The star formation history of Early-type galaxies: a combined UV & MID Infrared View

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Why Early Type Galaxies ?

Local Early type galaxies (ETGs) contain more than 60% of the stellar mass in the Universe *(Baldry et al 04)*

The small scatter in the C-M relation of (cluster) ETGs and FP hints for an early epoch of formation (or a synchronized formation) *(Bower, Lucey & Ellis 92, Renzini & Ciotti 93)*

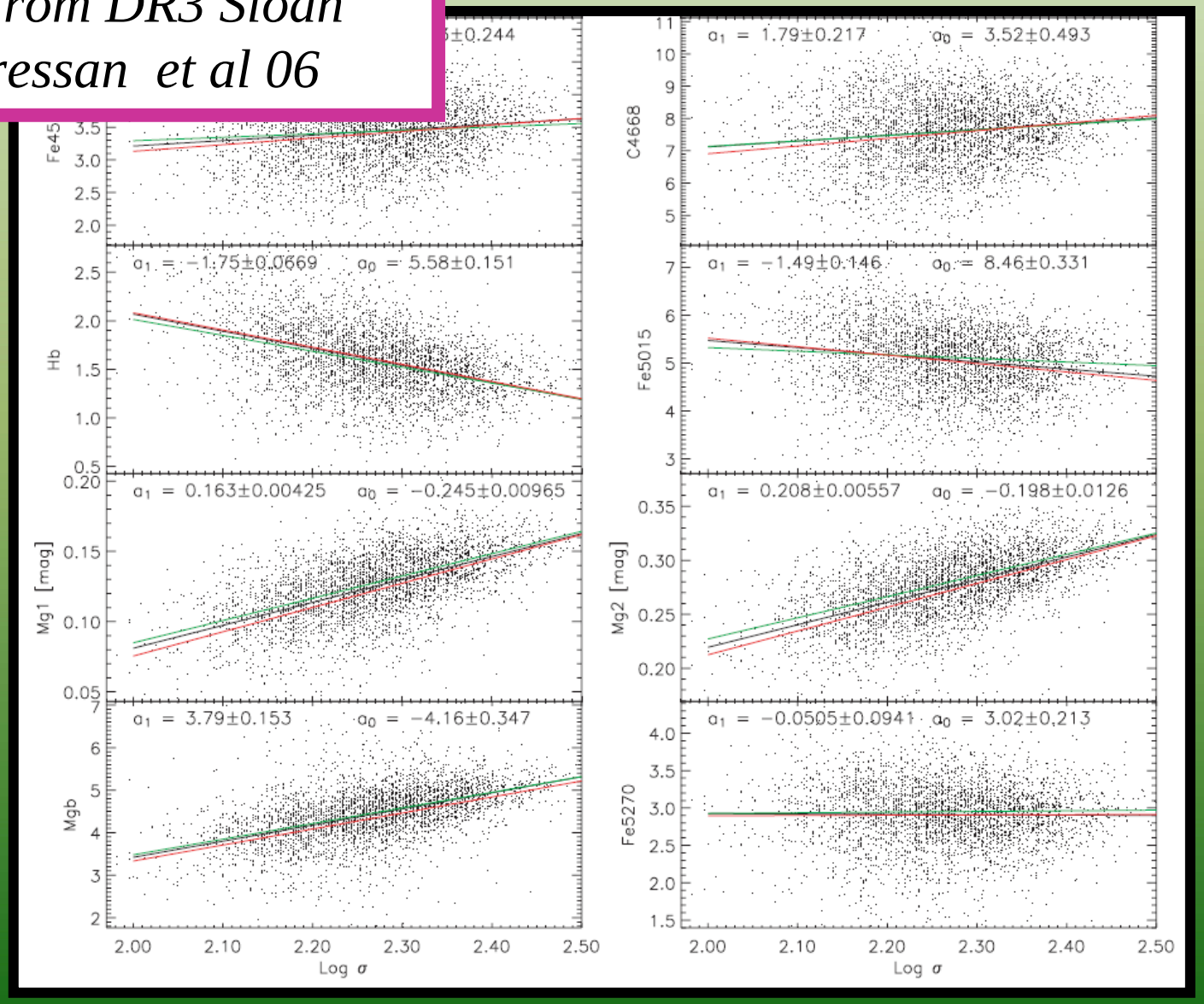
Ranking Stellar Populations in local ETGs probes the process of baryon assembly into stars in the (early ?) Universe

Evolution of ETGs in different environments:
different cluster regions, cluster vs. field ….
Thomas et al 05, Bernardi et al 06, Clemens et al 06,
Sanchez-Blazquez et al 06, Smith et al 06, Annibali et al 07

See review by Renzini 06

Narrow Band Indices

4000 ETGs from DR3 Sloan
Clemens, Bressan et al 06



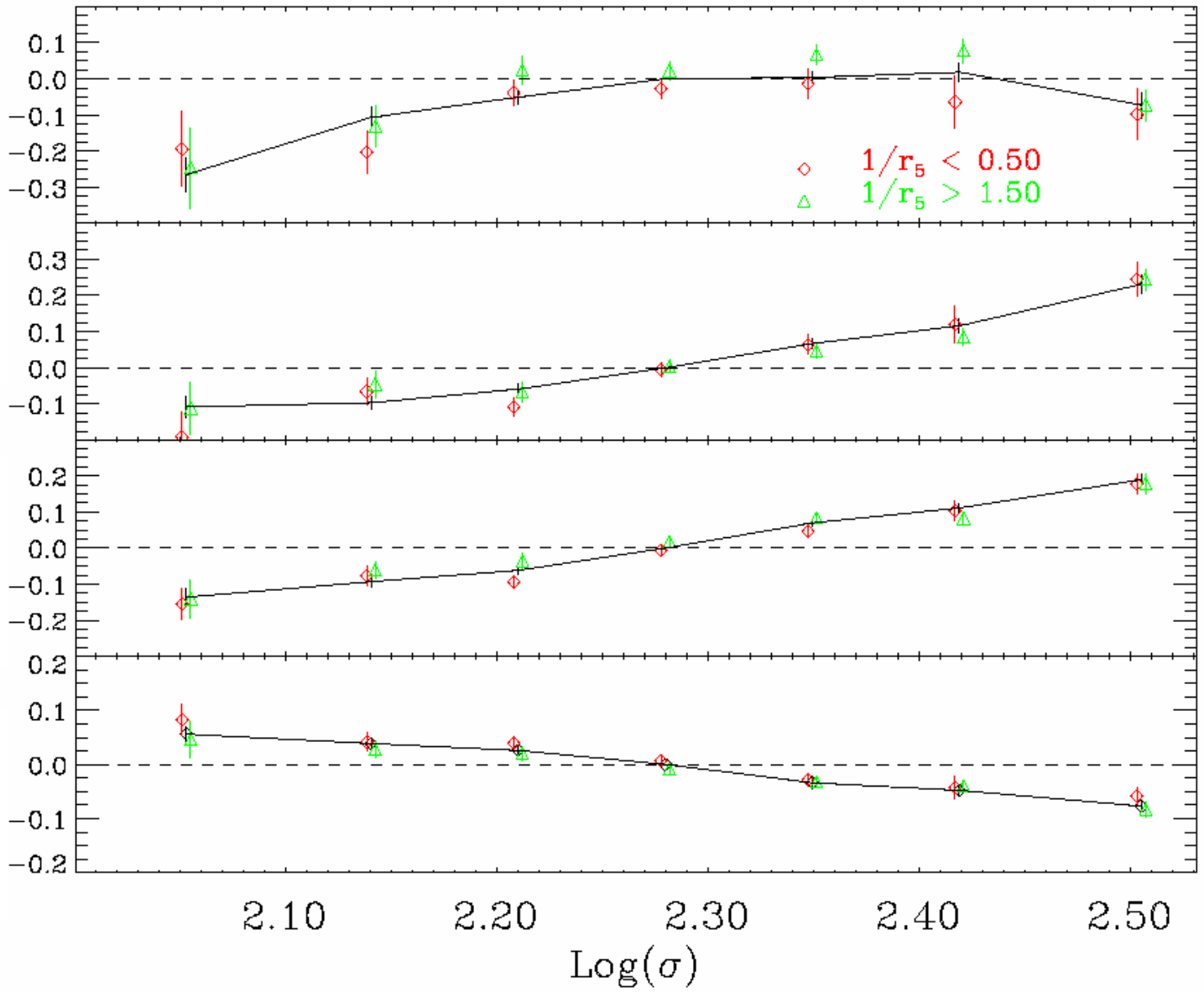
Results

δ Log Age

δ Log Z

δ Log [α/Fe]

δ Log [C/H]

