

*The Spitzer view
of stellar populations
in Early Type galaxies*

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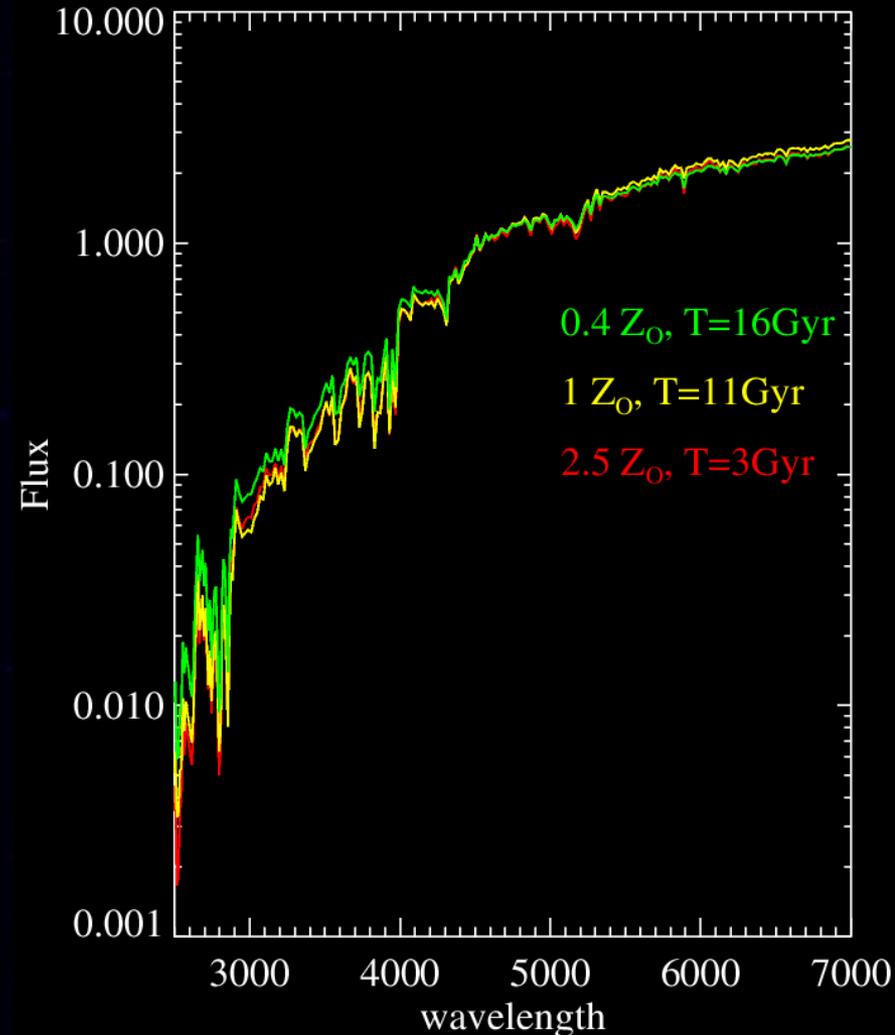
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Scientific prologue

- One of the most relevant topics in galaxy formation is the reconstruction of the history of baryon assembly in the early universe
- In recent decades, the high- z universe has become observable (HST, SCUBA...)
- Local Early Type galaxies are the fossil evidence of the star formation history of the early universe
- The *archeological* study of local Early Type galaxies offers the advantage of higher quality data than that from high- z studies. Local Early Type galaxies also offer hints on re-processing and secular evolution

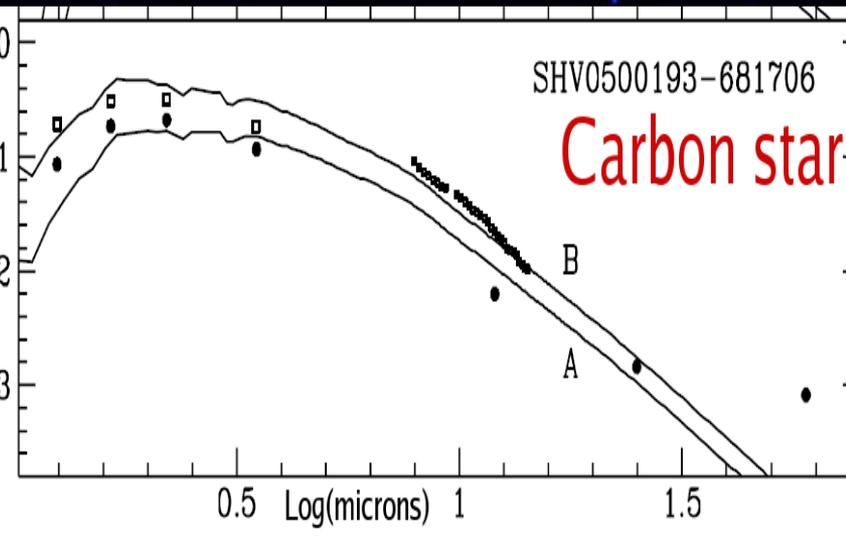
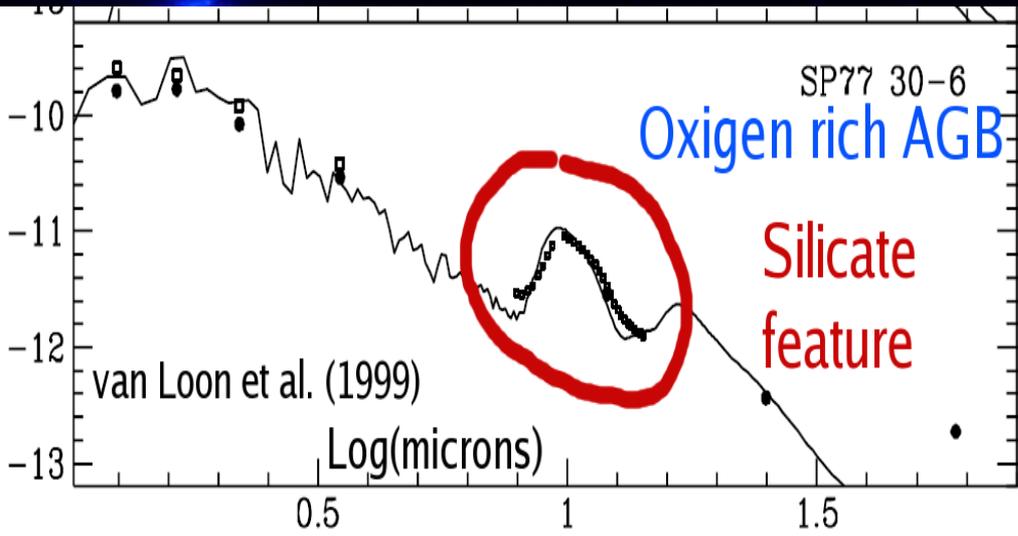
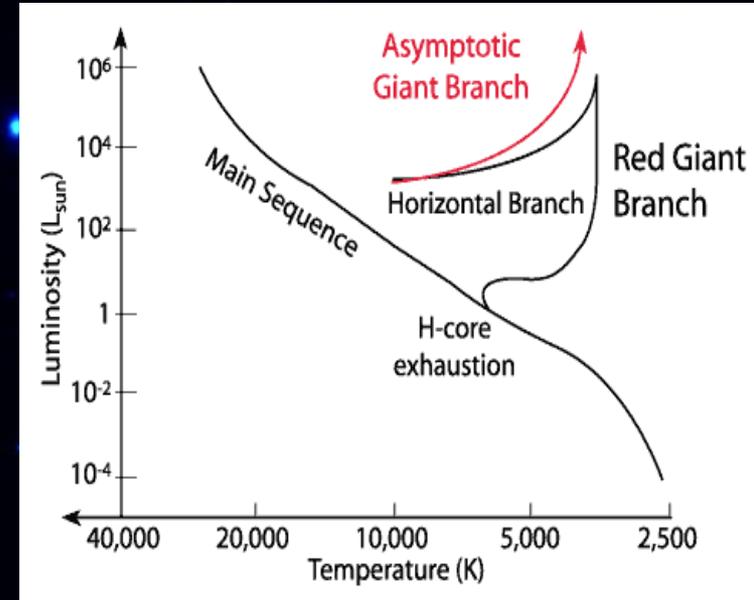
Age / Metallicity degeneracy

- The study of the star formation history in early type galaxies is affected by the well known Age / Metallicity degeneracy:
- In the optical region, the spectra of **old & metal poor populations** resemble those of **young & metal rich populations**
- Spectral indices can help but are affected by $[\alpha/\text{Fe}]$, ionized gas and reprocessing



