The evolution of field early - type galaxies and the origin of their ionized gas

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Field versus cluster ETGs

Archeological approach:

Narrow-band index studies suggest:

- younger ages in field than in cluster

(e.g. Bender+ 96; Longhetti+ 98, 99, 00; Trager+ 00; Kuntschner+ 02; Thomas+05; Denicolo' +05; Gallazzi +05, Clemens+06, 09)

- larger metallicities in field than in cluster

(e. g. Kuntschner+ 02; Thomas+05)

High - z studies:

No age difference between ETGs in clutser and field

(e. g., di Serego Alighieri et al. (2006); van Dokkum & van der Marel (2006))

The Sample

It is composed of 65 nearby (cz < 5500 Km/s) early–type galaxies:
50 (Rampazzo+05, A&A 433, 497) + 15 (Annibali +06, A&A 445, 79)

✓ Selection criteria:

ISM traces in at least one of the following:
IRAS 100 μm, X-ray, radio, HI and CO
+ 10 galaxies from Gonzalez (93) sample

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❖ Emission in 78 % of the sample (consistent with recent data of early-type, e.g. Falcón-Barroso et al. 2006)

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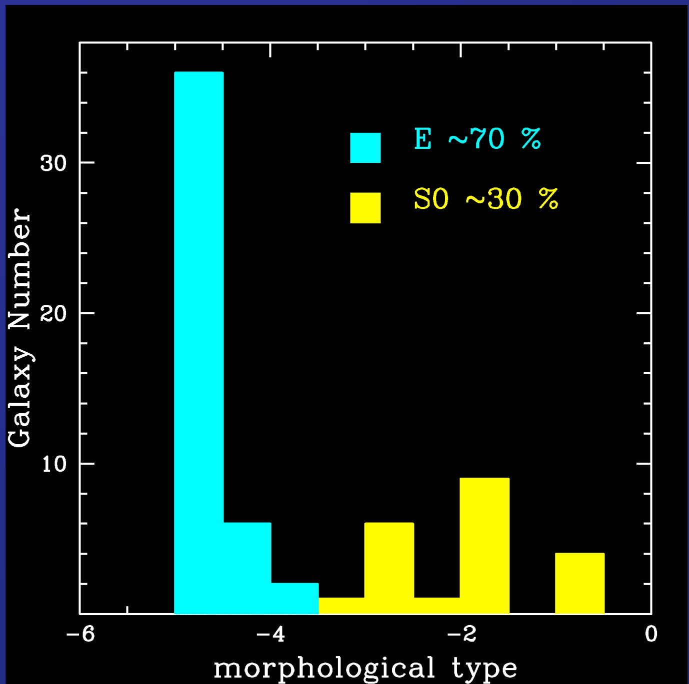
✓ Morphological types: 68 % E, 32 % S0



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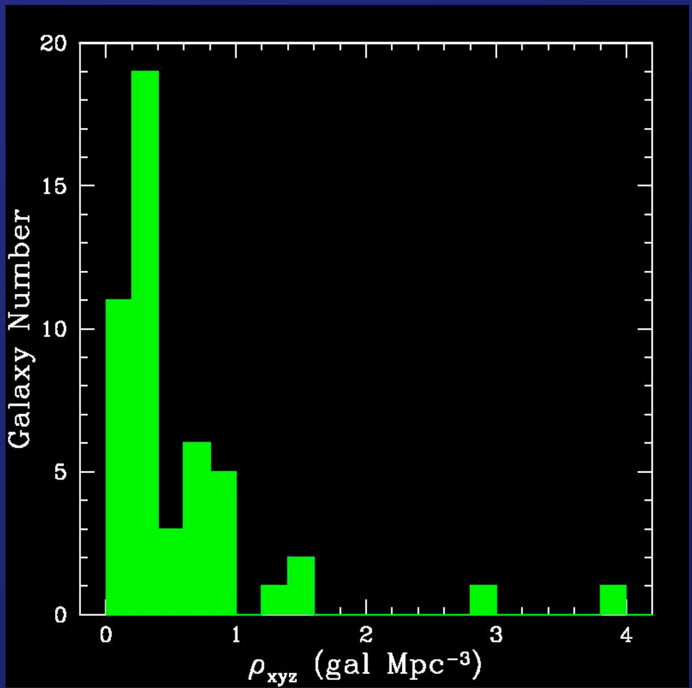
✓ Environment:

(0.1-4) gal / Mpc^3 (Tully 1988)



Lick Indices

(Rampazzo et al 2005 + Annibali et al. 2006)

- ✓ We have acquired intermediate resolution spectra with 1.5m ESO in the (3700-7000) Å range

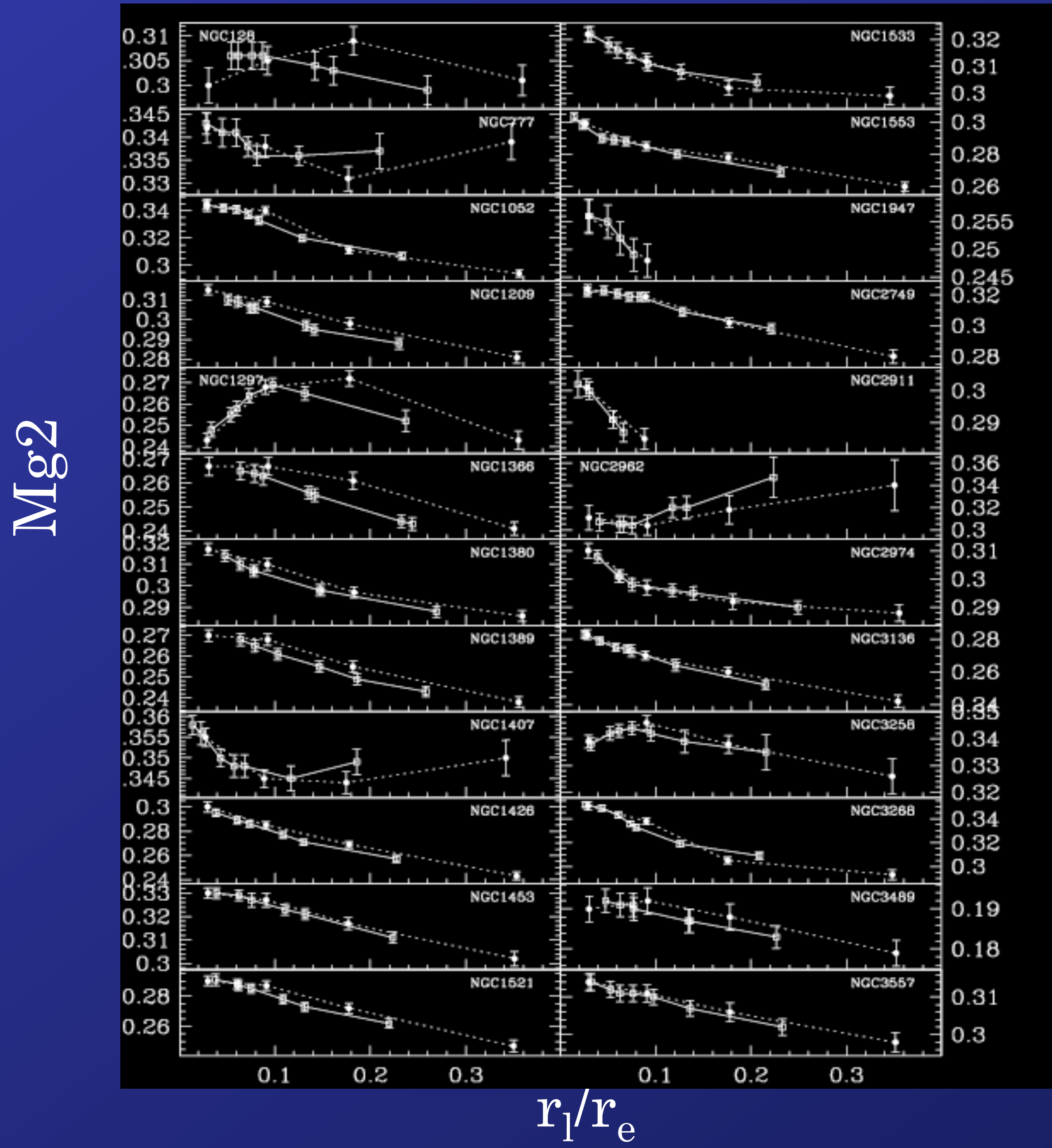
- ✓ Extraction of 7 apertures (1.5”, 2.5”, 10”, $r_e/10$, $r_e/8$, $r_e/4$, $r_e/2$) and 4 gradients ($r < r_e/16$, $r_e/16 < r < r_e/8$, $r_e/8 < r < r_e/4$, $r_e/4 < r < r_e/2$)

- ✓ Computation of 25 Lick Indices:

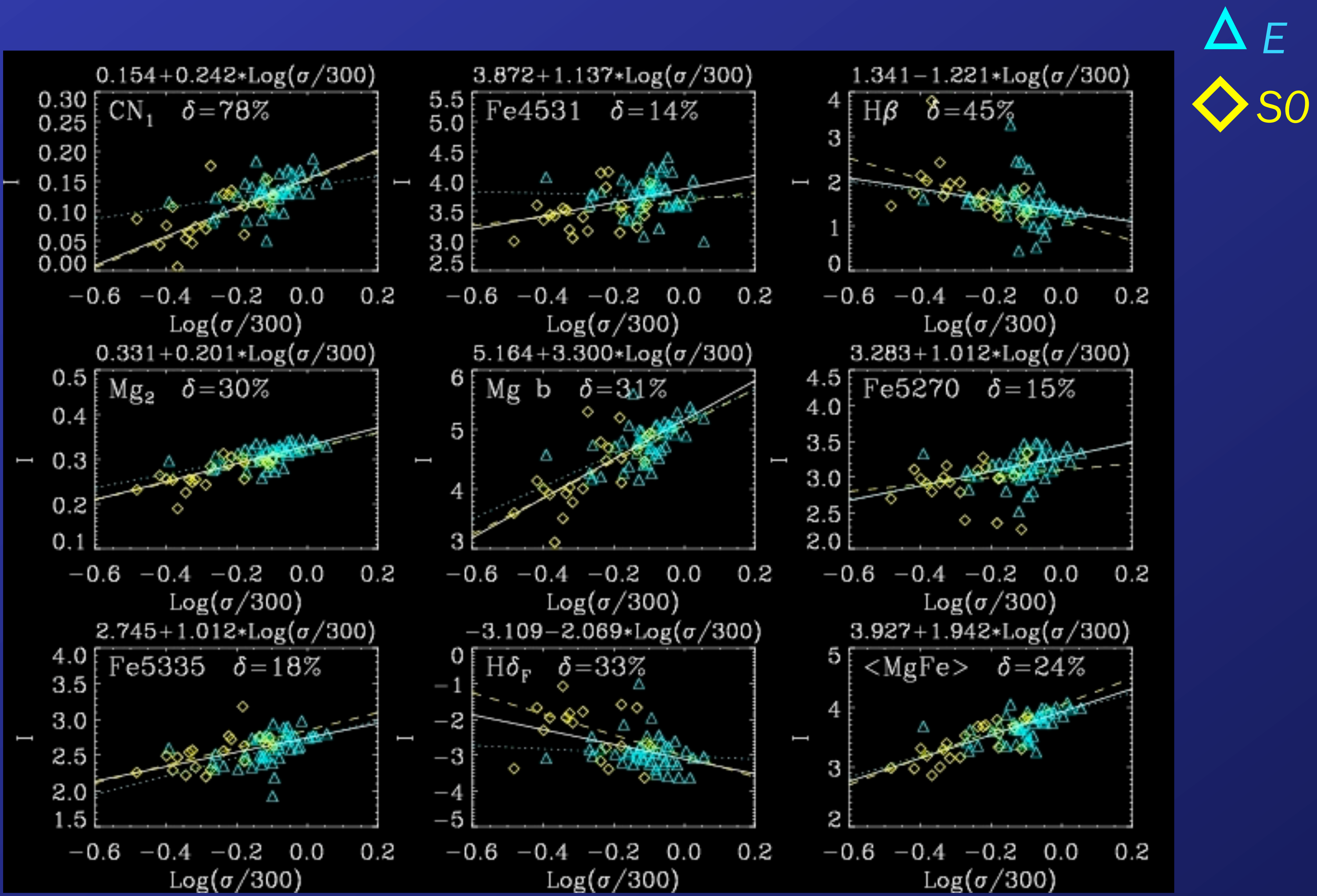
(21 from Trager +98 plus 4 from Worthey & Ottaviani 97)

- ❖ Correction for galaxy velocity dispersion
- ❖ Correction for emssion (Hβ)
- ❖ Calibration from Lick standard stars

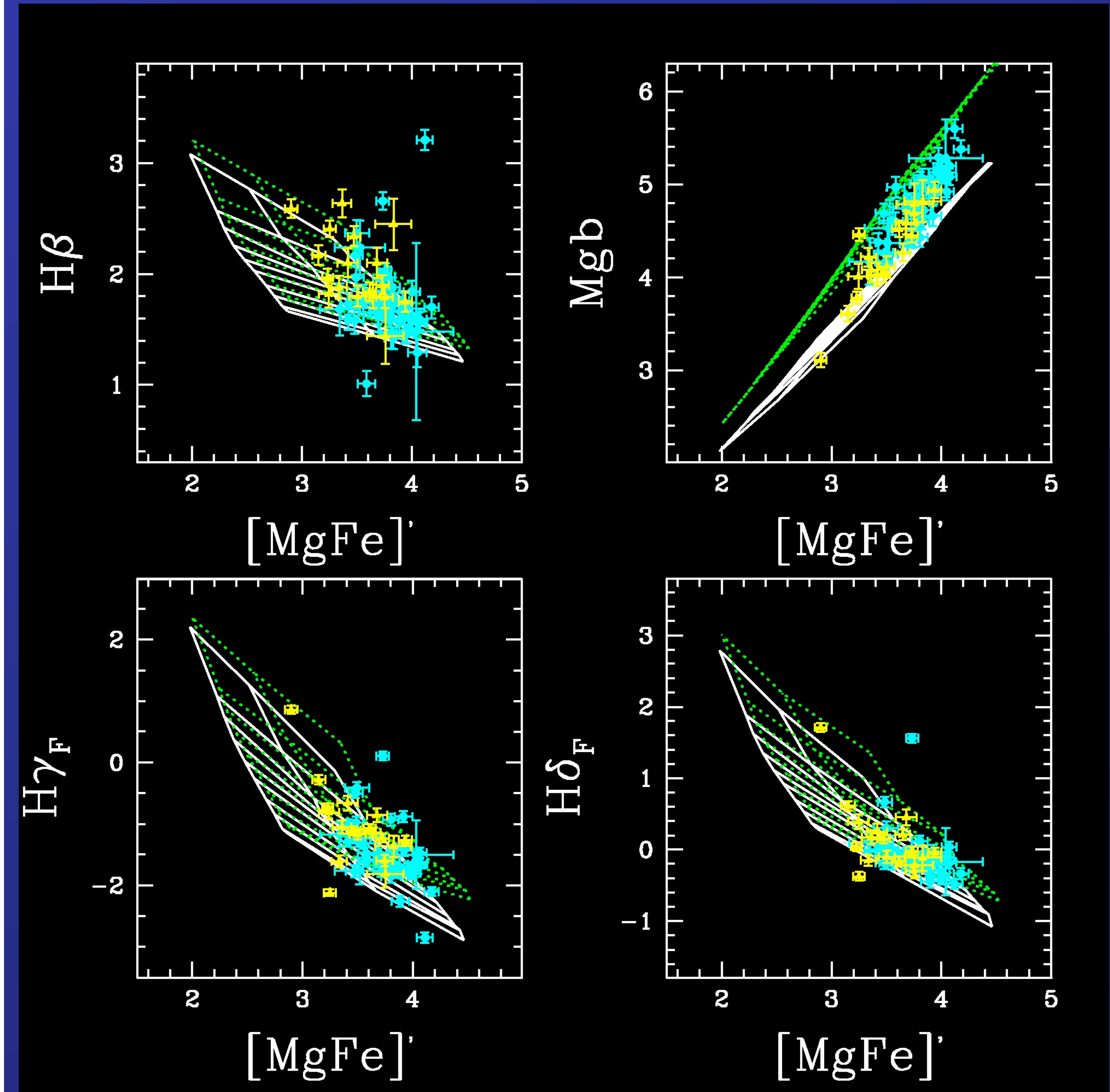
Index Gradients

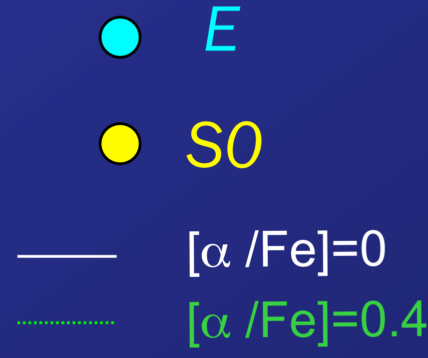


Indices versus σ



Lick- index diagostic diagram



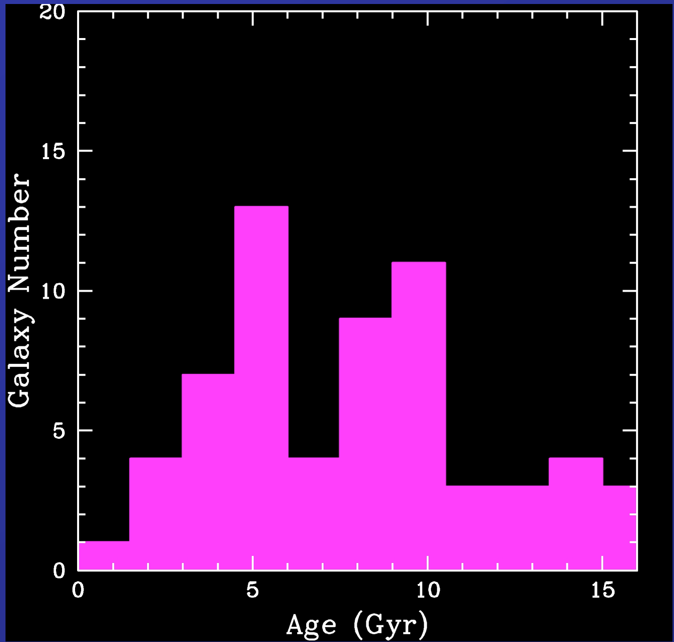


SSPs from Annibali et al 2007

1 Gyr <age<16 Gyr
0.008 <Z <0.05
0 < [α /Fe] < 0.4

Age, Z and [α/Fe]

(Annibali et al 2007)

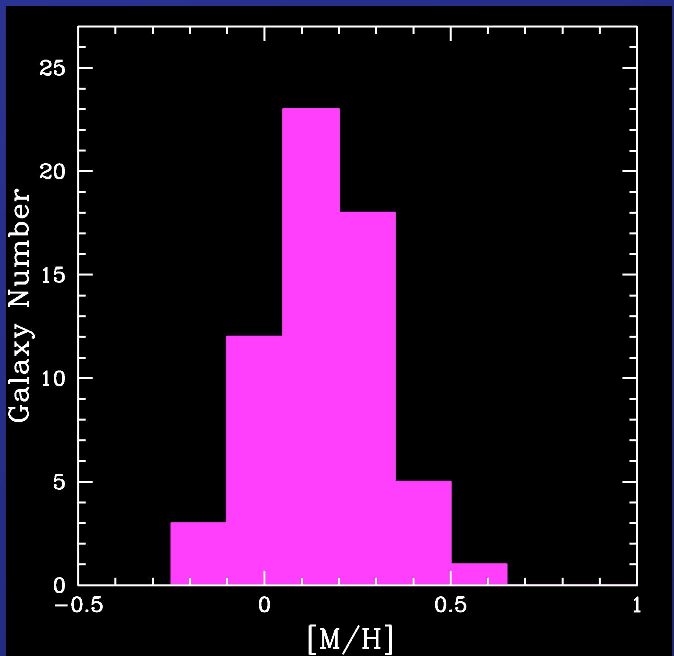


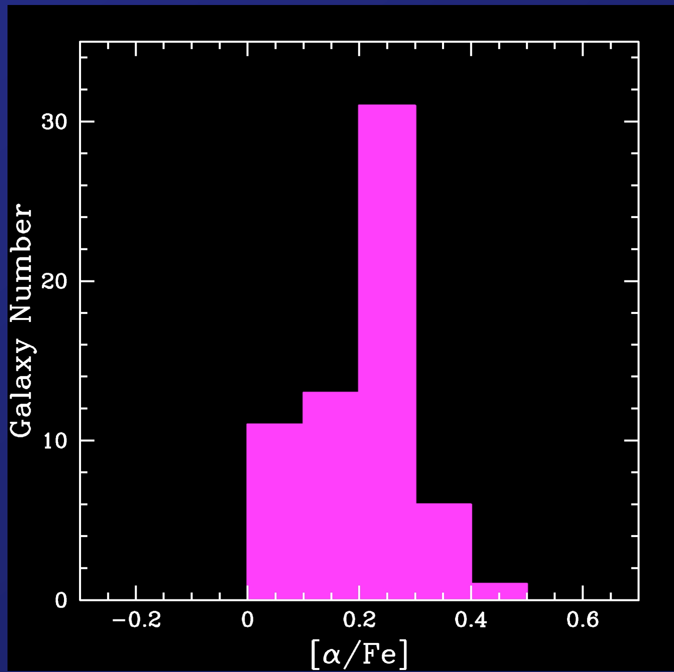
<age>=8 Gyr

<[M/H]>=0.21

<[α/Fe]>=0.21

NB: linked to SF time-scale!





