New explorations with DEEP of the metallicities of gas and stars at intermediate redshifts

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Publication Date:
2003

Permanent Link:
https://doi.org/10.3929/ethz-a-004584615

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New Explorations with DEEP of the Metallicities of Gas and Stars at Intermediate Redshifts

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19 Aug 2003 ETH Zurich
Outline

1) What is DEEP, DEEP1, & DEEP2?
2) Fe/H OF OLD STARS at $z \sim 0.9$
3) O/H of EMISSION GAS at $z \sim 0.75$
4) SUMMARY & FUTURE
The DEEP Collaboration

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Caltech: R. Ellis, C. Steidel, C. Conselice, G. Smith, T. Treu

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Supported by: NSF, NASA, UCO/Lick, CARA, Sun, Quantum
DEEP1 and DEEP2

• **DEEP1**: pilot survey for DEEP2, 1995-2001
  - Keck LRIS, HIRES, NIRSPEC, ESI spectra & HST V, I imaging
  - Targets: Groth Survey Strip (GSS) & SA 68
  - 600 redshifts in GSS to I~23.5 at z = 0.2 to 3.0
  - Kinematics, structure, luminosity & colors, SFR, abundances, etc.

• **DEEP2 1-Hour Survey (1HS)**: 90 Keck nights, 2002-2005
  - DEIMOS, R=5000 & CFHT B, R, I imaging
  - Targets: 3 fields 0.5x2 deg & Special one of 0.25x2 deg Extended Groth Strip which will have SIRTF, GALEX, and CFHT Legacy
  - 50,000 redshifts to R = 24.1 & using photo-z for z = 0.7 - 1.4
  - DEEP1 + large survey science: clustering, environment, densities, lensing...

• **DEEP2 3-Hour Survey (3HS)**: 30 Keck nights, 2002-2005
  - LRIS blue spectra of ~1000 galaxies to I~25, z ~ 1.4-2 in 1HS & GOODS
  - High S/N DEIMOS spectra of E/S0 galaxies in GOODS-N
  - Other (TBD)
DEEP2 1HS basics

• **4 Fields:** 14 17 +52 30 (includes Groth Survey Strip)
  16 52 +34 55 (zone of very low extinction)
  23 30 +00 00 (on deep SDSS strip)
  02 30 +00 00 (on deep SDSS strip)

• **Field dimensions:** 30’ by 120’ (15’ ¥ 120’ for Groth field)

• **Primary Redshift Range:** z=0.75-1.4, pre-selected using BRI photometry to eliminate objects with z<0.75

• **Magnitude limit:** R < 24.1 (CFHT B,R and I are available)

• **Grating and Spectra:** 1200 l/mm: ~6500-9100 Å
  [OII] 3727Å doublet visible for 0.7<z<1.4

• **Resolution:** 1.0” slit: FWHM=1.7Å ¥ 68 km/s
DEEP2 1HS vs Local Redshift Surveys

Volume ($h^{-3} \text{ Mpc}^3$)

Number of Galaxies

- CFA+SSRS
- PSCZ
- LCRS
- DEEP2
- 2dF
- SDSS
The advantage of high spectral resolution

- Improved **internal velocity** measurements with higher-resolution DEIMOS data

Resolved [OII] doublet with 220 km/s separation
1) DEIMOS was commissioned in mid-2002 and is FULLY OPERATIONAL

2) DEEP2 1HS: First Light JULY 2002
   3HS: Data in GOODS-N in Spring 03

3) Keck NIGHTS: 17 (10 clear) in 2002 w DEIMOS ; (54 Allocated) 18 in Spring 2003 w DEIMOS
   6 in Spring 2003 w LRIS-B (3HS)
   13 in Fall 2003 w DEIMOS

REMAINING 66 NIGHTS TBD THROUGH 2005

4) REDSHIFTs: 1HS: 30% collected
   2002 data (10%) yielded 5,000+ z’s with 1,600+ at z > 1
Galaxies exist in large numbers beyond $z = 1$.

$\# L > L^* \& z > 1$
Sample Keck Spectra (LRIS) & HST Images (WFPC2) from DEEP
Gas in distant galaxies have lower [O/H] & change is greater for fainter galx.

**Gas O/H vs Luminosity**

**Local galaxies**

**Distant galaxies** $z = 0.6-0.8$

**LBG** $z \sim 3$

Kobulnicky et al 2003

Phillips et al 2003
Galaxies at $z \sim 0.7$ with OIII 4363 deviate strongly from bulk of galaxies.
Fundamental plane to $z \sim 1$

Gebhardt et al. 2003

$0.75 < z < 1.0$

$0.3 < z < 0.75$

$SB \sim 2$ mag @ $z = 1$
Surface Brightness Residuals vs $z$

$Z_f = 1.3$ Model

DATA

$Z_f = 3$ Model

Fit to Field

Gebhardt et al. 2003
Luminosity evolves, but color does not change.
Drizzled SF Model in Color vs Lum Evolution

Formation $z = 1.9$

Age = 10 Gyr
$	au_0$ = 5 Gyr
$f_{mass}$ = 7%

Gyr since $z = 1.9$

2.5 Solar
Solar

MS1054 Cl $z = 0.83$

Flat U-B with 2.5$\odot$ + drizzle of SF

DATA

Gebhardt et al. 2003
Color vs Redshift

Raw R-I

Rest U-B

DEEP2 (10%)
5500 z’s

Weiner et al. 2003, Willmer et al. 2003

Color bimodality
Color vs Luminosity Selection to Match SDSS
O II 3727 in Red Galaxies

DEEP2/SDSS Coadded Spectra

DEEP2: 206 Galaxies, z~0.9
SDSS: LRG, 276 Galaxies, z~0.2

Normalized Spectrum

Wavelength (Å)

3701 3950 4200

K&H

H II

O II

Konidaris et al. 2003
H delta (~ Age) vs Redshift

Schiavon et al. 2003
Age & Metallicity of Red Galaxies

\[ \text{AGE} = 1.5 \text{Gy} \]

\[ [\text{Fe/H}] = -1.3, -0.7, -0.4, 0.0, +0.2 \]

Ages: 14, 8, 5, 2.8, 2.2, 1.5, 1.0 Gyr

+5% of 0.8 Gyr, [Fe/H] = +0.2

\[ <z> \sim 0.84 \]

No [OII] 3727

[Fe/H] +0.2
DEEP Summary

• DEIMOS on Keck is working and performing superbly
• DEEP1 is done with DEEP2 solidly underway
  • 1HS of 50,000 galaxies is 30% done; with 10%, already 1600+ at $z > 1$
  • 3HS has started in the GOODS-N field for E/S0 & “desert” galaxies
• Internal kinematics distinguishes DEEP2
• Red Galaxies at $z \sim 1$ show:
  • Very red rest-frame colors ($U-B \sim 0.4+$)
  • Significant Luminosity Evolution of $\sim 1.5$ mag by $z \sim 1$ (FP, LF, & size-L)
  • Young ages of 1-2 Gyr ($H\beta$) with super-solar Fe/H $\sim +0.2$ dex
  • Evidence for “drizzling” of continued star formation ($OII$)
• Strong Emission Lines at $z \sim 0.7$ show:
  • $O/H$ vs Luminosity relation suggesting evolution (lower $O/H$ at given L)
  • Lower luminosity galaxies show more evolution
  • Vast fraction of $O/H$ are moderate to high $\sim 1/4$ to 1 Solar
  • But some very luminous $\sim L^*$ galaxies show $O/H \sim 1/10$ Solar