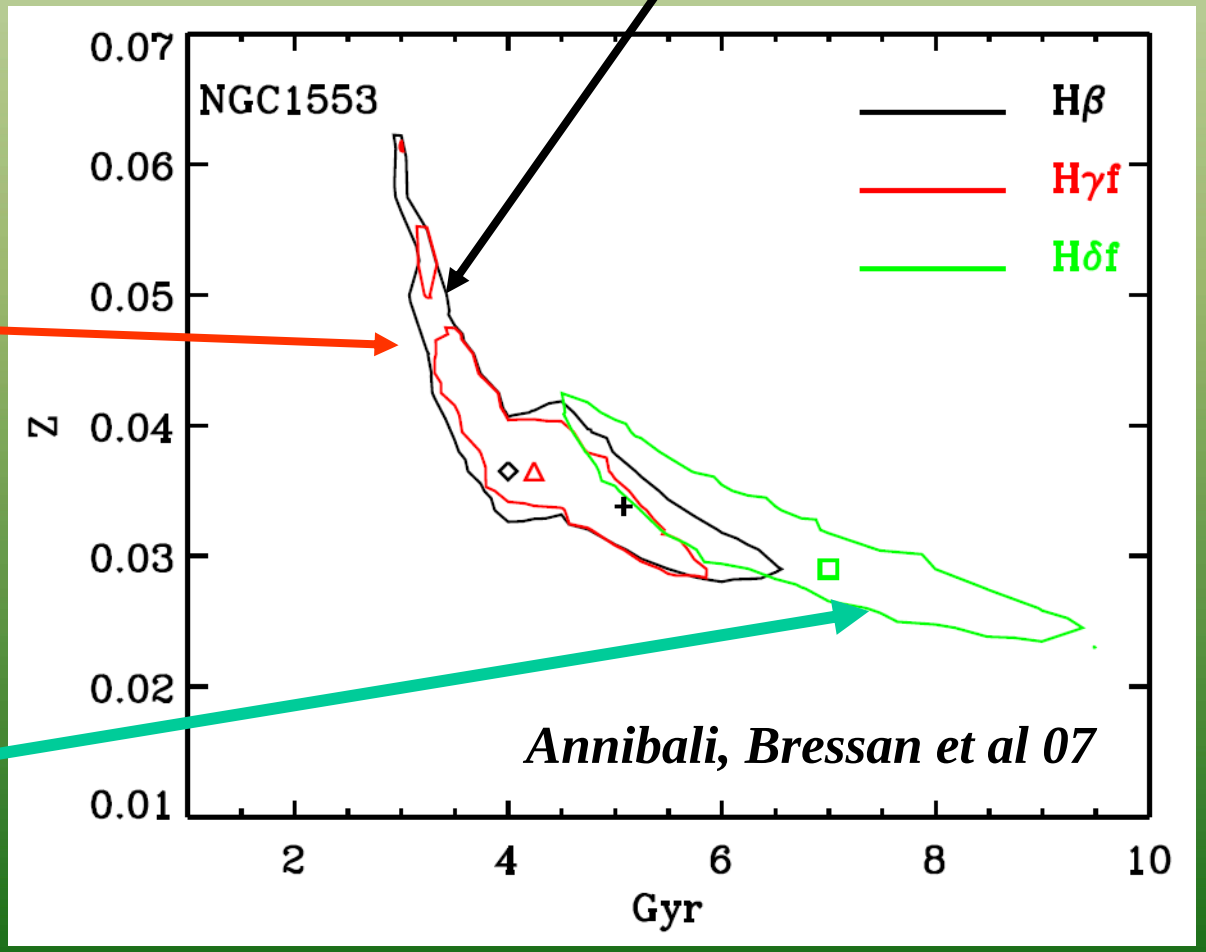


Effects of the Age-Metallicity degeneracy

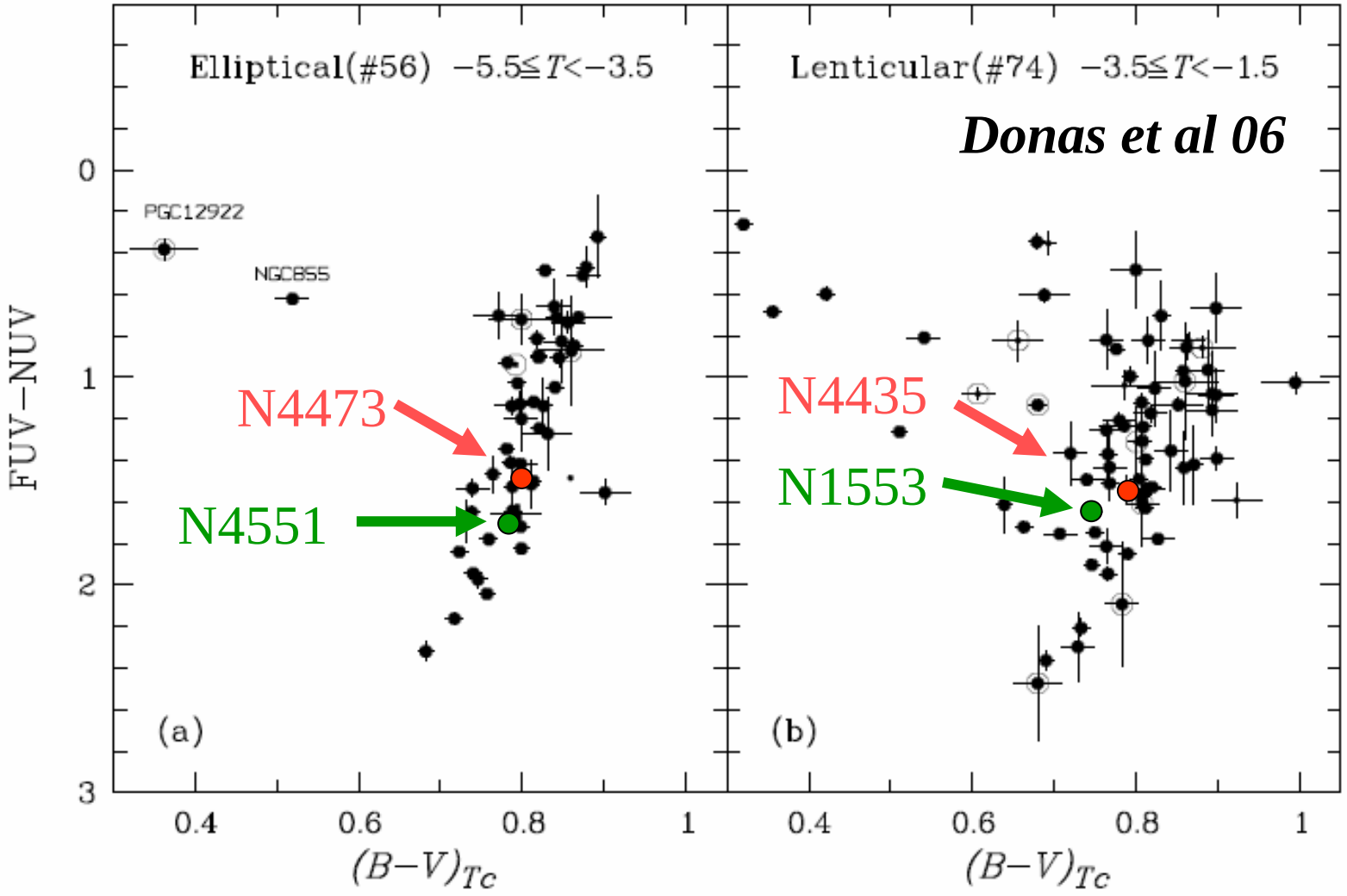
(Hβ, <Fe>, Mgb)

(Hγf, <Fe>, Mgb)

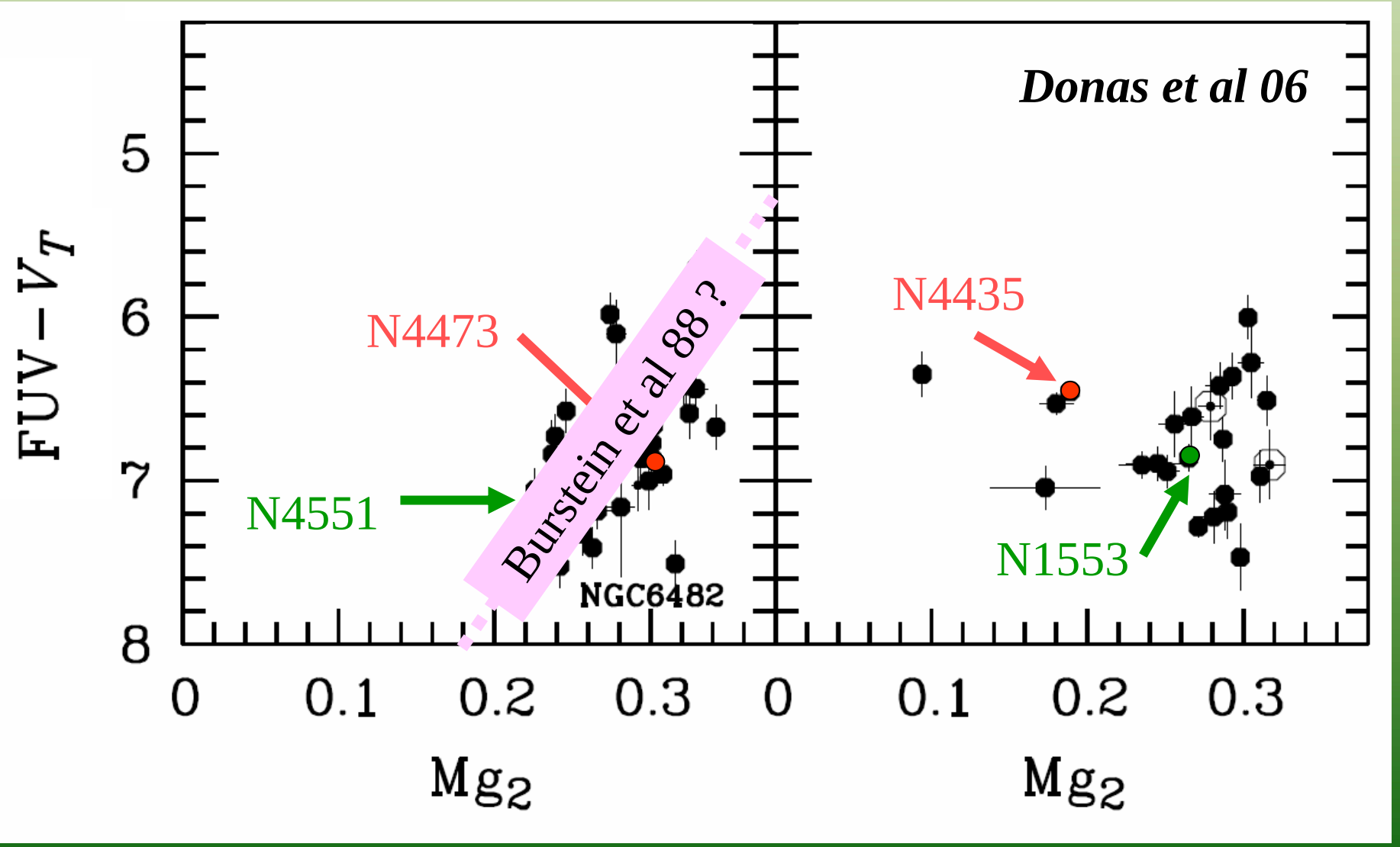
(Hδf, <Fe>, Mgb)



