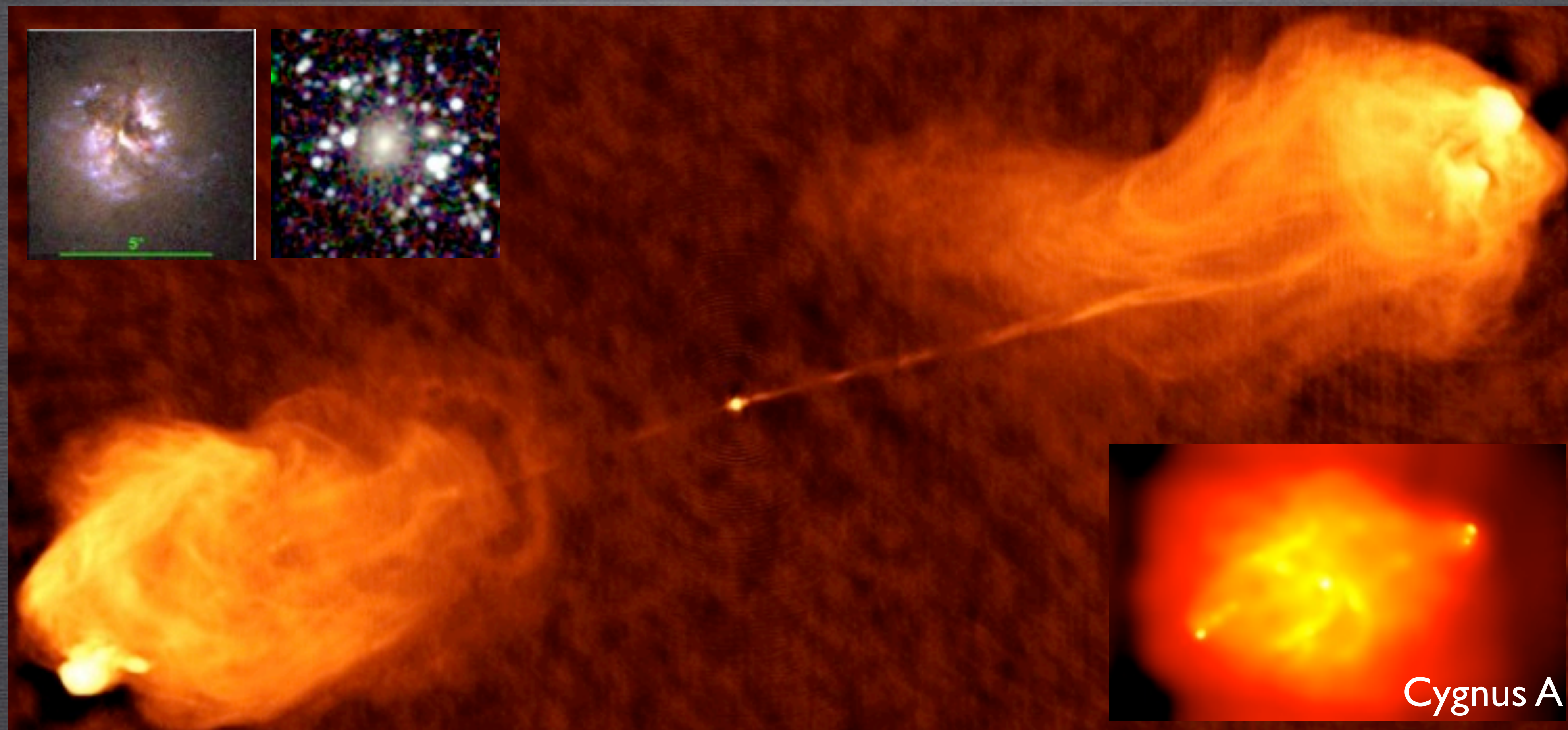
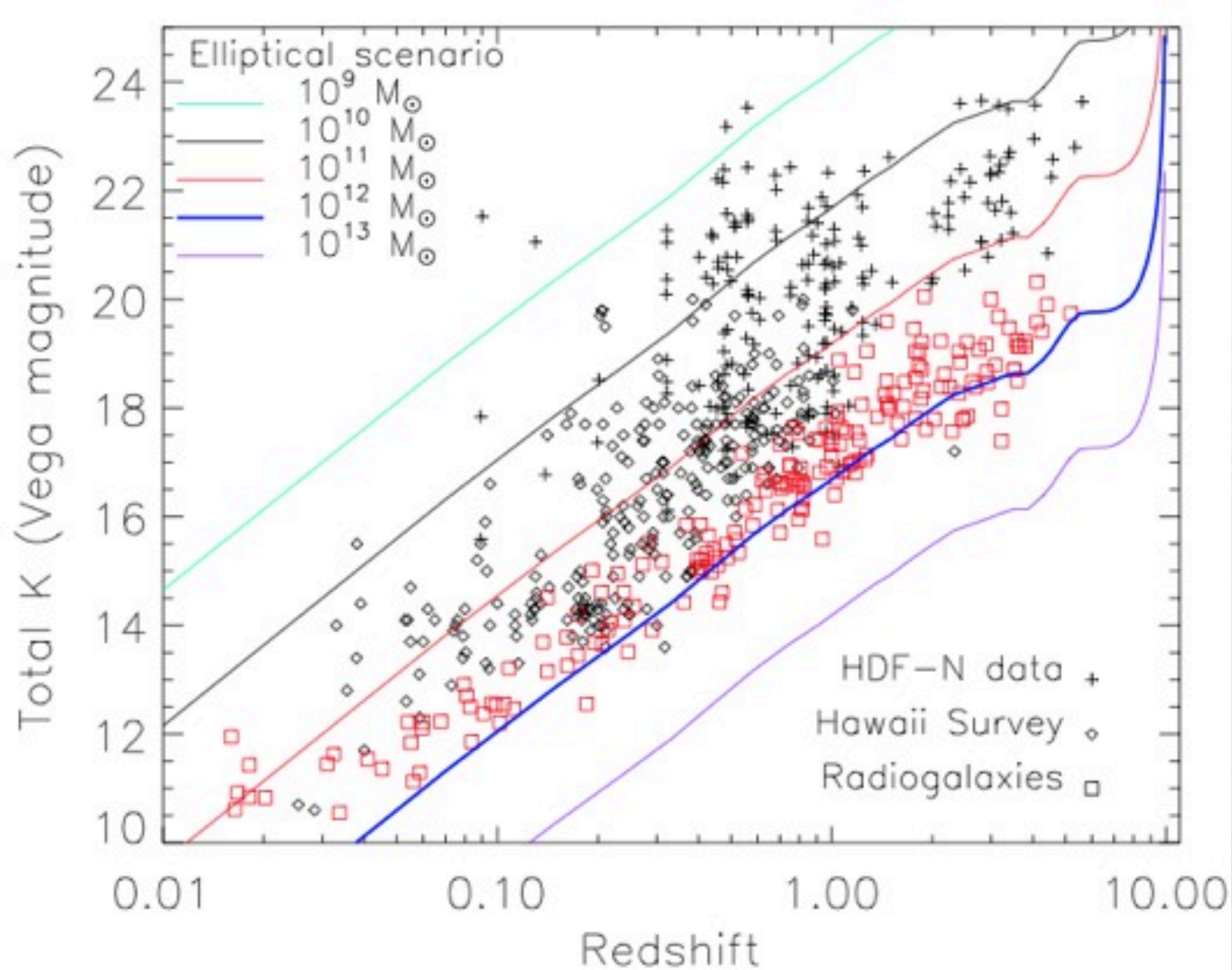


Star formation history in high redshift radio galaxies

Collaborators: B. Rocca-Volmerange (IAP), C. De Breuck (ESO), J. Vernet (ESO), N. Seymour (CASS), D. Stern (JPL), M. Lehnert (IAP), P. Barthel (KAI), P. Podigachoski (KAI)...

G. Drouart (OSO, Chalmers), ESO, 13 October 2014

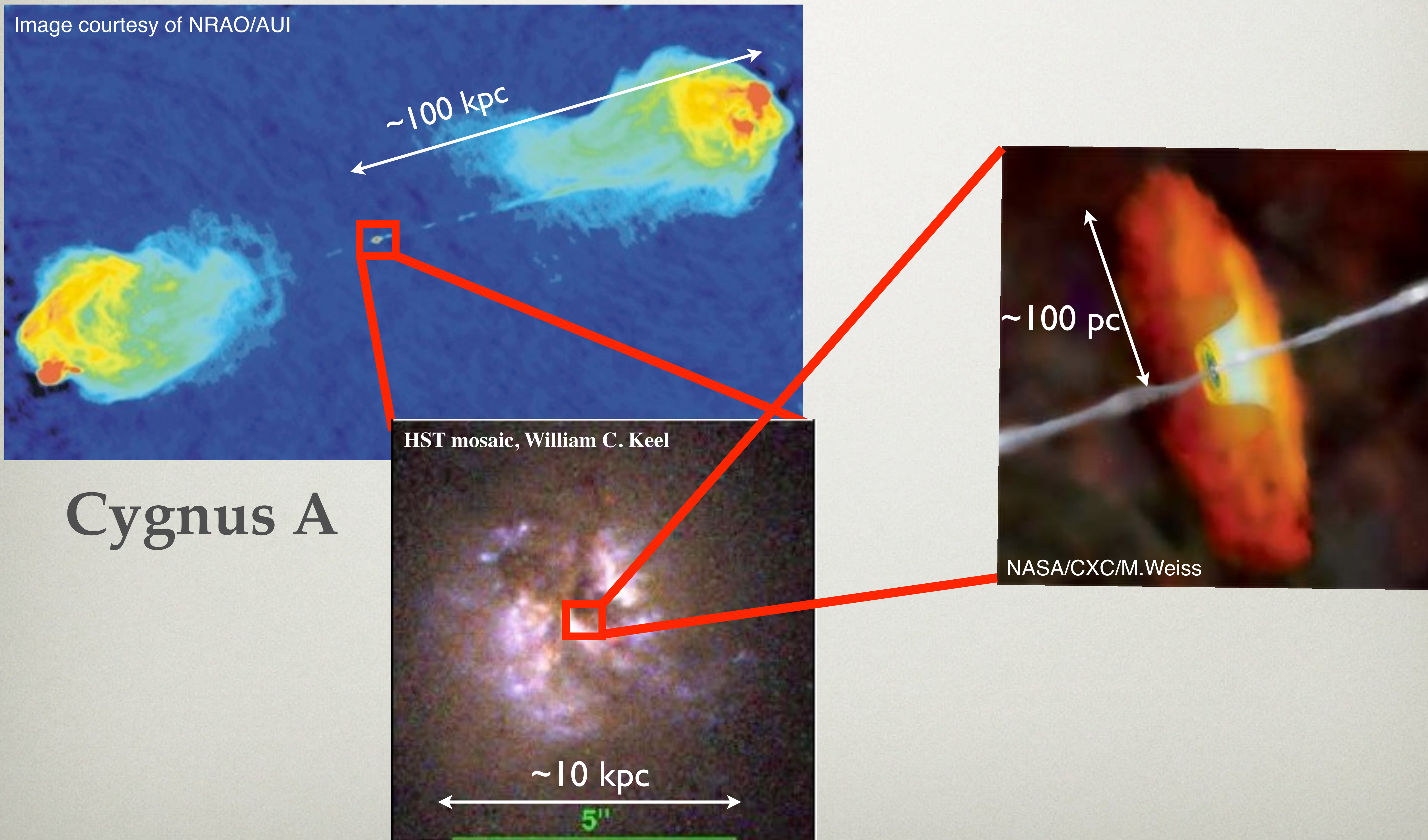
Why radio galaxies ?



