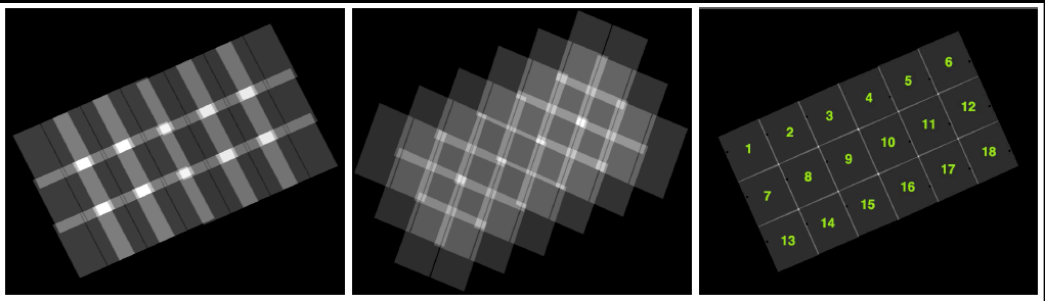
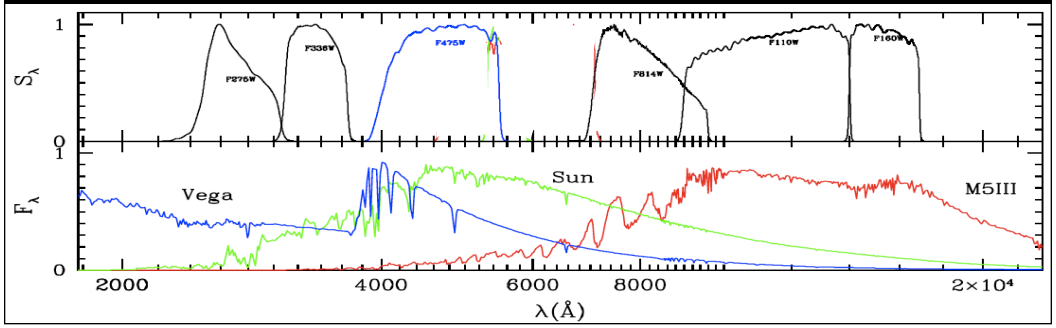
The Panchromatic Hubble Andromeda Treasury

STUC Update October 2013

Tiling M31 with 23 “bricks”