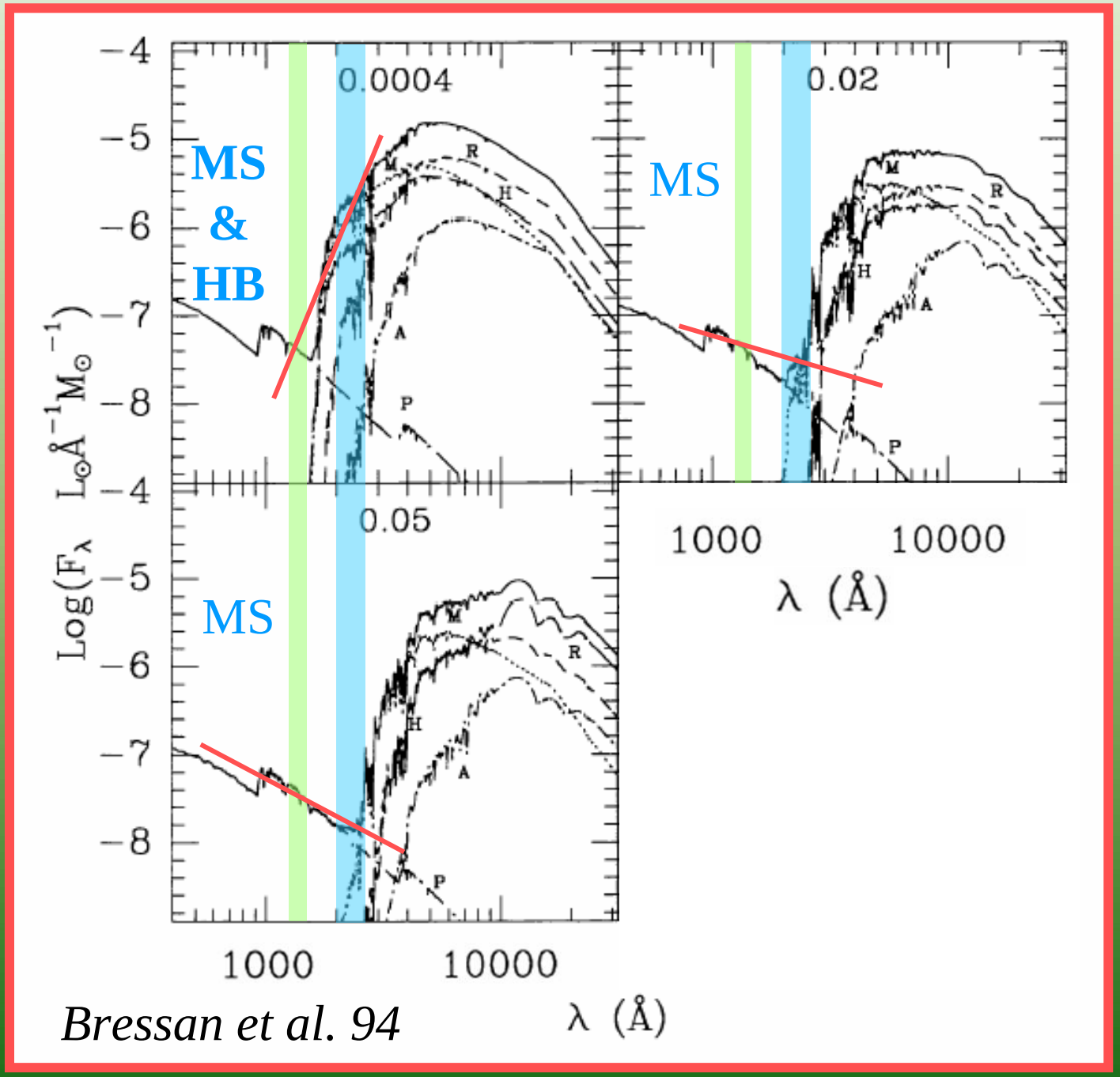
The UV view of ETGs: the Slope



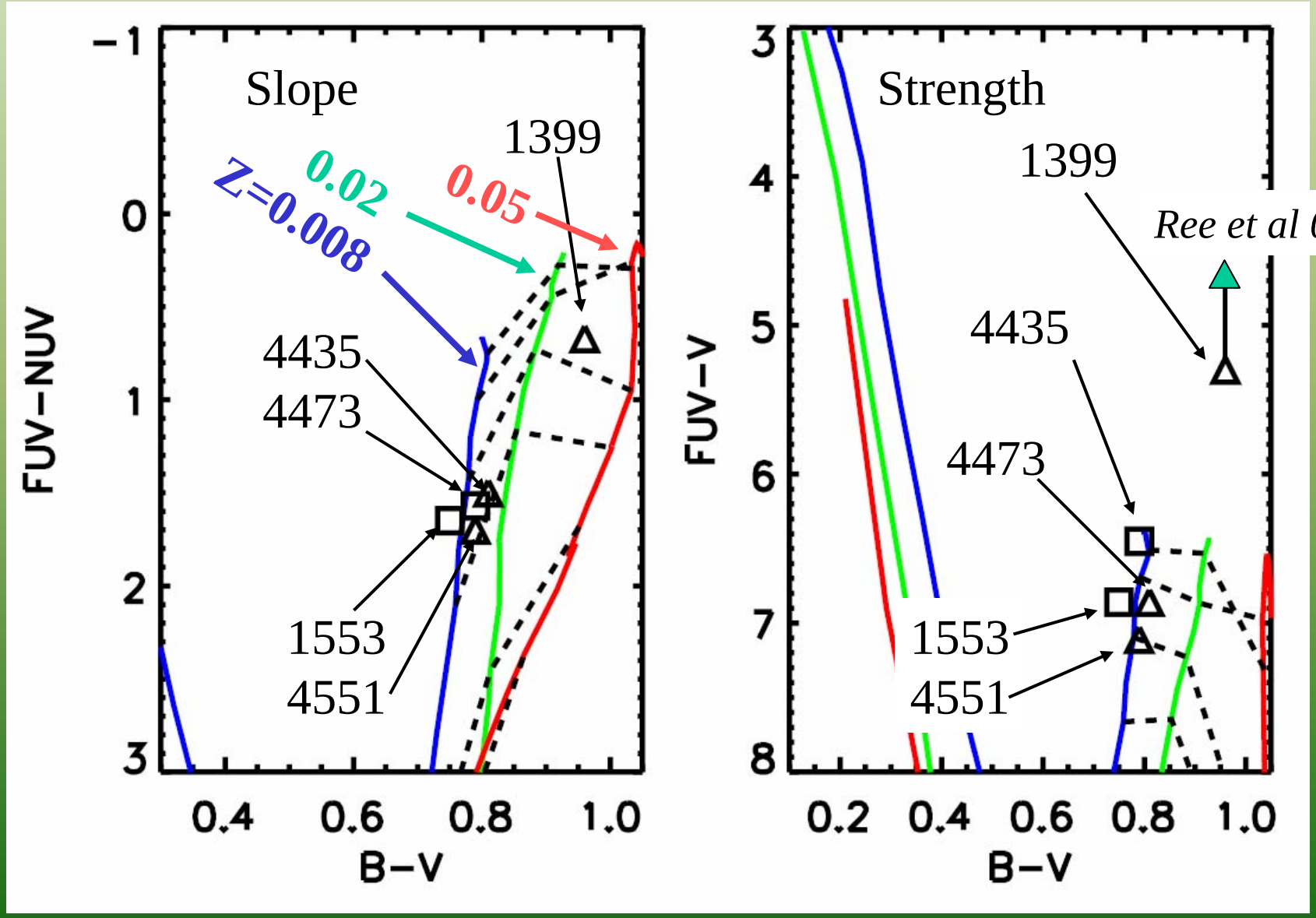
The UV view of ETGs: the Strength



FUV & NUV from old SSPs



SSPs in the UV

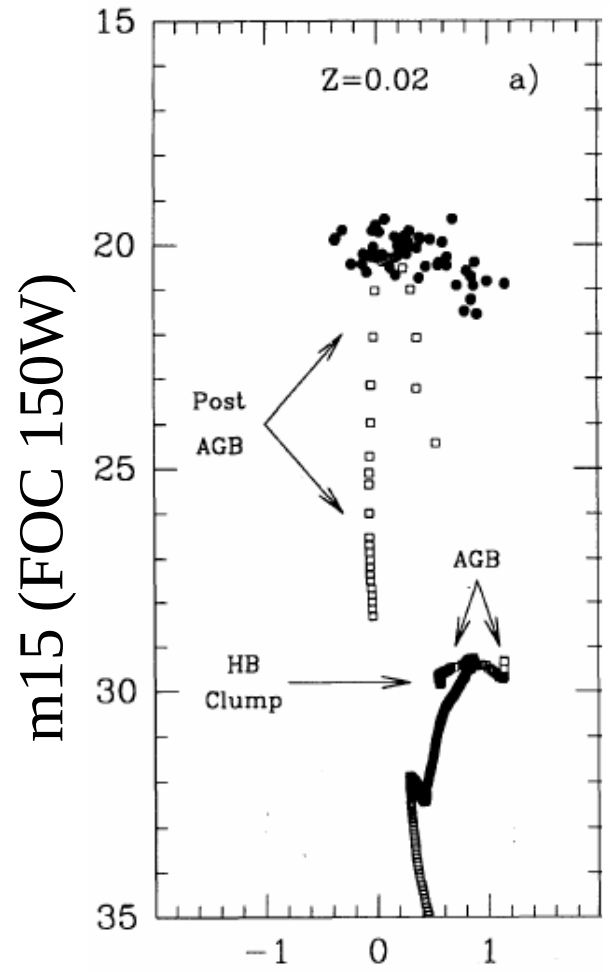


FUV-V

NGC 1399 (and other Es like NGC 4649) impossible to reproduc

Main chan

- Recent star formation (e.g
- Post AGB Stars:
  resolved in M31 bulg
- Metal rich HB stars (Bress
- Metal poor HB stars (Yi e