Rocca-Volmerange et al., 2004

- Bright objects at most wavelengths up to z>5 (Miley & De Breuck, 2008)
- Massive galaxies interpreted by elliptical galaxies up to z=5 (RV04, Seymour et al., 2007)
- Sit in denser environment: CARLA (Galametz et al., 2012, Wylezalek et al., 2013)

Radio galaxy in a nutshell

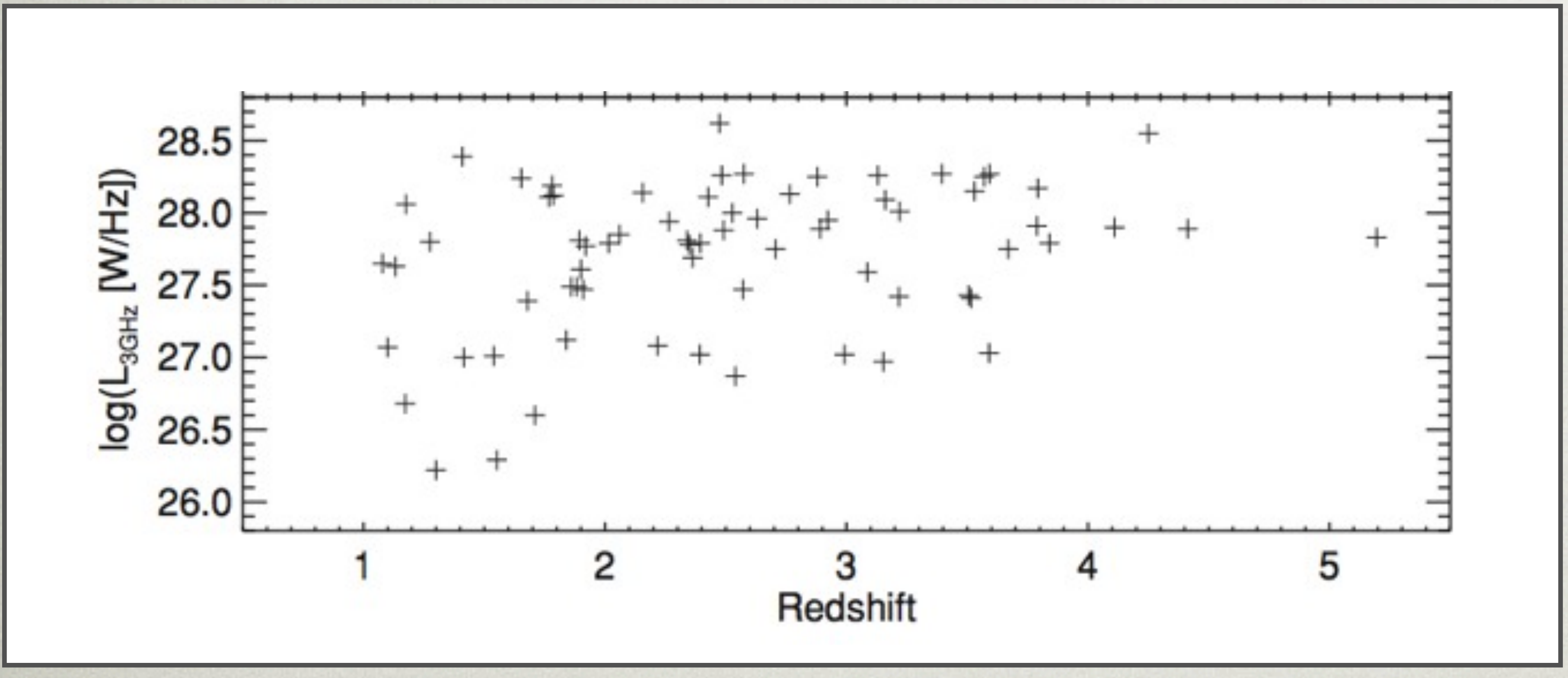


Cygnus A

Projet HeRGÉ

Herschel Radio Galaxy Evolution project
International team (~25 members)

- 70 powerful radio galaxies at 1 < z < 5.2



Parent sample of HzRGs (~260 objects), from 3C, 4C, 5C, 6C, 7C, 8C, USS, TXS, TN, PKS...

HeRGE sample

$$L^{3GHz} > 10^{26} W.Hz^{-1}$$

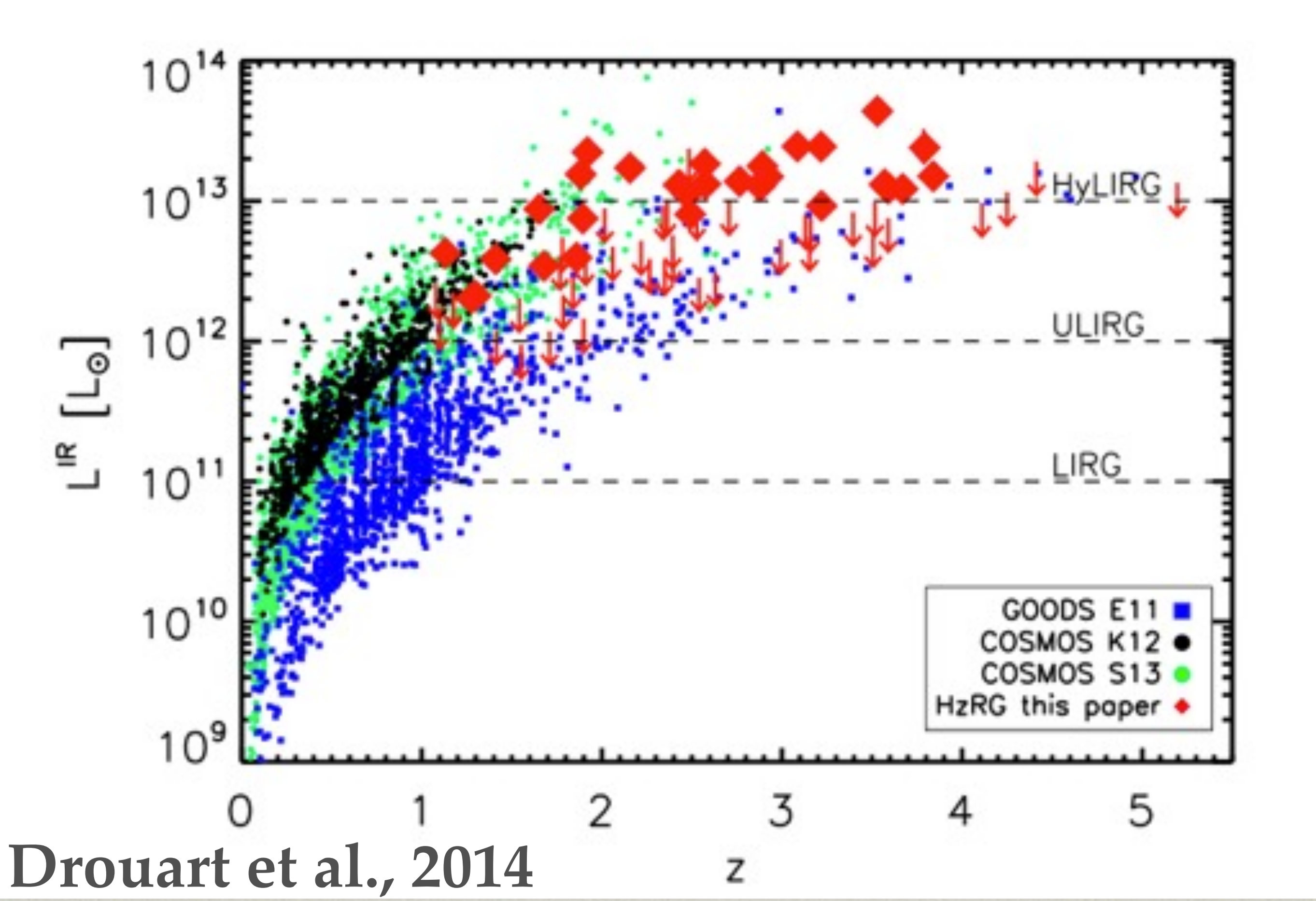
to cover homogeneously z-radio luminosity plane

Supporting data from UV to radio: *Spitzer*, **Herschel**, *HST*, VLT, Keck, SCUBA, VLA, ATCA, LABOCA, ALMA (cycle 1, cycle 2), CARMA

ARPEGE SAMPLE

Analysis of **R**adio galaxies with **PE**GASE for **G**alaxy **E**volution

- 12 radio galaxies spanning $1<z<4$ from HeRGE, selected from *Herschel* detection (higher IR emitters) and UV/optical/near IR data



Drouart et al., 2014

ARPEGE SAMPLE

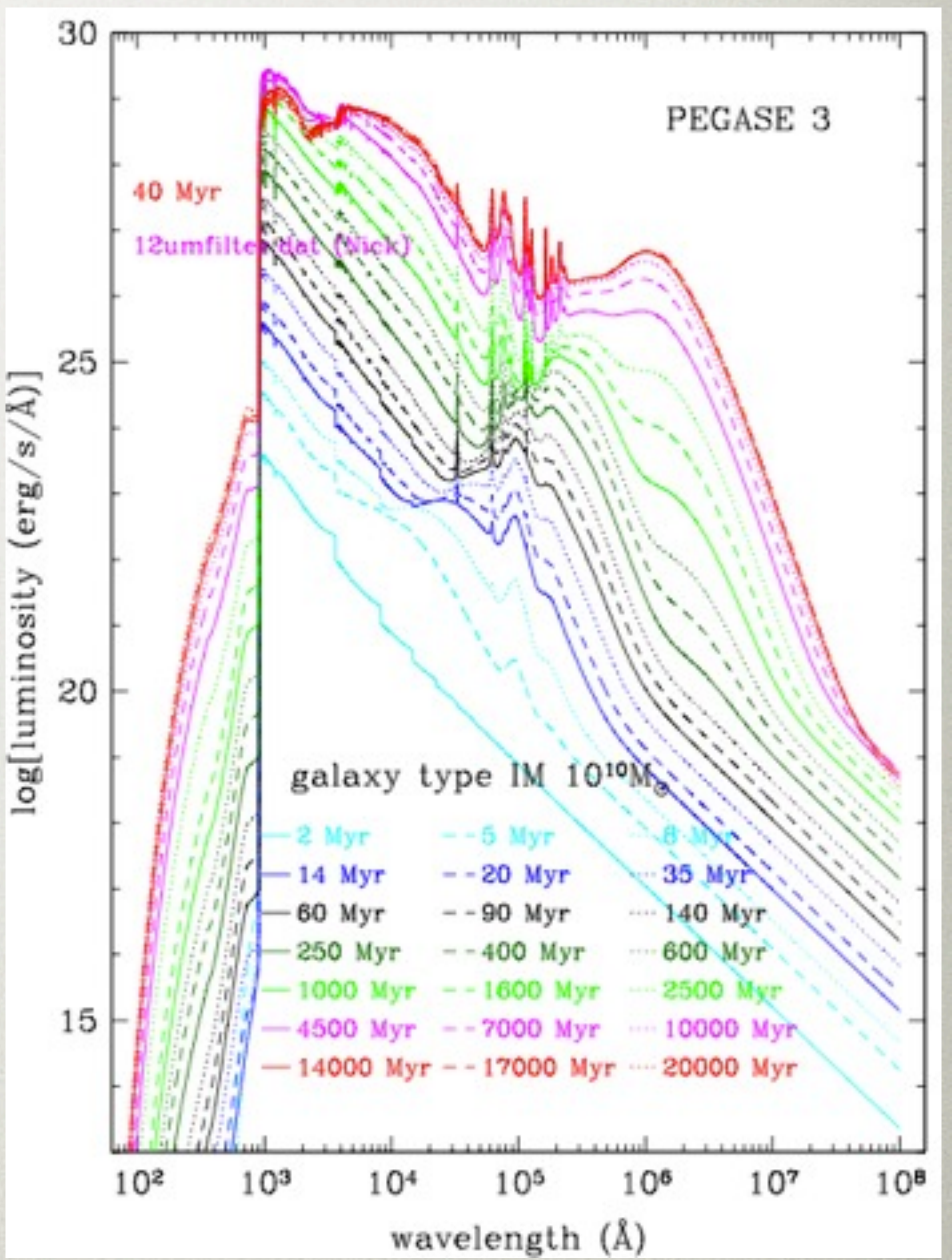
Analysis of **R**adio galaxies with **PE**GASE for **G**alaxy **E**volution

- 12 radio galaxies spanning $1<z<4$ from HeRGE, selected from *Herschel* detection (higher IR emitters) and UV/optical/near IR data
- UV-submm SED; >10 data points from broad band photometry (integrated properties, unresolved SPs)
- weak* to strong AGN contribution from UV to mid-IR
- UV restframe polarisation measurements (imaging and spectroscopy, FORS(VLT)/LRIS(Keck))

Evolutionary spectral synthesis with PEGASE 3

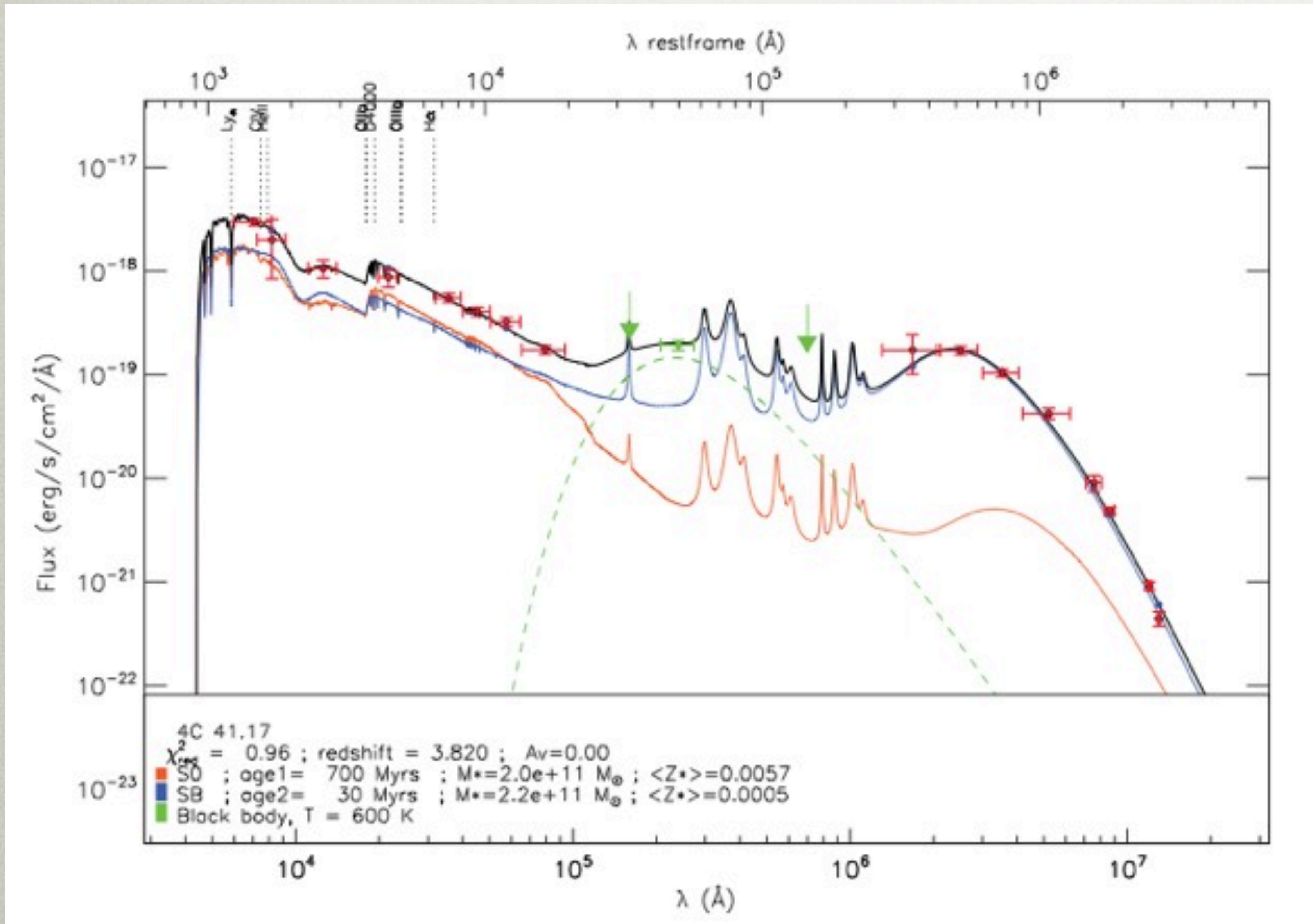
PEGASE.3 (Fioc M., Rocca-Volmerange B. & Dwek E., near sub.)

