A search for supernovae in galaxy clusters at 0.1 < z < 0.2

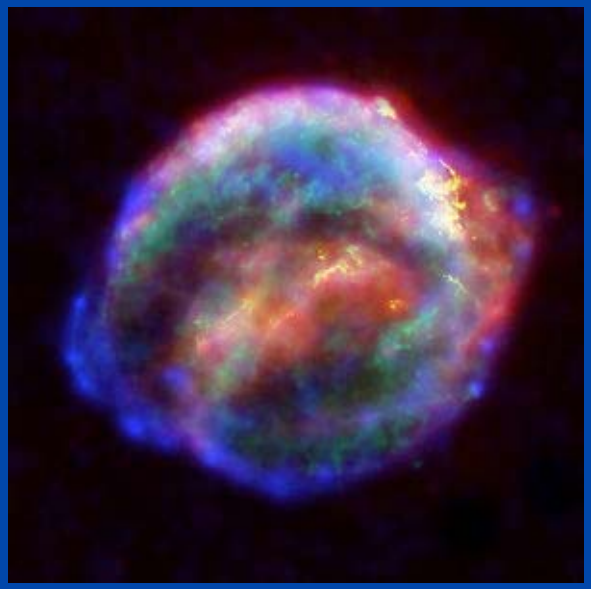
David J Sand (U of A)

Chandra Fellows Symposium 2007

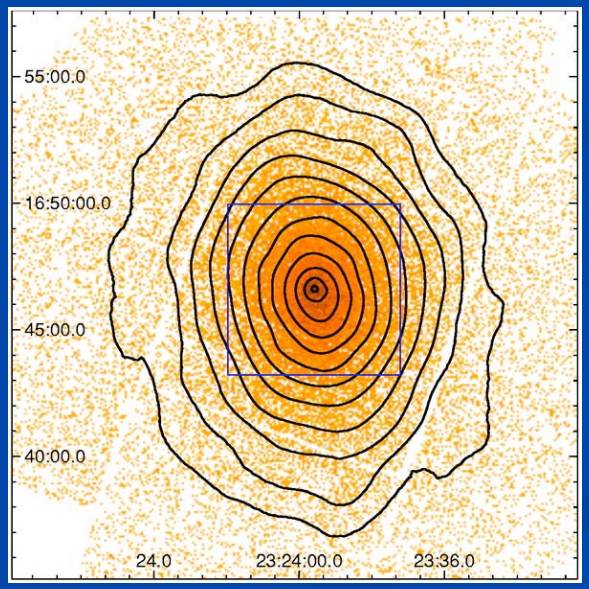
See arXiv0709.2519

SN in clusters

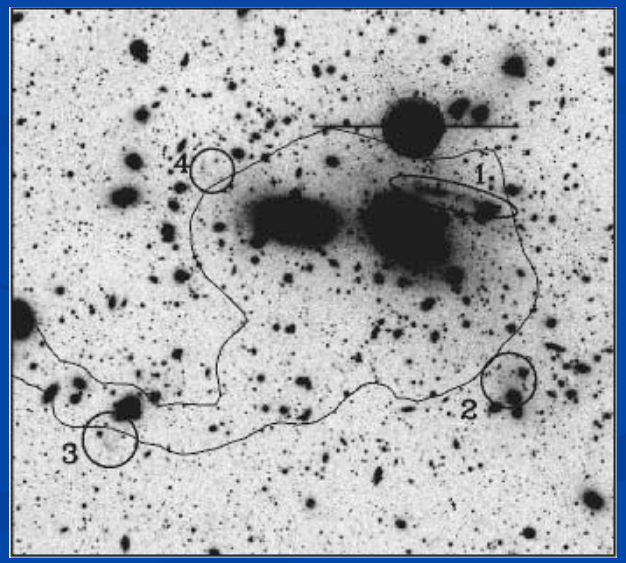
The metal enrichment of the intracluster medium, SN rate in clusters, and the amount of stellar mass in intracluster light are intimately related subjects



SNR



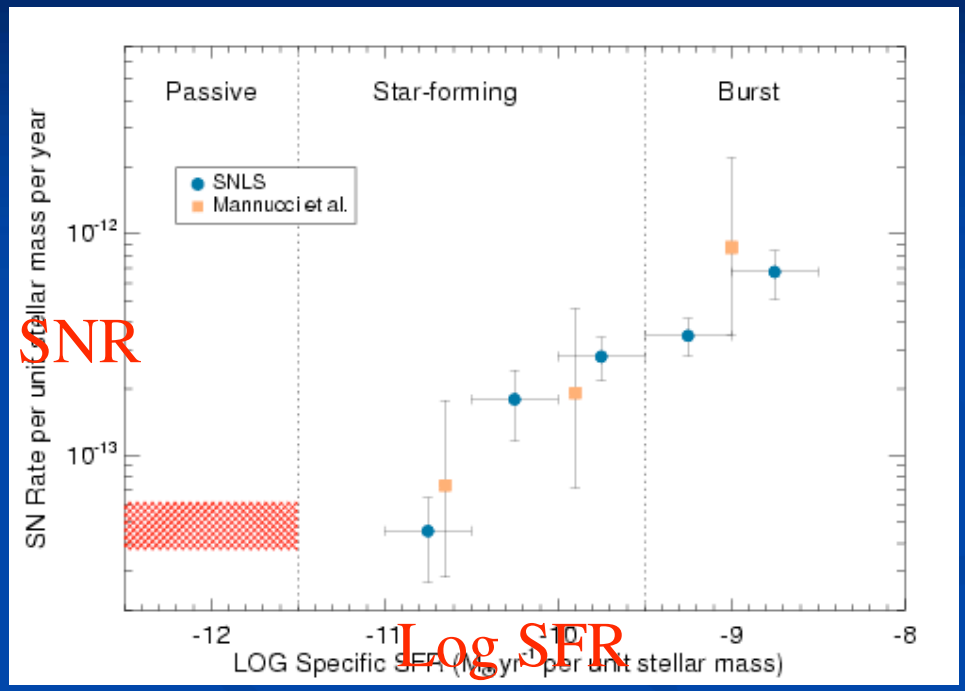
Chandra Image of ICM



ICL in Coma

SN Ia progenitors & rates

SNIa occur in both old, evolved stellar systems and in regions of high star formation (e.g. Mannucci et al. 2005; Scannapieco & Bildsten 2005; Sullivan et al. 2006) -- Two populations of progenitors??? Possible singly degenerate and double degenerate systems



