Subaru Hα Survey for the Coma Cluster

Survey Highlights and Hα Luminosity Function

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Coma Cluster

- One of well studied galaxy clusters located at z=0.023
  - Panchromatic coverage from X-ray to Radio
    (e.g. XMM, GALEX, WFCAM, Spitzer, VLA)
  - Follow-up Spectroscopy (for over 1000 galaxies)
  - ASC Treasury Program (Carter et al.)

- Important target as a local benchmark
  - Comparison with field, other clusters and high-z clusters
Hα Imaging of Galaxy Clusters

- Star formation activity of the cluster of galaxy
  - how significant faint dwarf population contribute to Hα LF
  - SFR of galaxies in different environment

- Hα observation was carried out for Coma and A1367 down to SFR of ~0.01 Ms/yr by Iglesias-Paramo et al. (2002)
  - Samples only active star-forming dwarf galaxies (e.g. NGC6822, NGC3109) and misses many less active galaxies
Hα Imaging of Galaxy Clusters

• Environmental processes
  – extended emission line regions found for NGC 4388 (Yoshida et al. 2002, 2004) and M86 (Kenney et al. 2008) in the Virgo cluster
  – How rare? Dependence on environment?
  Properties of host galaxy?

Yoshida et al. 2002, 2004

Kenney et al. 2008
Suprime-Cam Hα Imaging Survey

• Subaru Telescope provides us
  – sufficient survey depth by its 8.2m primary mirror
  – good image quality
    • Median seeing ~0.6” in R-band
    • Excellent tracking accuracy

• Suprime-Cam provides us
  – wide-field survey capability:
    FoV 34x27 arcmin^2 covered by ten 2k × 4k CCDs with 0.2”/pixel sampling
  – dedicated narrow-band filter which samples Hα emission at the redshift of Coma
Suprime-Cam Hα Imaging Survey

- Narrow-band filter (NB671)
  - $\lambda_{c}=6714$Å, FWHM=130Å
  - sample Hα line @ Coma redshift
  - goes as deep as 26.2 ABmag ($6.0 \times 10^{-18}$ erg/s/cm$^2$), corresponding to SFR of $2 \times 10^{-4}$ Ms/yr
  - 2 order of magnitude deeper than Iglesias-Paramo et al. (2002)
- 3 broad band filters: B, R, i’
  - continuum flux is estimated from weighted combination of B, R, i’-band fluxes
  - broad band colors are useful to discriminate distant [OIII] and [OII] emitting galaxies
- 3 different fields
  - cluster core, infalling region, outskirts

<table>
<thead>
<tr>
<th></th>
<th>Limiting Magnitude</th>
<th>Exposure Time (hr)</th>
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</thead>
<tbody>
<tr>
<td>NB671(Hα)</td>
<td>26.2</td>
<td>6.0</td>
</tr>
<tr>
<td>B</td>
<td>28.0</td>
<td>1.9</td>
</tr>
<tr>
<td>R</td>
<td>27.4</td>
<td>1.0</td>
</tr>
<tr>
<td>i’</td>
<td>26.9</td>
<td>1.0</td>
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Suprime-Cam Hα Imaging

Observations:
- Shallow Pilot Survey (2006)
- Main Survey for 3 fields (2007~2009)

Due to bad observing condition, the data are shallow (Ha: 3.5-5hr, B: ~1hr, R: ~1hr, i’: ~30min)
• Yamanoi et al. (in prep.)
  – B and R band LFs for three fields in different environment based on the statistical background subtraction
  – steep rise of faint-end slope of Schechter $\alpha \sim -2$
  – no significant difference in faint-end slope between three fields.
• Comparison with Other Surveys
  – Confirms the steep faint-end slope reported by various authors (e.g. Milne et al. 2007, Adami et al. 2007)
  – Suggests that the faint-end slope is actually steep from the core to the outskirts of the cluster
B,R,Hα composite
(Hα emission = red)
Extended H_α Emission Line Regions

- 14 extended emission line regions are found for the cluster core field
  (Yagi et al. 2007, 2010; Yoshida et al. 2008)

B,R,H_α composite
(H_α emission = red)
Extended $\text{H}\alpha$ Emission Line Regions