F275W F336W F475W F814W F110W F160W



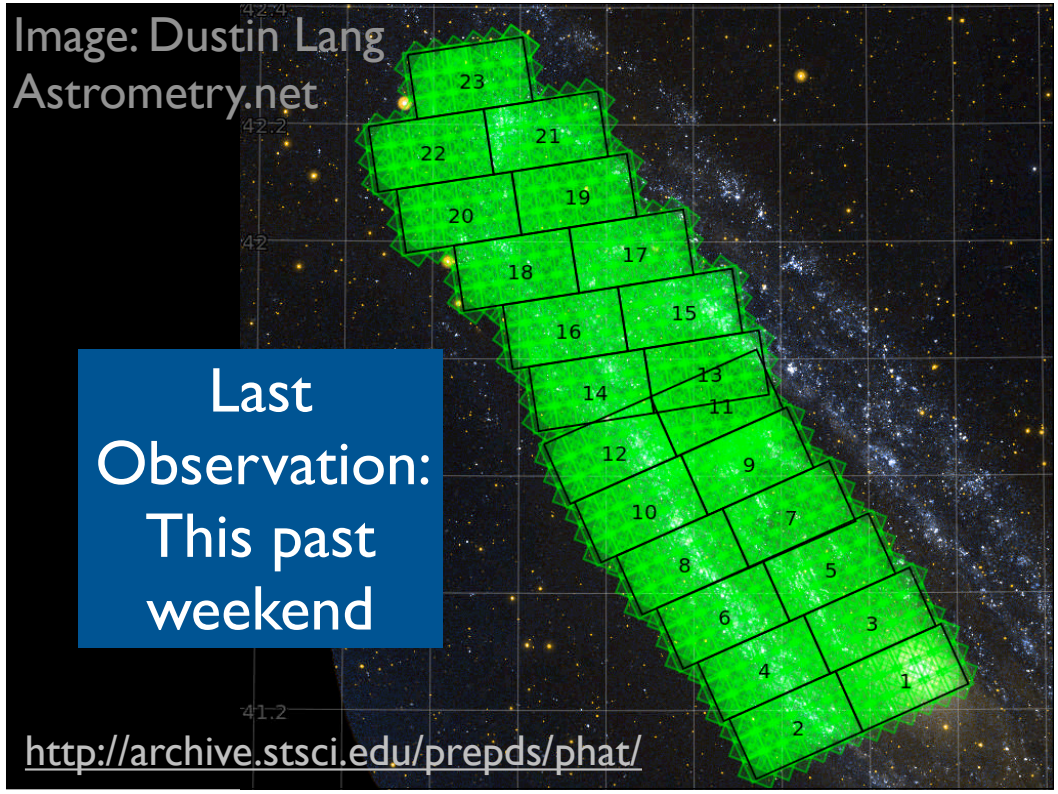


Image: Dustin Lang
Astrometry.net
Last Observation: This past weekend
http://archive.stsci.edu/prepds/phat/
23
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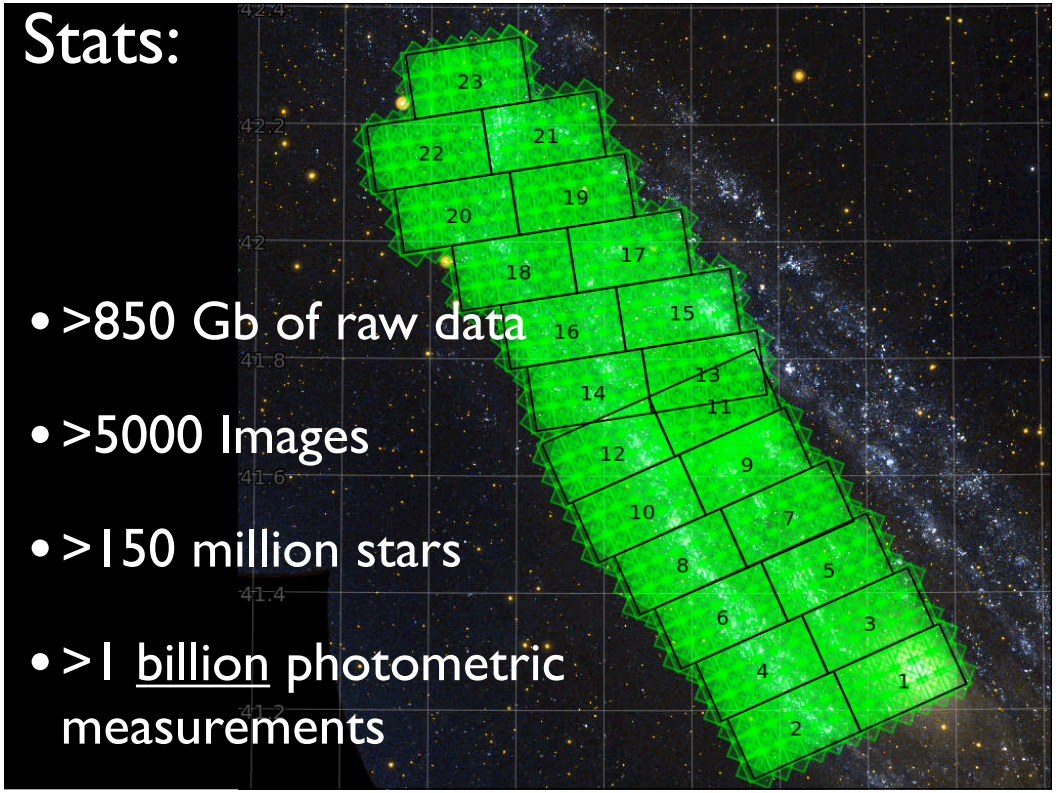
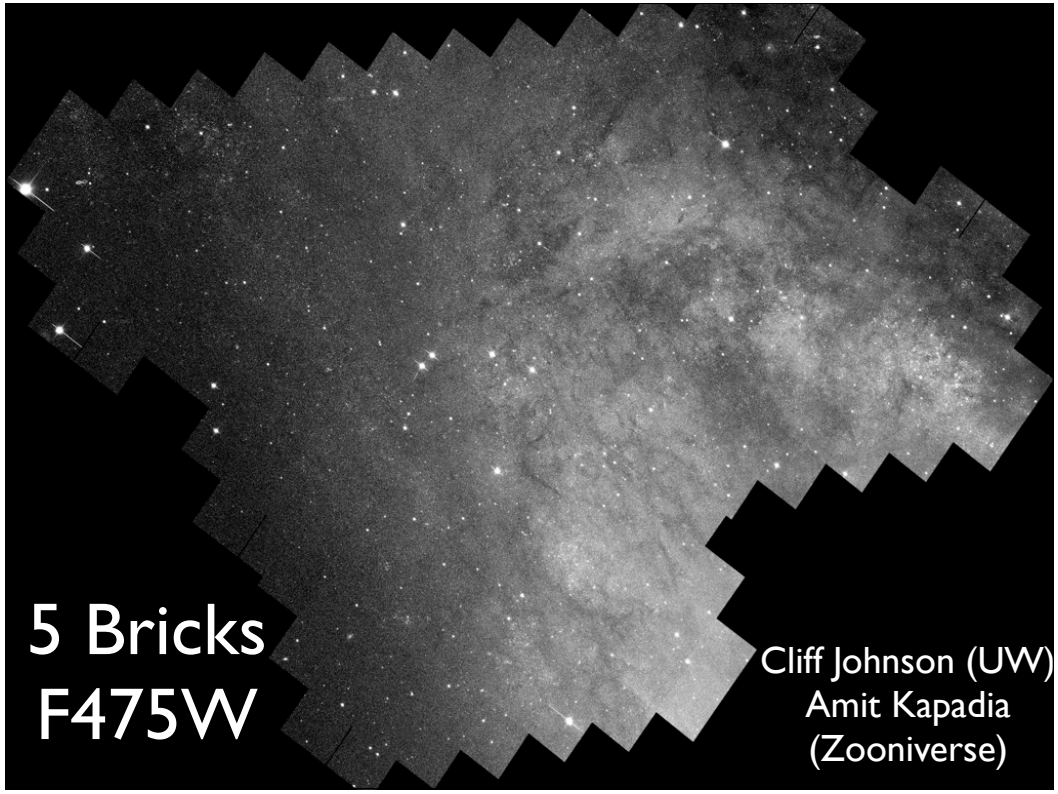
Stats:

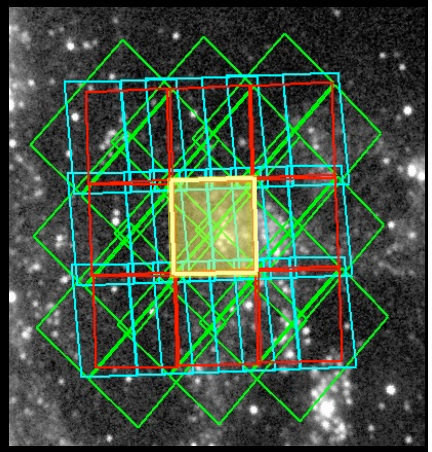


- >850 Gb of raw data
- >5000 Images
- >150 million stars
- >1 billion photometric measurements


5 Bricks
F475W
Cliff Johnson (UW)
Amit Kapadia
(Zooniverse)

Main Data Products

- 6-filter photometry
  Ben Williams, Andy Dolphin
- Superb astrometry
  5-10mas: Dustin Lang (CMU)
- Software
- Calibration
- Rich ancillary data



Cyan: UVIS
Green: ACS
Red: WFC3/IR

Photometry Status

- 99% of images have 1st generation single camera photometry complete.
- Most have been astrometrically aligned.
- Developed new machine learning techniques for CR identification
- Implemented new CTE techniques

Photometry Status

- 21 bricks have 2nd generation simultaneous 6-filter photometry (Thanks Amazon!)
- Will be starting 3rd generation full-stack photometry in early 2014.

Data Release Status

Astrometrically aligned single camera photometry

- 2011: 4 bricks
- 2012a: 1 brick
- 2012b: 9 bricks
- (Nov 2013): 9 bricks
- Migration to database!

Data Release Status

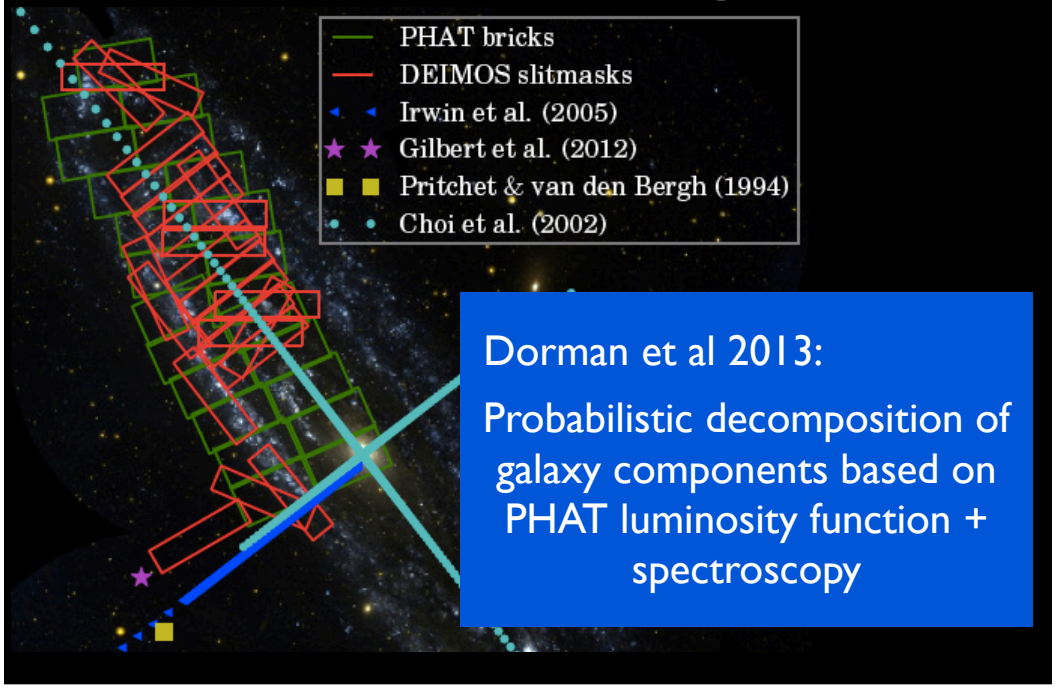
Astrometrically aligned 6-camera photometry

