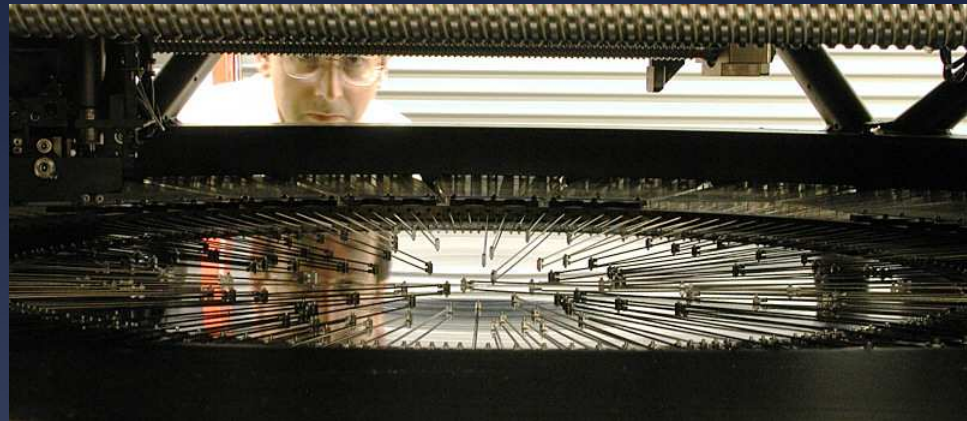


# The MMT/Hectospec M31 Survey



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Nathan Sanders  
Phil Massey  
James Rose  
Paul Harding  
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Hectospec – PI : Dan Fabricant

300 1.5 arcsec fibers over a 1 degree field – these feed one of two spectrographs with resolution of 1000 (3700-9200Å), and 30,000 (150Å per order)

Targeted objects are:

Clusters

HII regions

PNe

Stars

Unresolved light

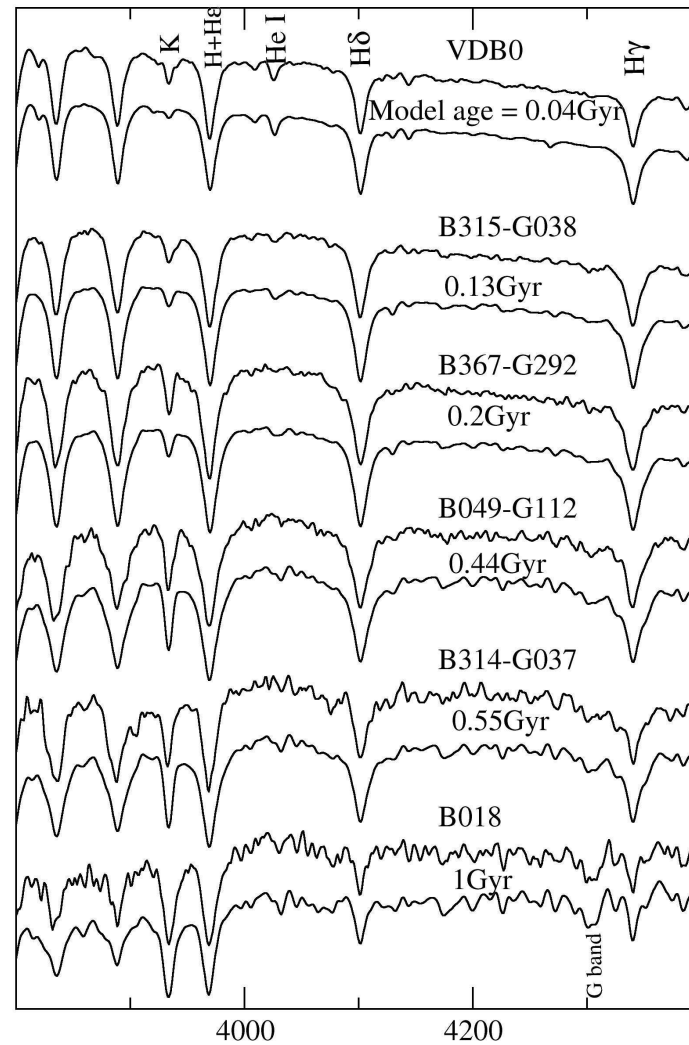
Clusters – main work here is in classifying previous “cluster” catalogs, using spectra and images, into: nothing, star, cluster or background, and then into cluster age groups.

Result is spectra of  $\sim 500$  clusters down to  $M_V \sim -4$ ,  $\sim 320$  of them old, globular clusters.

Spectroscopic sample of GCs is  $\sim 95\%$  complete inside of 20 kpc, for previously known disk clusters with  $M_V < -7$ ,  $\sim 80\%$  complete (from *PHAT*, we find that the parent sample for those disk clusters is  $> 90\%$  complete).