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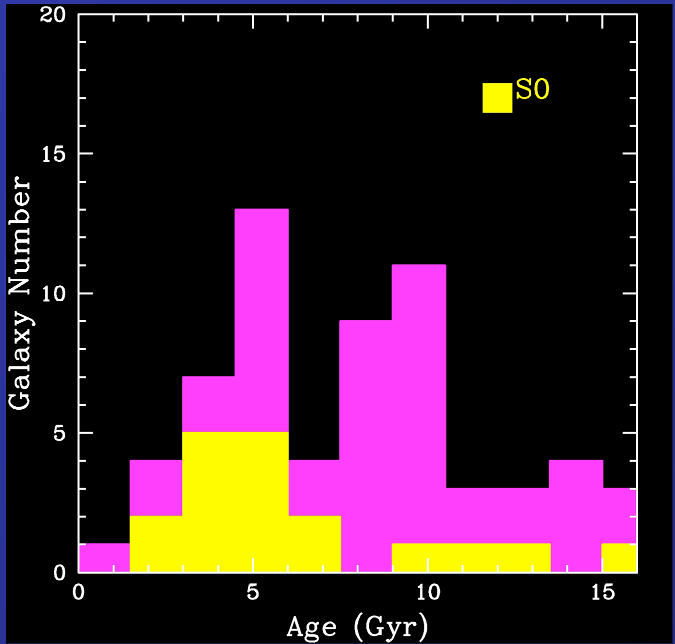
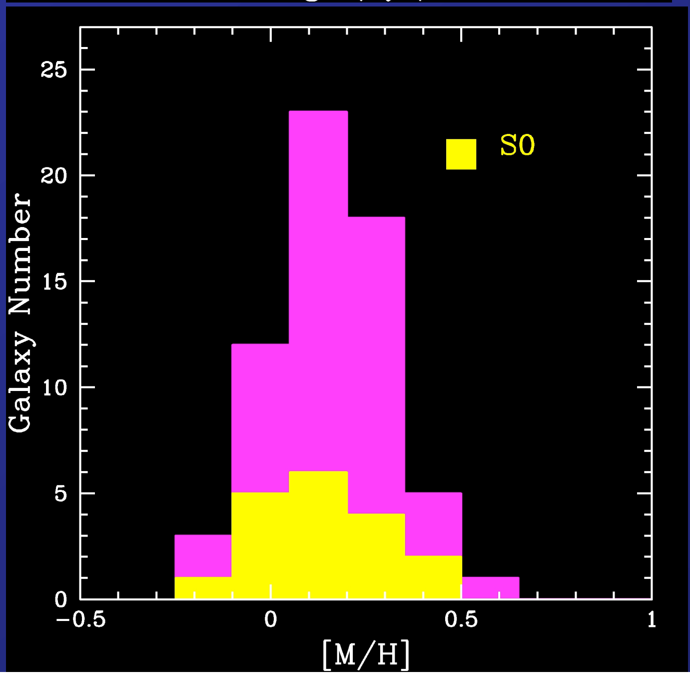
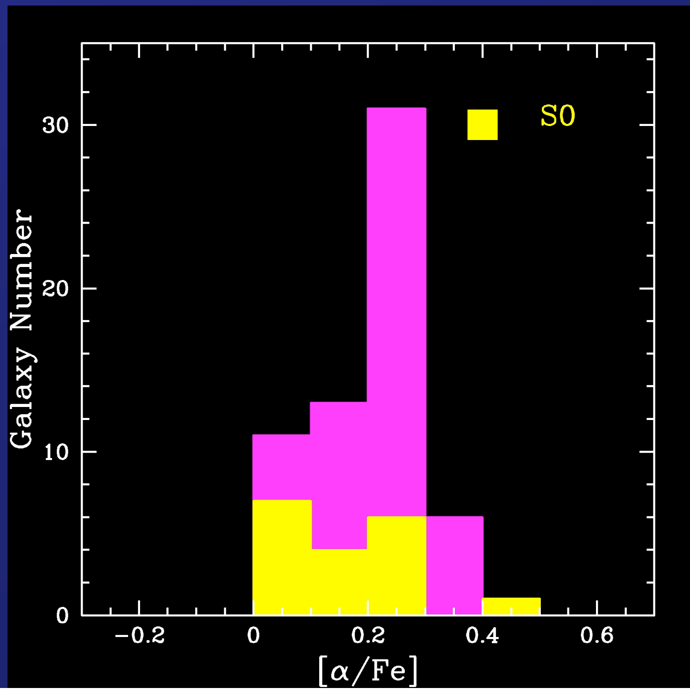


<age>=6.3 Gyr

<[M/H]>=0.19

<[α/Fe]>=0.17





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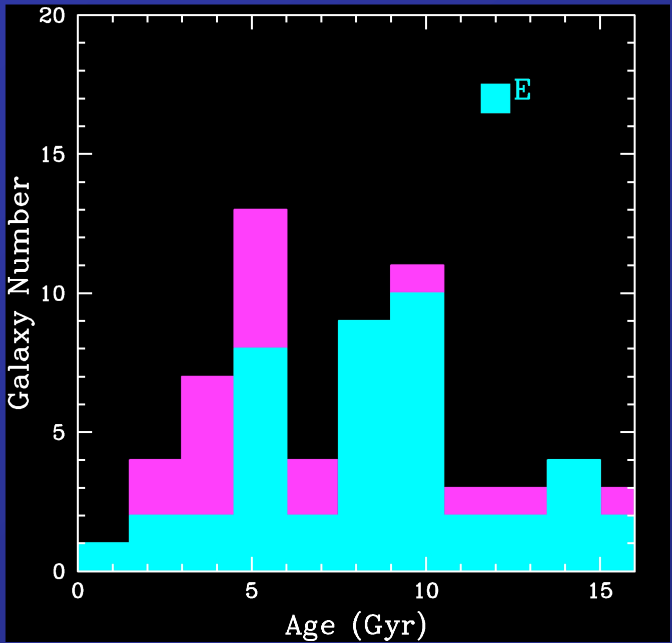
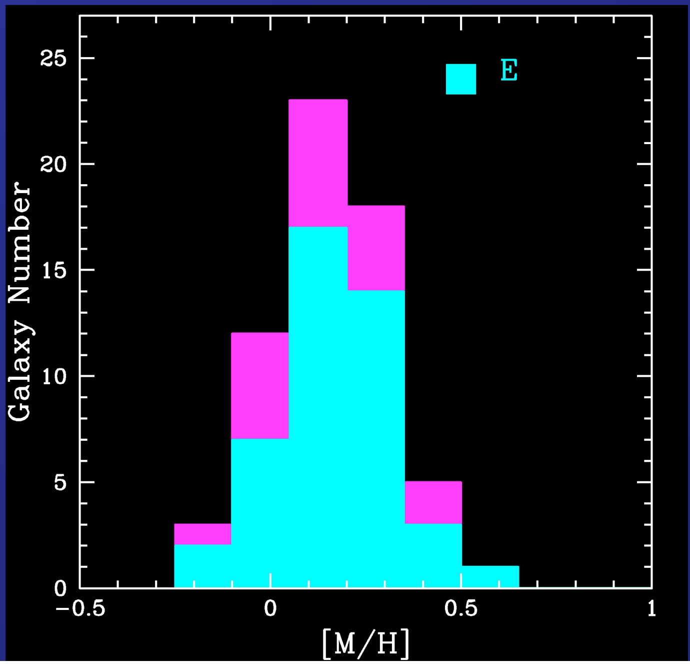
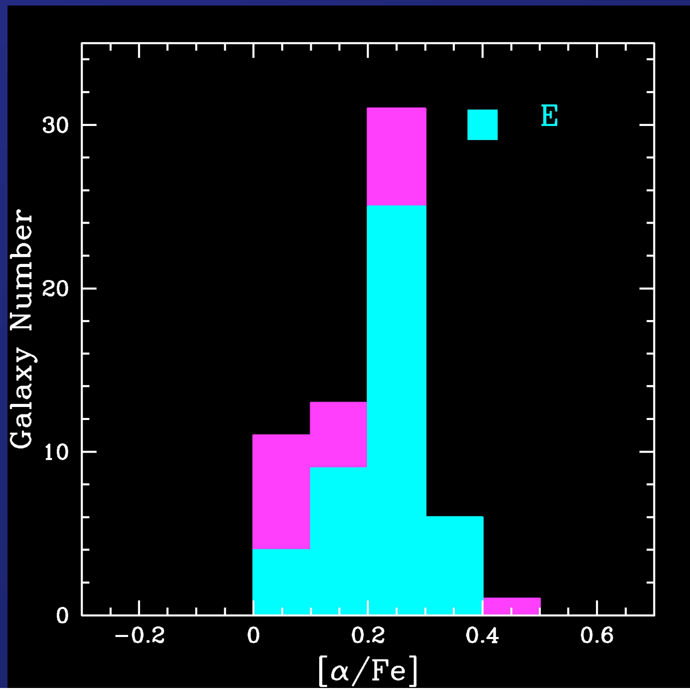


<age>=8.7 Gyr

<[M/H]>=0.22

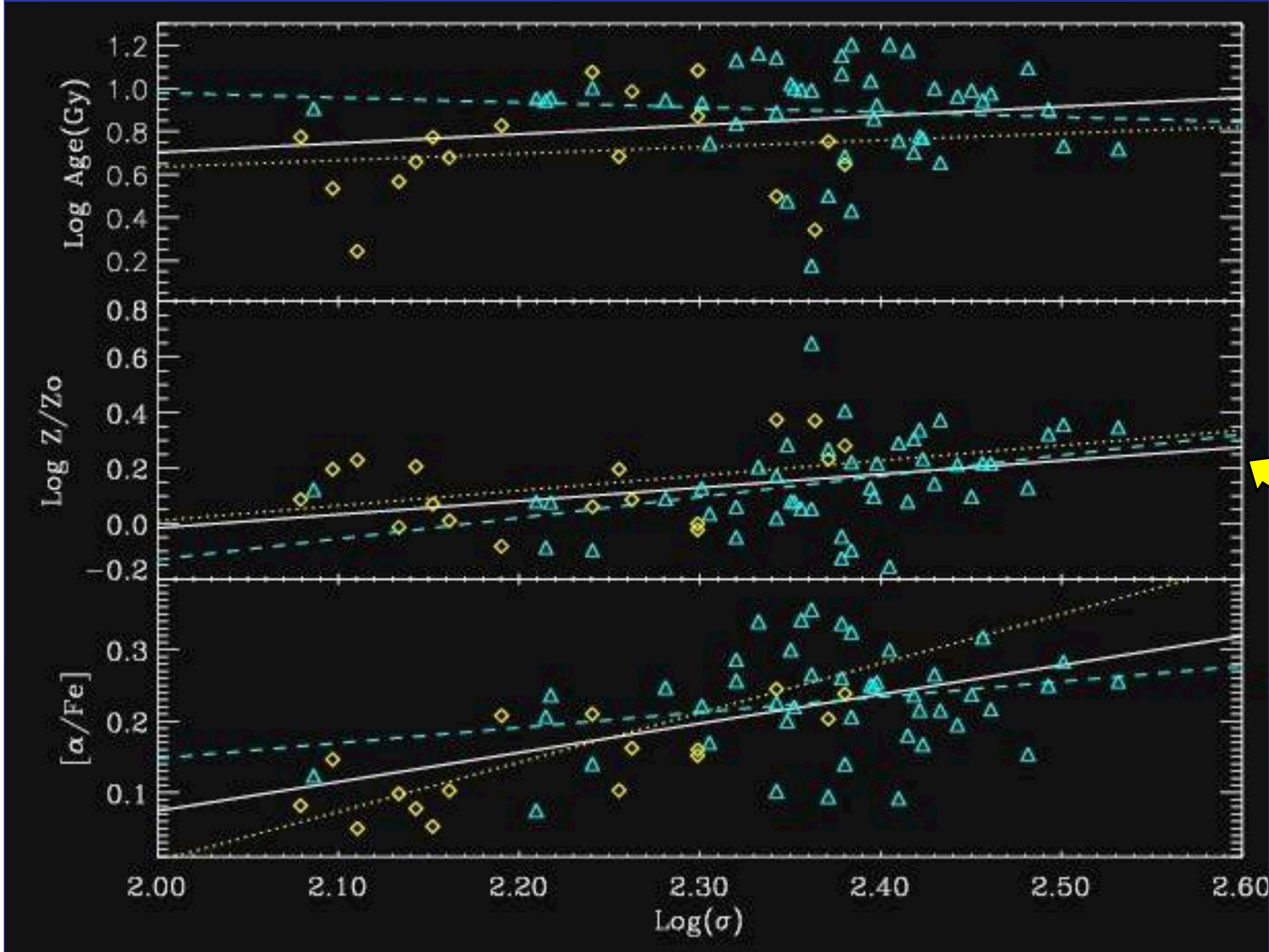
<[α/Fe]>=0.23





The Role of Galaxy Mass

(Annibali et al 2007)



△ E

◇ S0

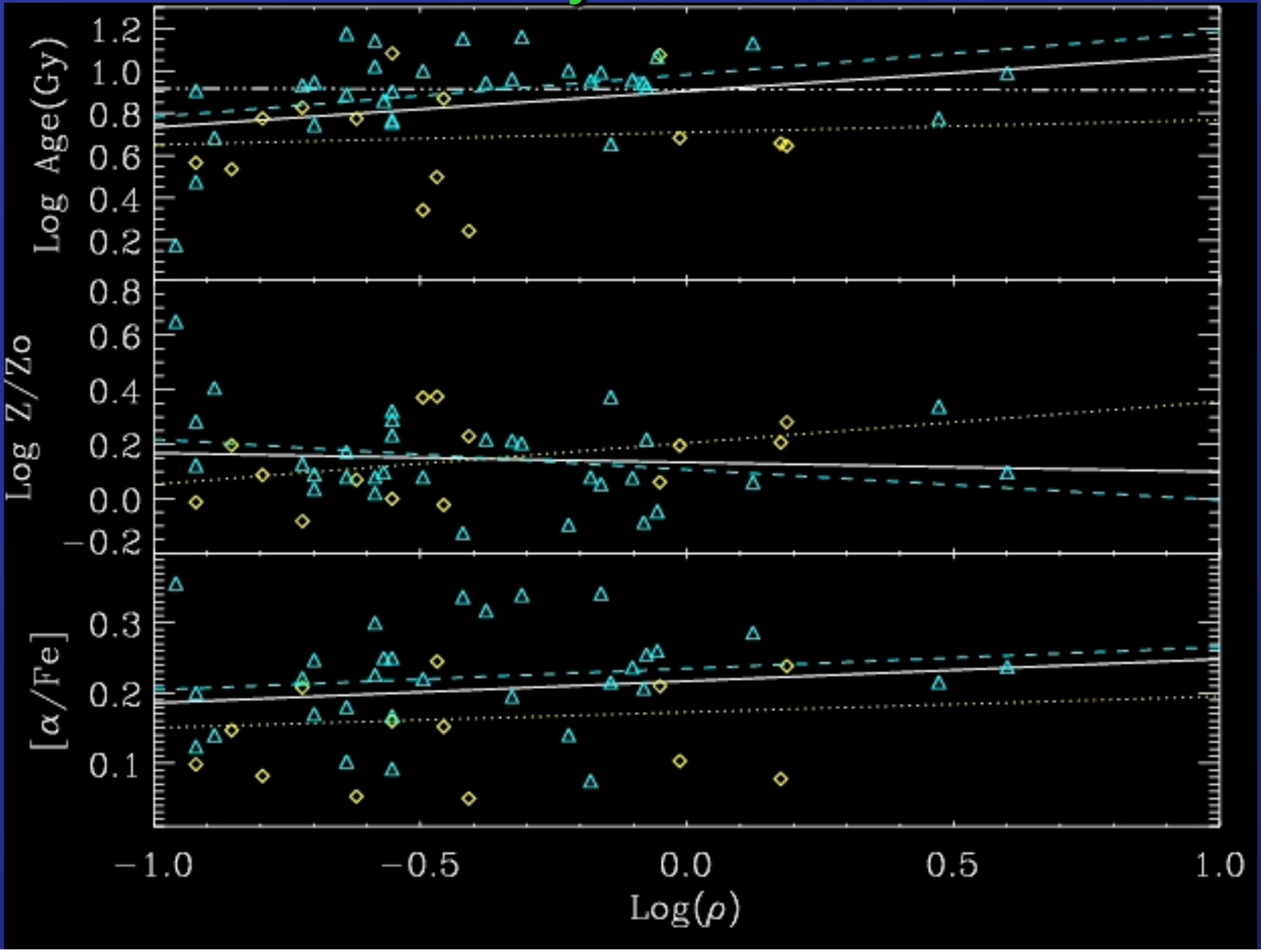
no clear correlation

Spearman test: 99% probability for a correlation to exhist

The Effect of Environment

ρ_{xyz} (gal × Mpc^{-3}) available for 73 % of the sample (Tully 1988)

The youngest galaxies are found in the lowest density environments



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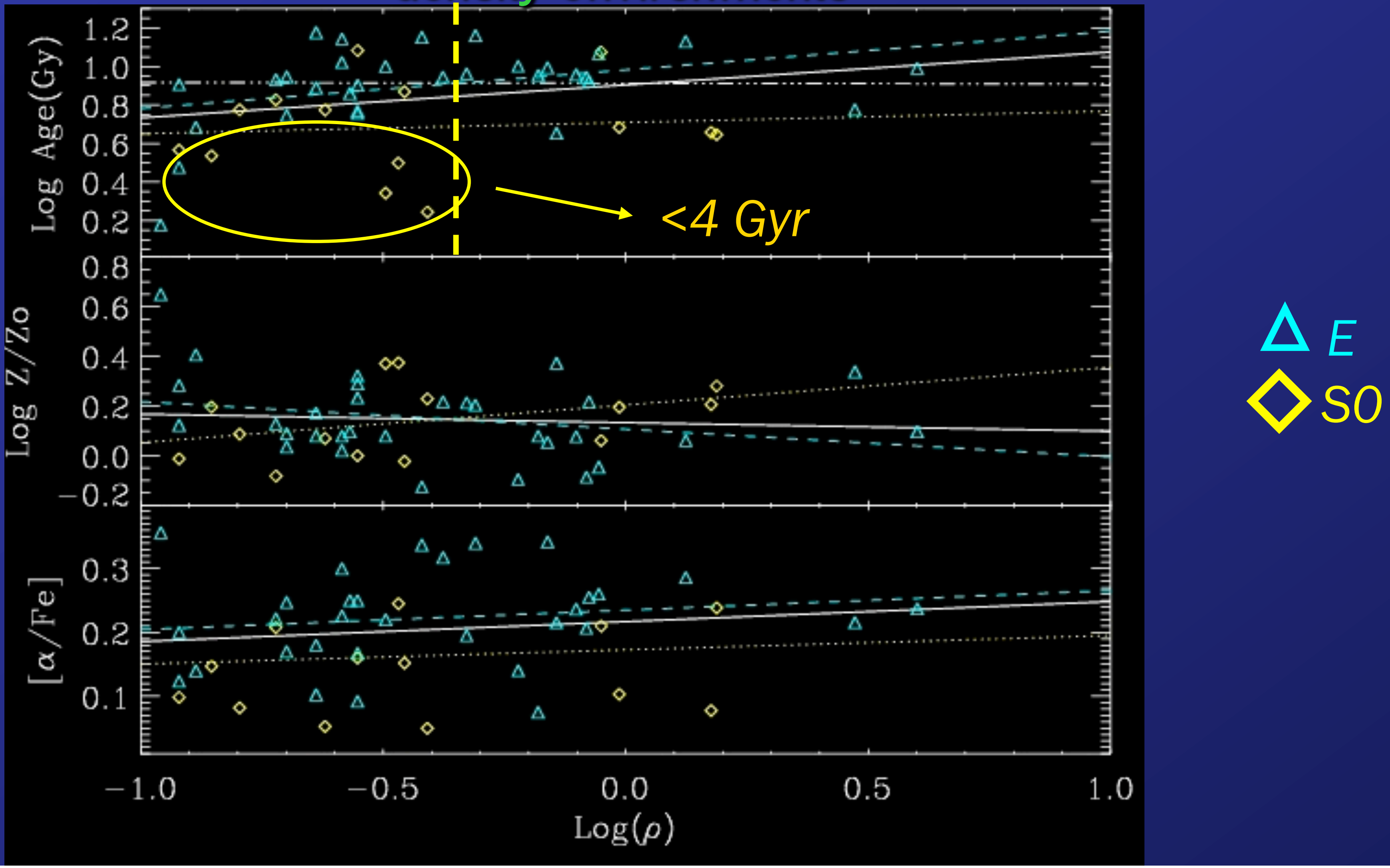
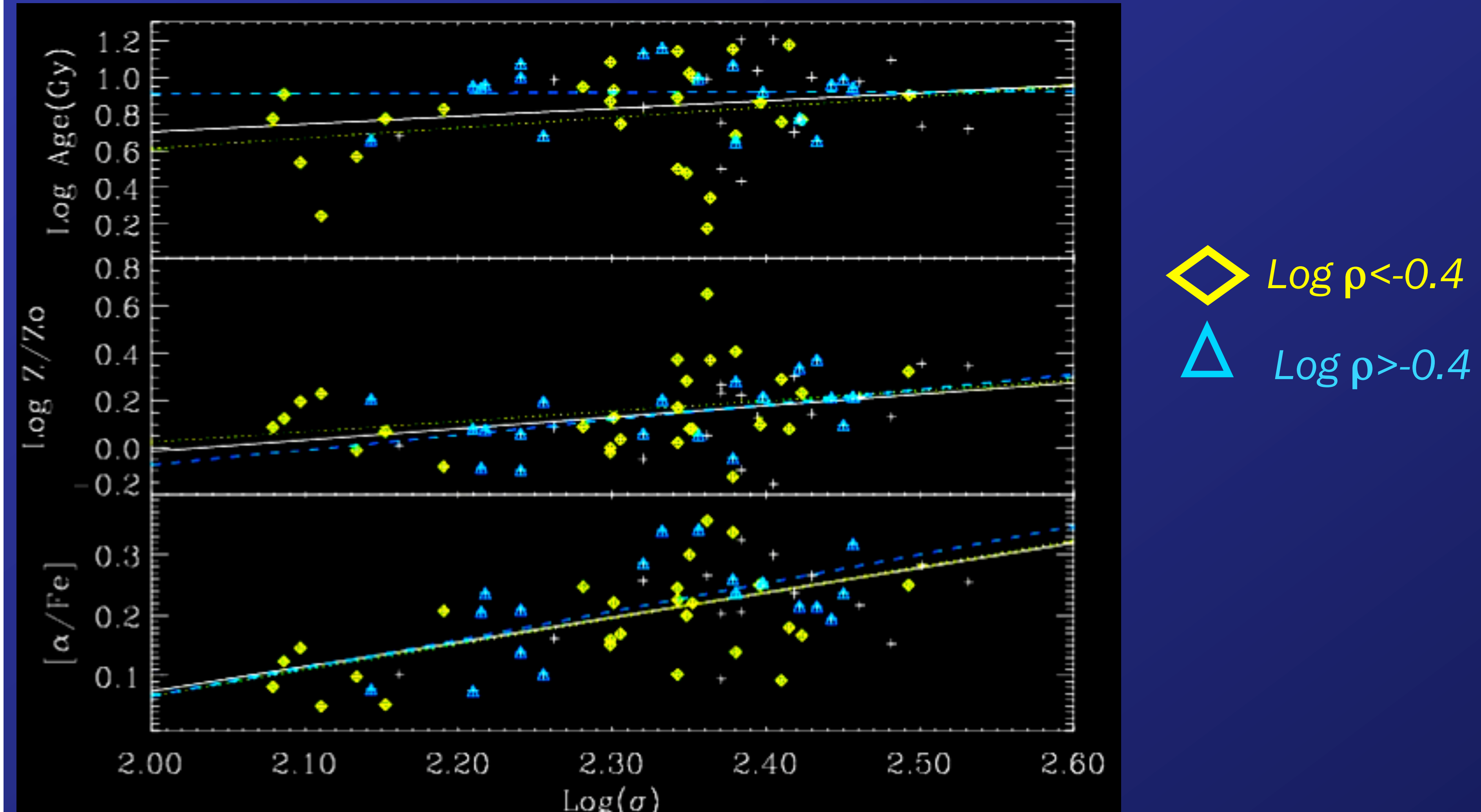