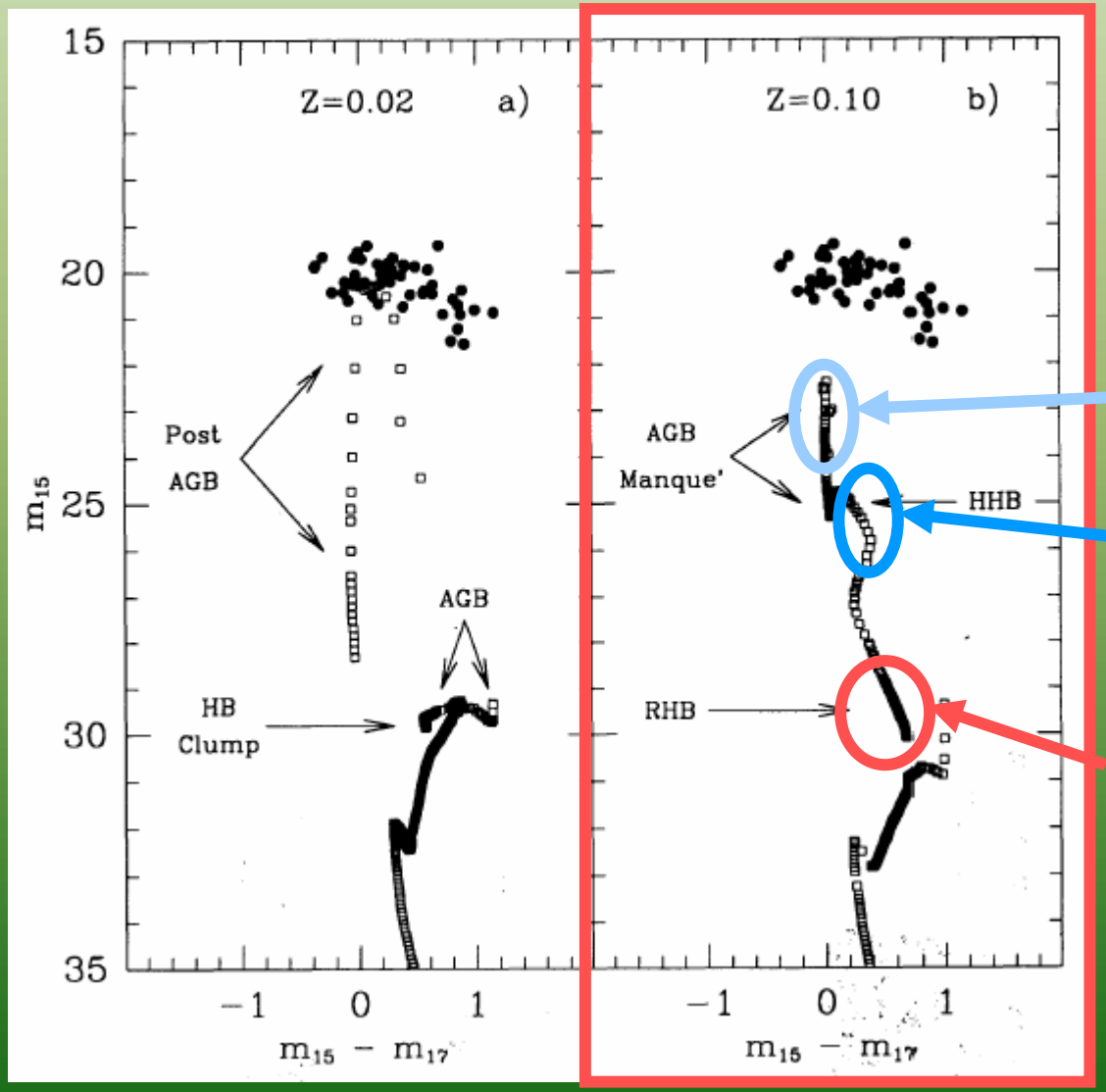


PAGBs in M31 Bulge

Contribution to FUV 30%-50%

Bertola et al 95

FUV-V: Old super metal rich stars



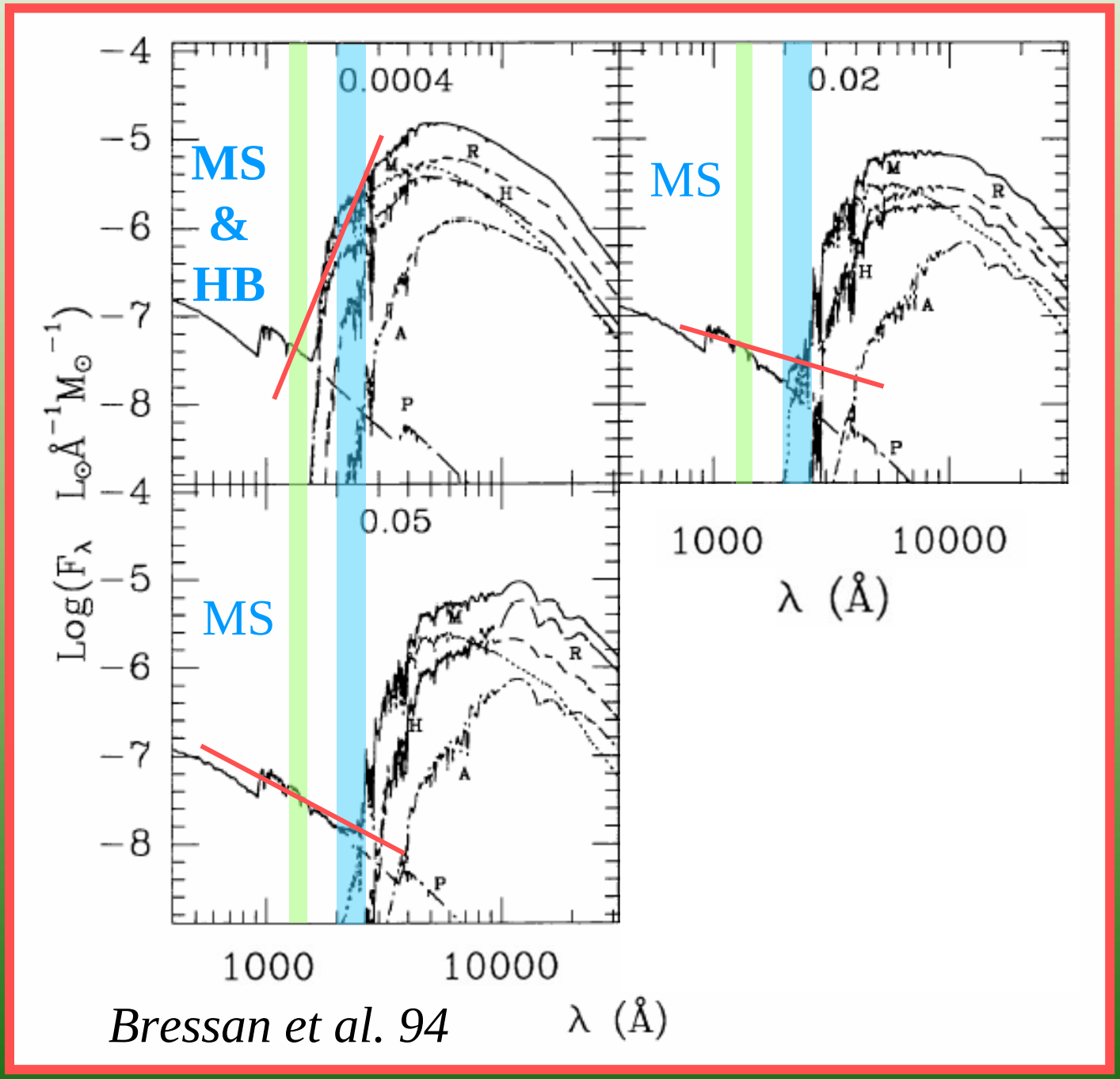
High Z → High Y → Fast envelope consumption by H-shell

AGB *Manque'*

HOT HB CLUMP

COLD HB CLUMP

The Super Metal Rich SSPs

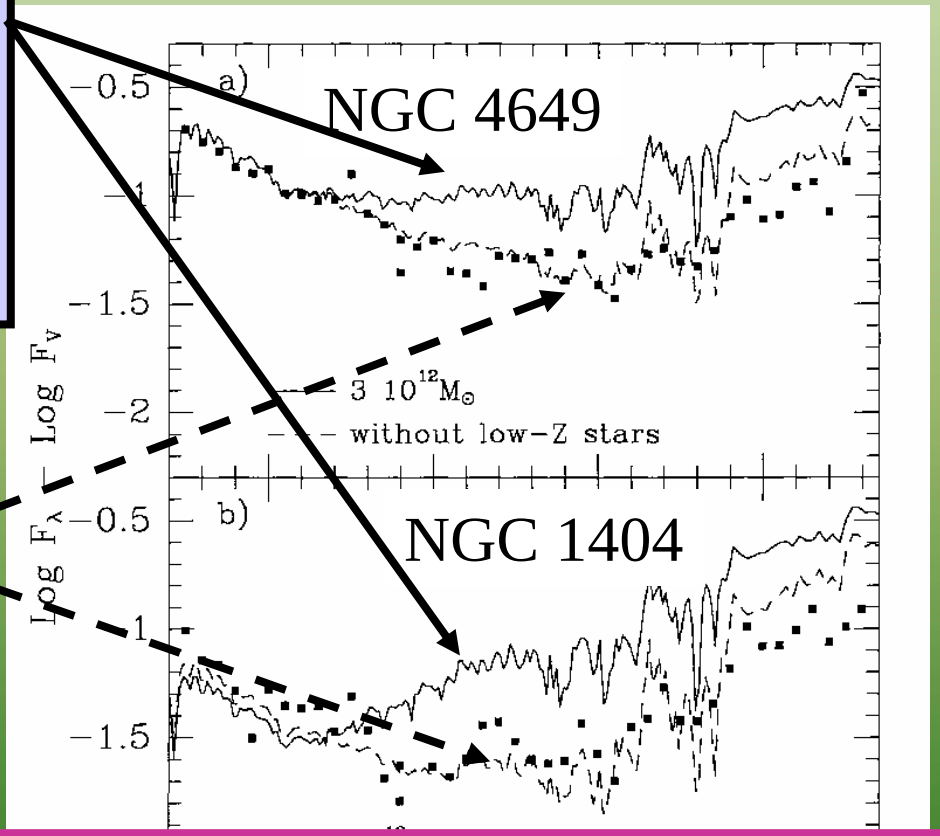


Bressan et al. 94

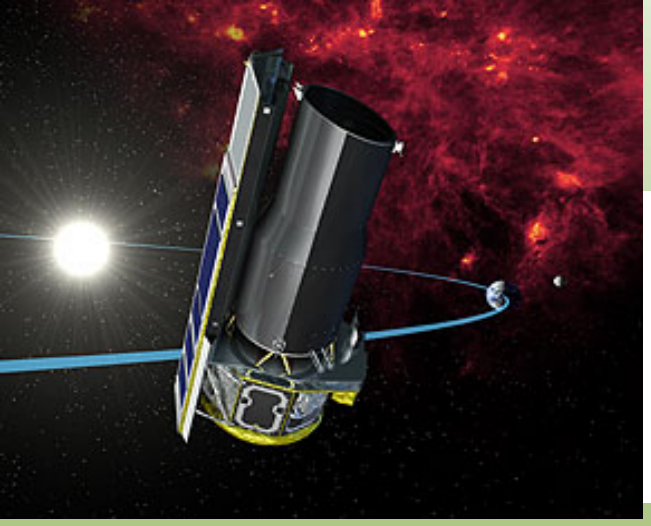
The nature of the rising branch

The NUV catastrophe of metal poor stars NUV REQUIRES VERY FEW STARS WITH Z<0.008 !!!

A few percent of Super Metal Rich Stars enough to reproduce FUV-V



!!!! Existence of correlation with Mg2 (& B-V colour) important to assess the nature of the FUV strength !!!!