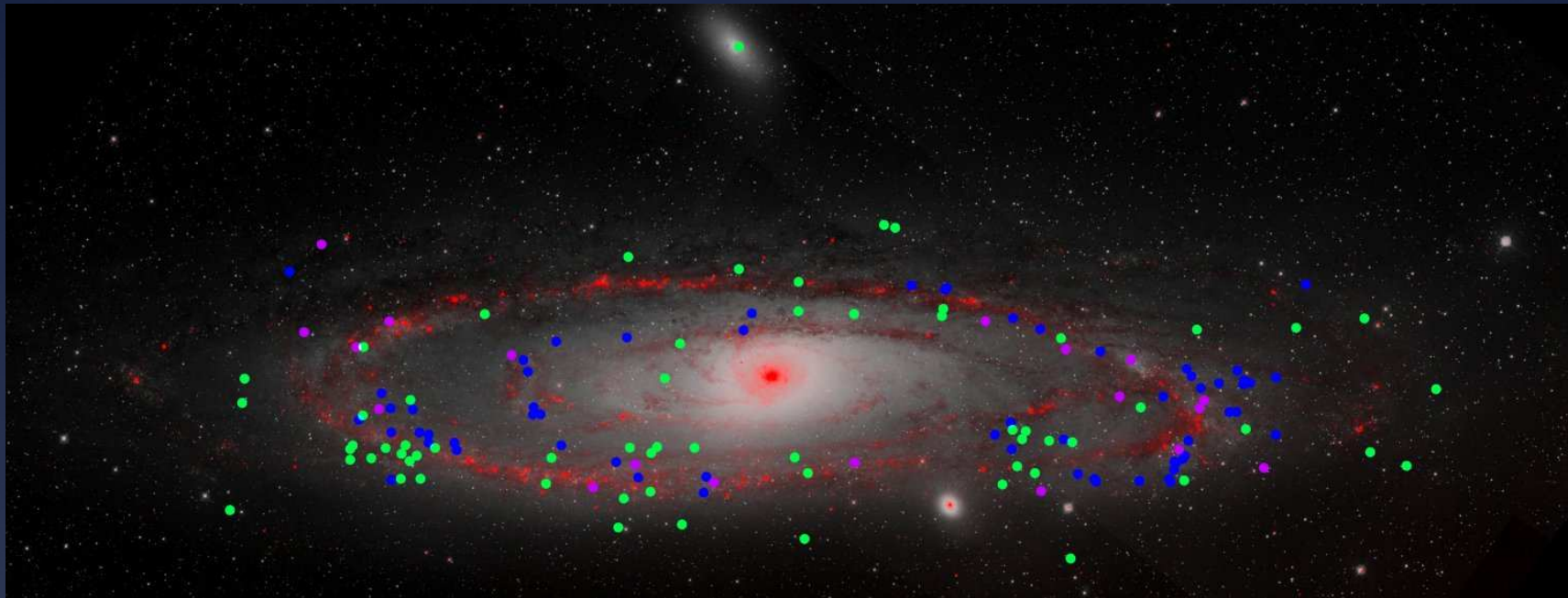


Determine  
ages by  
fitting  
model  
spectra



*Caldwell et al 2009*

## Young clusters with Mass $> 10^3$ Msun



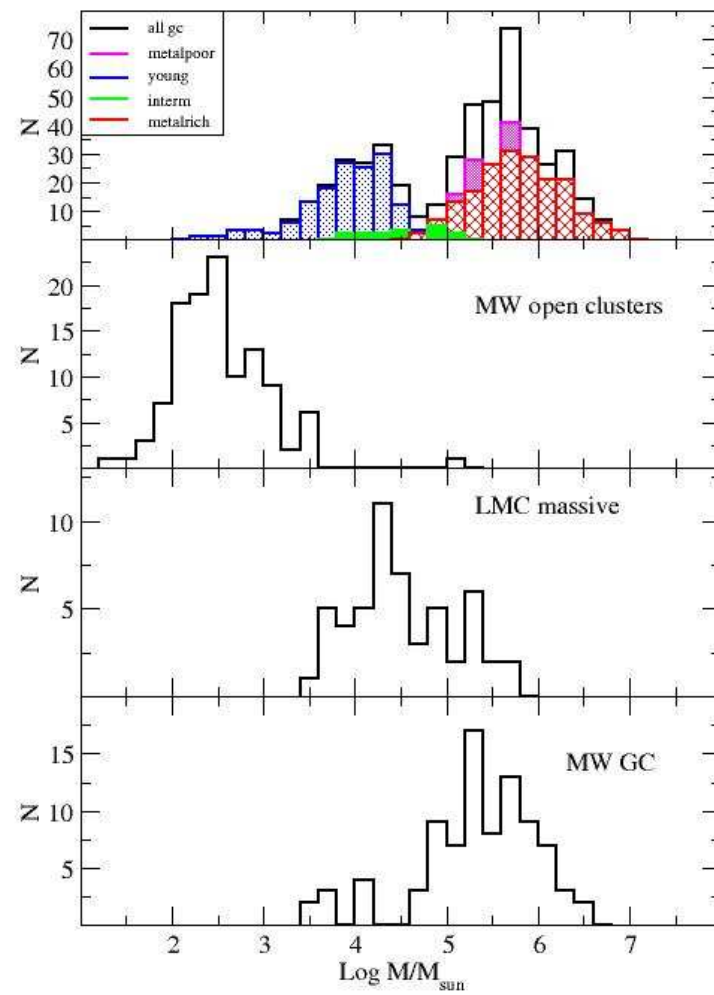
Coded by age:

Violet,  $t < 0.1$  Gyr

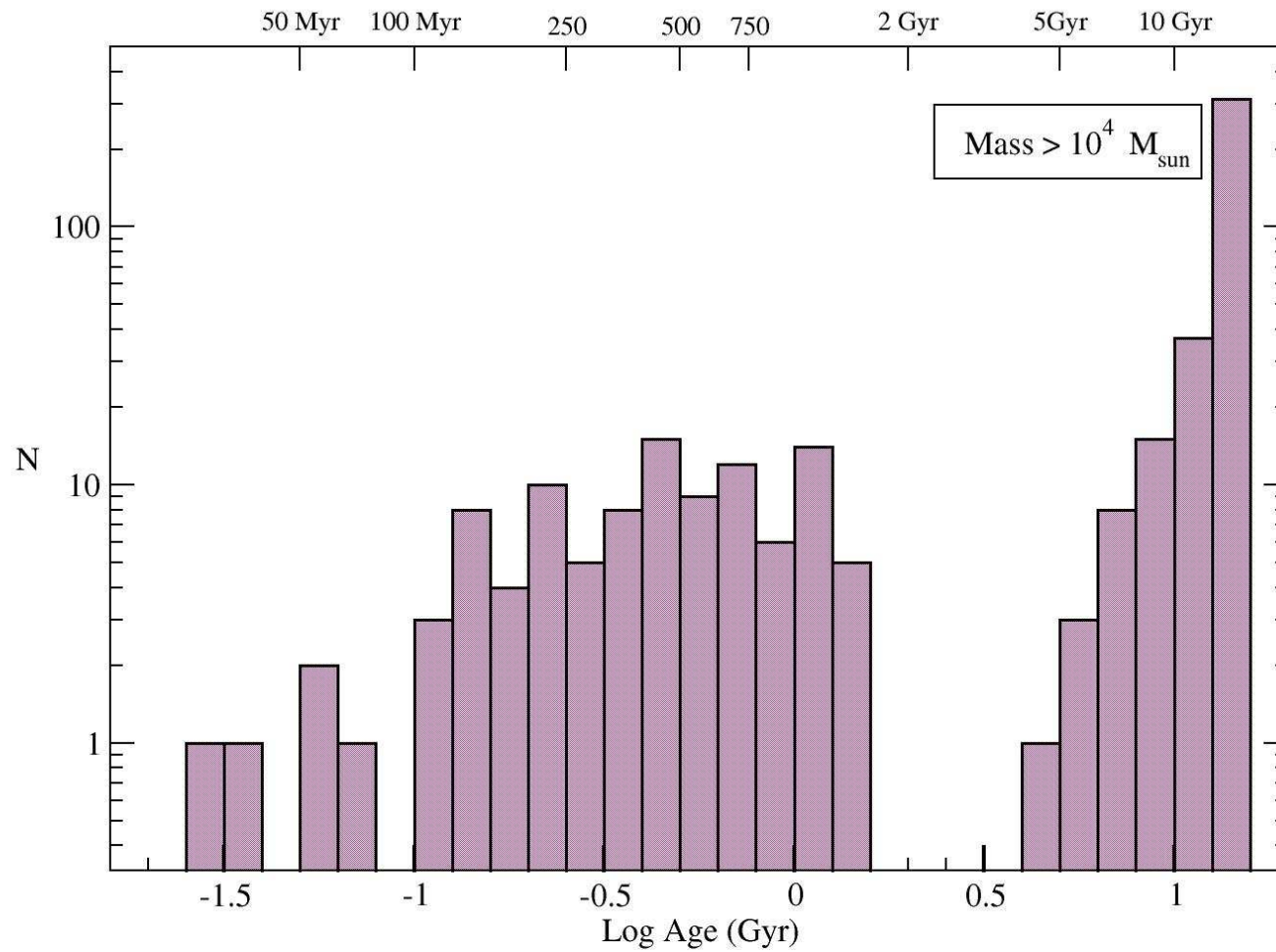
Blue,  $0.1 < t < 0.3$  Gyr

Green,  $0.3 < t < 2$  Gyr

Red is MIPS  
image



## Age Distribution



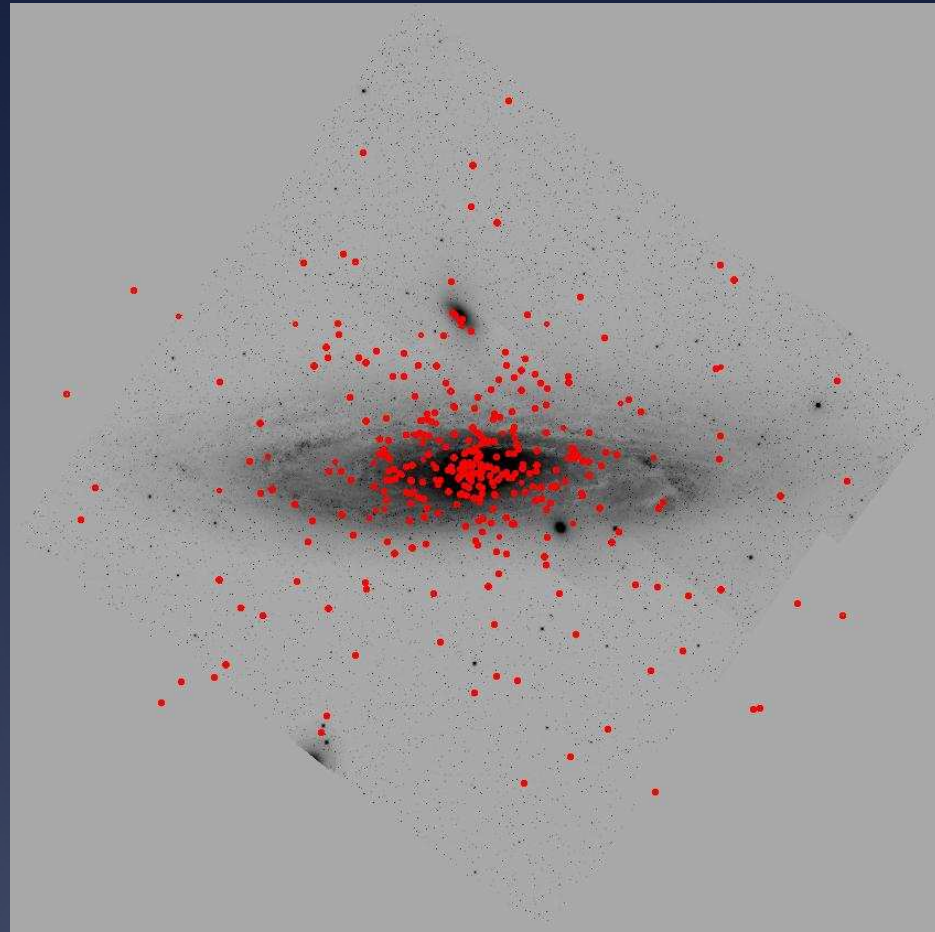


## Results:

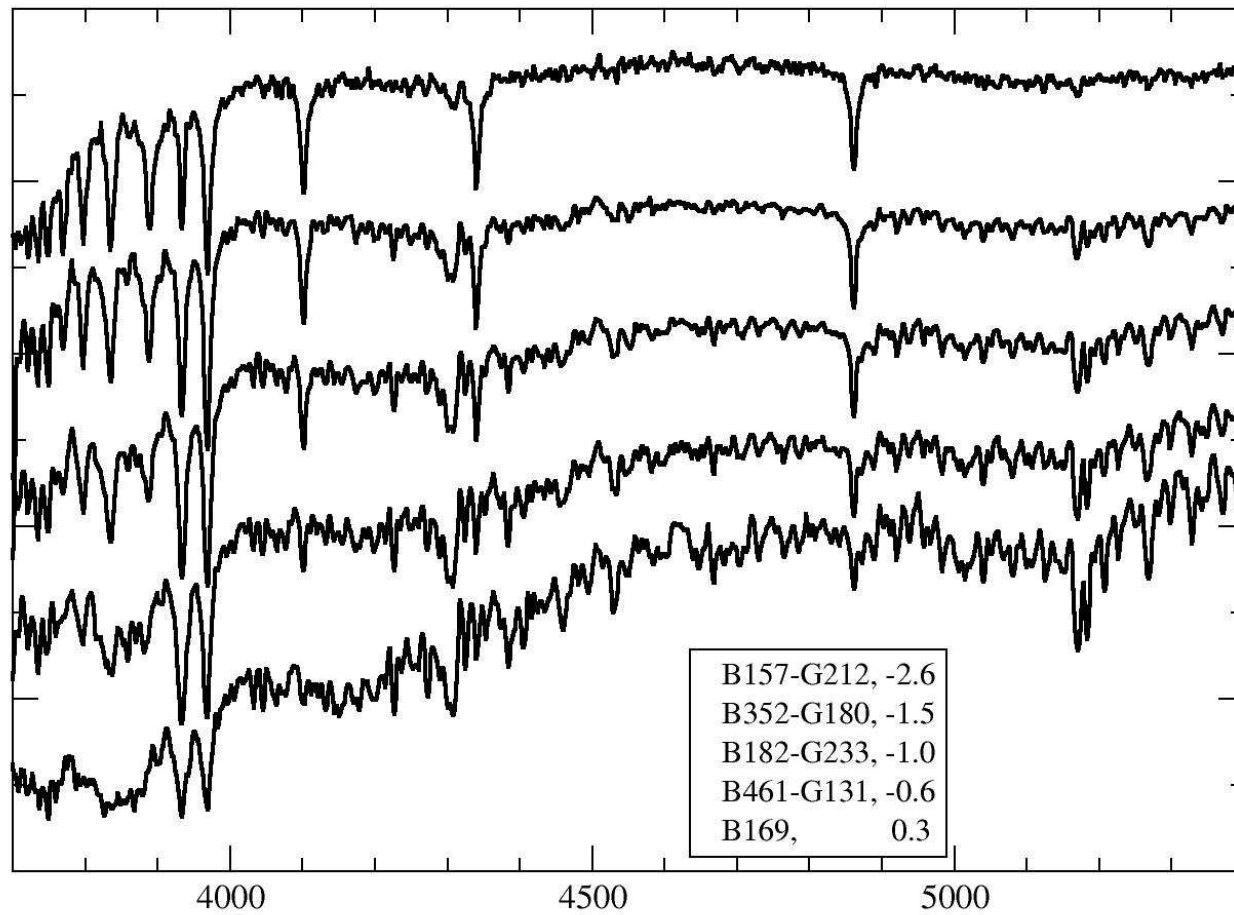
- A few young clusters as massive as  $10^5$  Msun, co-located with IR emission