AGB stars and SSPs in MIR

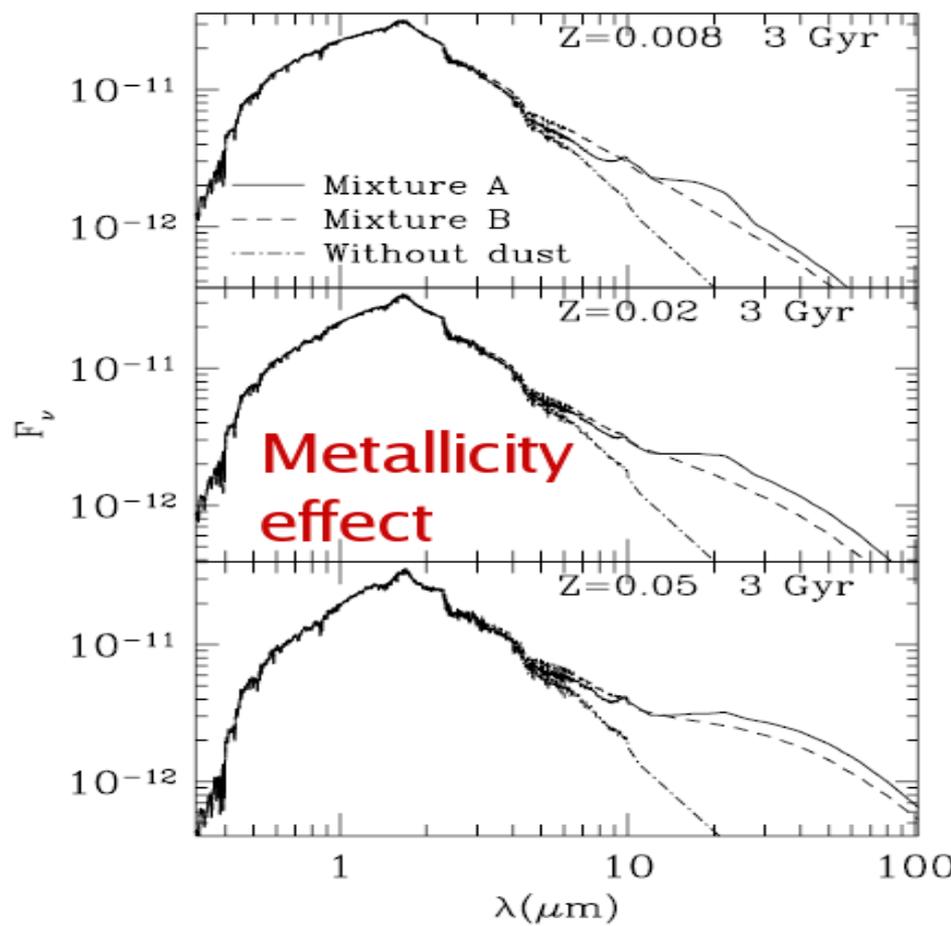
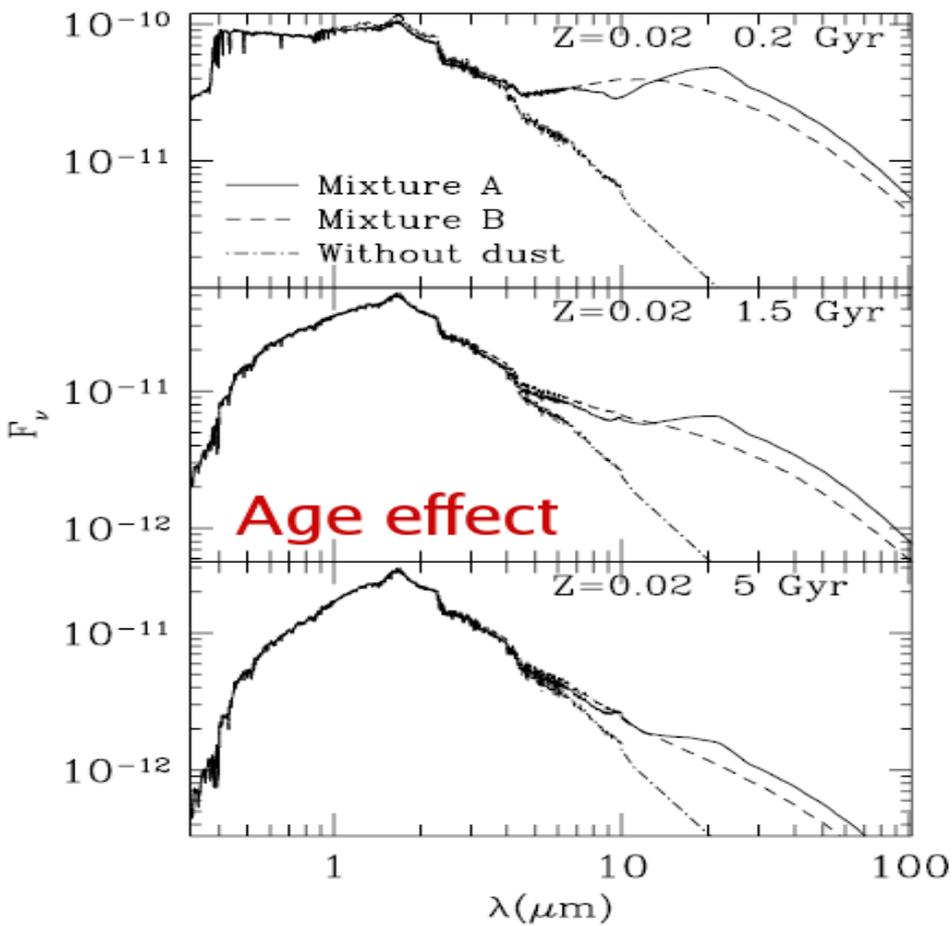
- AGB stars are luminous evolved stars with dusty envelopes
- Bressan, Granato & Silva (1998) suggested that circumstellar dust of **oxygen rich AGBs** leave a signature at **10 μ m** in **SSP spectra**



SSP in the MIR

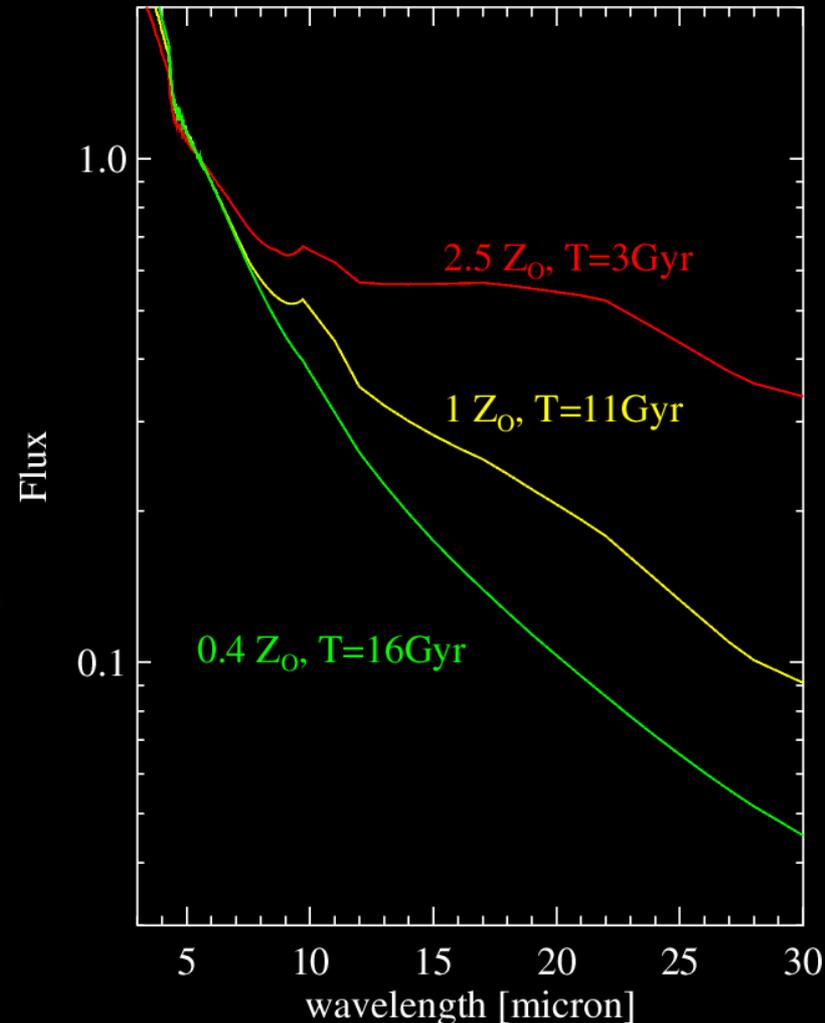
- Bressan, Granato & Silva (1998) computed SSP spectra including AGBs envelopes

- The AGB contribution **increases with metallicity** & **decreases with age**



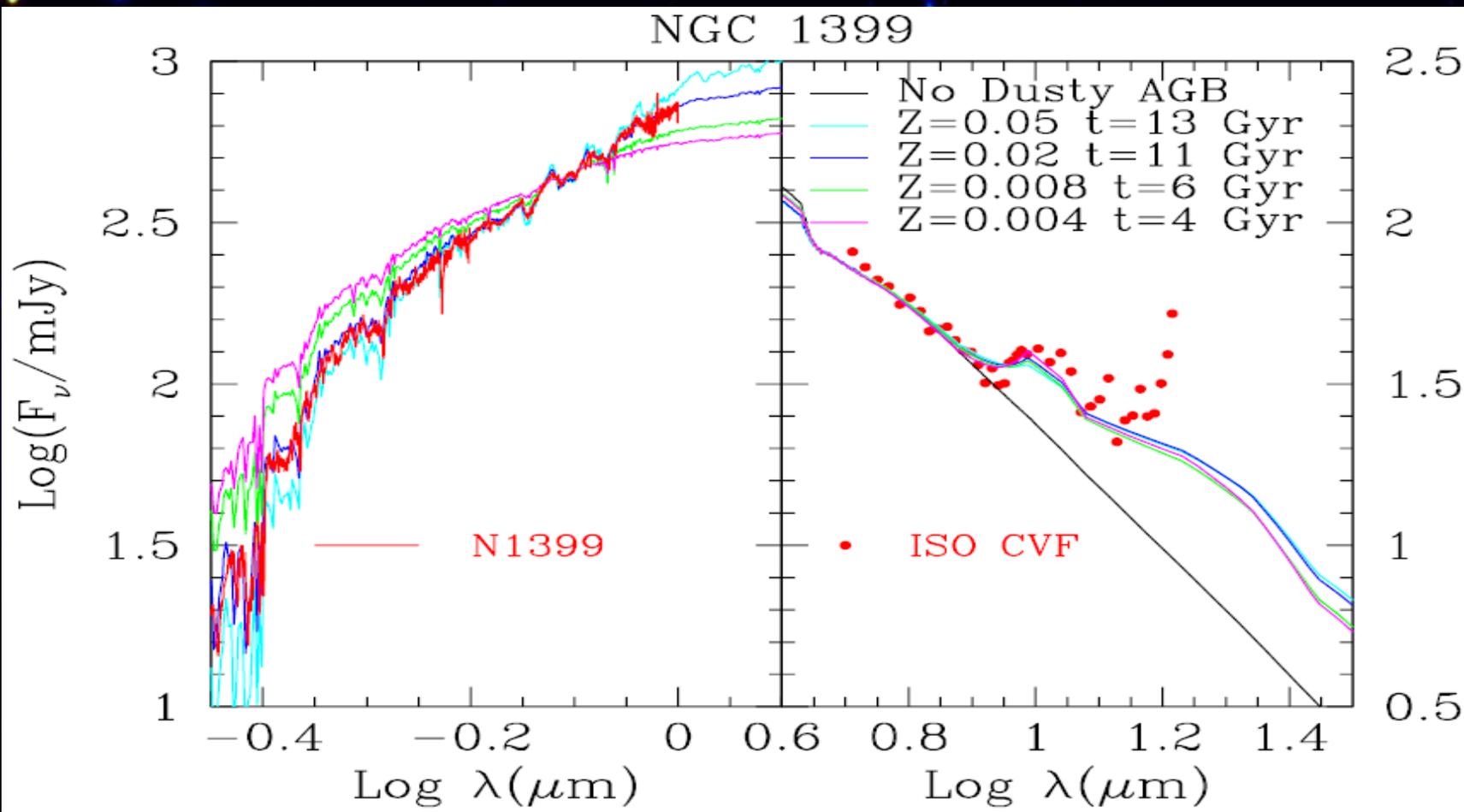
Breaking the degeneracy using the mid IR