The Effect of Environment

- ✓ Very young galaxies are present in LDE
- ✓ Environment has no effect on Z–σ and [α/Fe]–σ relations



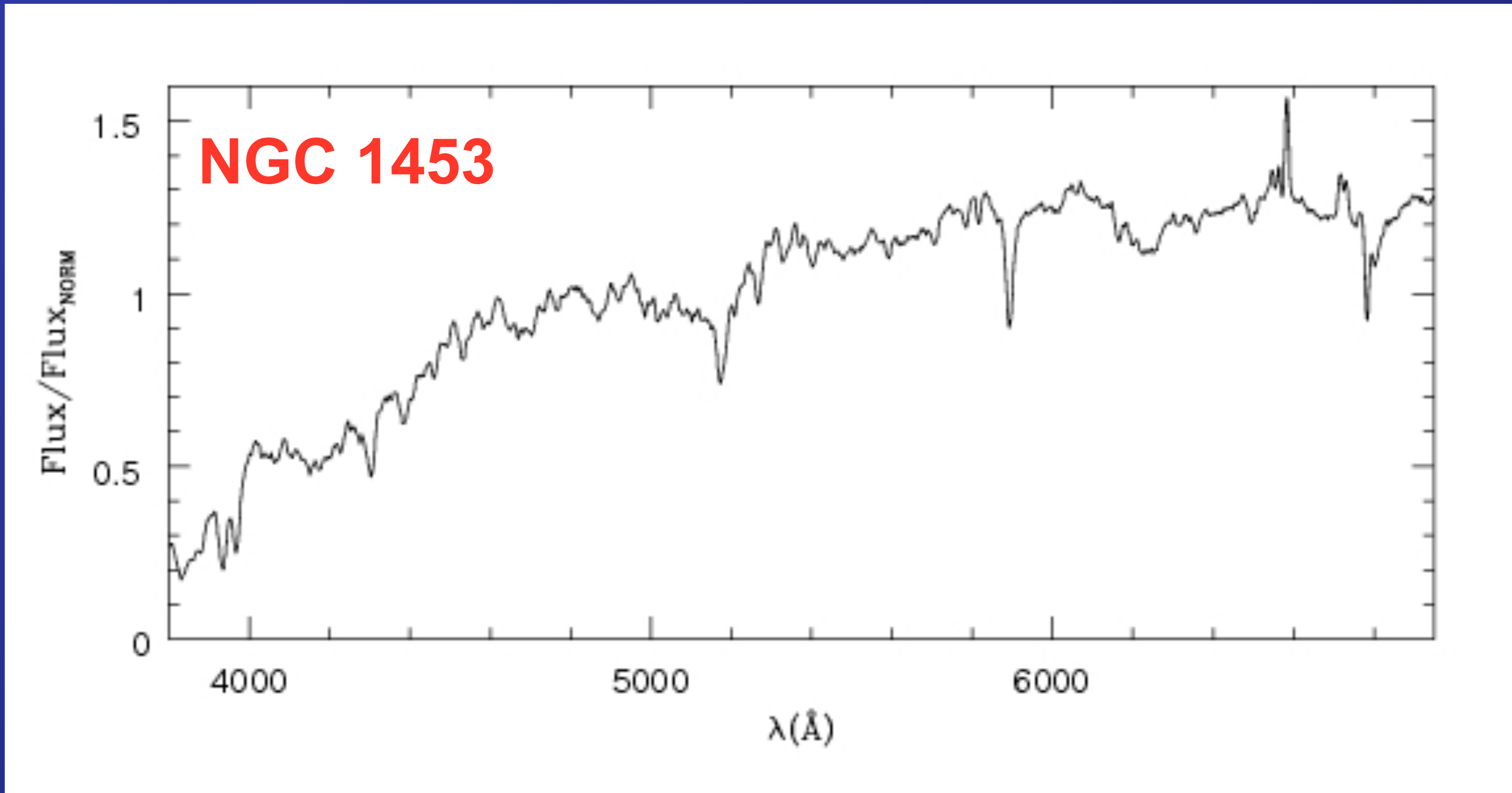
The Effect of Environment

- ✓ Very young galaxies are present in LDE
- ✓ Environment has no effect on Z–σ and [α/Fe]–σ relations

❖ Rejuveation episodes or more prolonged SF?

No difference in [α/Fe]–σ between LDE and HDE

Emission Lines



- ✓ Computation of the emission lines requires careful subtraction of the underlying stellar spectrum
- ✓ We fit the galaxy spectra with new SSPs (*Bressan (unpublished), Clemens et al. 2009, Chavez et al. 2009*) based on the MILES empirical stellar library

SSPs

Bressan (unpublished), Clemens et al. 2009, Chavez et al. 2009

✓ ISOCHRONES:

Massive stars: Padova 94 (revision by *Bressan, Granato & Silva 1998*, including MIR and new AGB mas loss)

Low and intermediate mass stars : Padova 08 (*Bertelli et al. 2008,* including Post -AGB stars)

✓ SPECTRAL LIBRARY:

Optical: MILES (*Sanchez-Blazquez et al. 06*), λλ 3525 - 7500 Å at 2.3 Å FWHM

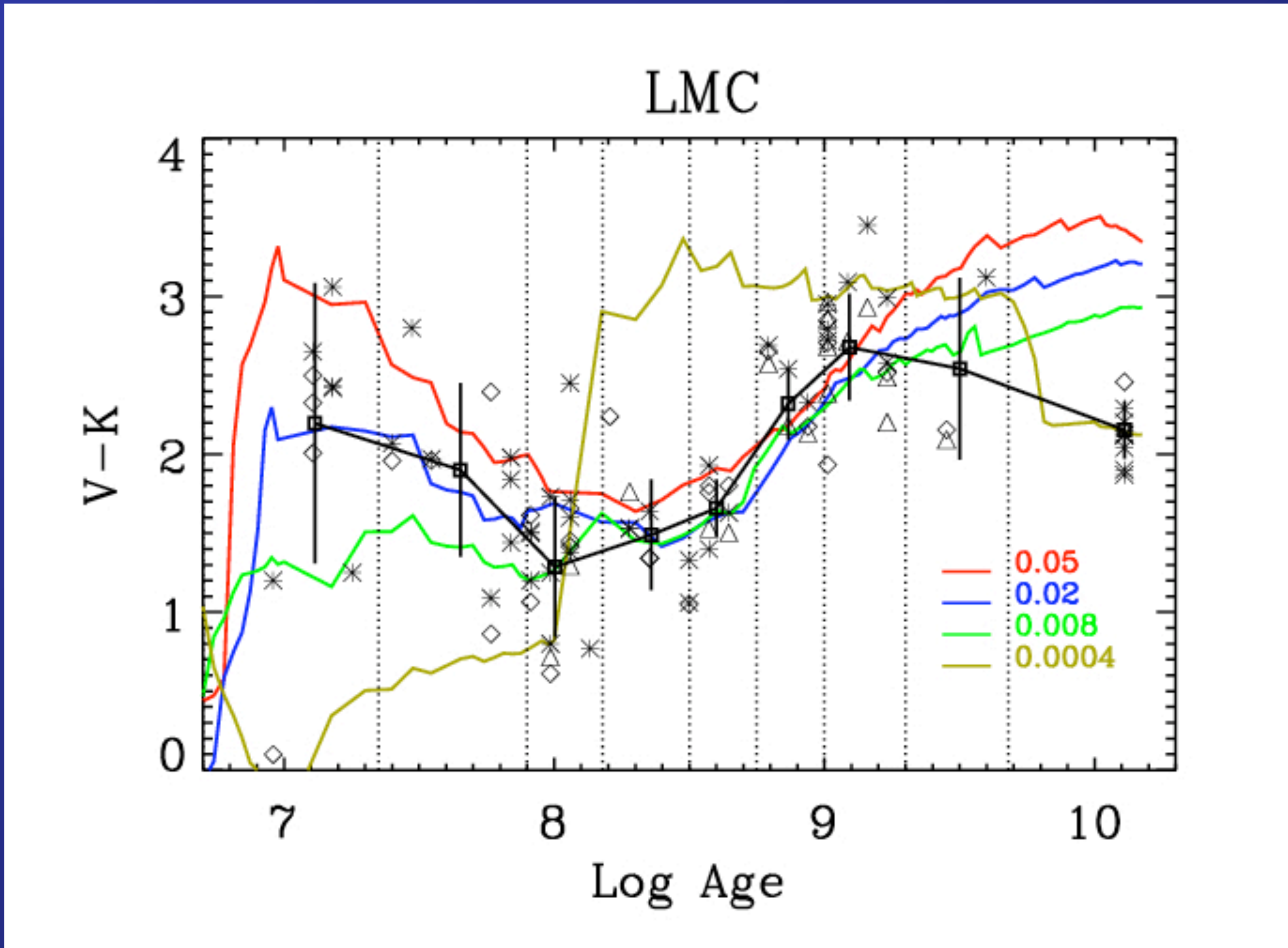
UV: (*Rodriguez-Merino et al. 2005*)

NIR: (*Lejeune et al. 1997*)

Cool stars integrated by NEXTGEN models (*Hauschildt et al. 1999*)

SSPs: calibration on LMC clusters

Bressan (unpublished), Clemens et al. 2009, Chavez et al. 2009



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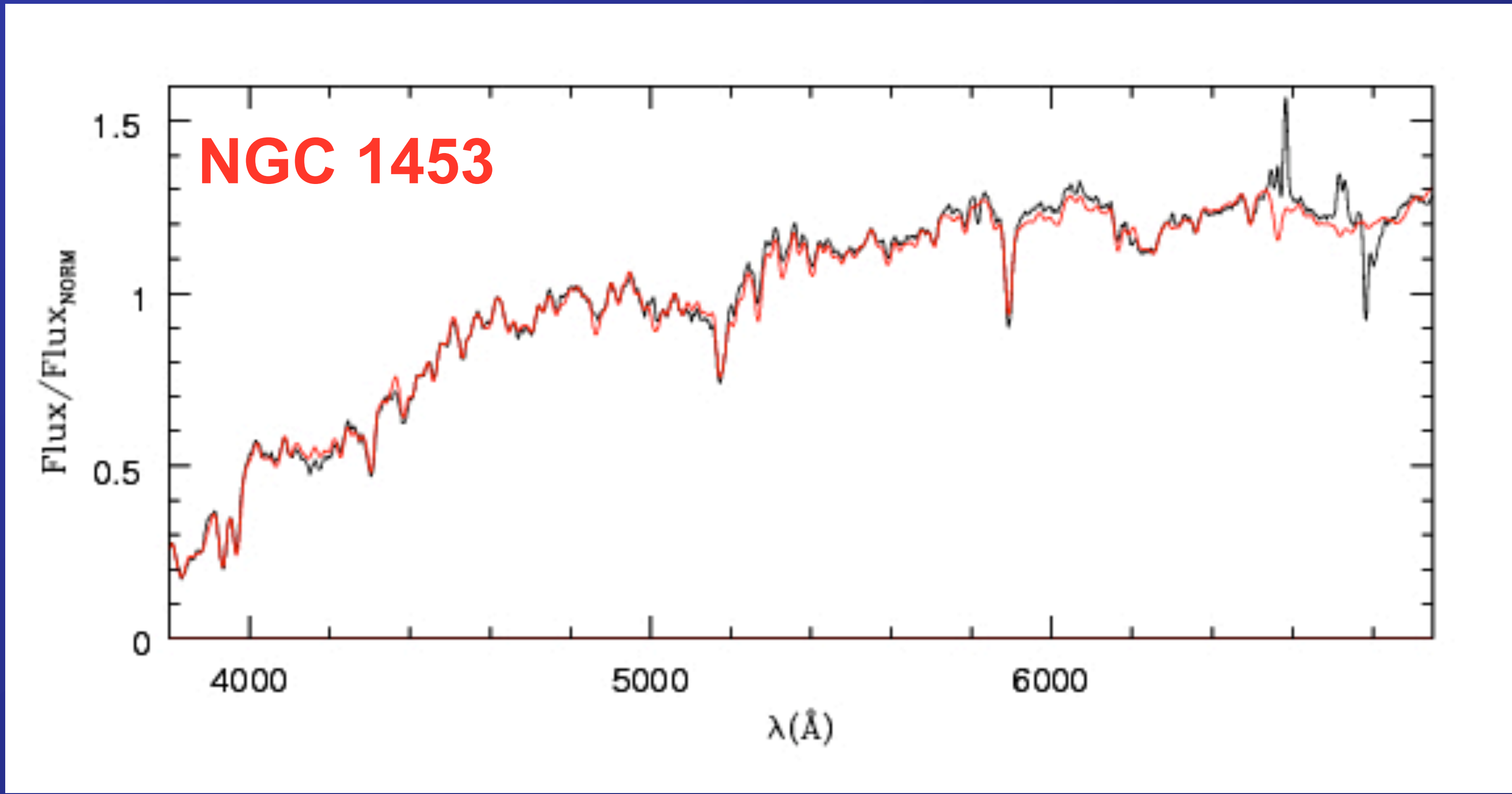

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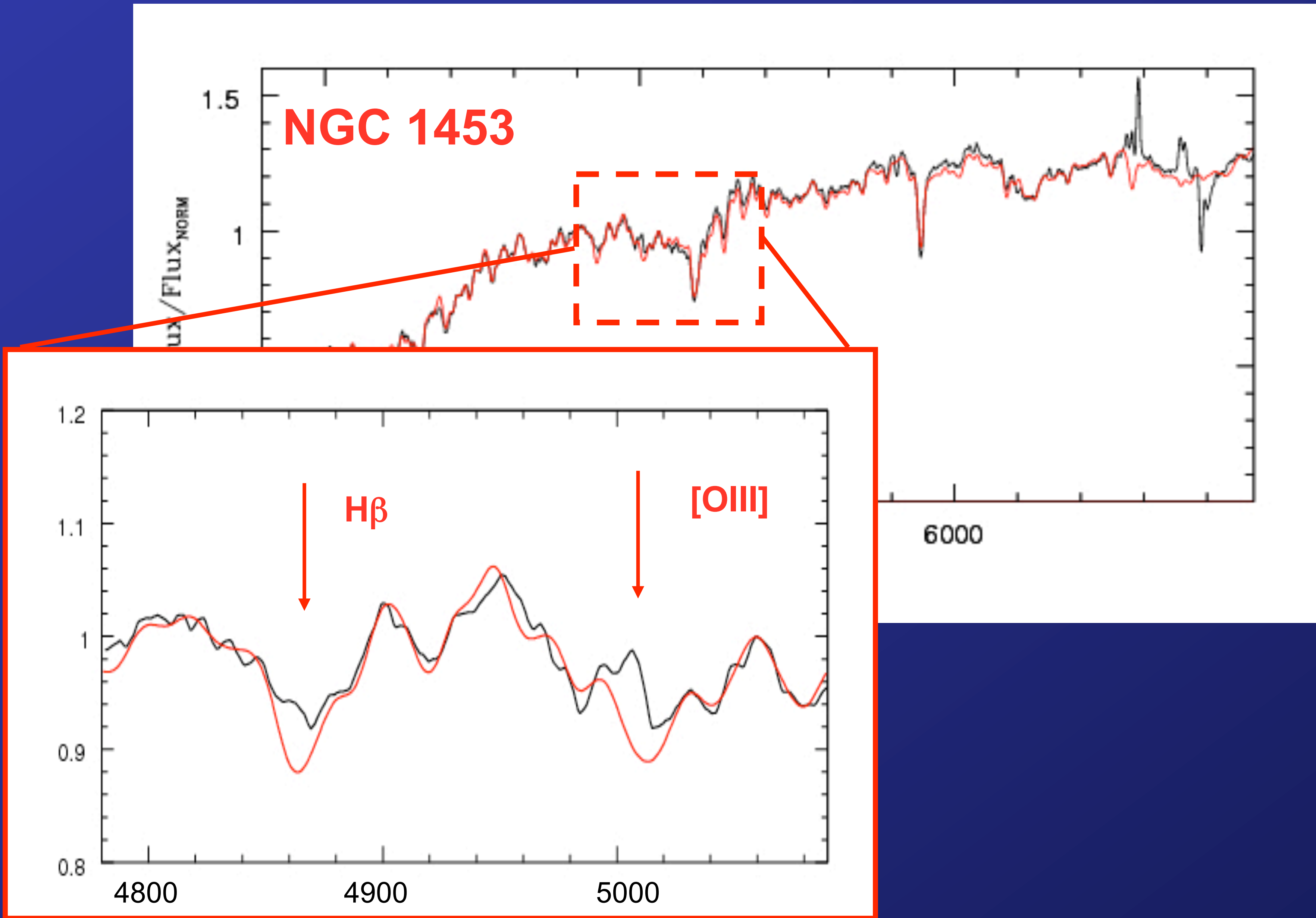
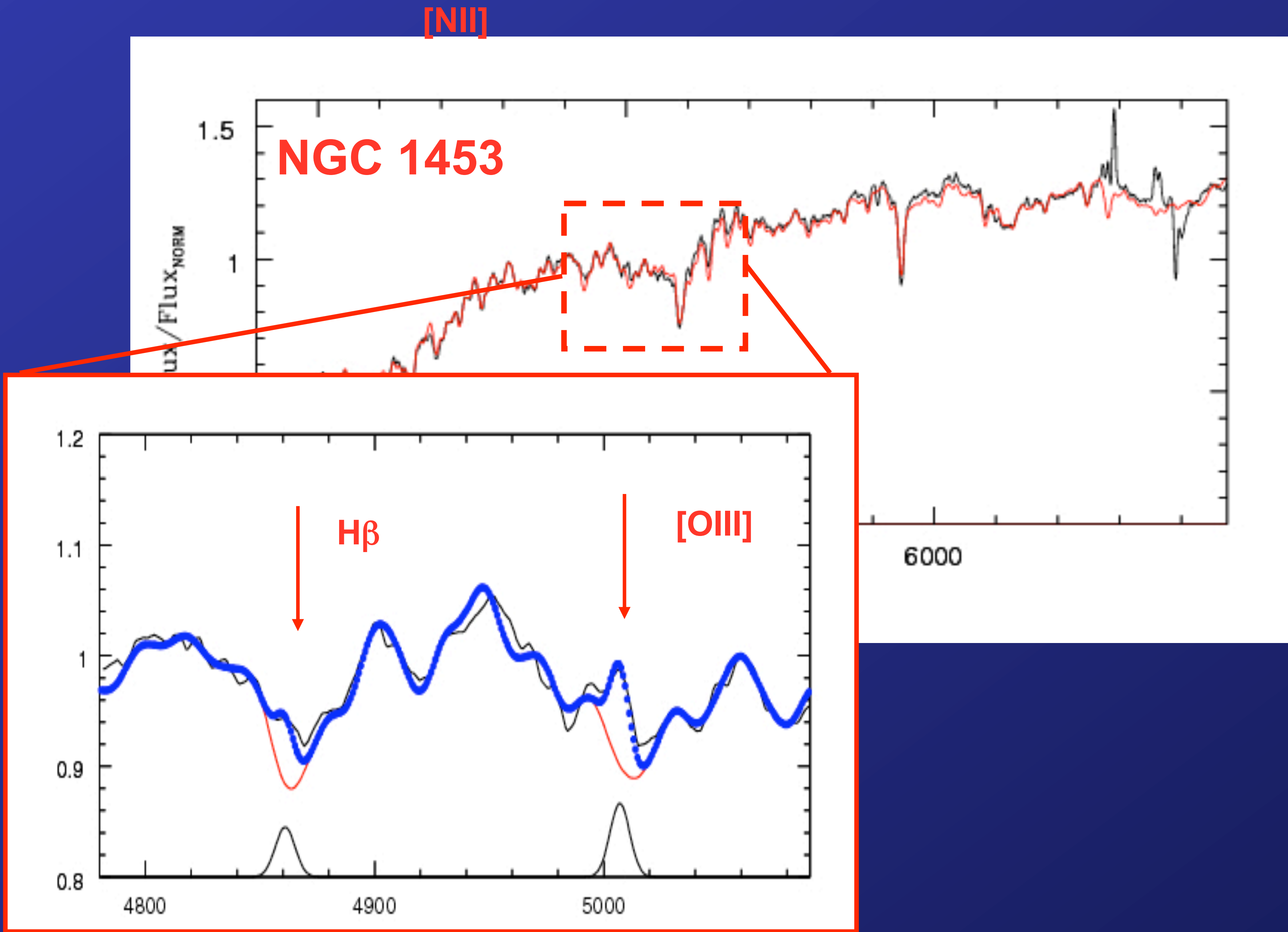
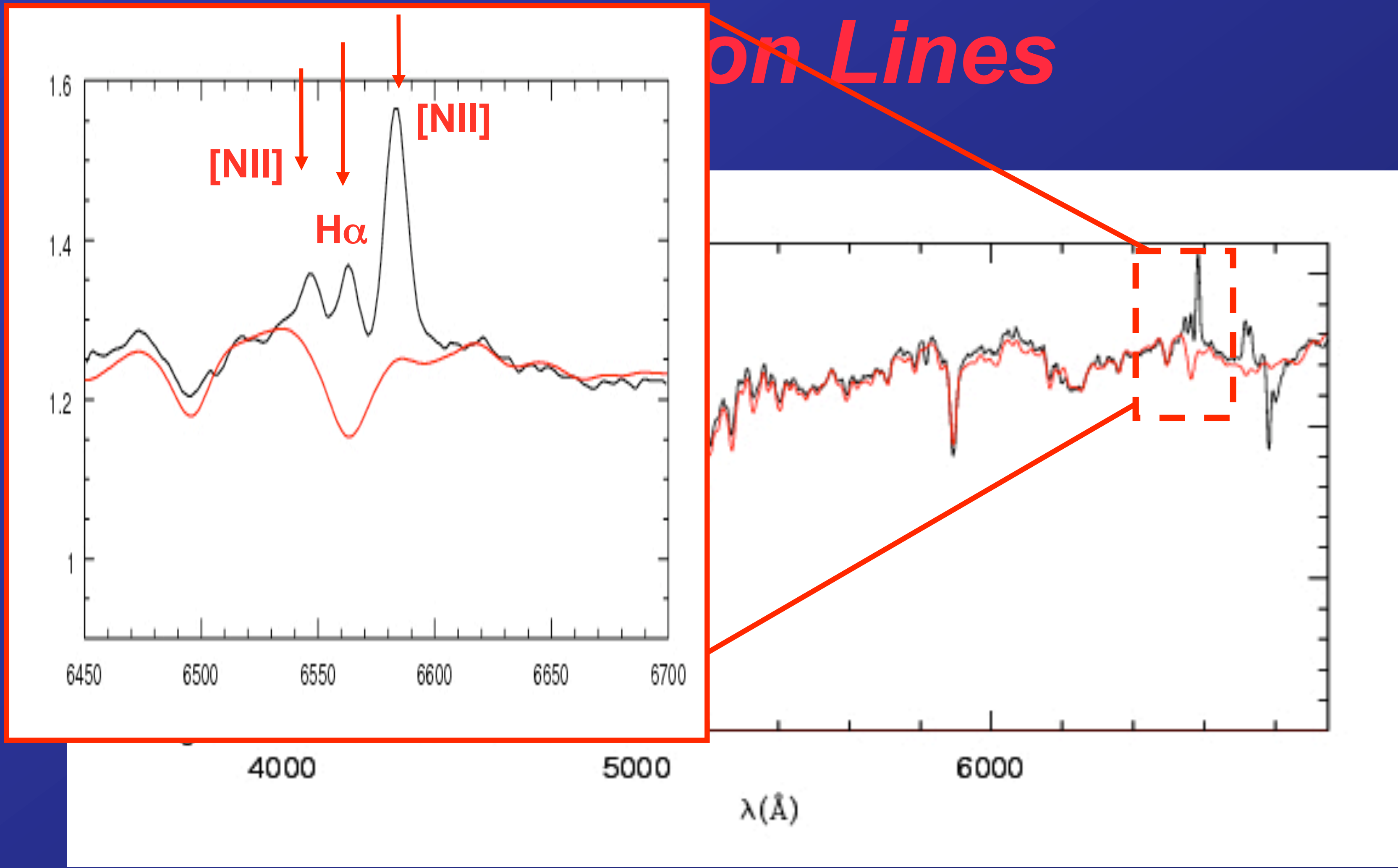


