My Lessons Learned from Leading the International Cluster Lensing And Supernova survey with Hubble Project

And their relevance to TMT Collaborations

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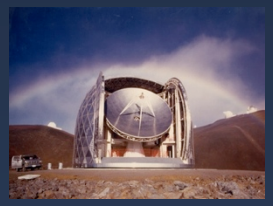
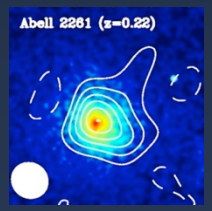
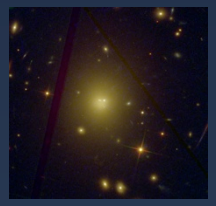
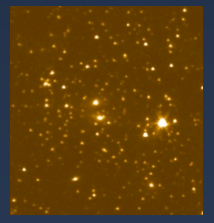
Multi-wavelength Data are Essential

- A complete understanding of most astrophysical phenomena requires data at many wavelengths.
- Science data archives are essential.

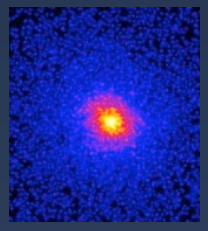
CLASH used data from HST, Spitzer, Chandra, XMM, Herschel, GALEX, Subaru, VLT, Magellan, Palomar, SOAR, GBT, VLA, CSO

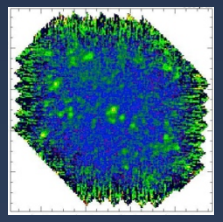









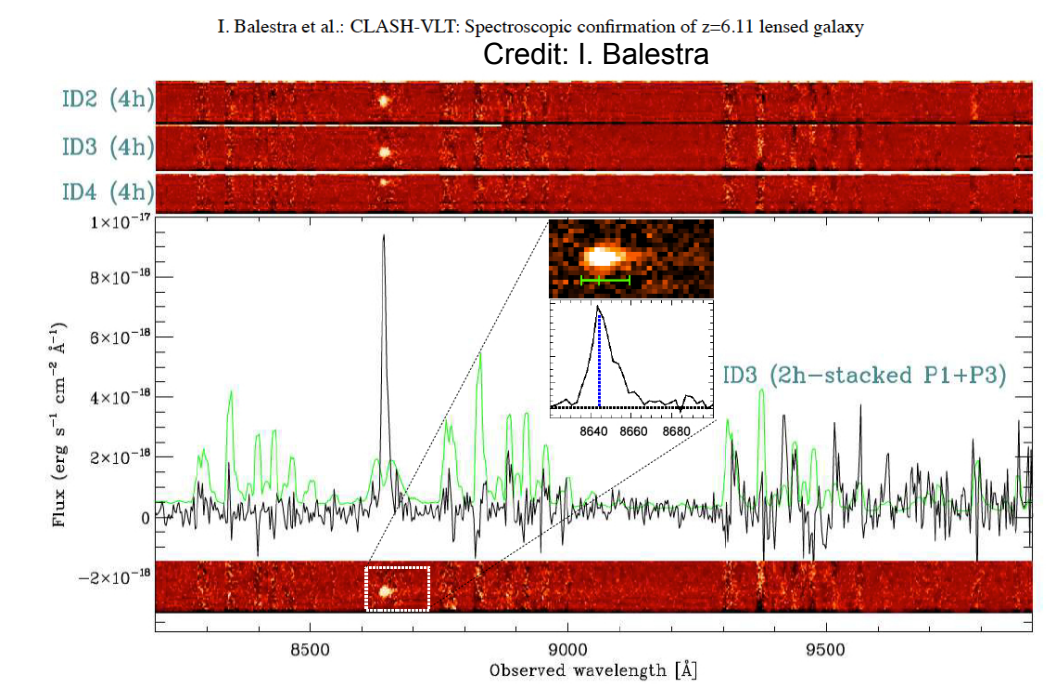


Multi-wavelength Data are Essential

- A large allocation of time on a major facility like TMT will be a major advantage for seeking time on other facilities.
- Joint time allocation programs can greatly facilitate this (e.g., NRAO, NOAO, HST, Chandra, Spitzer, XMM, Swift, etc.).
- In the TMT era, joint time allocations between ALMA, JWST, WFIRST, Athena, SKA and TMT should be considered.

