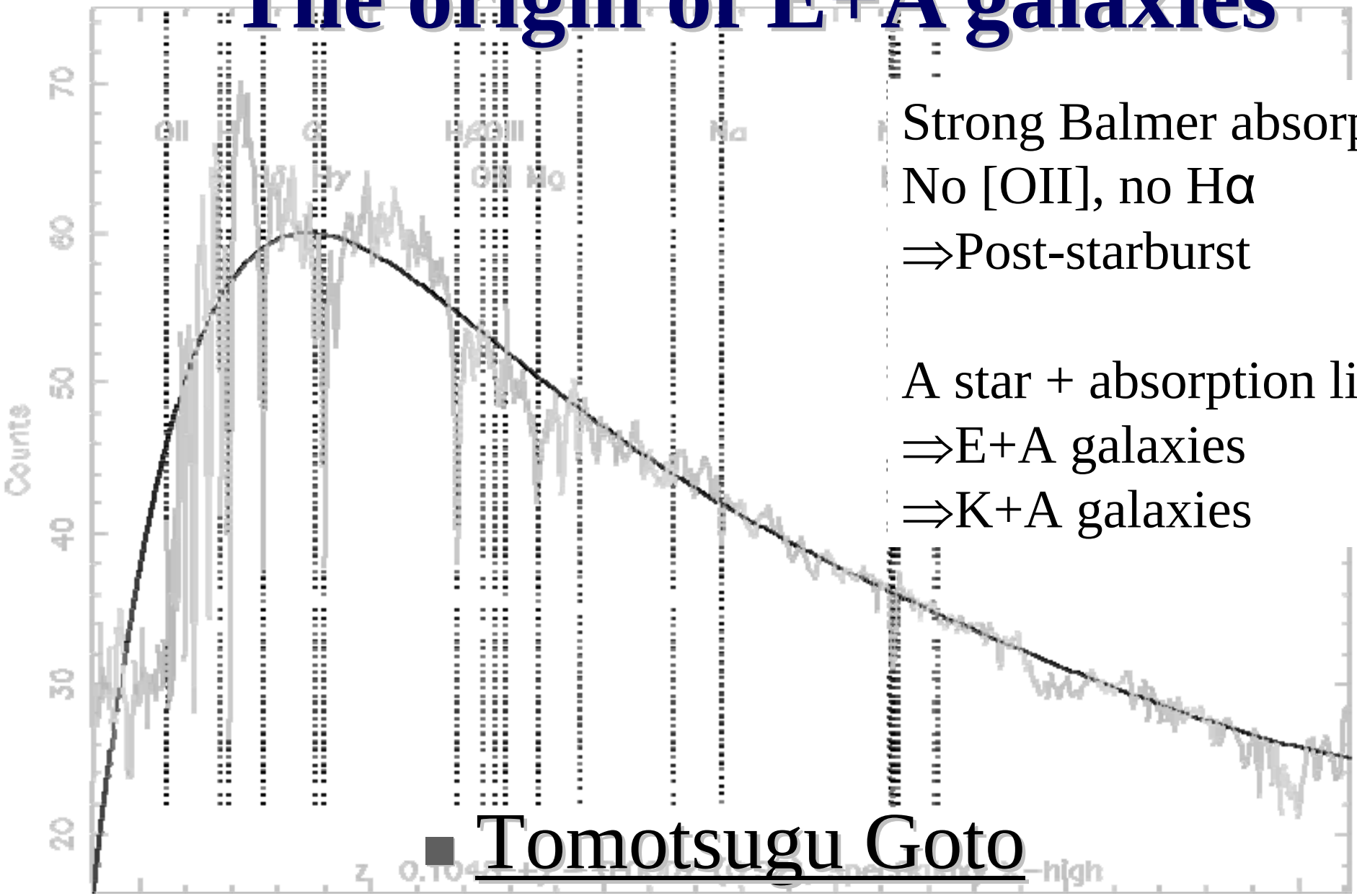
The origin of E+A galaxies



Strong Balmer absorption
No [OII], no Hα
⇒Post-starburst

A star + absorption lines
⇒E+A galaxies
⇒K+A galaxies

- Tomotsugu Goto

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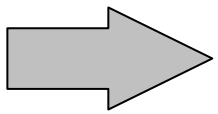
2 puzzles on E+A(post-starburst)

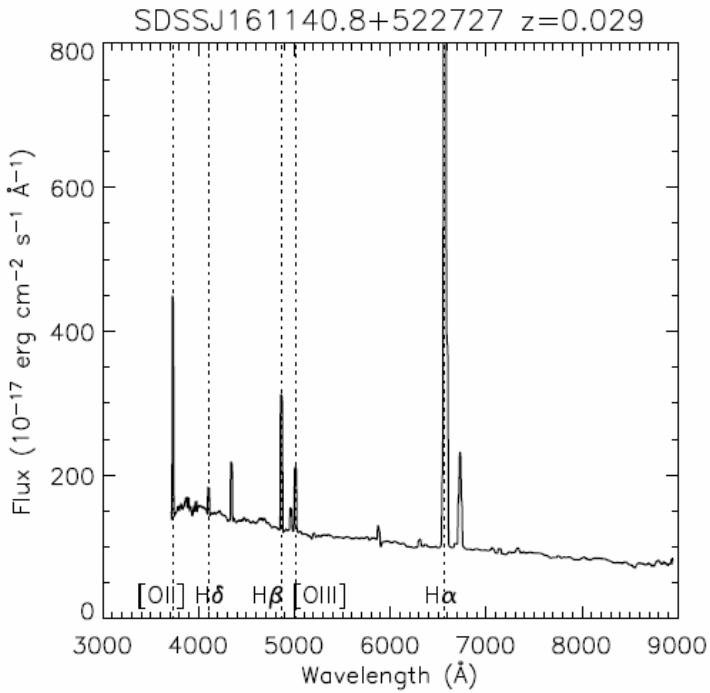
- What caused star burst?
- What stopped it?