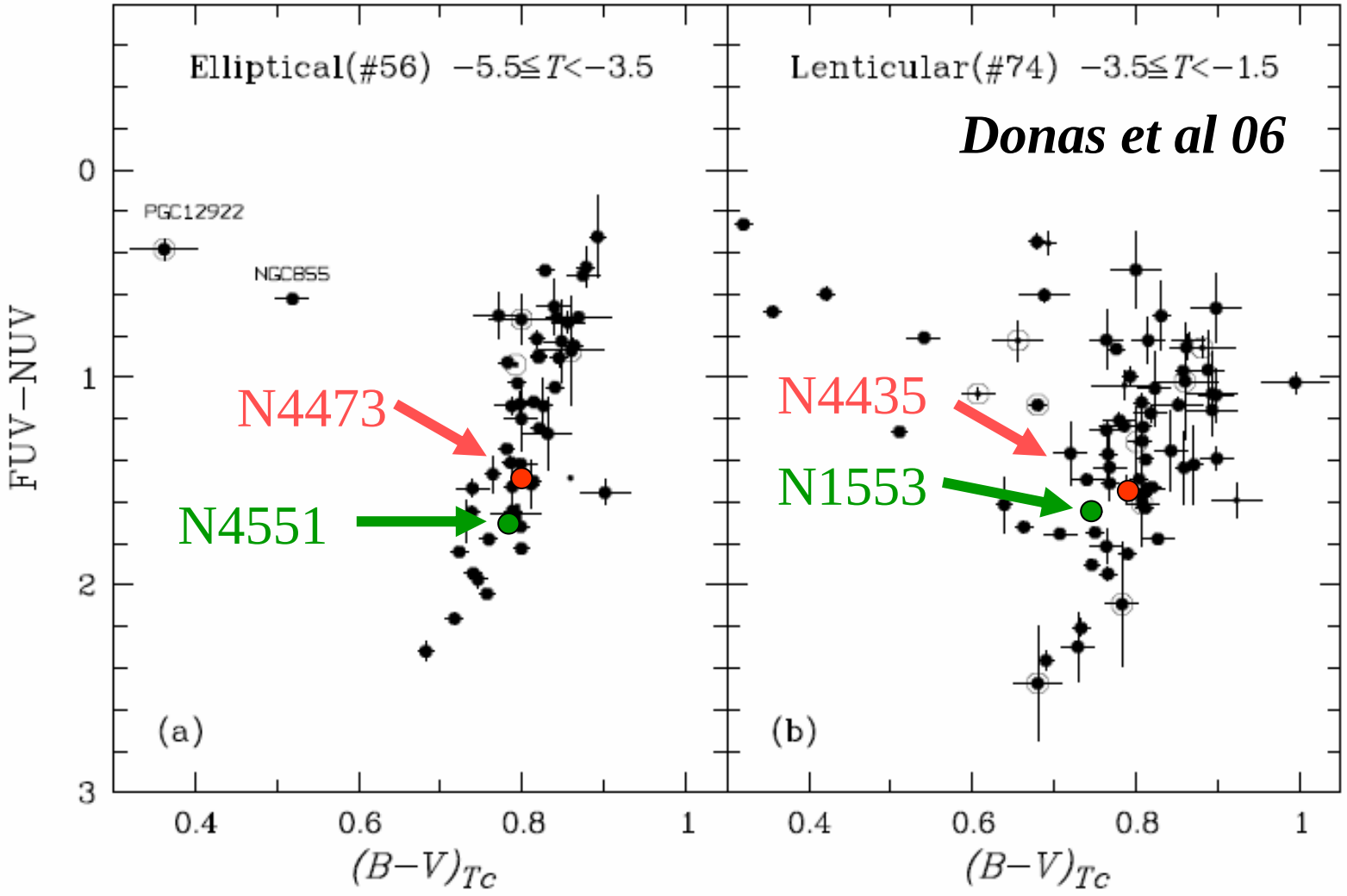
Systematic study of ETGs with Spitzer

- IRS LR spectroscopy of Early Type Galaxies on CM relation in Virgo Cluster (17 galaxies)
  Cycle 1 P.I. A. Bressan

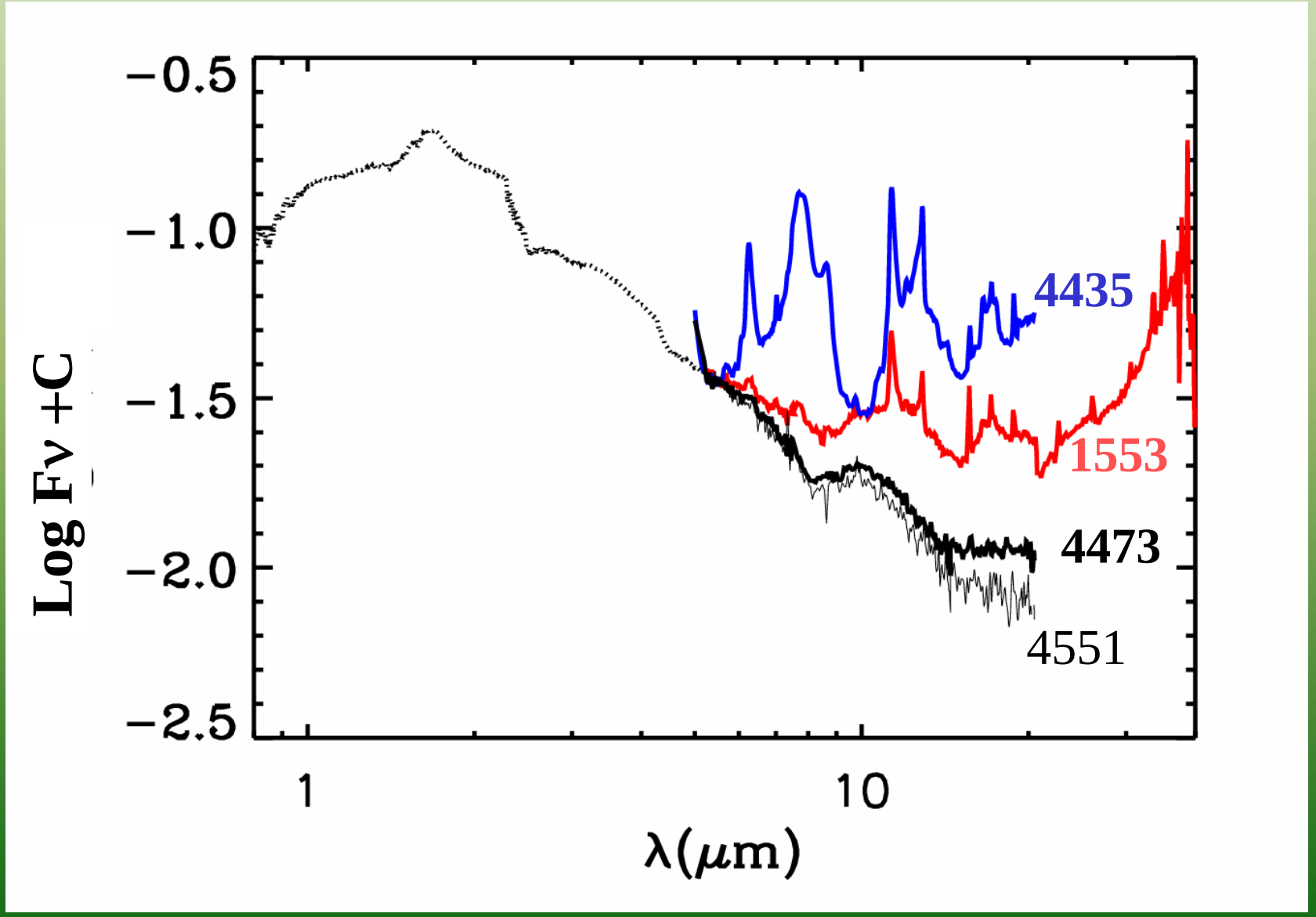
- IRS Blue Peak-Up (16 μm) and IRAC imaging of fainter Virgo members & brigthest Coma galaxies (80 galaxies)
  Cycle 2 P.I. A. Bressan

- IRS LR spectroscopy of Field Early type galaxies (20 galaxies)
  Cycle 3 P.I. R. Rampazzo

Four selected ETGs



MIR Specrum of four ETGs



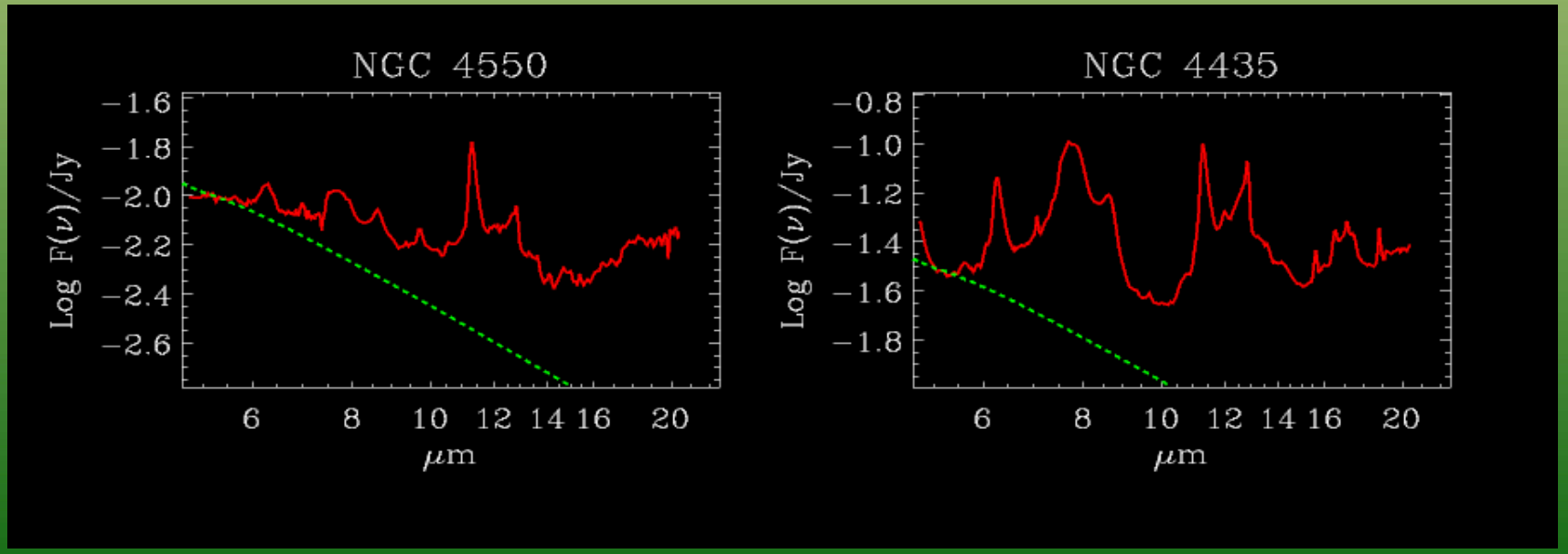
IRS LR spectroscopy of Early Type Galaxies in Virgo Cluster (17 galaxies)

10 μm bump ("Passive")
13 galaxies (76%)

NGC4339 NGC4365 NGC4371
NGC4377 NGC4382 NGC4442
NGC4473 NGC4474 NGC4551
NGC4564 NGC 4570 NGC4621
NGC4660

+ Emission Lines
2 galaxies (12%)

+ PAHs 2 galaxies (12%) (recent star formation ?)



ETGs in VIRGO

- **10 μm bump well detected by Spitzer IRS in 14 out of 16 E-type galaxies (87%)**
  - **No other feature present**
  - **10 μm bump is in agreement with Bressan et al. (98) SSP models that account for dust enshrouded AGBs**
- **2 ETGs show signature of recent/ongoing star formation**