- (Fall 2014): Database release of 2nd generation 6-filter photometry
- (2015): Legacy release of 3rd generation, full-stack photometry

1. Major Spectroscopic Campaigns

- Keck DEIMOS (stellar kinematics & spectral typing: Guhathakurta, Dorman, Kalirai, & Howley)
- MMT Hectospec (clusters, PNe: Caldwell)
- Palomar/MMT (HII regions: Skillman, Berg, Kirby)
- Keck MOSFIRE (metal-rich bulge giants: Kirby)
- LBT MODS (hot stars: Collins, Rix, Weisz)

DEIMOS: >10K spectra

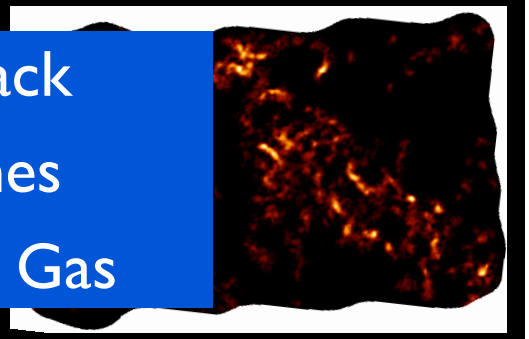


Dorman et al 2013:

Probabilistic decomposition of galaxy components based on PHAT luminosity function + spectroscopy

2. Gas (HI, CO)

- Feedback
- Lifetimes
- SFR vs Gas

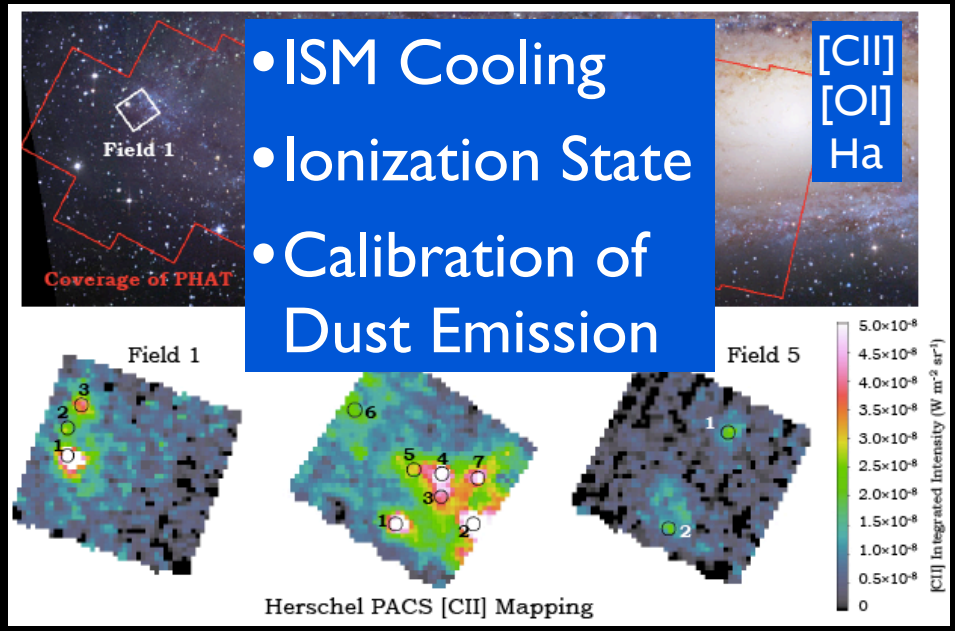


UV+Opt+IR
(PHAT)

CO w/ CARMA
PI: Andreas Shruba
Data in 8 bricks

In progress: HI w/ VLA (PI: Adam Leroy)

3. Herschel + IFU



- ISM Cooling
- Ionization State
- Calibration of Dust Emission

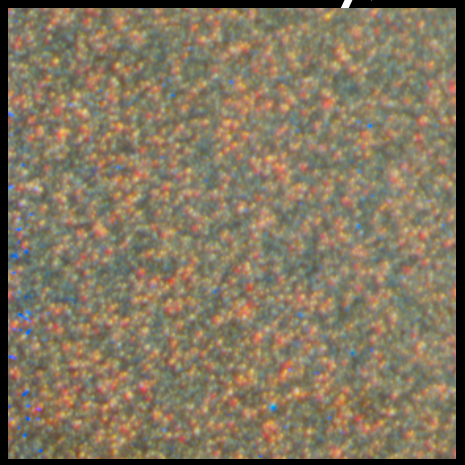
PI: Karin Sandstrom, w/ Maria Kapala (MPIA)

1. Overall Progess

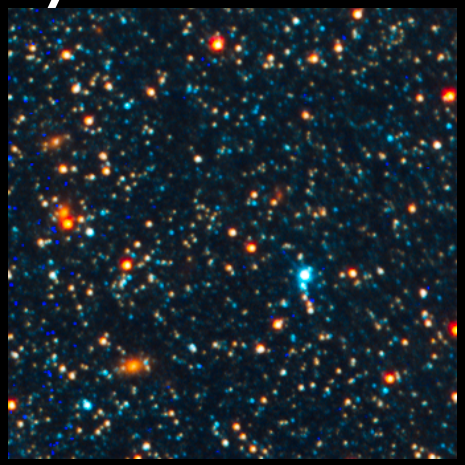
- "Have you achieved the science goals anticipated at the outset?"