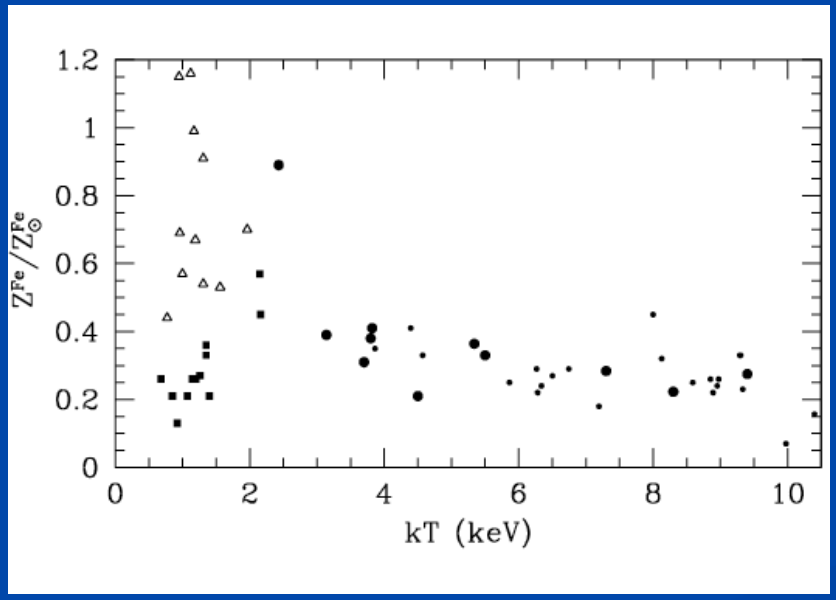
Is there some way to separate the two populations?

Perhaps in galaxy clusters -- simple SFH and dominated by ellipticals today?

Enrichment of the intracluster medium

SNIa provide ~0.7 M_{sun} of iron per event (e.g. Tsujimoto et al. 1995)

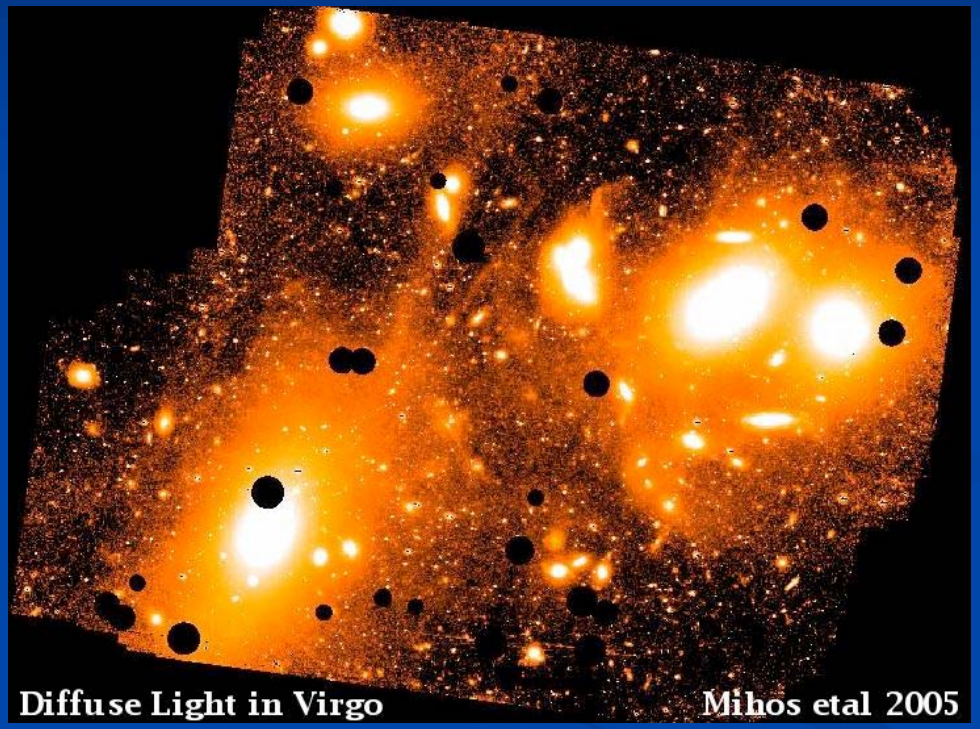
Clusters are excellent for studying metal enrichment -- they have a simple SFH and deep potential from which material cannot escape. Can be measured from the iron-K complex at ~7 keV.



Renzini 2003; see also Tozzi et al. 2003; Baumgartner et al. 2003

Content and quantity of intracluster light -- how much does it pollute the ICM?

- Gonzalez et al. (2005) have shown that the ICL is well fit by a separate $r^{1/4}$ profile and has a radial extent of ~100s of kpc
- Different measurements have shown that the ICL makes up ~30% of the total stellar budget
- Can intracluster SN be enriching the ICM in situ? -- preliminary calculations suggest up to ~50% of metals come from IC SN (e.g. Domainko et al. 2004; Zaritsky et al. 2004)



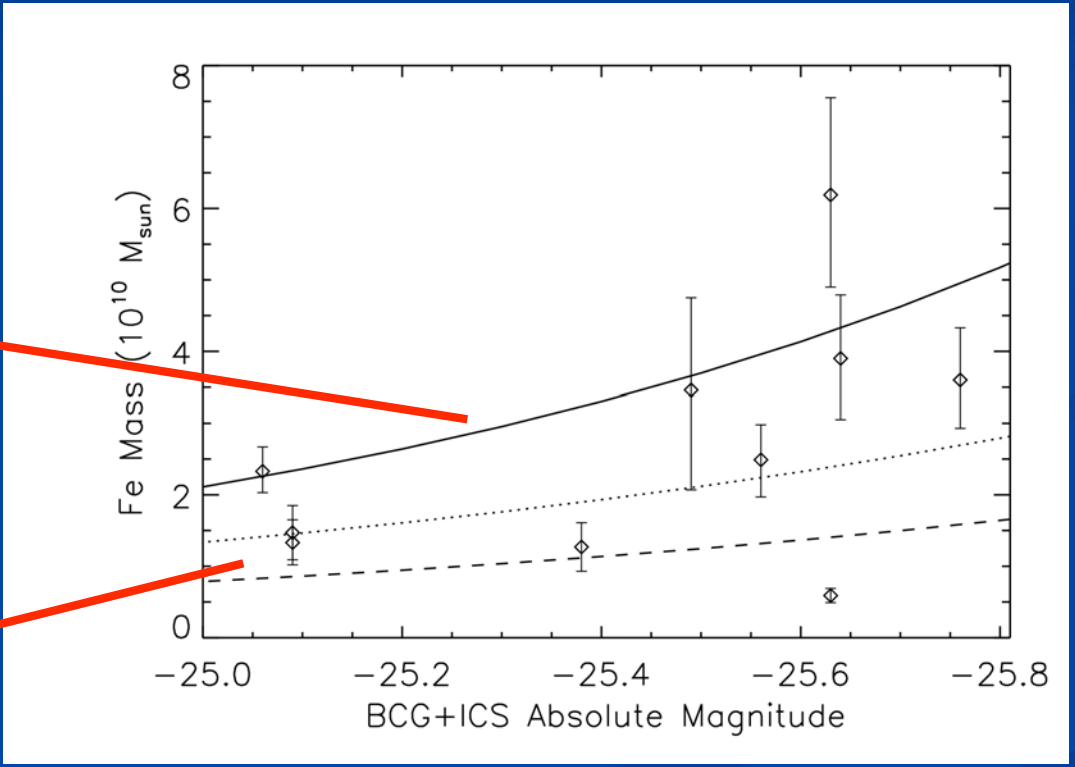
The ratio of hostless to hosted SN Ia gives a measurement of the mean ICL fraction (see also Gal-Yam et al. 2003)

Intracluster SN contribute a large fraction of the metals seen in the ICM

If ALL metals produced in galaxies and ICS are dumped into the ICM.