Emission Lines

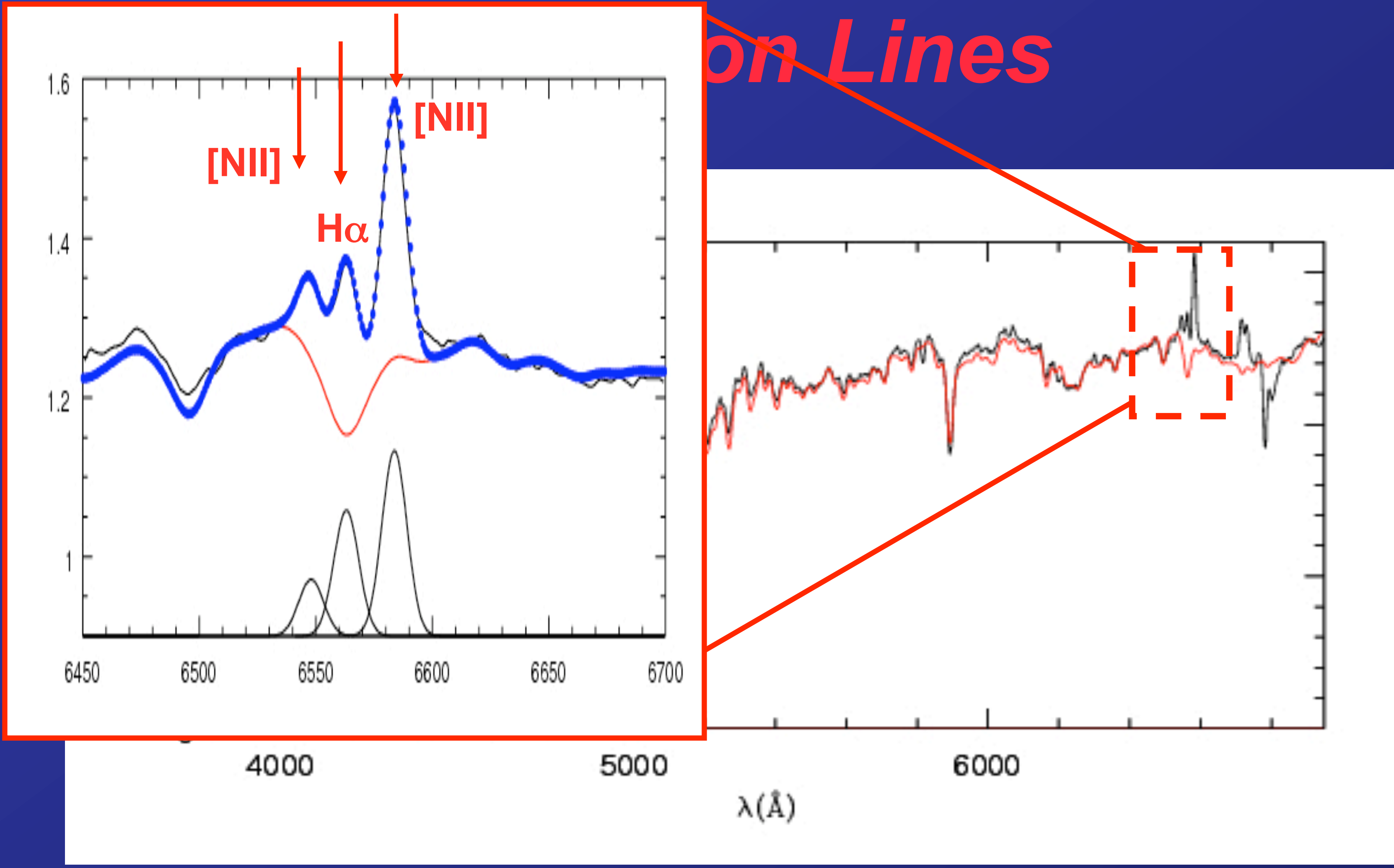


on Lines



1.6
1.4
1.2
1
6450
6500
6550
6600
6650
6700
[NII]
[NII]
Hα
4000
5000
6000
λ(Å)

on Lines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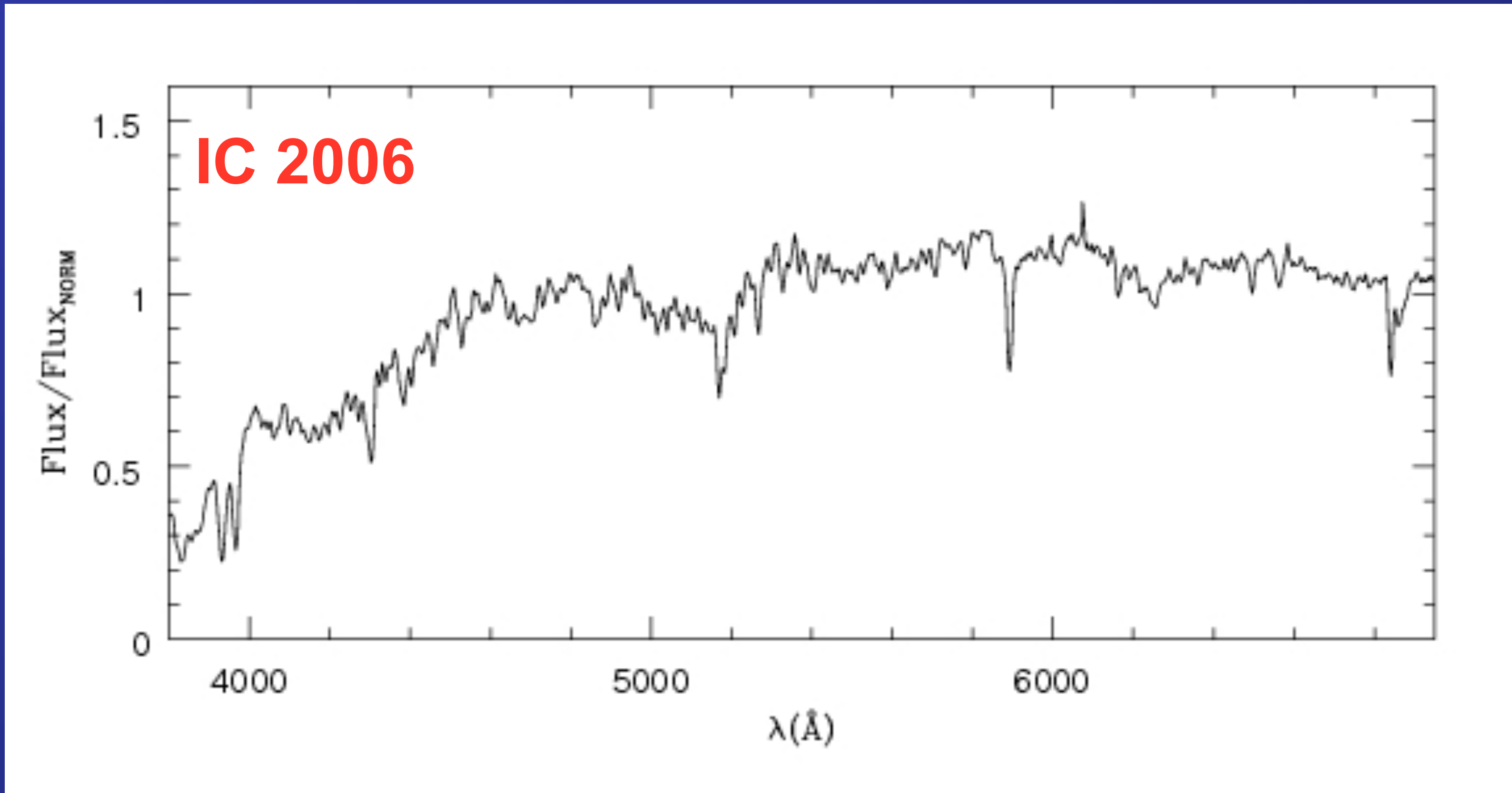

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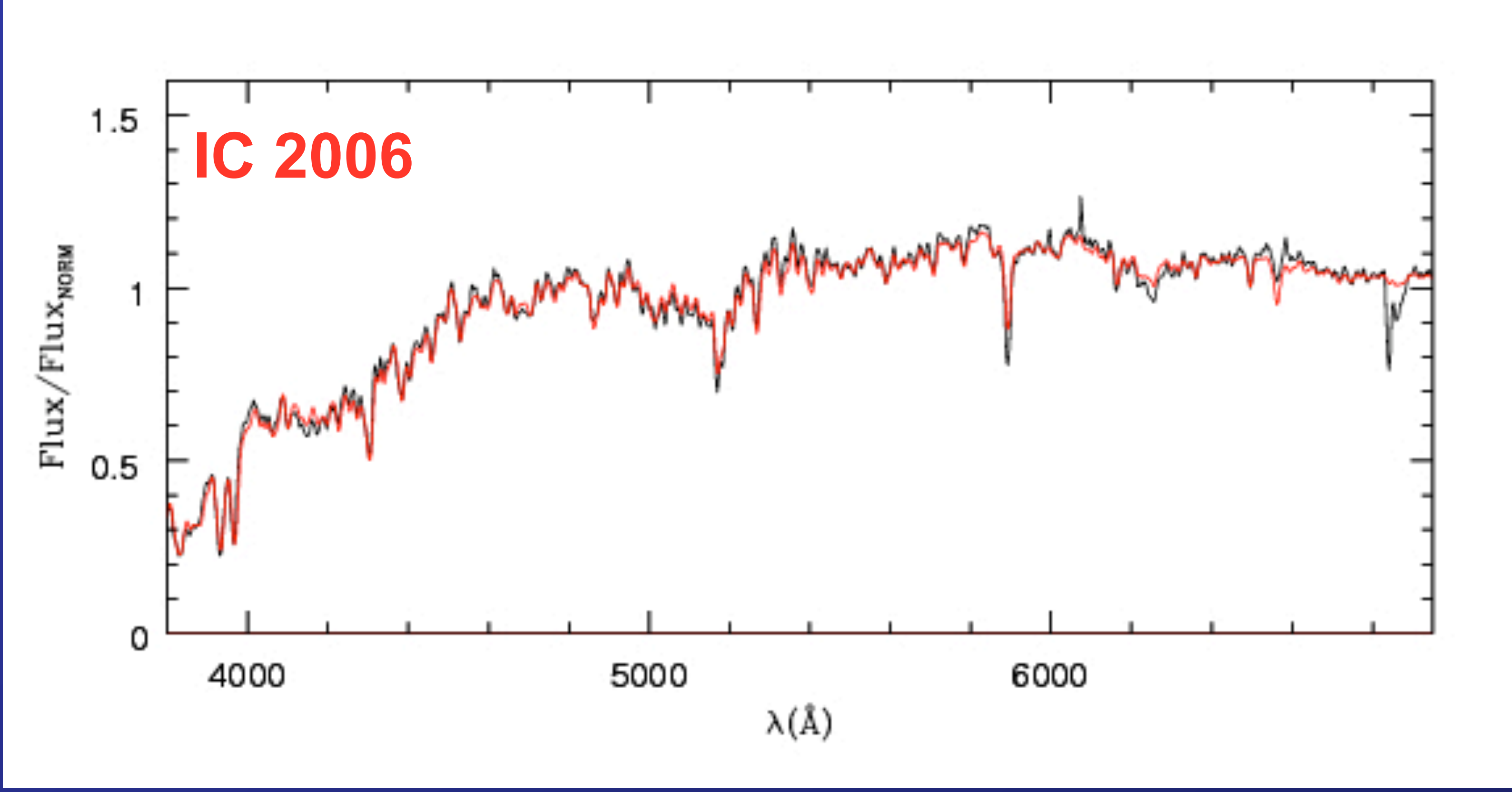
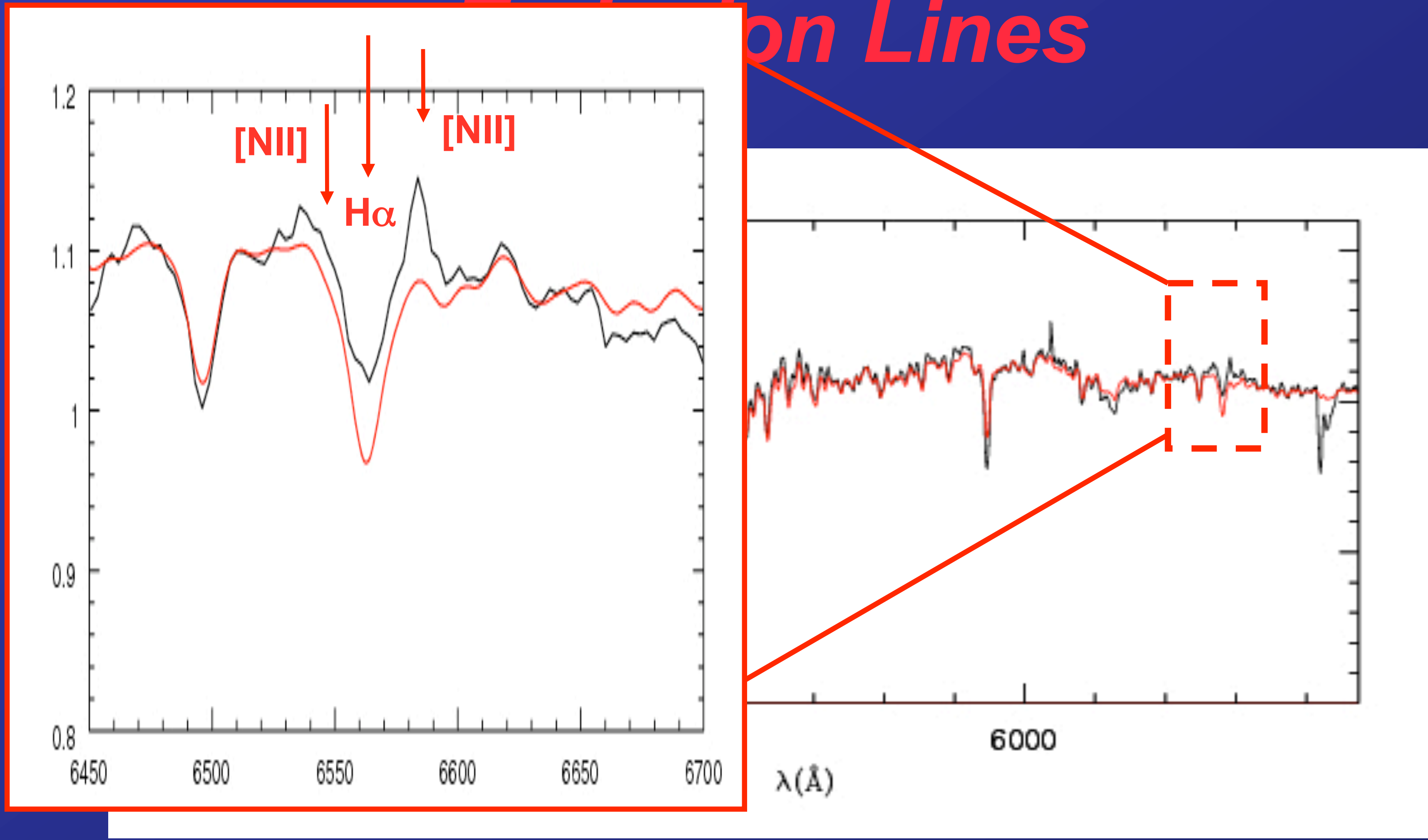
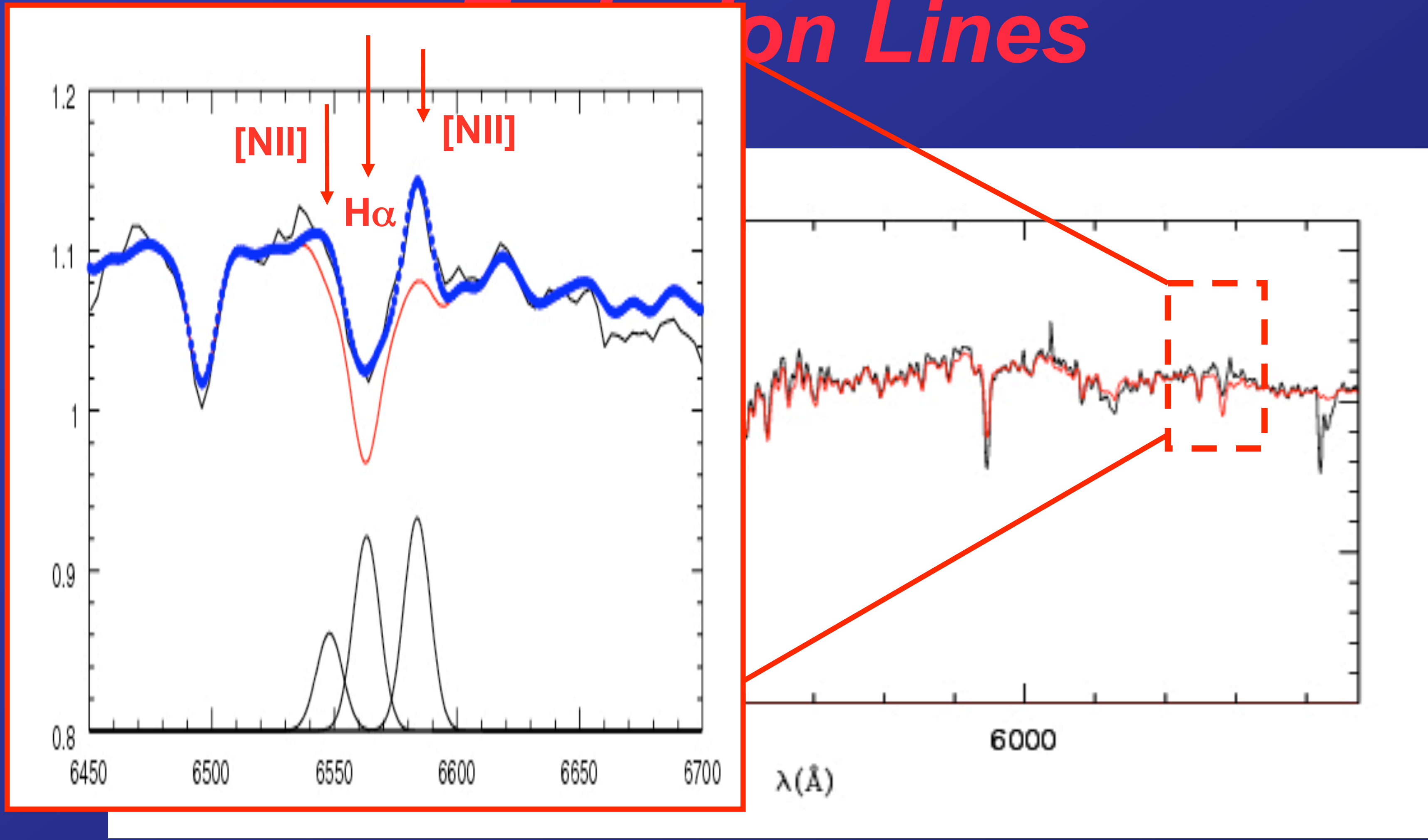


