Abundance Anomaly of Blue Compact Dwarf Galaxies

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Introduction I

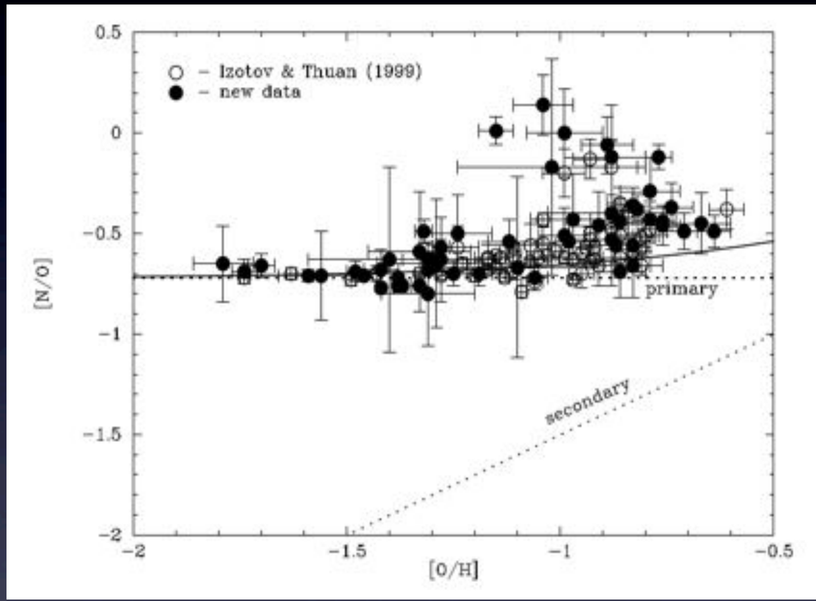
N/O of ISM and *Abnormal* Nitrogen Enrichment of (low metallicity) Galaxies

Thanks to my former speaker, Enrique Perez-Montero, I can skip my LONG Introduction!

❖ The nitrogen enrichment of massive galaxies is the secondary origin (Edmunds & Pagel 1978; Torres-Peimbert, Peimbert, & Fierro 1989; Vila-Costas & Edmunds 1993),
while low mass galaxies have the primary origin (e.g., Thuan et al. 1995; Izotov & Thuan 1999; Pilyugin et al. 2003; Izotov et al. 2011).

❖ It is generally believed that primary nitrogen in starburst galaxies is produced by intermediate-mass stars (Renzini & Voli 1981; Thuan, Pilyugin & Zinchenko 2010).

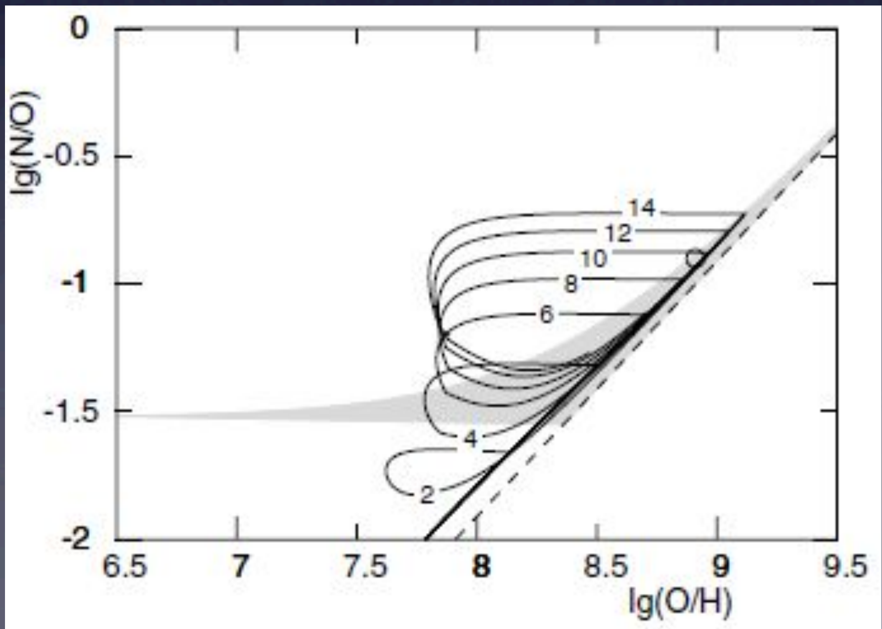
❖ But some of low metallicity galaxies have nitrogen overabundances (e.g. Izotov et al. 2001, Izotov et al. 2011).



Izotov et al. 2001 Fig 1.

Introduction I   Possible Origins of Nitrogen Overabundance

- **By the strong stellar winds of Wolf-Rayet stars**
  (Kobulnicky & Skillman 1996, Pustilnik et al. 2004, Lopez-Sanchez et al. 2011)
- **By gas in-falling**
  (Koppen & Hensler 2005, Amorin et al. 2010)
- **By Massive stars**
  (Izotov et al. 1999, Izotov et al. 2001, Venn 1999)
- **By the intermediate stars (e.g. Nitrogen overabundance of PNs)**
  (Centurion et al. 2003)



Nitrogen Overabundance by the gas in-falling effect

Koppen & Hensler 2005

Introduction II *Dynamical Effects* on the Chemical Enrichment

❖ Low metallicity galaxies of the outlier of Tremonti et al. (2002)' M-Z relations have disturbed morphology

Peeples et al. (2009)

❖ Luminous Infrared galaxies which are known as mergers have low oxygen abundances comparing to field spirals

Rupke et al. (2008)

❖ Based on a numerical simulation, galaxy mergers have lower metallicity

Rupke et al. (2010)

❖ Interacting pairs have systematically low metallicity and negative metallicity gradient due to the gas inflow.