- PEGASE 2* + far-IR dust emission
- Chemical evolution (in particular C and Si) determined (evolved super giants and AGB)
- Dust mass evolves with time
- Stochastic grain heating from energetic photons <=> contribution to star formation rate
- Monte Carlo simulations of radiative transfer
- Scattering/absorption, Draine's model population
- Column density factor $K_{N(HI)} \propto M/R^{-2}$ as a tuning factor
- 2 geometries: disk and spheroid



*available at www2.iap.fr/pegase

Pilot study on low AGN contribution HzRG

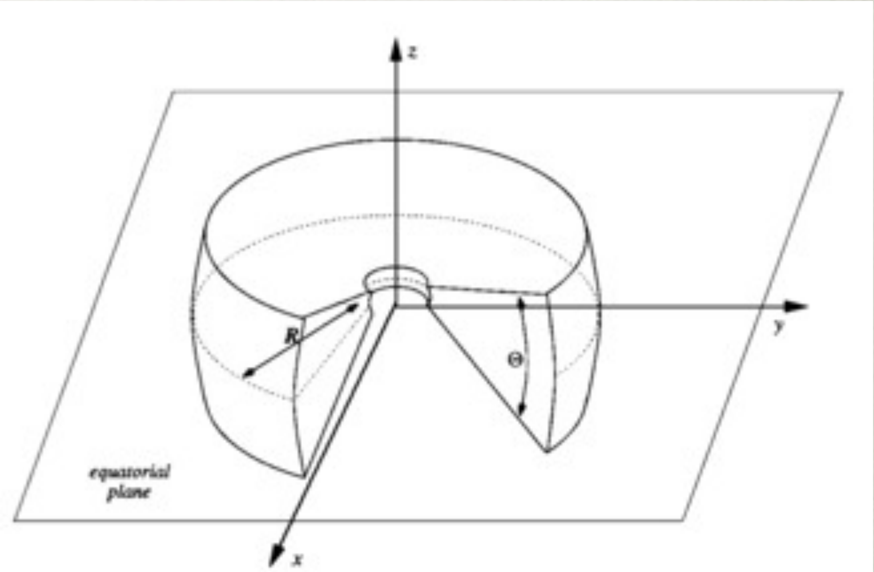


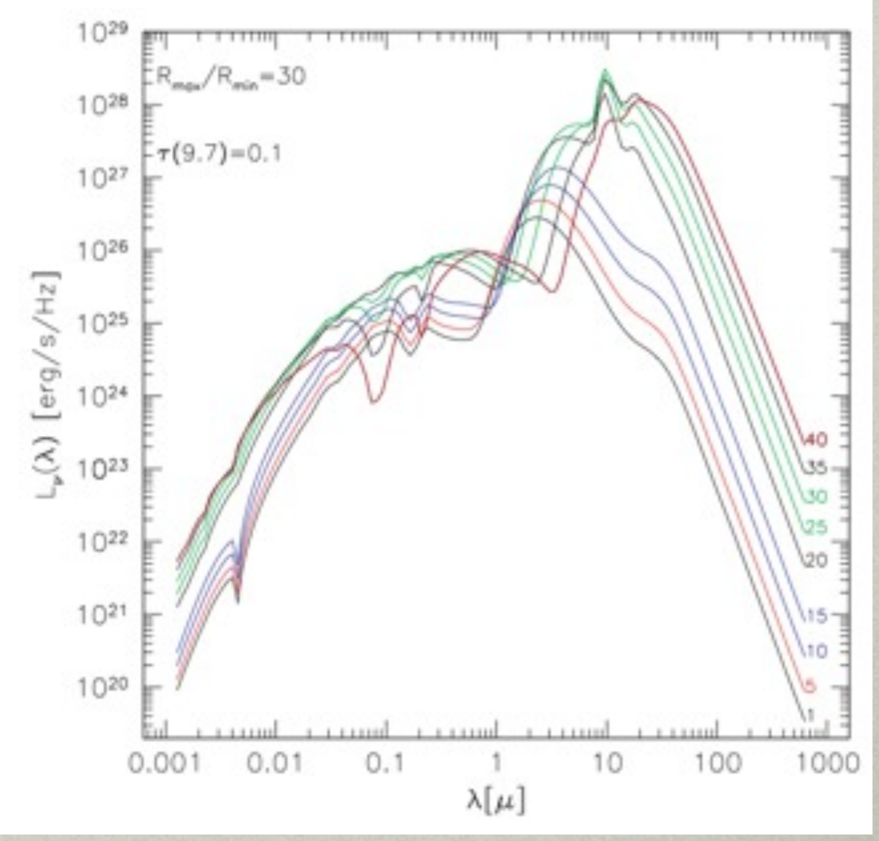
- two HzRGs at z=4
- low UV polarisation (<1% at 1500Å)
- evidence for 2 stellar populations: evolved+young

Rocca-Volmerange et al. 2013

AGN torus model, Fritz et al., 2006

- Continuous dust distribution
- Spherical coordinates
- 50/50 silicate/graphite composition
- 6 parameters:
  - **size**: $Y=R_{max}/R_{min}$
  - **equatorial optical depth**: $\tau_{9.7\mu m}$
  - **dust density profiles**: radial and azimuthal
  - **inclination**: i
  - **opening angle**: θ
- Radiative transfer equation solved by Λ-iteration method

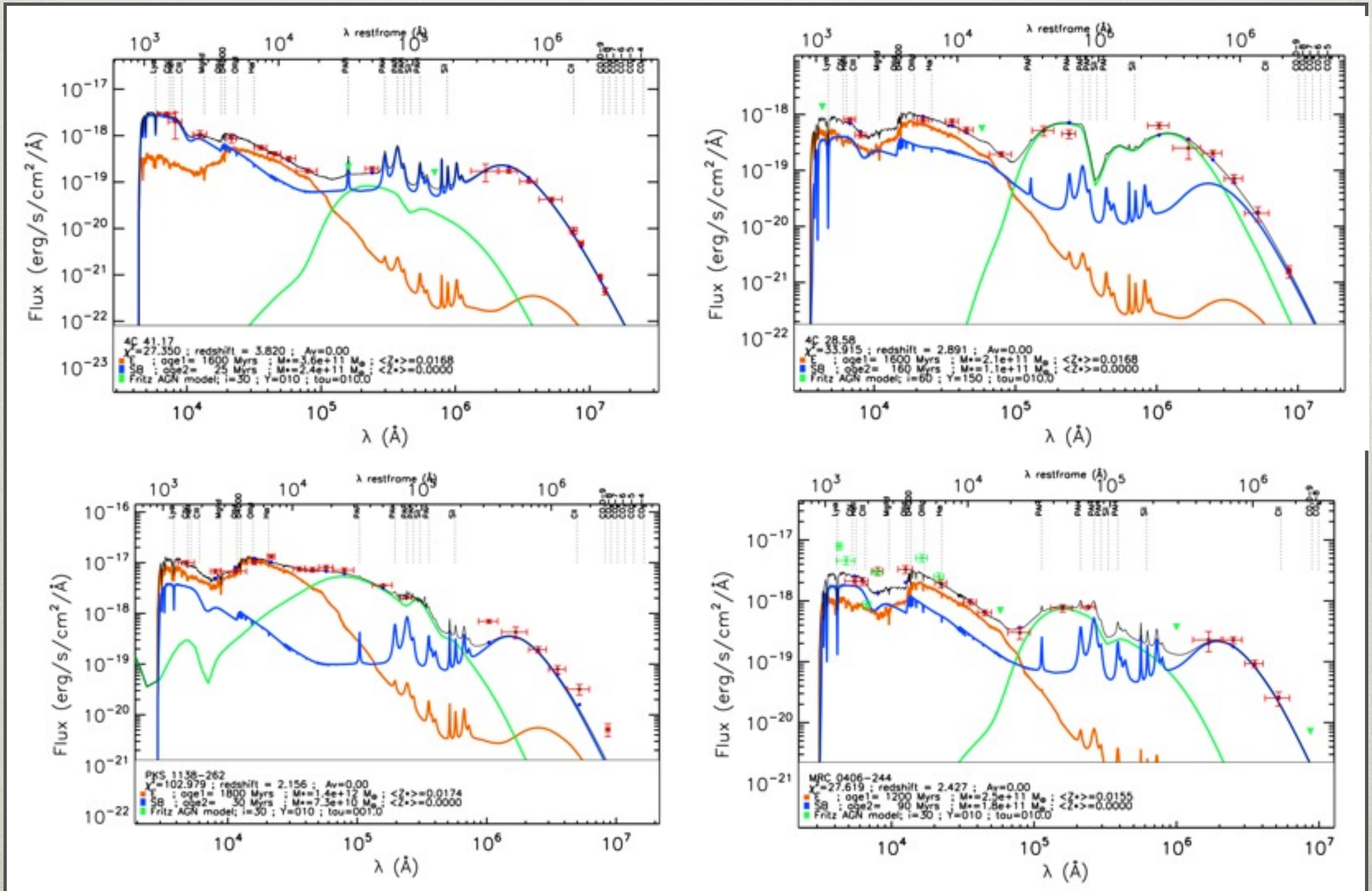




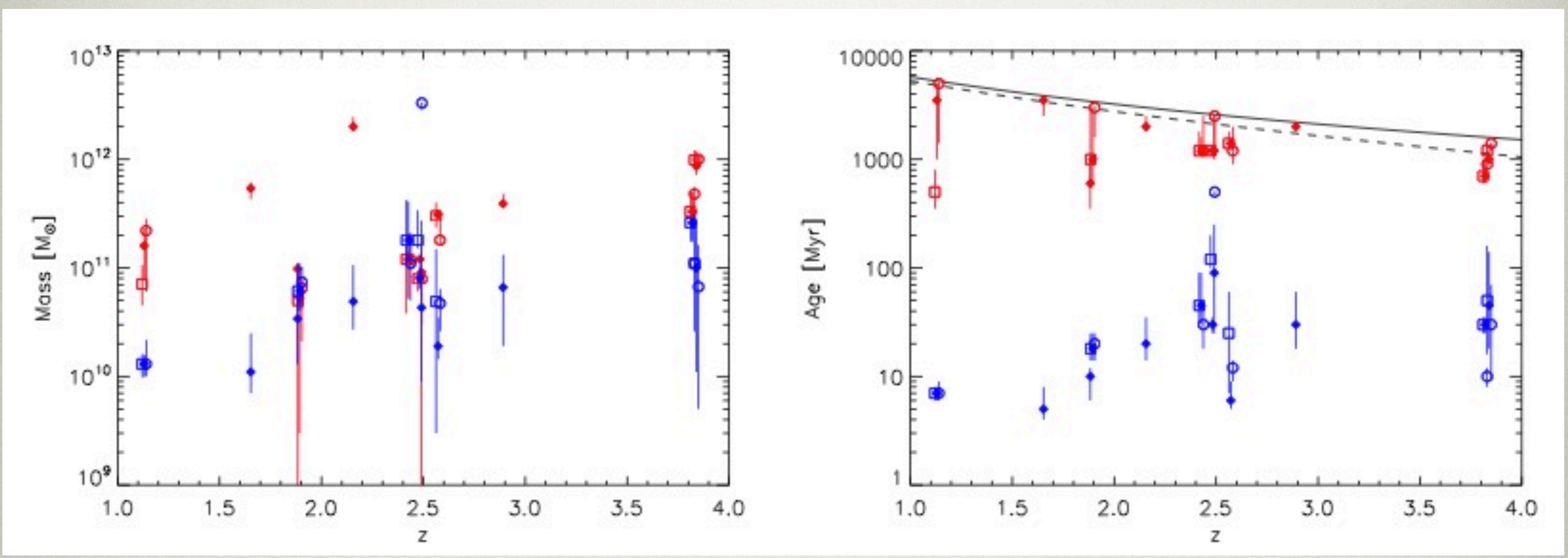
Fitting procedure

- Models: PEGASE.3 galaxy evolution (k+e-cor.) fits observations at z=0, by types) and Fritz et al., 2006 AGN torus model
- Library of templates:
    - by types: Elliptical ,S0, Spiral and Starburst
    - ages from 0 to 20Gyr, continuous coverage from UV to Sub-mm
- χ^2 minimisation procedure (Total of 10 free parameters: 3 normalisations (2 masses and AGN luminosity), 2 ages, inclination, opacity, size, column density, SB initial metallicity)