on Lines

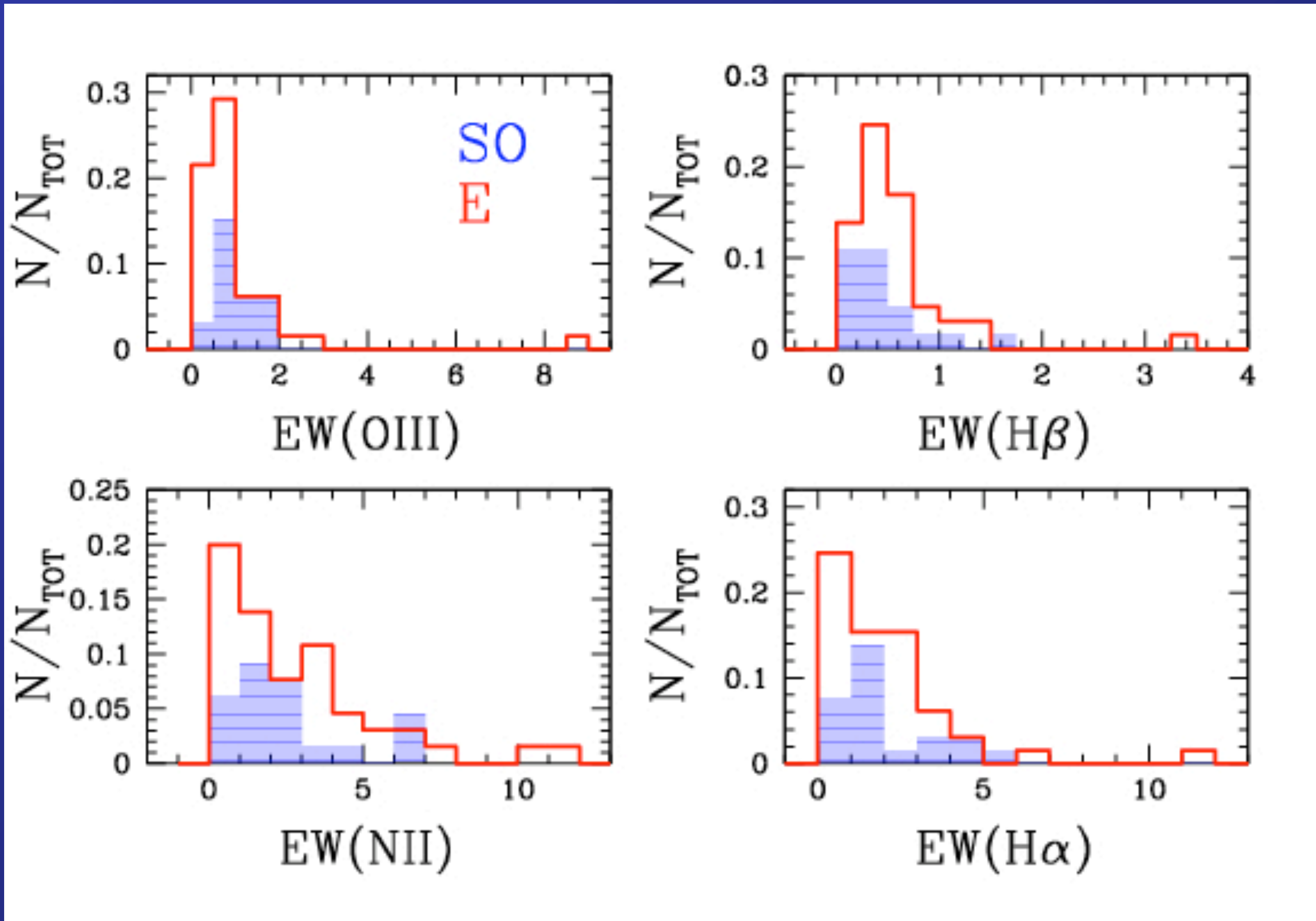


...on Lines

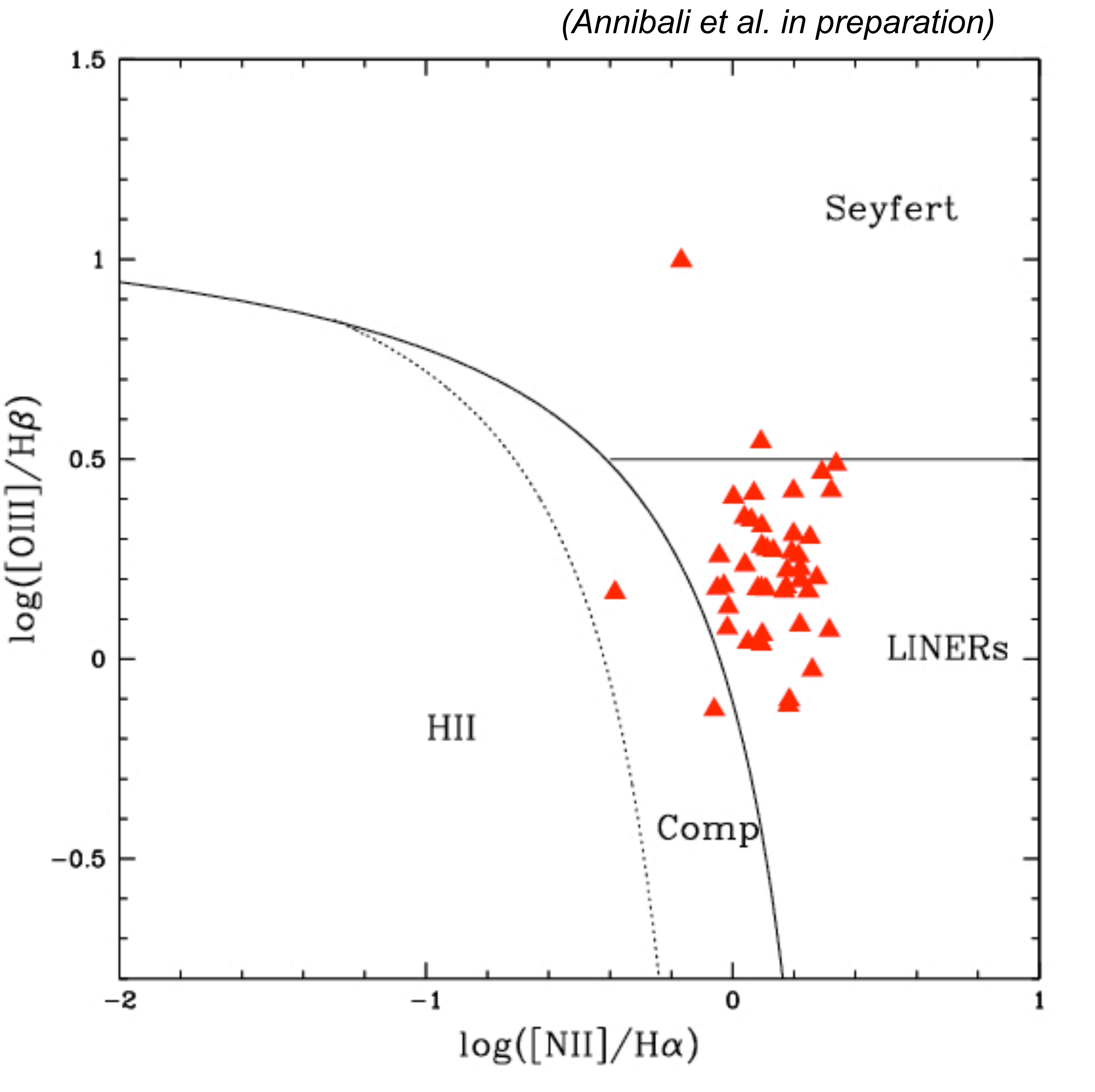


Emission Lines

(Annibali et al. in preparation)

