WIDE FIELD SURVEYS FOR EXTREME EMISSION LINE GALAXIES

tracing the youngest galaxies WITH NGCFHT

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Extreme emission line galaxies

• High equivalent width Balmer lines pick out young (or at least rejuvenated) galaxies with very high star-formation rates (line emission) relative to their stellar mass (measured by the continuum).

• Surveys of such galaxies can let us understand how metallicity grows in early galaxies and what the properties of the fueling (or refueling) gas are.
We’ve known since Sargent and Searle’s work in the 1970s that there are some very low metallicity galaxies in the local universe. The lowest metallicities known are about $12 + \log(O/H) = 7.2$ or about $1/40^{th}$ of the solar metallicity.

But these are generally small galaxies and we still only know of a small number of them.

Does this mean that we have stopped making new galaxies (or at least rejuvenating them)?

If so when did this happen? Also is there really a floor on the galaxy metallicity?

The lowest metallicity galaxy known for almost 3 decades I Zw 18 has $12 + \log(O/H) = 7.17$ or about $1/40^{th}$ of the solar metallicity.
Rapid evolution is seen in the maximum Hα and Hβ luminosities: reach maximum value around z=0.8
What happened over the z=0-1 range?
What has changed in the fueling process?

figures from Cowie, Barger, Hu & Zagursky 2013
High luminosity Ly<sub>a</sub> emitters also only appear at z = 0.8

Cowie et al 2011
Finding extreme emission line galaxies

- Wide field narrow band searches
- Distorted broad-band colors (emission-line contamination)
- Wide field grism spectroscopy (UV, optical, near-IR)
- Objects are sparse and faint in the continuum so they need to be picked out separately from continuum surveys
Finding extreme emission line galaxies

- In designing a possible NGCFHT survey I am going to draw on two large area surveys

- Kakazu et al. (2007) Half square degree narrow band survey with the Subaru camera

- 4-6 square degree Lyα and UV continuum selected grism surveys with GALEX. Cowie et al. (2011) at $z=0.2-0.45$ and Wold et al. (2013) at $z=0.7-1.3$

Both intensively followed-up with Keck DEIMOS
Bright UV continuum selected sample NUV<22.1 (2400A)

Cowie et al. 2011

USELs $\text{EW(H}\beta)>30A$

EELs $\text{EW(H}\beta)>100A$

SPARSE!
What do the spectra look like?

Left panel grism spectrum from the GALEX satellite:
Right panel optical spectrum from KeckII DEIMOS
Narrow band searches are a better way to find fainter emitters to a fixed limiting flux and equivalent width.
Half square degree survey through 100A filters in the 8100 and 9200A atmospheric windows:

Suprime imaging, Keck Deimos spectroscopy

Spectroscopic completeness

Line flux limit of $3 \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$

542 objects with observed EW greater than 100A

Kakazu et al 2007
The most extreme emission line galaxies generally have a detectable [OIII]4363 line:

Can measure metallicity with direct method and don’t need to rely on very suspect strong metal line diagnostics.
What is the science here?
Extreme emitters are small and have low extinction and low metallicity

Red=LAE
Blue=UV continuum

Results from GALEX 
z=0.2-0.45 survey (Cowie et al. 2011)
Need to correct for emission-line contributions (e.g. Schaerer & deBarros 2009)

For these data sets where we have both spectra and colors, we can correct the broad band colors for the known emission lines.

These corrections can be very large for extreme emitters.
• Without line correction galaxies are misinterpreted as old and red

• Really, the bulk of EELs are young and relatively dust free
A protogalactic track?

Galaxies grow along a well defined age-metallicity track with a smooth increase in mass and size.

Extinction builds up as the size increases.

Ly$\alpha$ is primarily seen in the young high EW(H$\alpha$) stages.

If galaxies are primarily young, as at high $z$, the Ly$\alpha$ fraction may be high, but probably not much more than 50%. At low $z$, the Ly$\alpha$ fraction is much lower, reflecting the low galaxy formation rate.
NGCFHT extreme emission line survey goals

• To accurately determine the metallicity-age (specific star formation rate) relation in the youngest galaxies
• To measure the evolution over the key $z=0-1$ redshift range
• To determine the dispersion in properties at a given galaxy age and whether this depends on environment
• To decide if there is a low metallicity floor in young galaxies and (if so) determine its value
These galaxies are sparse and faint: need to be specifically included in samples

To $N(AB)=24$

(flux=$3 \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$)

Get about 50 galaxies in a Suprime field, so about 500 in a NGCFHT/Hyper Suprime field
Survey Design

Hyper Suprime-Cam narrow band imaging:
100 square degree
NB816 1 hour 5 sigma =25.0 (AB)
NB912 1.5 hour

~15 nights with these two filters will give samples at
z=0.24, 0.40, 0.63, 0.84, 1.19, 1.47

NGCFHT: 1600 galaxies per field
4 hour exposures with R=2000 resolution, ~30 nights

Ultimate yield ~3000 extreme emitters
End
Morphologies (from GEMS)
Metallicity-luminosity

Based on direct method using the [OIII]4363 line

Local (Tremonti et al 2003)

z=0.8 Cowie and Barger 2008

Local floor
Galex
GRB
USEL

Blue z<0.5
Black z>0.5
Is there a preferred extinction law? (Milky way line of sight seems to work better than Calzetti screen)
Ly selected galaxies have much lower NII/H than other UV galaxies at the same redshift. They are lower metallicity.

Green triangles have strong \([\text{OIII}]4363\)
Metallicity and Balmer Equivalent widths are highly correlated: Age (Specific Star-formation rate)-metallicity relation

Figures from Barger, Cowie, and Hu 2013
They are much more luminous than the blue compact galaxies but have just as low metallicity.
Lower mass but similar star formation rates