Full ARPEGE sample



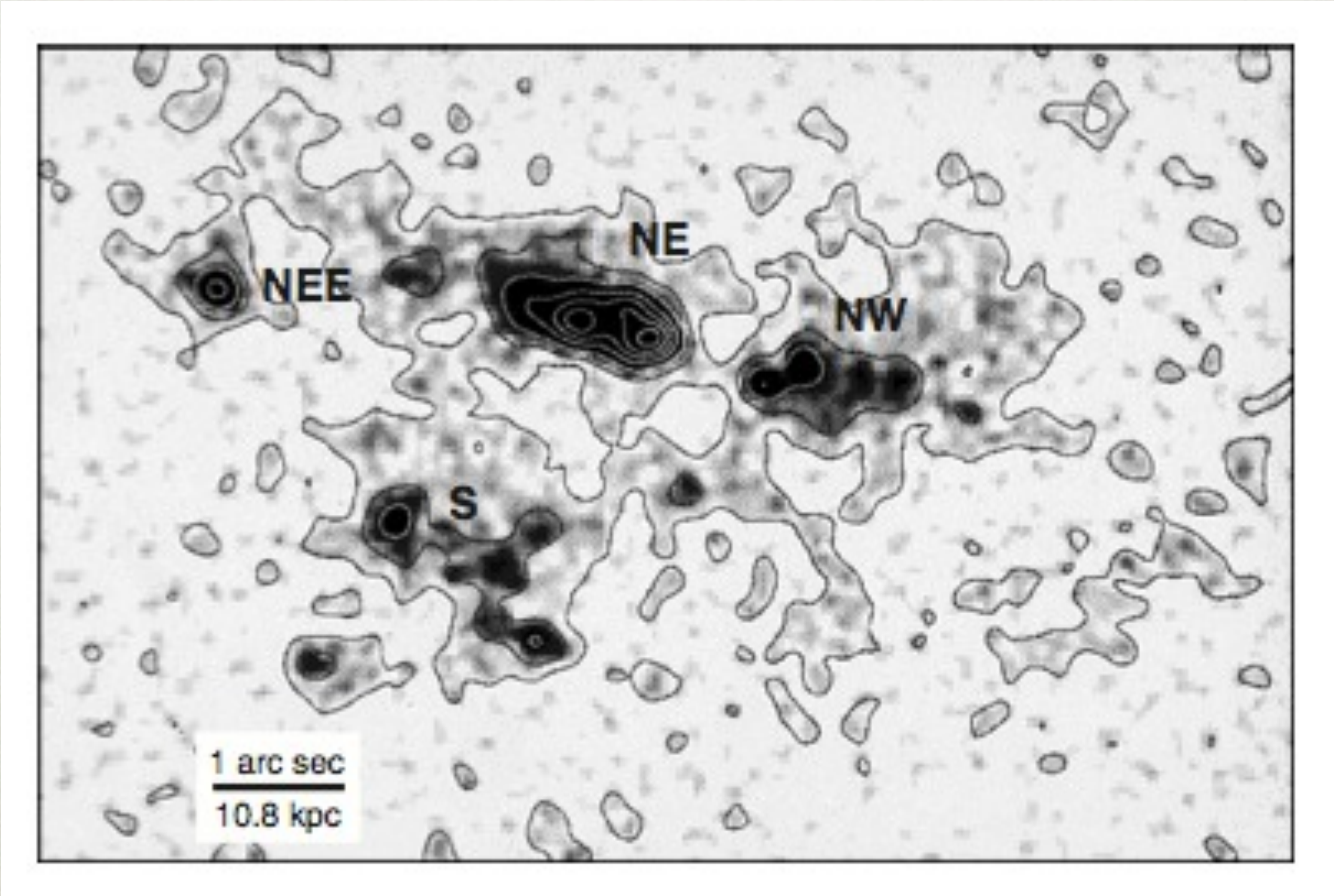
Mass and Age of the two stellar populations



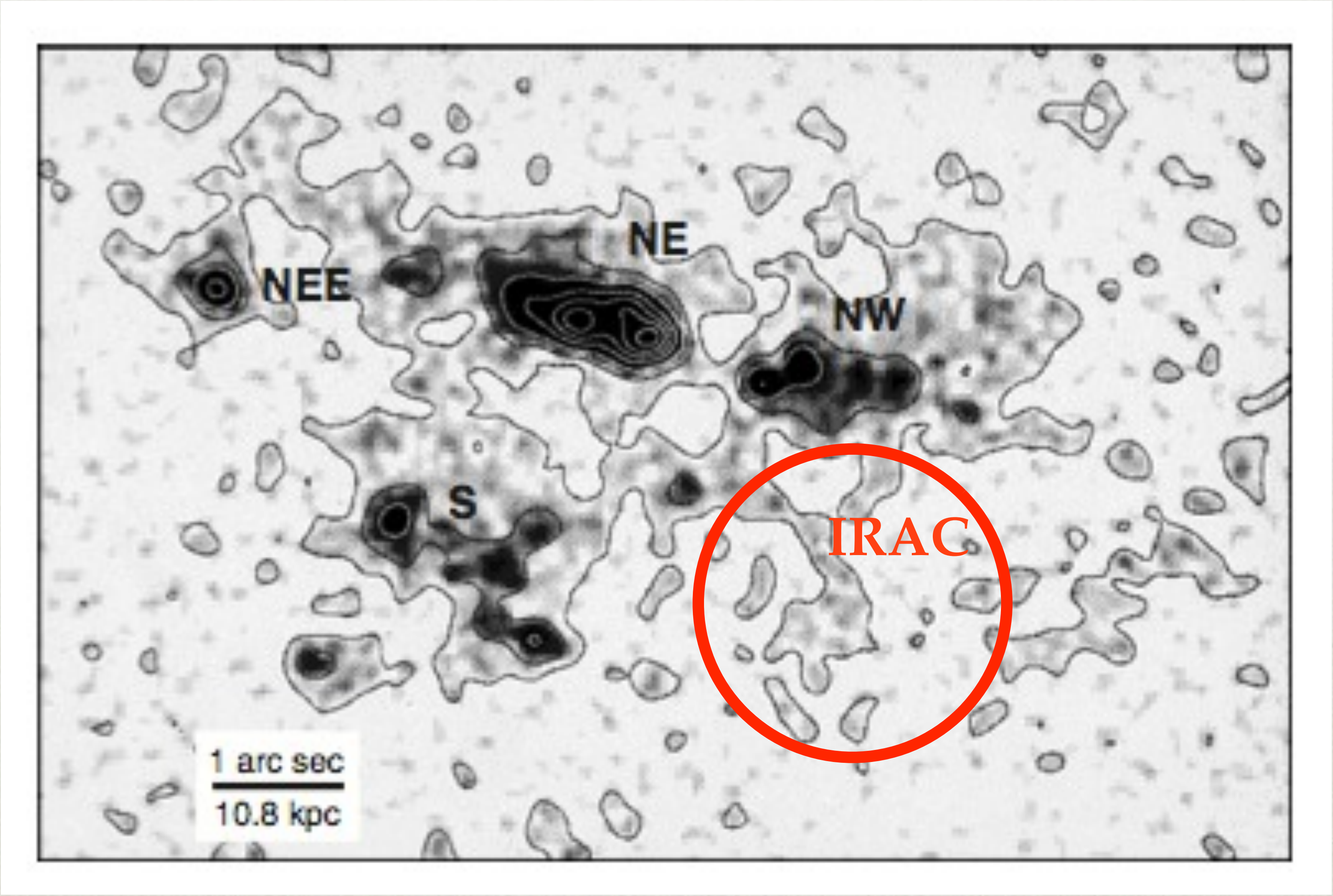
- 2 stellar populations: young(blue) and evolved(red)
- SB represent a significative part of the mass of the system
- UV/optical AGN polarisation can be ignored in most cases

Where does star formation take place ?