Bressan et al 06

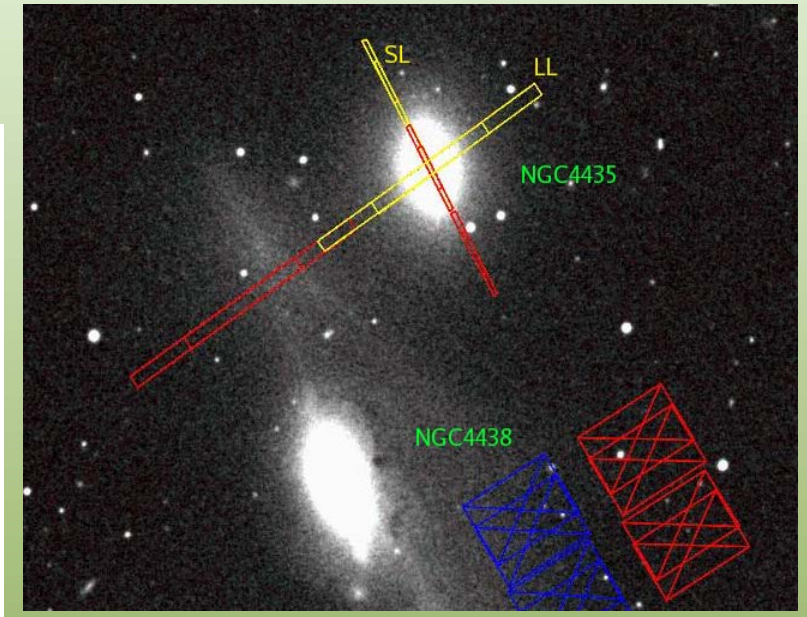
NGC 4435 *(Panuzzo et al 06)*

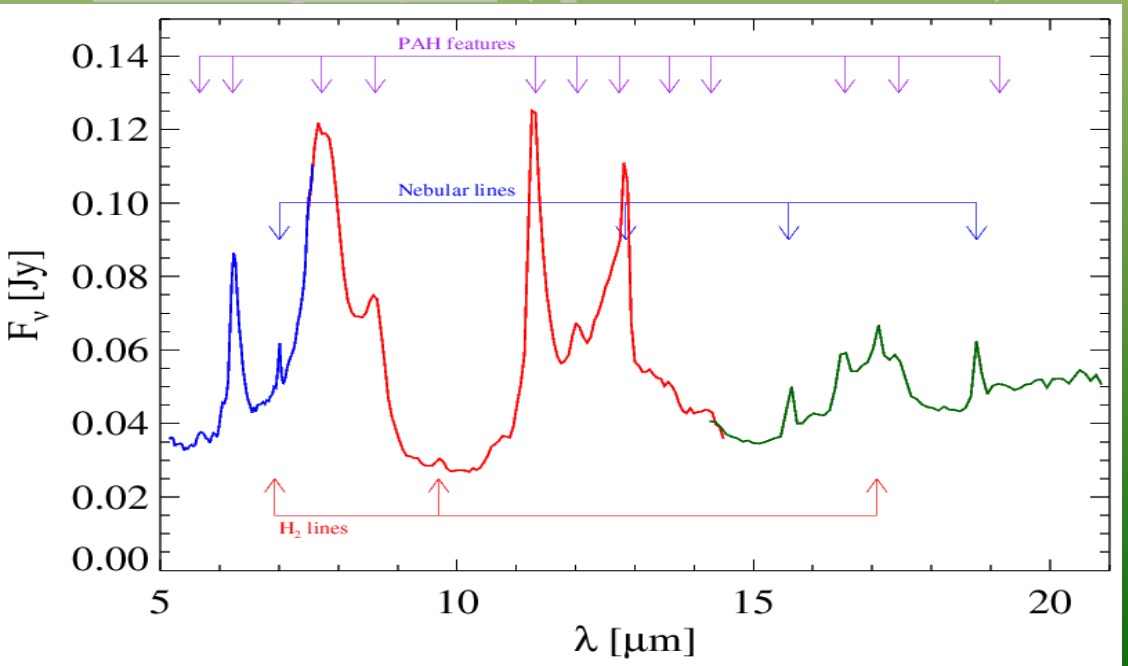
- **NGC 4435 is an SB0(7) in interaction with NGC 4438 (spiral): (HII-L)**

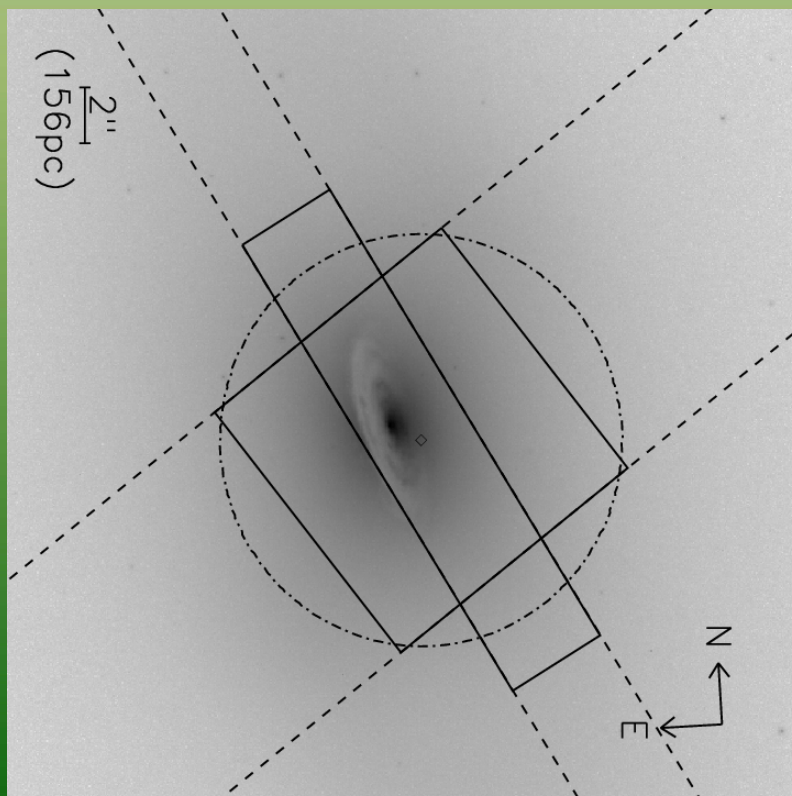
  ISM-ISM collision about 100 Myr ago

  (Vollmer et al 05)

- **M_{BH} by Coccato et al 05**
- **Opt. Pop. Study by Sarzi et al 05**
- **MIR spectrum typical of a star forming object (spiral NGC 7331)**

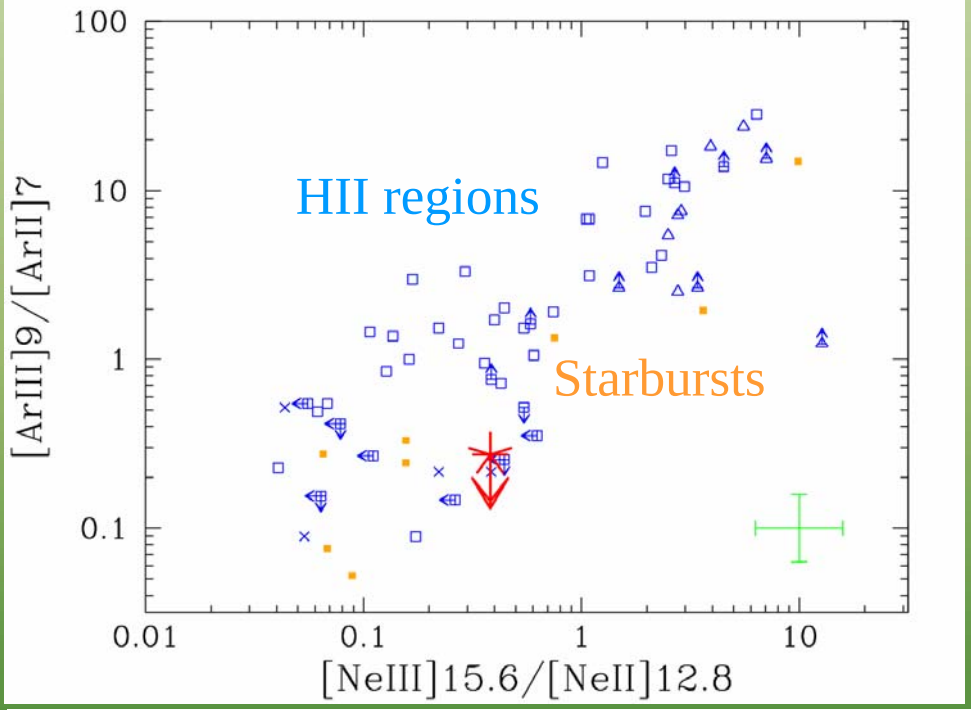






Emission Lines

- No high ionization lines detected (e.g. [Ne V], [S IV])



- **[NeIII]/[NeII] ~ 0.38**

→ **AGN contribution to ionizing flux < 2%**

EMISSION LINE INTENSITIES.

Transition/Ion	λ_{rest} (μm)	Flux (10^{-17} W m^{-2})
H_2 0–0 S(5)	6.9095	0.505 ± 0.411
[Ar II]	6.9853	3.787 ± 0.378
H Pfα	7.4599	1.567 ± 0.349
H_2 0–0 S(3)	9.6649	1.055 ± 0.288
[Ne II]	12.8136	6.972 ± 0.252
[Ne III]	15.5551	2.666 ± 0.168
H_2 0–0 S(1)	17.0348	1.808 ± 0.163
[S III]	18.7130	2.248 ± 0.119
[Fe II]	5.3402	< 1.92
H_2 0–0 S(7)	5.5112	< 1.76
H_2 0–0 S(4)	8.0250	< 1.53
[Ar III]	8.9914	< 1.03
[S IV]	10.5105	< 0.60
H_2 0–0 S(2)	12.2786	< 0.96
[Ne V]	14.3217	< 0.41
[Fe II]	17.9360	< 0.34

Ar and Ne abundance

→ **gas metallicity ~ Z**

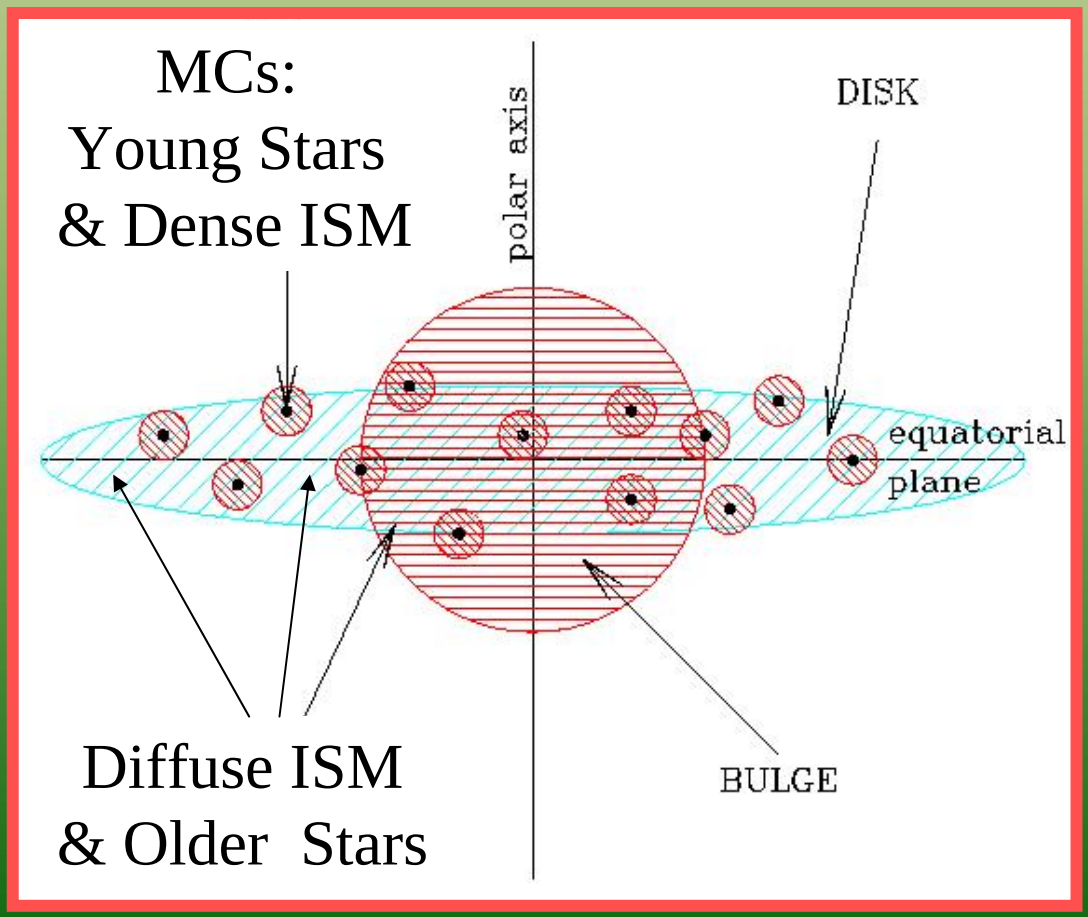
The Global (panchromtic) SED

- UV (Galex)
- Optical-NIR
- MIR (IRAC + IRS)
- FIR (MIPS, IRAS)
- RADIO
- Also X-Ray from SF

