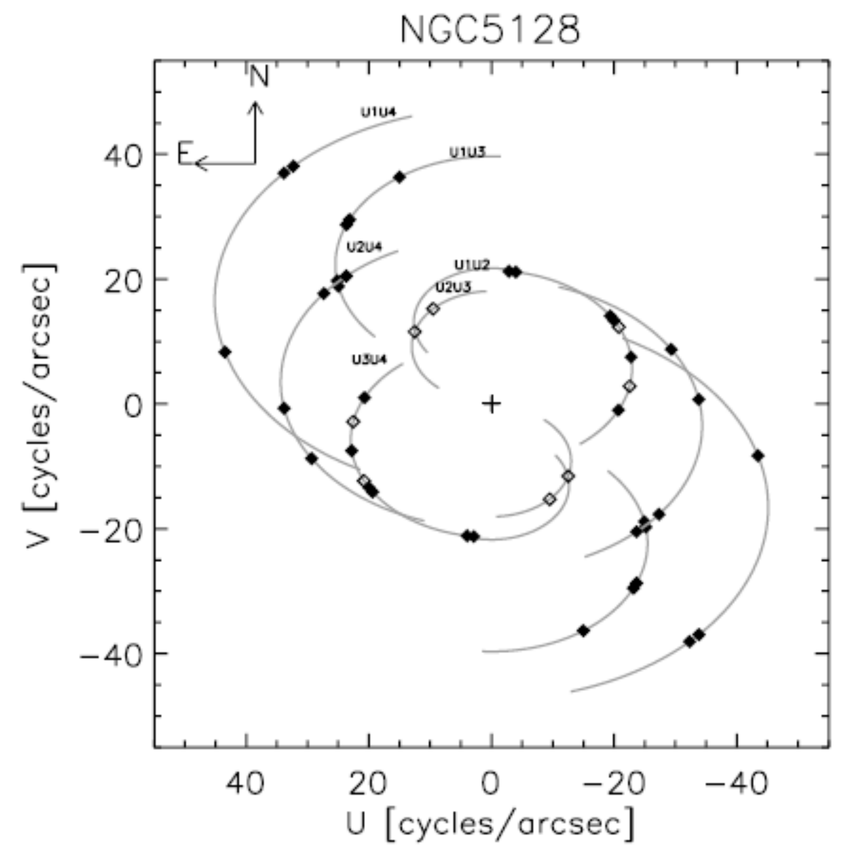


Figure 1: (u, v) coverage of the 2008 MIDI visibilities of Cen A at 12.5 μm. Observations that led to Meisenheimer et al. (2007) (4 visibilities) are shown as open diamonds, the 2008 observations

Burtscher et al. (2010), PASA, 27,490

But no “real” pictures
UV-plane fringes folded through models!

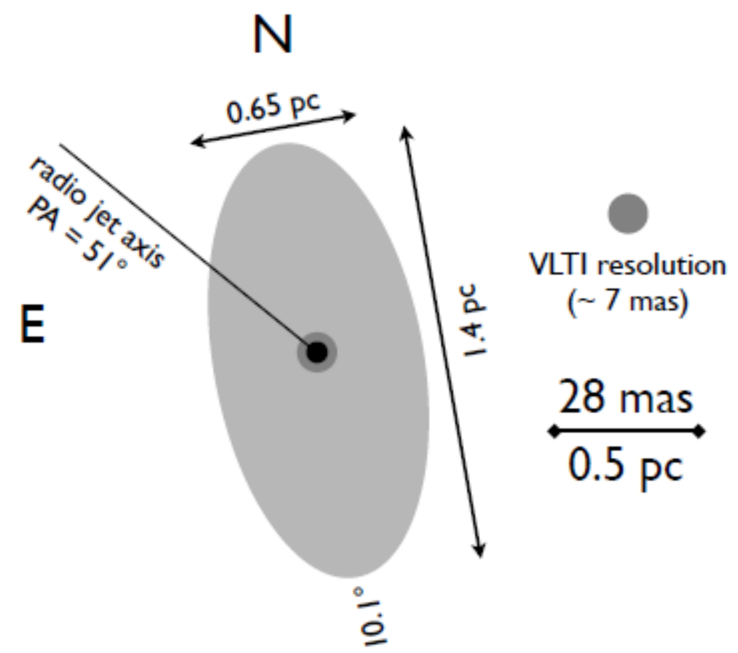


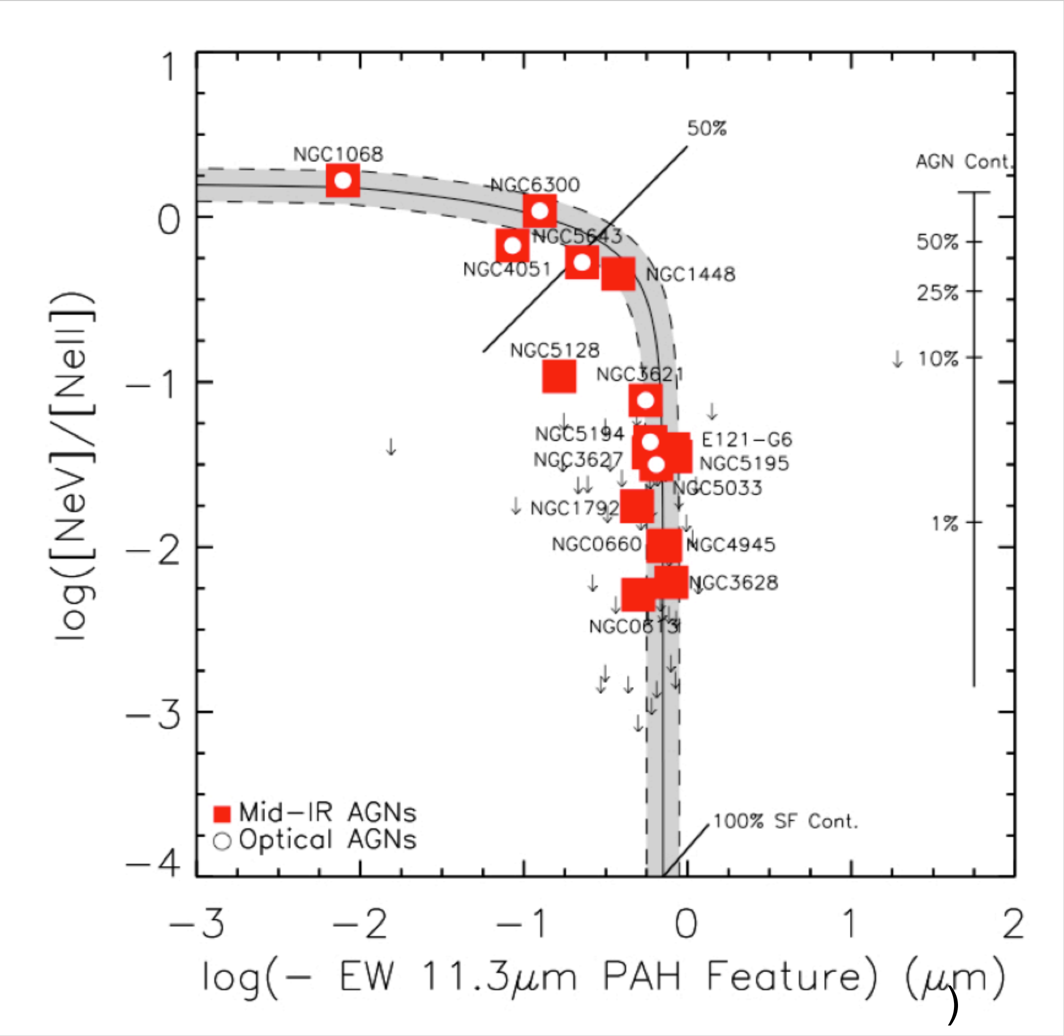
Figure 4: Two-component model for the nuclear mid-infrared emission of Centaurus A consisting of a uniform disk component and an unresolved point source that is smaller than the VLTI resolution (dark grey circle) and has been identified with the synchrotron core (black point) by Meisenheimer

Generic Science Goals

- Study nearby highly obscured nuclei
- Measure the kinematics of gas and stars at pc-scale resolution
  (**JWST PSF of 0.1" corresponds to ~5 pc at**
  d **= 10 Mpc**)
- Quantitative comparison between AGN and star formation
- Yields *spectral templates* for comparison with high redshift galaxies.
  - invaluable for the understanding of the early universe
  - Core science not only for JWST, but also for ALMA and 30m-class telescopes

Spectral Diagnostics

Some examples:

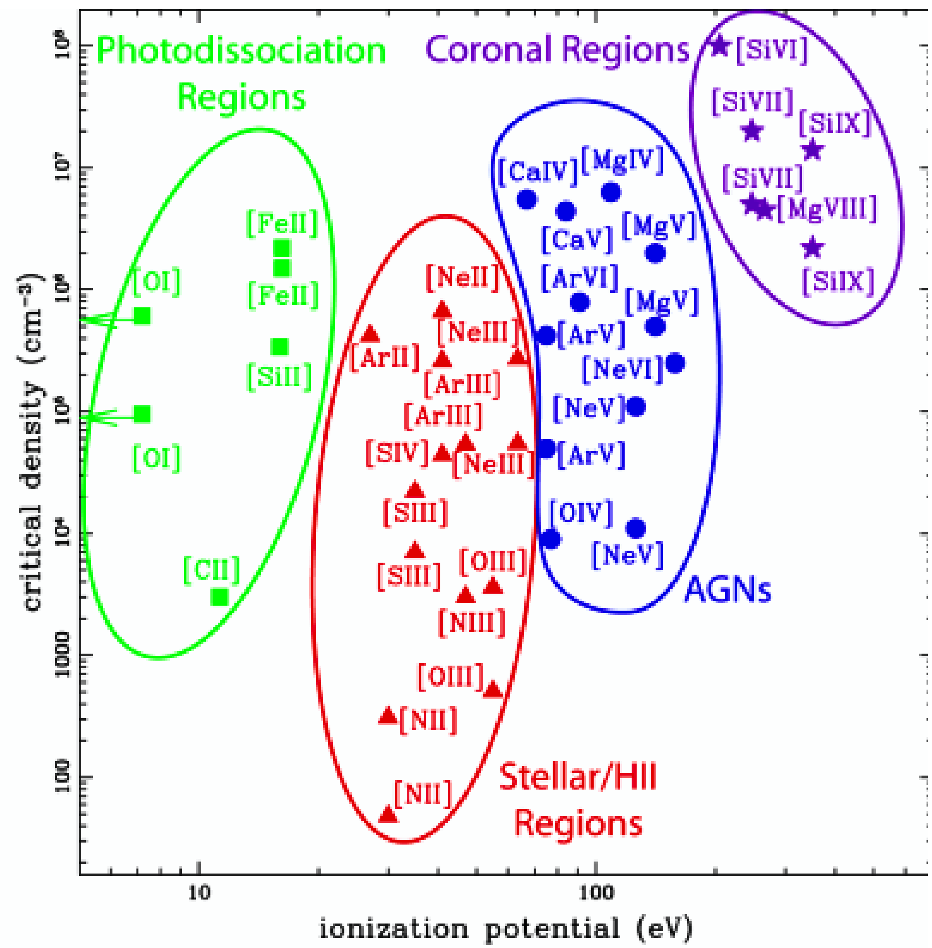


Goulding & Alexander (2009).

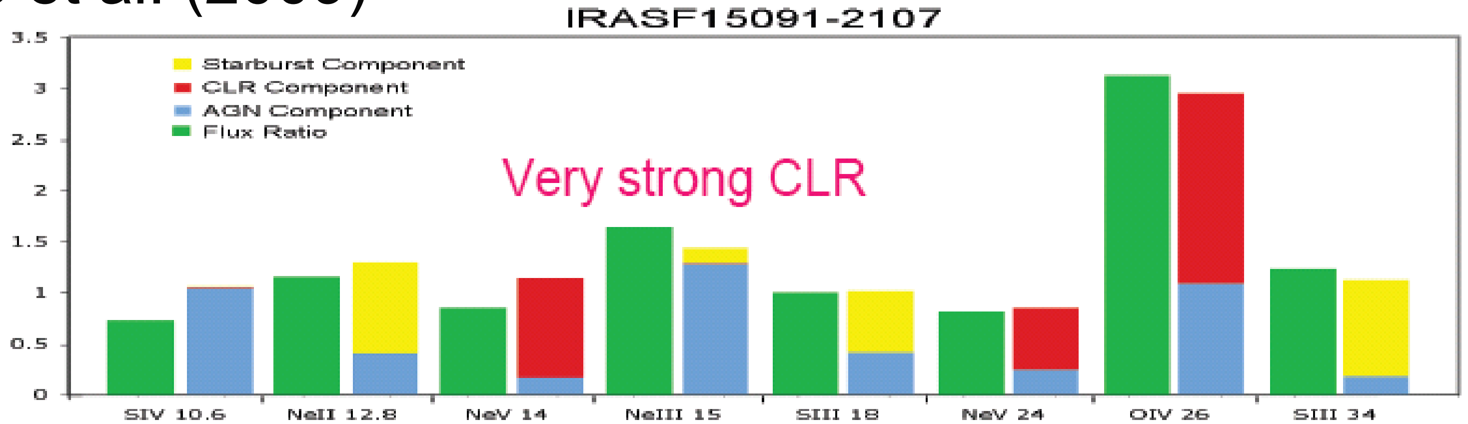
FIR Diagnostics and the Starburst-AGN connection

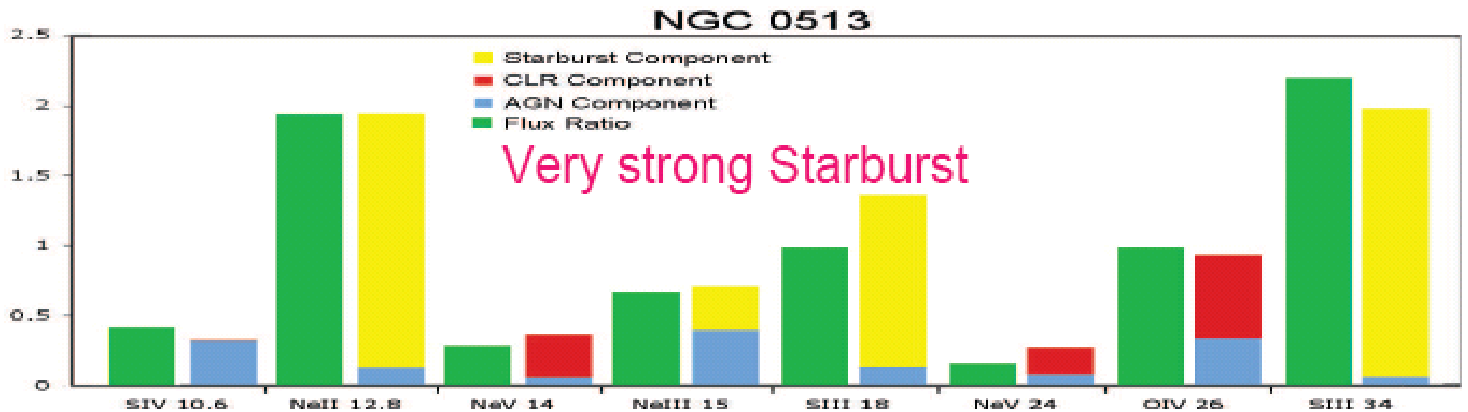
- Key diagnostic lines for physical/excitation conditions
  - PDR lines
  - Stellar HII lines
  - AGN tracers
  - Coronal lines

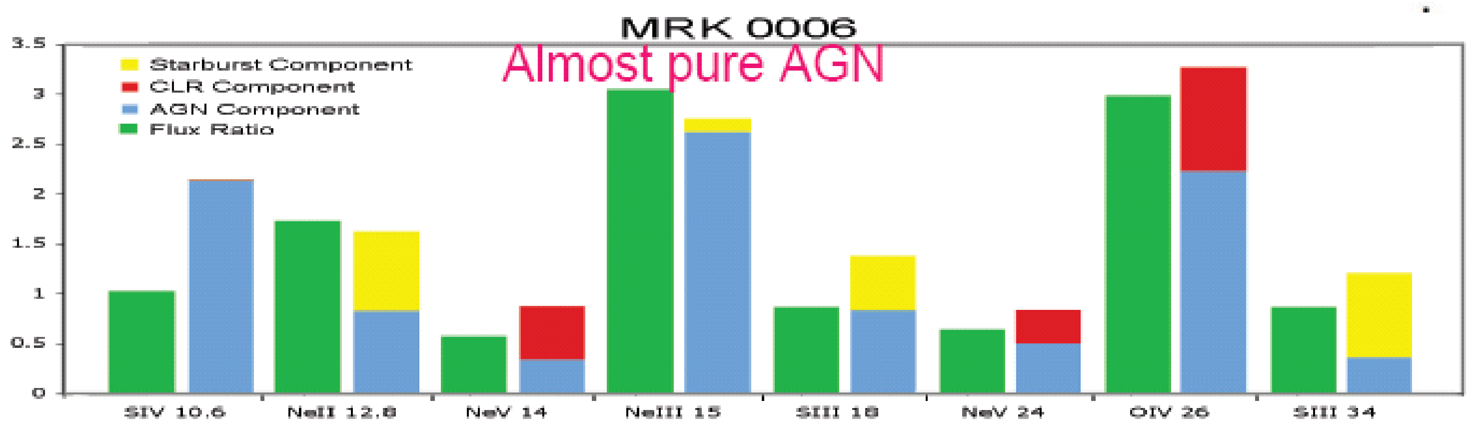
- Line ratios - give excitation and ionisation state, hence the shape of the SED responsible



Hainline et al. (2009)