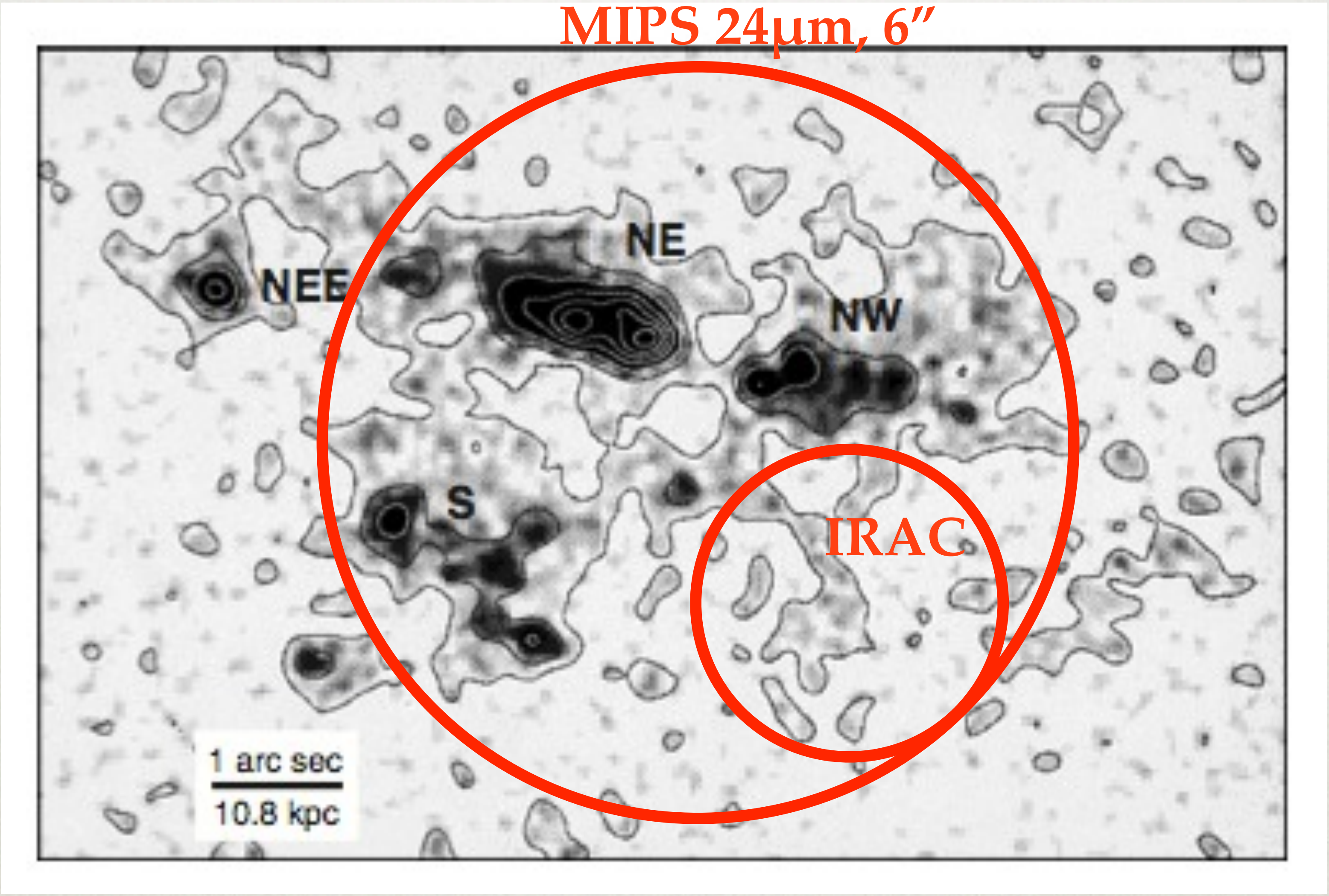
Pb! Resolution at long wavelength



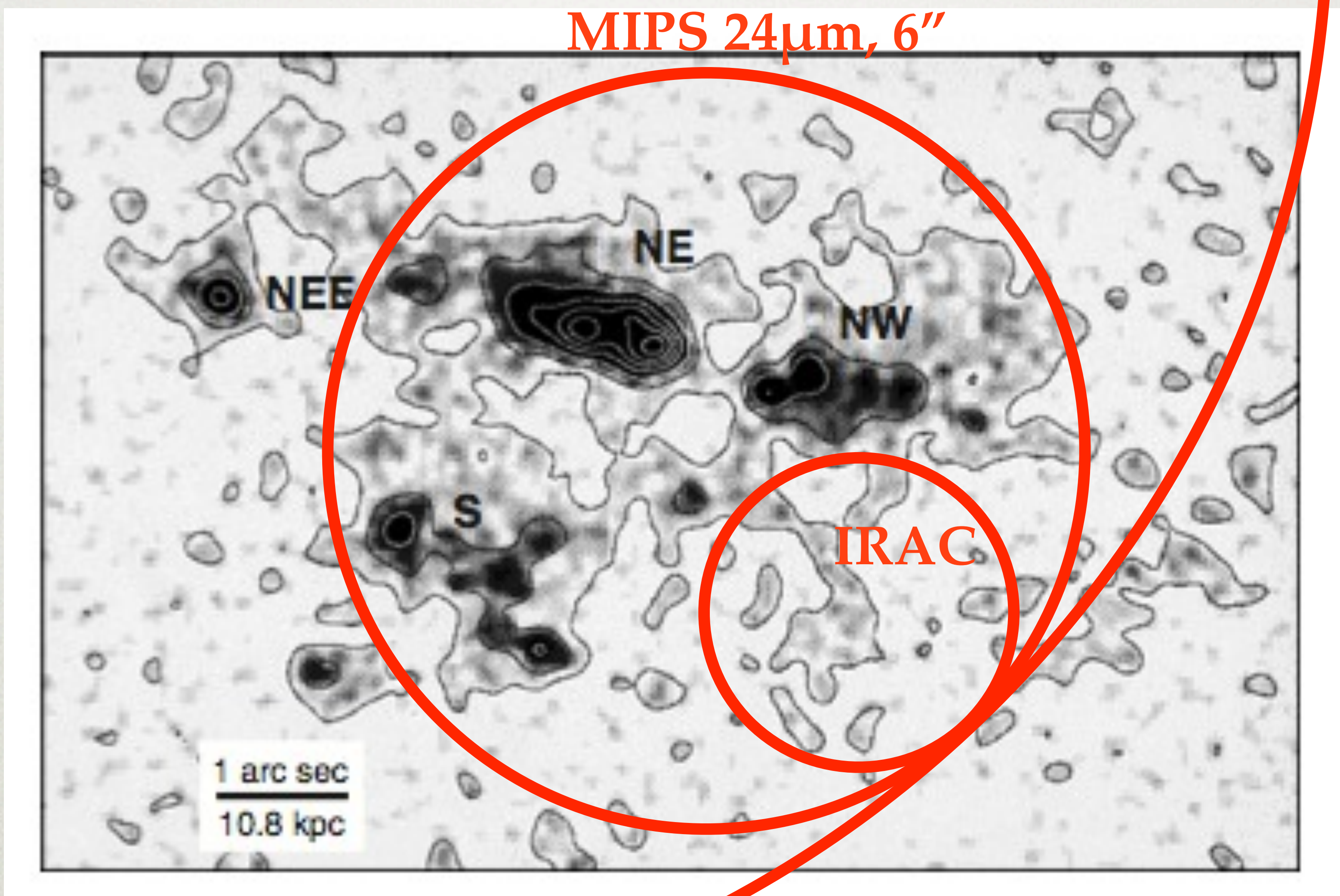
Pb! Resolution at long wavelength



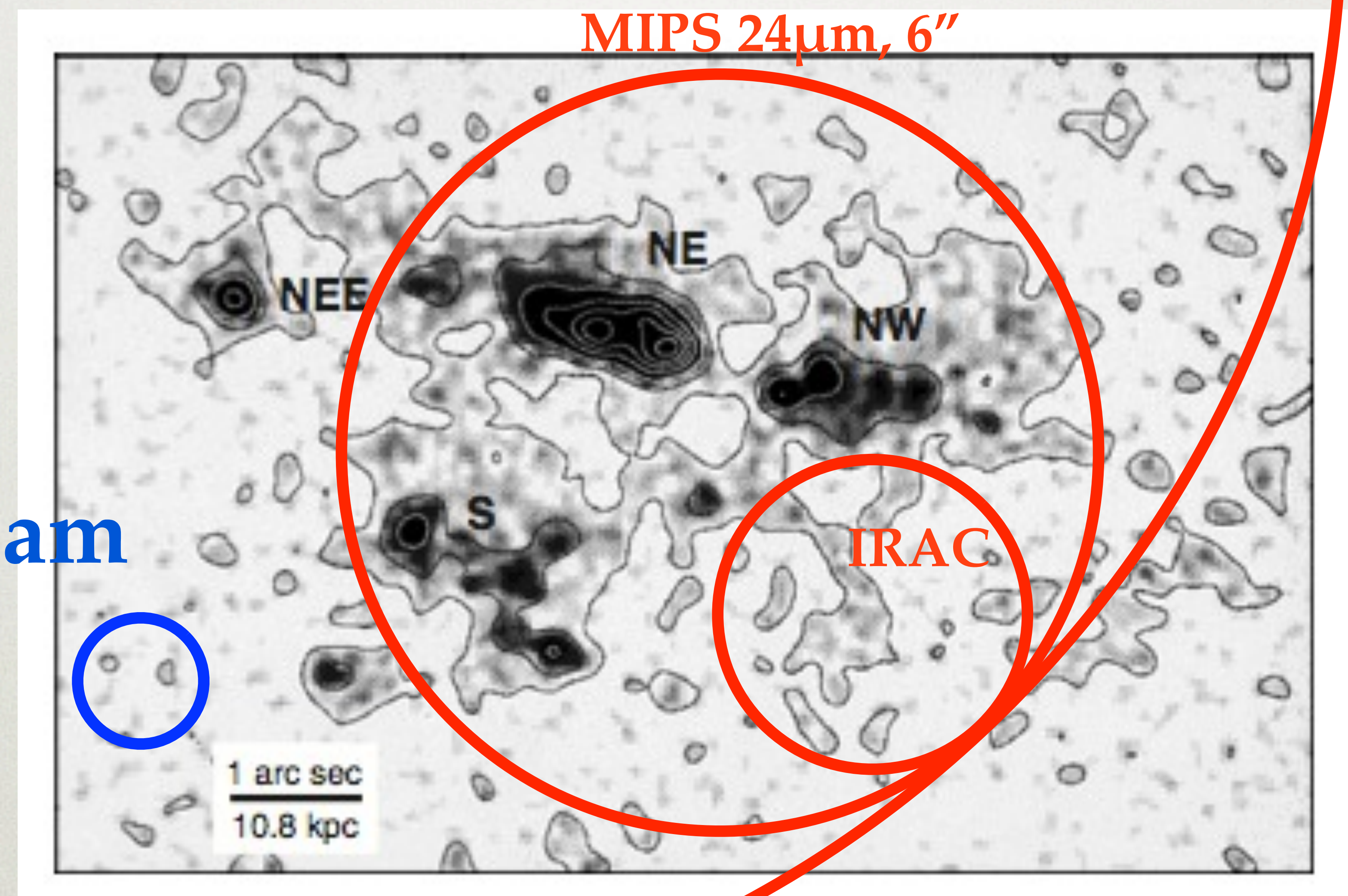
Pb! Resolution at long wavelength



Pb! Resolution at long wavelength



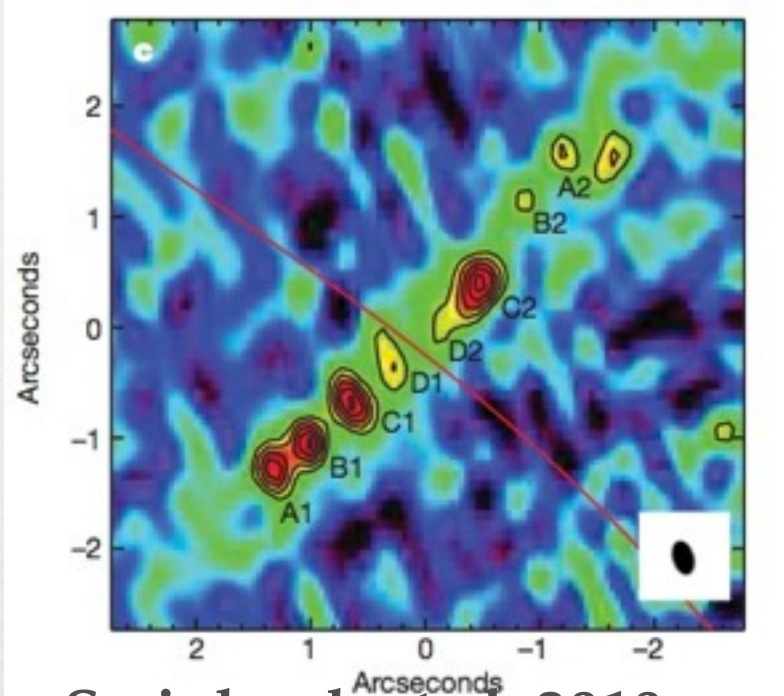
Pb! Resolution at long wavelength



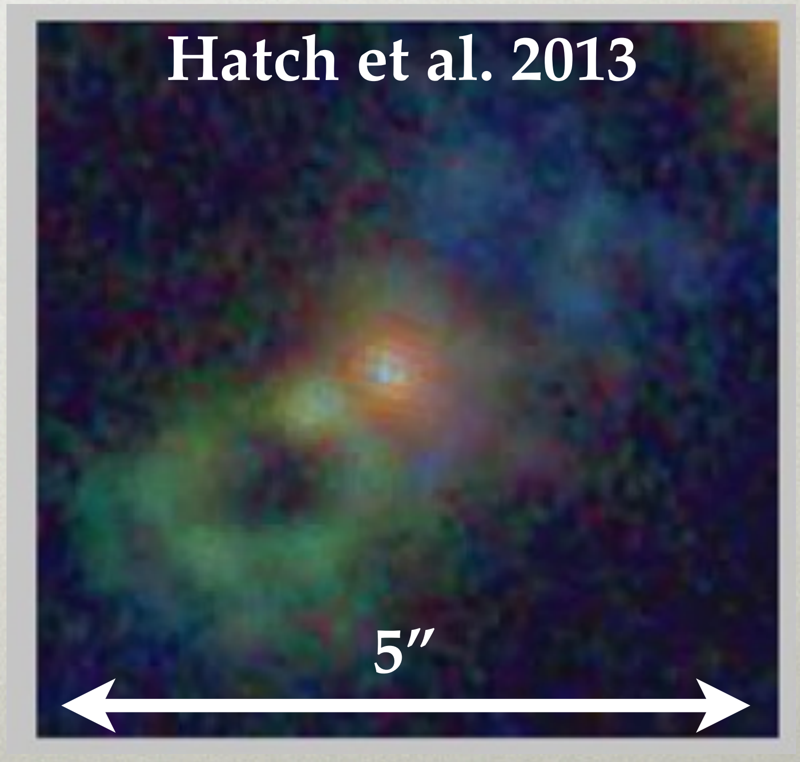
Cycle 1/2 ALMA program at ~1″ resolution (Gullberg et al., in prep)

In situ, multi-component star formation?

- Need for a sub-kpc scale resolution: ALMA and/or strongly lensed sources
- Star formation in large molecular clouds in the galaxy, most probably disk-like structure
- Central star formation? Local AGN do show a SB-AGN connection in central kpc (e.g. Asmus et al., 2011, Esquej et al., 2014)