- Age and metallicity have the **same effect** in the optical region
- Age and metallicity have **opposit effect** in the mid infrared region
- **Combining optical and MIR removes the degeneracy**
- Note that the MIR alone still suffers from degeneracy

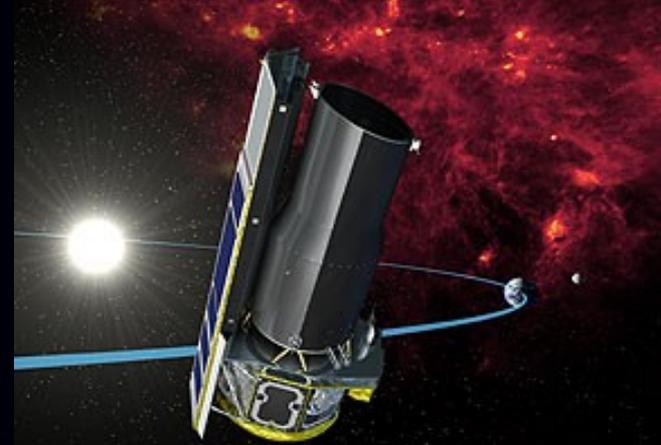


ISO results

- First application was with ISO CVS spectra (Bressan et al. 2001, ApSSS, 277, 251)
- Sensitivity and resolution prevented a definitive answer



What about *Spitzer*?



- **Spitzer** is a NASA infrared space telescope launched in August 2003
- Spitzer has an 85cm mirror and 3 instruments:
 - **IRAC**: a four-channel imaging camera (**3.6, 4.5, 5.8, and 8 μ m**), 5.2' x 5.2' FOV
 - **IRS**: a spectrometer with high ($R \sim 600$) and low ($R \sim 60-120$) resolution modules in the range **5-38 μ m** and imaging (peakup) at **16 and 23 μ m**
 - **MIPS**: imaging and photometry in broad bands at **24, 70, and 160 μ m** and low-resolution spectroscopy between 55 and 95 μ m.
- Background Image: Coma cluster seen by Spitzer [**3.6 μ m**, **8.0 μ m**, **24 μ m**]

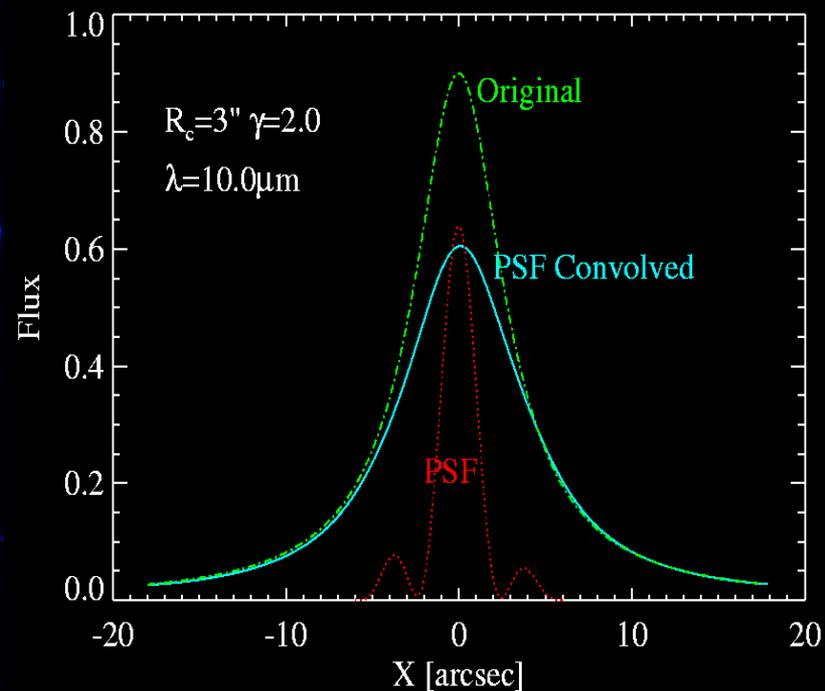
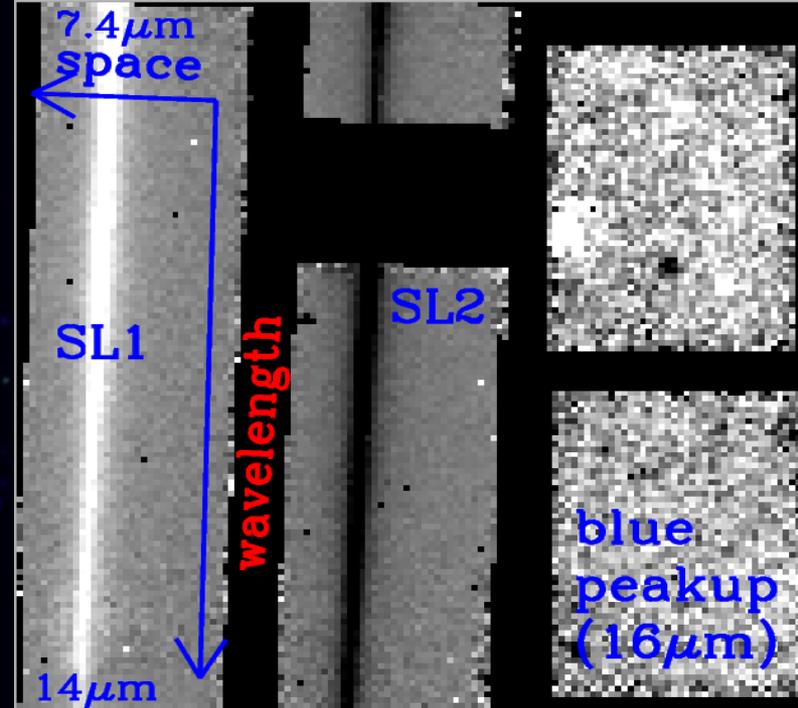


Spitzer & optical observations

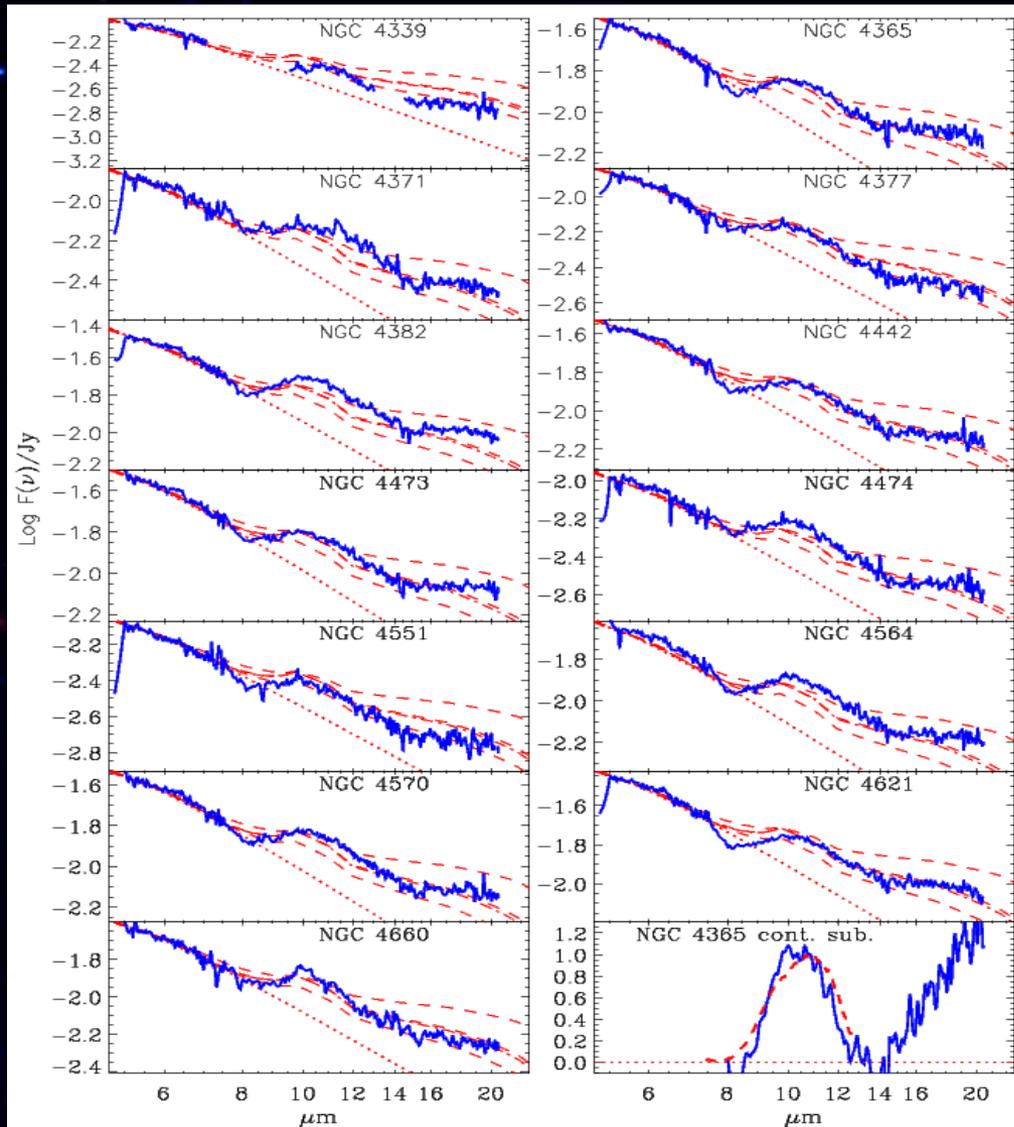
- We have started a project that systematically studies **early type galaxies in the MIR, optical and NIR**
- **Cycle 1: An IRS spectroscopic (5-21 μ m) campaign of Virgo bright early type galaxies (23 hours, 17 galaxies)**
 - see Bressan et al. 2006, ApJL, 639, 55 for data and Panuzzo et al. 2007, ApJ, in press, astro-ph/0610316
- **Cycle 2: An IRS peakup (16 μ m) & IRAC imaging (4.5 & 8 μ m) campaign of Virgo faint and Coma early type galaxies (49 hours, 91 galaxies)** completed
 - data reduction in progress
- **Cycle 3: An IRS spectroscopic (5-38 μ m) campaign of field early type galaxies (48 hours, 18 galaxies)**, ongoing
- Optical & NIR spectroscopic follow-up is ongoing

