

Beyond $12+\log(\text{O}/\text{H})=7$:

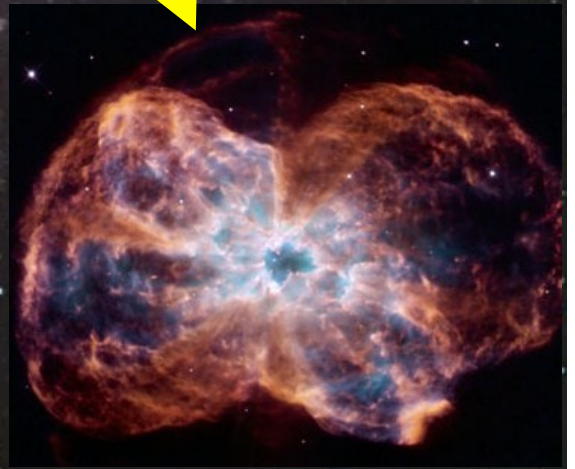
Search for extremely metal-poor galaxies
with HSC, PFS, and TMT

Tohru Nagao (Ehime U.)

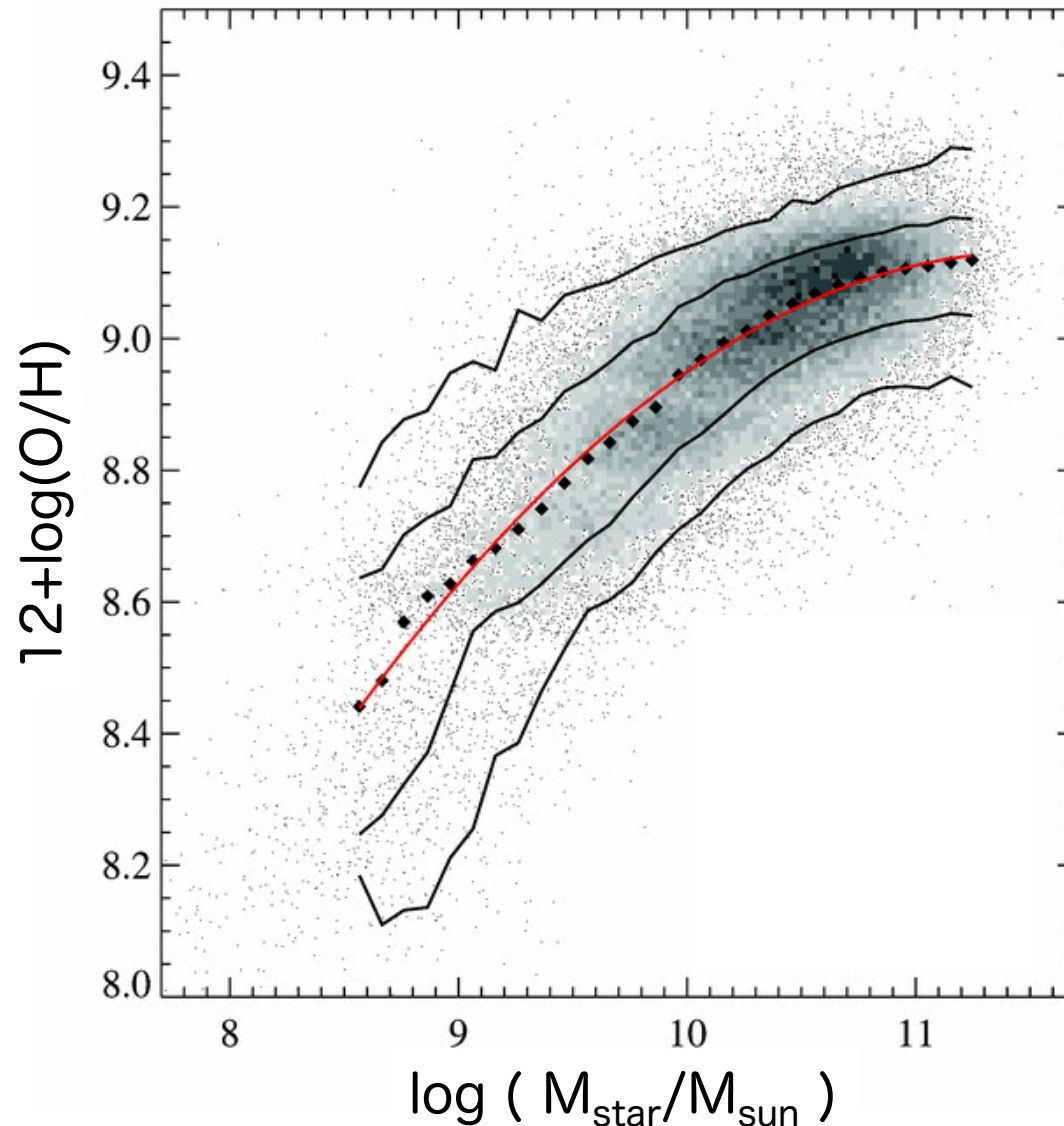
- Metallicity Measurements for Galaxies
- Extremely Metal-Poor Galaxies (XMPGs)
- Best Synergy: The HSC NB Dataset & PFS
- Observational Strategy

NAOJ Mitaka, 10 Dec. 2010
PFS Science Workshop

Why Metallicity?