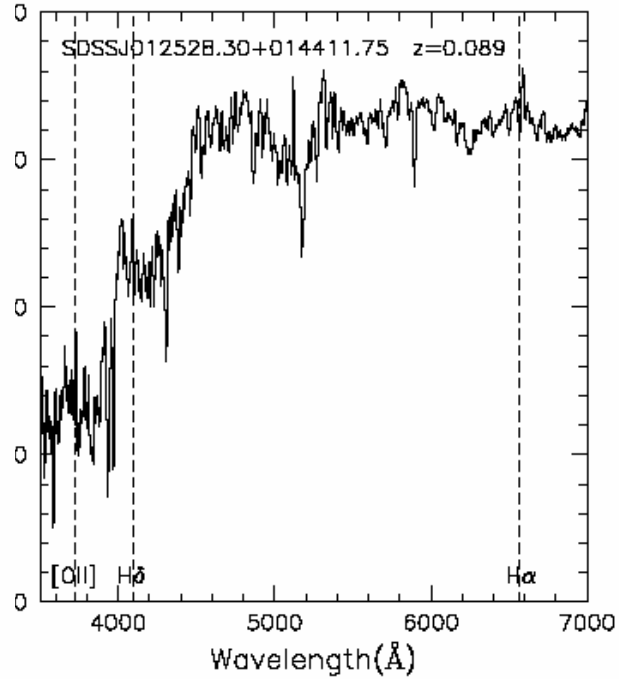
- Cluster related. Found to live in cluster region (MORPHS, Dressler & Gunn 83)
- Dust enshrouded star formation.(Poggianti et al. 1999; Smail et al. 1999)
- Merger/Interaction (Zabludoff et al 1996)

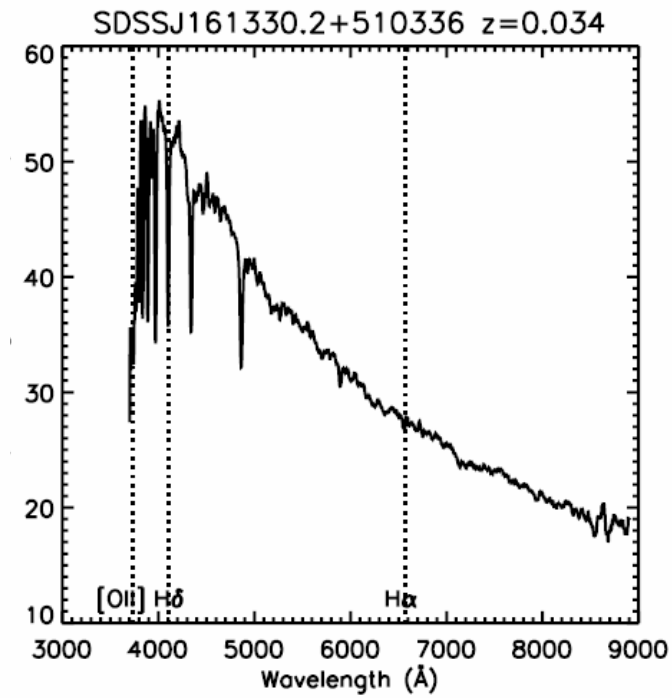


Still puzzles

- Very rare(21/11113 in LCRS). Phase is short(1Gyr). Million spectra of SDSS provide good opportunity to address this 20-year-old puzzle.
- Galaxy evolution in action.







- not much information on past SFH
- truncation of SF: galaxy evolution in action

How to find E+As

Goto, T. et al. 2003, PASJ, 55, 771

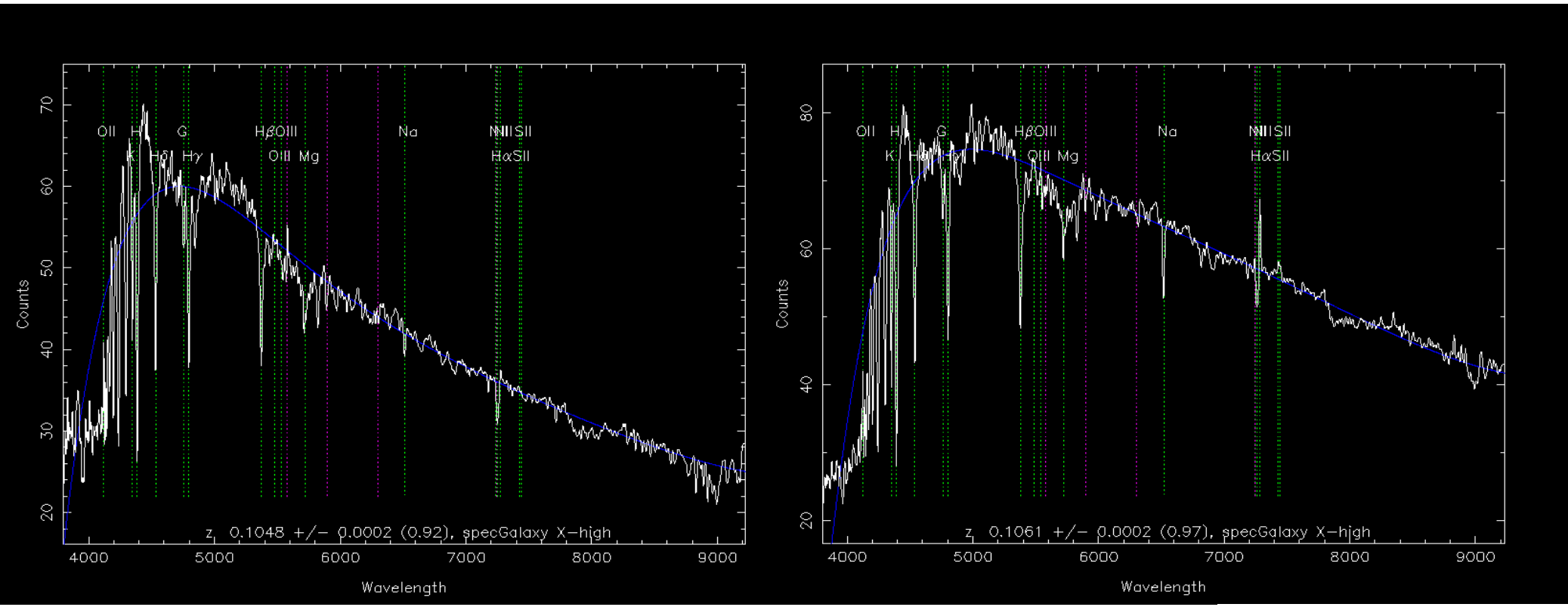
- HδEW>4Å (2.42%)
- 4 categories.
  - E+A: Hα<1σ, [OII]<1σ, No emission lines. (0.04%)
  - HDS+[OII]: Hα<1σ, [OII]≧1σ (0.09%)
  - HDS+Hα: Hα≧1σ, [OII]<1σ (0.04%)
  - HDS+em: Hα≧1σ, [OII]≧1σ, Significant emission lines. (2.25%)

The largest catalog of 266 E+As out of 250,000.