Kewley et al. (2008)

❖ The large nitrogen overabundance could be connected with merger events by WR enrichments

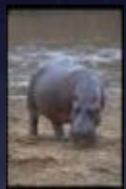
Pustilnik et al. (2004)

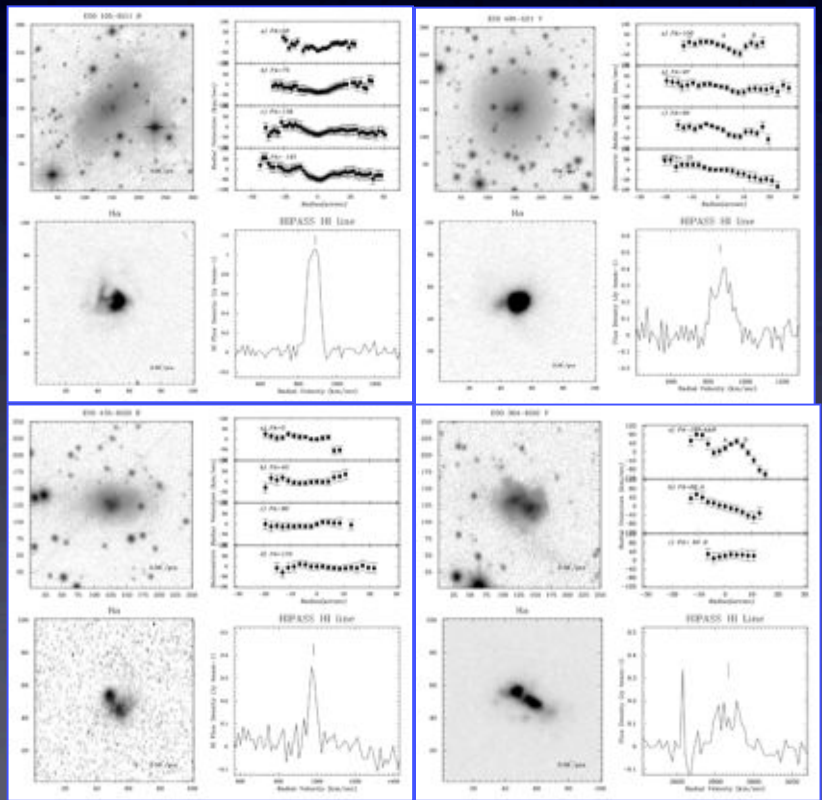
Introduction III   4 *Dynamical* BCD Classes

❖ Based on local environment, the new classification scheme of BCDs (Blue Compact Dwarf Galaxies) is suggested ***Isolated, Post-merging***, ***Detached Interacting***, and ***Merging-in-progress*** (Sung et al. 2002).

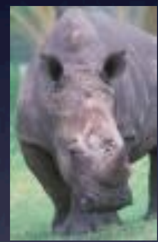
❖ For more than 5000 BCDs from SDSS DR7, the statistics 4 BCD classes are 33%, <1%, 56%, & 12%

Isolated
33% ?





Post –Merging
< 1% ??



Detached
Interacting
56%

Merging-in-
Progress
12%

Sung et al. 2002, Sung 2012

Our purposes of this work are……

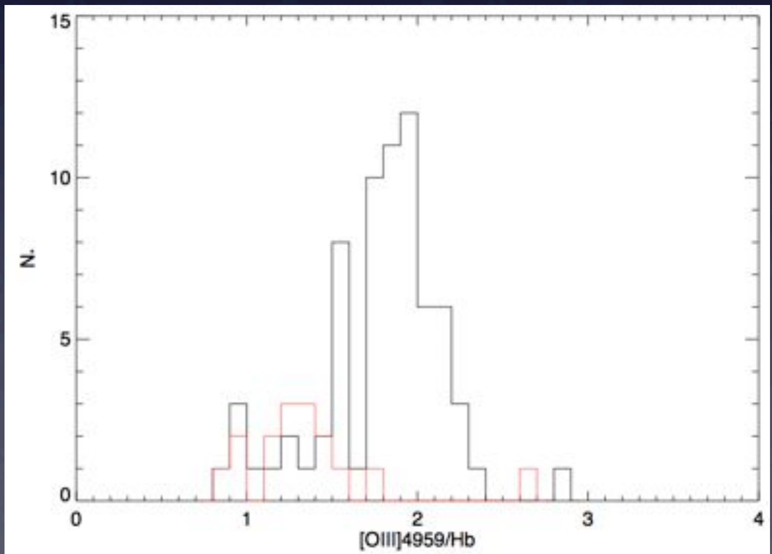
Based on optical and UV data from SDSS DR7 and GALEX GR6, and other data,

- ❖ to find the relationship between morphology and star formation history of low metallicity galaxies (BCDs)
- ❖ to explain the relation between the chemical enrichment of the interstellar medium of BCDs, and star formation history, and dynamical environment.
- ❖ to explain the origin of the nitrogen overabundance of BCDs.