Not yet, but didn't expect to have at this time!

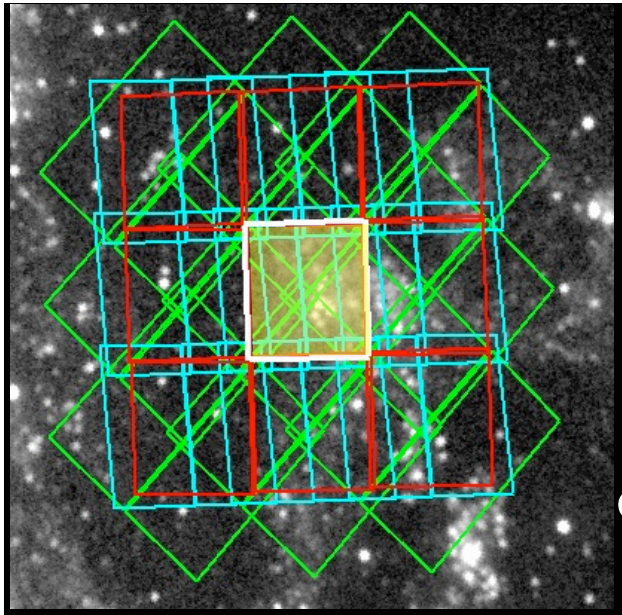
Crowded field photometry is really, really hard.



Outer Bulge of M31



Outer Disk of M31

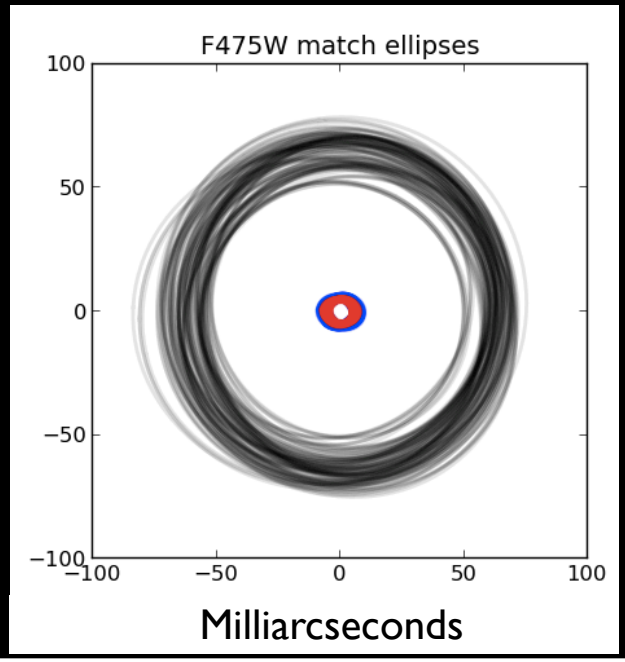


Cyan: UVIS Green: ACS Red: WFC3/IR
267 chips in 163 exposures
>50Gb memory

Simultaneous, multi-camera photometry of ~10^6 stars in 100's of overlapping, distorted images w/ CTE

Has never been done before!

0.005-0.01” relative astrometry

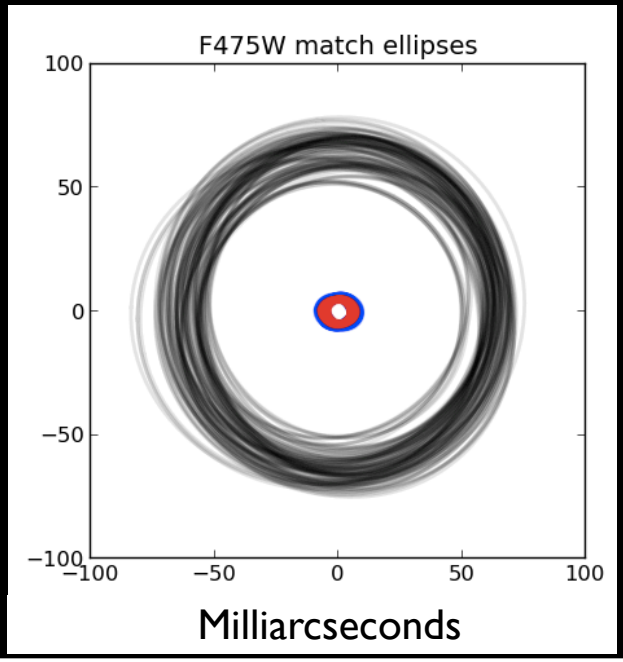


Relative to other F475W images

Relative to other F814W images

Alignment to CFHT reference image (absolute)