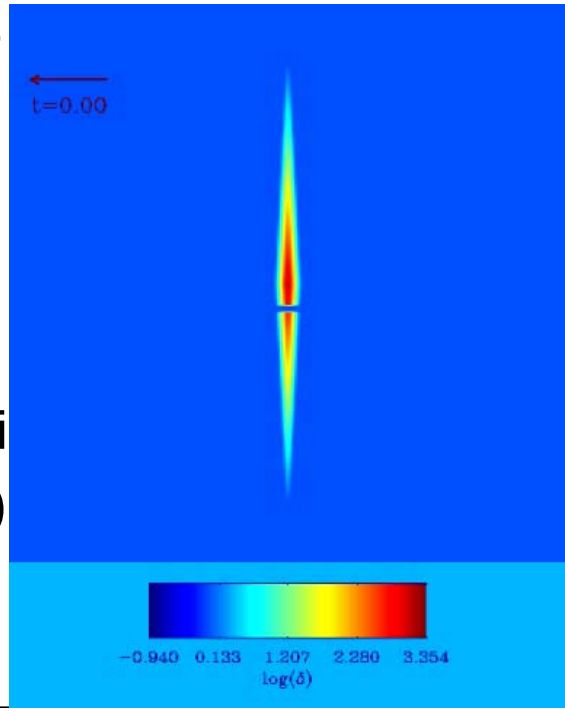
Table 1. Number of galaxies in
AGN are not included in the samp

Category	Number
E+A	133
HDS+em	2900
HDS+Hα	108
HDS+[OII]	42
All Hδ-strong	3183
All	94770

E+A Spectra


OII
H
K
Hδ
G
Hγ
HβOIII
OIII Mg
Na
NIIISII
HαSII
Counts
Wavelength
z 0.1048 +/- 0.0002 (0.92), specGalaxy X-high
z 0.1061 +/- 0.0002 (0.97), specGalaxy X-high

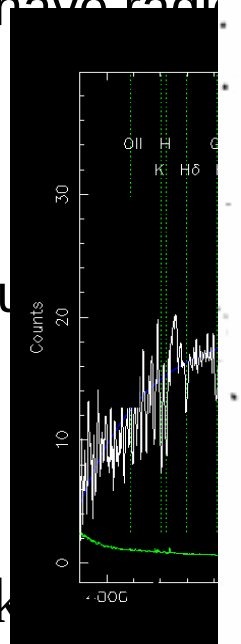
Three Scenarios for E+A

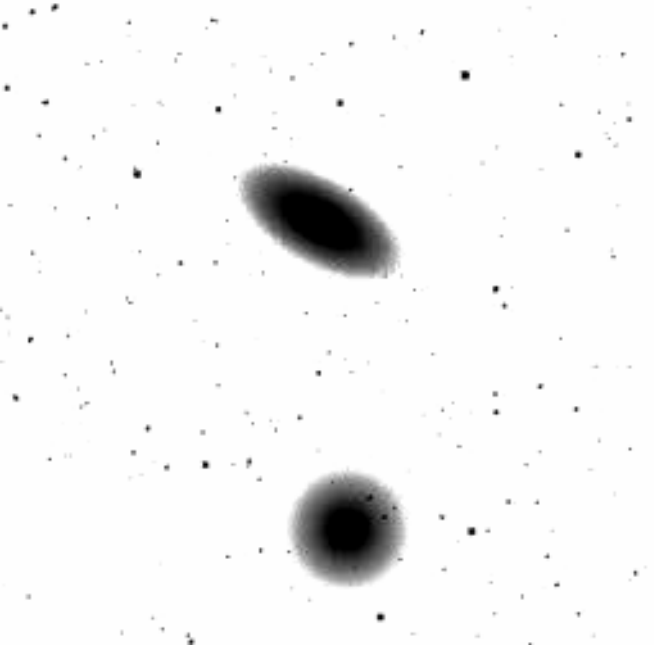


1. Cluster Related (ram pressure, tidal interacti
potential, …etc; Dressler et al. 1999; Poggianti et al. 1999)

2. Dusty Starburst (2/15 of E+As hav
Smail et al. 1997;)

3. Interaction/Merger (tidal featu
1996)





E+A is E+A

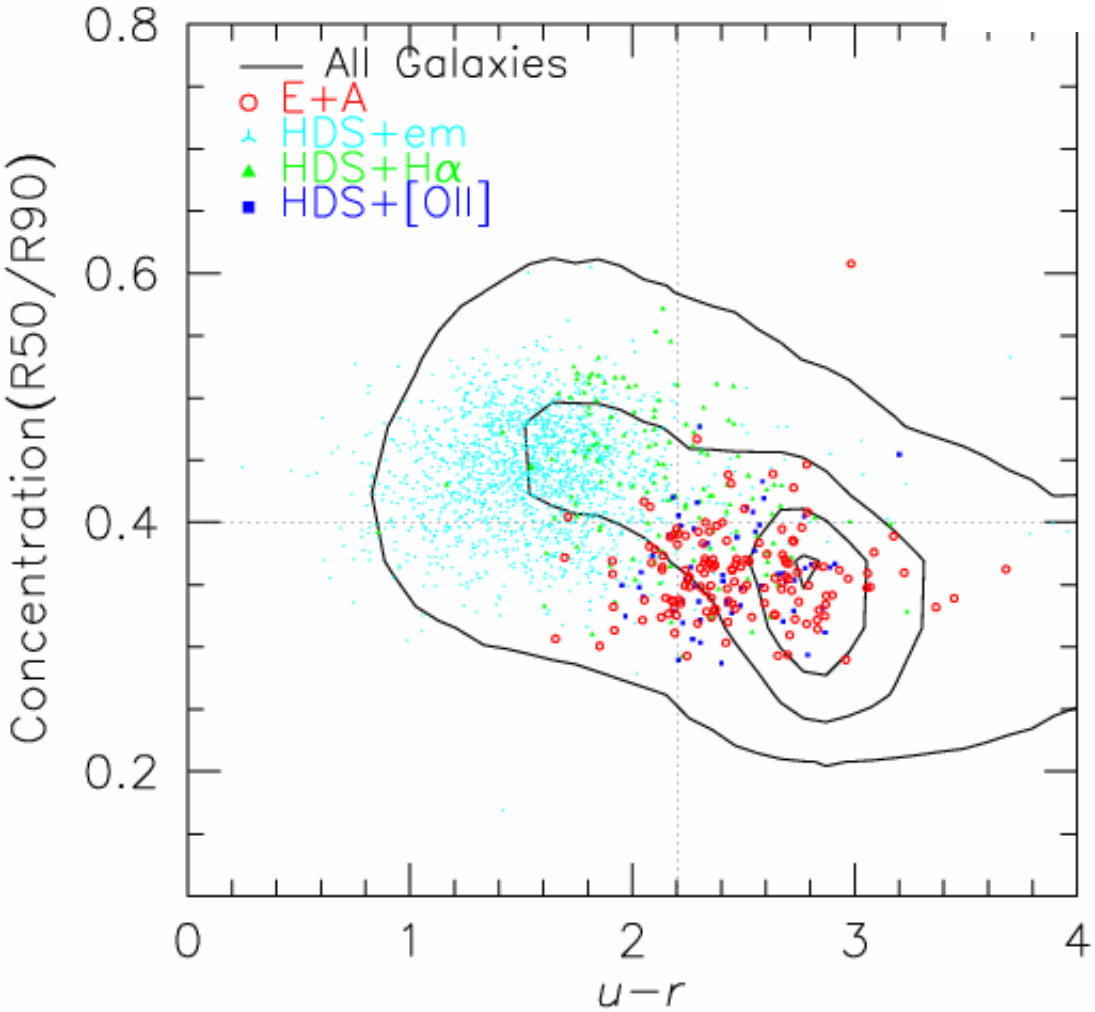
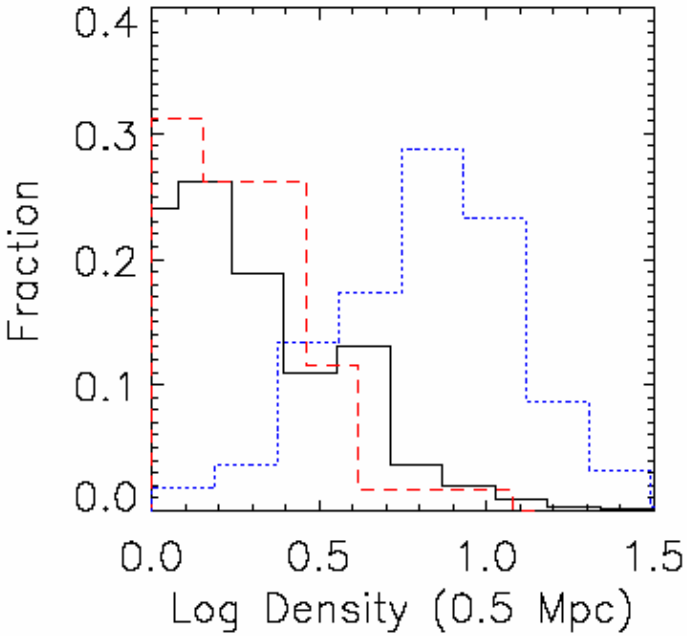