NGC7469: the AGN – starburst link

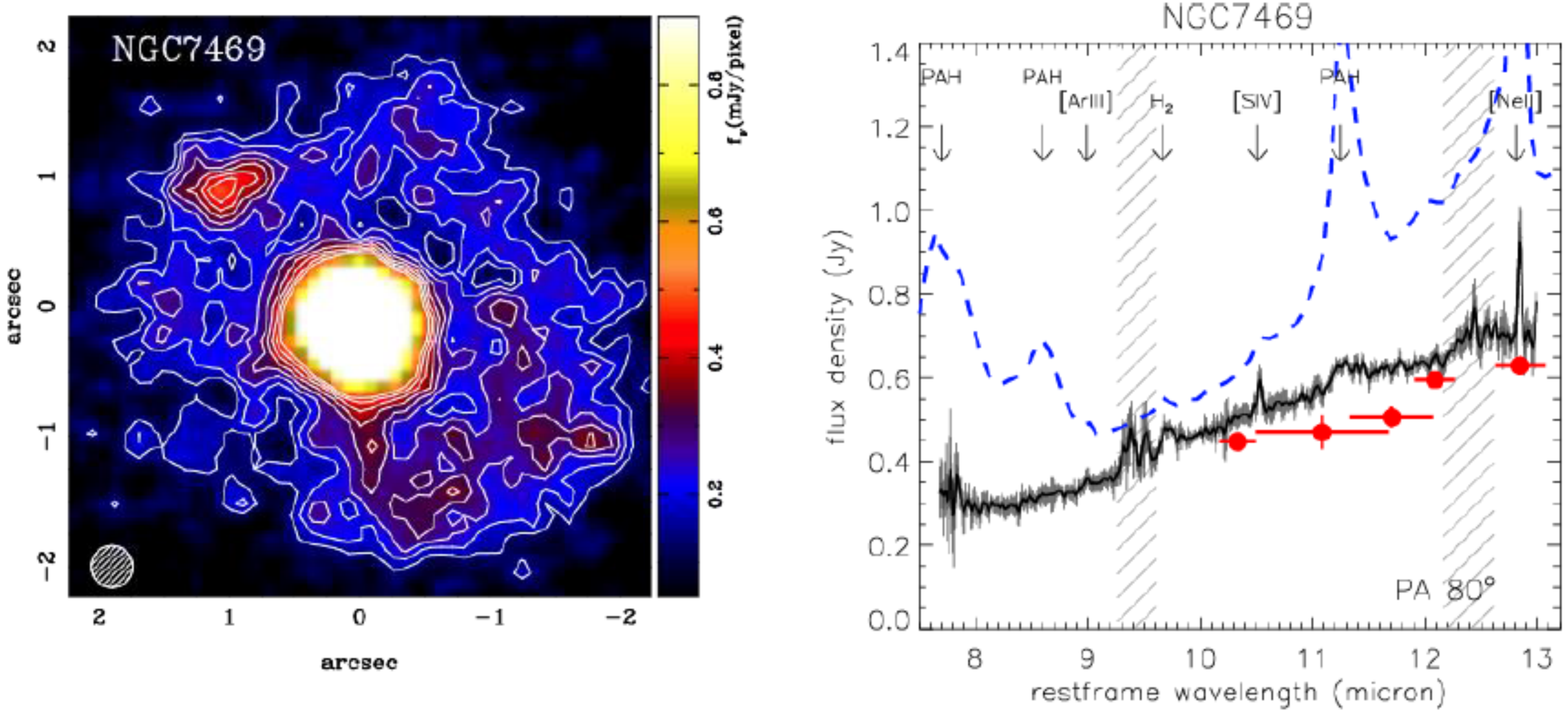
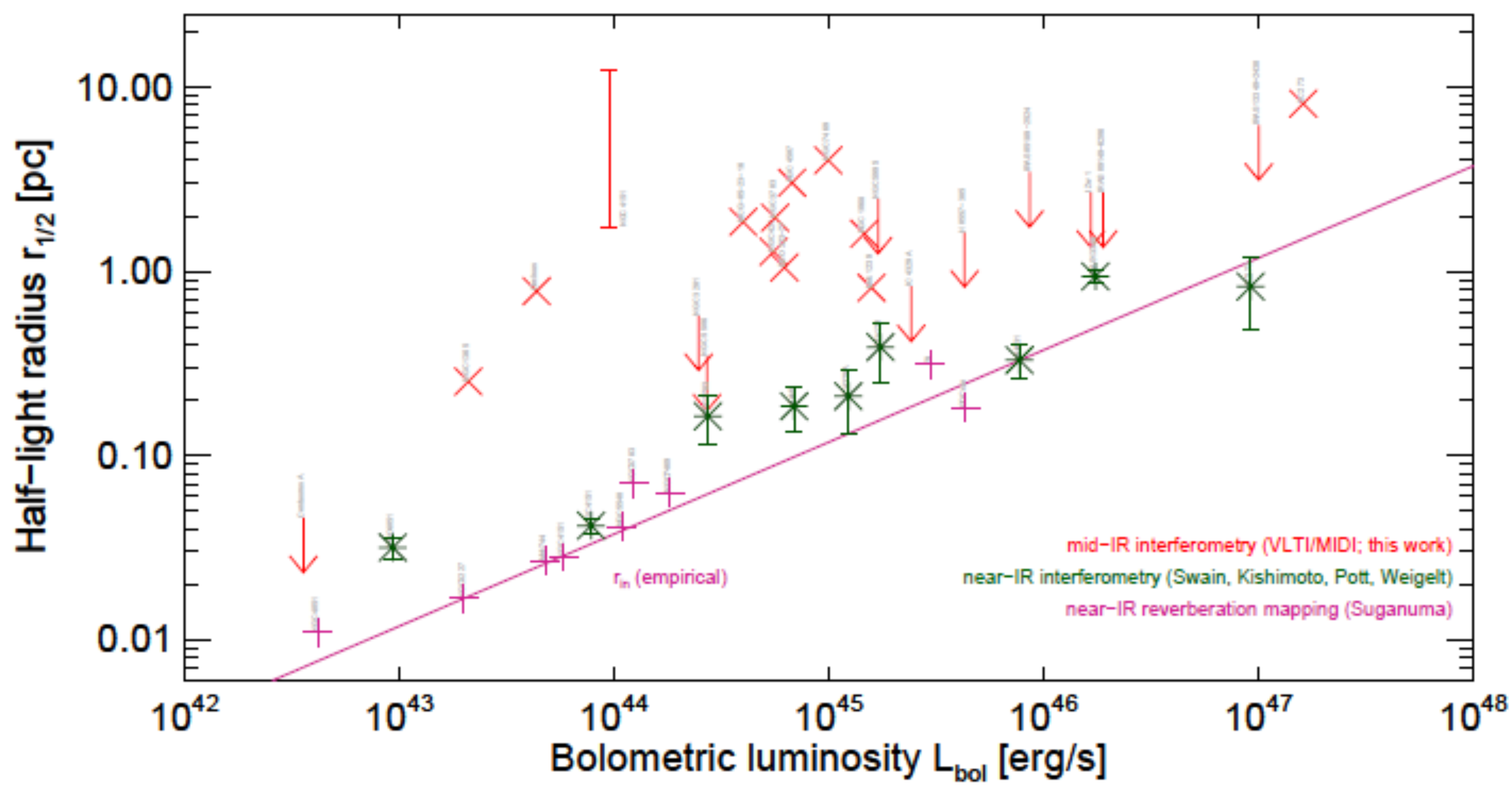