Total metal contribution from IC SNe

Sivanandam et al in prep



Data points are from XMM observations of clusters with direct measurements of the ICL (Gonzalez et al. 2005)

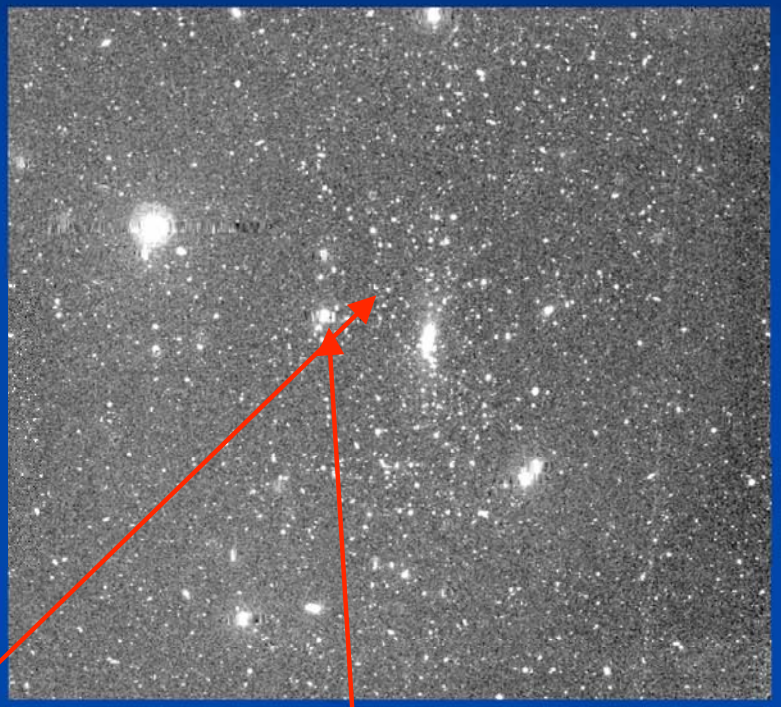
Arizona cluster supernovae search

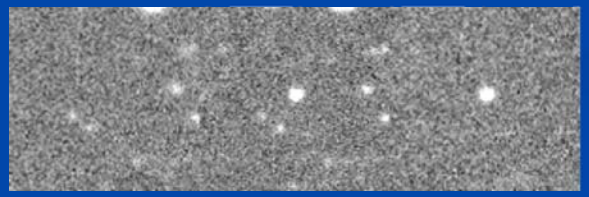
~60 X-ray selected galaxy clusters at $0.1 < z < 0.2$

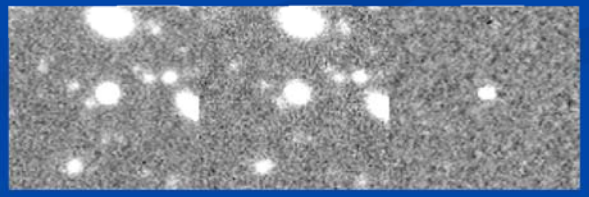
Revisit fields ~monthly in the g-band at the 90-inch

Follow-up spectroscopy at the MMT within 5 days to weed out foregrounds and core-collapse SN

Goal: Find 10-20 cluster SN-Ia



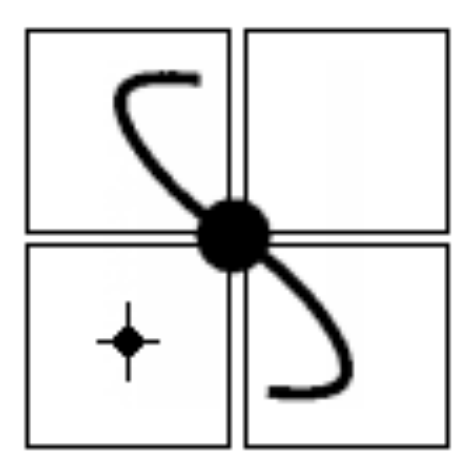




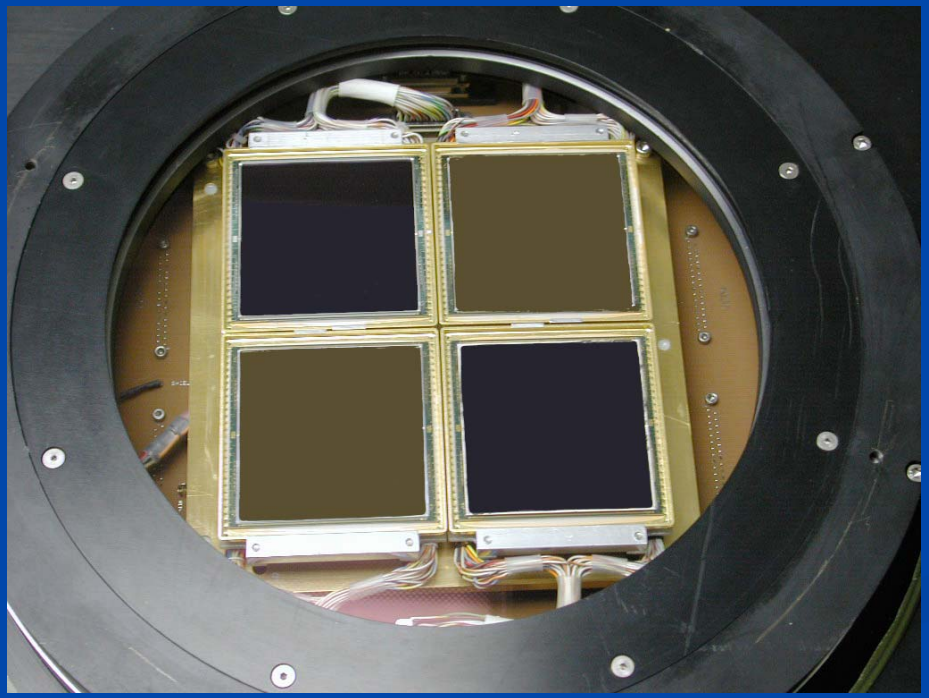
Three principle goals:

1. Determine the mean fraction of intracluster star light.
2. Determine the SN-Ia rate to place clear constraints on the SN-Ia ‘delay time’ -- the time between formation of a stellar system and the eventual explosion of some of its members as SN-Ia. This may be a clean way to probe the ‘older’ progenitor population in clusters
3. Combine these two measurements to determine the contribution of intracluster SN to the global chemical enrichment of clusters

90 Prime on the 2.3m Bok Telescope



Blue sensitive, 1 degree FOV, 0.45”/pixel



We center each cluster on chip 1 (30’ FOV) and use chip 3 as a control -- each chip is separated by ~500 arcsec

Typical seeing: ~2 arcsec

The complete initial campaign

Received 11 nights of 90-inch time to write an image pipeline and demonstrate that we can ID transients on ~hour time scales. -- DONE

Received 12 90-inch nights + 5 MMT spectroscopic nights. Unfortunately, 11/12 90-inch nights were ruined due to weather/instrument problems. 1 night of Blue Channel Spectrograph time was used to follow up the 1 good 90-inch night.

