Update on the CLASH MCT Program

Marc Postman, P.I.
STUC Meeting
November 9, 2012

MACS 1149+2223   z = 0.544
Bilbao, Spain – science team meeting
October 16 - 19, 2012

CLASH team demographics:
• 55 people
• 24 institutions in 10 countries
• 30% U.S. / 70% non-U.S.
• 32% women / 68% men
• 45% postdocs / students
• 22% junior faculty
• 33% senior researchers
CLASH Program Status

• The HST program is now 80% complete. 20 of our 25 clusters are fully observed (as of Oct 30):
  – All 5 high-magnification clusters done (lens-selected)
  – 15 of the 20 x-ray selected clusters done

• HST Observations for the full program are expected to be completed by July 2013.
  – completion of the 5 remaining clusters in x-ray selected sample.
Cluster Lensing And Supernova survey with Hubble

SCIENCE HIGHLIGHTS 2012
CLASH Gallery: First 20 Clusters

A383 (0.187)
A209 (0.206)
A2261 (0.224)
RXJ2129 (0.234)
A611 (0.288)
MS2137 (0.313)
RXJ1532 (0.345)
RXJ2248 (0.348)
MACS1115 (0.352)
MACS1931 (0.352)
MACS1720 (0.391)
MACS0416 (0.42)
MACS1206 (0.440)
MACS0329 (0.450)
RXJ1347 (0.451)
MACS1149 (0.544)
MACS0717 (0.548)
MACS2129 (0.570)
MACS0647 (0.584)
MACS0744 (0.686)
Two $z > 9$ Lensed Galaxies

$z = 9.6$ object in MACSJ1149+2223

$z = 10.8$ object in MACSJ0647+7015


Highest redshift candidate discovered to date
Photometric redshift $z = 10.8 \pm 0.5$ (95% CL)

<table>
<thead>
<tr>
<th>High Redshift Candidates</th>
<th>age of universe</th>
<th>object</th>
<th>F160W AB mag</th>
<th>reference</th>
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</thead>
<tbody>
<tr>
<td>10.8 ± 0.5 (95% CL)</td>
<td>420 Myr</td>
<td>MACS0647–JD</td>
<td>25.9, 26.1, 27.3</td>
<td>Coe12</td>
</tr>
<tr>
<td>10.3 ± 0.8 (68% CL)</td>
<td>450 Myr</td>
<td>UDFy–39546284</td>
<td>28.9 (5.8σ)</td>
<td>Bouwens11</td>
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<tr>
<td>9.6 ± 0.2 (68% CL)</td>
<td>490 Myr</td>
<td>MACS1149–JD</td>
<td>25.7</td>
<td>Zheng12</td>
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</table>

<table>
<thead>
<tr>
<th>Highest Redshifts Spectroscopically Confirmed</th>
<th>age of universe</th>
<th>object</th>
<th>AB magnitude</th>
<th>reference</th>
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</thead>
<tbody>
<tr>
<td>7.215 (spec–z)</td>
<td>720 Myr</td>
<td>SXDF–NB1006–2</td>
<td>24.6 narrow band</td>
<td>Shibuya12</td>
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<tr>
<td>7.213 (spec–z)</td>
<td>720 Myr</td>
<td>GN–108036</td>
<td>25.5 Y (1μm)</td>
<td>Ono12</td>
</tr>
</tbody>
</table>
Spectral Energy Distributions

MACS1149-JD: \( z = 9.6 \pm 0.2 \)
Stellar mass: \( \sim 1.5 \times 10^8 \) Msol
SFR: \( \sim 1.2 \) Msol/yr
Age: < 200 Myr (95% CL), \( z_{\text{Form}} < 14.2 \)
\( r_{1/2} \): \( \sim 0.14 \) kpc (de-lensed)

MACS0647-JD: \( z = 10.8 \pm 0.5 \)
Stellar mass: \( 10^8 - 10^9 \) Msol
SFR: \( \sim 4 \) Msol/yr (Salpeter IMF)
Age: < 400 Myr (95% CL)
\( r_{1/2} \): < 0.10 kpc (de-lensed)

In both cases, best fit SED is a starburst galaxy
Observed positions and fluxes are consistent with our lens models. Models are based on 20 strongly lensed images of 8 other galaxies.
Dramatic evolution in SFRD?
Not required for CLASH results.
Some BCGs exhibit significant SF activity.
Large Flat Core in A2261 BCG

Abell 2261 (z=0.224) ~$10^{10}$ M$_\odot$
SMBH


Red circle denotes uncertainty in existing VLA radio source position. New E-VLAA-array data has been obtained and is being analyzed now.