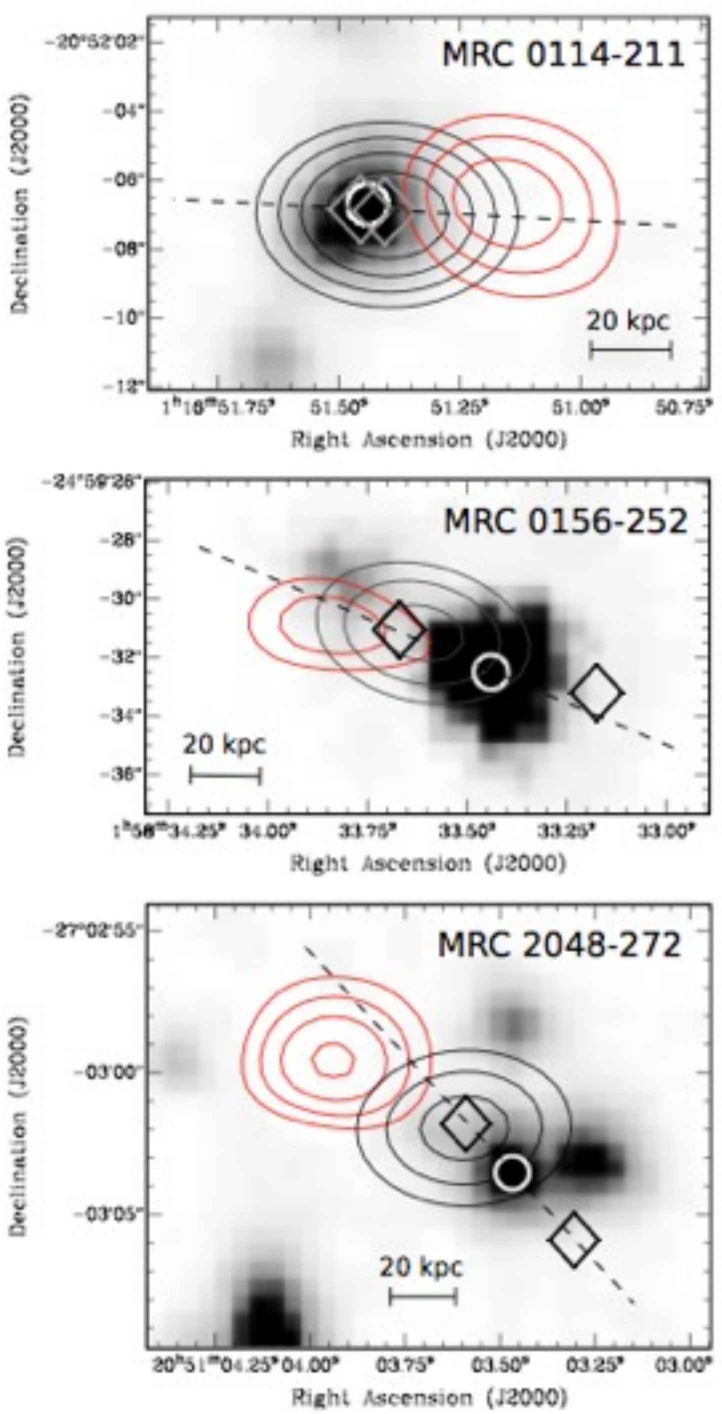


Swinbank et al. 2010

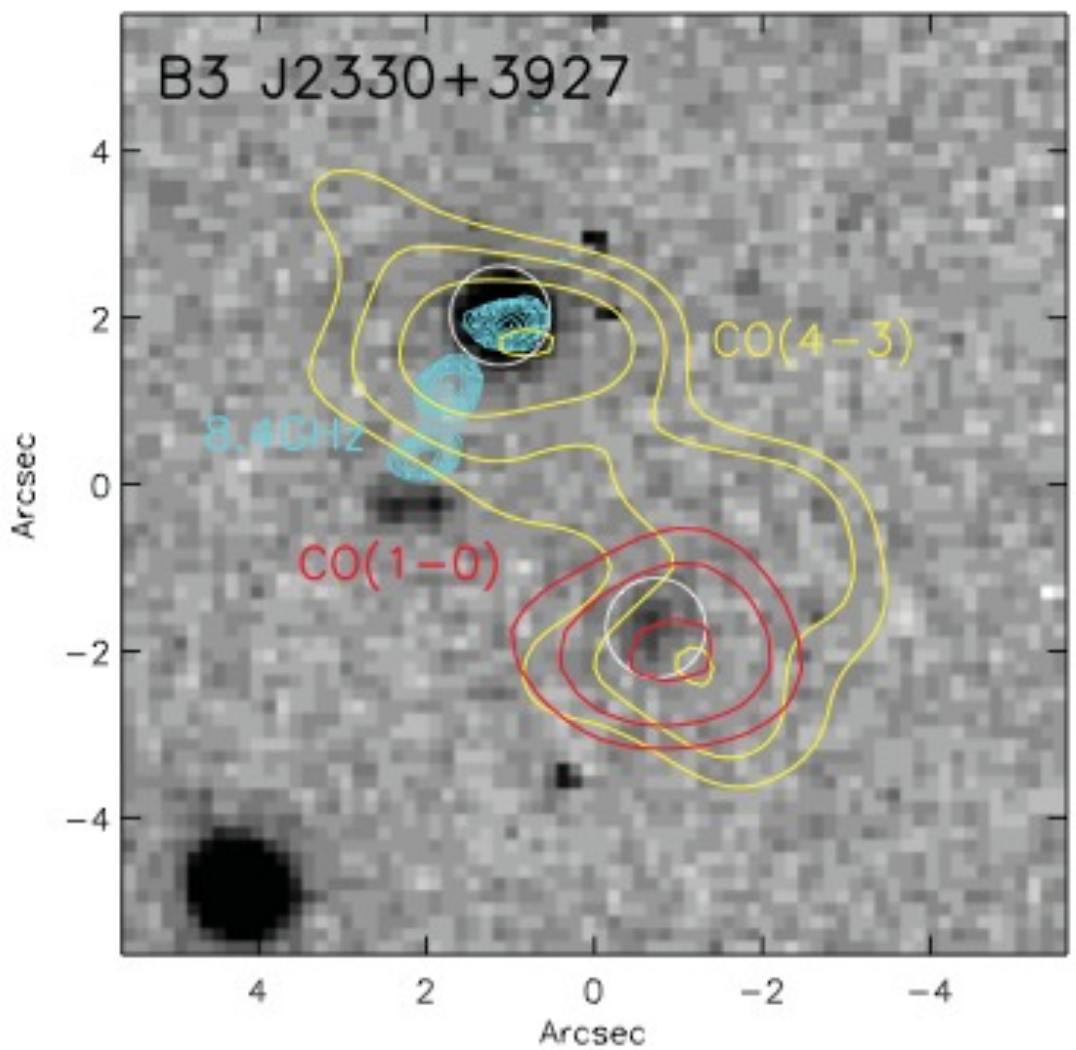


Hatch et al. 2013

Ex situ, Star forming Companion?



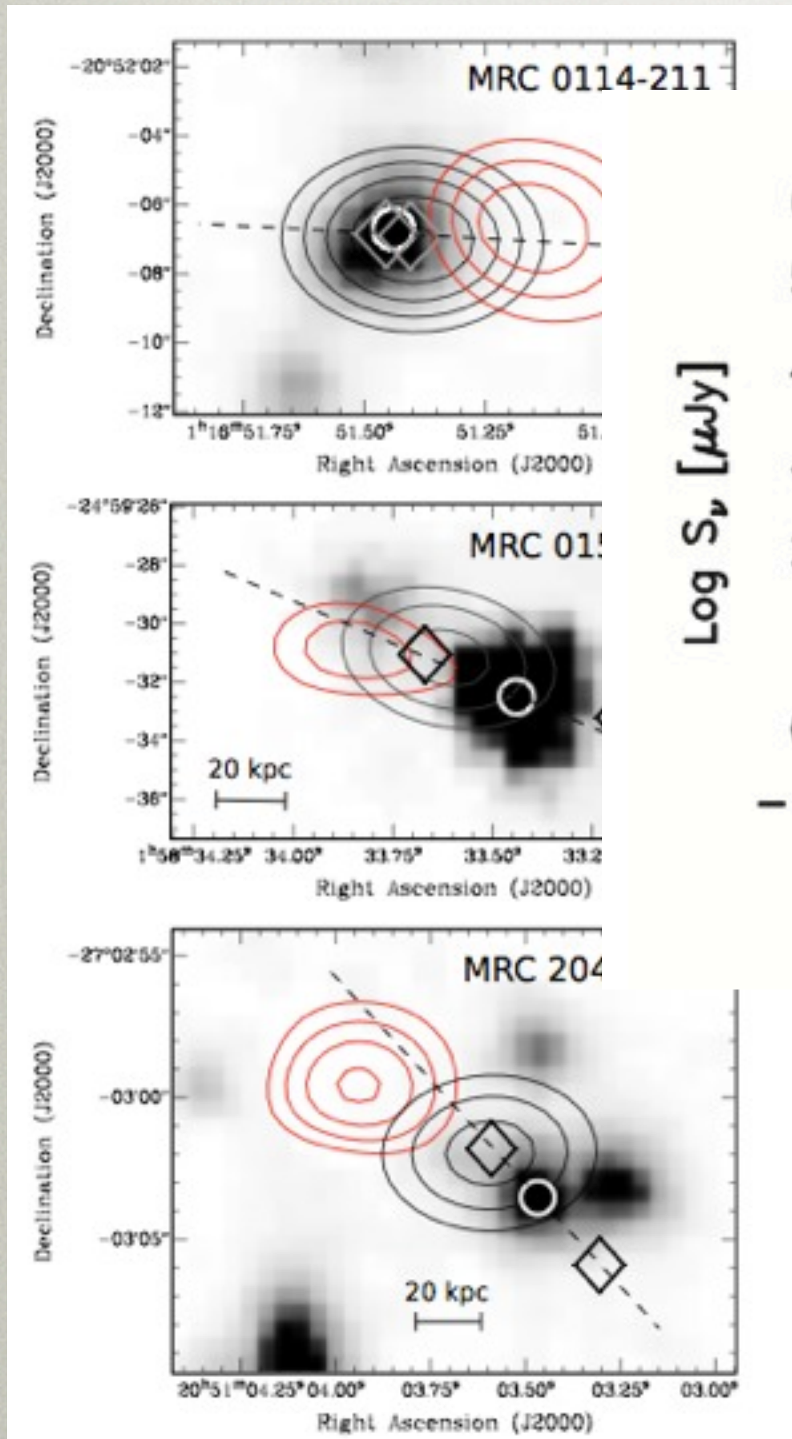
Emonts et al., 2014



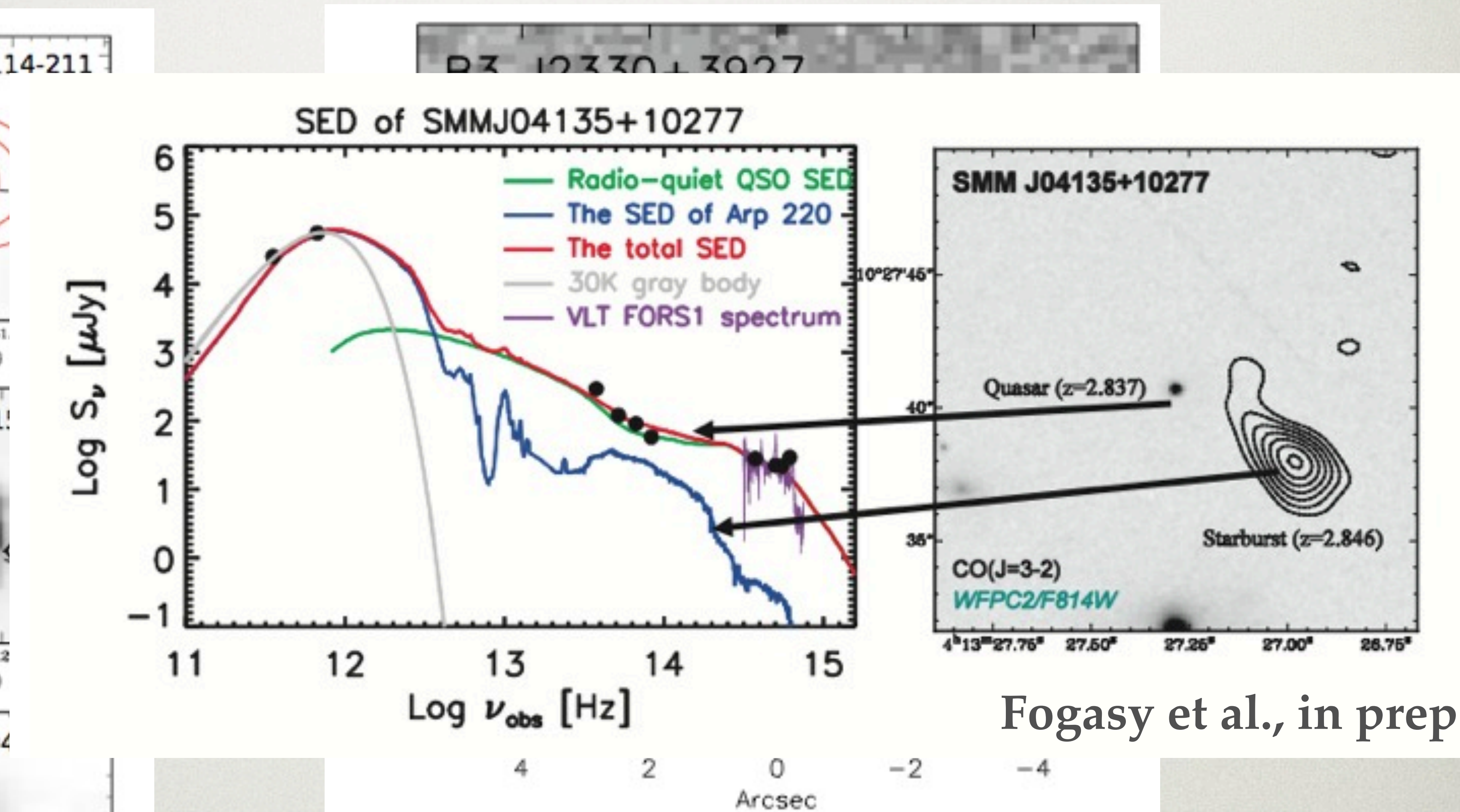
Ivison et al., 2012

Molecular gas not centered on the source ! possible (very) obscured star forming companion !

Ex situ, Star forming Companion?



