Intra-cluster “light and supernovae” with ILMT

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Galaxy clusters (and groups)

- Among the largest and most massive bound structures in the Universe

- Typical dynamical masses in the range $10^{13} - 10^{14} \, M_\odot$
  -- of which up to 10% mass may be in the baryonic phase

- No. of galaxies typically 100 or so over ~1 Mpc extent (e.g., Abell and Zwicky clusters)

- Galaxy groups are less massive counterparts of clusters with number of galaxies typically 10s or so. (e.g., Hickson groups)
In between galaxy clusters – Intra cluster Medium (ICM)

• ICM is hot (10^7-10^8 K), tenuous (n<10^{-4} cm^{-3}), metal-rich and often filled with stars.

ICM can be detected in:

• Diffuse X-rays (hot gas – thermal, IC)
• Diffuse radio continuum (synchrotron, IC)
• Rarely in optical bands (diffuse emission from stars)
+ Ultra diffuse galaxies (almost merged with the ICM)
Ultra-diffuse galaxy

- Coma cluster has about 1000 such UD galaxies
- A part of Coma cluster passes through ILMT FoV
ICL comes from low-mass stars in tidal debris created during galaxy-galaxy interactions and built up over a long period.
Intra-cluster Supernovae in Abell 85

- ICL-SN are host-less supernova Type-Ia, now detected in a few galaxy clusters through dedicated/targeted surveys.

- ICL-SN act as proxy to intra-cluster light detection, with much higher sensitivity
Importance of ICL-supernovae

• Elemental abundance (Fe in particular) in the ICM

• Entropy of ICM (heating)

  ➢ Expected number is 10% – 30% of all SN in groups/clusters as ICL-SN.

  ➢ One ICL-SNIa per century in a $10^{14} M_\odot$ cluster

• Baryonic mass (intra-cluster light)

  ➢ Possibly some diffuse radio emission
Redshift evolution of SNIa
Past Diffuse-galaxy/ICL surveys

• Required surface brightness sensitivity in r-band ~29-30 mag/arcsec$^2$ in 3”x3” box.

• Size of telescope aperture is less important – capability to image with excellent uniformity (<0.1% rms) in the sky background is the most important factor.

- ILMT is expected to provide highly uniform images through TDI imaging process of the same sky observed multiple times.
Past SN surveys

- **MENAeACS; Sand et al. 2011**: On 3.6-m CFHT; On 58 x-ray selected clusters (0.05< z < 0.15); 240-sec g’ and r’ images taken over one year period.
  
  23 SN-Ia detected out of which 4 are host-less

- **SDSSII-SN survey; Dilday et al. 2010**: Observed Stripe82 (2.5° x 120° region) for 9 months (in three 3-month campaign; once every four days) in TDI mode; Detected total 500 SN-Ia in 0.05 < z < 0.4.
  
  In 563 (MaxBCG+C4; z<0.3) clusters, 9 SNIa events recorded, out of which 3 are host-less.

- **Woots; Gal-Yam et al. 2008**: 1-m WISE telescope; non-uniform sampling of fields over 3-4 years on 161 Abell clusters (0.06 < z < 0.2). 7 SNIa events and 2 are host-less.
What do we get? --- in ILMT stripe survey

- Search for objects made in Decl. range of

  \(29d\ 07'\ 00''\ --- 29d\ 37'\ 00''\) (0.5 deg wide stripe)

- \(\sim 3075\) clusters (full or part) fall in the ILMT FoV.

- 218 are among the most rich and most massive clusters  
  (Zwicky, ABELL, MaxBCG, RX clusters) at \(z < 0.7\)

- \(\sim 1000\) are moderately rich and massive (i.e., WHL clusters)
Most of the known galaxy clusters are at $z < 0.7$
SNIa may be possible to detect up to 0.5 with ILMT single-scan and up to 0.7 in co-added scans over 5-7 nights.
## ILMT vis-à-vis other large surveys

<table>
<thead>
<tr>
<th>Survey</th>
<th># rich clusters</th>
<th>Net Cadence*</th>
<th>Redshift</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENeaCS 3.6-m</td>
<td>58</td>
<td>6 months</td>
<td>z &lt; 0.15</td>
</tr>
<tr>
<td>WOOTS 1.0-m</td>
<td>161</td>
<td>18 months</td>
<td>z &lt; 0.2</td>
</tr>
<tr>
<td>SDSS-II 2.5-m</td>
<td>563</td>
<td>9 months</td>
<td>z &lt; 0.4</td>
</tr>
<tr>
<td>ILMT 4.0-m</td>
<td>218</td>
<td>30 months</td>
<td>z &lt; 0.7</td>
</tr>
</tbody>
</table>

* (Cadence): Approximate period after taking in to account visibility in sky of the fields

### Deep surveys

<table>
<thead>
<tr>
<th>Survey</th>
<th>Area</th>
<th>SBS* - r band</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDSS Stripe82</td>
<td>275 deg²</td>
<td>27 mag arcsec²</td>
</tr>
<tr>
<td>DECaLS Legacy</td>
<td>9000 deg²</td>
<td>28 mag arcsec²</td>
</tr>
<tr>
<td>Dragonfly WFS</td>
<td>330 deg²</td>
<td>29.5 mag arcsec²</td>
</tr>
<tr>
<td>LSST</td>
<td>20,000 deg²</td>
<td>? 31 mag arcsec²</td>
</tr>
<tr>
<td>ILMT</td>
<td>140 deg²</td>
<td>? 29-29.5 mag arcsec²</td>
</tr>
</tbody>
</table>

* SBS (Surface Brightness Sensitivity) over 3”x3” @3-sigma
What can we get? ---- ILMT stripe survey

Total sampled cluster mass = 3075 x (5x10^{13} \, M_\odot) \sim 10^{17} \, M_\odot

Total sampled time period for a field = 1/2 x 5yr = 2.5 years

Total integration time for a field = 100 \, spn x 150dn = 15k \, sec

**Expected outcomes**

- **25 ICL-SN** in 5 year period !! (High-z clusters may have higher SN rate)

- Final co-added image expected to reach surface brightness sensitivity to 3-sigma r\sim 29.4 \, mag \, arcsec^2 in 3”x3” box

- Expect to detect thousands of new Ultra diffuse galaxies

- Also, new galaxy clusters may be detected at z > 0.5 !!
Galaxy clusters with ILMT
(Summary)

• Expected to detect **intra-cluster light in several clusters, thousands of new ultra diffuse galaxies and hundreds of new galaxy clusters at z > 0.5** - baryonic mass fraction in ICM and its evolution.

• Ratio of SN-CC and SN-Ia in clusters as a function of redshift – constraining star formation history across redshift in galaxy clusters.

• Expected to detect a good number of host-less ICL-SN-Ia – understanding energy sources and abundances in ICM, evolution of galaxy clusters.