Transient detection in real time

Automated pipeline developed to reduce data, difference images with best archived reference image (using Alard's algorithm), detect potential transients and post them to a group web site for human review.

Typically ~10 candidates; 2-3 real

Human confirmed transients are batch submitted to NED and GCVS to screen out known AGN/QSOs and variable stars

The Arizona Cluster Supernovae Search 10/10/2006 11:57 AM

The Arizona Cluster Supernovae Search

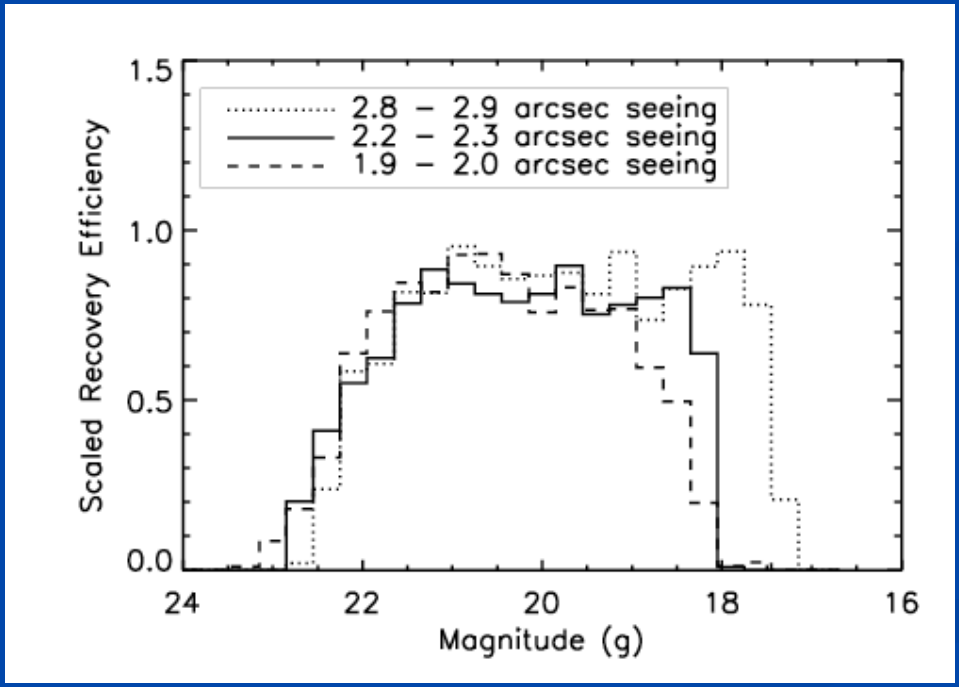
We are going to find a GANG of supernovae in galaxy clusters using 90Prime on the Bok 90-inch telescope.

#	Clusters	Redshift	Coordinates (J2000)		Finder	Epoch 1	Epoch 2	Epoch 3	Epoch 4
1	A565	0.105	07:07:24.8	+71:45:22.0	A565.jpg	01/28/06 Seeing SNe Cands	02/24/06 Seeing SNe Cands Short Cands	04/22/06 Seeing SNe Cands Short Cands	
2	A572	0.104	07:14:09.5	+54:39:50.0	A572.jpg	01/28/06 Seeing SNe Cands Short Cands	02/24/06 Seeing SNe Cands Short Cands	04/24/06 Seeing SNe Cands Short Cands	
3	A580	0.118	07:25:52.8	+41:25:00.0	A580.jpg	01/28/06 Seeing SNe Cands Short Cands	02/24/06 Seeing SNe Cands	04/23/06 Seeing SNe Cands Short Cands	
						01/28/06			

http://jerome.as.arizona.edu/~dsand/clusterhtml/clustertable.html Page 1 of 8

Transient detection efficiency

Place fake point source ‘SN’ into images to understand detection efficiency as a function of seeing, AM, and background (in galaxy vs. hostless)



Typically 85-90% detection efficiency from g~18-22

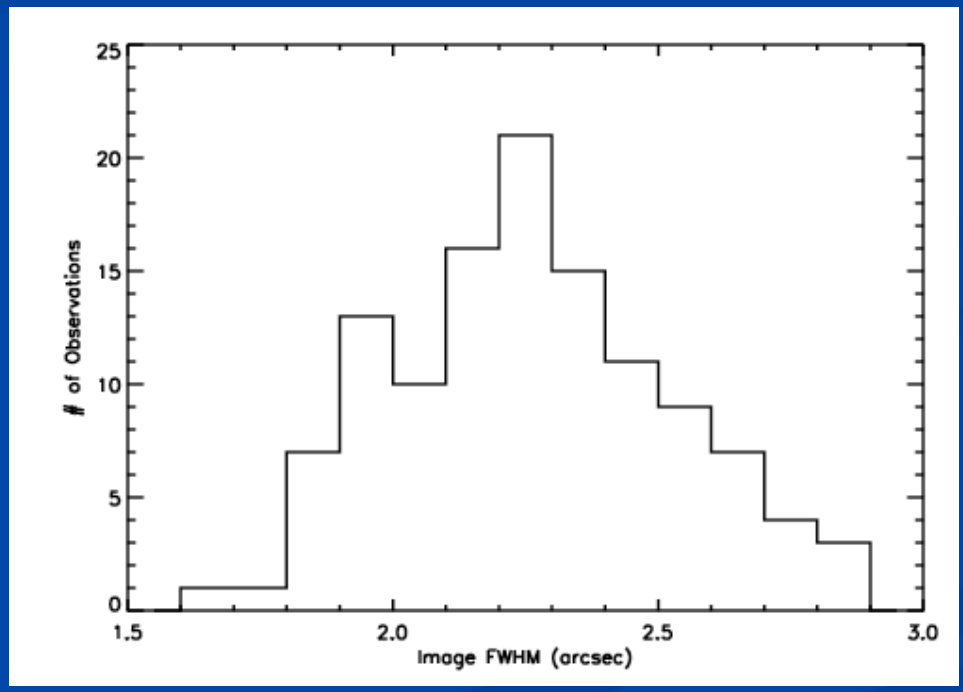
We mask aggressively near saturated stars.

Conditions at the 90-inch

Typical image FWHM is ~2-2.5”. Worst on Kitt Peak and worse than standard lore for the 90-inch.

Does not deter from survey goals, and during >2.5” seeing, extra exposures are taken.

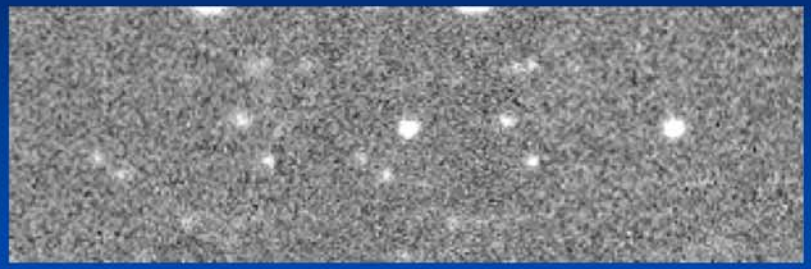
If seeing >3”, I go to bed.