The Mass-Metallicity Relation in Galaxies

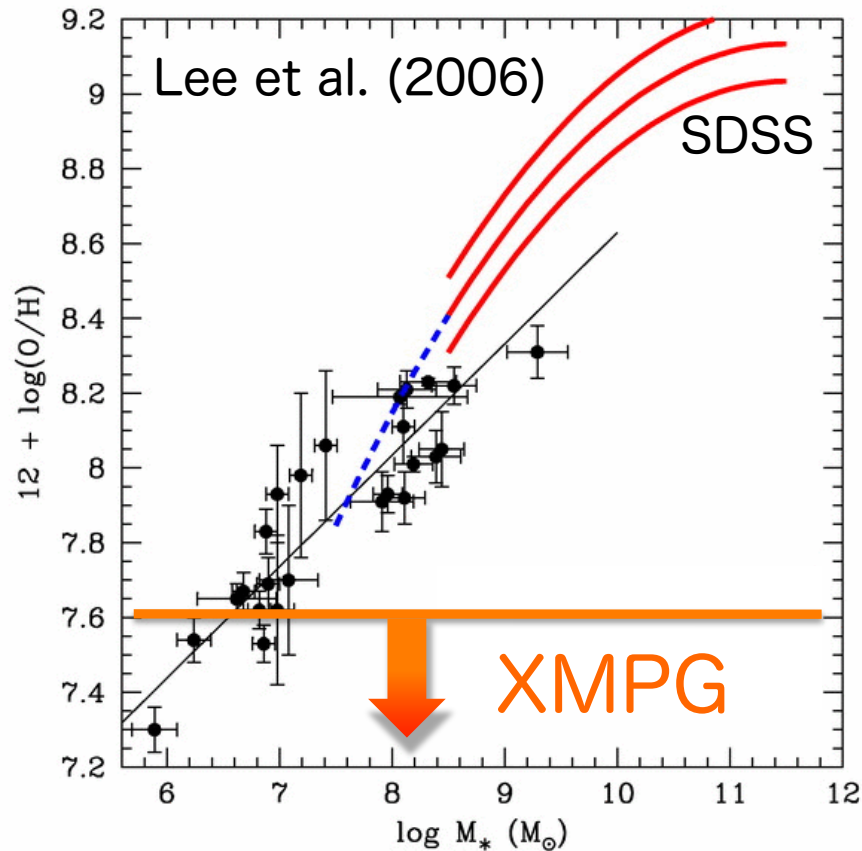


...suggesting the importance of galactic outflows (superwinds)

Gas-phase metallicity of SDSS 53000 galaxies at $z \sim 0.1$

Tremonti et al. (2004)

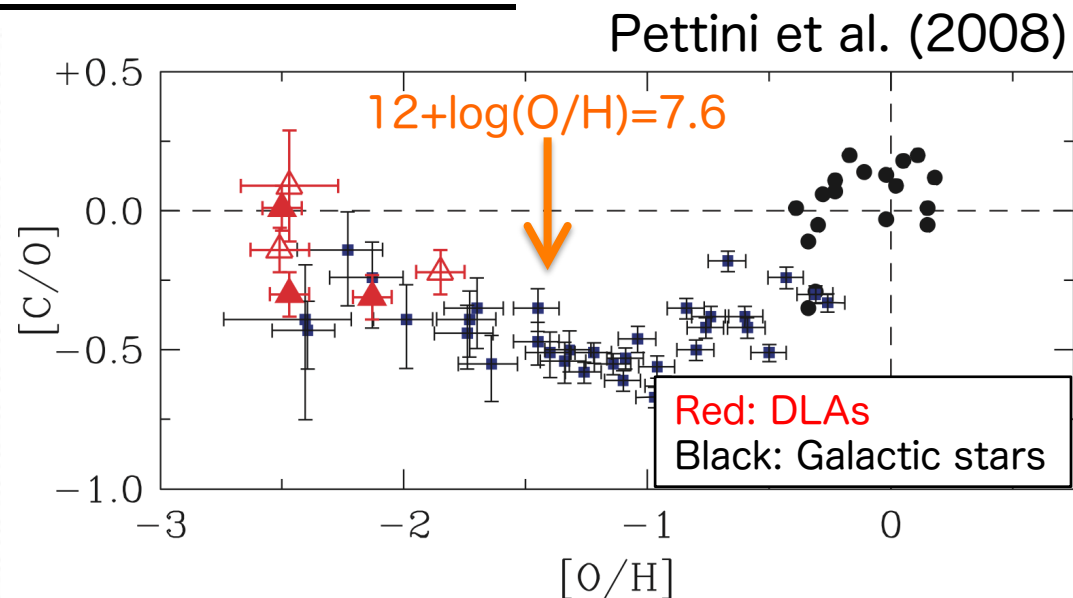
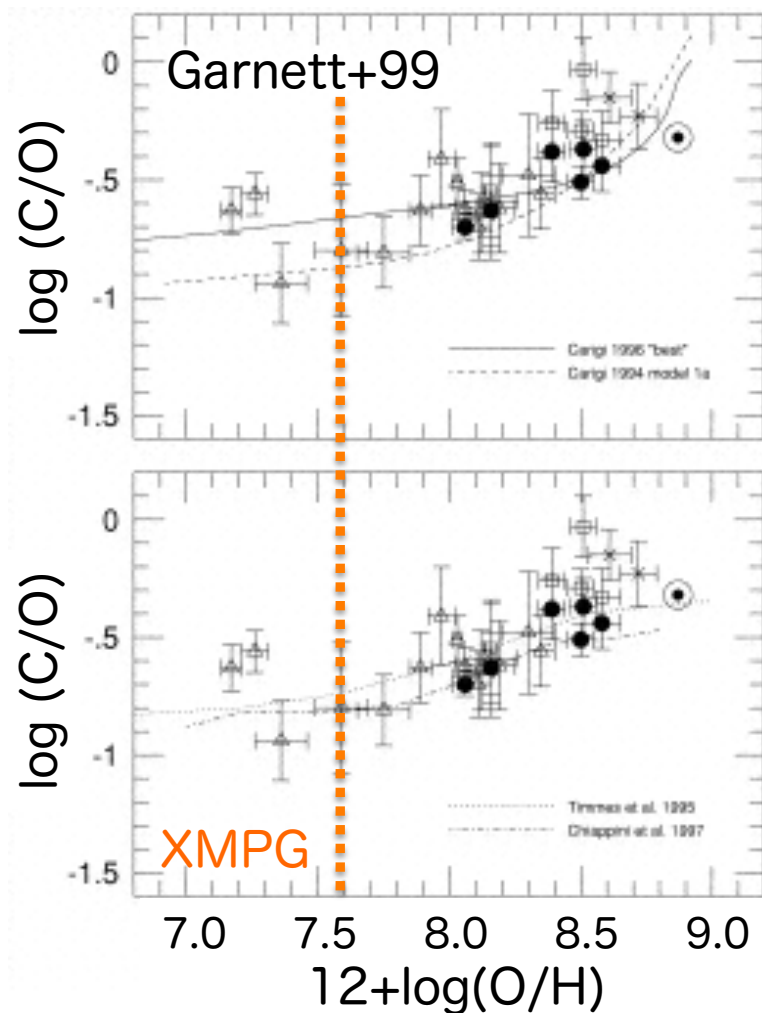
The Mass-Metallicity Relation at Low-M