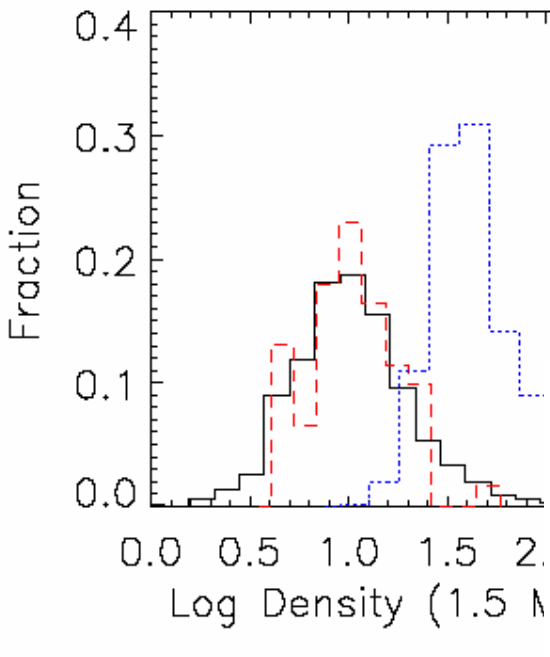
Fig. 5. Distributions of each subclass of galaxies in *Cin* v.s. $u-r$ plane. The contours show the distribution of all 94770 galaxies. The large open circles, triangles, squares, and small dots represent E+A, HDS+[OII], HDS+Hα and HDS+em galaxies, respectively.

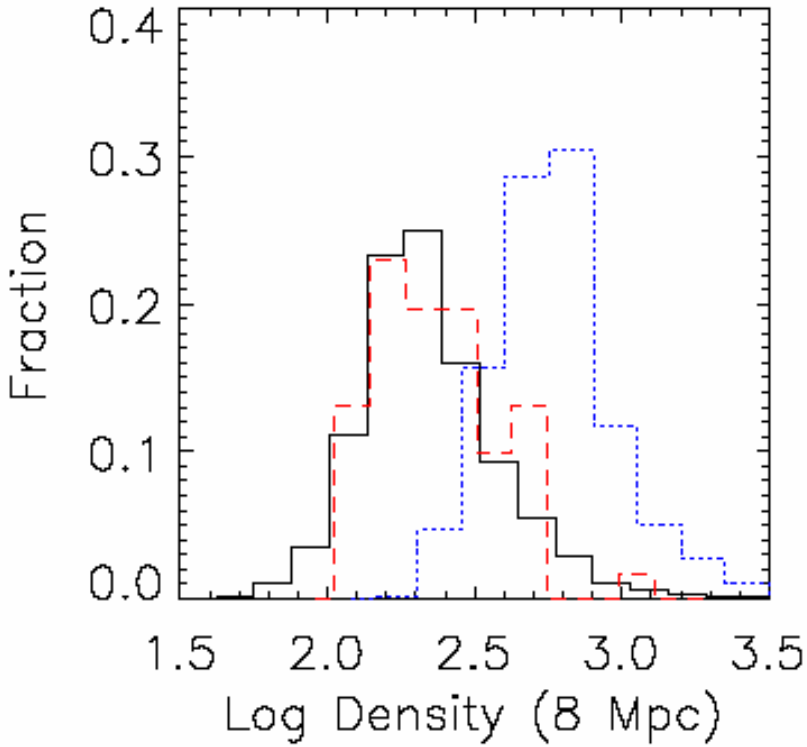
"E+A" is sometime called "K+A" because of its disk-like morphology.
However,…