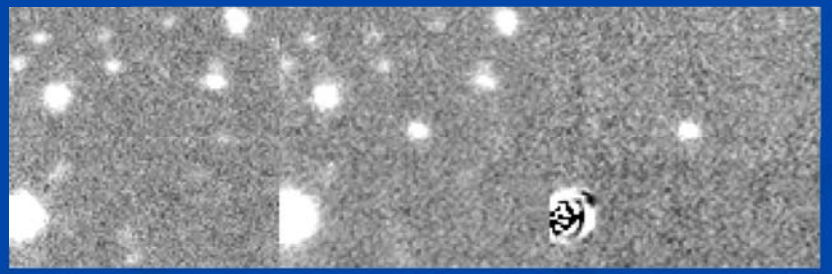


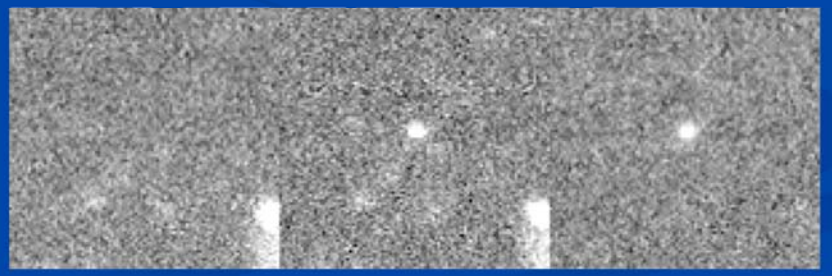
ICL SNe Candidates

In our pilot photometric campaign, we found 4 hostless events, all with $R > r_{200}$ from the cluster center. Either these are not real, there is an excess of ICL at $R > r_{200}$ or star formation is causing an increase in SN rate.

IC candidates are checked by summing all available imaging epochs to rule out a faint host -- to the best of our ability

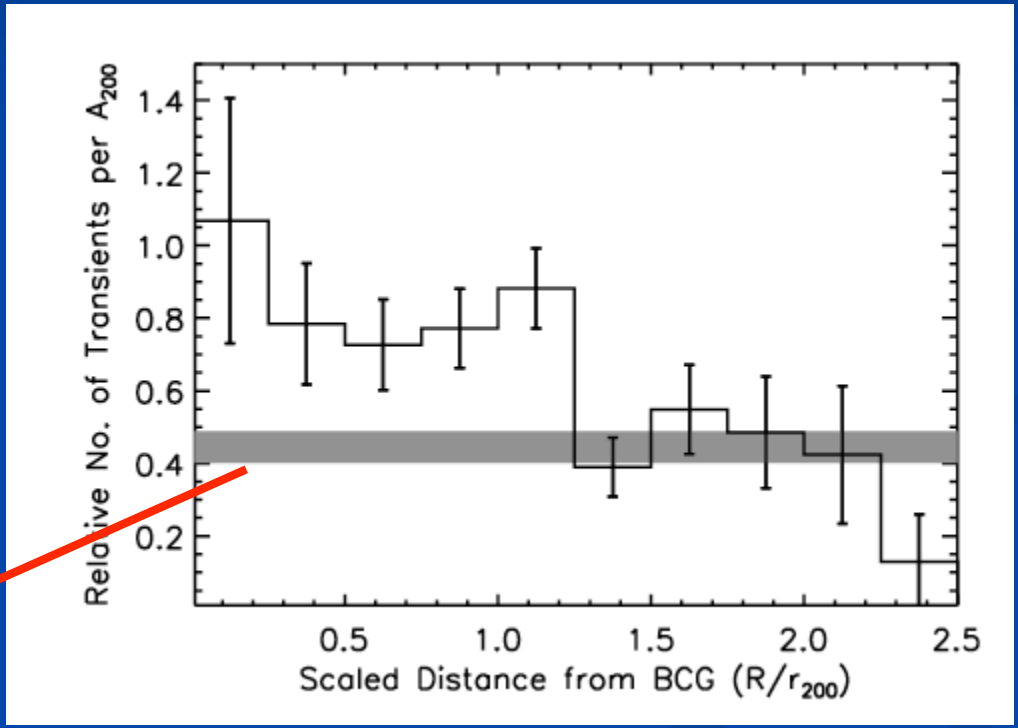






Detection of Central Excess of Cluster Events?

Taking the X-ray luminosity of each cluster, we calculated M_{200} and r_{200} using the L_X -M_{200} relation found by Reiprich & Bohringer 2002.

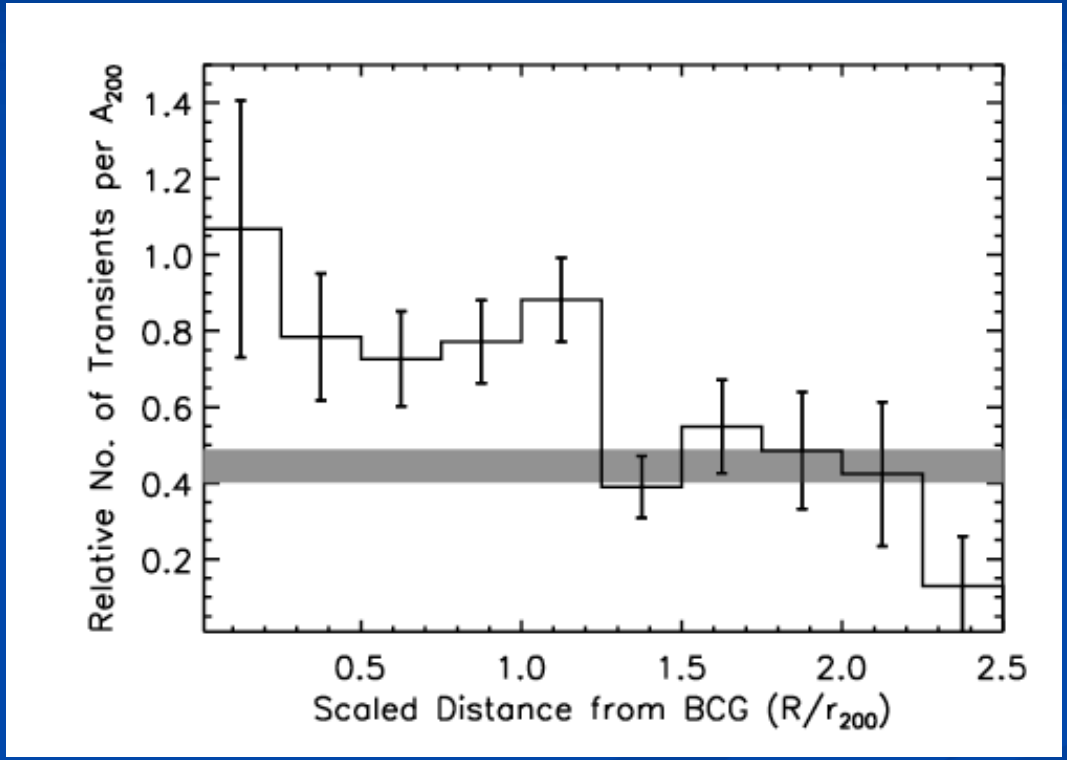


Used chip 3 transients to determine 'background' rate.

