The Spitzer view of stellar populations in Early Type galaxies

Speaker: Pasquale Panuzzo
INAF Padova

Team: A. Bressan, L. Buson, M. Clemens, R. Rampazzo, G. L. Granato (INAF PD), L. Silva (INAF TS), J. R. Valdes, O. Vega (INAOE), F. Annibali (STScI), W. W. Zeilinger (Univ. Wien), L. Danese (SISSA)
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 10µm 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.

![Graphs showing age and metallicity effects on SSP spectra](image-url)
Breaking the degeneracy using the mid IR

- Age and metallicity have the **same effect** in the optical region
- Age and metallicity have **opposite 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 8µm), 5.2' x 5.2' FOV
  - **IRS**: a spectrometer with high (R~600) and low (R~60-120) resolution modules in the range 5-38µm and imaging (peakup) at 16 and 23µm
  - **MIPS**: imaging and photometry in broad bands at 24, 70, and 160µm and low-resolution spectroscopy between 55 and 95µm.

- Background Image: Coma cluster seen by *Spitzer* [3.6µm, 8.0µm, 24µm]
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\(\mu\)m) campain of Virgo bright early type galaxies (23 hours, 17 galaxies)
- **Cycle 2:** An IRS peakup (16\(\mu\)m) & IRAC imaging (4.5 & 8\(\mu\)m) campain of Virgo faint and Coma early type galaxies (49 hours, 91 galaxies) completed
  - data reduction in progress
- **Cycle 3:** An IRS spectroscopic (5-38\(\mu\)m) campain 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 10µm emission**.
- The emission is spatially extended (from spatial profiles of spectra).
- It is circumstellar dust.
- The **10µm 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

---

Bregman et al. 2006 model (Piovan et al. 03)

10Gyr observed
Preliminary comparison

- Yamada et al. 2006 spectroscopic study indicates that NGC4451 is significantly younger & more metal rich than NGC4365.
- This would imply a larger AGB feature in NGC4551 than in NGC4365.
- The opposite is seen in our spectra.

Analyses of optical and NIR observations are in progress.
First Spitzer IRS results: active galaxies

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

- 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, 16.0µm.
• 17.4µm & 19.1µm features from C$_{60}$?

• The low dust continuum allows us to clearly see the structure of the 17µm system, and the presence of a broad (FWHM~1µm) 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 SFR~0.09M☉/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 $\lambda<13\mu m$
- 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 $\lambda>13\mu m$ (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\(\mu\)m to measure the photospheric
  - 8\(\mu\)m to check for PAH and star formation
  - 16\(\mu\)m to measure the AGB feature
- Include Coma cluster
- Data analysis is ongoing

NGC4621
blue peakup (16\(\mu\)m)
GO3: 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
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 10µm 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 found any trace of AGN
- The estimated epoch of the SF onset (~180Myr) suggests that the **SF was activated by the interaction before the ISM-ISM collision** (~100Myr)
- 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**