Previous sample might be contaminated by HDS+Hα

Environment of E+A Galaxies







Not by cluster,

not by large-scale structure

Three Scenarios for E+A

1. Cluster related (ram pressure, tidal interaction, merging…etc; Dressler et al. 1999; Poggianti et al. 1999)

2. Dusty Starburst (2/15 of E+As have radio SF; Miller et al. 2002; Smail et al. 1997;)

3. Interaction/Merger (tidal features in 5/21 E+As in Zabludoff et al. 1996)

Optical-Infrared color: *r-K*

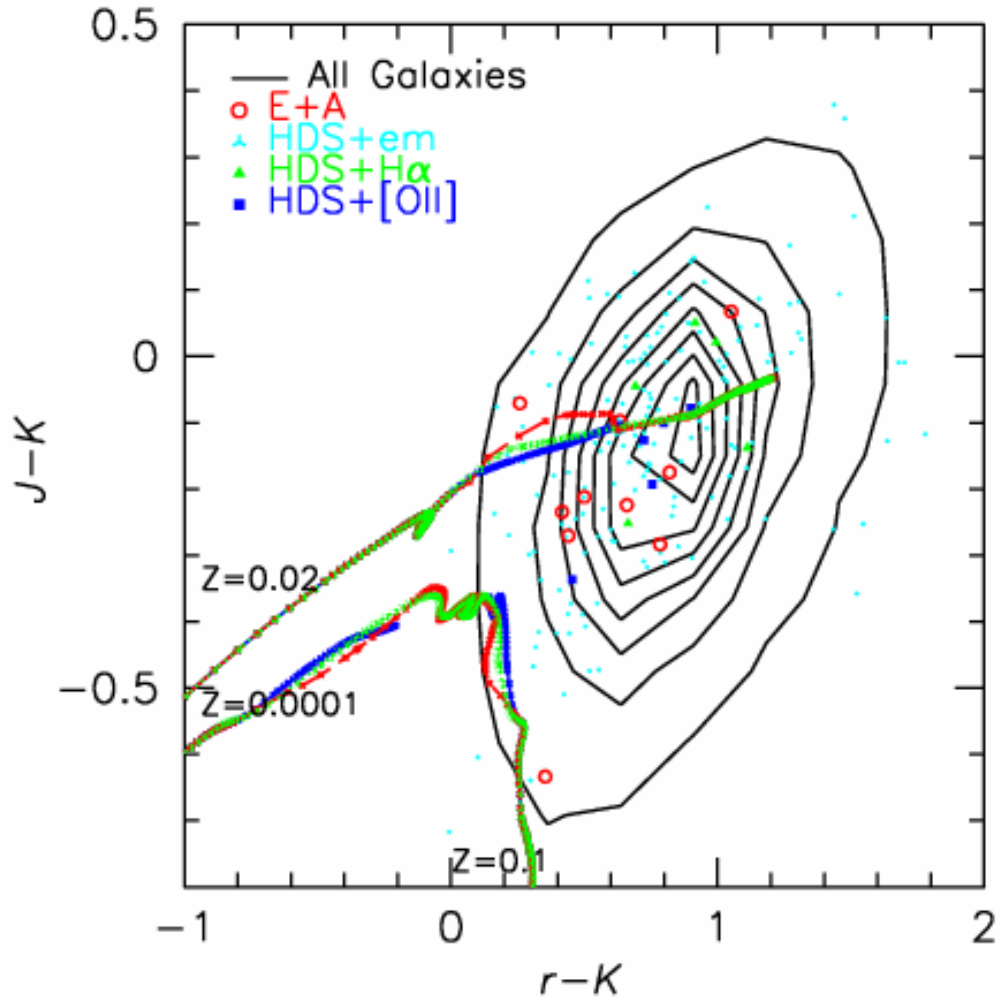


Fig. 12. $J-K$ is plotted against $r-K$. All magnitudes are in restframe AB system. The contours show the distribution of all galaxies in our sample. The open circles, small dots, triangles and squares represent E+A, HDS+em, HDS+Hα and HDS+[OII], respectively. The dashed, solid and dotted lines show the models with instantaneous burst, constant star formation and exponentially decaying star formation rate. Three sets of the models are plotted for different metallicities.

E+As are not dustier.

(c.f., 5 dusty starbursts in Smail et al. are ~1mag redder.)

Radio Estimated SFR

Goto, T. 2004, A&A, 427, 125

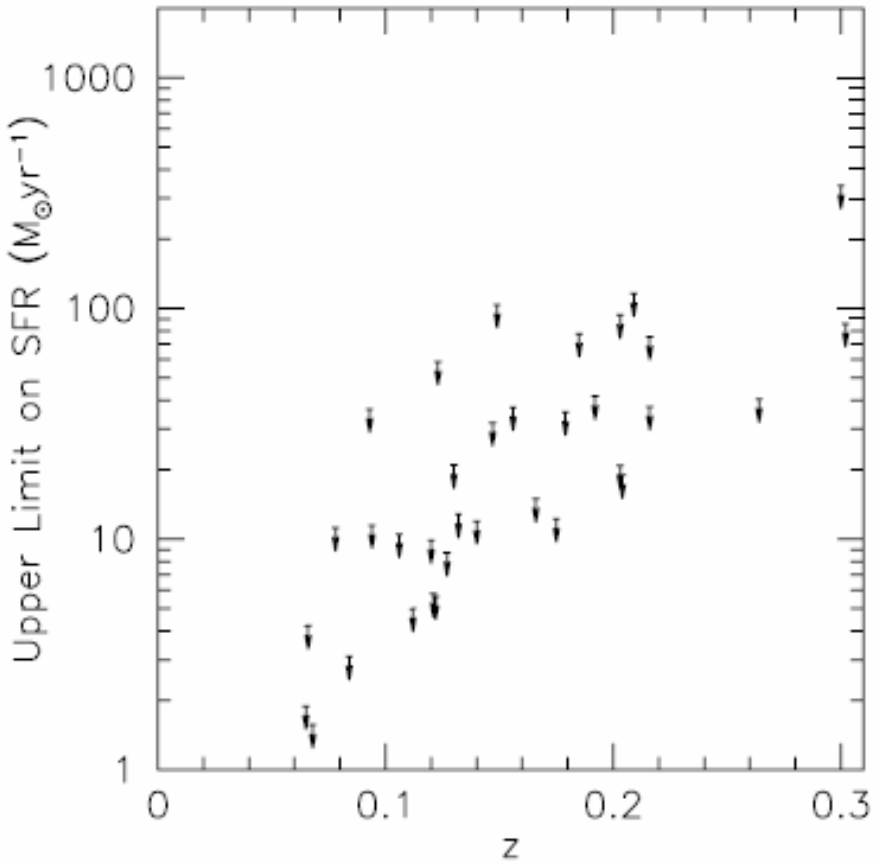


Fig. 3. Upper limits on SFR calculated using the radio 20cm continuum are plotted against redshift. None of our target galaxies were detected in the observation. Therefore, all data points show upper limit on the radio estimated star formation rate calculated from the 3 σ of the rms sky noise. Note that the SFR is computed by integrating IMF over 0.1-100 $M_\odot$. The SFR over 5-100 $M_\odot$ is 5.5 times smaller than our value.

E+As are not dusty starbursts.