Extremely Metal-Poor Galaxies

The M-Z relation extends
for 6 dex in stellar mass !!
($12 + \log(\text{O}/\text{H}) < 7.6$: XMPGs)

Chemical Properties of XMPGs: C



Relation with CEMP stars?

High C-yield in PopIII stars??

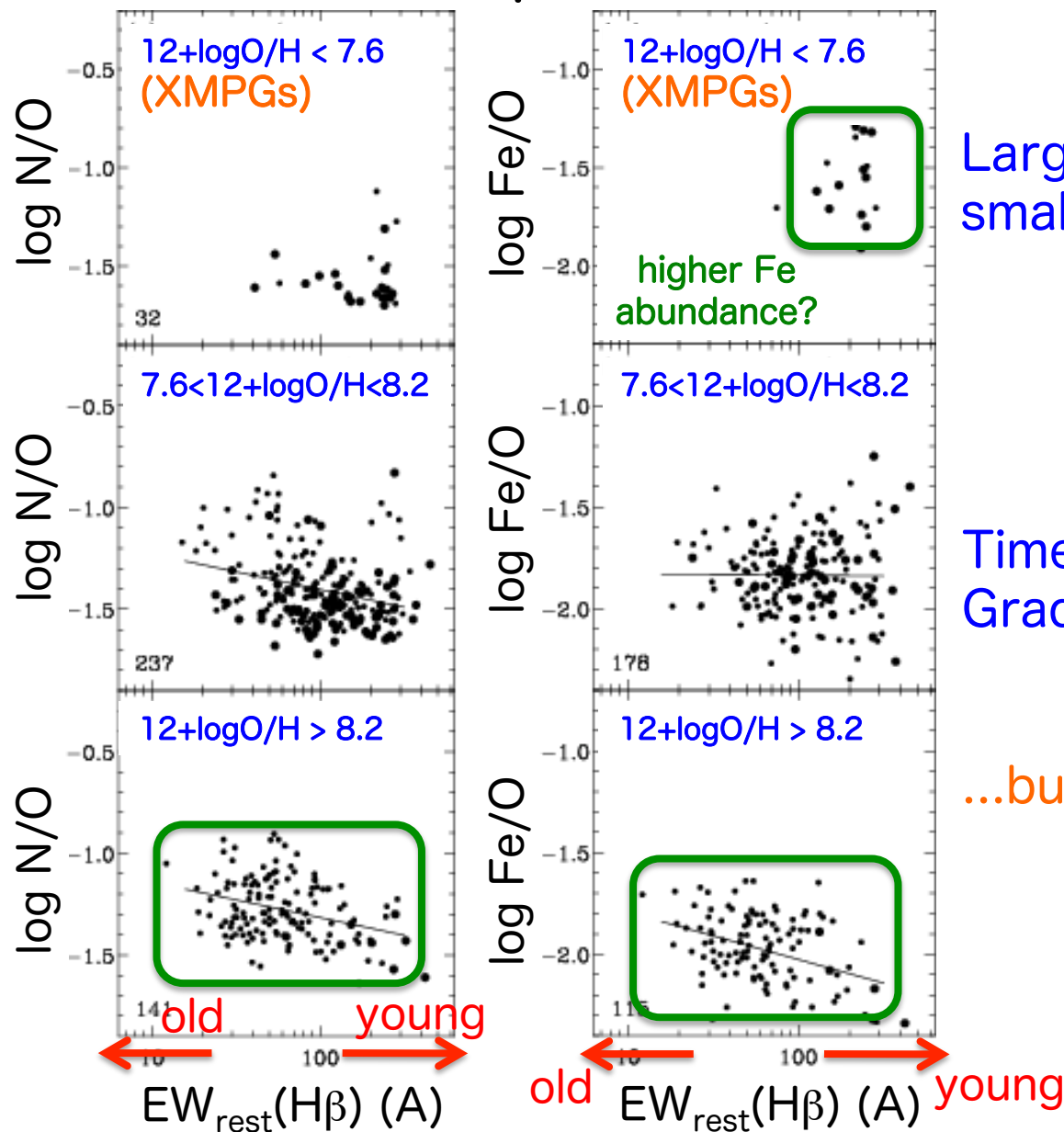
(Cooke et al. 2011)