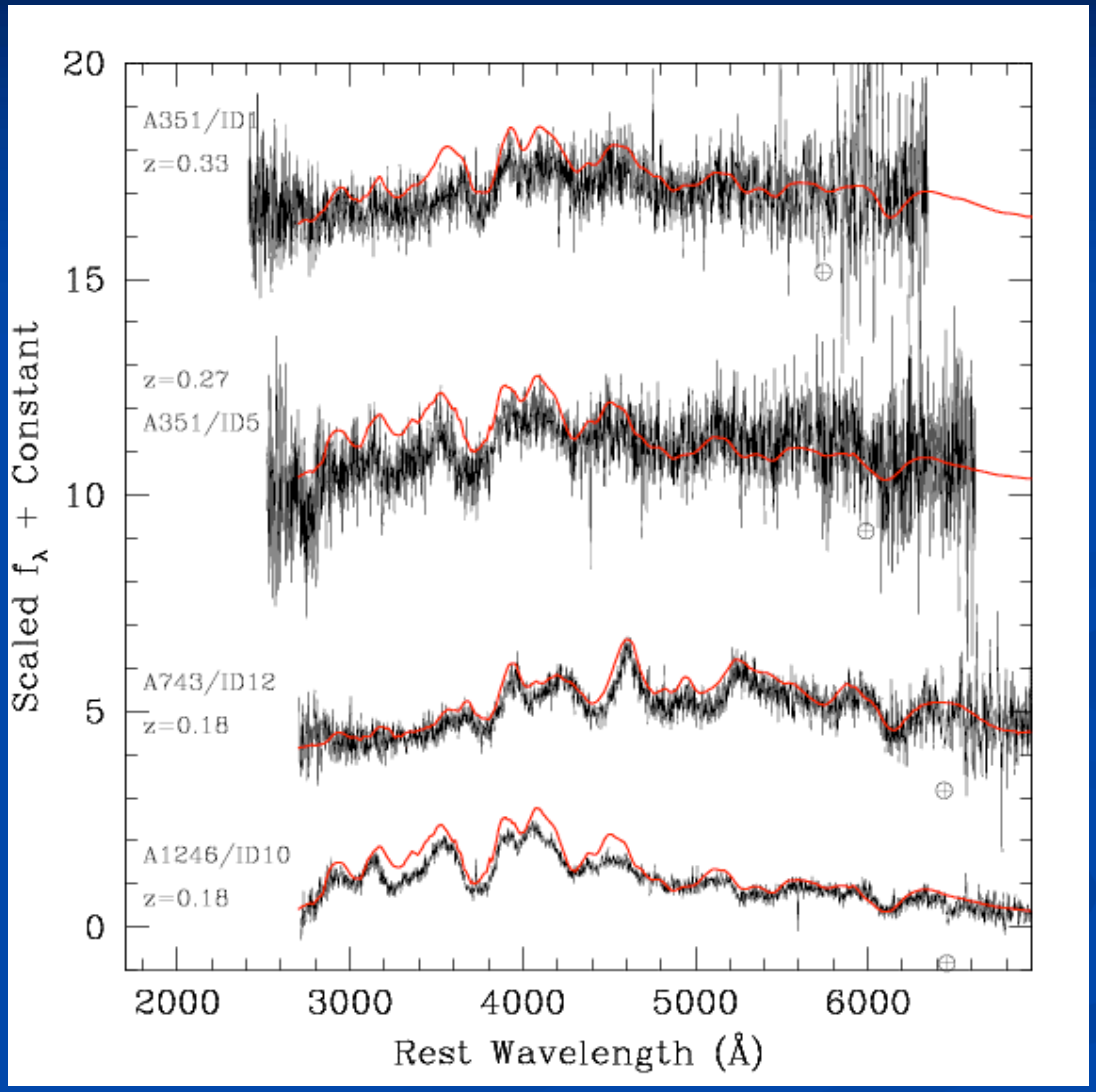
What are these excess transients?

Out of ~40-50 excess transient events, we expect only ~10 to be cluster SN-Ia (Sharon et al. 2007) or core collapse SN.

Is the central excess also due to cluster AGN, as seen in X-ray (e.g. Ruderman & Ebeling 2005) or optical studies (Martini et al. 2007)?