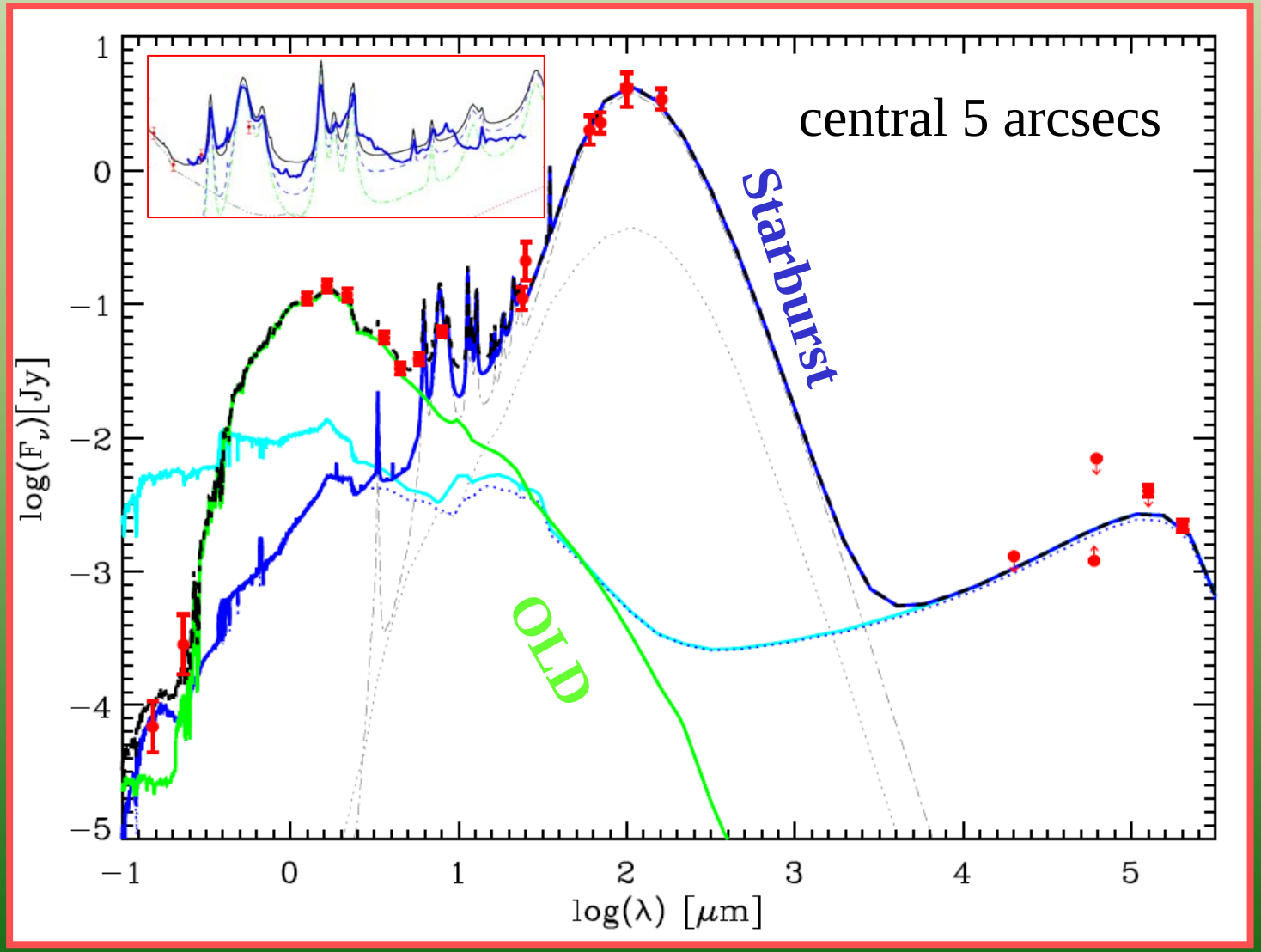
The Model: GRASIL

(*http://web.pd.astro.it/galsynth*)

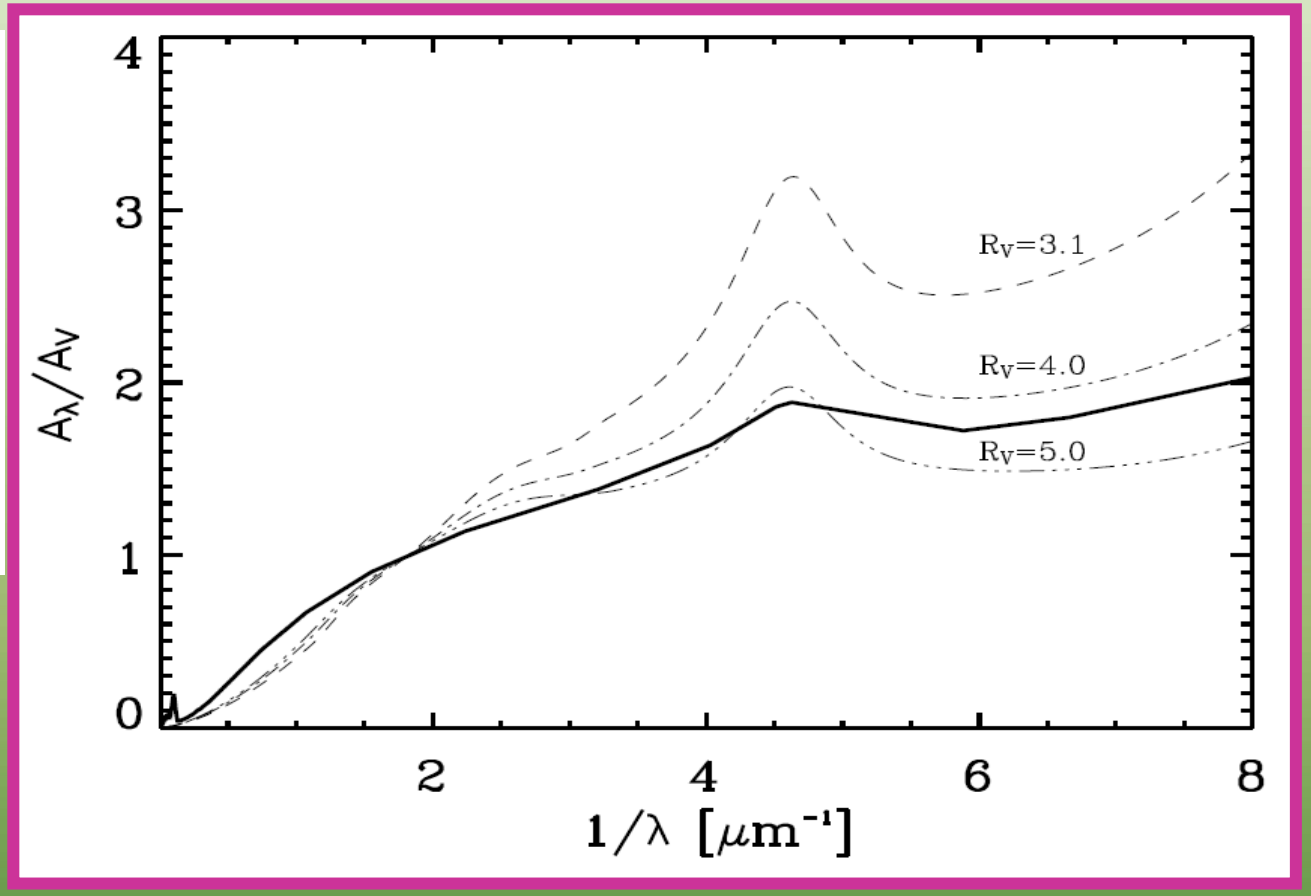
Silva et al 98	*(SED UV-FIR)*
Bressan et al 98	*(SSP in MIR)*
Bressan et al 02	*(SED Radio)*
Panuzzo et al 03	*(SED E. Lines)*
Vega et al 05	*(PAH revision)*