Relation with high $L_{[\text{CII}]157\mu\text{m}}/L_{\text{FIR}}$
at high- z (i.e., low- Z_{gas})?

(Maiolino, Nagao, et al. 2009)

Enhanced C at low- Z_{gas} ??

Chemical Properties of XMPGs: N and Fe

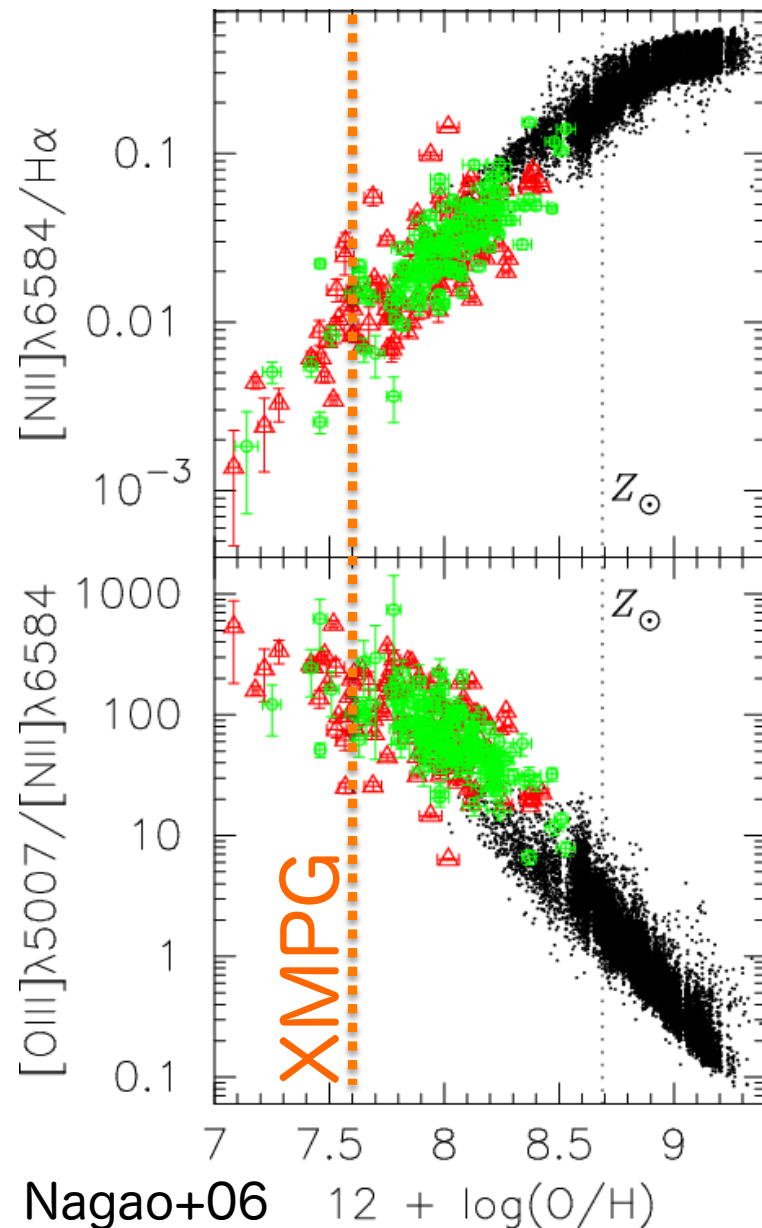


Large EW(H β) objects show smaller N/O and Fe/O ratios

Time delay of N enrichment & Gradual grain destruction

...but, how about XMPGs?

XMPG Search: The Case of SDSS



Izotov et al. (2006):

Only 6 XMPGs in SDSS DR3 sample
(~50000 galaxies !!!)

→ success rate: ~0.01%...

Izotov+: 136 [OIII]4363 detected, 6 XMPGs
literature: 120 [OIII]4363 detected, 19 XMPGs

Why is the search of XPMGs difficult?