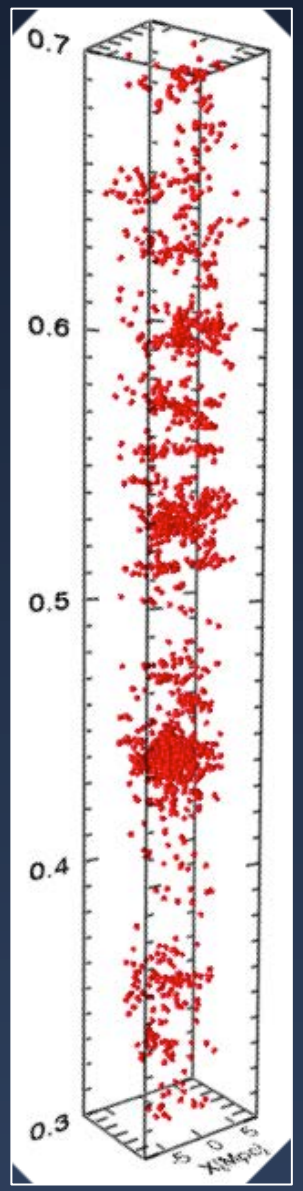
Spectroscopic Data are Essential

- TMT (and other concurrent large ground-based telescopes) will be superb deep spectroscopic survey instruments.
- Spectroscopy of cluster galaxies and of lensed-background galaxies is an essential ingredient in the study of galaxy evolution with CLASH.
- Spectroscopic data will be essential for the interpretation of imaging data from various other facilities (and from TMT itself).



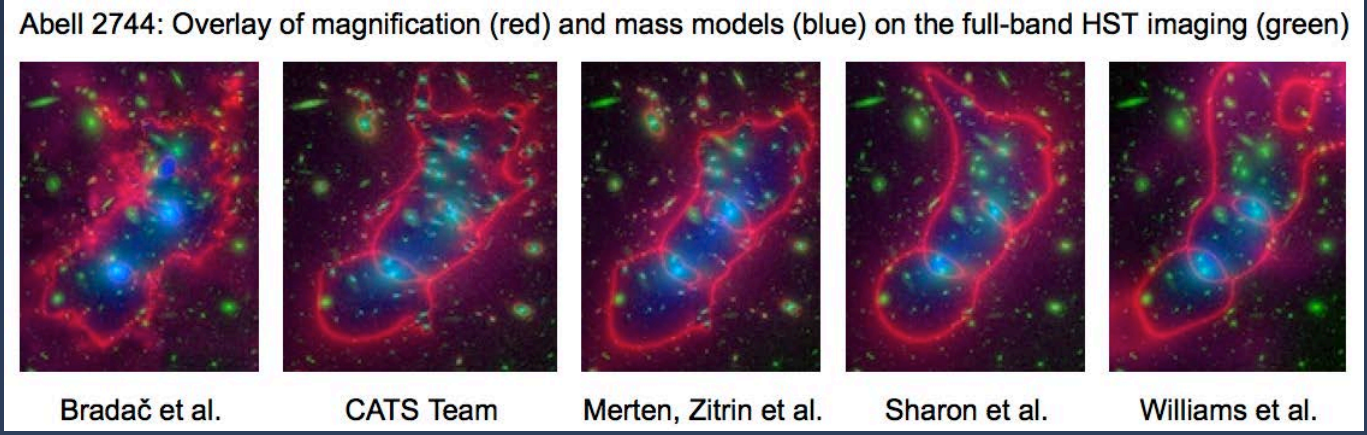
Credit: I. Balestra

Credit: P. Rosati



Plan for a Robust Data Pipeline

- Having well-tested data pipelines is essential.
- For key data products, consider at least two independent pipelines (tests robustness of results).
- Select at least some team members who are skilled at astronomical software development. You will rely on them immensely. Give them "builder" status.



CLASH Data Product Teams

- HST Phase II prep & Raw Data Calibration: L. Bradley
- HST Drizzled Mosaics: A. Koekemoer
- HST Source Catalogs: D. Coe, D. Kelson
- Photometric Redshifts: N. Benitez, D. Coe, S. Jouvel, A. Molino
- Wide-field Ground-based Images & Catalogs: E. Medezinski, A. Molino, M. Nonino, S. Seitz, K. Umetsu
- Spitzer Mosaics & Catalogs: L. Moustakas, X. Shu, L. Ubeda, W. Zheng
- X-ray Data & Parameters: M. Donahue
- Spectroscopic Data: I. Balestra, D. Kelson, P. Melchior, A. Mercurio, M. Nonino, P. Rosati, et al.
- Mass Models (Lensing): M. Carrasco, D. Coe, C. Grillo, J. Merten, S. Seitz, K. Umetsu, A. Zitrin
- mm-wave (SZ) Data: N. Czakon, S. Golwala, J. Sayers, S. Siegel
- sub-mm (Herschel) Data: K. Fogarty, R. Larson, M. Postman (based on data from Egami et al.)