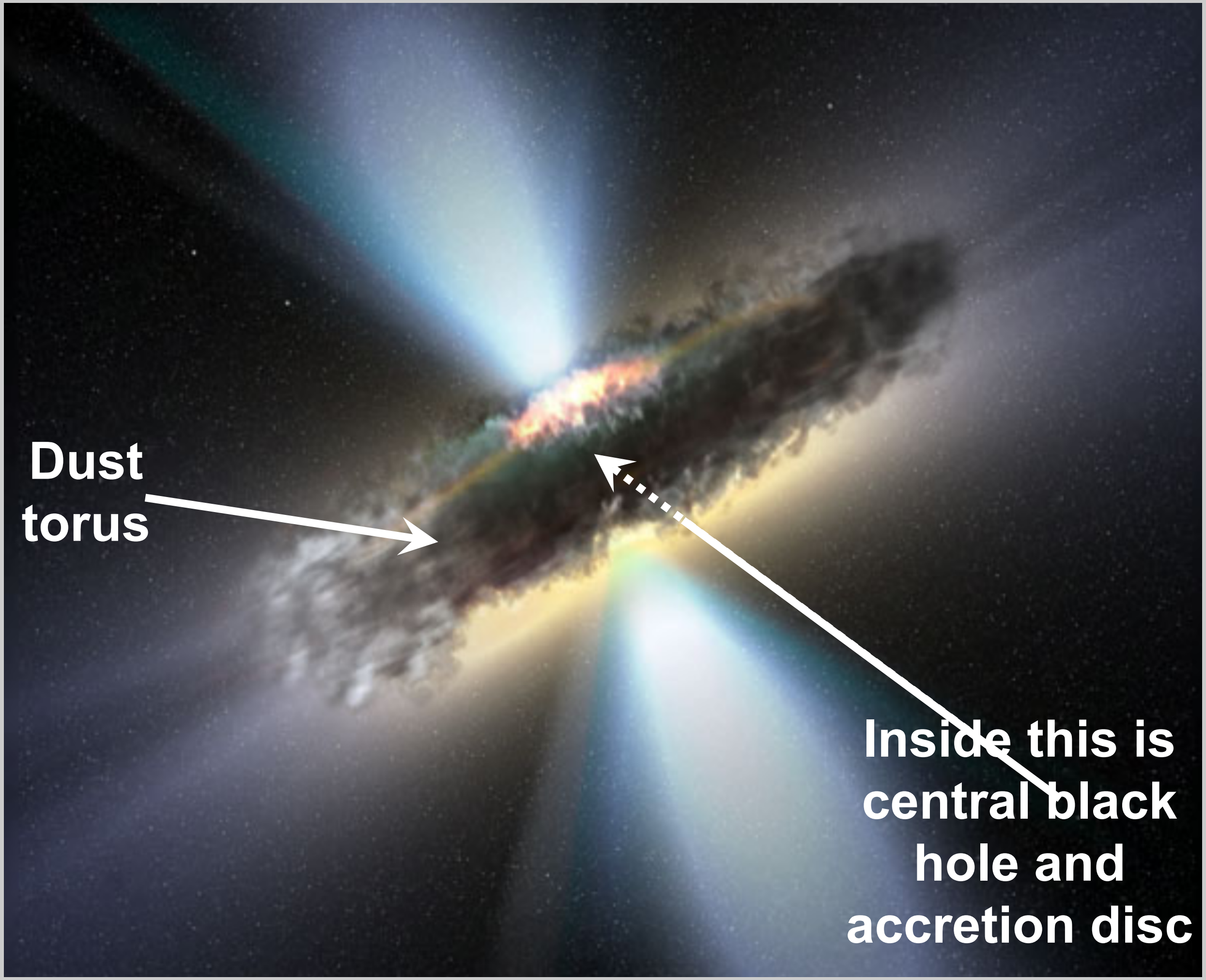
Figure2. Left. High angular resolution (0.3”) image at 8.7μm of NGC7469 showing the bright Seyfert 1 nucleus and the ring of SF. The images were taken with the T-ReCS instrument on the 8m Gemini Telescope with a plate scale of 0.09”/pixel. The hatched region represents the FWHM of the observation.

Near and mid-IR emission from AGN the situation is rather confused

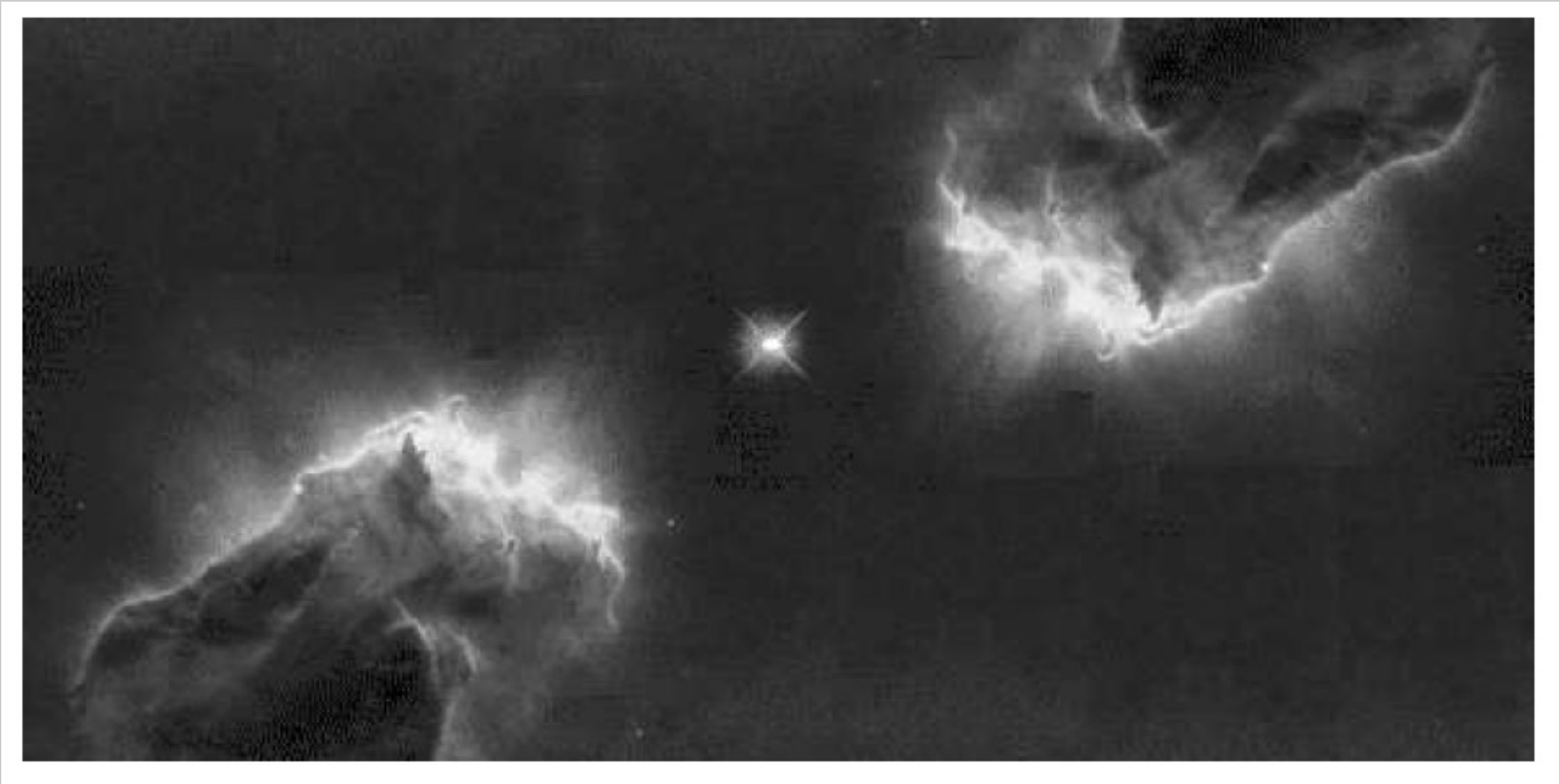


$$r_{\mathrm{in,Barvainis}} = 1.3 L_{\mathrm{UV},46}^{1/2} T_{1500}^{-2.8} \mathrm{pc}$$

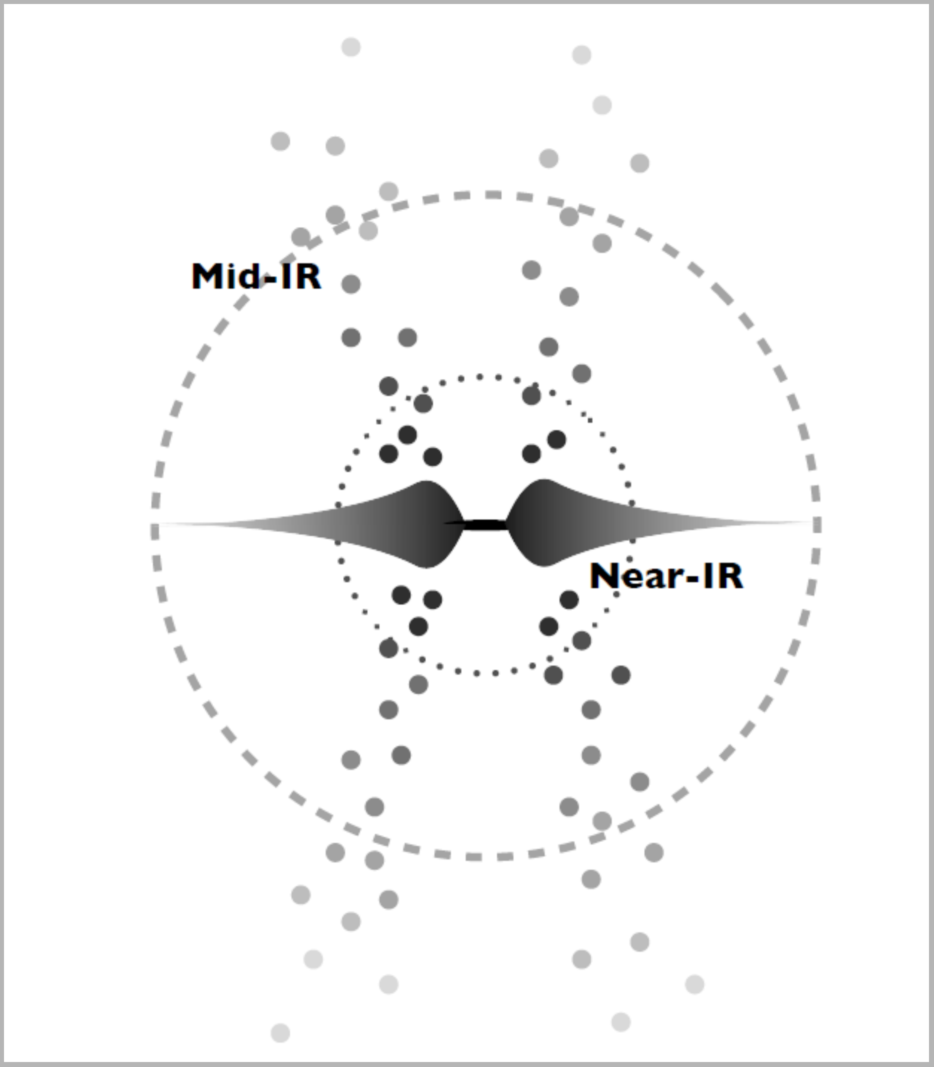
The simple torus model for AGN is now being challenged