Black: SDSS galaxies (Tremonti+04)

Green: SDSS low- Z_{gas} sample (Izotov+06)

Red: Compiled from literature (Nagao+06)

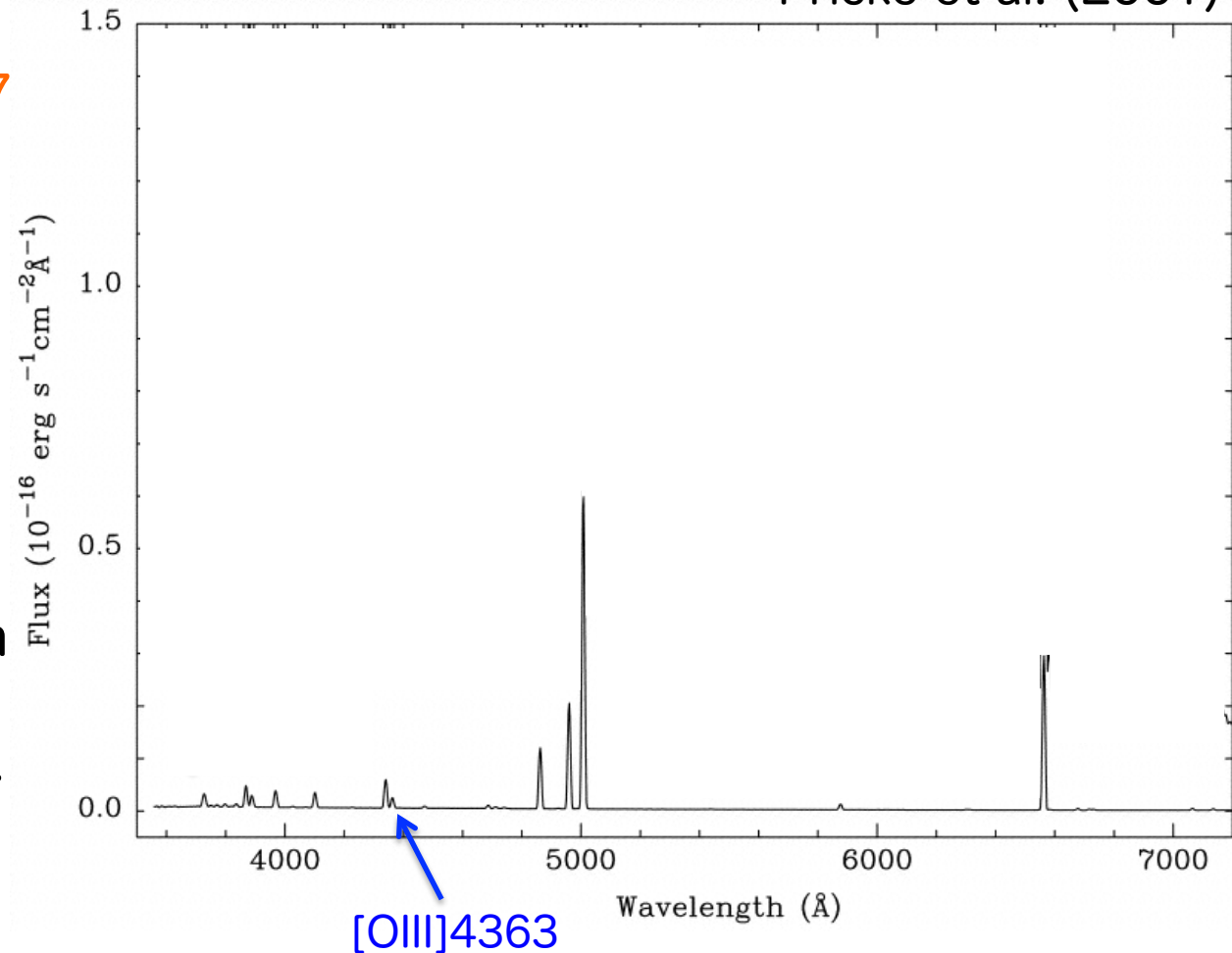
XMPG Optical Spectrum

Fricke et al. (2001)

XMPG: Tol 1214-227
 $12+\log(\text{O}/\text{H})=7.52$

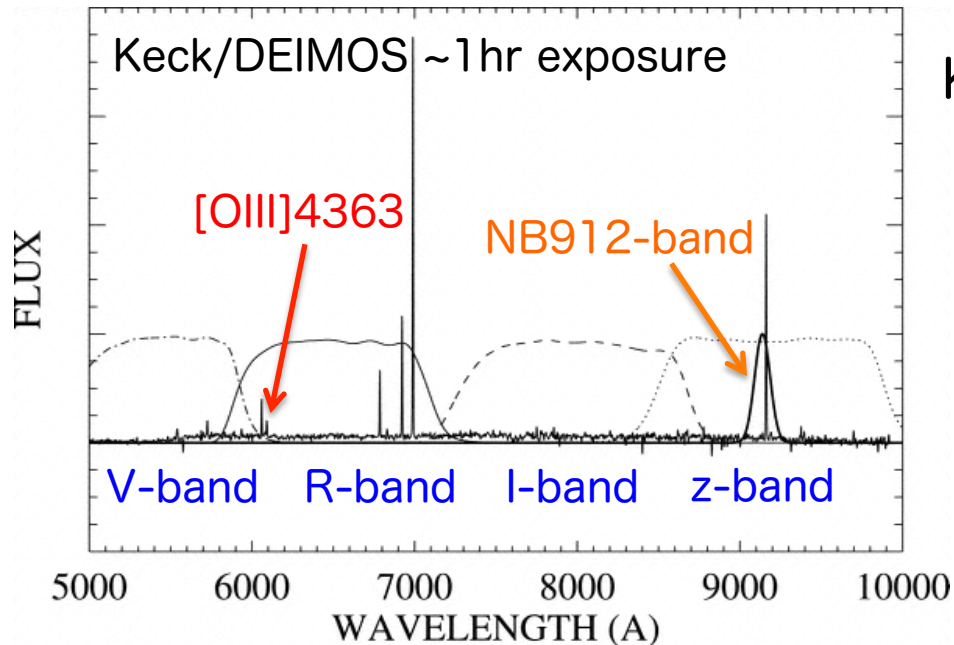
Most of photons are
emission lines, NOT
continuum emission!!