- No clusters between 2-4 Gyr more massive than  $10^4$  Msun.

Old Clusters:  
Spectra of 320, out of ~370  
known.

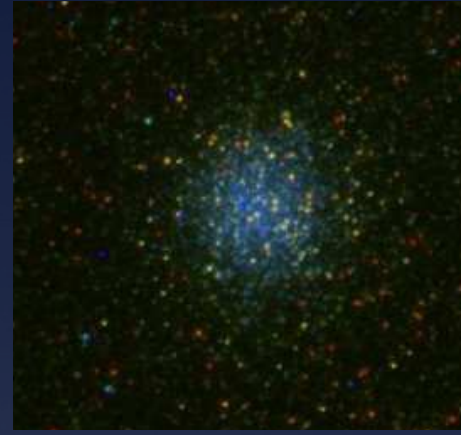
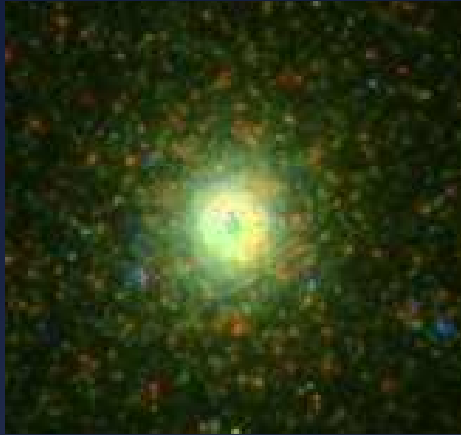
(beware of papers using more  
than ~400 GCs within the optical  
disk – such catalogs are  
contaminated with young disk  
clusters)