Emonts et al., 2014

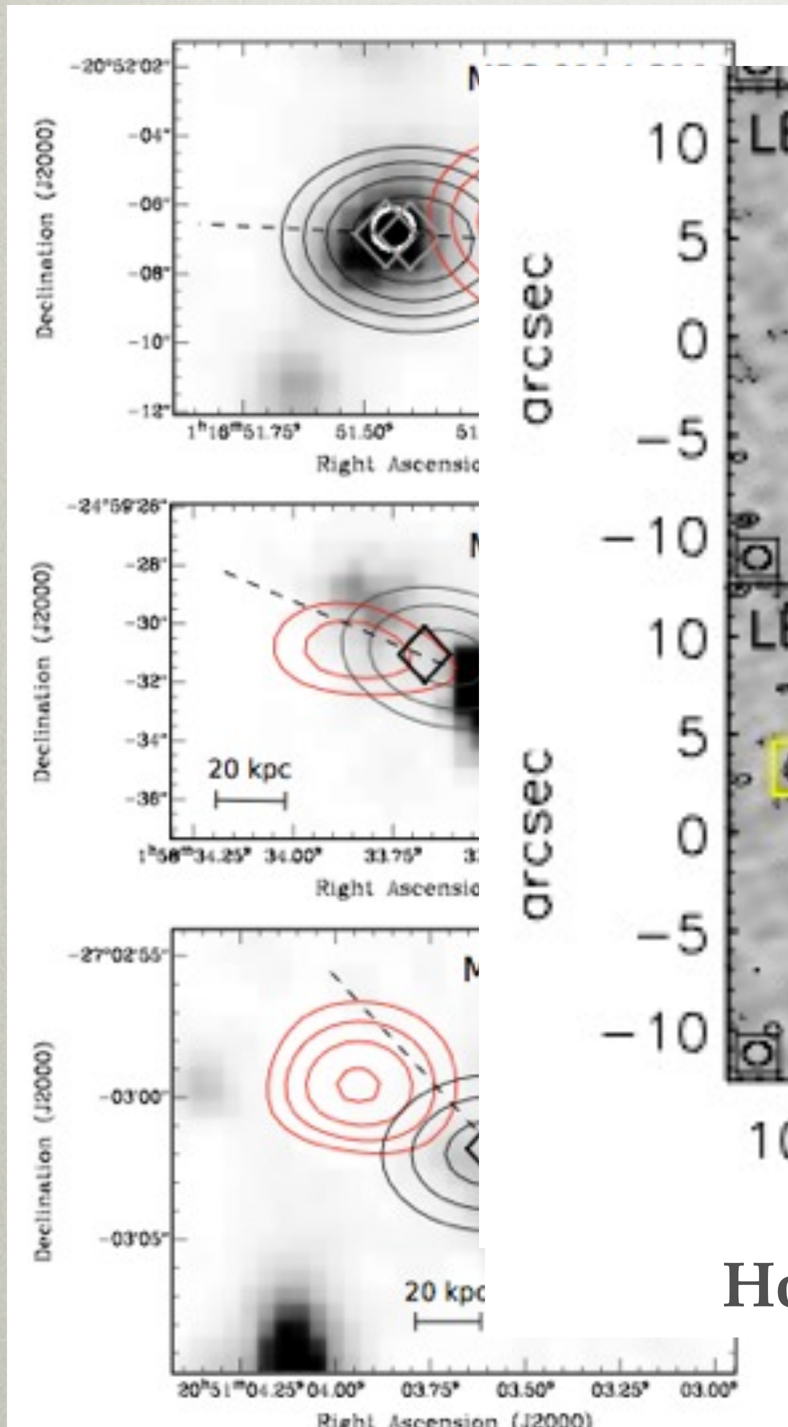


Fogasy et al., in prep

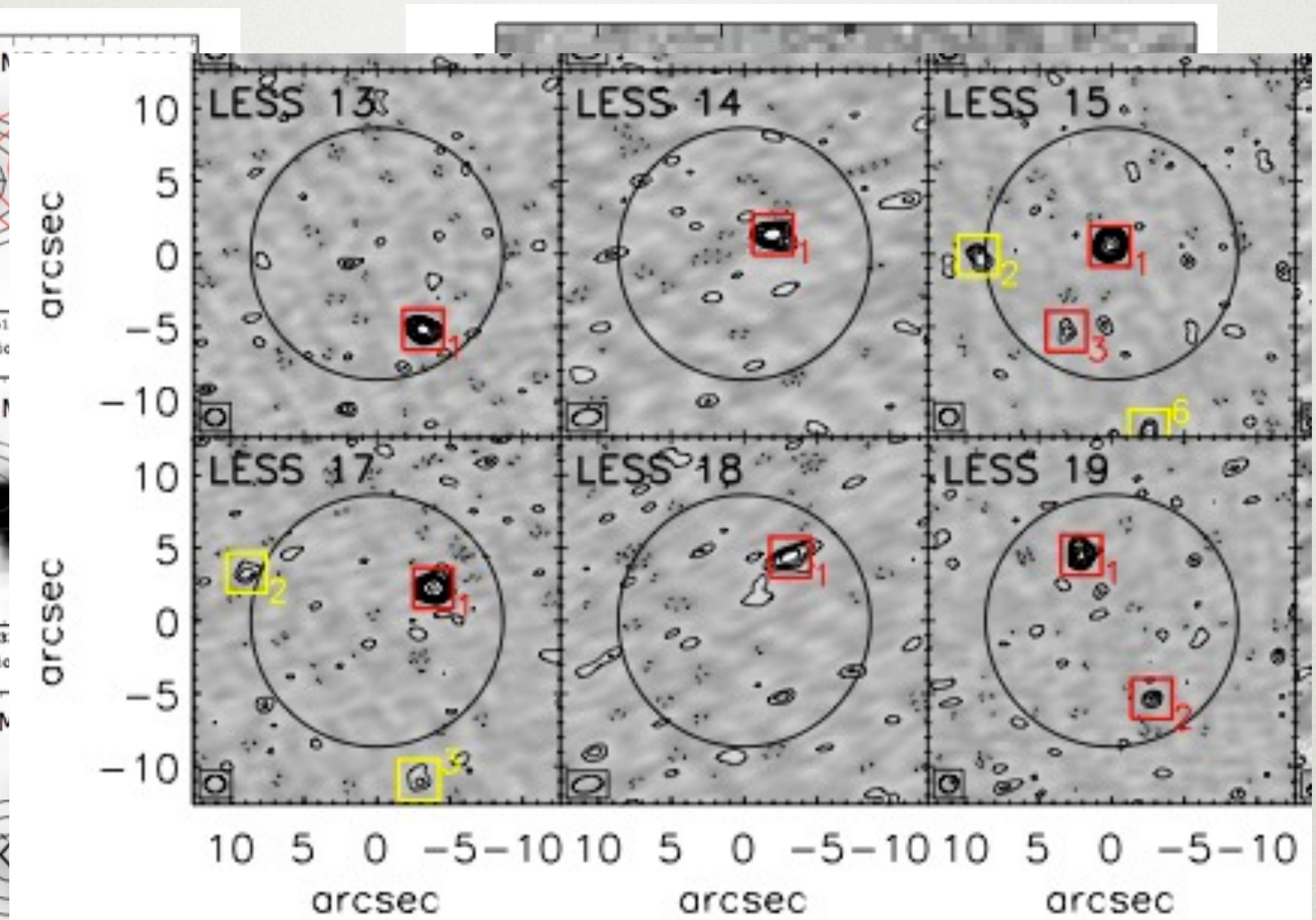
Ivison et al., 2012

Molecular gas not centered on the source !
possible (very) obscured star forming companion !

Ex situ, Star forming Companion?



Emonts et al., 2014

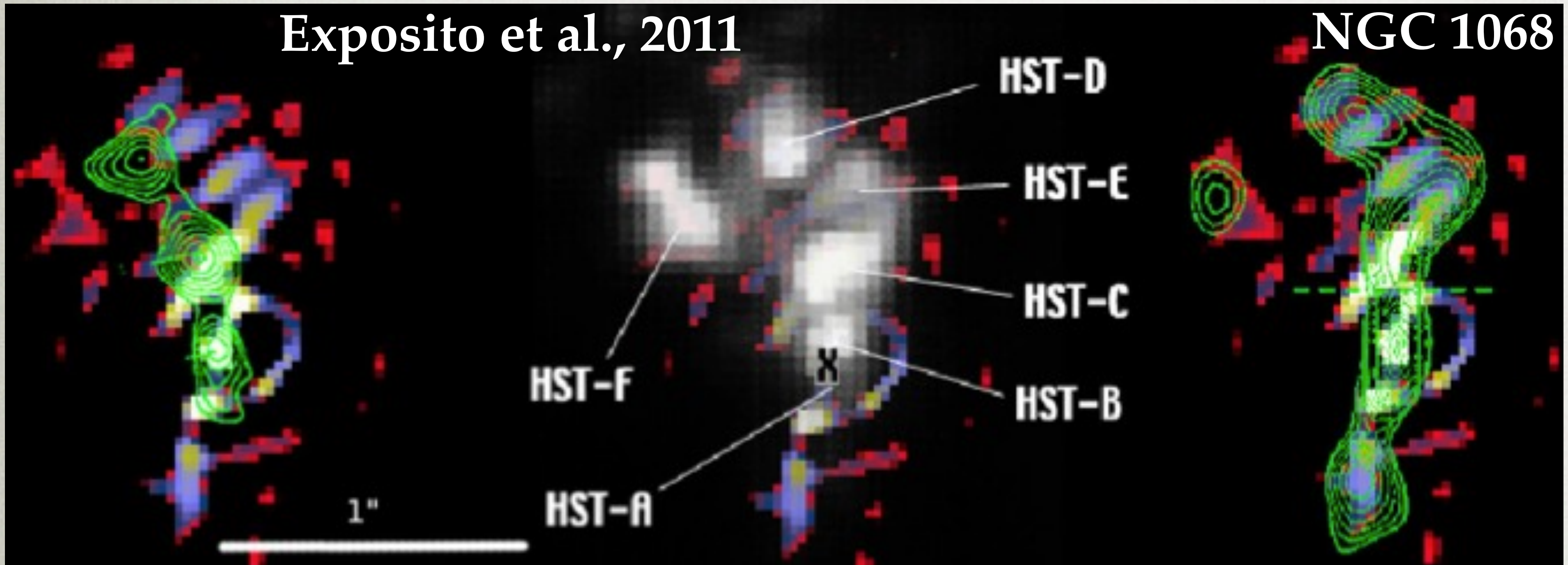


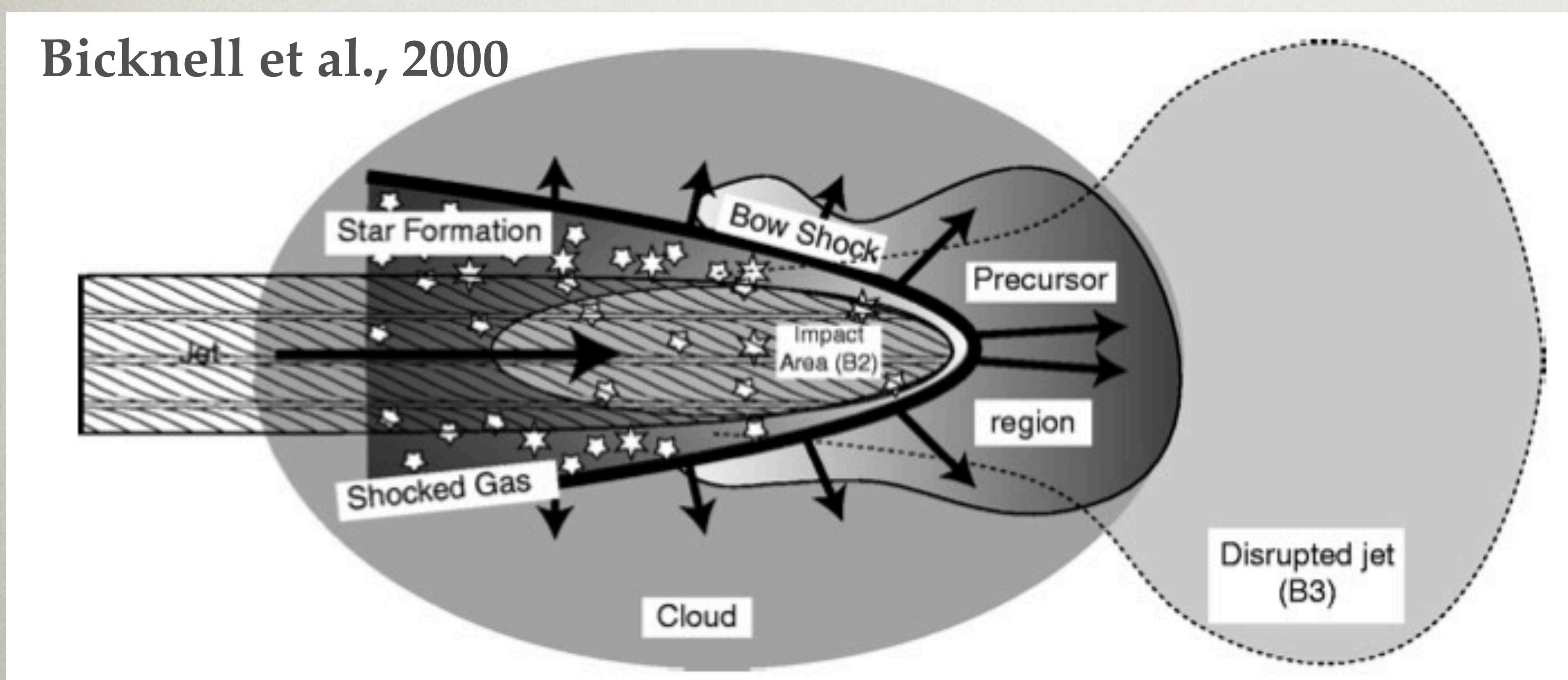
Hodge et al., 2013

e source !

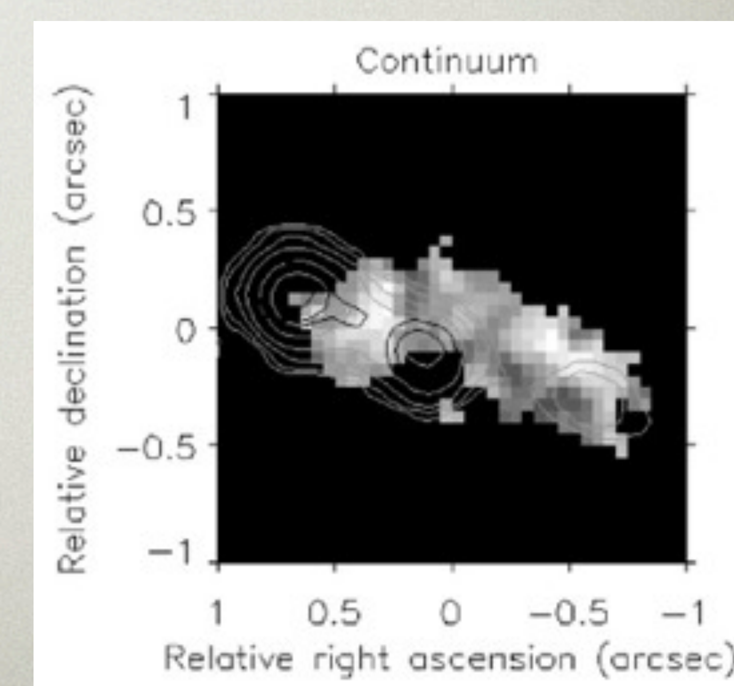
possible (very) obscured star forming companion !