Broad-band selection
(such as SDSS data)
fails to find XMPGs...



Pre-selection with narrow-band data
should be the right way for XMPG search!

XMPG Search: The Case of NB Survey



Kakazu et al. (2007)

NB816 & NB912, $\sim 0.5 \text{ deg}^2$

Selection criteria:

$N816 < 25$ & $I - N816 > 0.8$

$N912 < 25$ & $z - N912 > 1.0$

both corresponds to $EW_{\text{obs}} > 100 \text{ \AA}$

[OII]3727, H β , [OIII]5007, or H α

Photometric sample of strong NB: 542

Targets for spectroscopic runs: 161

[OIII]4363-detected objects: 17

Extremely metal-poor galaxies: 10

Success rate of the NB XMPG survey: $10/161 \sim 6\%$

XMPG number density: $542 \times (10/161) \times (1/0.5) \sim 67 \text{ deg}^{-2}$

Target number density: $542 \times (1/0.5) \sim 1000 \text{ deg}^{-2}$

XMPG Search: The Case of HSCNB+PFS

HSC Ultradeep (3.5deg²)

NB526: $m_{\text{lim}}=26.8$

NB717: $m_{\text{lim}}=26.4$

NB816: $m_{\text{lim}}=26.6$

NB921: $m_{\text{lim}}=26.4$

NB973: $m_{\text{lim}}=25.0$

HSC Deep (~28 deg² ??)

NB816: $m_{\text{lim}}=25.3$

NB921: $m_{\text{lim}}=24.9$

Depth: OK !!

30 deg² for NB<25

→ 2000 XMPGs (among 3e4 obj.)

XMPG survey with PFS

~at $0.05 < z < 1.0$

~6hour/FoV x 18FoV = >15nights

Requirements to PFS

~lambda coverage:

3900 - 9800Å for O/H

(3900 -13000Å for N/H)

~lambda resolution: R=2000-3000

~fiber number: >2000/FoV

Synergy with TMT

~For detailed chemical composition
such as C, Fe, Cl, ...

HSC for candidate selection
PFS for XMPG identification
TMT for abundance studies

Summary

Extremely metal-poor galaxies: very early stage of chemical evolution

- ~ abundance ratios tell us various info on early galaxy evolution
- ~ only <50 XMPGs ever known

New XMPG survey by focusing on NB-selected galaxies at $z < 1$

- ~ to obtain statistical sample of XMPGs
- ~ to go beyond $12 + \log(\text{O}/\text{H}) = 7$ (the current record is ~ 7.1)
for the study of possible “primordial” galaxies at $z < 1$

Observational strategy:

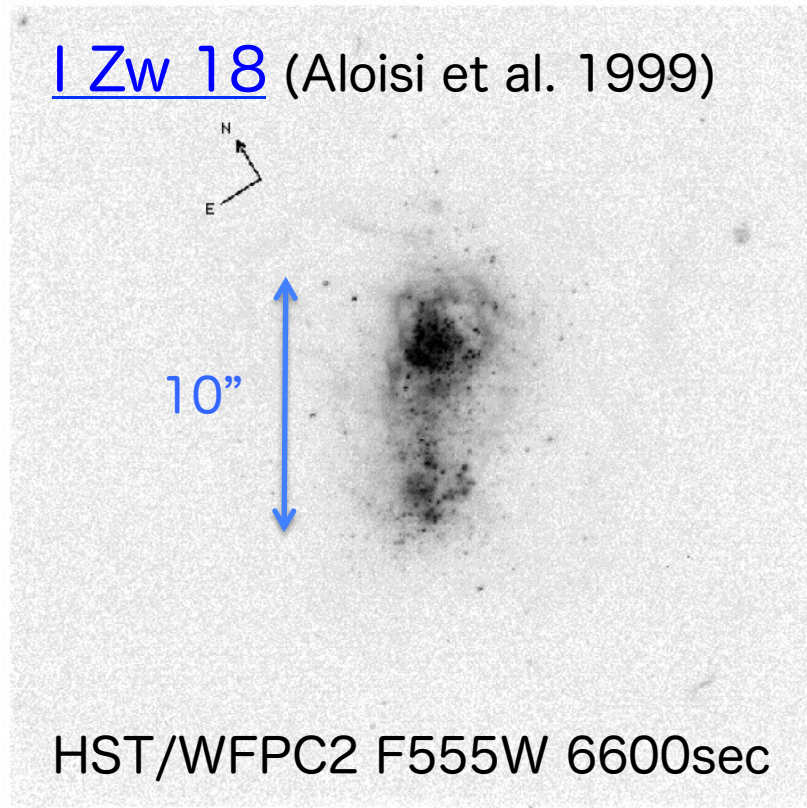
- ~ HSC: providing unique targets with NB ($\text{NB} < 25\text{mag}$, 30deg^2)
- ~ PFS: identifying ~ 1000 XMPGs by detecting faint [OIII]4363 and measuring O, N, S, Ne elemental abundance ratios
- ~ TMT: analyzing abundance ratios of C, Fe, Cl, Ar, ...