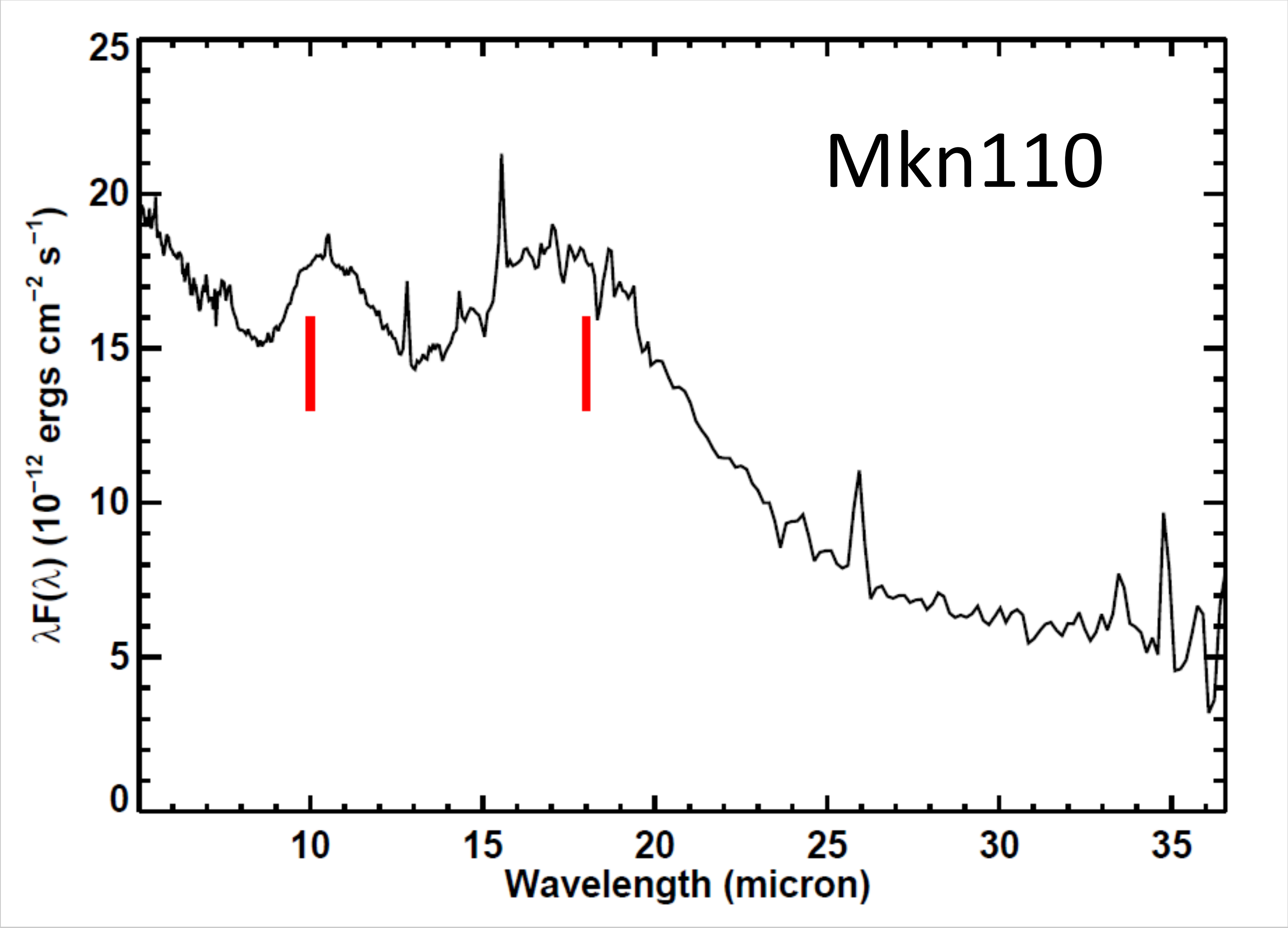
Hot Inner part of the Torus



AGN emission in the near to mid-IR



Why do some AGN have really very strong MIR silicate emission?



AGN + star-formation within the nucleus

- Separate these two components on scales of 10's of parsecs
- Trace the PAH emission in the vicinity of the AGN, to see if it is destroyed by the intense UV radiation field. Also Study the diffuse PAH emission further out
- Derive the morphology, mass, kinematics and excitation conditions in the ionised gas, using high excitation lines eg. [NeII], [NeV], [SIV] etc…
- Study the warm dust distribution, and temp. gradient close to the AGN

NGC6240: obscured AGN and starbursts

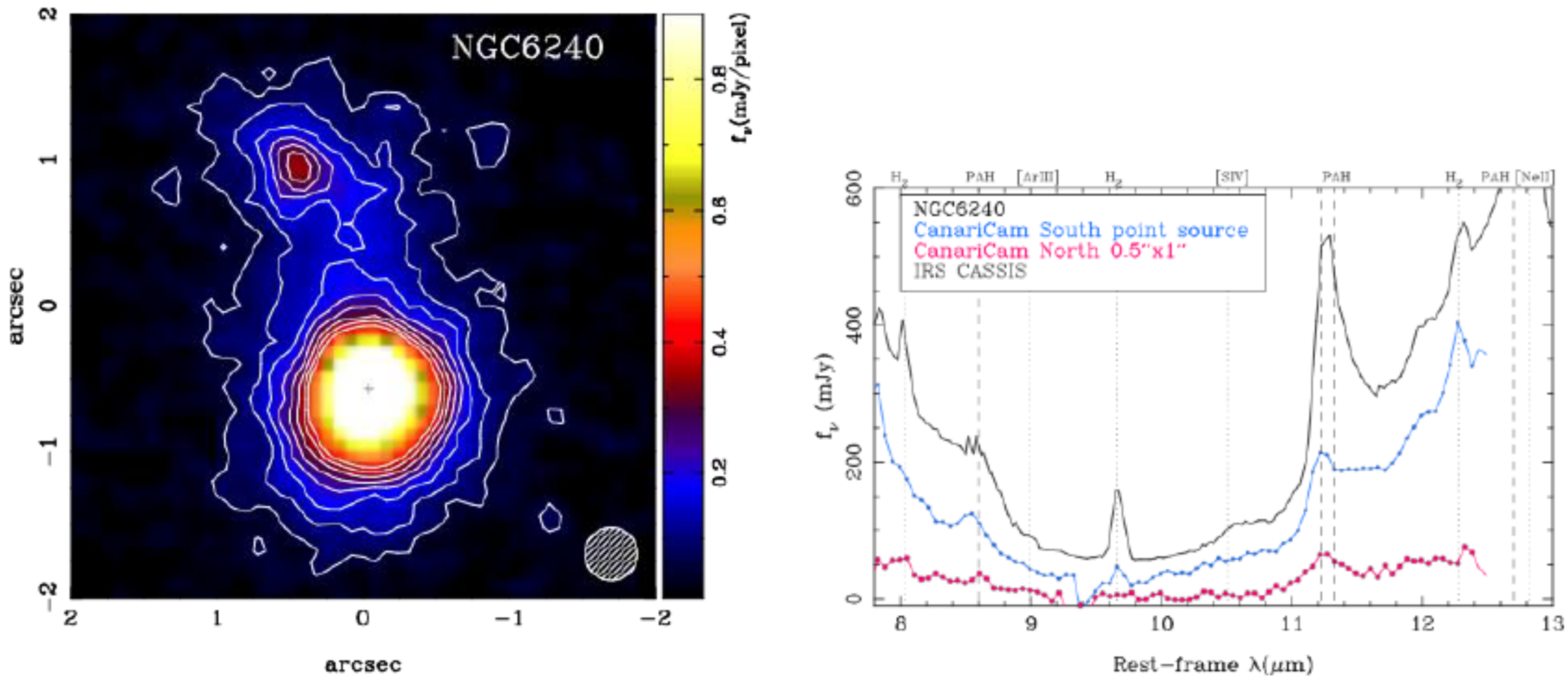
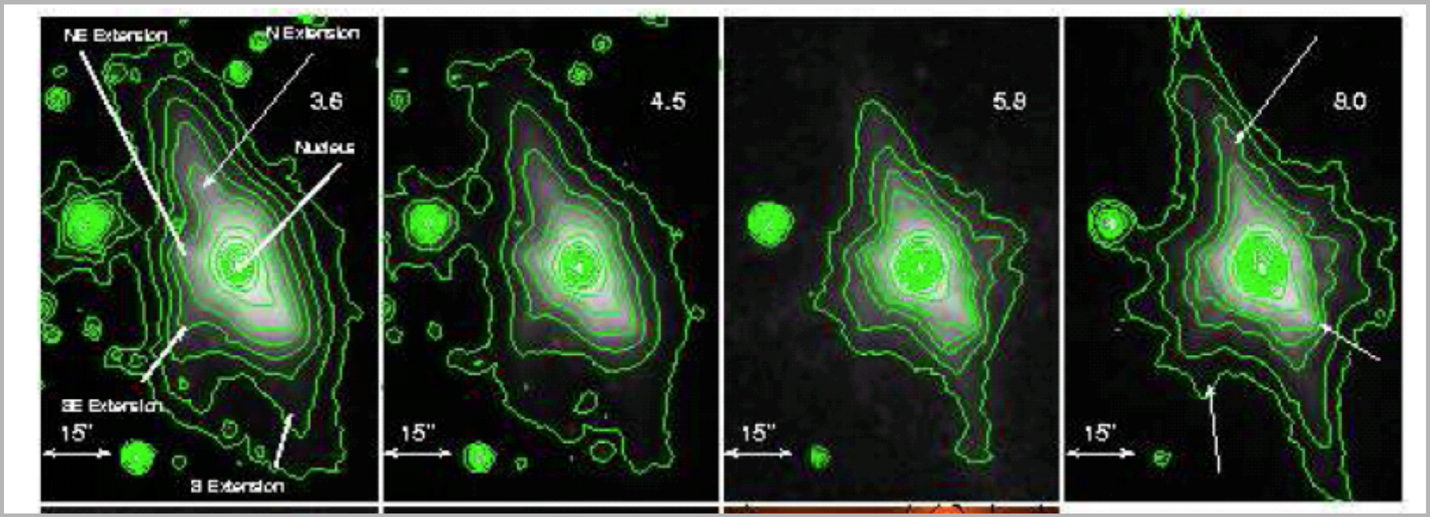