Open Team Access to All Data Products

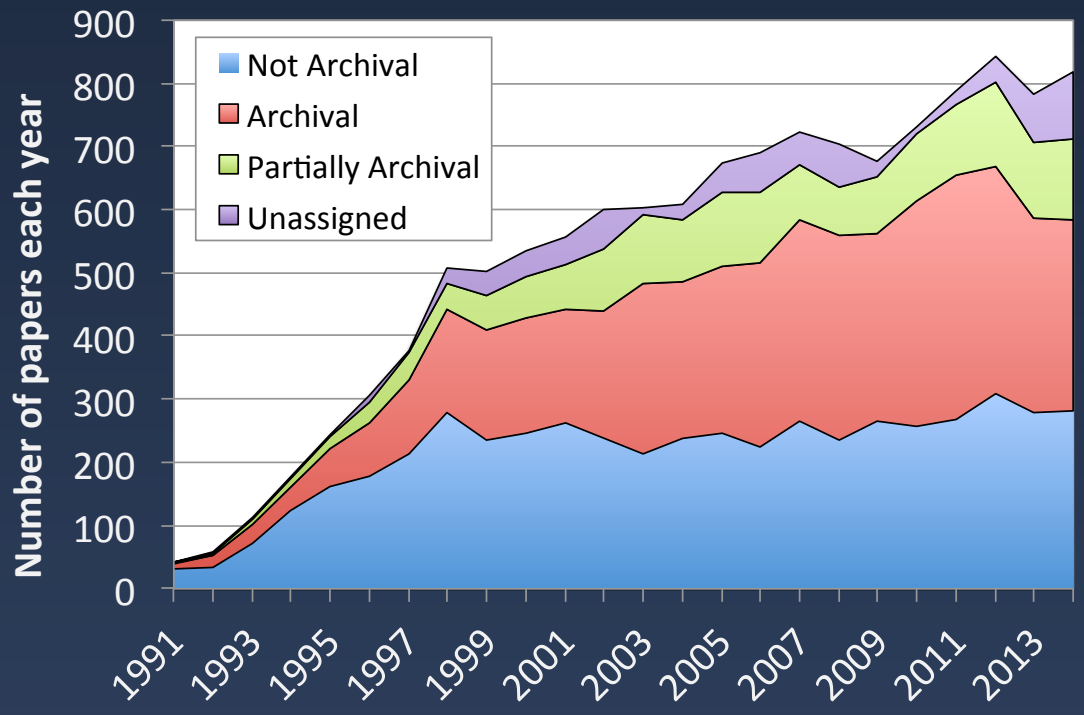
- The productivity of the team is optimized if all members of the team have easy access to all data products from the program.
- Some teams have chosen to compartmentalize access to data products.
- For CLASH, we found full open access to all data was a very successful approach.

High Level Data Products Maximize Community Science

- Generating science-ready, high-level science products (HLSPs) is key to enabling great archival science.
  - There is a false savings in delivering only raw data products: the costs of processing data then are incurred many times over by different users in different locations.
  - Archives that deliver only raw data are much less useful – and are much less used – than archives that deliver science-ready products.

Data Archives are Essential

- The NASA astrophysics data archives are a model for open access to data.
- Archival research greatly enhances the science at a small fraction of the total mission cost.



The publication rate for totally archival Hubble papers has exceeded the non-archival (GO/PI) publication rate every year since 2003.

Don’t Fear Immediate Release of Data!

- Zero proprietary periods are becoming the norm for many large programs.
- Combined with good archive interfaces, broad community access:
  - will greatly increase science productivity;
  - doesn’t result in P.I. teams being scooped (provided adequate GO funding is available);
  - more likely to lead to further follow-on projects (e.g., CLASH → Frontier Fields Initiative)

CLASH Publication History

First Observation: Nov 18, 2010
Final Observation: July 9, 2013
65 refereed papers to as of June 2015

Most Complex Analyses are Done When All Data is Acquired

- Multi-year projects require multi-year funding.
- Most active and complex analyses often happen once all the data are acquired.
- Allow at least 2 to 3 years beyond last data acquisition date for continued scientific analyses. It is often when the highest impact papers are produced.

Establish Team Membership and Authorship Policies Early On

- CLASH team worked well, in part, because:
  - we established the parameters of when new members should/could be added;
  - we established authorship policy early in the collaboration;
    - Inclusion of “builders” on first paper led by each collaborator.
    - Opt-in policy for subsequent papers.
    - Any team member could lead a paper.

International Teams

- Allows broadest range of scientific talent.
- Brings access to many (and diverse) observational and computational facilities.
- "Extended Work Day" is a real advantage, if you provide the right coordination.

- Live communication across 13 time zones can be challenging.
- Funding team members is more complex (e.g., NASA cannot fund non-US researchers).
- But involvement in "high profile" programs often increase chances of getting funding from various national research programs.

Face-to-face Team Meetings are Essential

CLASH Meeting at RAS, London 2013

Team meetings yield closer scientific relationships and foster open and vigorous exchange of ideas. Team meetings are also essential for nurturing “esprit de corps” – a feeling of pride, fellowship and common loyalty shared by the team. Do not underestimate the importance of this latter item in building a successful scientific collaboration.

Funding to support at least one major team meeting each year (and possibly one or two smaller splinter meetings) should be included in the budget for large science programs.

Summary

- The keys to successful large international astronomical collaborations include:
  - Open access to multi-wavelength data archives;
  - Investment in developing robust data pipelines and analysis software early on;
  - Access to science-ready data products;
  - Robust sources of funding for the research teams and team travel;
  - Clear authorship and team membership guidelines.