Sample

- 91 highly excited luminous BCDs at 0.2 < z < 0.35 from SDSS DR7
  - Absolute luminosity: -19 < M_g < -22mag
  - Stellar Mass : 7.5 < log(M*) < 10.6
  - [OIII]4959/Hβ > 0.7 & S/N ([OIII]4363) > 1.5
- To be covered nearly whole Hα light → to get the Hα luminosity from Sloan spectroscopy & UV (NUV & FUV) luminosity from GALEX

And 7 nearby sample



Our sample (91 galaxies) 0.2 < z < 0.35	*Abundance :Te* method Hα SFR (*SDSS* DR7 with aperture correctio UV SFR (*GALEX GR6*) : 37 BCDs
Local Merger BCD (5 galaxies)	*Abundance :Te* method Hα SFR (Kennicutt et al. 2008) UV SFR (*GALEX GR6*)
Local post-merger BCD (2 galaxies) Sung et al. 2002	*Abundance :Te* method No Hα SFR UV SFR (*GALEX GR6*)

All galaxies have [OIII]4959/Hβ > 0.7

Basic Data

Elemental Abundances :

- line measurements and corrections : IRAF & Izotov et al. (1994)
- using the direct *Te* method from STSDAS Nebular package and *ICF*s from Izotov et al. (2006) → many discussions yesterday!

Classifications : Morphology & Wolf-Rayet galaxies

- Wolf-Rayet galaxies : He II 4686 lines (Conti 1991)
- **Morphology : Disturbed (21 BCDs) or Round sample (70 BCDs)**