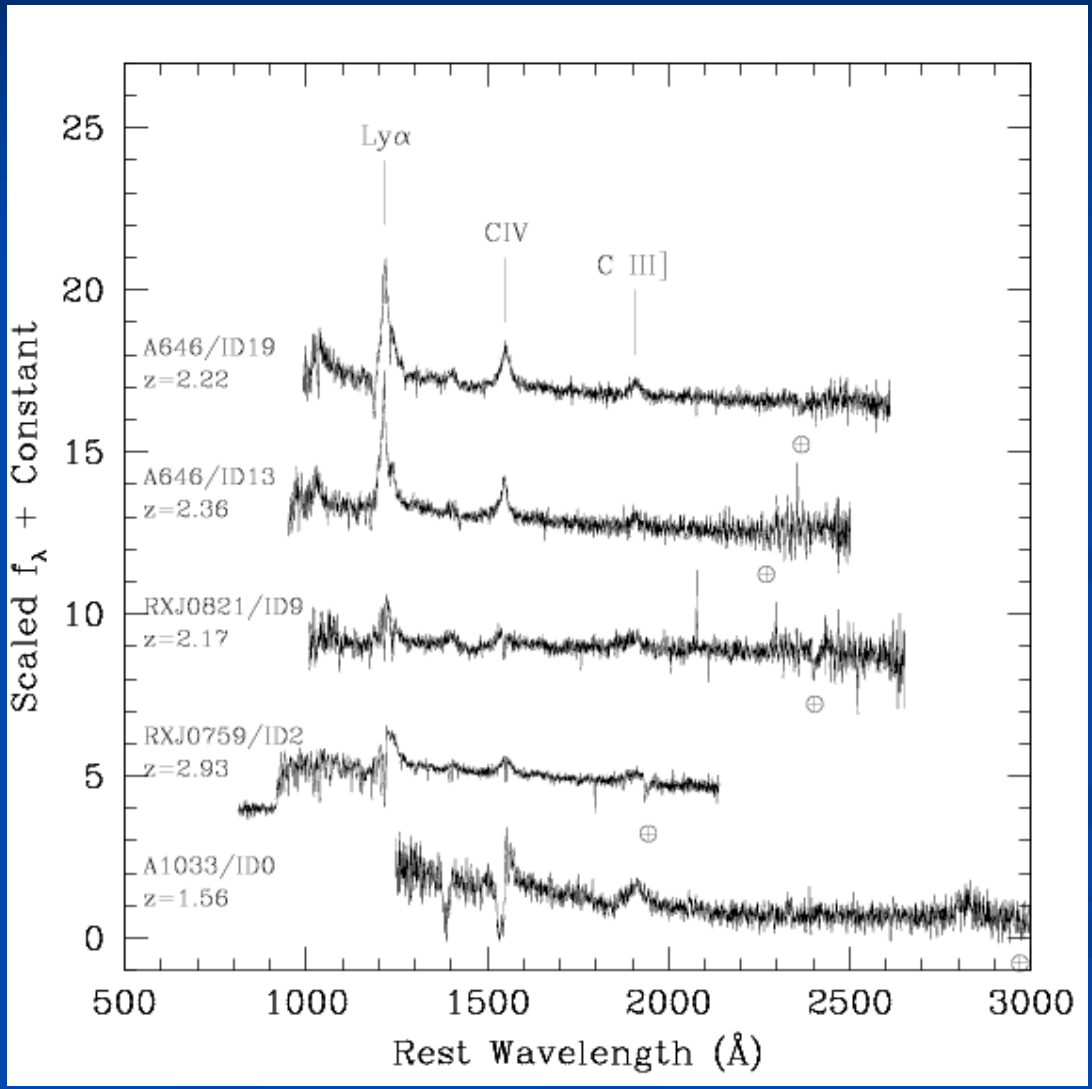
Initial Spectroscopy



More Spectra

z~2 QSO's

Other spectra include cluster galaxies (which need subtraction to search for SN), lower z QSOs, 1 CC SN in the foreground and variable stars

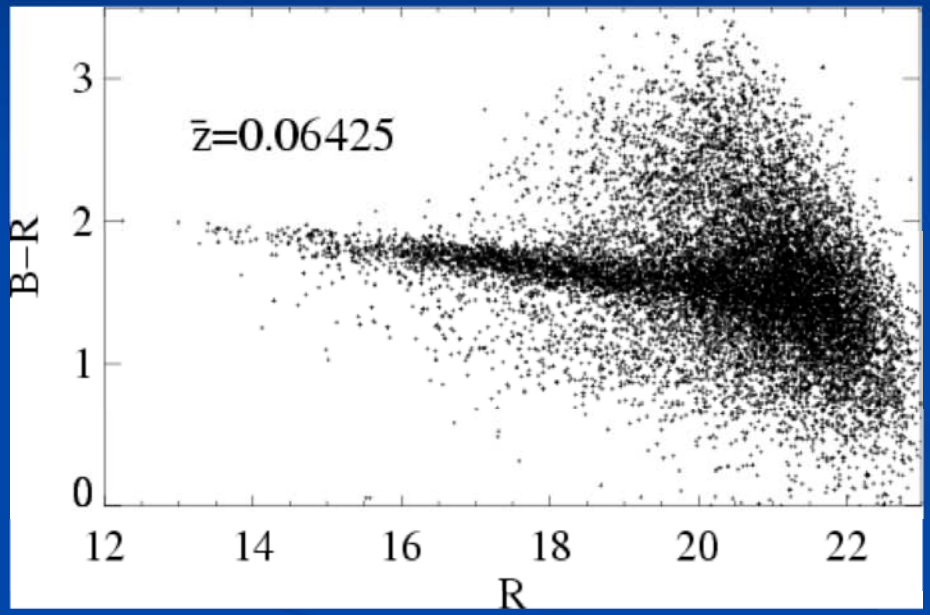


Other methods for IDing SNIa

We will never get the spectroscopy to follow up all of our events in a timely fashion.

-Multi-band imaging of clusters to get cluster red sequence. Events associated with cluster ellipticals almost certainly cluster SNIa.

-Followup spectroscopy of the host galaxies using the undersubscribed 90 inch spectrograph will screen out foreground/background galaxies and obvious QSOs.



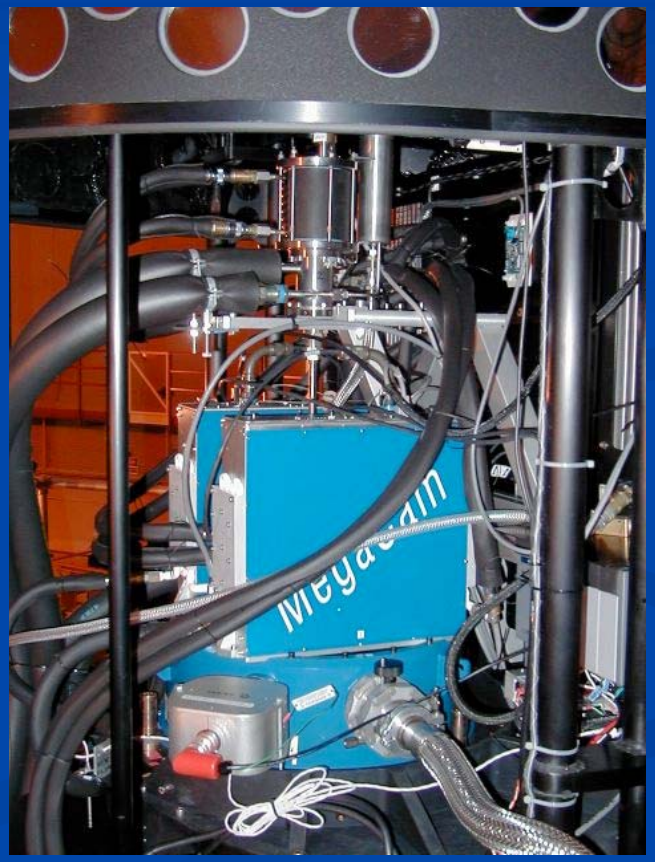
Future -- Moving imaging to CFHT/Megacam

(with Hoekstra & Pritchet)

The plan -- Monitor ~70 galaxy clusters at $0.05 < z < 0.15$ in g and r band every month for 2 years

--In the end, stack the images to measure the truncation radius of cluster galaxy DM halos as a function of clustercentric radius with weak lensing

--Monthly monitoring will yield ~60 cluster SN Ia and ~10 IC SN Ia. We are pursuing spectroscopy at MMT, KP-4m, Gemini, et al…



Recap

- We have begun a SN search in ~60 X-ray selected galaxy clusters at $0.1<z<0.2$ with the 1 degree imager on the UA 2.3m
- An automated transient detection pipeline is in place, and our detection efficiencies are well understood
- Initial spectroscopy has been encouraging and will continue. We plan to use other methods to probabilistically determine if a given event was a cluster Ia or not.
- We are moving the imaging portion of survey to the CFHT…stay tuned!
- Once the survey is complete, we will be able to place constraints on the SNIa rate associated with old stellar pops and the metal enrichment of the ICM