Data Reduction of IRS spectra

- A proper flux calibration was provided only for point sources, **not for extended sources**
 - the PSF is larger than the slit
 - the wavelength range makes the PSF change considerably along the spectrum
- We simulated the PSF smearing on a 2D King profile and the slit selection
- This allows us to **reconstruct the intrinsic SED emitted within the slit**



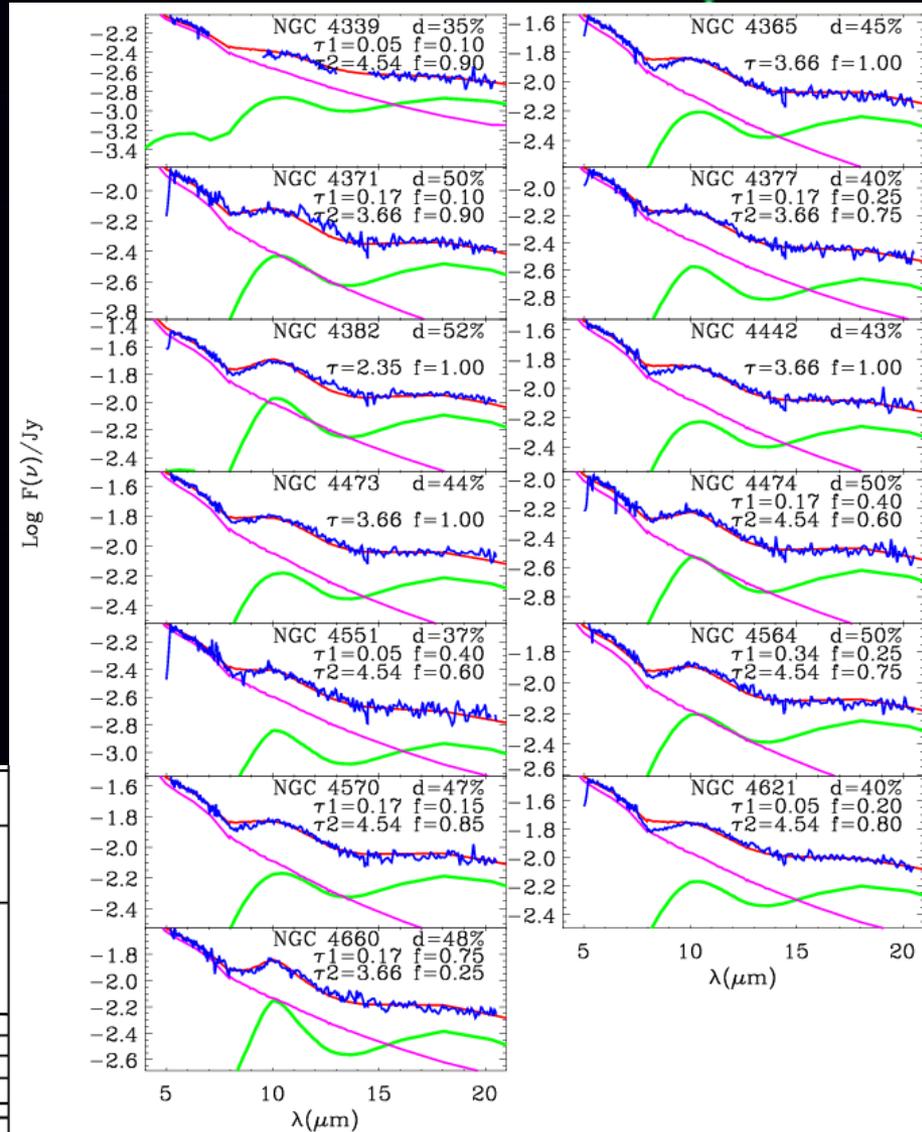
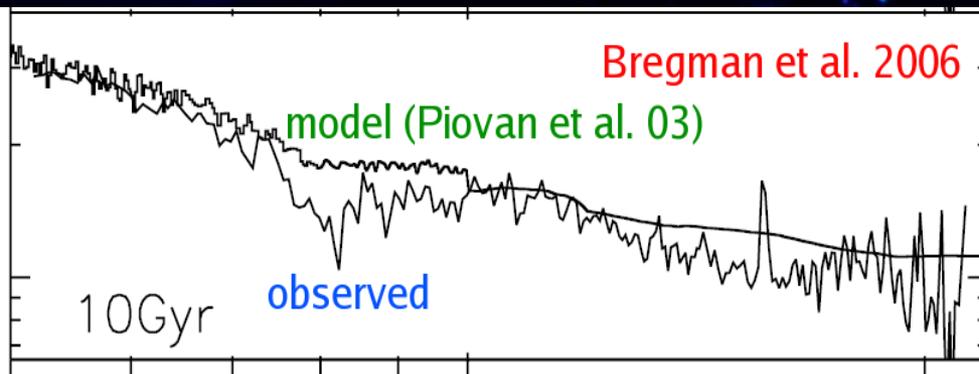
First Spitzer IRS results: *passive* spectra



- Most (13/17) of the galaxies show **passive spectra** (i.e. **no lines, no PAHs**) and **clear 10 μ m emission**.
- The emission is spatially extended (from spatial profiles of spectra)
- It is circumstellar dust
- The **10 μ m emission** feature is very similar to observed AGB outflows (Molster et al. 2000) and to Bressan et al. (1998) SSP models

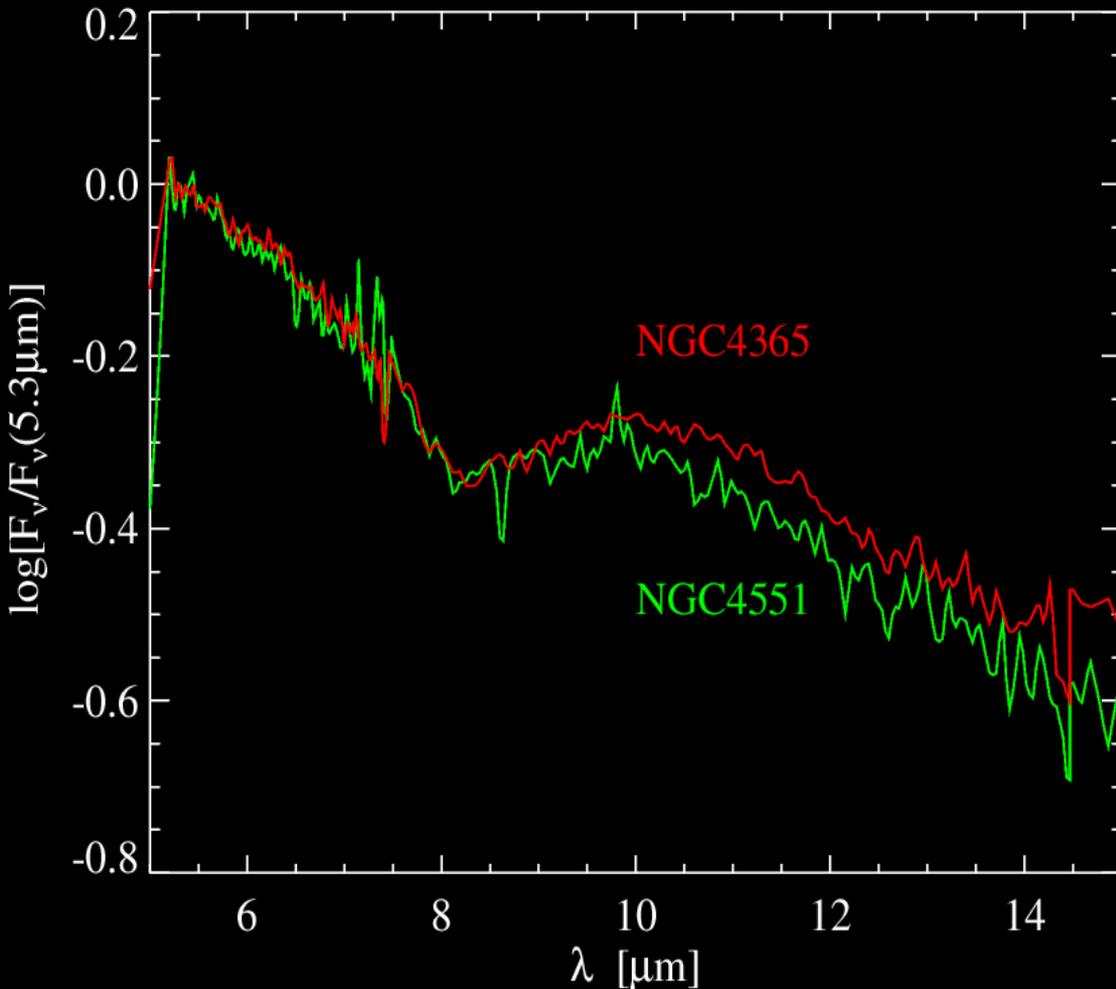
Emission feature analysis

- The emission is well fitted with **optically thick** oxygen-rich envelopes
- Bressan et al. (1998) SSP models predict smaller optical thickness
 - the AGB phase is complex and needs a proper modelling
 - work in progress for new SSP models