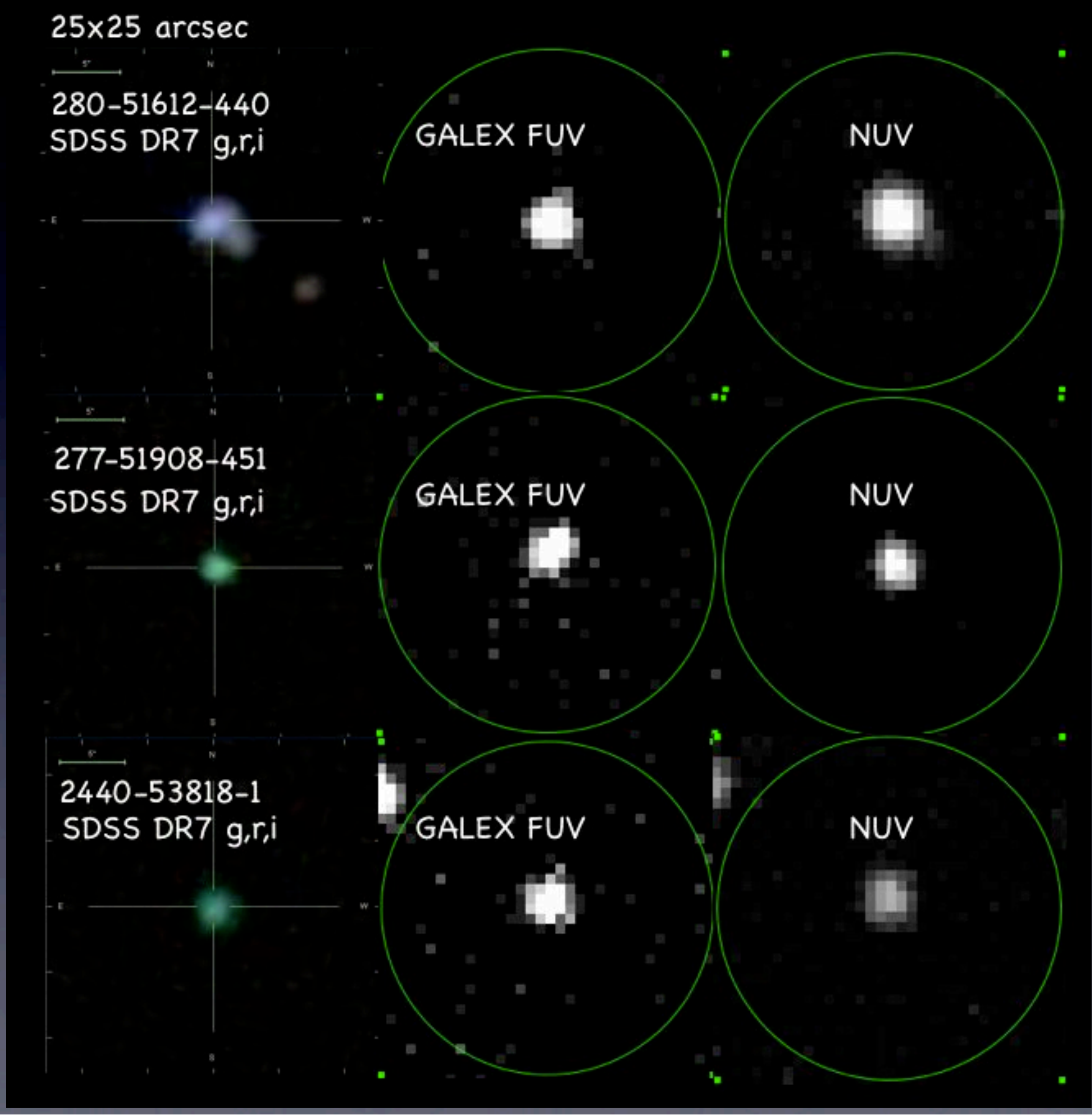
SFR calculations

- Hα SFR : spectroscopic measurement Hα flux = ~80%, aperture correction , SFRs by Kennicutt (1998)
- UV SFR : Internal & Galactic Reddening by Cardelli et al. (1989), k-corrections from calculated SEDs by Starburst99, SFRs by Kennicutt (1998)

Stellar Mass Estimation

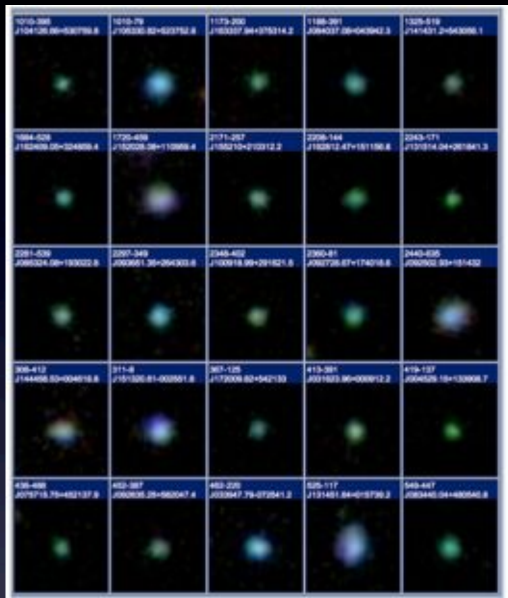
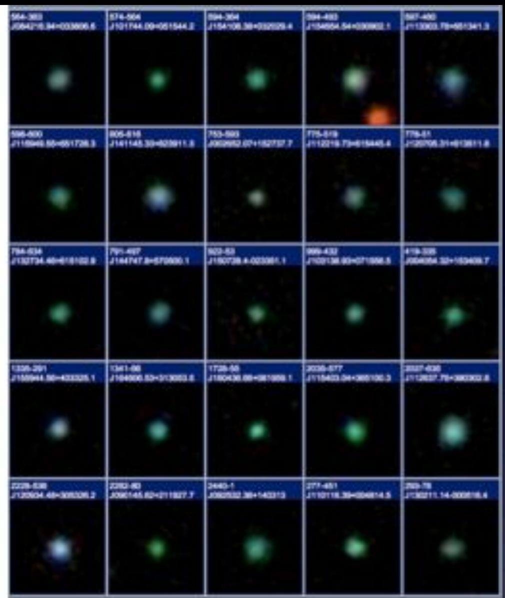
- SED fitting

Sample Images

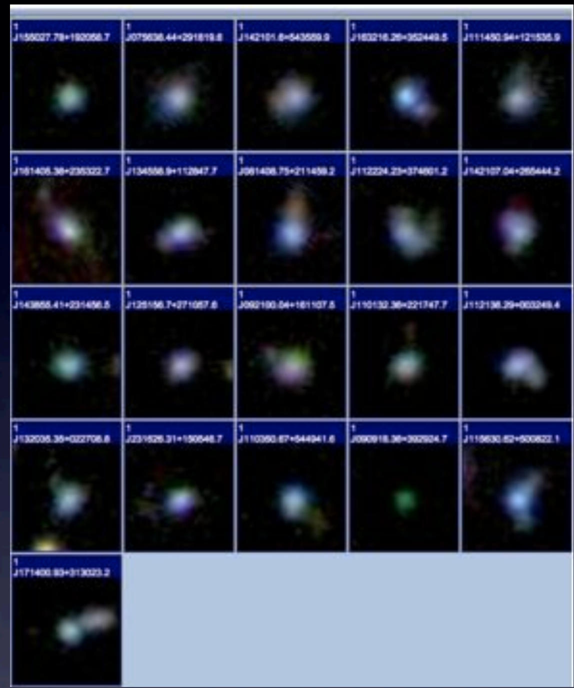


Morphology

- Disturbed sample : Merging-in-progress , may some of Detached Interacting
- Round sample : Detached Interaction, Isolated, Post-mergers