Has required revisions in:



- Angle between cameras
- Relative chip positions
- Distortions
- Multidrizzle
- Treatment of CTE

New Scientific Techniques

- Probabilistic IMF measurements
- Citizen science cluster identification
- Probabilistic cluster analysis (photometry + profiles)
- Probabalistic 6-filter spectral energy distribution fitting of stars (L_{bol}, T_{eff}, A_V, R_V)
- New artificial star techniques

Science Highlights

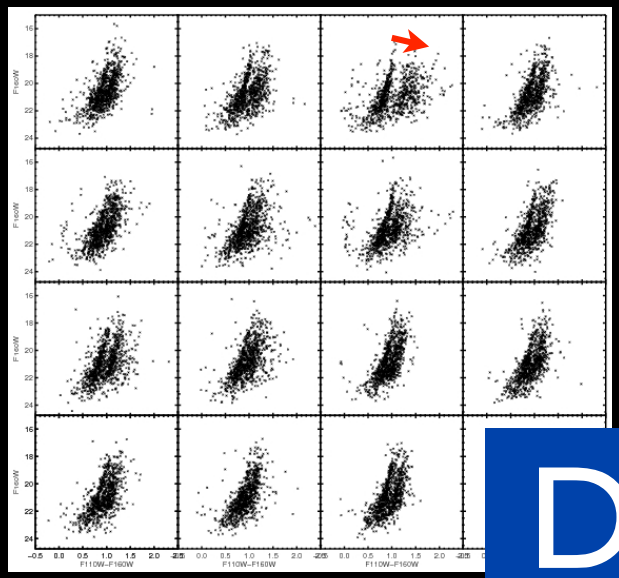
- Survey paper (Dalcanton et al 2012)
- First cluster catalog paper (Johnson et al 2012)
- UV stars in bulge (Rosenfield et al 2012)
- Kinematics of the inner halo (Dorman et al 2012)
- Halo profile from blue HB stars (Williams et al 2012)
- Age dating semi-resolved clusters (Beerman et al 2012)
- Techniques for IMF fitting (Weisz et al 2013)
- SNR progenitor masses (Jennings et al 2013)
- Cluster mass functions (Fouesneau et al 2013)
- Calibrating UV age dating (Simones et al 2013)
- Kinematic decomposition (Dorman et al 2013)
- Scarcity of Carbon stars in the bulge (Boyer et al 2013)
- Dust mapping (Dalcanton et al 2013)

"Has the project produced scientific results that were not expected?"

Oh, heck yes!

- Blue horizontal branch as tracer of the inner halo
- UVX stellar populations
- Dust mapping