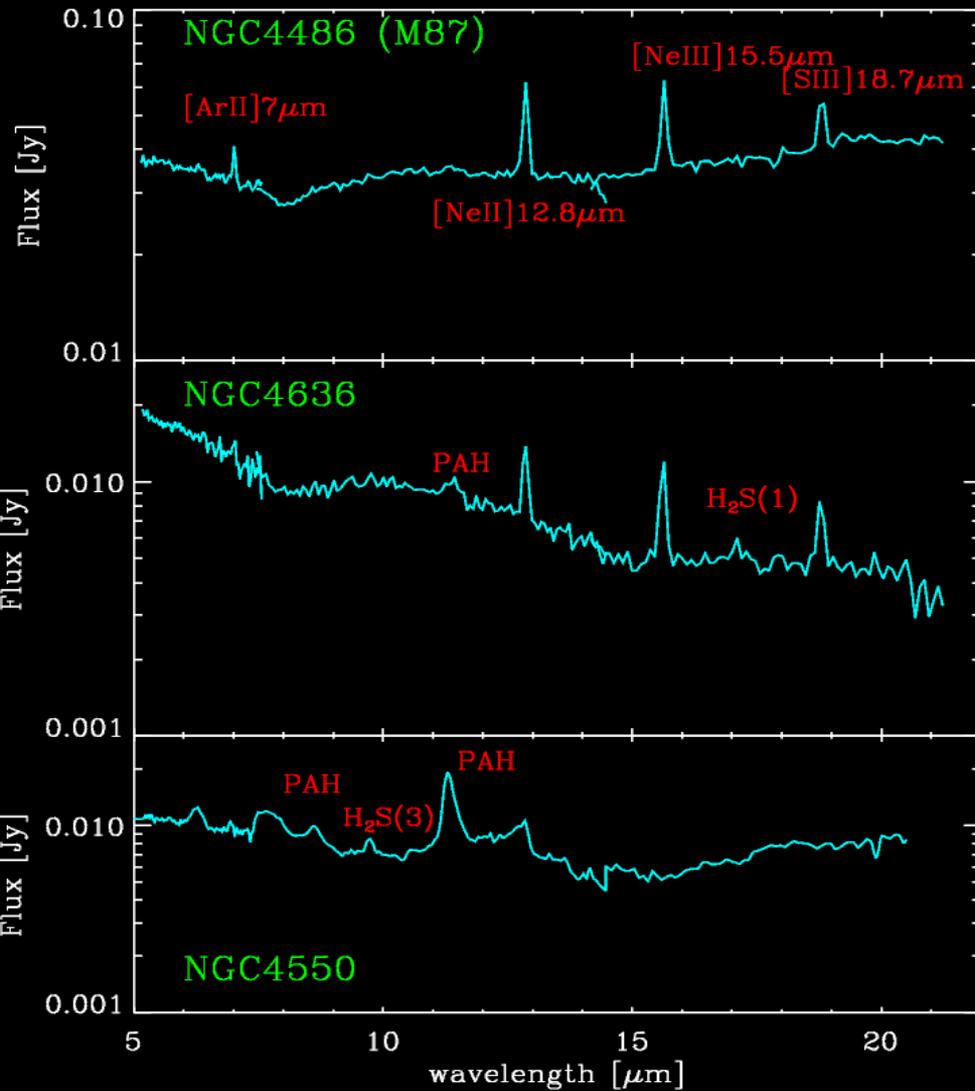
Preliminary comparison

- analysis of optical and NIR observations are in progress

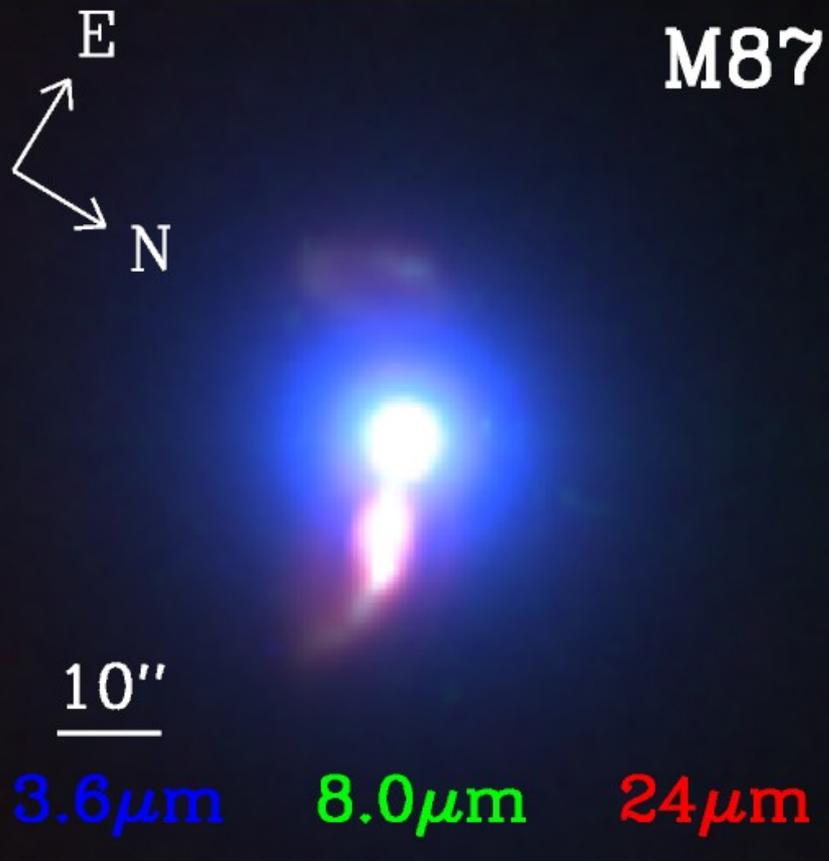


- Yamada et al. 2006 spectroscopic study indicates that NGC 4451 is significantly younger & more metal rich than NGC 4365
- This would imply a larger AGB feature in NGC 4551 than in NGC 4365
- The **opposite** is seen in our spectra

First Spitzer IRS results: *active galaxies*

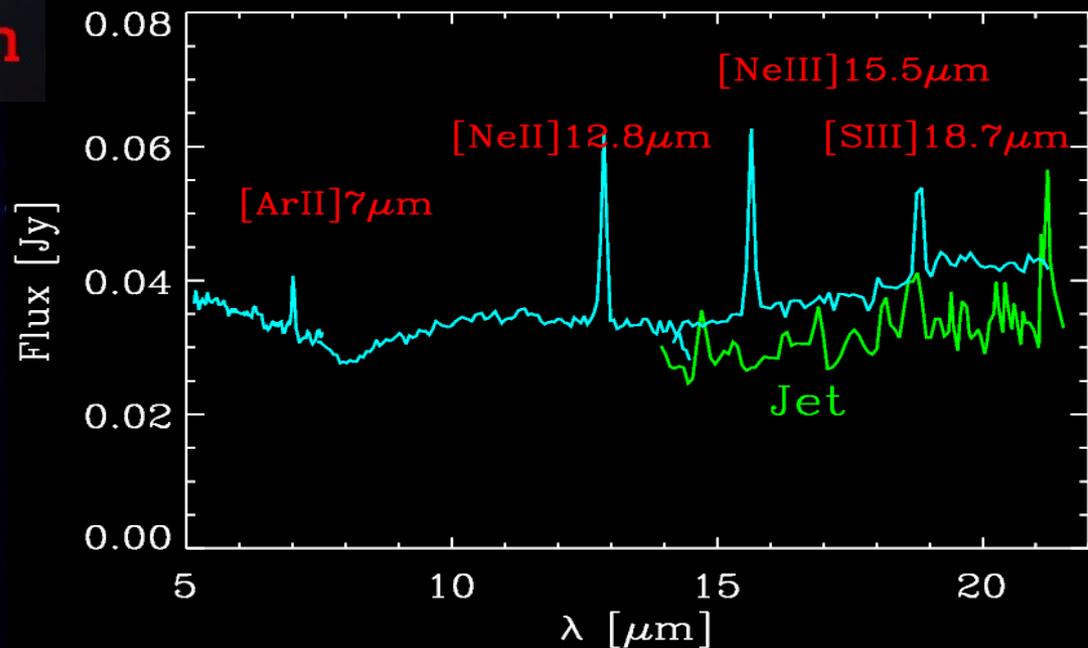


- Some galaxies (4/17) show “activity”
- 2 with line emission ([ArII], [NeII], [NeIII], [SIII]):
 - M87, AGN
 - NGC4636, LINER
- 1 with PAH features & H₂ lines (NGC4550, optical LINER)
- 1 Star forming: NGC4435