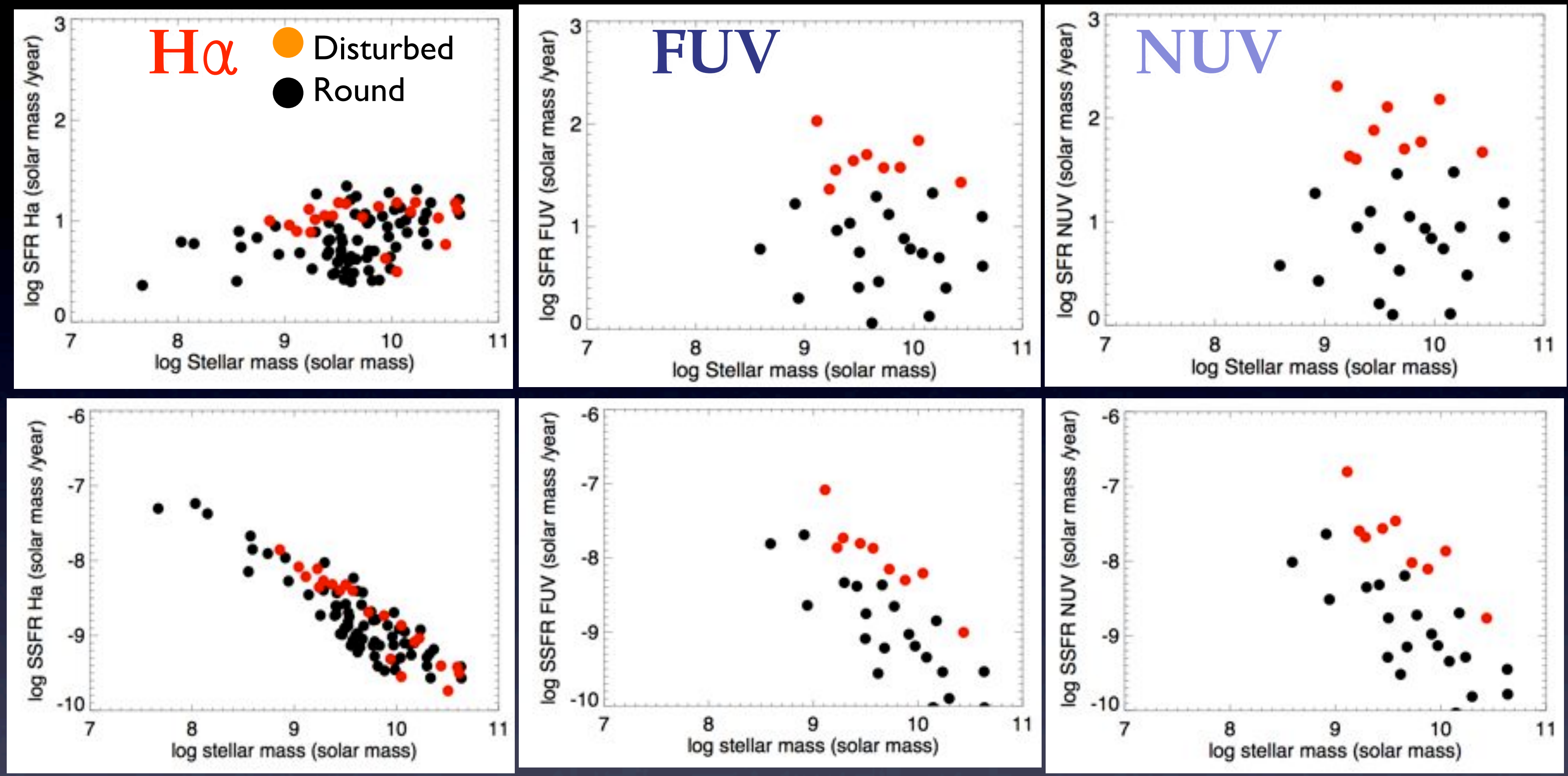

Round Sample



Disturbed sample

Discussion I

SFR (Hα) and SFR (UV)



SFR (Ha)/ SFR (UV) : a good indicator of very recent star formation history
(Sanchez-Gil et al. 2011)

- Disturbed sample tent to have high SFRs comparing to round sample
- Disturbed sample are higher SSFR at the same stellar mass.