Core “break” radius vs. absolute rest-frame V magnitude
MACS1206 (z=0.45)
Total mass profile from completely independent methods

Dynamical analysis (Biviano et al. 2012)

(WL convergence)

Stacked Weak Lensing Analysis

Umetsu et al., in prep

CLASH (11 relaxed)
S/N(+) = 27
S/N(×) = 0.6

Averaged mass profile constraint:
\( \langle M_{\text{vir}} \rangle = 9.4^{+1.3}_{-1.2} \times 10^{14} \, M_\odot/h \)
\( \langle c_{\text{vir}} \rangle = 5.5^{+0.8}_{-0.7} \)
\( \langle z \rangle = 0.35 \)

Projected radius, \( R \, [h^{-1} \text{kpc}] \)

\( \langle \Delta \Sigma + \rangle \) [\( h^{10} \, 15 \, M_\odot \, \text{Mpc}^{-2} \)]

\( \langle \Delta \Sigma \times \rangle \) [\( h^{-1} \, 15 \, M_\odot \, \text{Mpc}^{-2} \)]

Results from stacked WL tangential-shear analysis
Simulations: relaxed clusters at \( z=0.35, \sigma(\text{log} M_{\text{vir}}) = 0.11 \)

Averaged mass profile constraint: \( \langle M_{\text{vir}} \rangle = 9.4 \times 10^{14} \, M_\odot/h, \langle c_{\text{vir}} \rangle = 5.5 \)

11 X–selected CLASH clusters at \( z=0.35 \)

CLASH-WL vs. Rozo+12 for \( z<0.4 \) CLASH clusters

A383, A2261, A611, M0329, M0744, M1115, M1206, MS2137, RXJ1347, RXJ1532, RXJ1215
CLASH Concentration – Total Mass Relationship
SaWLens Results to date (Half of the CLASH x-ray selected sample)

Concentration $c_{\text{vir}}$

Virial Mass $M_{\text{vir}} \left[ 10^{15} M_\odot \right]$

Redshift

Simulations: relaxed clusters (Bhattacharya et al.)

Merten et al. in prep
CLASH Publication Stats

Accepted and/or Published Papers by CLASH team: 9 papers since last STUC presentation (Nov 2011), with a total of 120 citations accumulated since Dec 2011.

Submitted and/or Published Papers by others that directly use data:


Submitted and/or Published Papers that are motivated by CLASH:

CLASH Publication Stats

Papers currently in preparation (to be submitted within next 6 - 9 months):

1. Donahue et al. “X-ray Properties of CLASH Clusters”
5. Zitrin et al. “Mass Profile of the Merging Cluster MACSJ0416”
7. Bradley et al. “Magnified 6 ≤ z < 9 Galaxies in CLASH Clusters”
9. Kelson et al. “Implications of the CLASH Red Sequence From z=0.3-0.5”
11. Merten et al. “Substructures in MACSJ1206”
CLASH Data Usage

• Initial data release (65 mas images, color jpeg) for 17 CLASH clusters has been completed.
• Second data release (30 mas images, source catalogs) for 13 CLASH clusters has been completed.
• Total data volume delivered to MAST: 145 GB
• Community usage:
  – 704 GB downloaded by 671 distinct IP addresses
  – Usage ratio: ~5 : 1
CLASH High-Level Science Data Products

Currently released data products:

- Co-added images: in native resolution, on 30 mas grid, and on 65 mas grid (all generated with mosaic-drizzle pipeline)
- Source Catalogs: derived from ACS+IR detection image, IR-only detection image. Catalogs include photo-z estimates, isophotal photometry, aperture photometry, positions, ellipticities, star-galaxy discrimination.
- Color jpegs (made with Dan Coe’s *trilogy* code), with interactive zoom, pan on MAST website