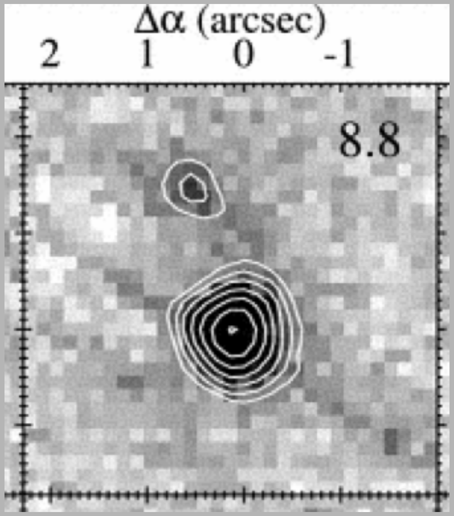
Figure3. Left. High angular resolution (0.4") image at 8.7μm of the nuclear regions of NGC6240 taken with GTC/CanariCam with a pixel size is 0.08". The hatched regions represent the FWHM of the observations. Data from Alonso-Herrero et al. (2014). Right. High angular resolution GTC/CanariCam spectroscopy of the northern and southern nuclei of NGC6240 compared with the Spitzer/IRS spectrum which emcompases approximately the FoV shown in the left. Data from Alonso-Herrero et al. (2014).

Why imaging of nearby galaxies with JWST ?

Spitzer images of NGC6240 (Bush et al. 2008): <u>cannot resolve much detail with an 85cm aperture</u>



Keck MIR-image (Egami et al. 2006):
<u>cannot detect any extended emission from ground</u>



MIRI will provide the best of both worlds

Obscured AGN

links with similar situations seen in the far-universe eg. Compton thick AGN (Scuba galaxies etc.)

- Quantify the properties of the twin AGN found in the same nucleus
- Detailed study of the kinematics of the twin black holes, by means of the diffuse ionised gas distribution surrounding them
- Study the processes of gas accretion, and the consequences of having two BH potentials interacting with the stellar component

Outflows: jets and winds

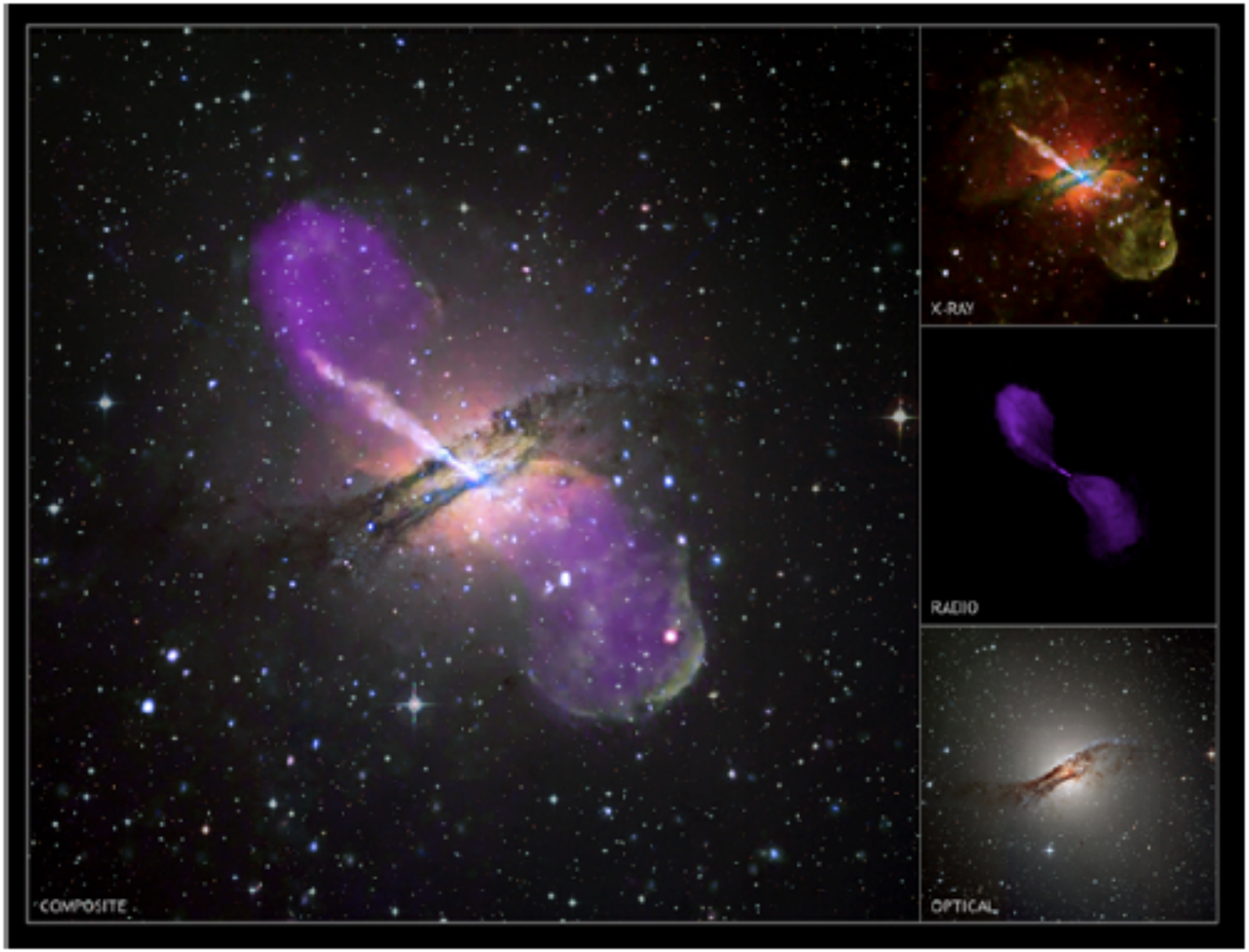
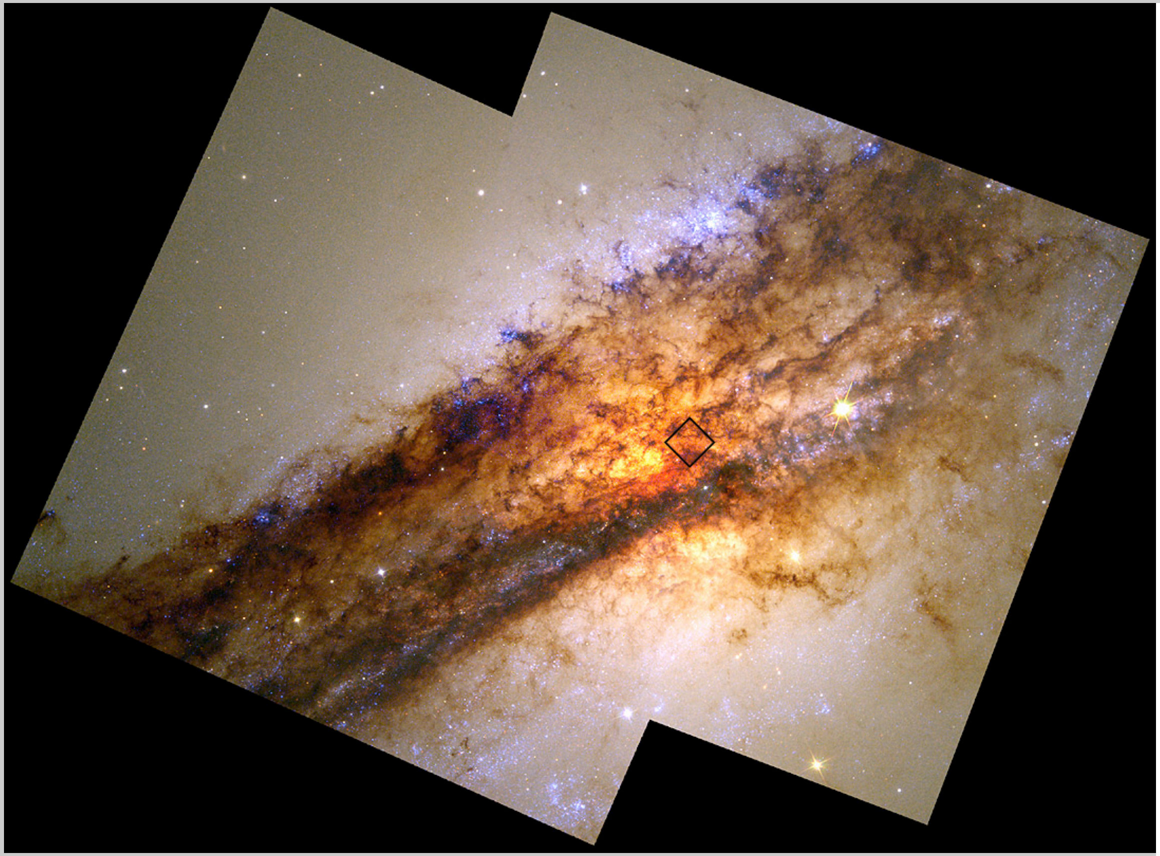