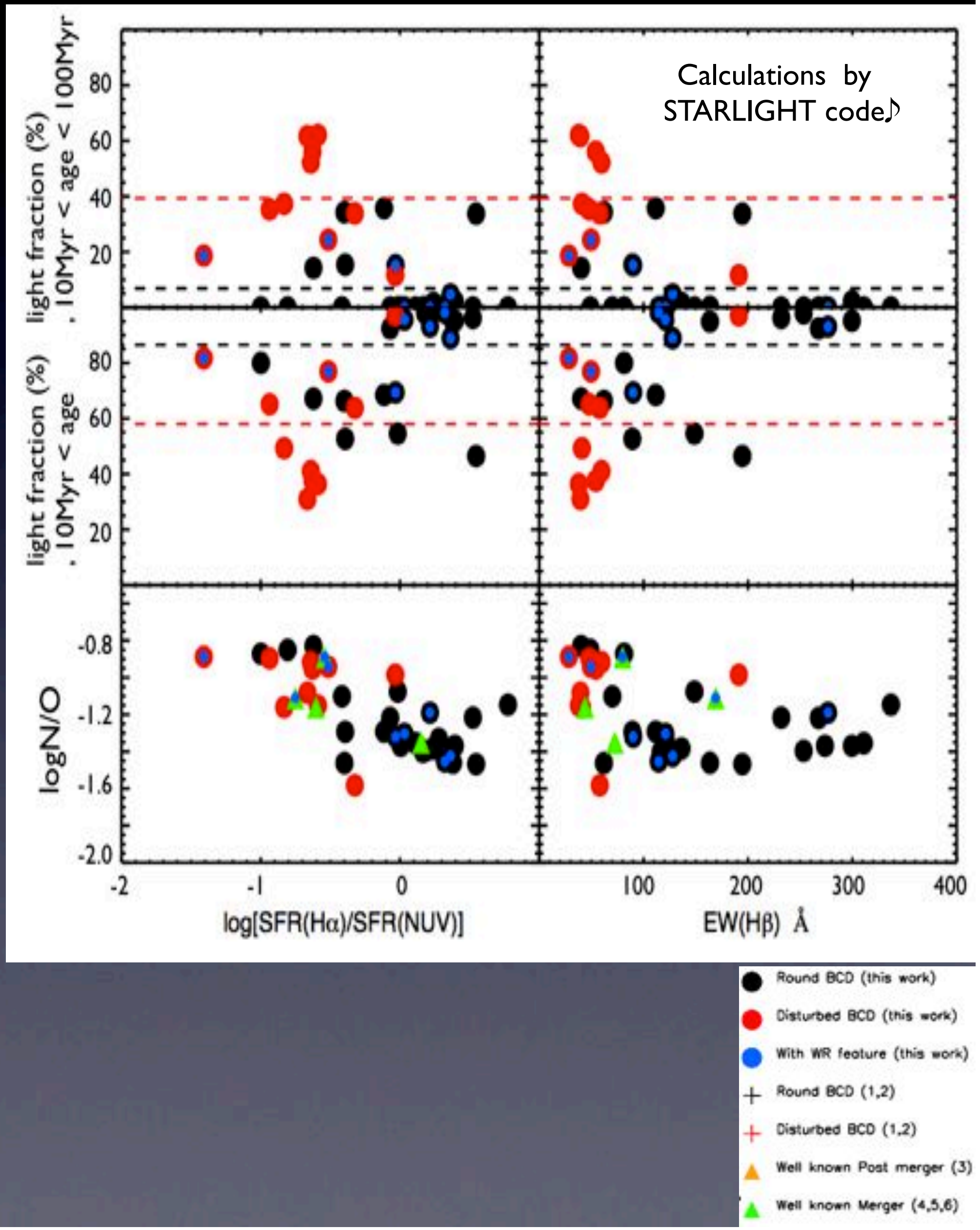
Discussion I SFR (Hα) /SFR (UV) Ratio, SFH & Morphology

Disturbed sample have lower SFR(Ha) / SFR (UV) ratio than round sample

→to have undergone longer star formation
→to have more old stars (on the diagram of SFR(Ha)/SFR(UV)–EW (Hb))
→maybe mergers (Bekki 2008)

Few round sample with low SFR(Ha) / SFR (UV) ratio are possible post-merger candidates.

Disturbed sample tent to be lower SFR(Ha) / SFR(UV) ratio and **higher N/O ratio up to -0.8**



Discussion II Oxygen Dilution & Nitrogen Enrichment

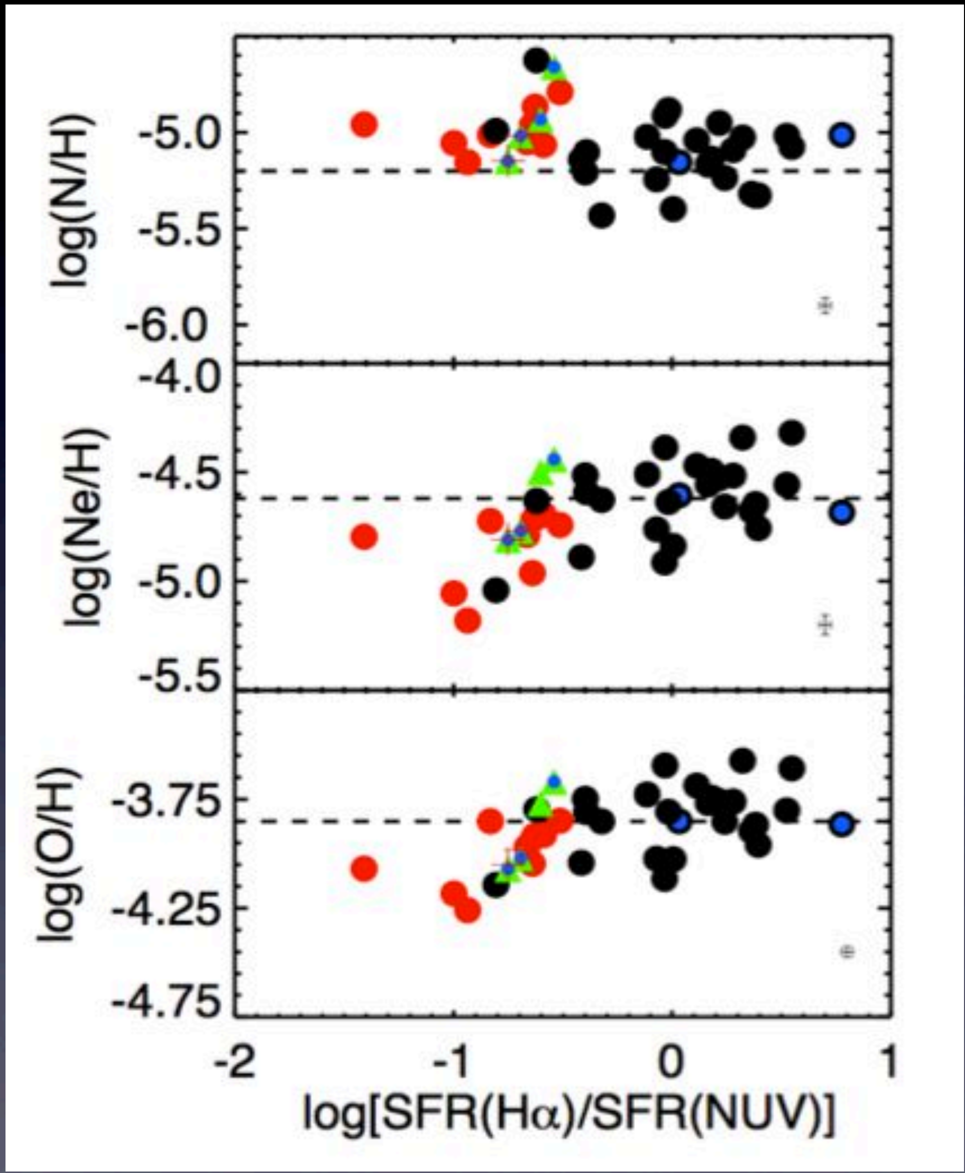
Disturbed sample (mergers) with lower SFR (Ha) / SFR(UV) ratio have lower O/H & Ne/H, while higher N/H.