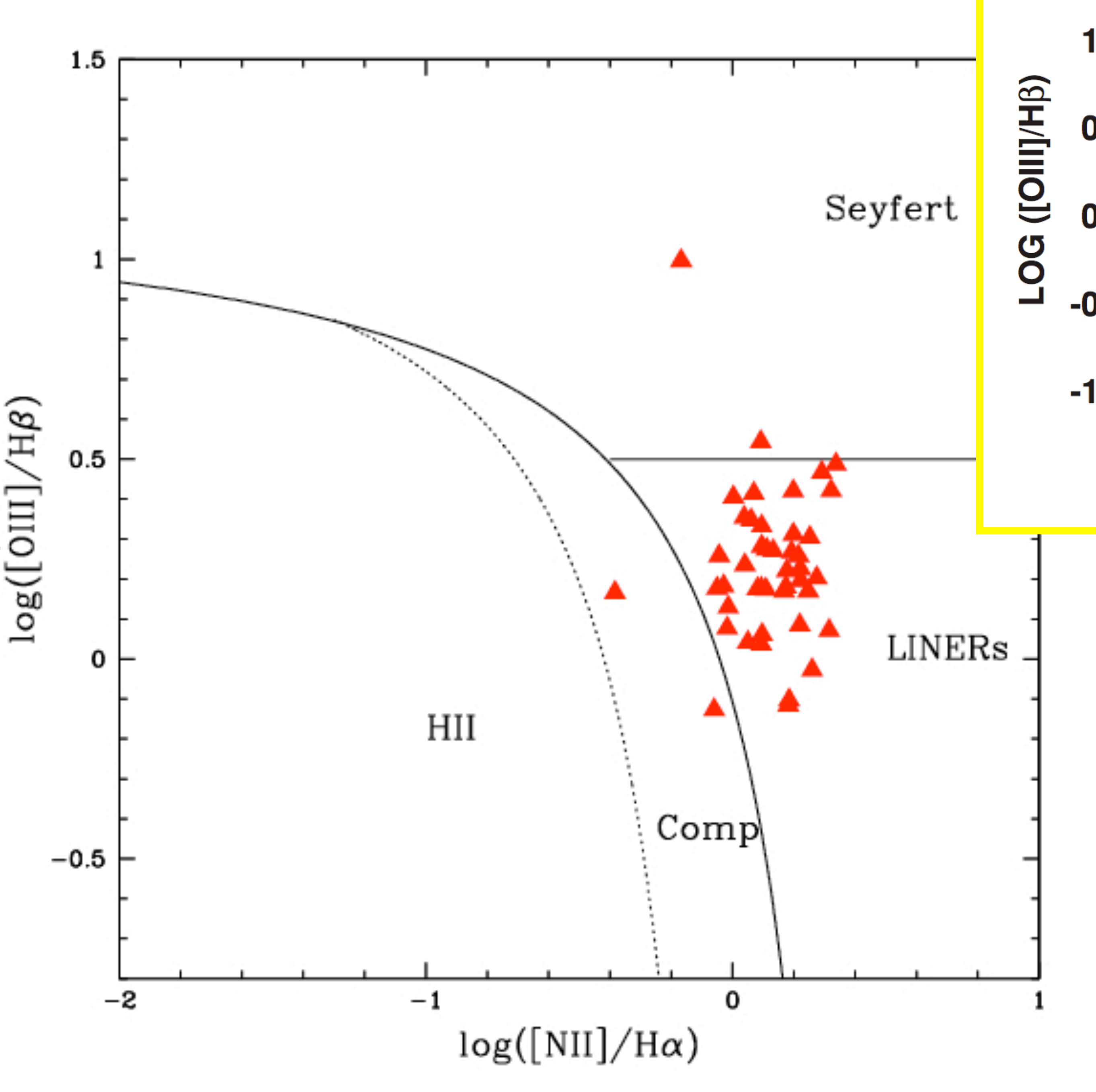


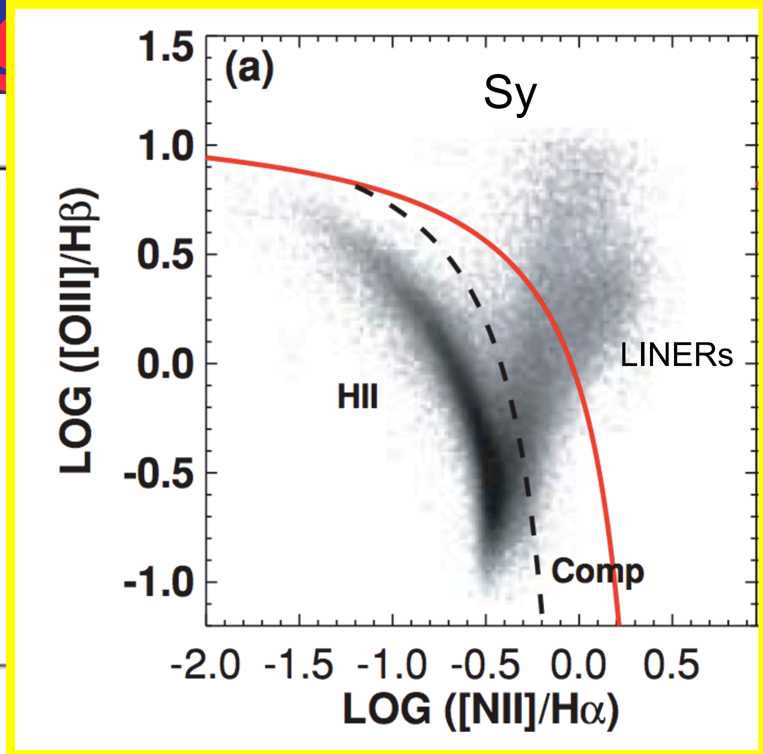
Diagnostic Diagram



$r < r_e/16$

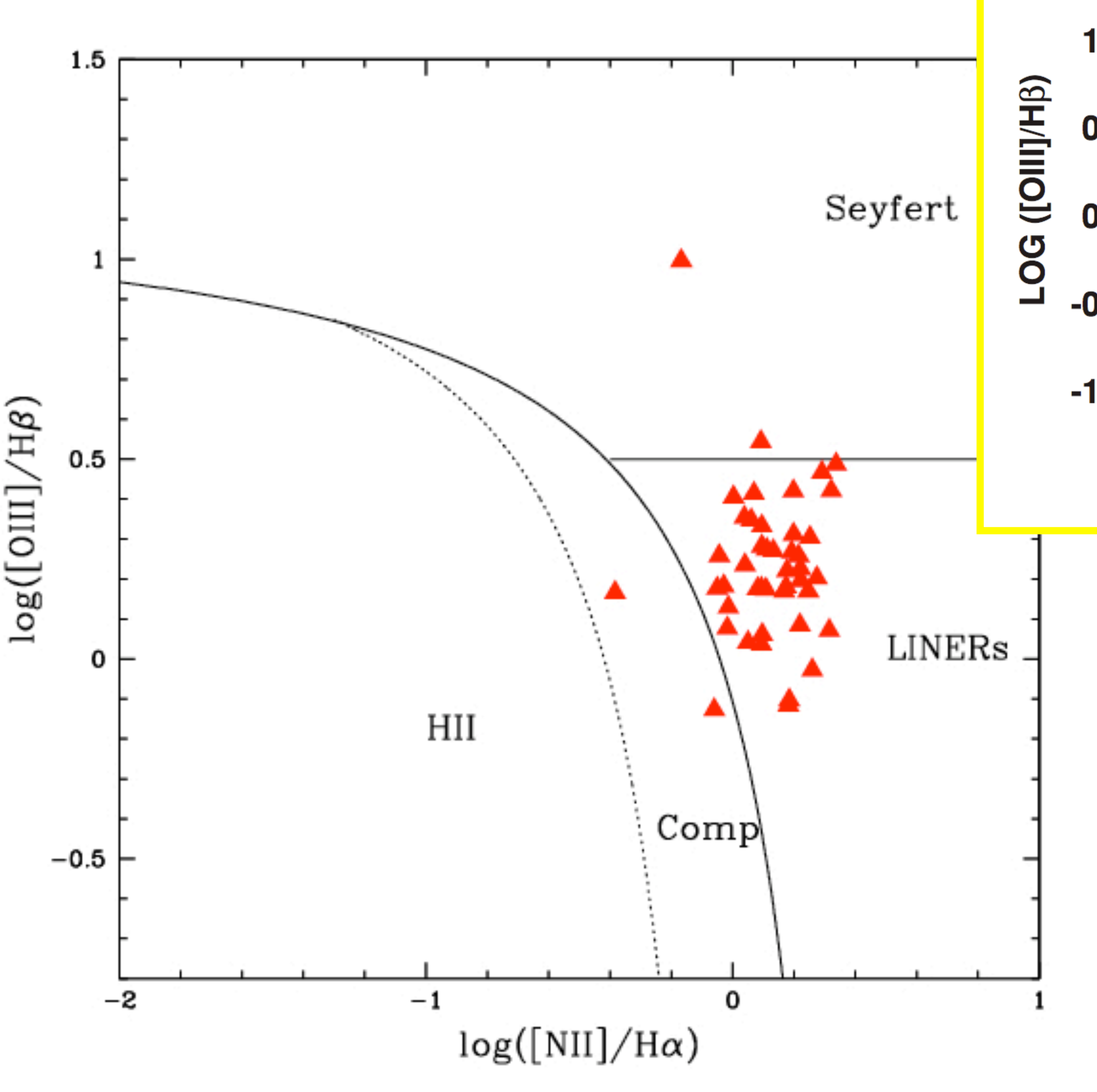
Diagnostic Diag

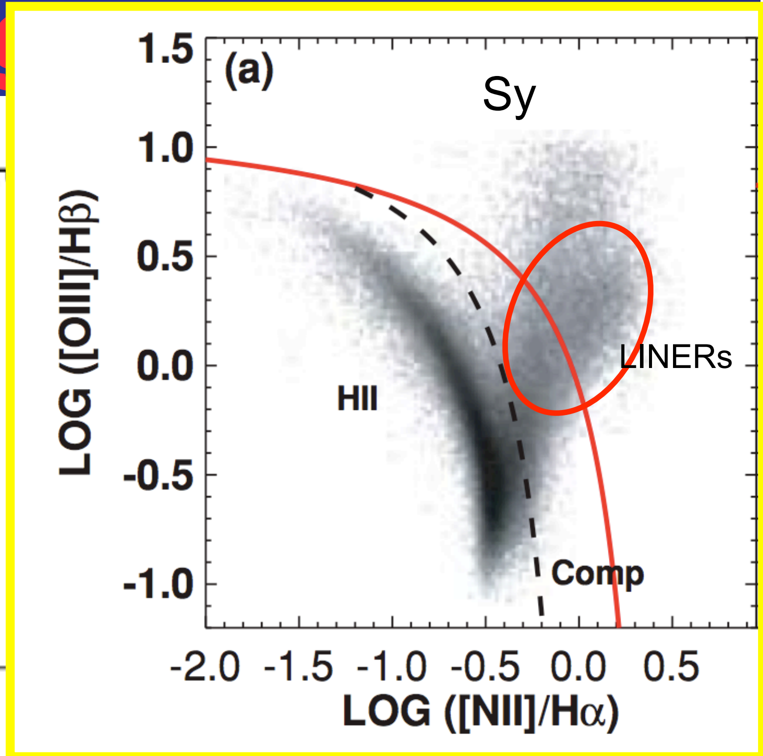




Kewley et al. 2006

Diagnostic Diag





Kewley et al. 2006

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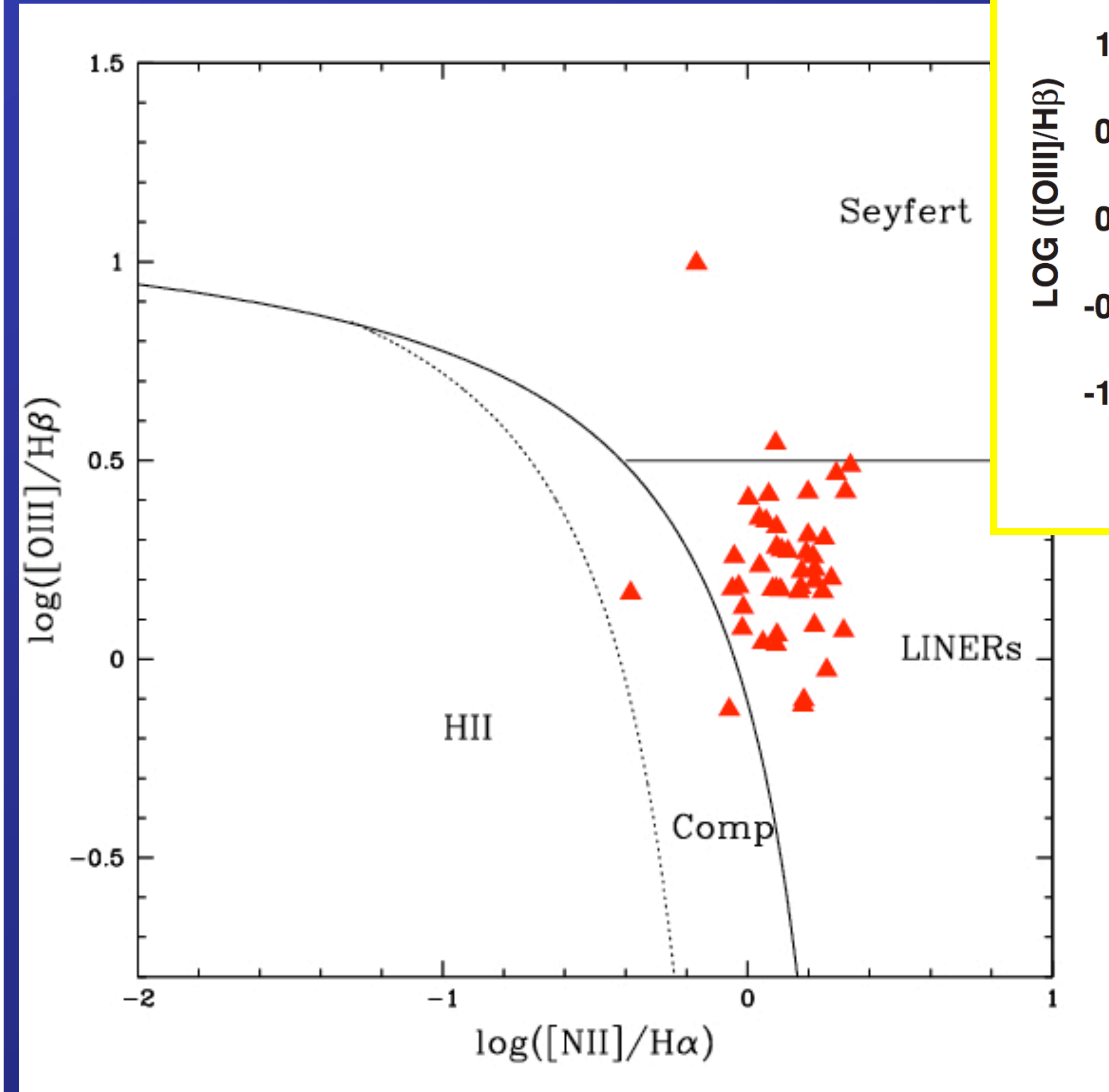
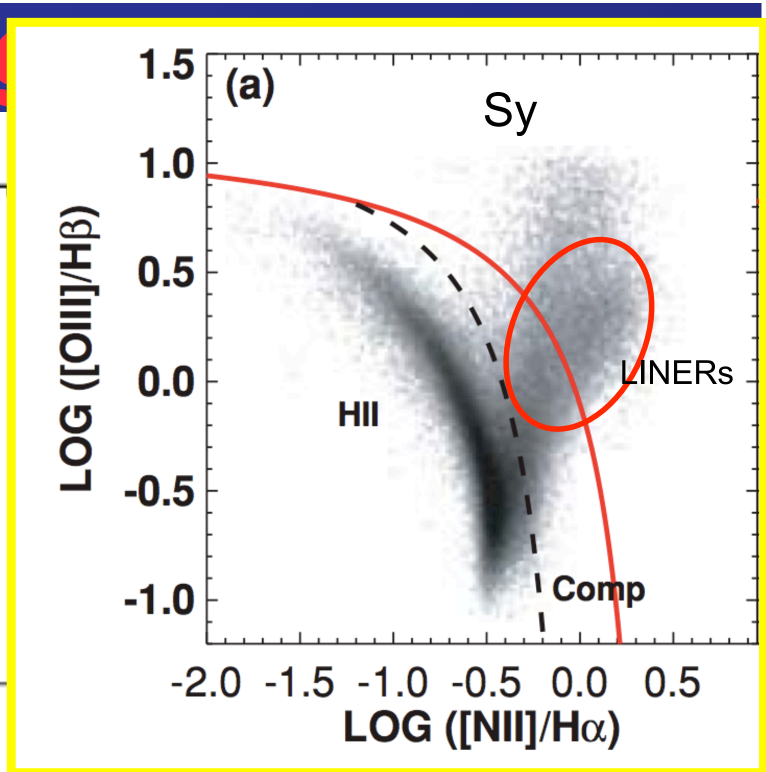




Kewley et al. 2006

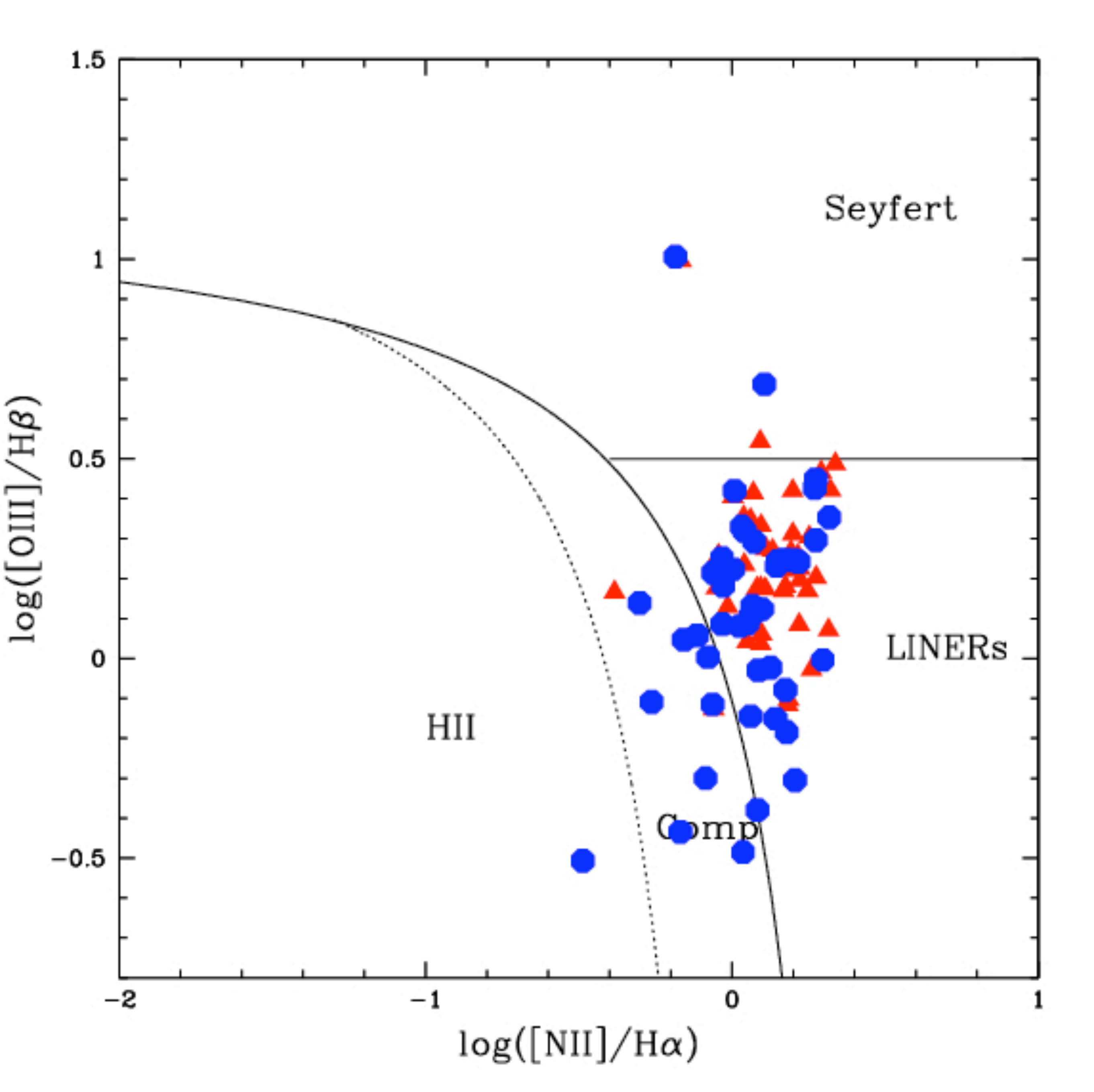
LINERs:

Low accretion rate AGNs ?
(e.g., *Kewley et al 06*)

Photoioniz from hot stars ?
(e.g., *Sarzi et al 06*)

Shocks?

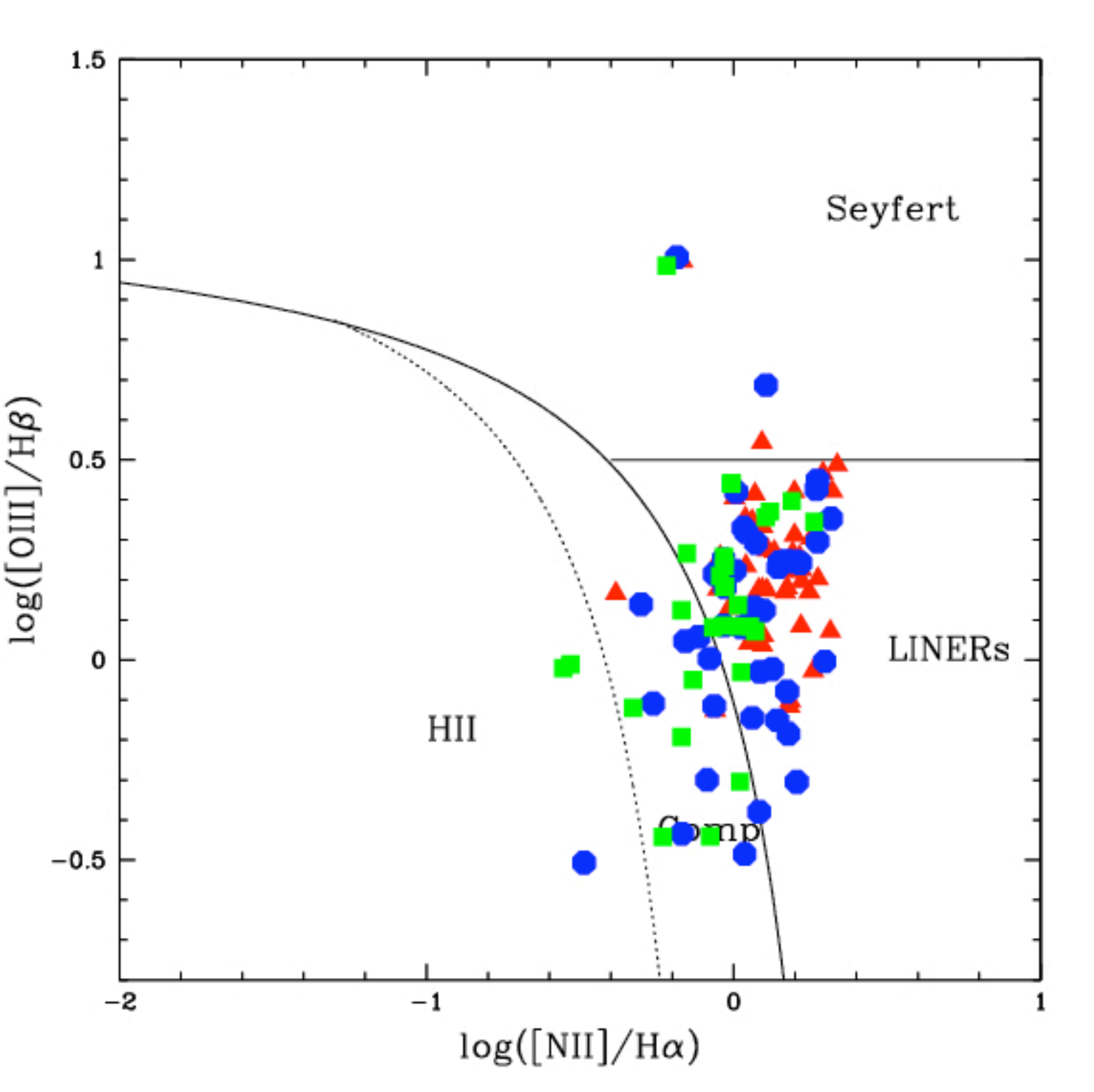
Diagnostic Diagram



$r < r_e/16$

$r_e/16 < r < r_e/8$

Diagnostic Diagram



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$r_e/8 < r < r_e/4$

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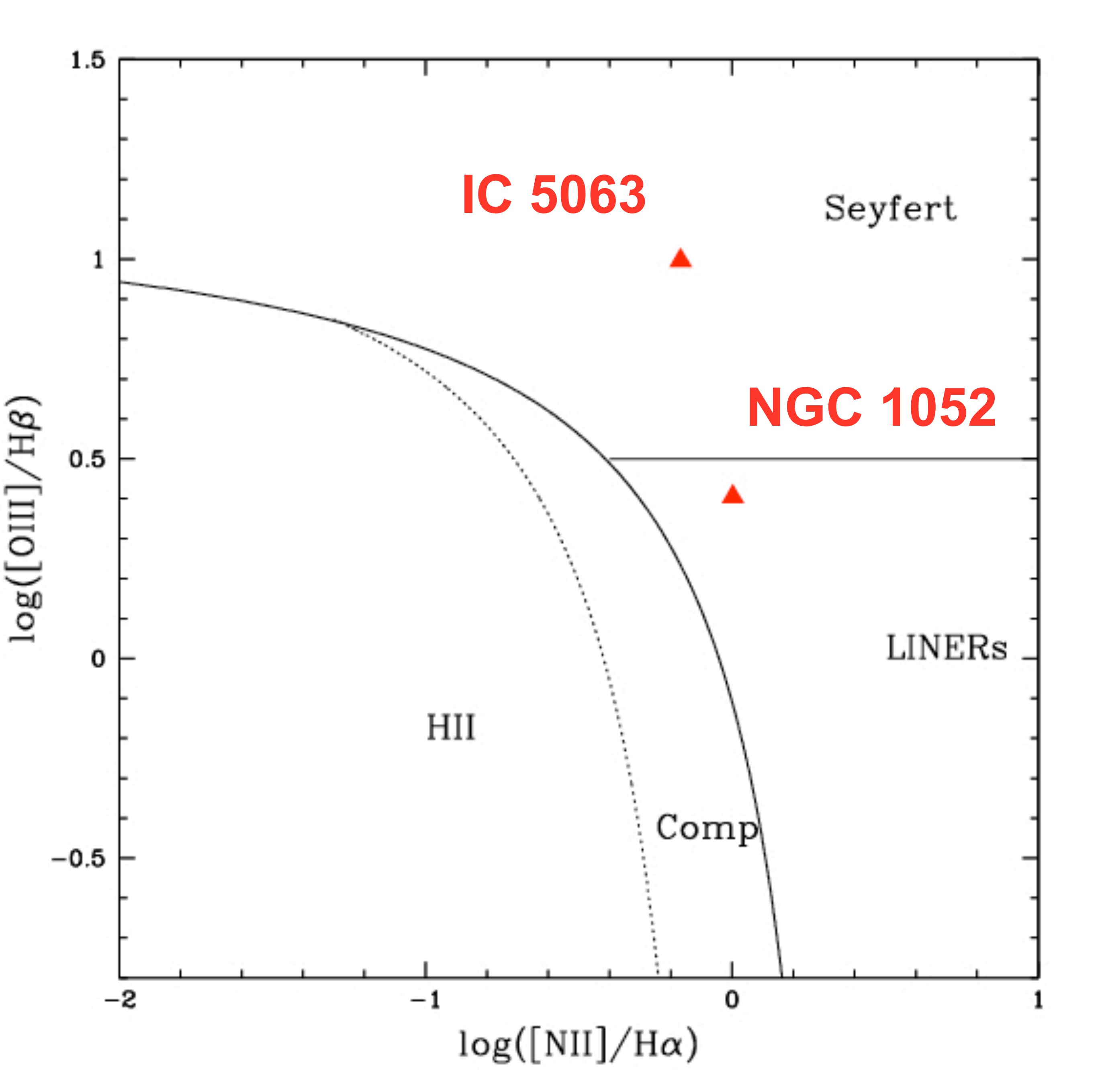

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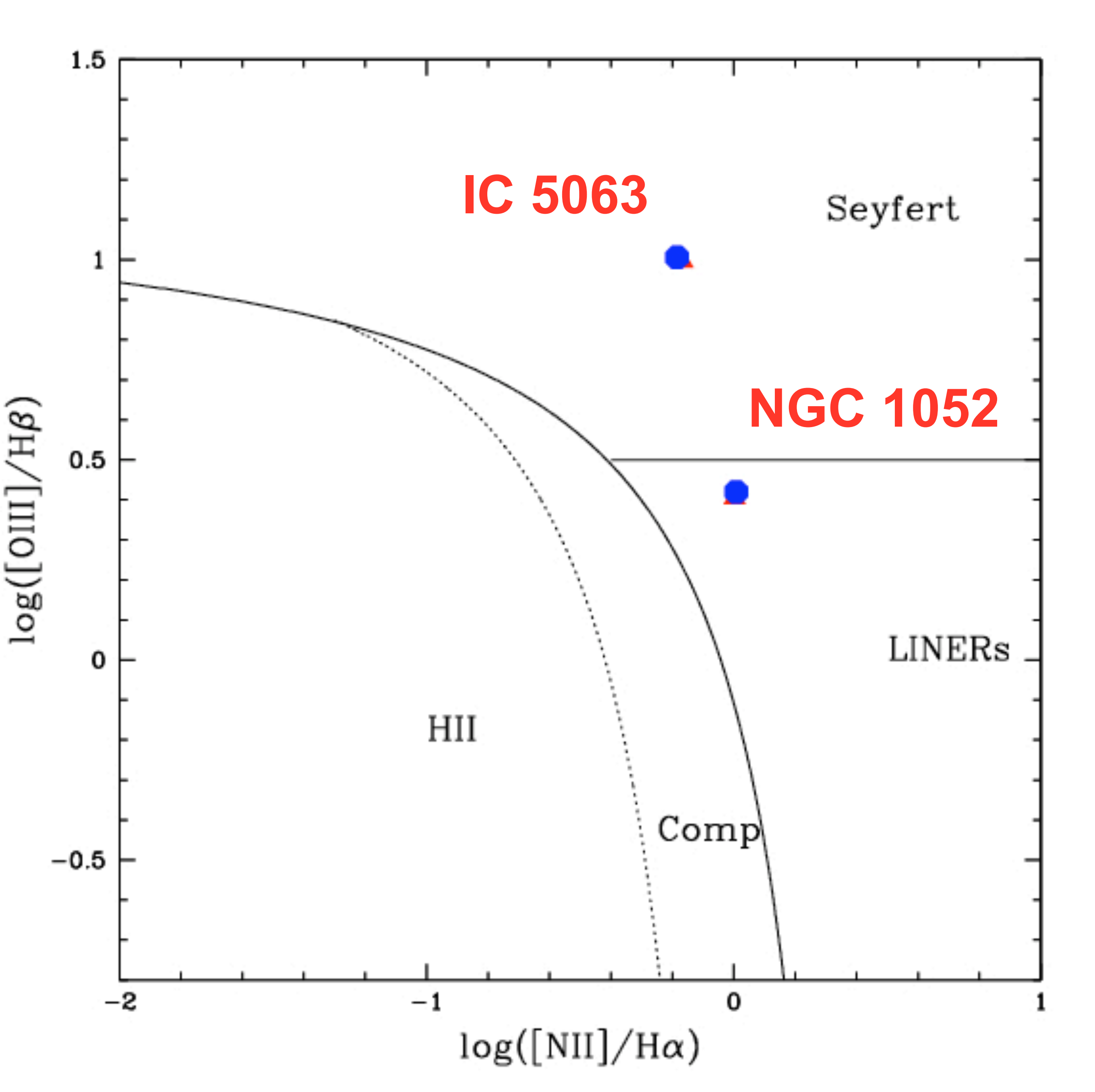