Jet-induced star formation ?





- Involve short timescale of star formation
- Estimates consistent for 4C 41.17 (Steinbring et al. 2014)



Conclusions

- SEDs reveal (at least) 3 components: 1 starburst, 1 evolved population and 1 AGN
- PEGASE.3 code confirms 1 massive component formed at high redshift in a short timescale
- HzRGs are significantly growing between $1<z<4$,
  starburst: dense media, >10% total mass of the system
- Triggering mechanism is not clear, ALMA will provide crucial information on the location of submm emission

EXTRA-SLIDE

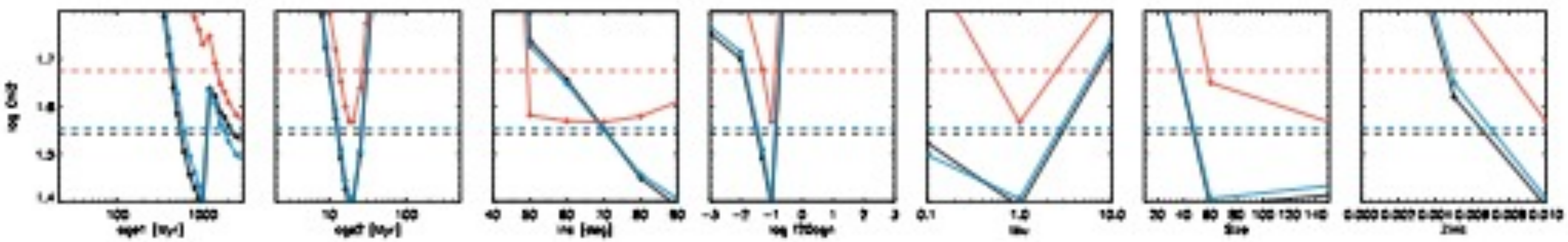


Fig. A.16. Parameter space for MRC0324 for the elliptical E template. The colour code is the same than Fig. A.13.

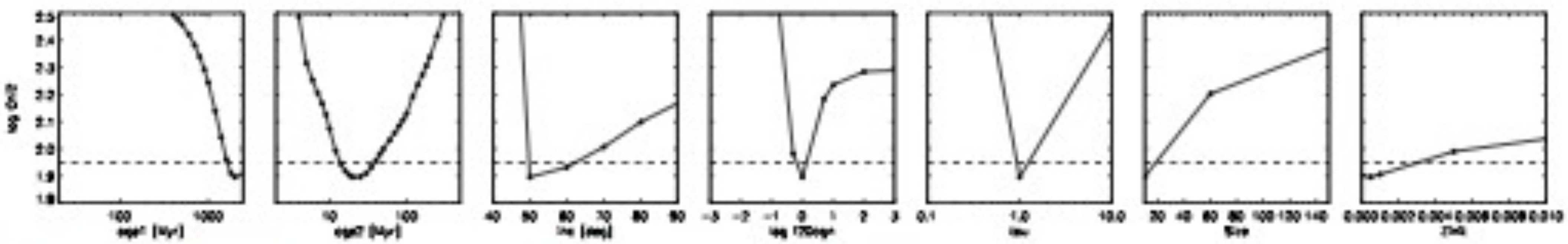


Fig. A.17. Parameter space for PKS1138 for the elliptical E template. The colour code is the same than Fig. A.13.

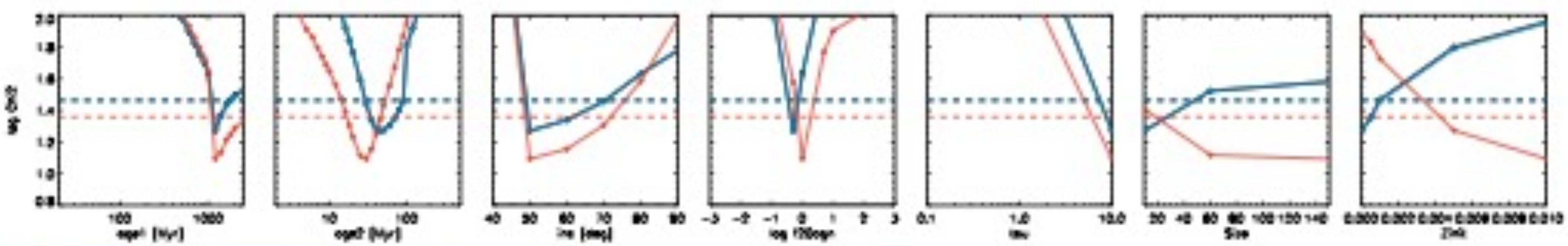
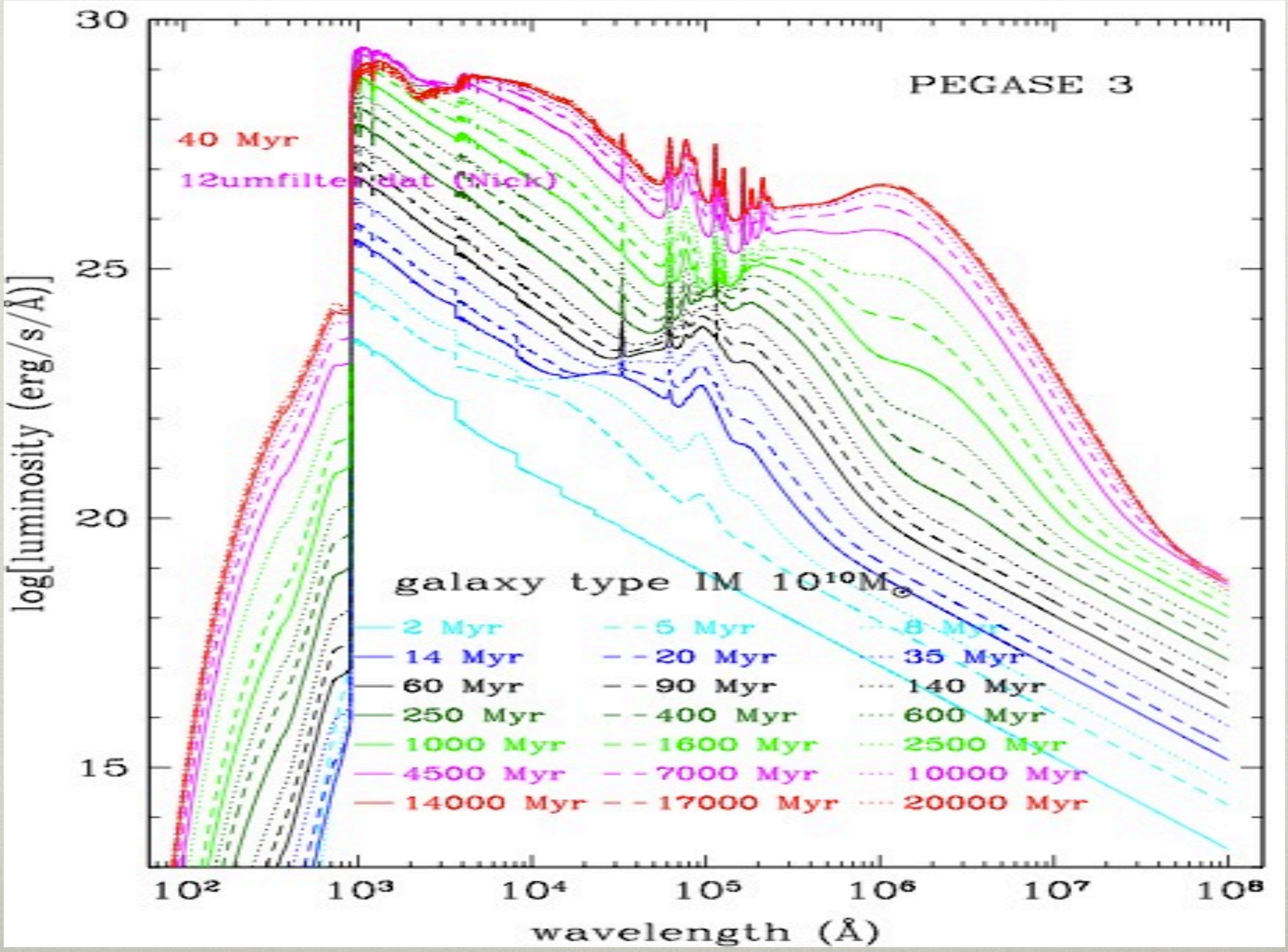
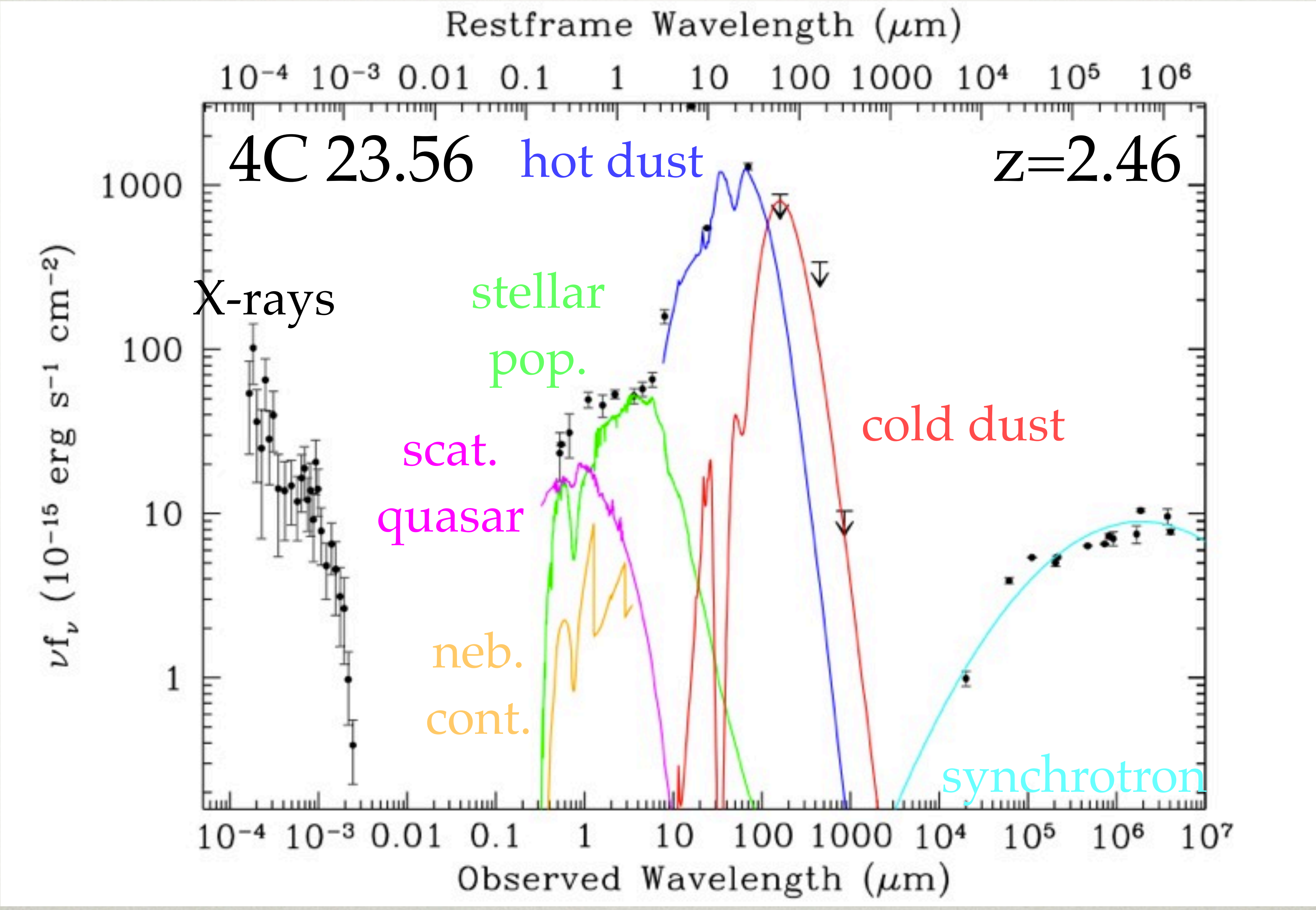


Fig. A.18. Parameter space for MRC0406 for the elliptical E template. The colour code is the same than Fig. A.13.


PEGASE 3
40 Myr
12umfilter.dat (Nick)
log[luminosity (erg/s/Å)]
wavelength (Å)
galaxy type IM $10^{10} M_\odot$
2 Myr
5 Myr
8 Myr
14 Myr
20 Myr
35 Myr
60 Myr
90 Myr
140 Myr
250 Myr
400 Myr
600 Myr
1000 Myr
1600 Myr
2500 Myr
4500 Myr
7000 Myr
10000 Myr
14000 Myr
17000 Myr
20000 Myr

SED of a HzRG



Miley G. & De Breuck C., 2008

How are the progenitors our massive local ellipticals formed?