Requirements to PFS:

- ~ λ coverage: $3900\text{\AA} < \lambda < 9800\text{\AA}$ (or up to $1.3\mu\text{m}$ for N/O)
- ~ λ resolution: $R \sim 2000\text{--}3000$

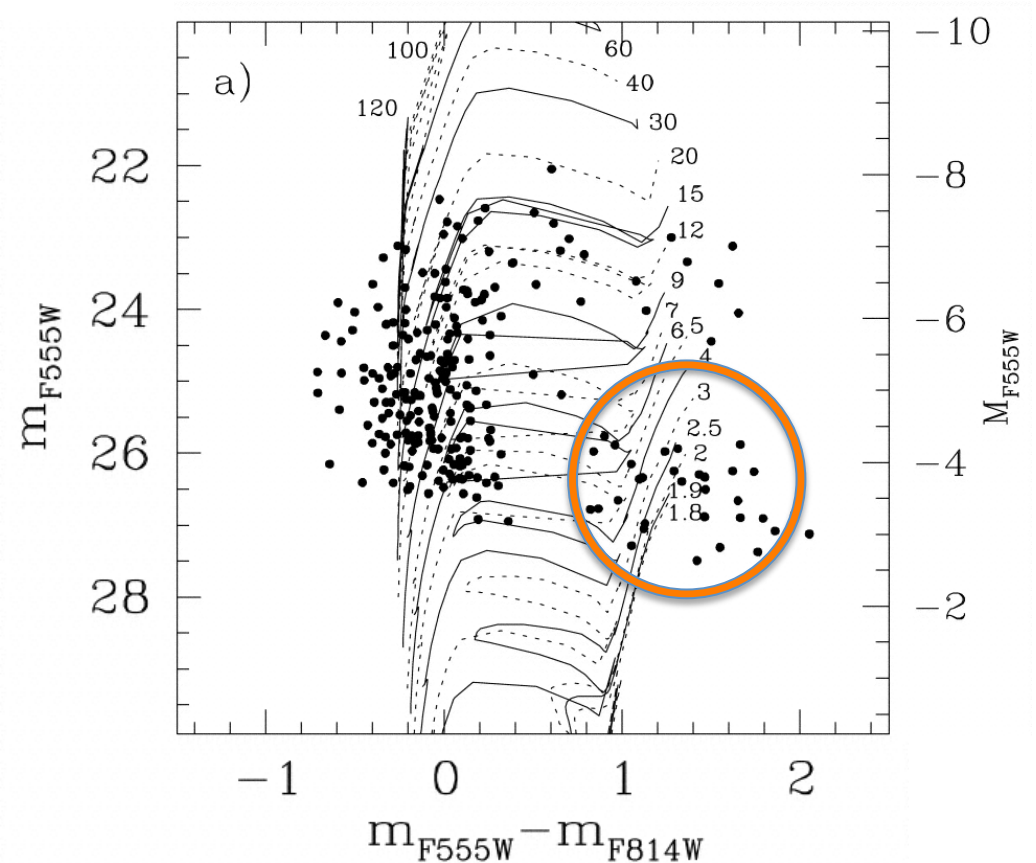
Appendix

Metal-Poor Blue Compact Dwarf Galaxies



$12 + \log(\text{O}/\text{H}) = 7.2$ ($Z_{\text{gas}} = 0.02 Z_{\text{sun}}$)