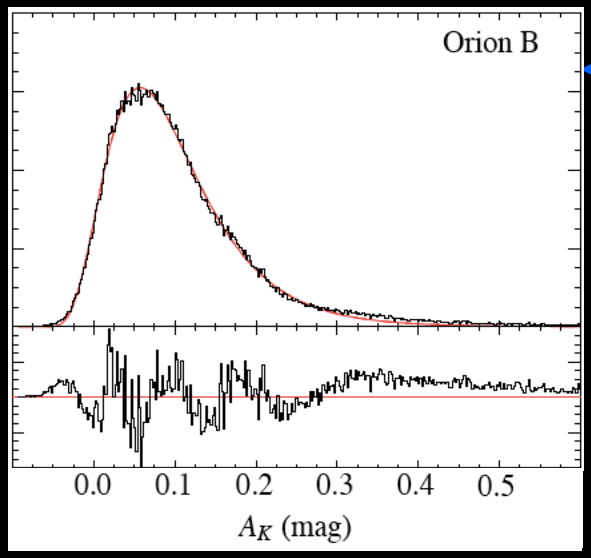
Red Giant Branch is Doubled

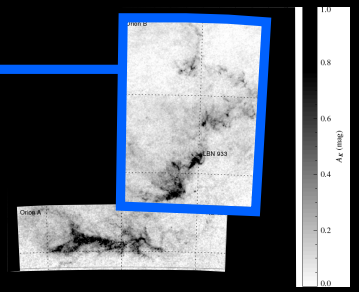


F110W-F160W CMD of Single WFC3/IR frame, subdivided in 4x4 grid

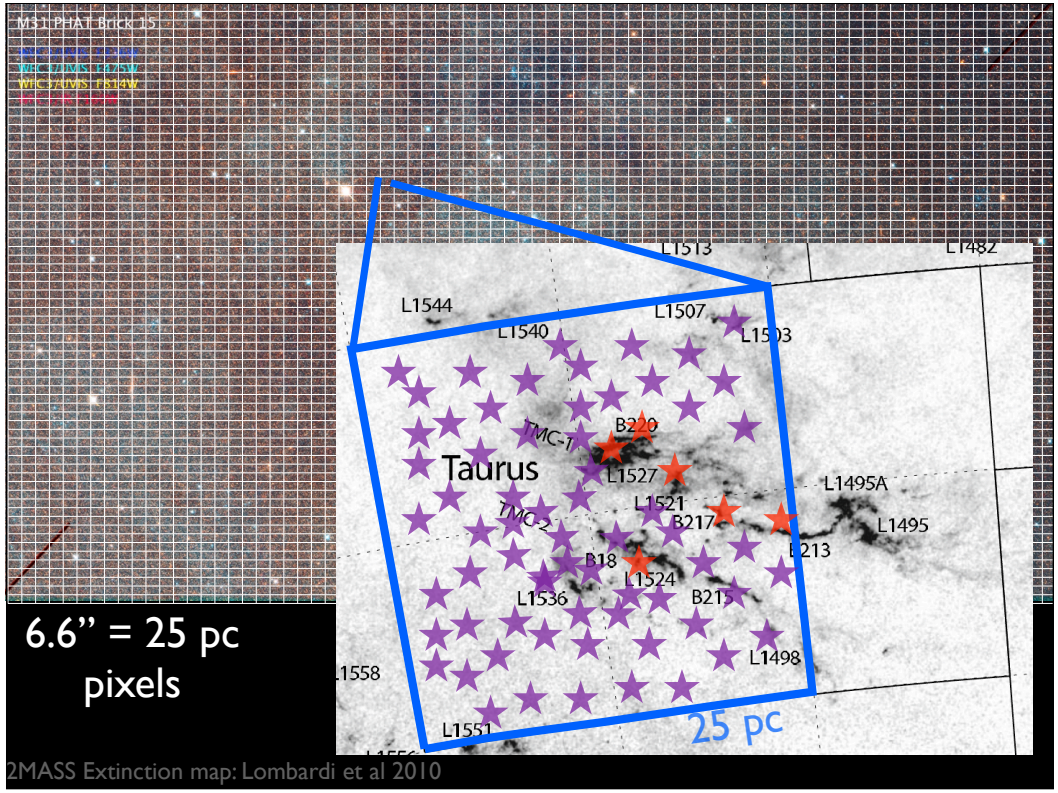
Dust!