M87

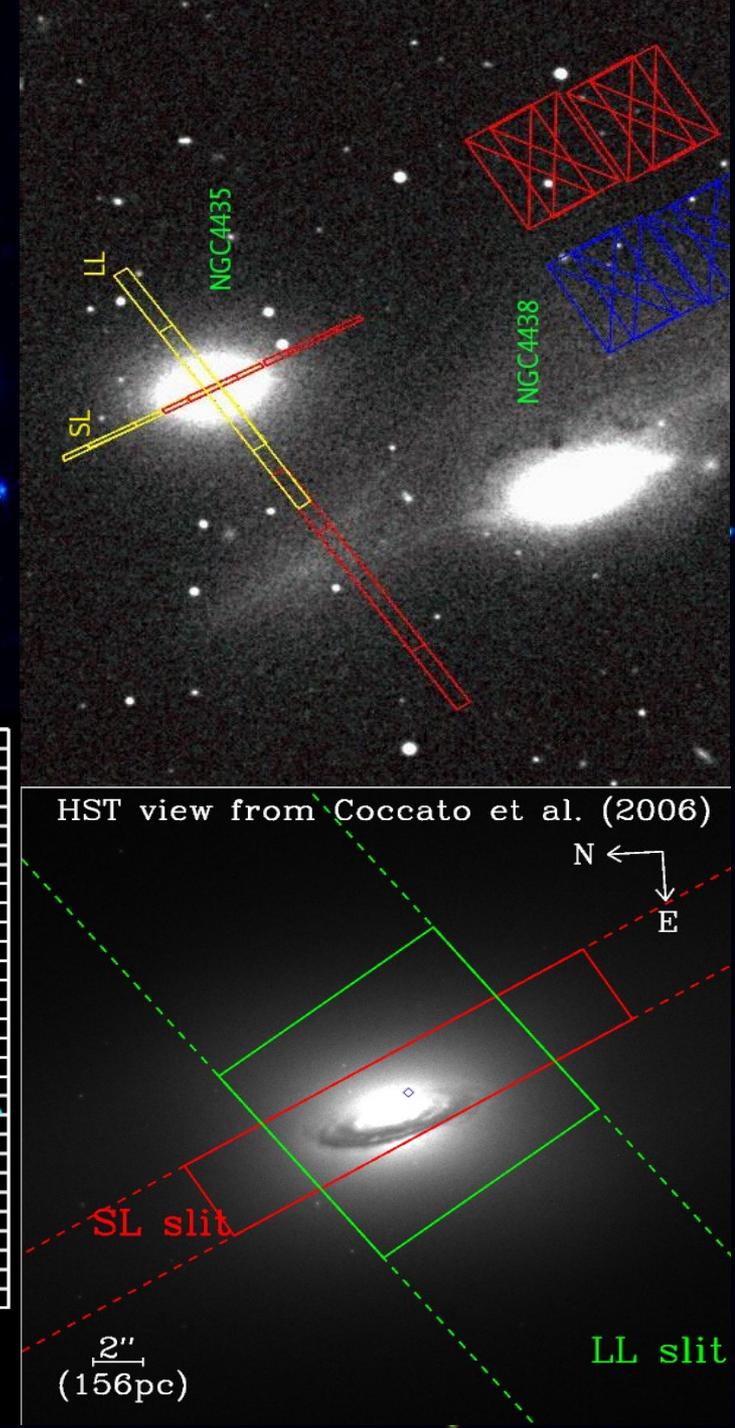
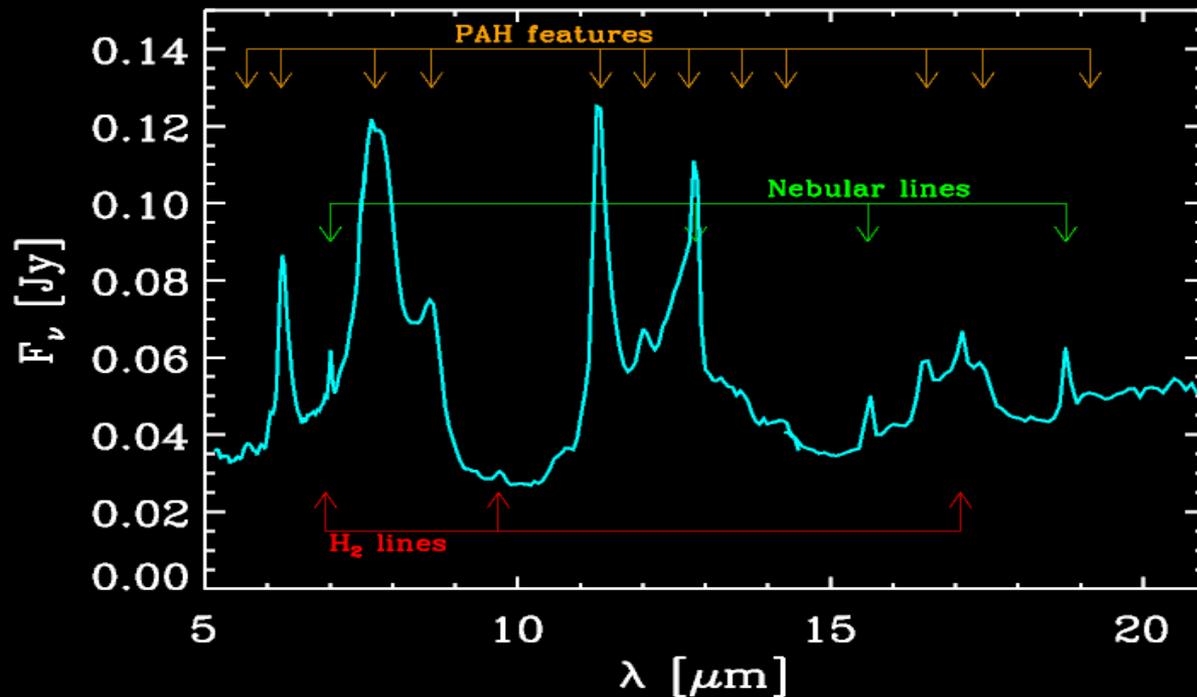
- work is in progress to study M87 SED
- The SED is given by two components:
 - an old SSP with AGB feature
 - an AGN component



- The nucleus shows emission lines, while the jet doesn't emit lines (maybe [SIII]?)

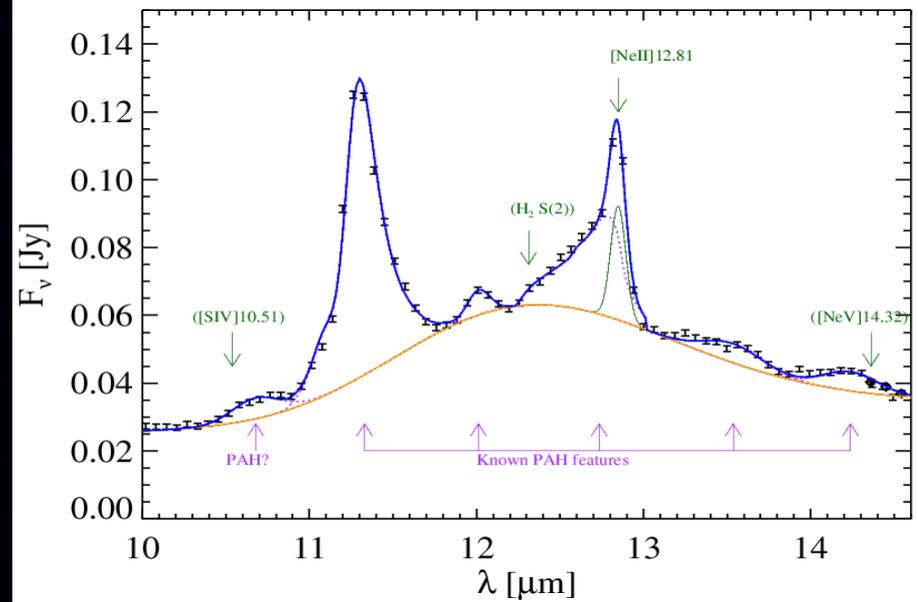
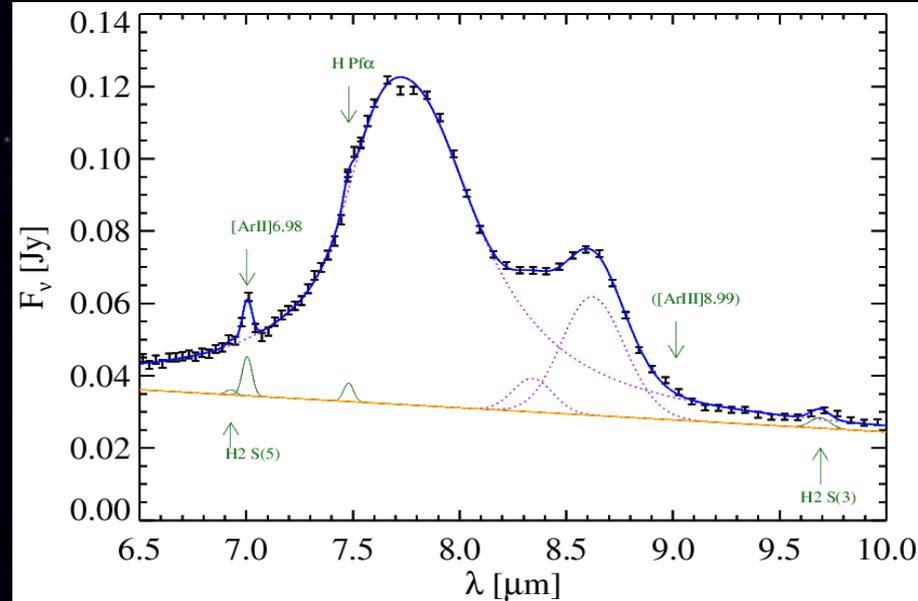
Star formation in NGC4435

- NGC4435 is an SB0(7) in interaction with NGC4438. It has a dusty circum-nuclear disk
- The MIR spectrum is typical of a star forming object