Goto

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Hδ_EW vs Time

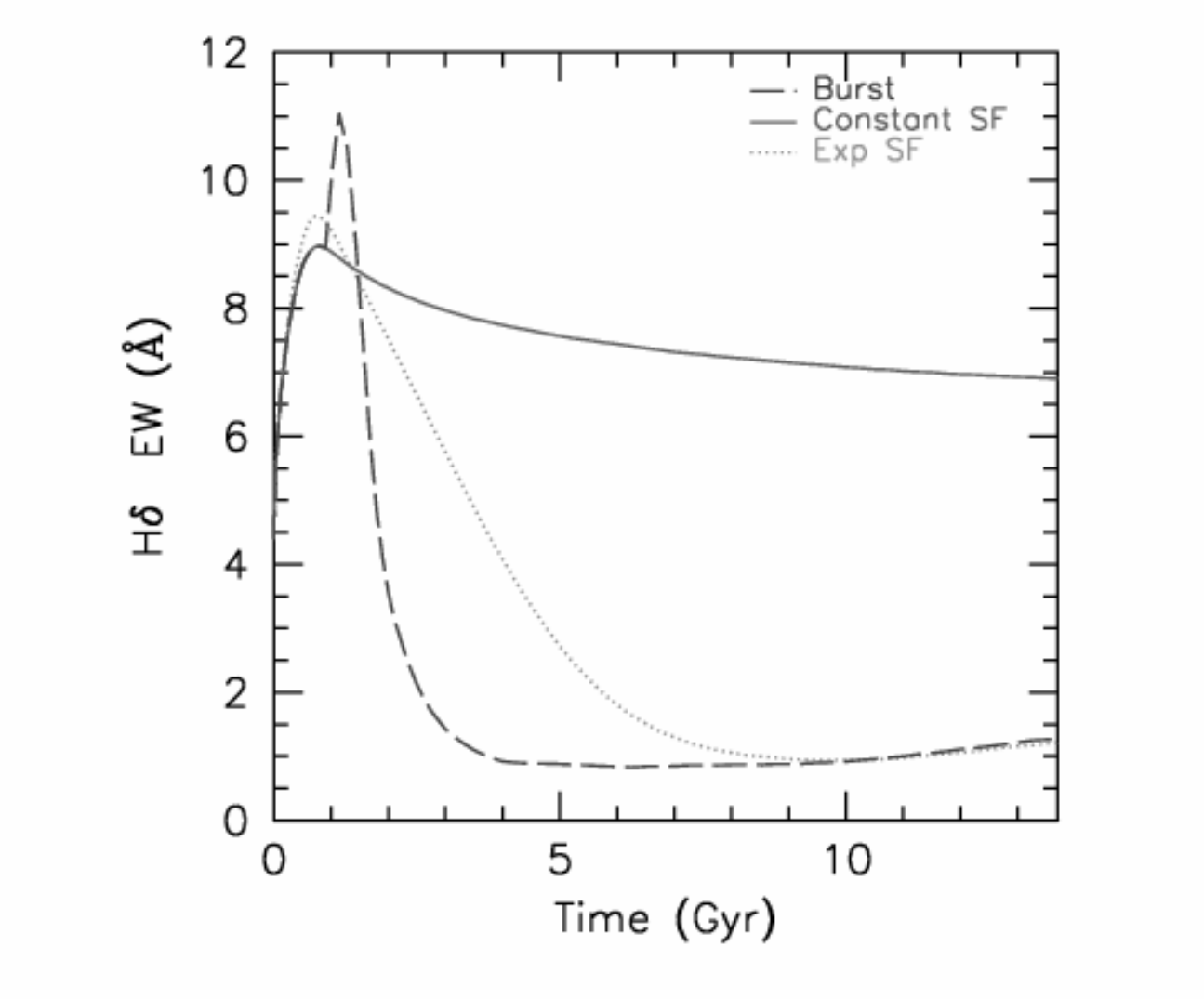
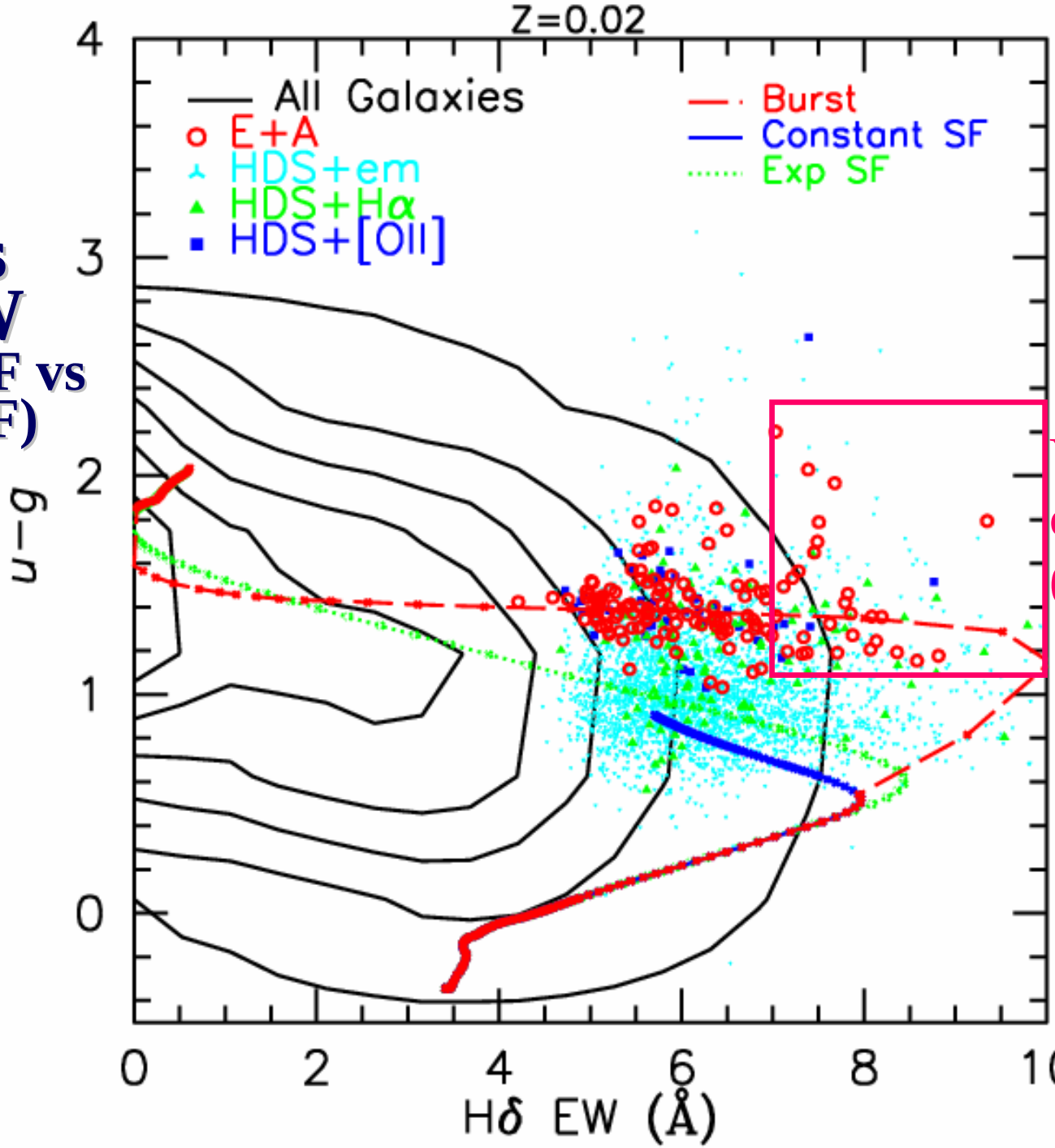