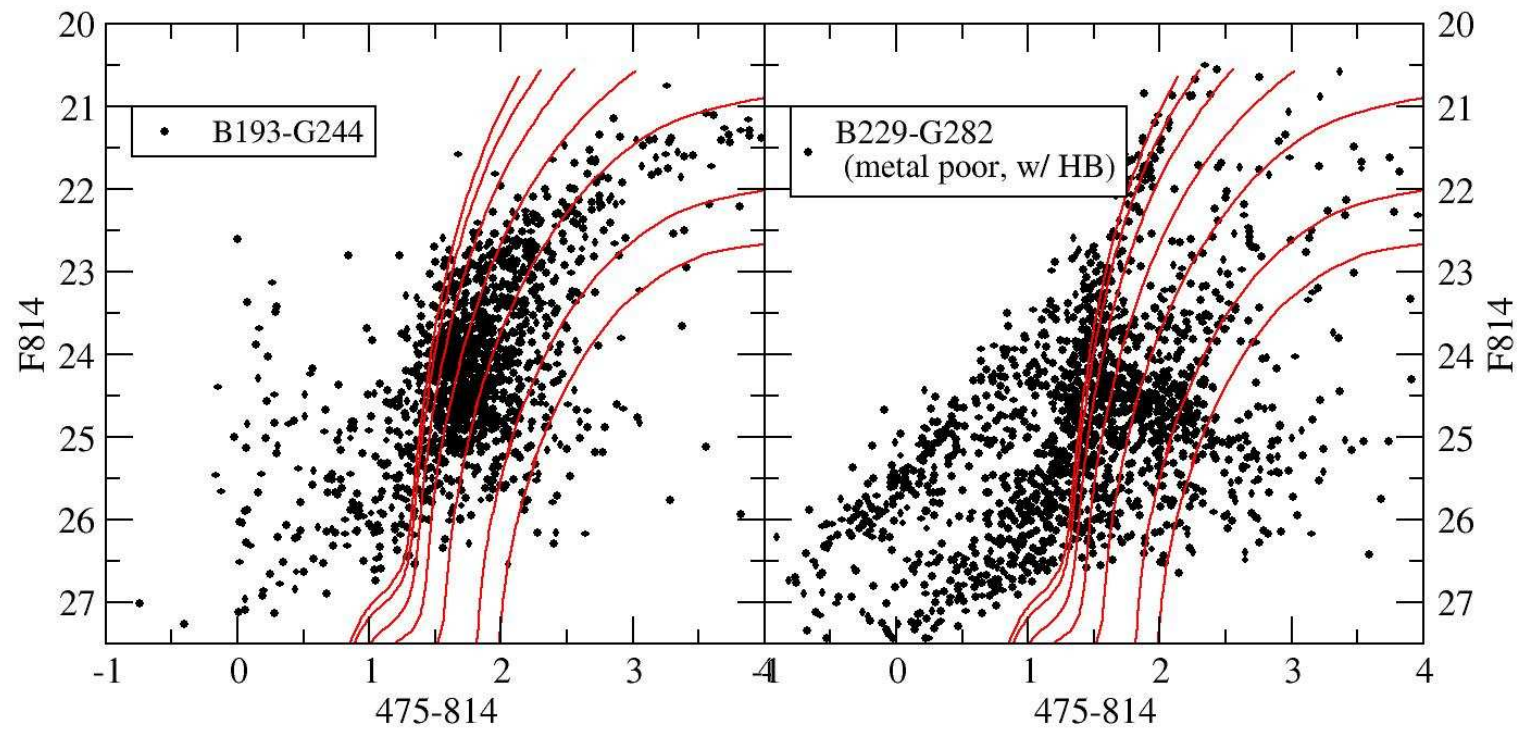
*Caldwell et al. 2011*



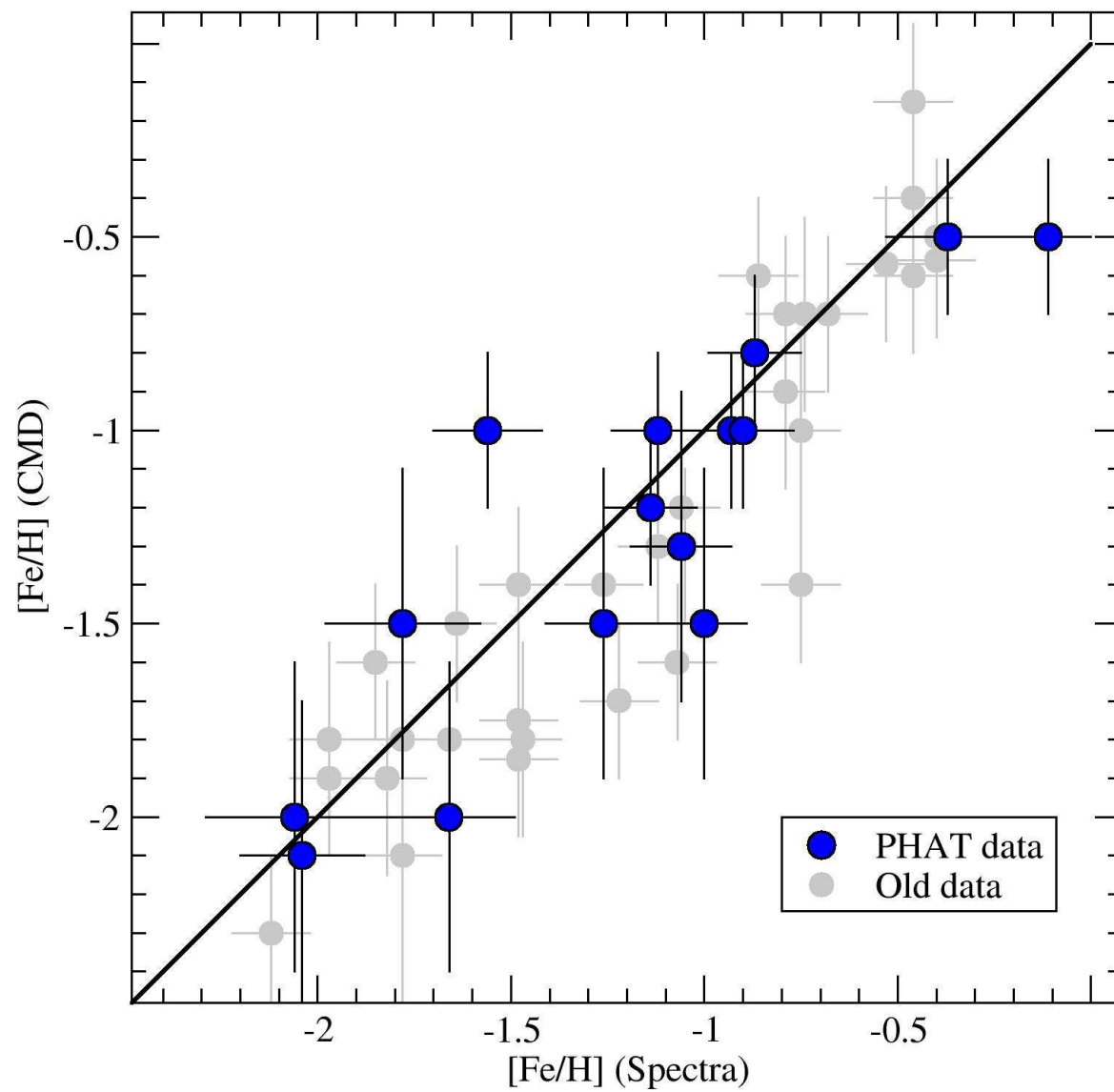
Clusters with a range of  $[\text{Fe}/\text{H}]$