The Inner Density Profile of Galaxy Clusters

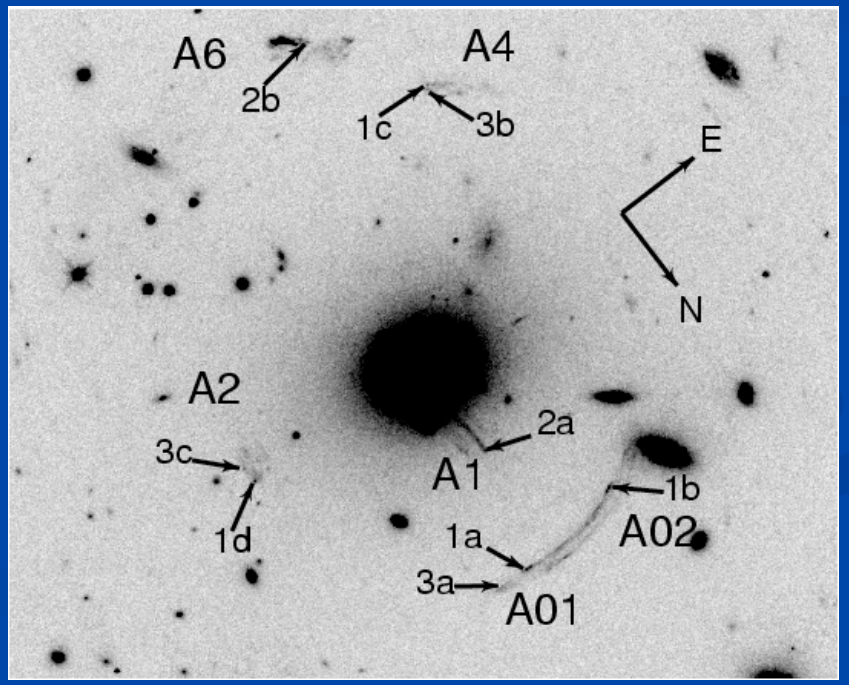
David Sand -- U of Arizona

Collaborators - T. Treu, R. Ellis, G. Smith, J-P Kneib

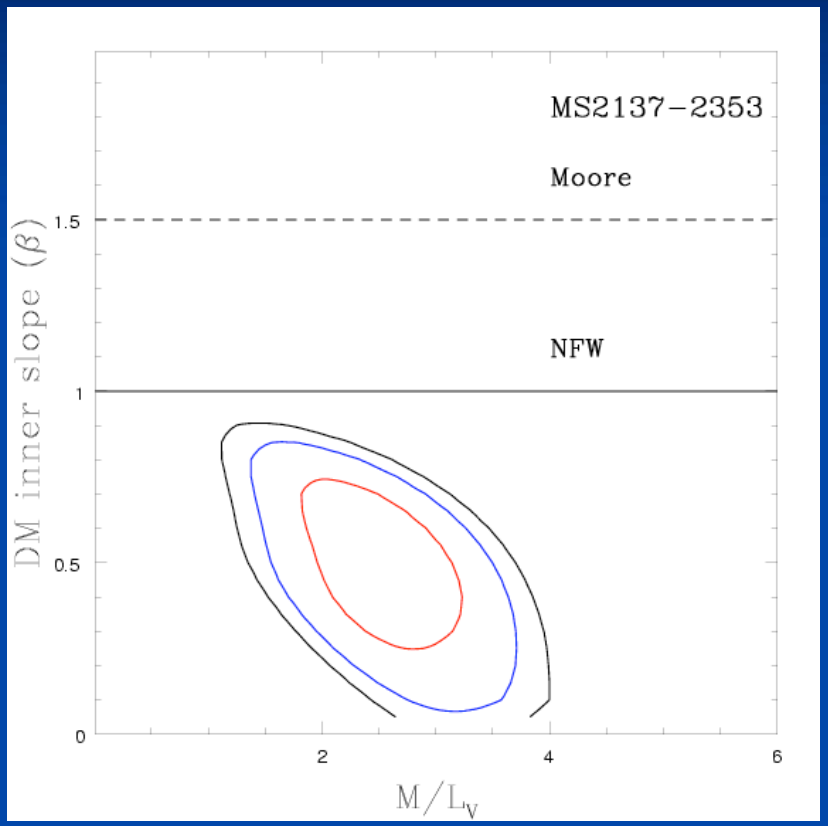
Full 2D modeling of MS2137 & A383
(Sand et al. submitted)

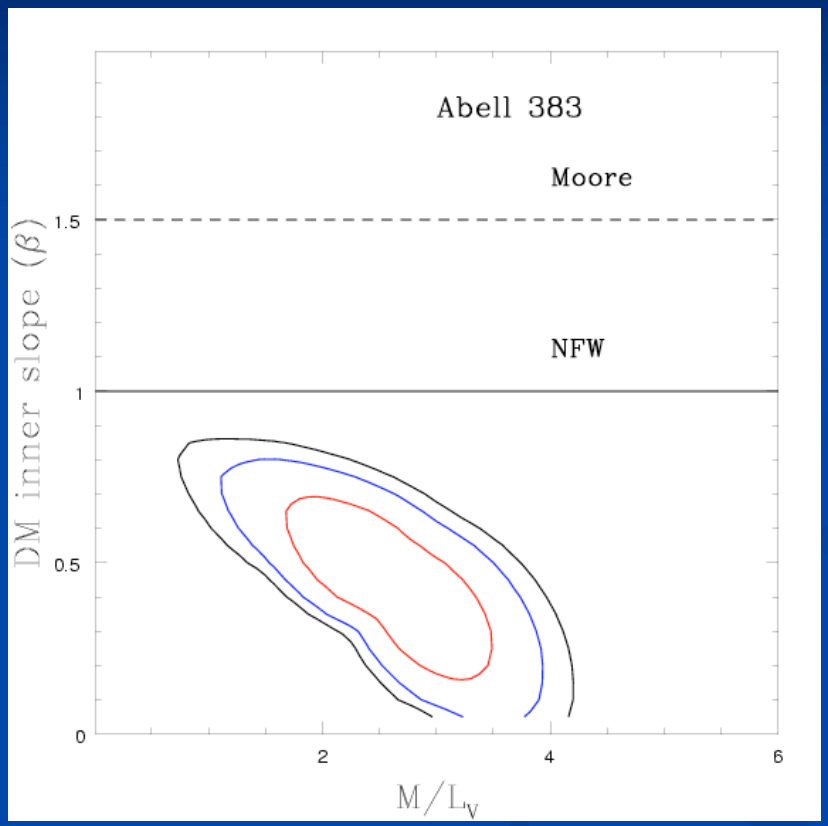
- We have modified J.P. Kneib's LENSTOOL software to include generalized NFW mass profiles.
- LENSTOOL accounts for ellipticity (both in luminous and dark matter components) and substructure (e.g. associated with visible galaxies).
- Can take into account the full multiple imaging constraints
  - Two background sources associated with the tangential and radial arcs
  - Multiple images determined from spectroscopy, surface brightness conservation and iterative lens modeling.
  - Two features on the tangential arc and one on the radial arc are identified.

MS2137 lensing interpretation



Constraints on Inner Slope with observationally motivated prior of r_{sc} =100-200 kpc





The best-fitting r_{sc} is poorly constrained.

If scale radius = 400 kpc, then best fitting inner slope is $\beta = 0.75$ (for MS2137)

Need a mass probe at high radii!!