NGC 4435: UV- Radio fit with GRASIL OLD + Starburst



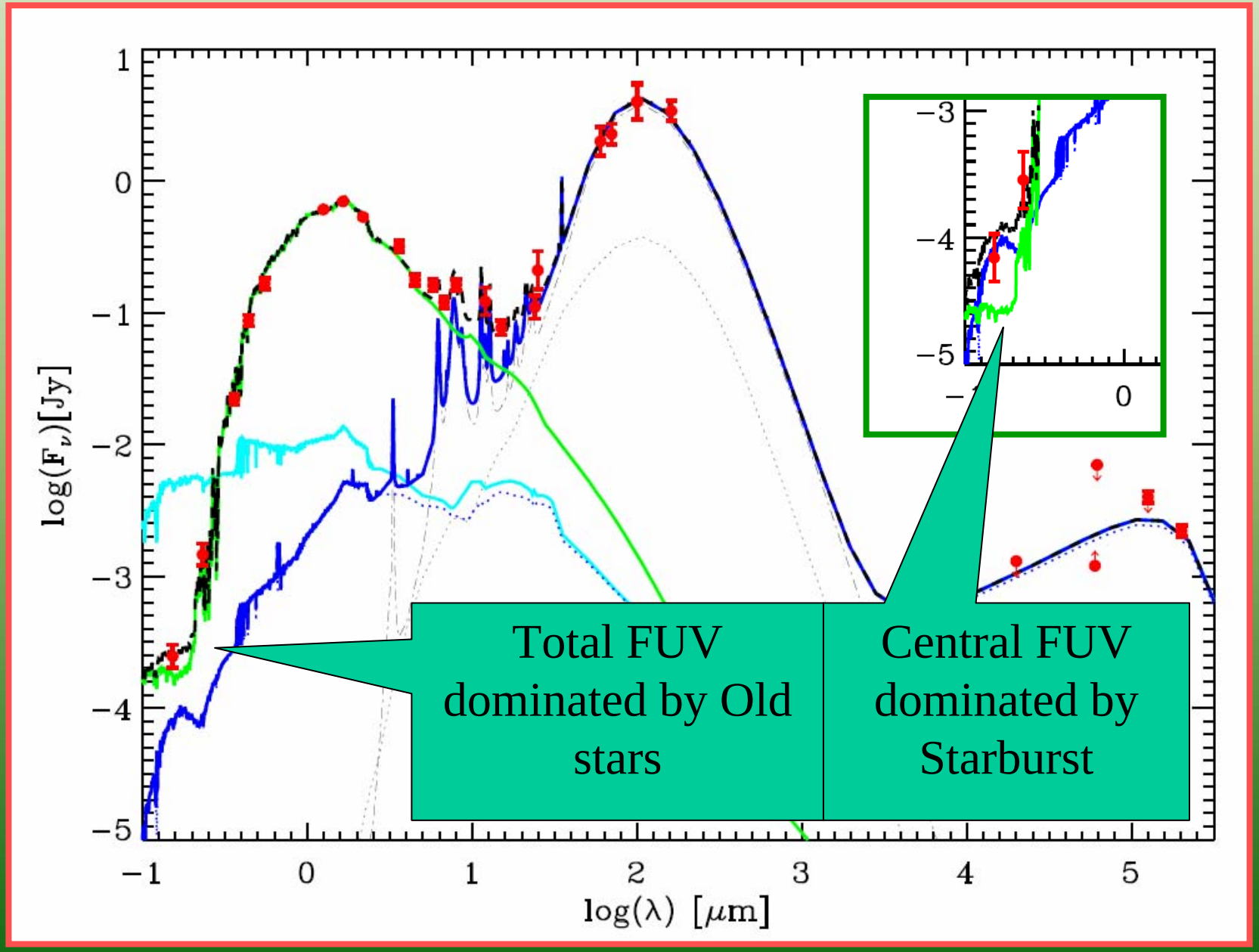
The attenuation in the starburst



The attenuation results from a combination of

1. **Dust properties (set to reproduce Rv = 3.1)**
2. **Dust and stars geometry**
3. **Star escape time from MCs**

NGC 4435: Total Magnitudes



NGC 4435 central aperture:

Old: M ~ 8 10^9 M_s Age ~ 8 Gyr Z = 0.02

Young:

post starburst with residual SFR ~ 0.07 M_s/yr

Age ~ 200 Myr **<SFR> ~ 0.7 M_s/yr**

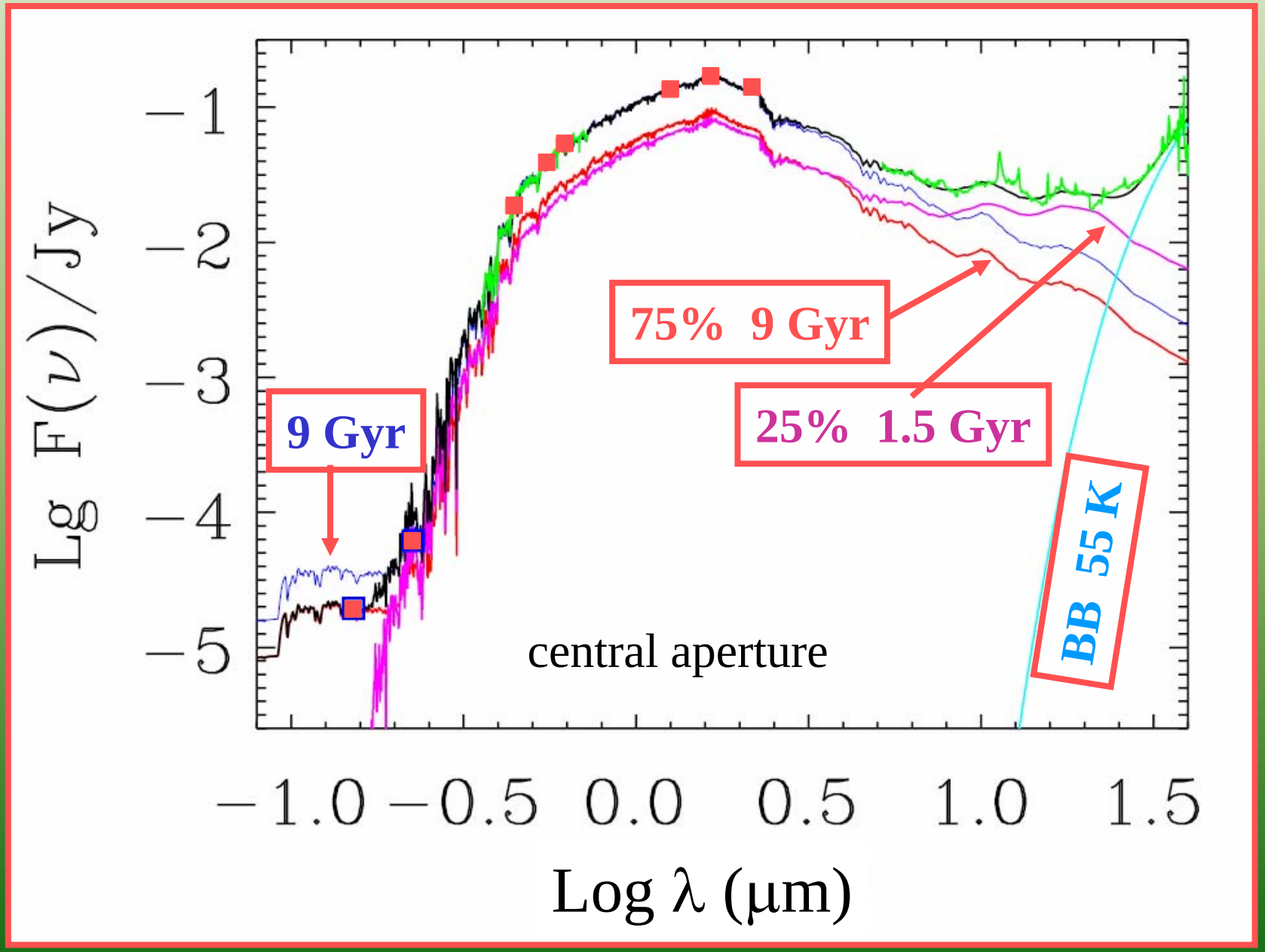
M_{BURST} ~ 1.2 10^8 Ms ~ 1.5% $M_{GAL\ (5\ arcsec)}$

Attenuation: complex interplay between dust properties, geometry & escape time

FUV dominated by Starburst NUV by Old *

NGC 4435 total: **UV-MIR dominated by Old ***

NGC 1553: preliminary study

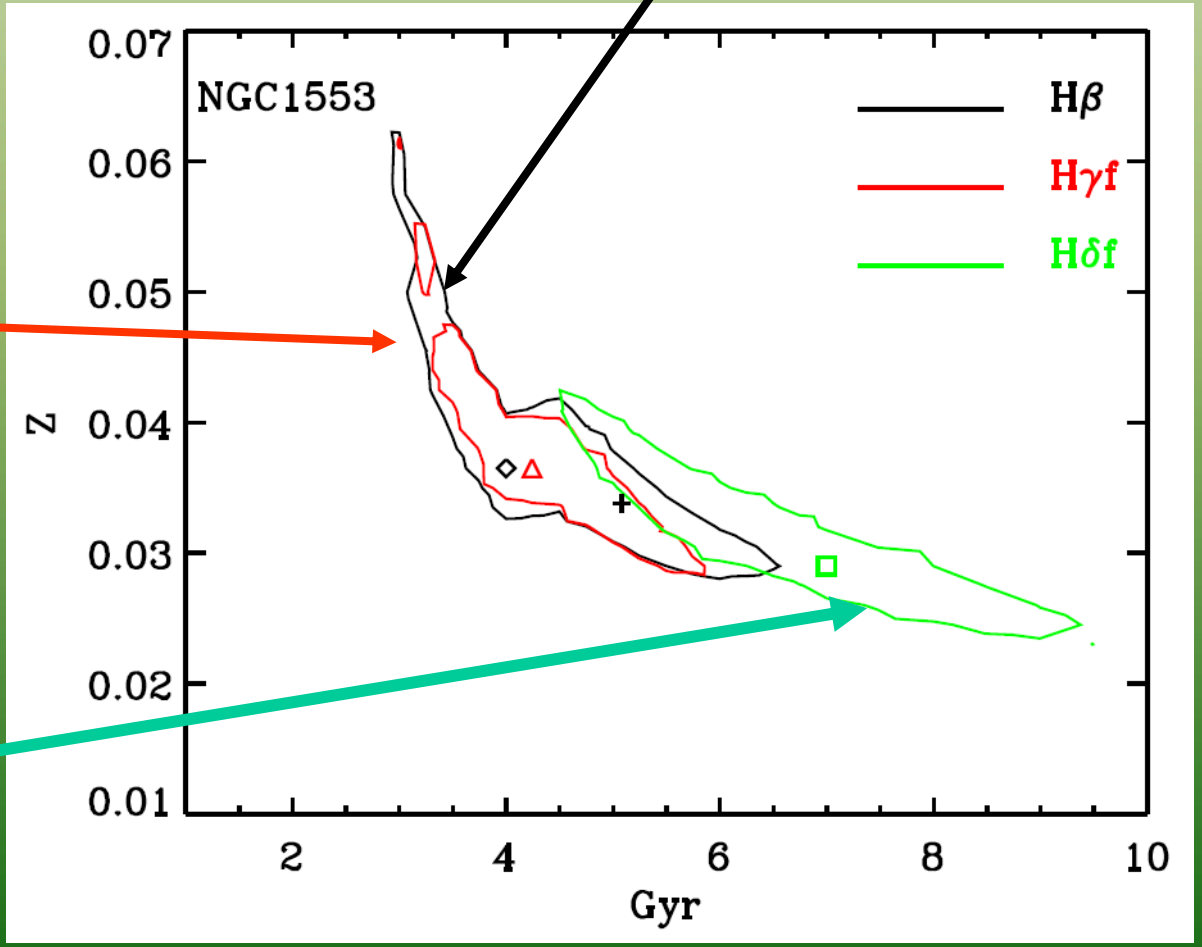


The Age-Metallicity degeneracy

(Hβ, <Fe>, Mgb)

(Hγf, <Fe>, Mgb)

(Hδf, <Fe>, Mgb)



NGC 1553 (~ IRS aperture)

Single Old Population (9 Gyr) may fit Optical & NIR
- remember degeneracy
But: FUV higher than observed
NUV lower than observed
MIR lower than observed

FUV + NUV + (Optical-NIR) + MIR
indicate a composite population

Old:	**75%**	**Age ~ 9 Gyr**	**Z = 0.02**
Intermediate:	**25%**	**Age ~ 1.5 Gyr**	**Z = 0.02**

FUV from Old Stars NUV composite population !

Conclusions

Galex & Spitzer offer important complementary new windows for the study of E-type galaxies

Presence of intermediate age stellar pops. traced by

- **10 μm bump of AGBs**
- **relatively lower FUV from PAGBs**

Both UV and MIR are sensitive to tiny amount of star formation

The attenuation results from a combination of

1. **Dust properties**
2. **Dust and stars geometry**
3. **Star escape time from MCs**

High quality data better analysed with high quality models !