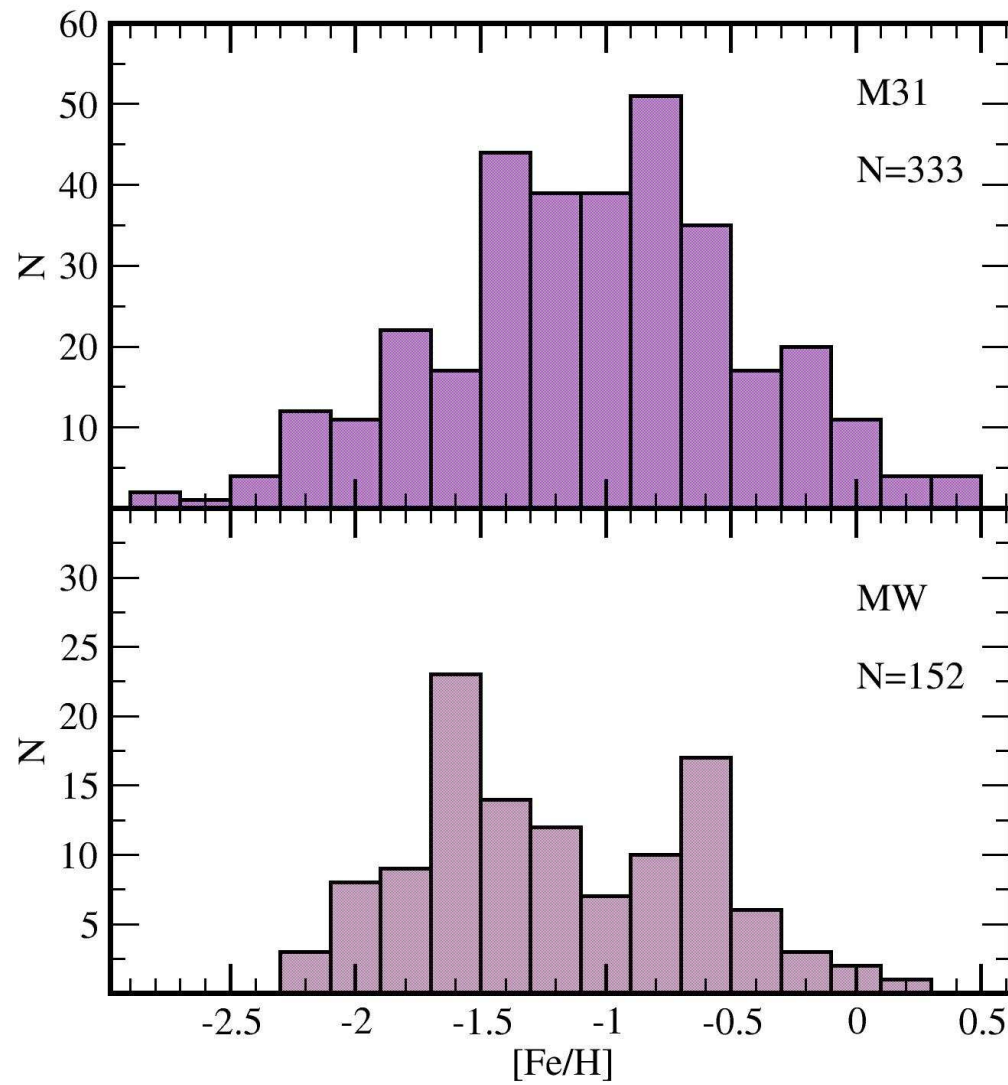


from PHAT data









$[Fe/H]$  derived  
from a calibration  
supplied by MW data.