Products to be released no later than mid-2014:

- Strong and weak lensing models (convergence, shear & magnification maps).
- Subaru catalogs with photo-z information for sources within central 27 arcmin.
- Spitzer photometry and SZE maps for all clusters.
- BCG-subtracted images and 2D BCG models (in all ACS and NIR filters).
- High-z (z > 5) galaxy candidate lists for all clusters.
- Redshifts and spectra (now over 8,000 spectra available).
- Interactive cut-out display (via MAST archive website).
# CLASH Data Release Schedule

<table>
<thead>
<tr>
<th>Cluster</th>
<th>HST Obs. Begin</th>
<th>HST Obs. End</th>
<th>1st Data Release</th>
<th>2nd Data Release</th>
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<tbody>
<tr>
<td>Abell 383</td>
<td>11/18/2010</td>
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<td>Abell 611</td>
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Next slide has the schedule for Cycle 20 (5 remaining clusters)
## Cycle 20 CLASH Schedule

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Program ID</th>
<th>First Plan Window</th>
<th>Last Plan Window</th>
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</thead>
<tbody>
<tr>
<td>Abell 1423</td>
<td>12787</td>
<td>Dec 14 – 16, 2012</td>
<td>Feb 12 – 14, 2013</td>
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<tr>
<td>MACS1311-0310</td>
<td>12789</td>
<td>Apr 11 – 15, 2013</td>
<td>Jul 6 – 9, 2013</td>
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</table>

Final HST data product releases for CLASH MCT should occur sometime in the first quarter of 2014, if the above schedule holds.
• UVIS CTE –mitigated as of spring 2012 with post-flash. But STScI needs to implement the UVIS post-flash correction file in calwf3. Currently not implemented. Results in non-uniform background in the UVIS filters. Temporary solution is to use 2D sky subtraction model. Also urgent to get the CTE correction for UVIS implemented.

• Scheduling and execution of program has been superb. Kudos to STScI for the support. Guard dark frame exposures have proven invaluable. Keep those going for MCTs.

• Developed improved sky subtraction procedures and are regenerating all CLASH photometry catalogs for subsequent release (by end of 2013).
Budget

• CLASH MCT budget has been cut over the requested level in each cycle.
• Net reduction over the past 3 years has been 21% ($4.41M requested, $3.49M approved). Net reduction of ~$920K.
• Main impacts of cuts will be in the out-years (2014 – 15):
  – Possible reduction in volume of supporting data that is made available publicly. All HST-based products will be released.
  – Reduced number of students supported (-2) and shortened postdoc terms (total of about 0.5 FTE).
  – Some reduction in out-year team travel.
• Large non-U.S. component of CLASH team makes our efforts somewhat more robust to these cuts. But that makes the team meetings all the more critical in maintaining the team’s scientific momentum.
The Science Research Mentoring Program at the American Museum of Natural History (AMNH) is a two-year after-school program of classes and mentored research, supported by NASA grant award NNX09AL36G.

Students take courses that are co-taught by scientists and educators, and then apply to work in small groups with mentors who are graduate students or postdoctoral researchers at AMNH.

The culminating event is a conference-style graduation where each group presents a poster and a short talk to an audience of peers, family members, and other invited guests.

Or Graur, a member of CLASH from Tel Aviv University / AMNH, is a mentor in the program, and has had 6 high-school students search for supernovae in the CLASH data.
• Class of 2011-2012 discovered a CLASH supernova in the near-IR.

Host galaxy (z = 0.27) before and during a supernova event in CLASH data. The supernova was discovered in the subtraction image in the third panel. These images were produced by the students.

• Class of 2012-2013 will discover real and fake supernovae and measure detection efficiency.
Gravitational Lens App for smart phones and the web

• Smart phone lens database app is being developed, in part, by CLASH co-investigator Dr. Leonidas Moustakas (JPL). Currently has over 500 lenses.
• Includes both cluster and galaxy scale lenses. Initial target audience is professional astronomers but collaborating with Zooniverse and Citizen Science to adapt it for public at large.
• Proto-type exists (see image at right). Not yet on app store. A companion website, with DB search tools, is also being prepared.
• Smart phone app builds upon software used in the Exoplanet application.