Fig. 10. Hδ EWs are plotted against time (age) for three star formation histories with the GISSEL model. The dashed, solid and dotted lines show the models with instantaneous burst, constant star formation and exponentially decaying star formation rate. The models in this figure assume Salpeter IMF and solar metallicity.

u-g vs HδEW (current SF vs recent SF)



Young E+As: closer to burst (130-470 Myrs)

Young E+A Spectra (HδEW>7Å)

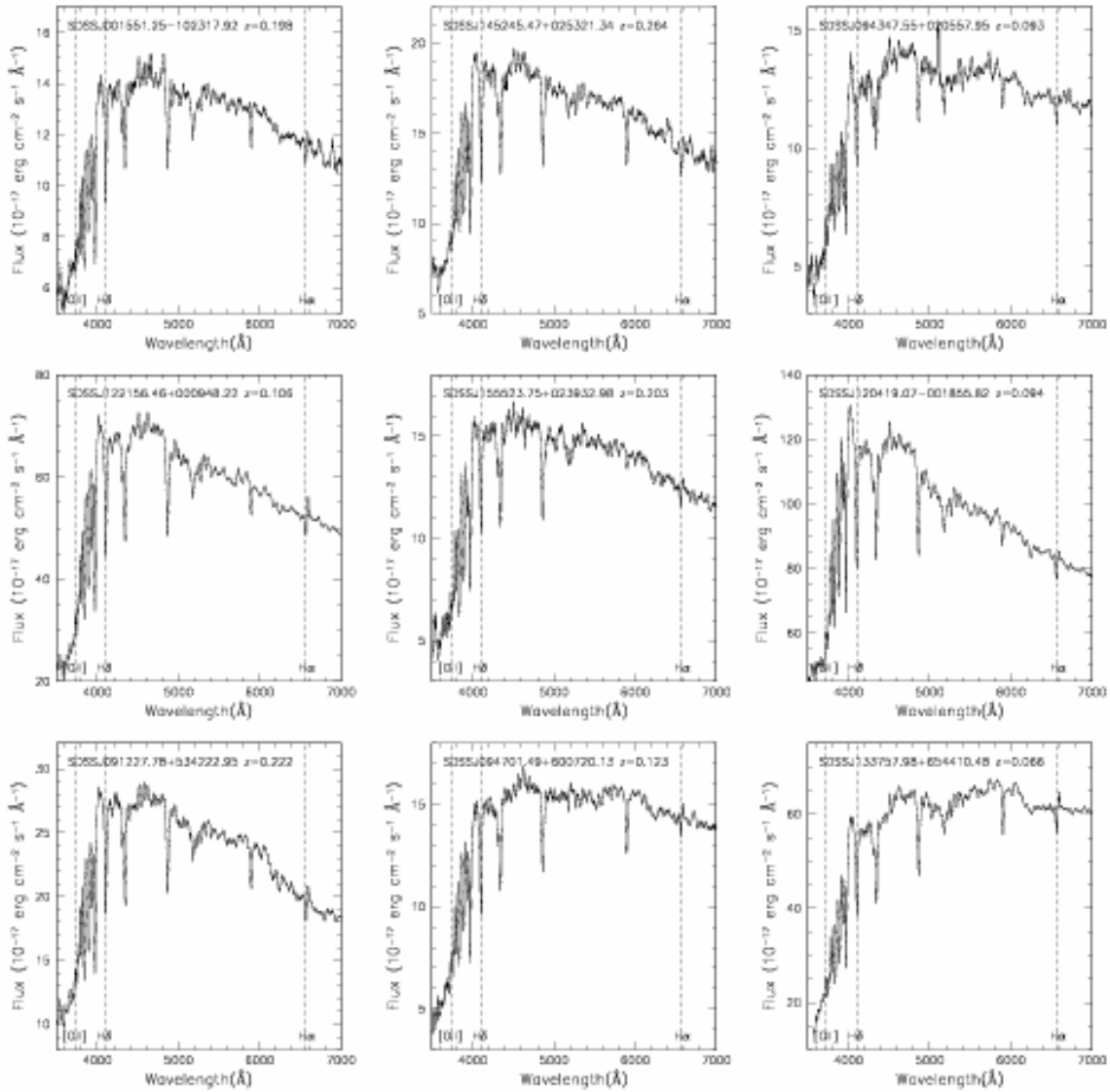


Fig. 16. Nine example spectra of young E+A galaxies (E+As with Hδ EW >7 Å). Spectra are shifted to restframe and smoothed using a 20Åbox.