Color coded  
velocities

$[\text{Fe}/\text{H}] > -0.2$

$-0.6 > [\text{Fe}/\text{H}] > -0.2$

$-0.8 > [\text{Fe}/\text{H}] > -0.6$

$-1.2 > [\text{Fe}/\text{H}] > -0.8$

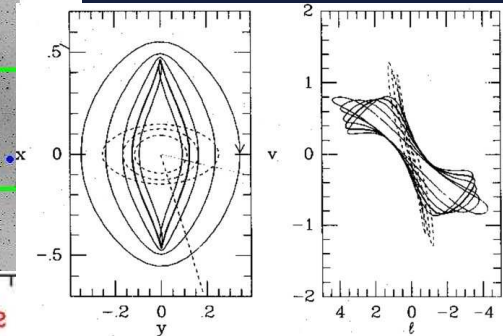
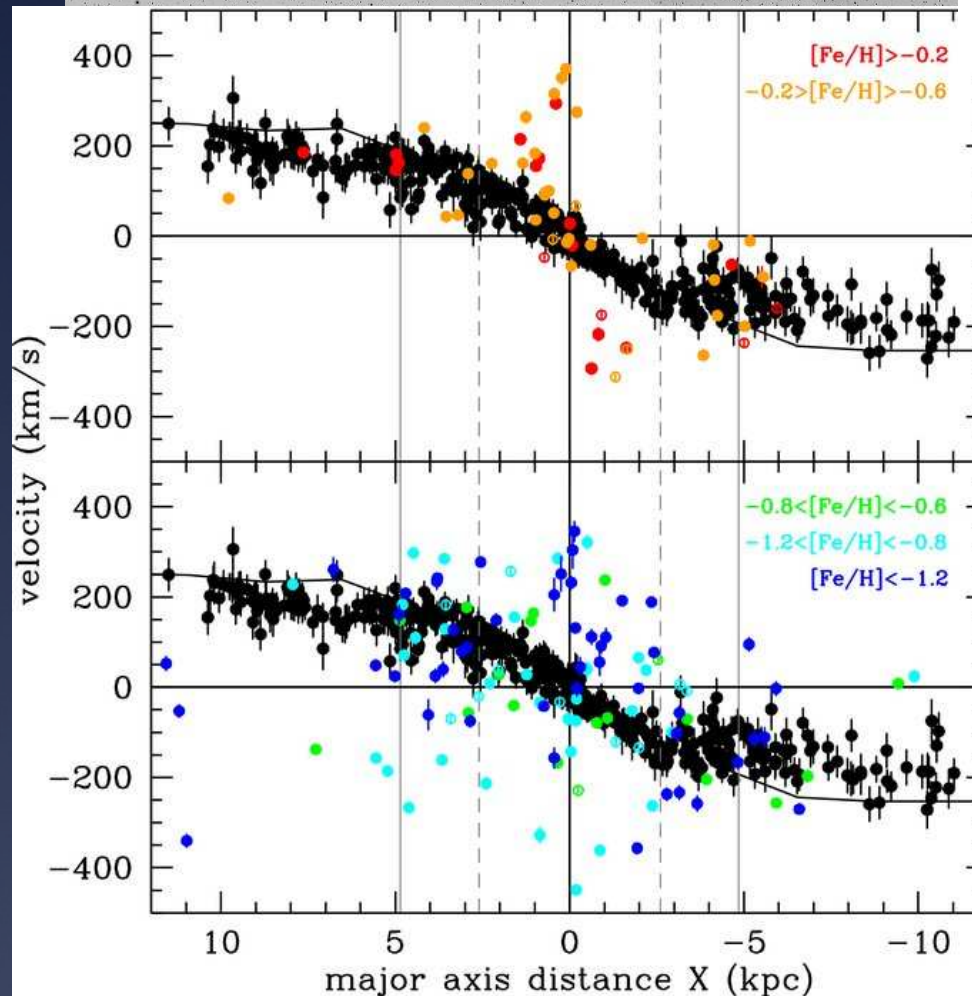
$[\text{Fe}/\text{H}] < -1.2$

Morrison et al. 2010

Within 2 kpc  
of the major  
axis.

~Red –  
metal rich  
( $[\text{Fe}/\text{H}] > -0.6$ )

~Blue –  
metal poor  
( $[\text{Fe}/\text{H}] < -0.6$ )



Binney et al. 1991

Black dots are from  
diffuse light

But why just  
the metal-rich  
clusters?



## Results:

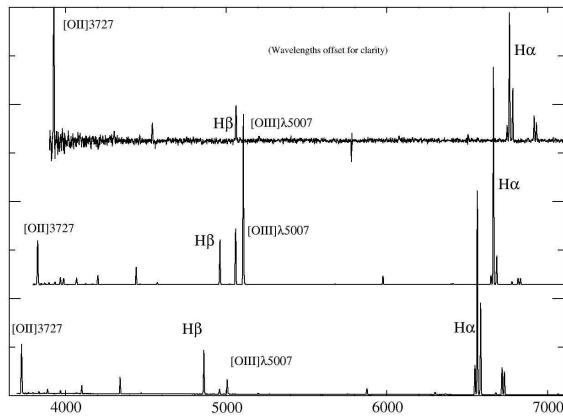
- A few young clusters as massive as  $10^5$  Msun, co-located with IR emission
- No clusters between 2-4 Gyr more massive than  $10^4$  Msun.
- Metallicity distribution is not strongly bimodal
- Metal rich clusters in bulge show response to a bar potential
- Aside of those, metal rich clusters are a disk kinematic population (but not cold), and though the metal-poor cluster system is a hotter component, it has some systemic rotation ( $\sim 100$  km s $^{-1}$ )