Image credit: Chandra

Radio Galaxies: Centaurus A



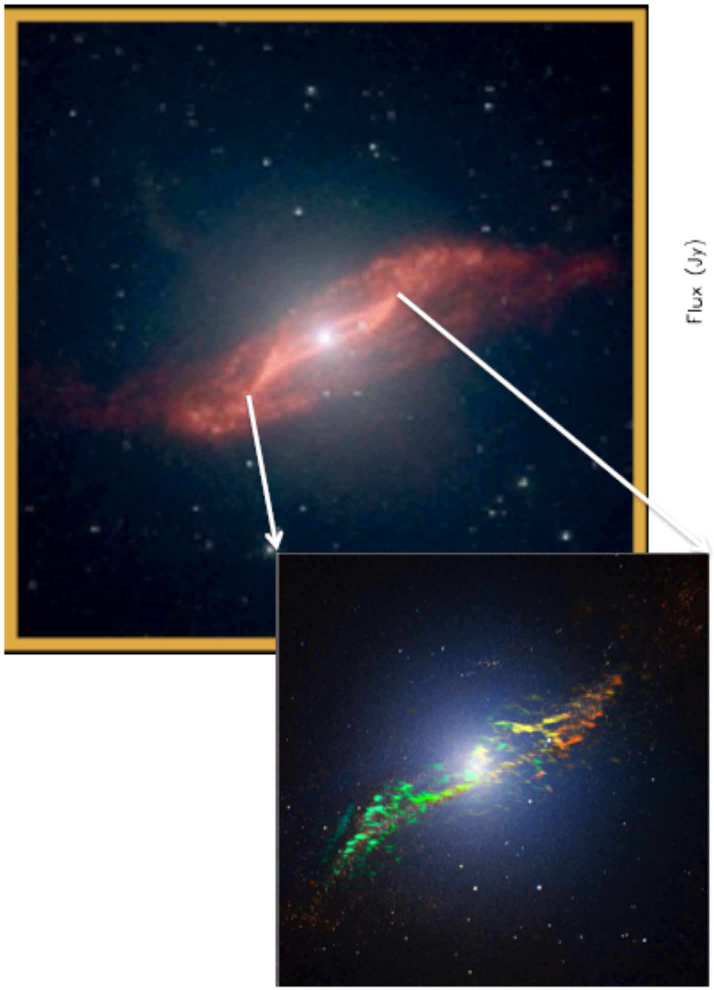
Closest radio galaxy.
z=0.001825
0.038 kpc/"

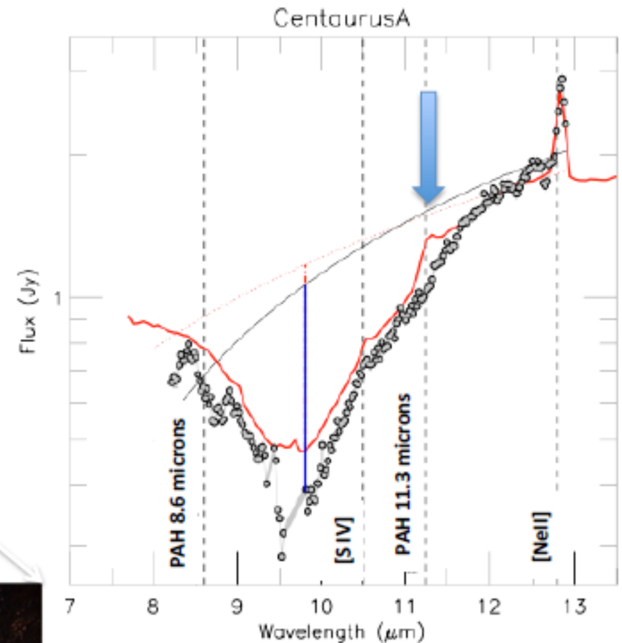
Edge on
Dust lane
Supermassive BH
(about 55×10^6 M_{sun})
Relativistic jet (X-ray/radio)

Jet-medium interaction
(jet-induced star formation
Mould et al. 2000)
Already Baade & Minkowsky
(1954) proposed the galaxy had
undergone a merger with a
smaller spiral galaxy

Previous work on Cen A

Image size: 15X14 arcmin





Gonzalez-Martin 2013

T-ReCS spectra: open circles. *Spitzer*/IRS spectra: red lines.Low spectral resolution (R~60-120). The continuum fits to the T-ReCS and IRS spectra are shown as solid and dotted lines, respectively

TRecs: 0.65 (slit, arcsec) -→ 12 (pc)