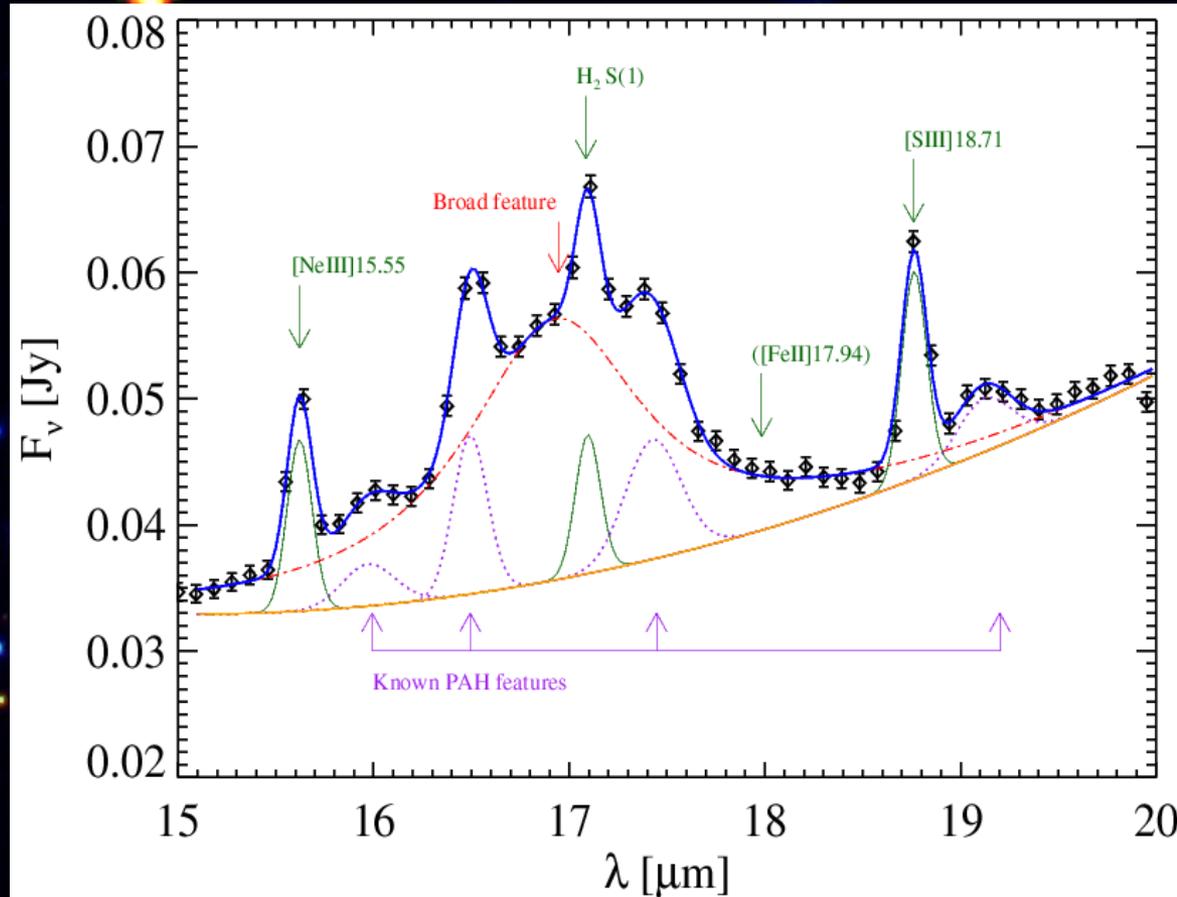
NGC4435 MIR SED analysis

- Results reported in Panuzzo et al. 2007, ApJ, accepted (astro-ph/0610316)
- We have analysed the spectrum by decomposing it in components (continuum, PAHs, emission lines)
- No high ionization line (e.g. [NeV], [SIV]) was detected
- [NeIII]/[NeII]=0.38 reveals that there is no (>2%) AGN contribution to the ionizing flux



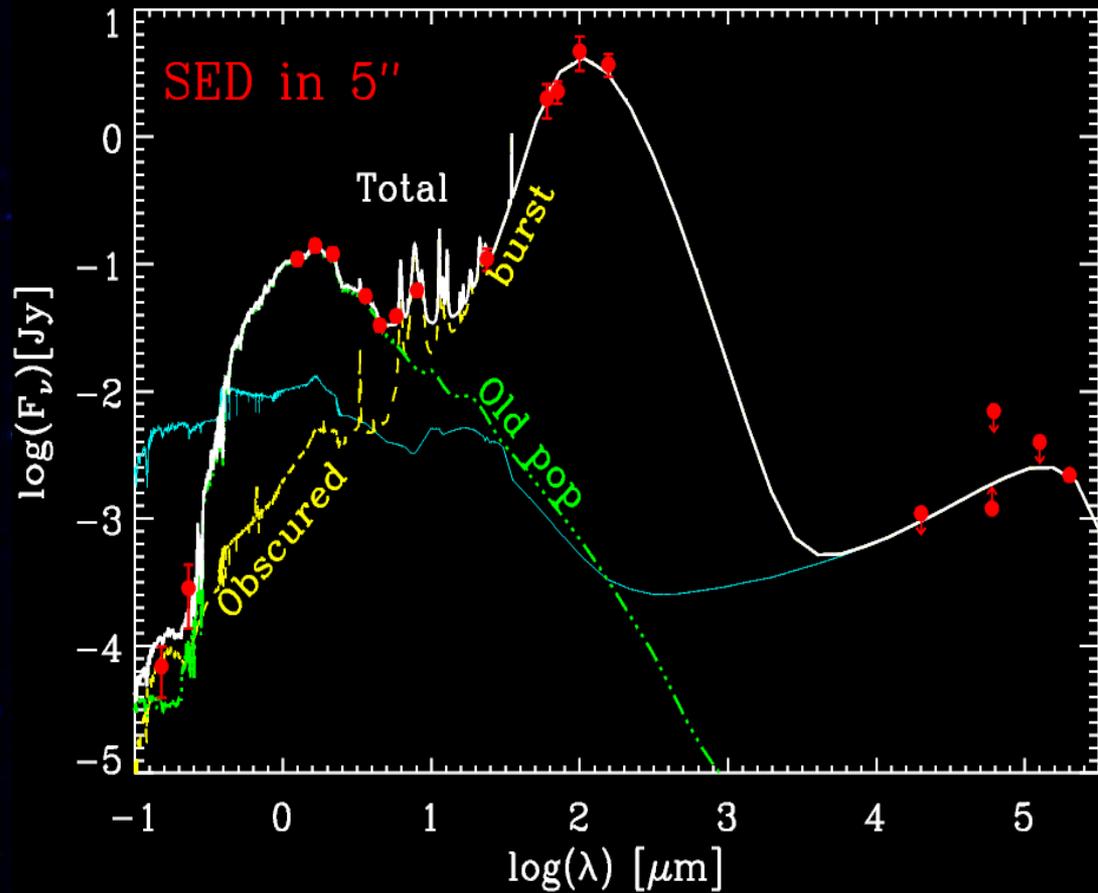
- Detected rotational H_2 lines show the presence “warm” (200K) and “hot” (630K) molecular gas in PDRs. The temperature is lower than in AGNs
- All typical PAH features observed, plus some uncommon: 10.7, 13.5, 14.2, 16.0 μm
- 17.4 μm & 19.1 μm features from C_{60} ?

- The low dust continuum allows us to clearly see the structure of the 17 μm system, and the presence of a broad (FWHM $\sim 1 \mu\text{m}$) emission feature (confirmed by Smith et al. 2007)



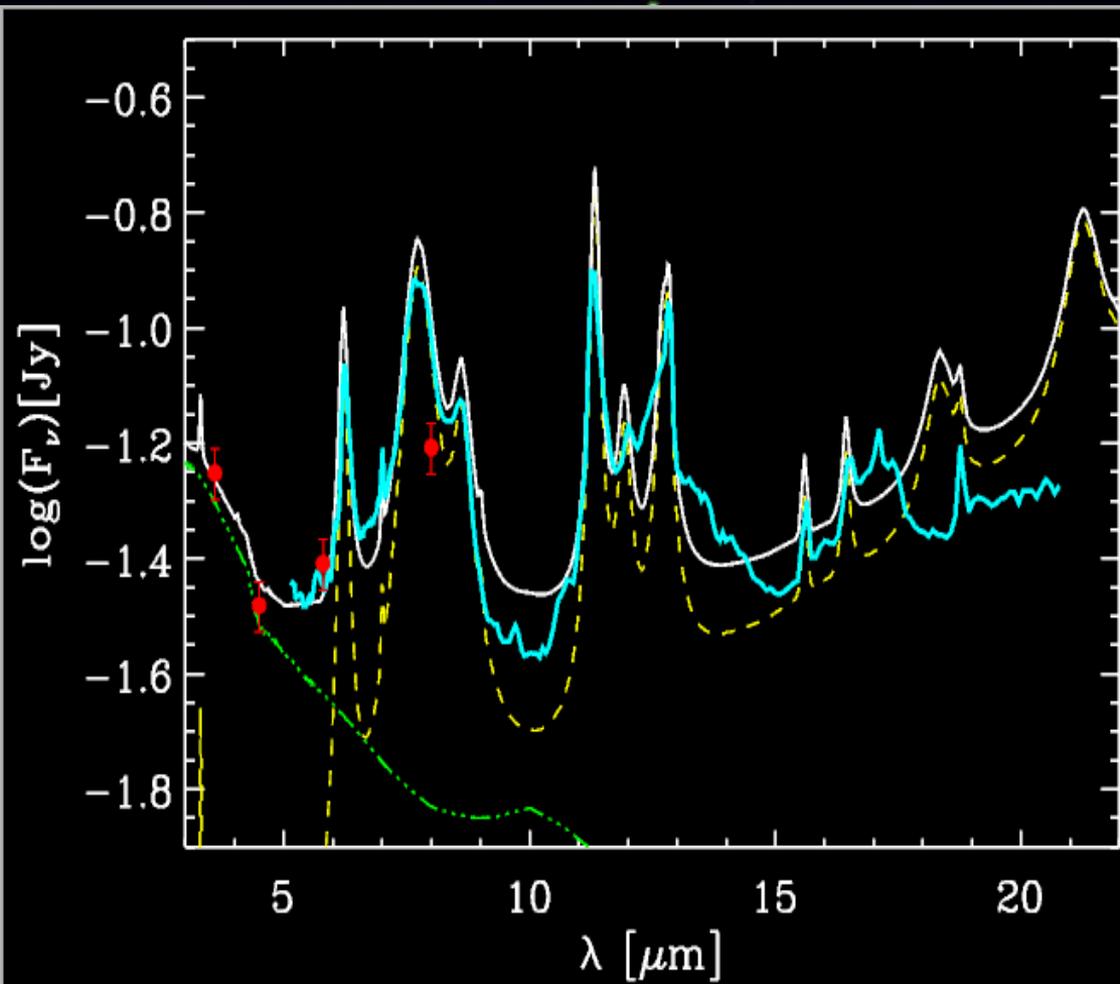
NGC4435 SED vs models

- We used our spectro-photometric model for dusty galaxies GRASIL (Silva et al. 98, Bressan et al. 02, Panuzzo et al. 03, Vega et al. 05...) to fit the global SED
- The model suggests an **ageing starburst** started ~ 186 Myr ago and an e-folding time of 55 Myr with $\text{SFR} \sim 0.09 M_{\odot}/\text{yr}$
- The epoch of SF onset precedes the epoch of perigalactic passage
- SF is triggered by the interaction
- The mass of the burst is 0.3% of total mass