## HII Regions

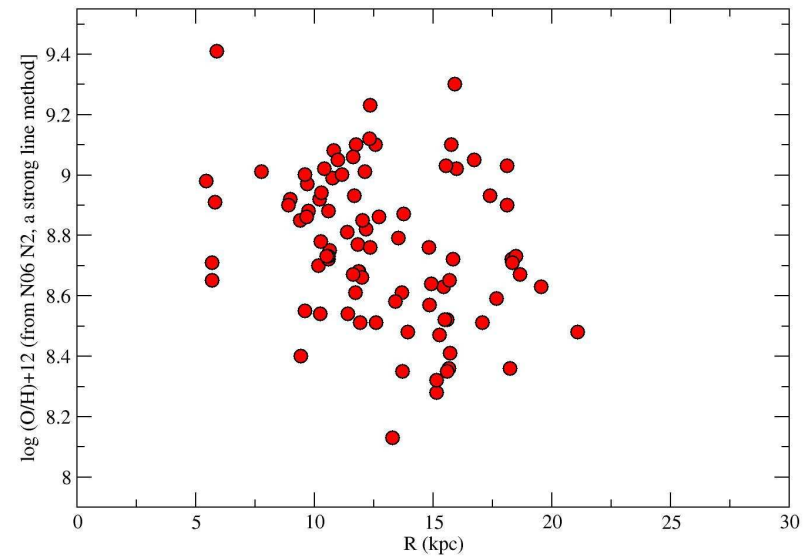
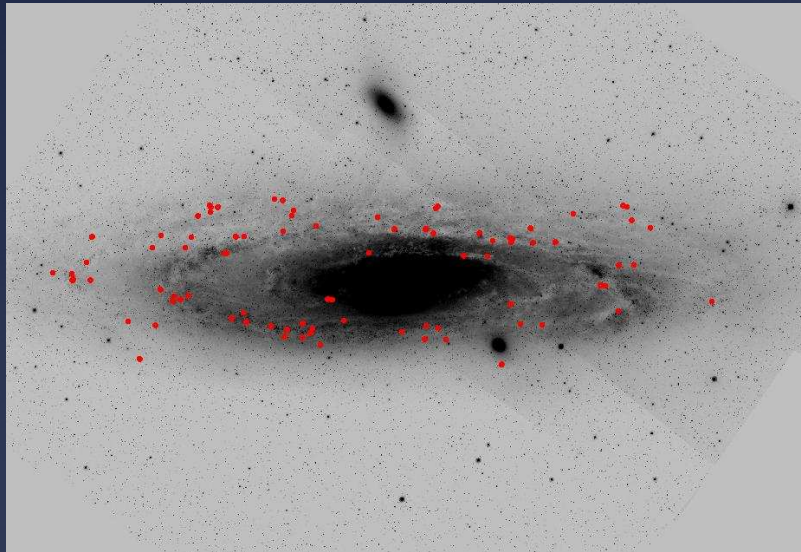
Selected from LGGS images to be small, appropriate for a 1.5'' fiber spectrograph. Lately, we've added in more objects from the Azimlu et al. (2011) catalog, based on the same source material.

Problems with our Hectospec set are twofold:

- 1) Many objects are stellar in appearance, some are indeed emission-line stars (PNe or Symbiotic Stars), others are not
- 2) Because the gas is metal rich and the HIIr are faint, the [OIII]4363 line needed for  $T_e$  is weak, and often undetectable. Thus, strong line methods have to be employed.



\* Large scatter in O/H, small gradient, which however, is consistent with previous measurements.



*Nathan Sanders et al., 2012 (under review)*

## Results:

- A few young clusters as massive as  $10^5$  Msun, co-located with IR emission
- No clusters between 2-4 Gyr more massive than  $10^4$  Msun.
- Metallicity distribution is not strongly bimodal
  - Metal rich clusters in bulge show response to a bar potential
  - Aside of those, metal rich clusters are a disk population, and as previously shown, metal-poor clusters are a hotter component, though even it has some systemic rotation
- HII region O/H abundances using strong line analysis show a large scatter (check with  $T_e$  analysis using auroral lines)



Other projects not discussed here :

- High resolution of the GCs for internal velocity dispersions, leading to M/L ratios (Strader, Caldwell & Seth 2011)
- Abundance ratios in GCs (see Schiavon poster here)
- Supergiant & emission-line stars (w/Phil Massey)
- PNe work (also in Sanders et al.)
- *PHAT* connection – velocities & ages of lower mass disk clusters
- Integrated light spectra over the inner galaxy

M31 Old Star Cluster Images, Ordered by Estimated Mass

http://www.cfa.harvard.edu/oir/eg/m31clusters/m31clusterso\_frames.html

forecast PHAT PHAT clusters Netflix atlantic Salon slate M31 web wikipedia instantwatch... Classics MMT Sky Cam wapost

[Main M31 Menu](#)

Contents: M31 old star clusters ordered by estimated mass, entries beyond the start of the SK listings have no estimates. Most of the Kim et al. clusters (SK) are still no more than candidates. Contributed by Nelson Caldwell

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- [3.B151-G205](#)
- [4.B082-G144](#)
- [5.B129](#)
- [6.B042-G104](#)
- [7.G001-MII](#)
- [8.B088-G150](#)
- [9.B338-G076](#)
- [10.B225-G280](#)
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- [14.B063-G124](#)
- [15.B124-NB10](#)
- [16.B218-G272](#)
- [17.B019-G072](#)
- [18.B039-G101](#)
- [19.MITA140](#)
- [20.B163-G217](#)
- [21.B311-G033](#)
- [22.B182-G233](#)
- [23.B058-G119](#)
- [24.B174-G226](#)
- [25.B020-G073](#)
- [26.B017-G070](#)
- [27.B012-G064](#)
- [28.B116-G178](#)
- [29.B193-G244](#)
- [30.B405-G351](#)
- [31.B096-G158](#)
- [32.B178-G229](#)

Next Previous

B088-G150 old

00:42:21.0  
41:32:14.2

Type: old  
[Fe/H]<sub>spec</sub> : -1.82  
Velocity: -489.9, HS  
 $m_v$ : 15.40  
Log Age: 10.2  
Log Mass: 6.50  
Comments:

ACS F606W

LGS V

LGS I

IRAC 3.6

DSS

Next Previous

[http://www.cfa.harvard.edu/oir/eg/m31clusters/M31\\_Hectospec.html](http://www.cfa.harvard.edu/oir/eg/m31clusters/M31_Hectospec.html) or google m31 Hectospec.



THE END