Atlas Image of Young E+As

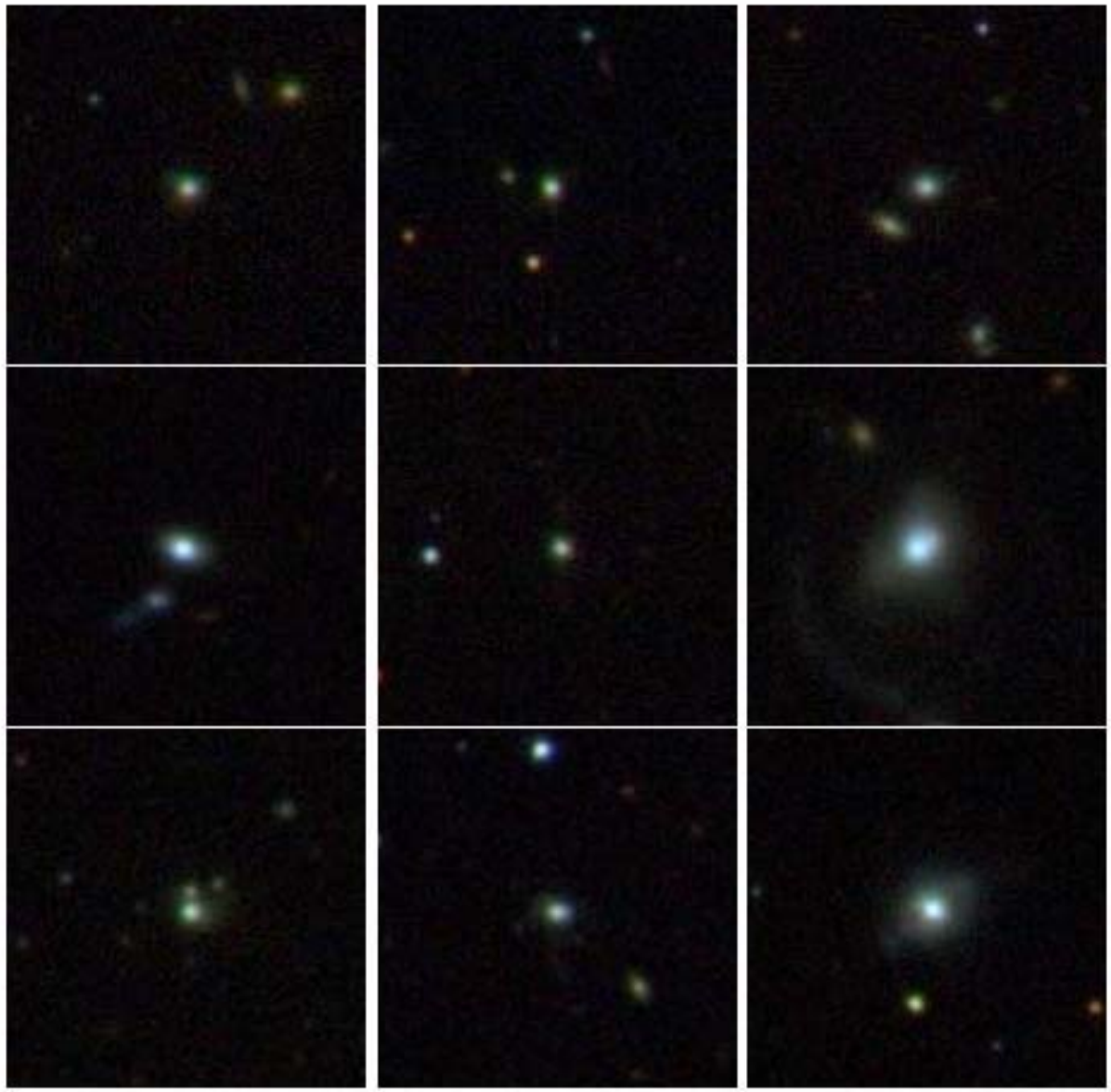
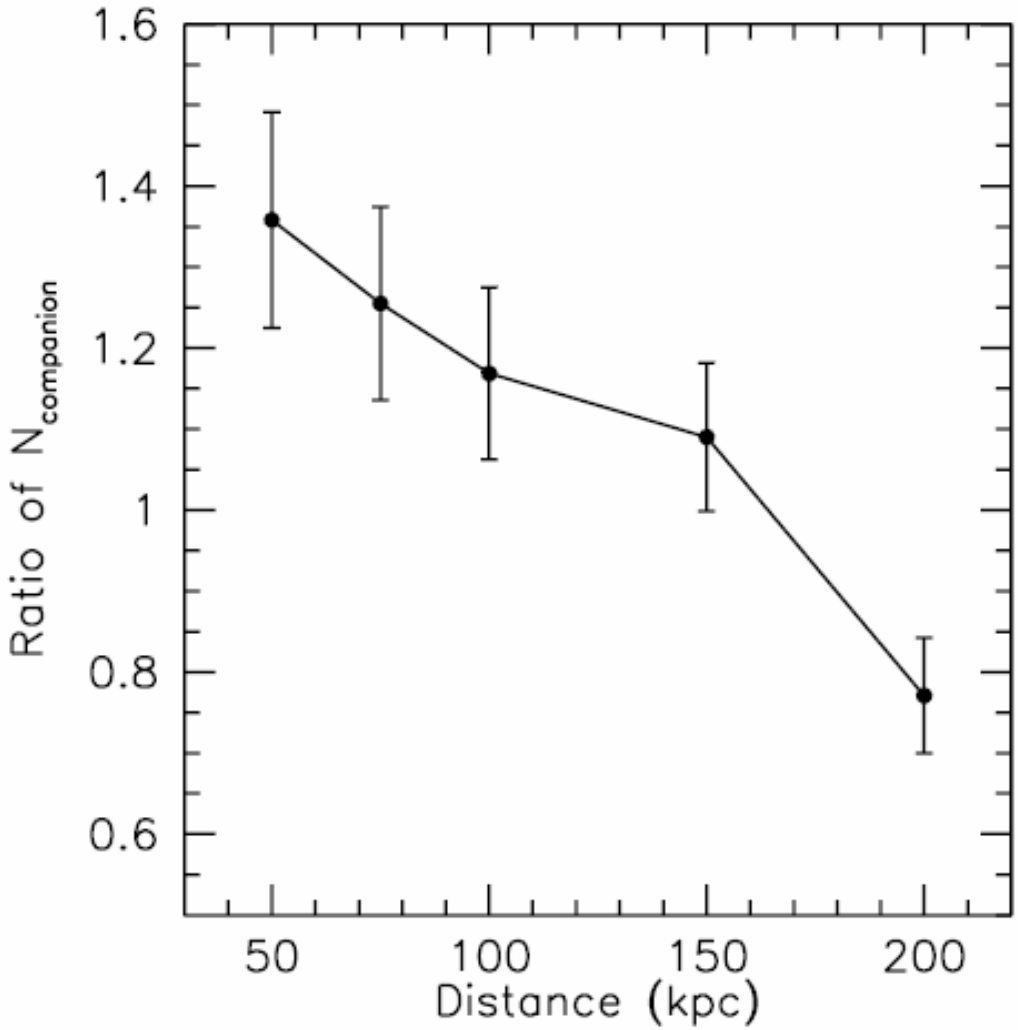


Fig. 17. Nine example images of young E+A galaxies (E+As with Hδ EW >7 Å). Image size is 60"×60" and north is up. Each panel corresponds to that in figure 16.

$N_{accompanying\ galaxies}$



More accompanying galaxies for young E+As at <100kpc scale.

Goto, T. 2005, MNRAS, 357, 937

Figure 3. The number ratio of companion galaxies of E+As to that of random (field) galaxies.

Three Scenarios for E+A

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3. Interaction/Merger (tidal features in 5/21 E+As in Zabludoff et al. 1996)

The Origin of E+As

- ✓ E+As are in all environment including the field.
  - ➔ E+As are not cluster/LSS origin.
- ✓ Optical-IR color is not redder; radio SFR<10Msun/yr.
  - ➔ E+As are not likely to be Dusty Starburst.
- ✓ Excess in $N_{\text{accompanying galaxies}}$.
  - ➔ Merger/interaction is most likely to be responsible for the E+As. Consistent with E morphology.

- ***Hδ-Strong Galaxies in the Sloan Digital Sky Survey I: The Catalog***
  Goto, T. et al. 2003, PASJ, 55, 771
- ***Are E+A galaxies dusty-starbursts?: VLA 20 cm radio continuum observation,***
  Goto, T. 2004, A&A, 427, 125
- ***266 E+A galaxies selected from the Sloan Digital Sky Survey Data Release 2: the origin of E+A galaxies***
  Goto, T. 2005, MNRAS, 357, 937

Papers in progress

- **Color gradients => Yamauchi & Goto, MNRAS in press**
- **Spatially resolved spectroscopy => Yagi & Goto, AJ in press**