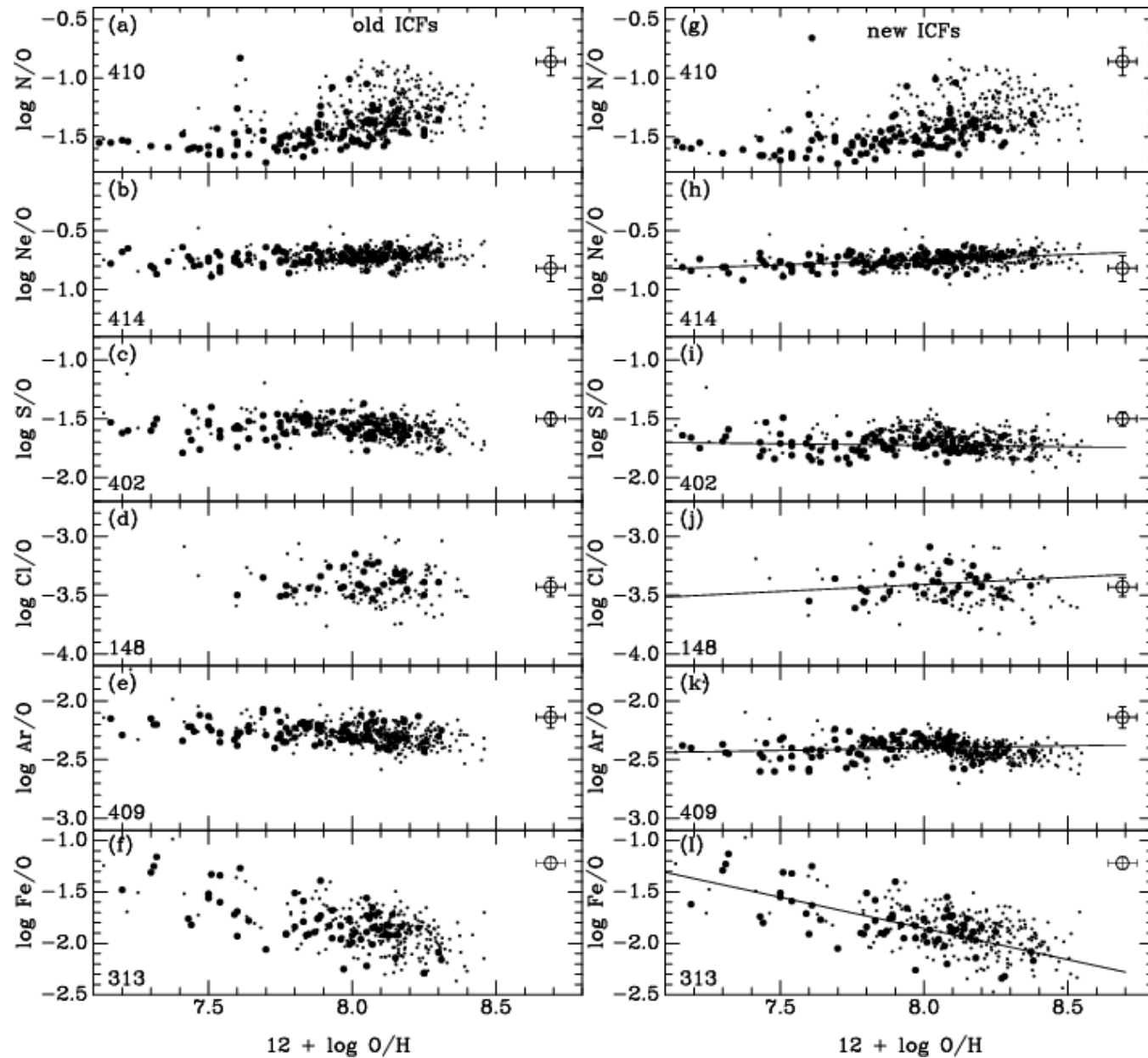
A Local “Primordial” Galaxy?



Presence of faint RGB/AGB stars

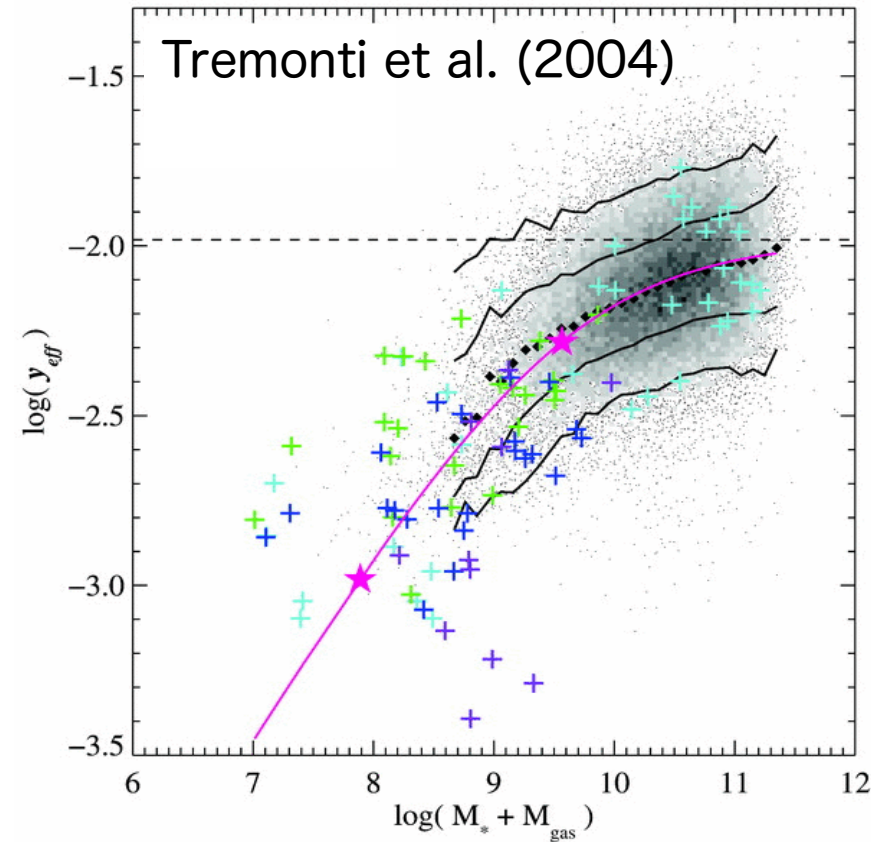
0.5-1 Gyr old (not primordial...)

Gas-Phase Elemental Abundance Ratios



Izotov+06

Effective Yield as a Function of Galaxy Mass



$Z = y \ln(\mu_{\text{gas}}^{-1})$ for closed-box
→ y_{eff} : effective yield
→ strong superwind at low-M