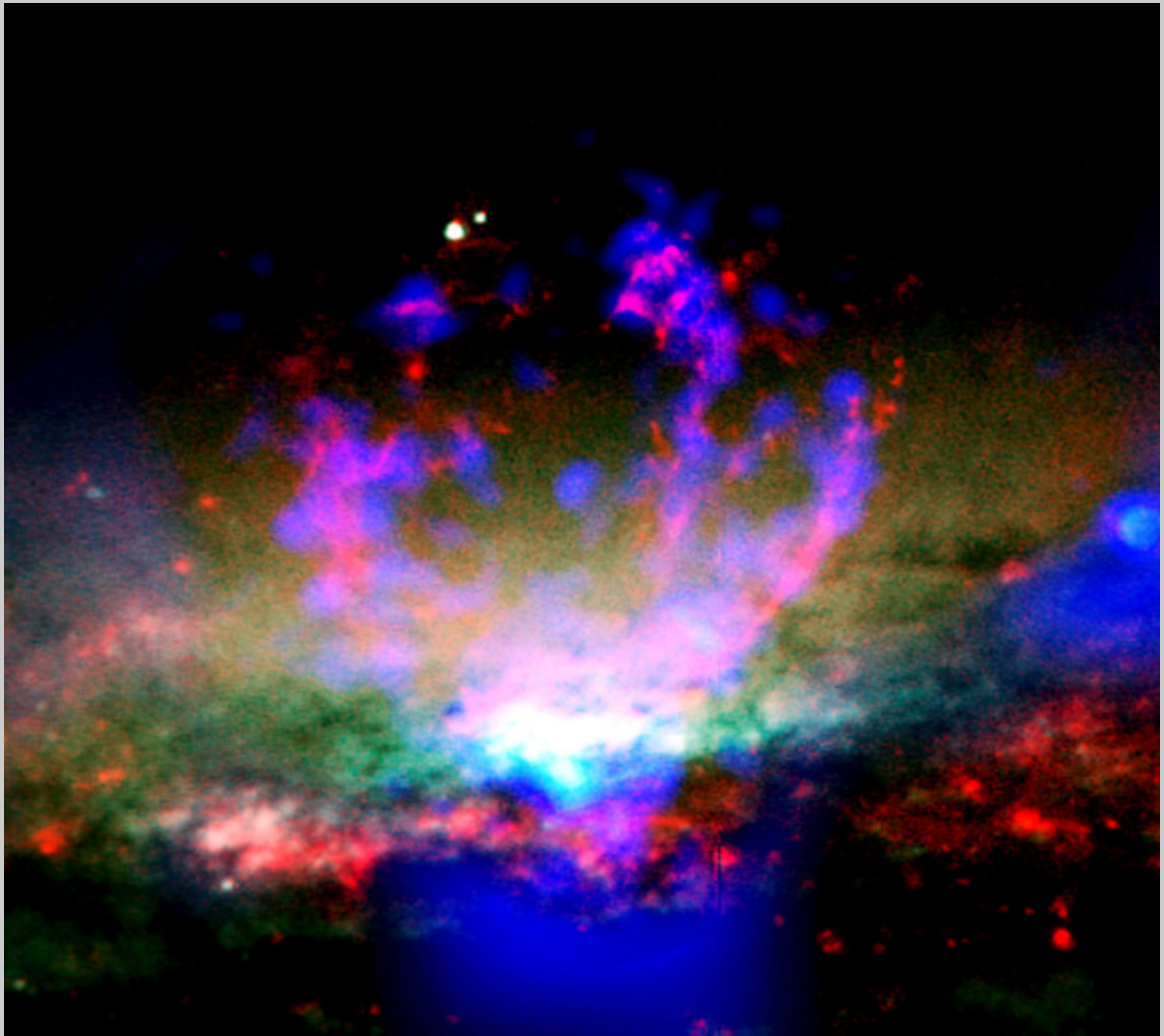
The physics of jets

- Provides emission line diagnostics of processes occurring within the jet environment of scales of a few parsecs
- Evidence for jet induced star-formation. Separate the contributions of shock excitation and photionisation of the gas
- Better understanding of the energetics of the jet, and (hopefully), its launch mechanism

Pure starburst galaxies eg. M82, NGC253

Spitzer data on M82 shows complex structure of dust, ionised and molecular gas (may apply to high redshift Lyman break galaxies)

Refer to the talk about molecular hydrogen given by Pierre Guillard

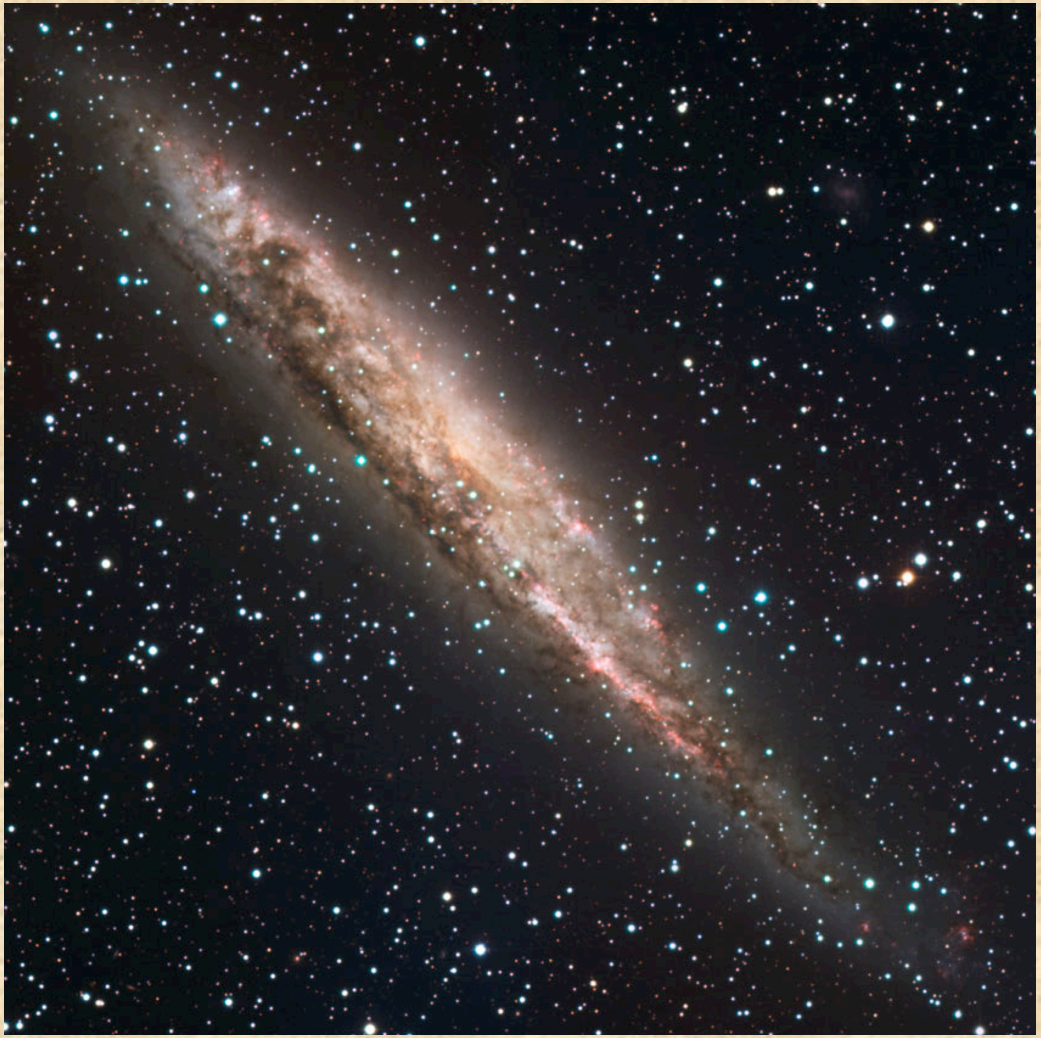


Conclusions

- Nearby galaxies can provide exemplars for the studies of objects in the distant Universe
- Need to design JWST observations fully within the context of complementary data eg. ALMA, infrared VLTI (MATISSE), and the radio
- The key spectral diagnostics span right across JWST's wavelength range. Therefore it would clearly be of high added value to coordinate observations
- There are many nearby galaxies (too many!), so careful consideration must be given to sample the full range of parameter space, without undue duplication

THE END… sunset over Noordwijk, last sunday

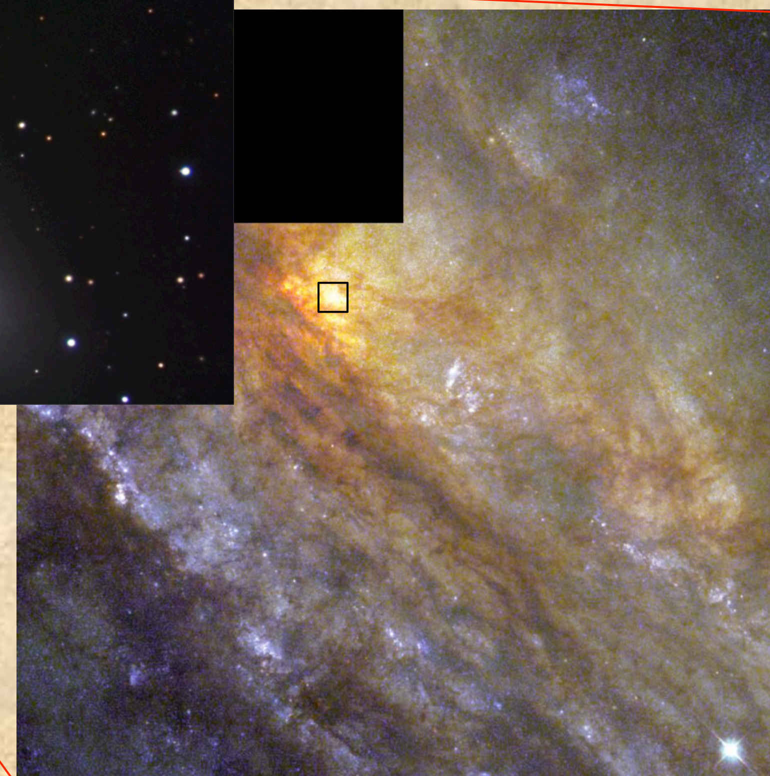
NGC 4945



16'

- d = 3.8 Mpc
- nearby Compton-thick AGN
- extreme silicate absorption
- no IR counterpart of AGN detected yet
-
-

NGC 253



- d = 3.9 Mpc
- nearest massive galaxy ($8 \bullet 10^8$ $M_\odot$) with powerful starburst
- has superwind, similar to M82
- high extinction towards nucleus
- excitation mechanism of IR clumps uncertain