→ Oxygen and Neon abundances are diluted more , while Nitrogen is enriched more for mergers than for round sample (mainly starburst triggered by detached interacting or flying-by, etc)

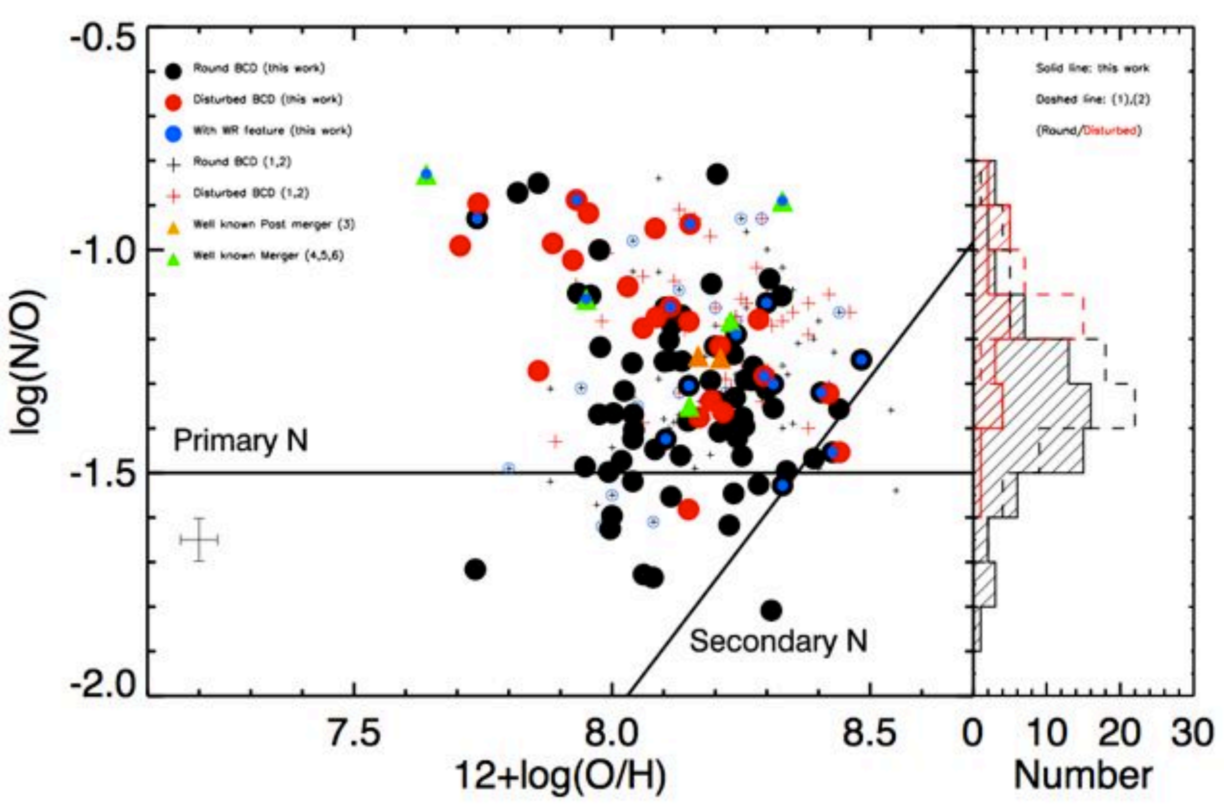
→ to confirm previous results for oxygen abundance (Rupke et al. 2010 Pustilnik et al. 2004)

→ Oxygen and Neon may be diluted by the gas in-falling. But the nitrogen needs the internal enrichment process.