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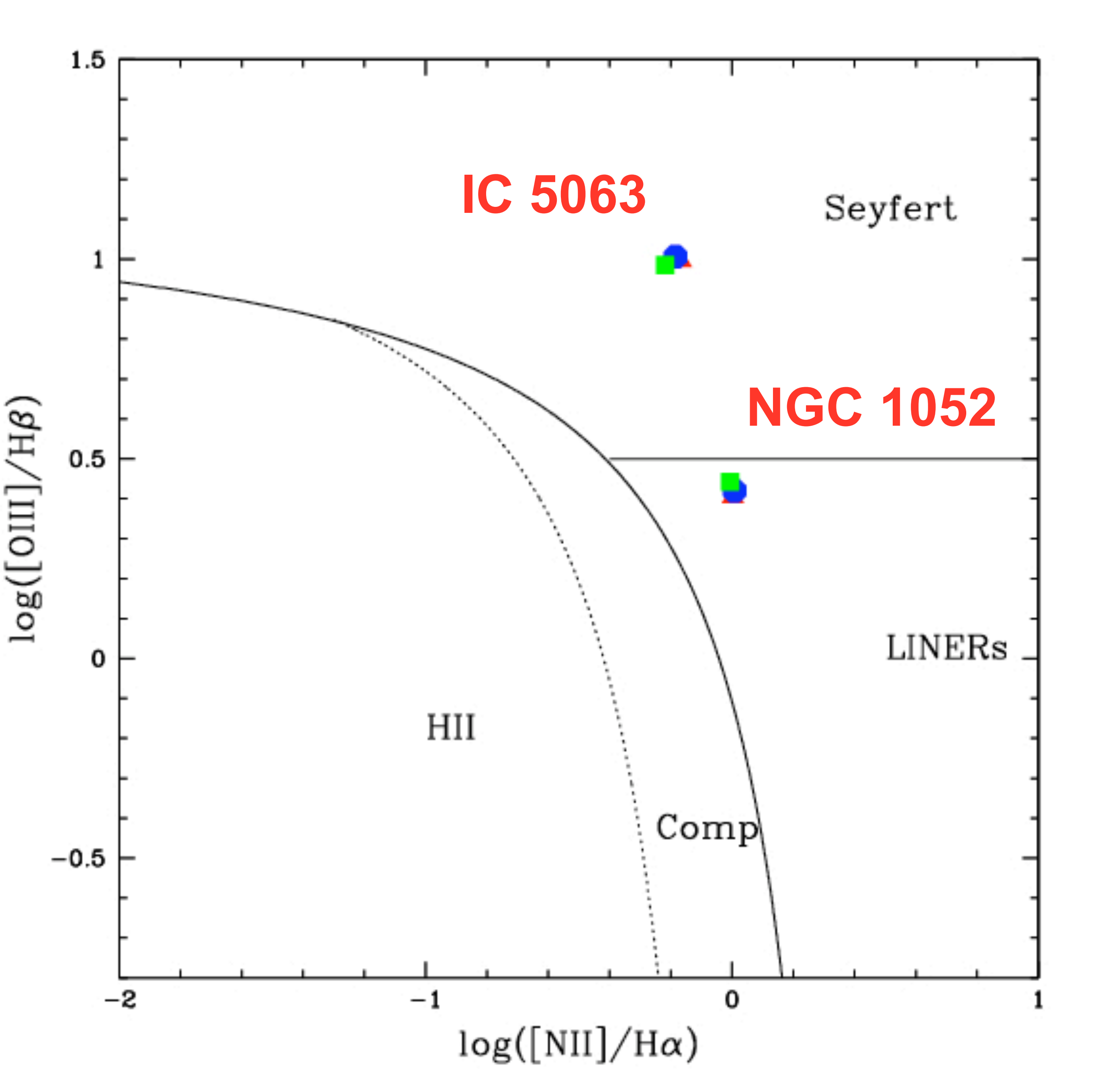


$r < r_e/16$

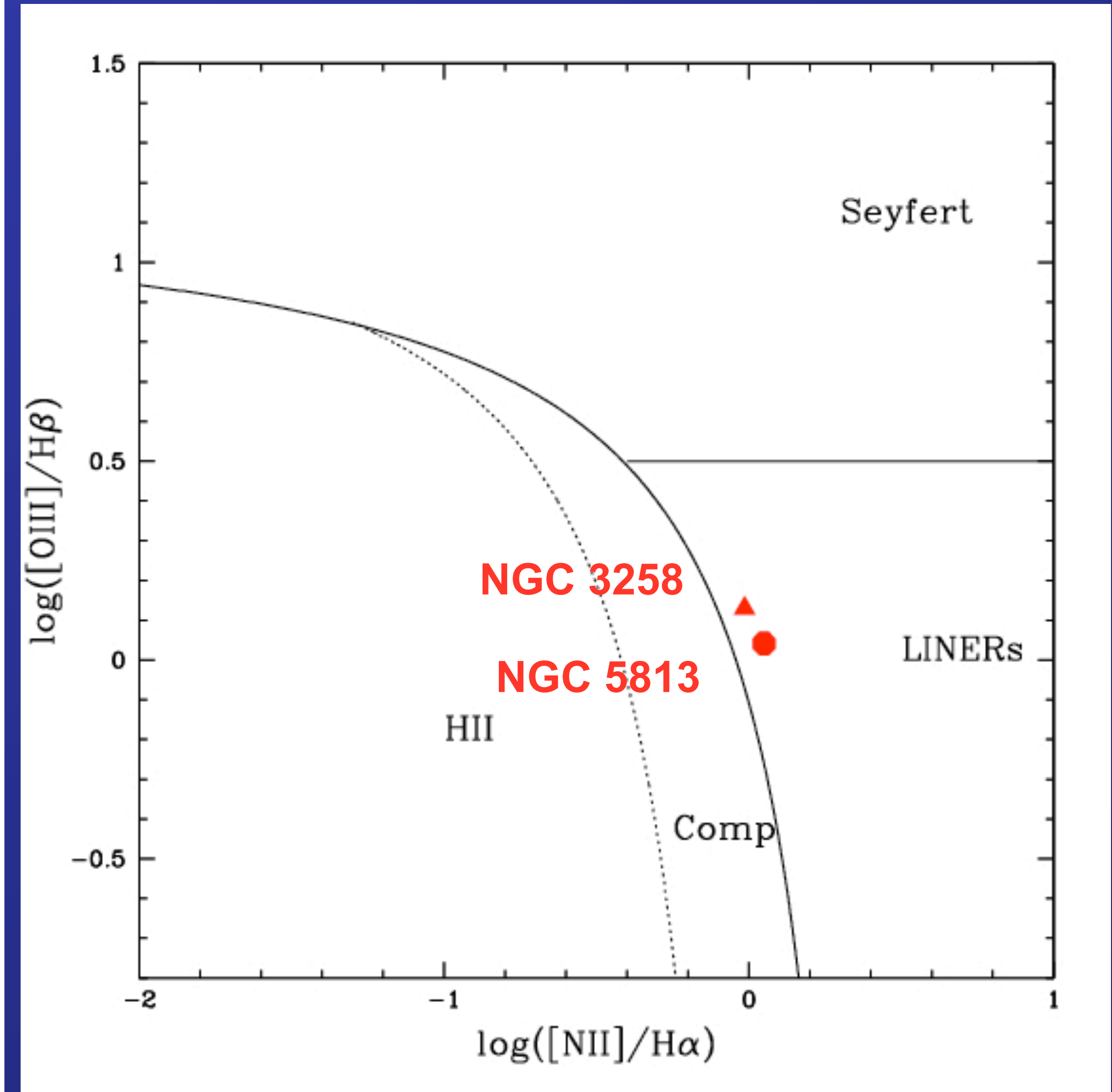
$r_e/16 < r < r_e/8$

$r_e/8 < r < r_e/4$

The MIR View

(see poster of Rampazzo et al.)

IRS - Spitzer data for 39 ETGs out of 65 (*PIs: Bergman, Kaneda, Rampazzo*)



The MIR View

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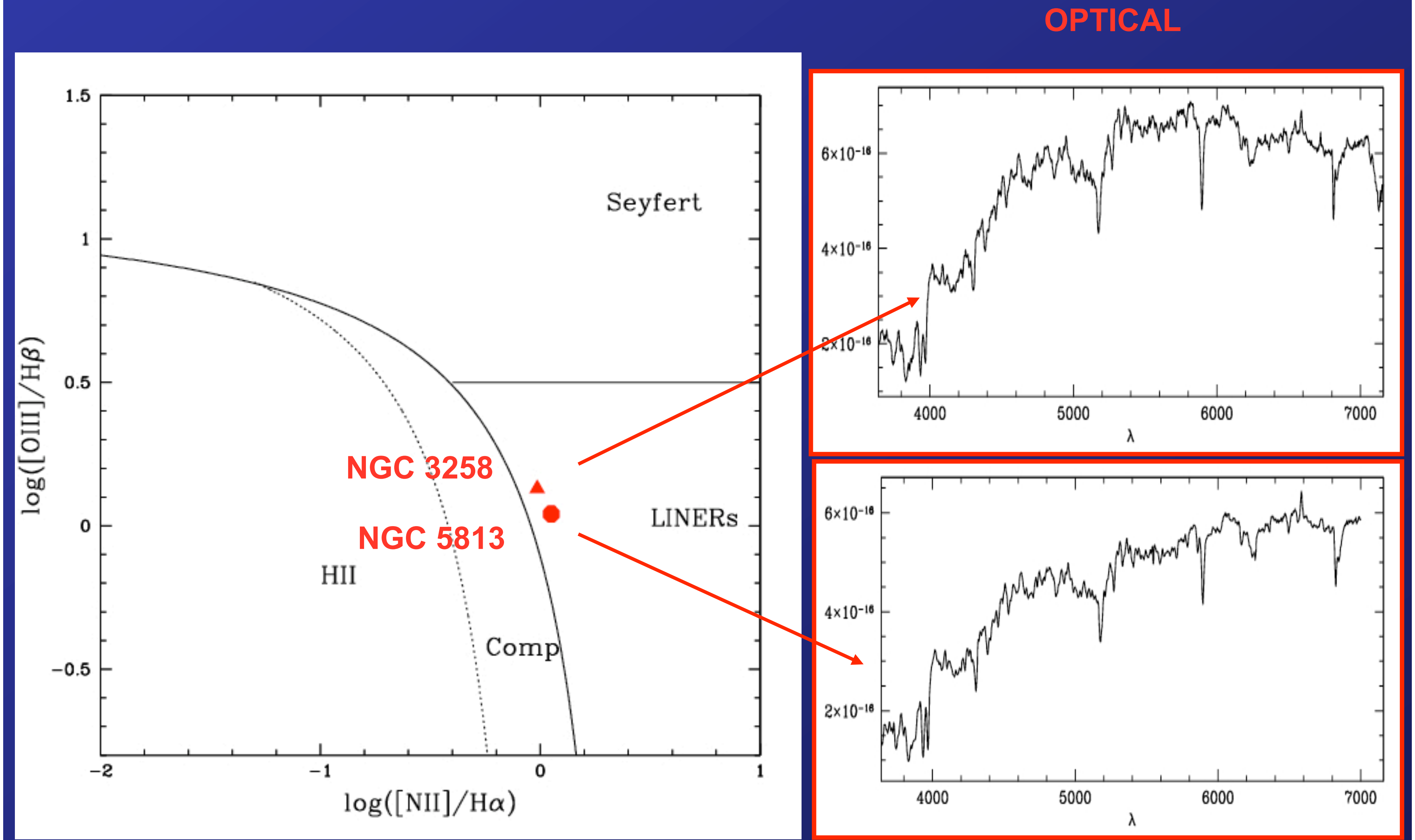


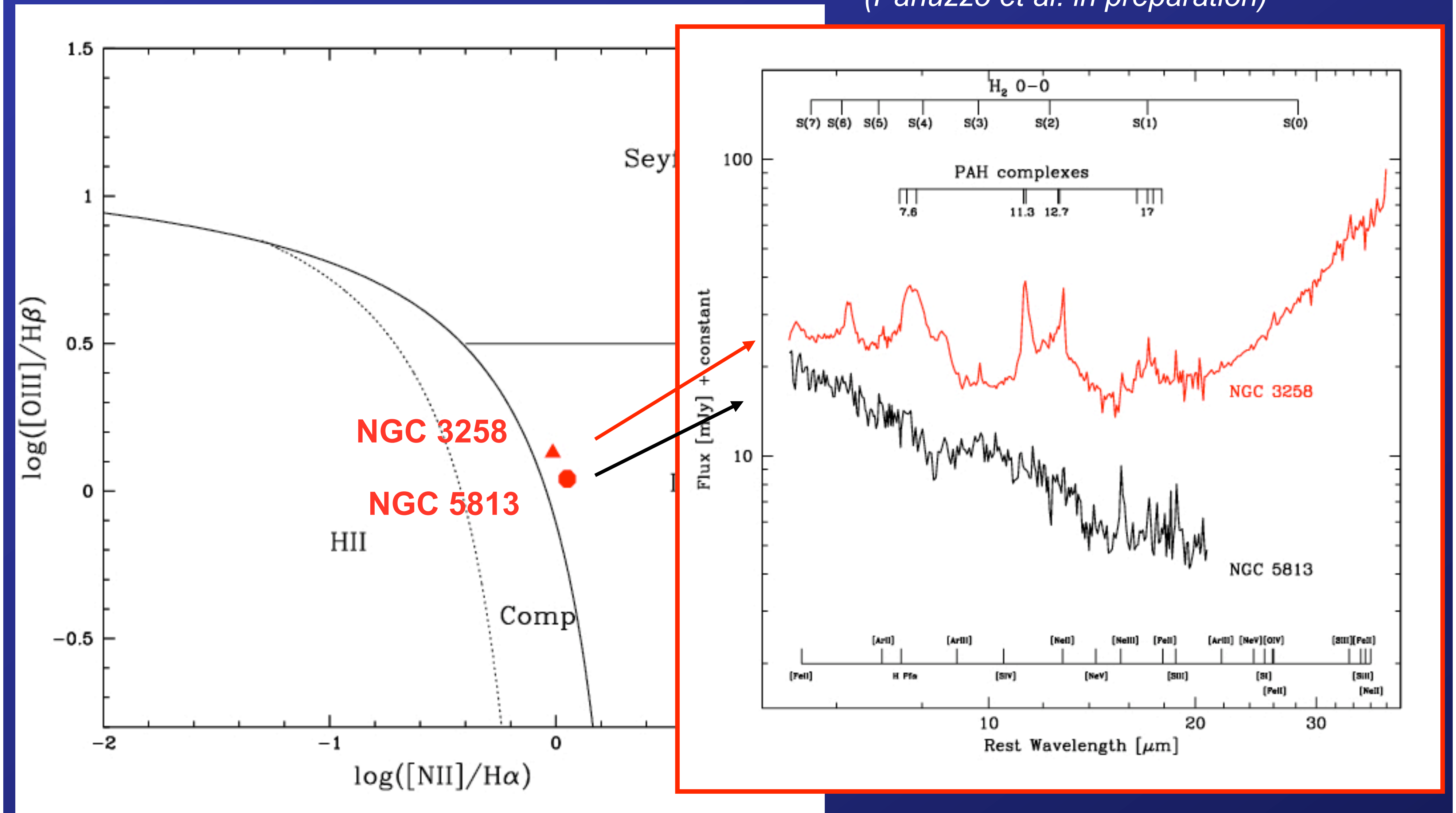
The MIR View

(see poster of Rampazzo et al.)

IRS - Spitzer data for 39 ETGs out of 65 (*PIs: Bergman, Kaneda, Rampazzo*)

MID INFRARED

(Panuzzo et al. in preparation)



Conclusions and future perspectives

- ✓ We derive <age>= 8 Gyr, <[M/H]>=0.2 and <[α/Fe]>=0.2 for the total sample. S0 are ~2 Gyr younger and slightly less metal rich and α-enhanced than E.

- ✓ The galaxy potential well is the main driver of the chemical path, more massive galaxies exhibiting the more efficient chemical enrichment and shorter SF timescales.

- ✓ Galaxies in LDE show signature of recent rejuvenation episodes.

- ✓ Emission lines are measured from the spectra by fittting the underlying stellar contribution with new SSPs models based on empirical spectral libraries and calibrated against LMC clusters.

- ✓ According to standard emission - line diagnostic diagrams the majority of the galaxies are classified as LINERs. Powering source not clear yet (need to further investigate correlation with the stellar population parameters).

- ✓ MIR seems very promising in making more light…

New Simple Stellar Populations with α–enhancement

(Other α–enhanced models in the literature: Tantalo, Bressan & Chiosi 98; Trager+00; Thomas+03; Thomas, Maraston & Korn 04; Tantalo & Chiosi 2004; Tantalo et al. 04; Korn, Maraston & Thomas 05).

Our new SSPs are based on:

- Padova Stellar Isochrones (Bressan+94, Bertelli+94)
- Narrow–band index Fitting Functions (Worthey+94, Worthey & Ottaviani 97)
- Index Responses to element abundance variations (Korn+05)
- Revision of index dependence on element abundance (tests with ATLAS12)

Our models are computed for:

Ages: (1 - 16) Gyr; Z: (0.0004 - 0.05); [α/Fe]: (0 -0.8)

DOWNLOAD @:

www.stsci.edu:/~annibali or

http://www.inaoep.mx/~abressan

See also paper : Annibali et al. 2007
A&A 463, 455

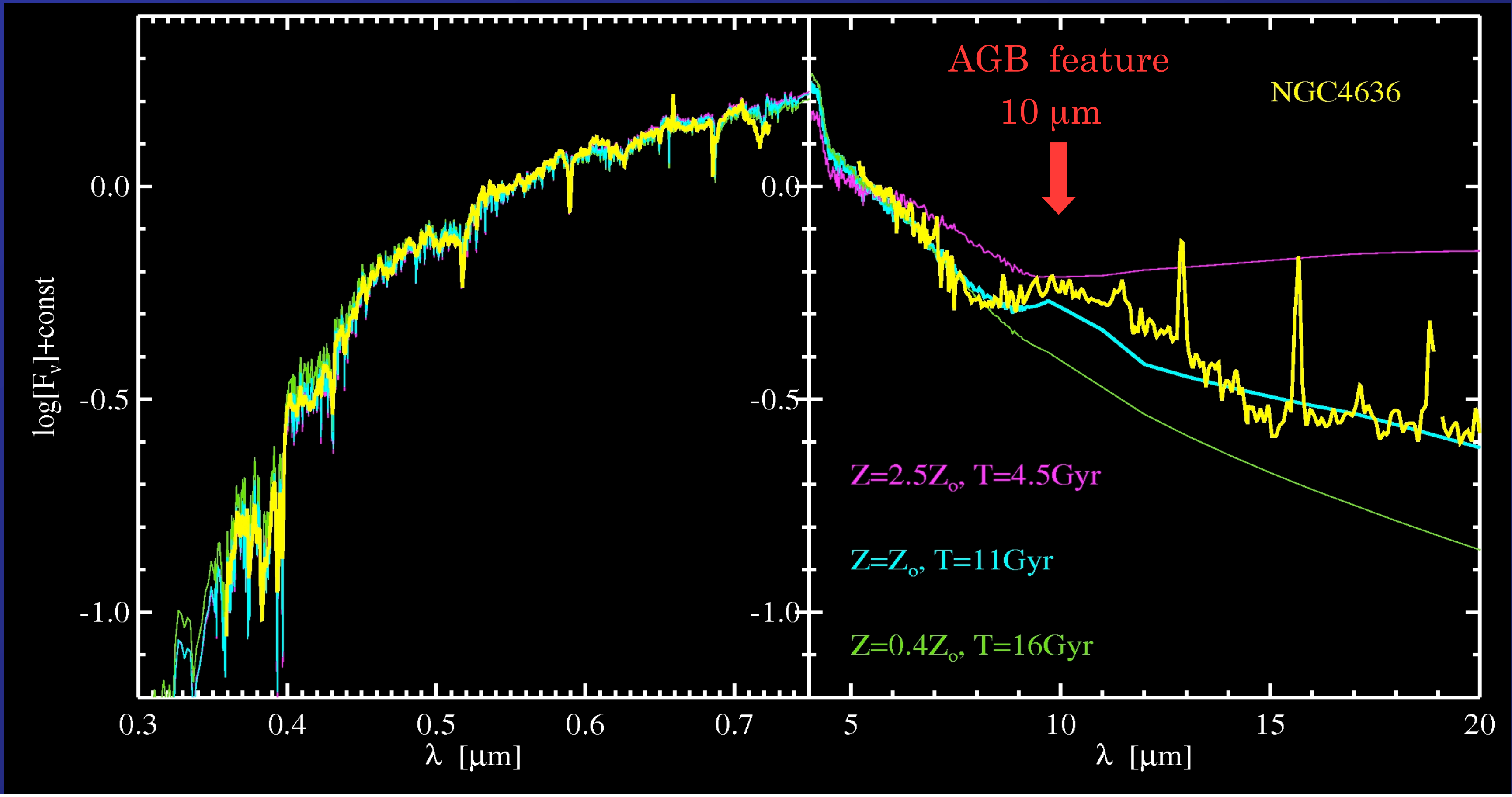
Constraining the mass in Rejuvenation episodes

OPTICAL + IR + UV

Constraining the mass in Rejuvenation episodes

OPTICAL + MIR

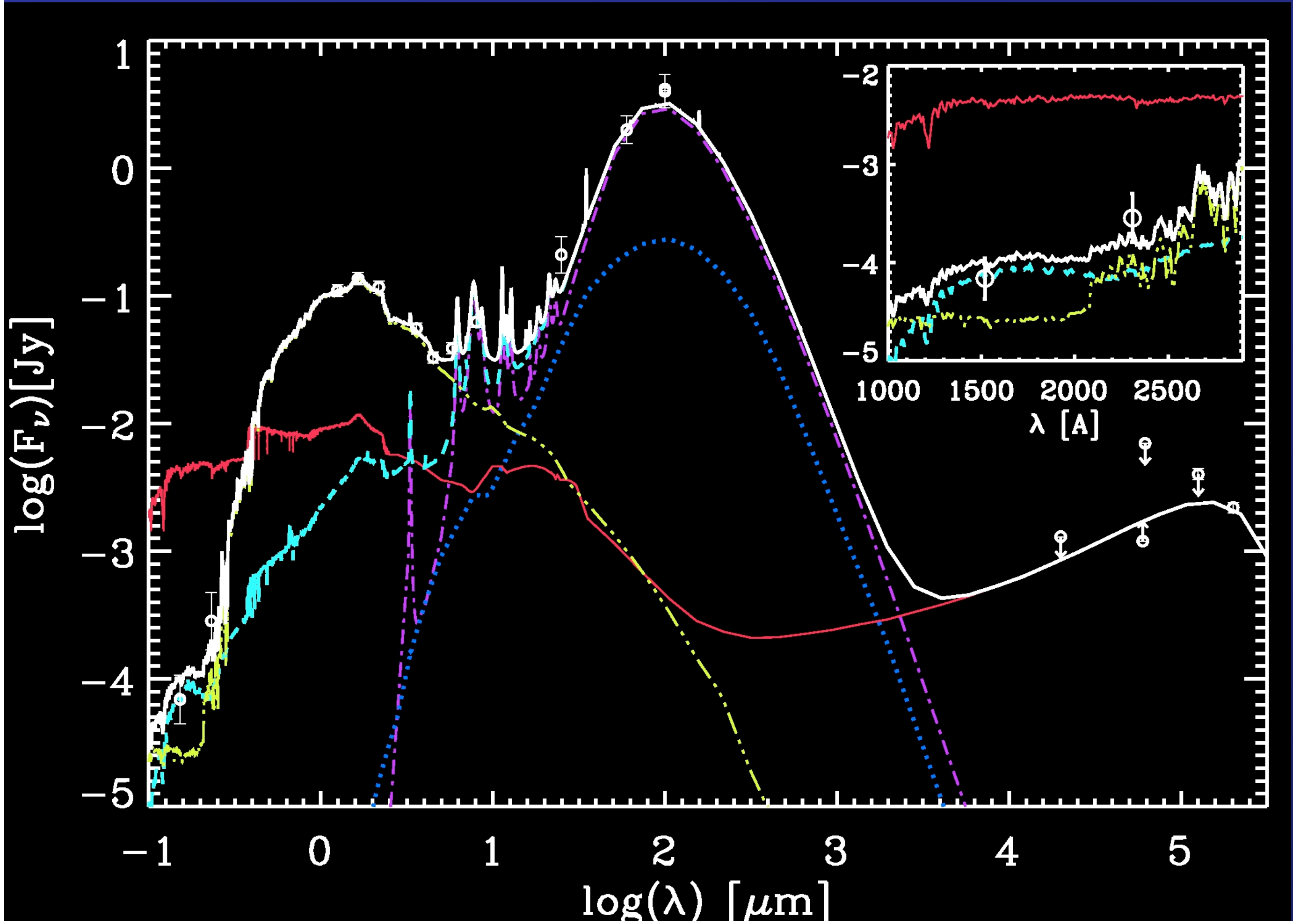
- ✓ MIR (Spitzer) combined with optical bands very powerful in breaking age-metallicity degeneracy (Virgo ETG, Bressan et al. 2006)