- Spatial/Velocity Distribution

Extended emission line regions avoid the cluster core

Parent galaxies reside near the red/blue edges of the distribution (i.e. large velocities relative to the cluster)
Extended $H\alpha$ Emission Line Regions

- **Color Distribution**
  - Most parent galaxies are blue (account for 57% of g-r<0.5, r<17.8 galaxies)
  - Less massive ones tend to have detached $H\alpha$ emitting clouds and are in poststarburst phase
  - More massive ones tend to have connected $H\alpha$ emitting clouds to the parents with starburst

→ We suggest that the parent galaxies are infalling into the cluster center with their gas being stripped off and forming the $H\alpha$ emission line regions

Detailed spectroscopic study for the extended emission line regions
→ See poster by Yoshida et al. in this conference
• We analyzed cluster core field following the standard technique to derive the H$_\alpha$ luminosity function (e.g. Ly et al. 2007, Shioya et al. 2008)

• Sample Selection
  – Continuum flux is estimated from B,R,I fluxes
  – Cont.-NB671 > 0.07 (EW>10A)
  – Cont.-NB671 > 3$\sigma$
  – NB671<24.5

• No [NII] contamination correction nor internal absorption correction is applied at this moment

Coma1
Hα Luminosity Function

- **Hα LF** shows monotonic rise for less luminous range
  - \( \frac{d(\log N)}{d(\log L)} \sim -0.7 \)
  - corresponding to \( \alpha \sim -1.7 \)

- Contamination from background [OIII], [OII] emitters
  - Estimated from [OIII] and [OII] emitter luminosity function for NB704
    - (Ly et al. 2007)
  - Can be negligible

- Contamination from intra-cluster PNe
  - Estimated from PNe in Sextans A, B
    - (Magrini+ 2005)
  - Hα+[NII]~10^{34-35} erg/s: can be negligible(?)
H$\alpha$ Luminosity Function

- **Spatial Distribution**
  - There are some regions where H$\alpha$ emitters are concentrated
  - Some of them are associated with extended emission line regions listed by Yagi et al. (2010)
Hα Luminosity Function

- Hα emitting objects found around extended emission line regions (EELR, Yagi et al. 2010) account for bright part of Hα LF
- Even if those objects are excluded, the faint-end slope remains unchanged.
  - \( \frac{d(\log N)}{d(\log L)} \sim -0.7 \)
Nature of Faint H\(\alpha\) Emitting Objects

- H\(\alpha\) luminosity decreases as NB magnitude goes faint
- \(d\log L(\text{H}\alpha) \sim 1\) at a given magnitude
- H\(\alpha\) emitters in extended emission line regions (EELR) always have higher H\(\alpha\) luminosity at a given magnitude
Nature of Faint Hα Emitting Objects

- **Surface Brightness**
  - Hα emitters in EELRs are on average lower surface brightness (i.e., more extended) at a given magnitude

- **Broad-band Color**
  - Although the fraction of blue objects is high, Hα emitters are not always blue

![Graphs showing surface brightness and broad-band color distributions for Hα emitters in EELRs, 3σ Hα emitters, and all galaxies.](image-url)
Summary

• Broad-band Luminosity Function
  – shows steep rise of faint-end slope of Schechter \( \alpha \sim -2 \)
  – no significant difference in faint-end slope between three fields.
  – confirms the steep faint-end slope reported by various authors (e.g. Milne et al. 2007, Adami et al. 2007)
  – suggests that the faint-end slope is actually steep from the core to the outskirts of the cluster

• Extended H\(\alpha\) Emission Line Regions
  – parent galaxies with emission line regions avoid the cluster core and reside near the red/blue edges of the distribution
  – suggests that the parent galaxies are infalling into the cluster center with their gas being stripped off and forming the H\(\alpha\) emission line regions

• H\(\alpha\) Luminosity Function
  – shows monotonic rise for less luminous range
  – \(d(\log N)/d(\log L) \sim -0.7\), corresponding to \(\alpha \sim -1.7\)
  – H\(\alpha\) emitters in EELRs always have higher H\(\alpha\) luminosity at a given magnitude and are lower surface brightness objects