→ The ISM enrichment of luminous BCDs are depended on morphology, i.e. dynamical environment.



Discussion III Nitrogen Overabundance and its Origins

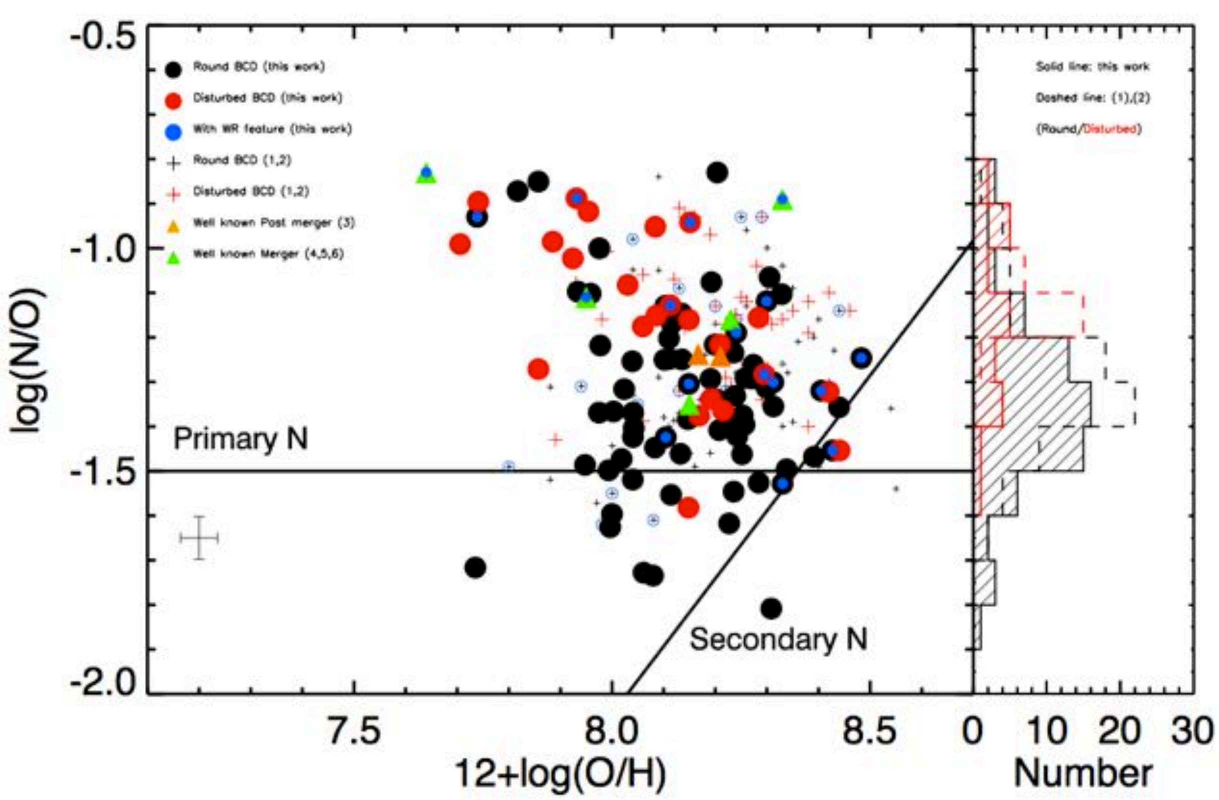


[1] : Izotov & Thuan
[2] : Izotov et al. 2006
[3] : Sung et al. 2002,
[4] : Lopez-Sanchez 2010
[5] : Lopez-Sanchez & Esteban.2010
[6] : Pustilnik et al. 2004

Some galaxies have higher N/O overabundance up to N/O -0.8.
→ too high N/O ratio to be explained by the gas in-falling scenario only
→ to need the internal nitrogen enrichment process

Higher nitrogen overabundance sample are mainly disturbed sample comparing to lower nitrogen overabundance ones.
→ the different recent star formation histories related to dynamical environments give the different nitrogen enrichments.

Discussion III Nitrogen Overabundance and its Origins



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[6] : Pustilnik et al. 2004

BCDs with Wolf-Rayet features (with blue dots) are mainly round sample.

→ But, considering their short lives of Wolf-Rayet stars, round sample with relatively younger star formation have likely high probabilities to detect Wolf-Rayet features.

→ Wolf-Rayet stars seems to be still the most important origin of the nitrogen overabundance, and also less massive fast rotating stars may be another important origin.

CONCLUSIONS

❖ Nitrogen overabundance (anomaly) of luminous BCDs depends on morphology.

❖ Recent (few Myrs to ~100 Myrs) star formation history based on Hα & UV flux for luminous BCDs can explain dynamical environments of the galaxies.

❖ The different SFHs from the dynamical environments give the different chemical enrichments .

❖ Nitrogen overabundance of low metallicity galaxies cannot be fully accounted the gas in-falling. But both of nitrogen self enrichment process by fast rotating massive stars may the most important roles of the nitrogen overabundance of low metallicity BCDs