Constraining the mass in Rejuvenation episodes

OPTICAL + IR + UV

- ✓UV (GALEX) data sensitive to mass of young stars and extinction
- ✓FUV / NUV sensitive to ratio of young to old stellar populations



NGC4435:
8 Gyr (98.5%)+ 200 Myr (1.5%)
(Panuzzo et al. 2007)

New UV and MIR data for Field ETGs

GALEX and Spitzer data for galaxies selected from the optical sample of 65 field ETGs (Rampazzo et al. 05 + Annibali et al. 06)

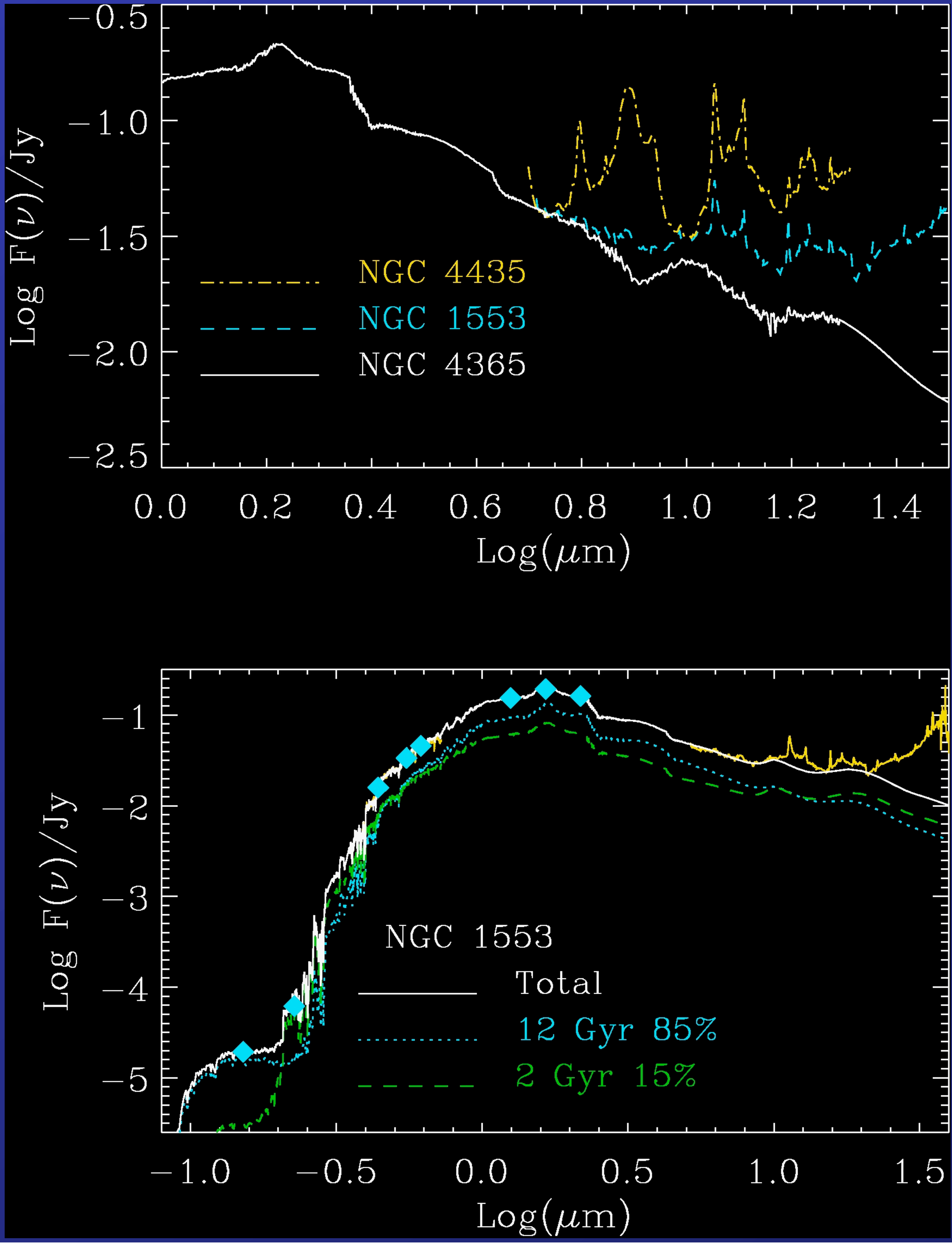
Spitzer IRS

- ✓ 19 ETGs (active), Cycle 1 and 2
- ✓ 18 ETGs Cycle 3 (PI Rampazzo: P30256)
  - $F_{60\mu m}$ / Ks_{tot} <0.6
  - measure of ρxyz
  - no foreground stars

+

GALEX FUV / NUV imaging

- ✓ 14 ETGs in Cycle 1 and 2
- ✓ 16 ETGs Cycle 3 (PI Rampazzo: GI3-0087)



NGC1553

From optical, lum-weighted age of 5 Gyr!

Conclusions

Study of a sample of 65 Field early-type galaxies:

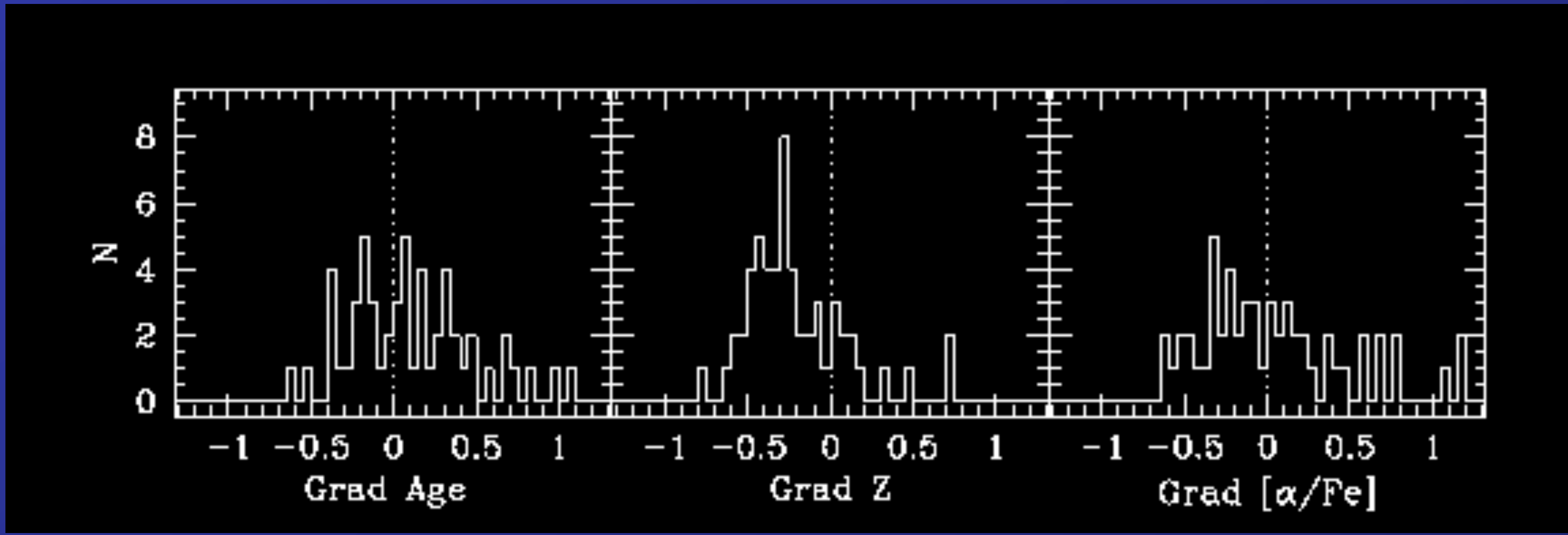
- ✓ We derive <age>= 8 Gyr, <[M/H]>=0.2 and <[α/Fe]>=0.2 for the total sample. S0 are ~2 Gyr younger and slightly less metal rich and α-enhanced than E.

- ✓ The galaxy potential well is the main driver of the chemical path, more massive galaxies exhibiting the more efficient chemical enrichment and shorter SF timescales.

- ✓ Galaxies in LDE show signature of recent rejuvenation episodes.

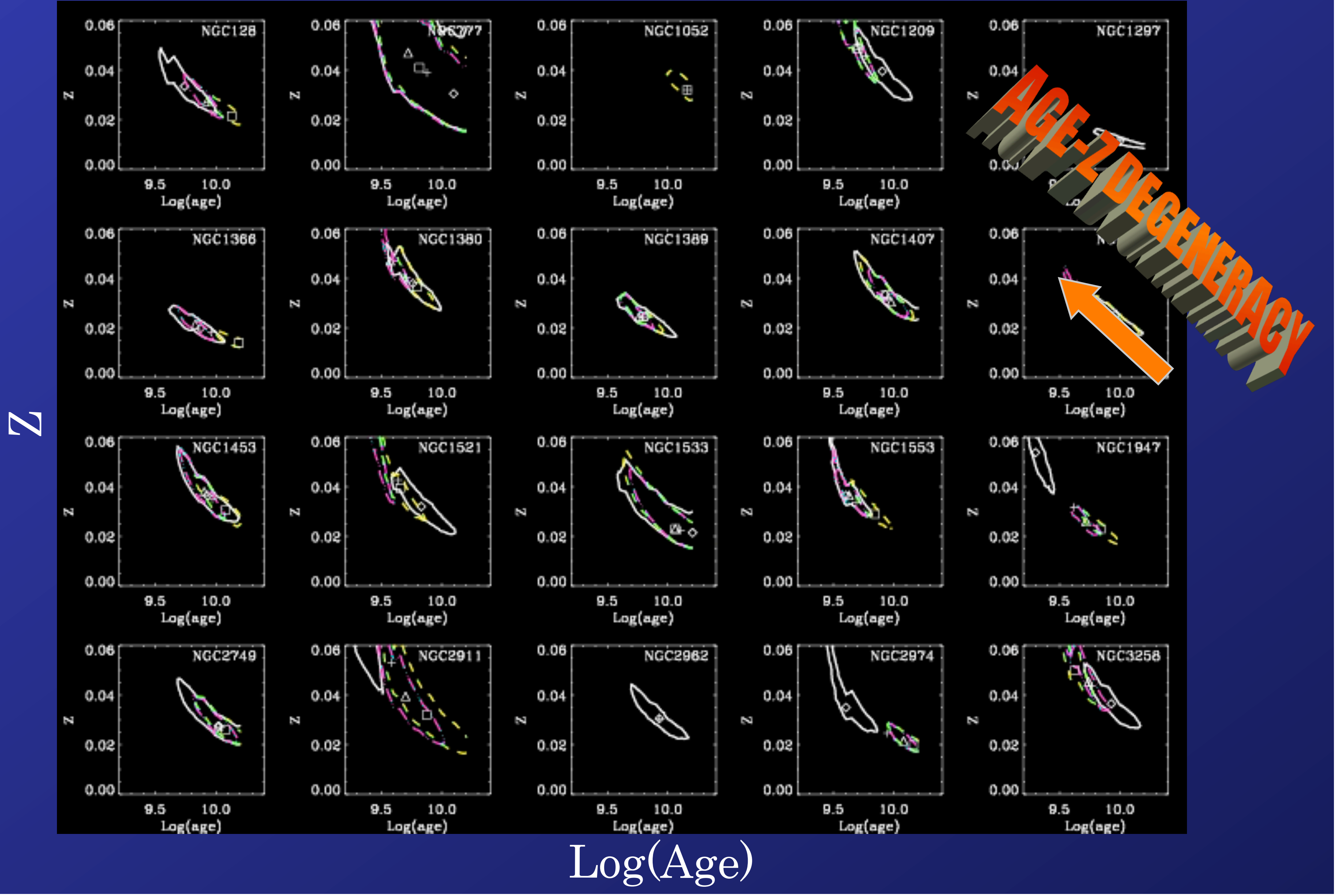
- ✓ The combination of OPTICAL + IR + UV data will provide the age and mass involved in rejuvenation episodes.

Gradients

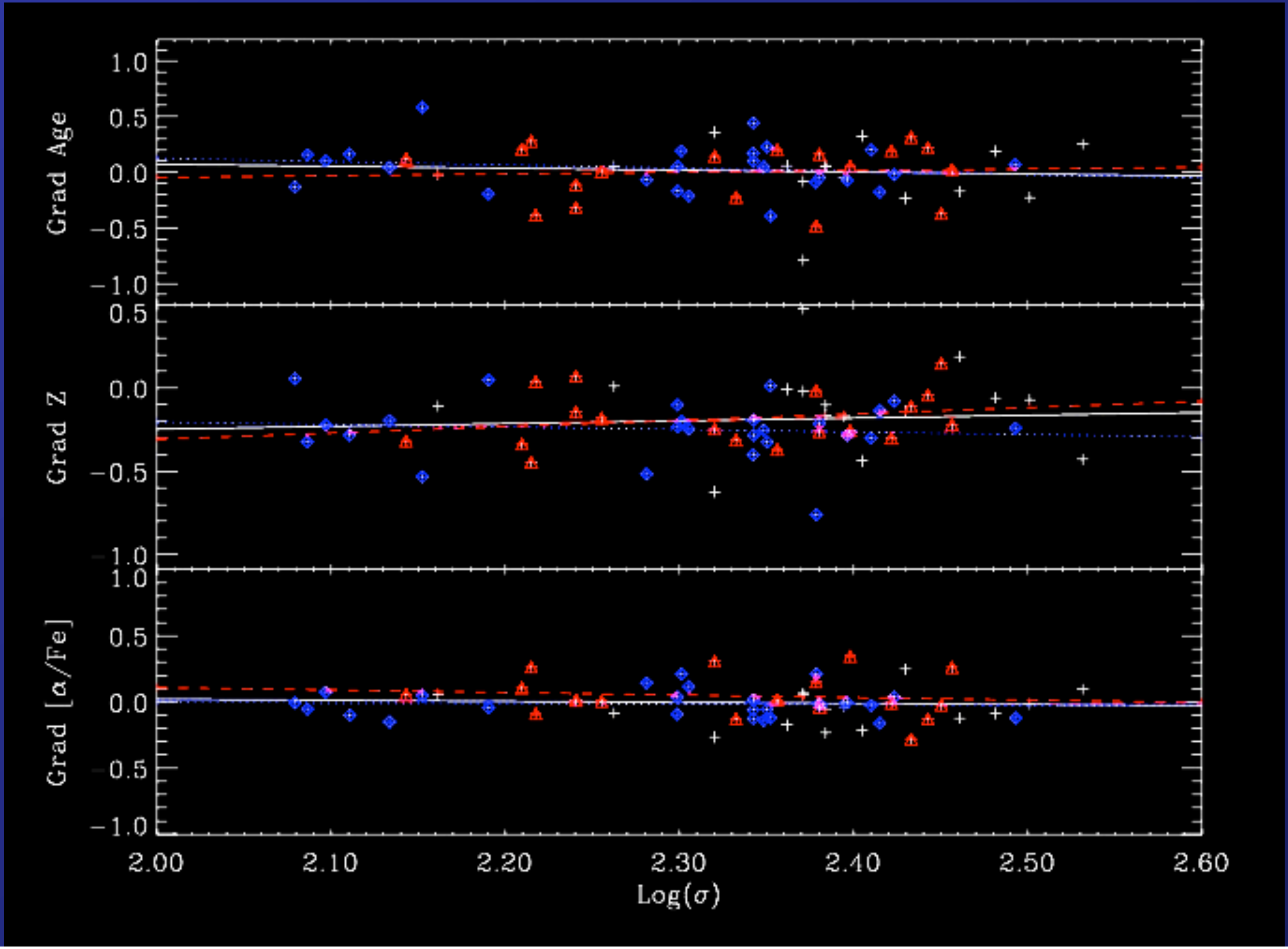


The presence of a well established gradient in Z but not in [α/Fe] indicates that SF proceeded on similar timescales across $r_e/2$ but with larger efficiency in the center.

Age – Metallicity Degeneracy



Gradients



Grad Age
1.0
0.5
0.0
−0.5
−1.0
Grad Z
0.5
0.0
−0.5
−1.0
Grad [α/Fe]
1.0
0.5
0.0
−0.5
−1.0
2.00
2.10
2.20
2.30
2.40
2.50
2.60
Log(σ)

Effect of Environment

- ✓ Very young galaxies are present in LDE
- ✓ Environment has no effect on Z–σ and [α/Fe]–σ relations

❖ Rejuveation episodes or more prolonged SF?

No difference in [α/Fe]–σ between LDE and HDE

❖ What is the mass involved in the rej episode?

- ✓ 15 % of the sample rejuvenated
- ✓ we assume epoch of formation ~ 8 Gyr
- ✓ since then all galaxies experience rej event with probability of the halo merging rate, ~ $(1+z)^{3/2}$ (La Fevre+00)

mass fraction of the young population is only 12 %

Field vs cluster early–type galaxies

- ✓ Scaling relations show larger scatter than in cluster
- ✓ Scaling relations evolve faster with z than in cluster
- ✓ Narrow-band index studies suggest :
  - ❖ younger ages than in cluster

    (e.g. Bender+ 96; Longhetti+ 98, 99, 00; Trager+ 00; Kuntschner+ 02; Thomas+05; Denicolo' +05; Gallazzi +05, Clemens+06)
  - ❖ larger metallicities than in cluster

    (e. g. Kuntschner+ 02; Thomas+05)

delayed SF?
more prolonged SF?
secondary episodes of SF?

The Sample

It is composed of 65 nearby (cz < 5500 Km/s) early–type galaxies:

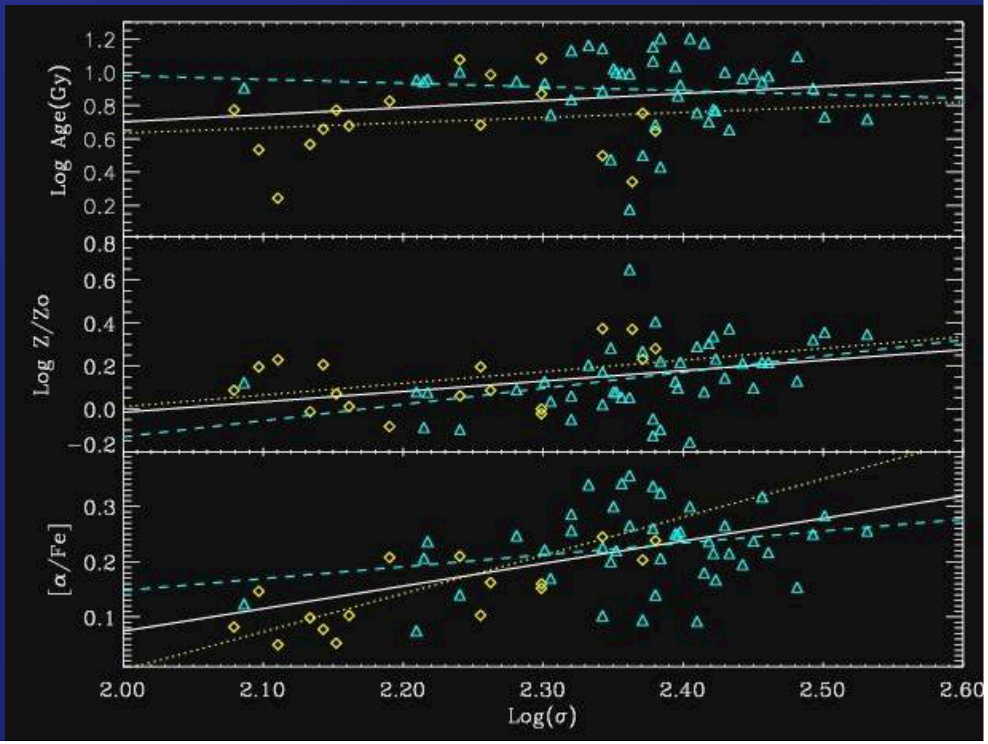
50 (Rampazzo+05, A&A 433, 497) + 15 (Annibali +06, A&A 445, 79)

The Effect of Galaxy Mass

(Annibali et al 2007)

- ✓ No clear trend of age with σ
- ✓ Significant trend of Z with σ
- ✓ Significant trend of [α/Fe] with σ

Galaxy gravitational potential drives chemical enrichment



Emission Lines