MIR SED

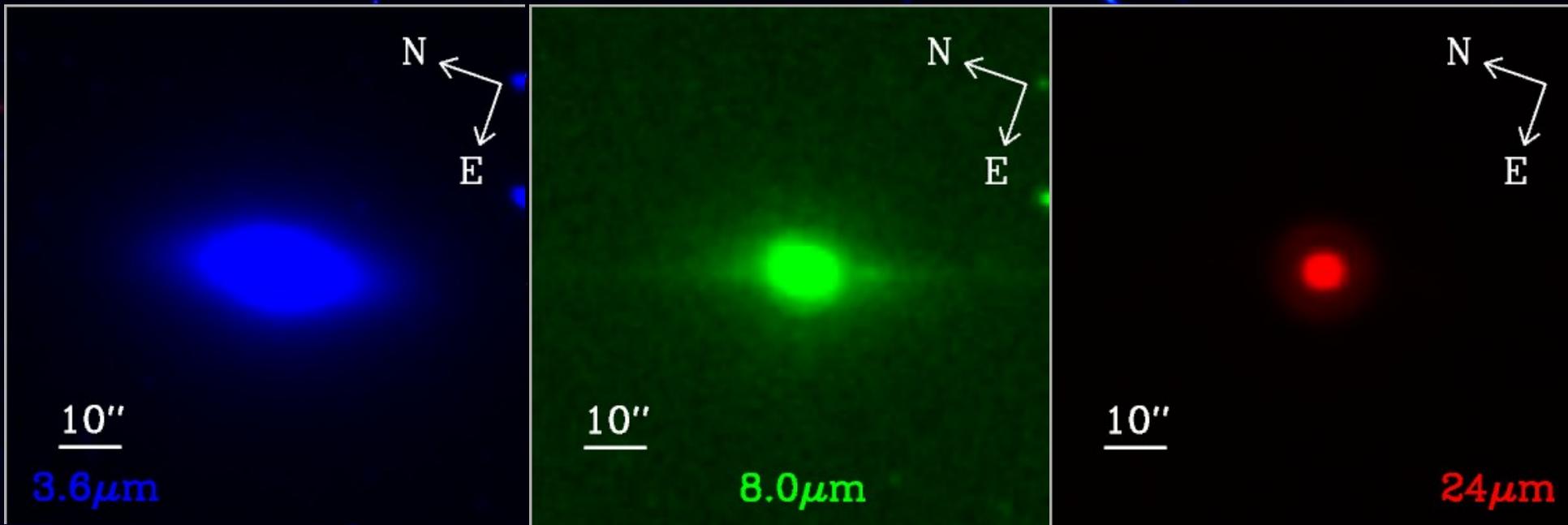
- The continuum & PAH features are well fitted for $\lambda < 13\mu\text{m}$
- Our PAH model is based on Li & Draine 01 (Vega et al. 05)



- **Spitzer (and ISO) observations are showing that the knowledge of PAHs is still inadequate, especially for $\lambda > 13\mu\text{m}$** (Smith et al 04, Peeters et al 04)
- We plan to use NGC4435 data to improve the model of PAH emission
- See Smith et al. 2007 for an atlas of PAH

further results NGC4435

- Observed X-ray consistent with only SFR
- SED and emission line fit suggest ~ solar metallicity
- The decomposition of NGC4435 in a burst + a old population can be clearly seen looking at IRAC and MIPS images



GO2: Imaging of faint ETGs

- Only bright early-type galaxies can be observed with Spitzer IRS spectroscopy
- To extend the brightness range we proposed imaging observation with IRAC and IRS peakup
 - 4.5 μm to measure the photospheric
 - 8 μm to check for PAH and star formation
 - 16 μm to measure the AGB feature
- Include Coma cluster
- Data analysis is ongoing

NGC4621

blue peakup (16 μm)

10''



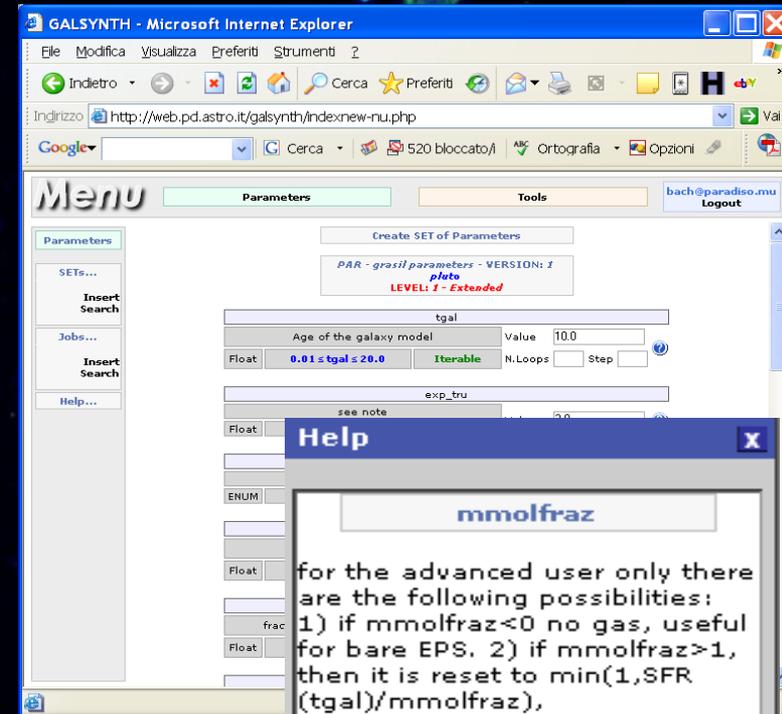
G03: Field early type galaxies

- We selected a sample of early type galaxies in low density environments
 - We have high quality optical data all the targets
- Recent optical studies (e.g. Annibali et al. 2006) suggest that field ETGs are younger than ETGs in clusters.
 - Consequence of accretion/merging episodes?
- They should show a more prominent AGB emission than cluster galaxies
- A higher fraction should show “activity”
 - Spitzer is perfect in spotting also tiny SF activity
- Observations are in progress
 - Stay tuned!

GALSYNTH: a friendly WEB interface to run GRASIL

<http://web.oapd.inaf.it/galsynth>

- Anyone can register and be a user
- Users have their workspaces
- Interactive editing of parameters, with explanations and bound checking, including iterations
- Sets of parameters can be saved, modified, reused.
- Batch jobs are executed on a pool of our computers for free!
- When job completed, user is notified and downloads models



GALSYNTH - Microsoft Internet Explorer

File Modifica Visualizza Preferiti Strumenti ?

Indietro Cerca Preferiti

Indirizzo <http://web.pd.astro.it/galsynth/indexnew-nu.php>

Google Cerca 520 bloccato/ ABC Ortografia Opzioni

Menu Parameters Tools bach@paradiso.mu Logout

Create SET of Parameters

PAR - grasil parameters - VERSION: 1
pluto
LEVEL: 1 - Extended

tgal

Age of the galaxy model Value 10.0

Float 0.01 ≤ tgal ≤ 20.0 Iterable N.Loops Step

exp_tru

see note

Float

ENUM

Float

frac

Float

Help

mmolfraz

for the advanced user only there are the following possibilities:
1) if mmolfraz < 0 no gas, useful for bare EPS. 2) if mmolfraz > 1, then it is reset to min(1, SFR (tgal)/mmolfraz), where SFR is in Msun/yr. This may be used to have mmolfraz proportional to SFR.

Conclusions

- We proposed a method to break the age-metallicity degeneracy of early type galaxies using Spitzer
 - three Spitzer proposals were approved for this project
- **The 10 μ m emission of evolved stars is well detected in Spitzer spectra, in agreement with models predictions**
 - Most of the galaxies do not show other features
- **Detailed comparison with models, with optical & NIR, for age and metallicity determinations is the next step**
 - new SSP models are needed
- The study was extended using Spitzer IRAC and IRS imaging to fainter galaxies in Virgo and Coma
 - data analysis is ongoing

Conclusions (2)

- **NGC4435** shows a star forming MIR spectrum. Model suggests a fading starburst with residual SFR
 - We didn't find any trace of AGN
- The estimated epoch of the SF onset ($\sim 180\text{Myr}$) suggests that the **SF was activated by the interaction before the ISM-ISM collision** ($\sim 100\text{Myr}$)
- NGC4435 is a typical example of rejuvenation episode due to an interaction
 - The mass involved in the burst is 0.3% of the total
- We were able to estimate the metallicity of NGC4435 using the model
- Data of cycle 3 will shed light on the role of the environment