In MW Molecular Clouds: Log-Normal Distributions of Extinctions



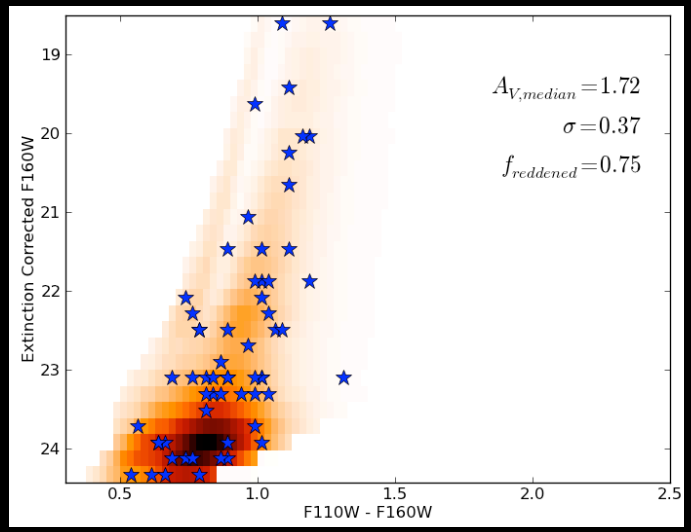


Reflects properties of turbulent ISM

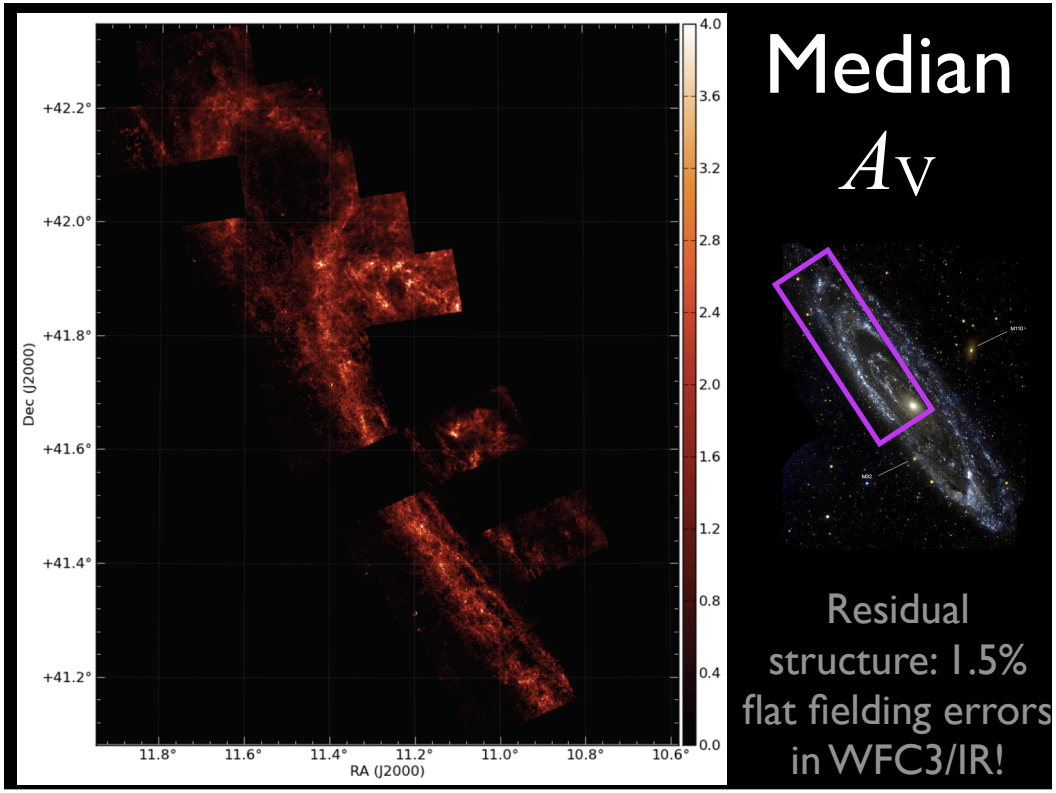

M31 PHAT Brick 15
WFC3/UVIS F475W
WFC3/UVIS F814W
L1544
L1540
L1513
L1482
L1507
L1503
B220
TMC-1
Taurus
L1527
L1521
B217
TMC-2
B18
L1524
L1536
B213
L1495A
L1495
B215
L1498
L1558
L1551
6.6” = 25 pc
pixels
25 pc
2MASS Extinction map: Lombardi et al 2010

Fit CMD in 25 pc pixels

Foreground + Log-Normal $p(A_V)$

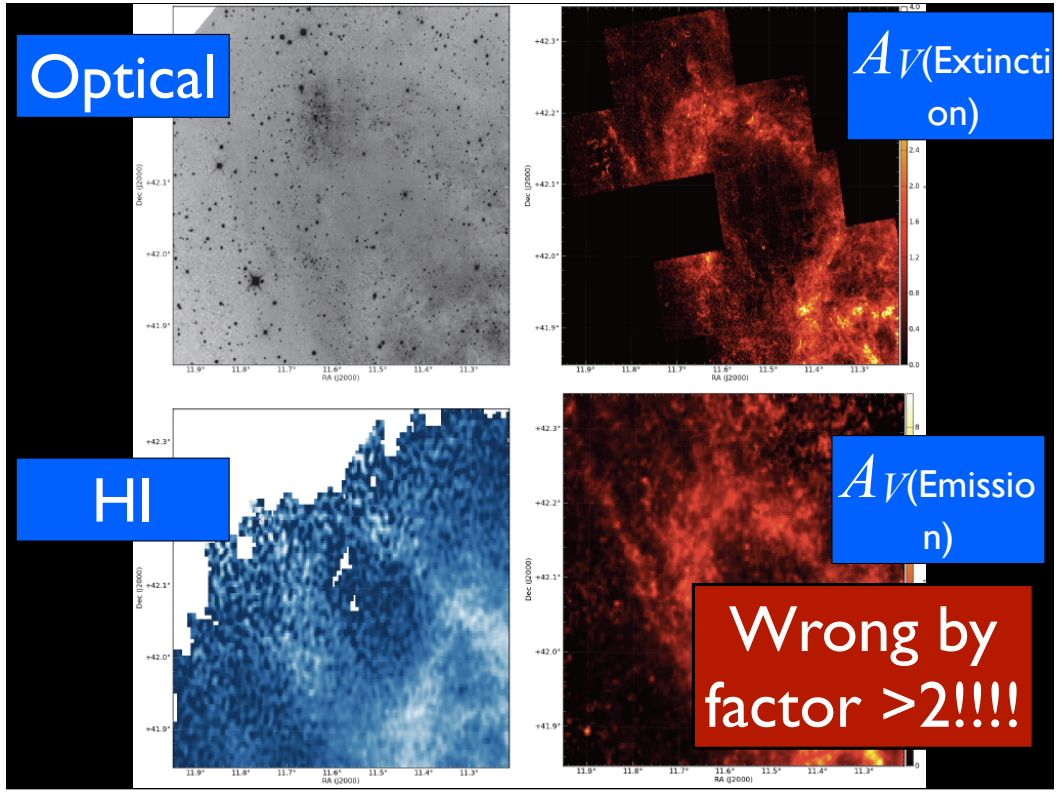


- Median A_V
- Width s of log-normal
- Fraction of reddened stars f_{red}

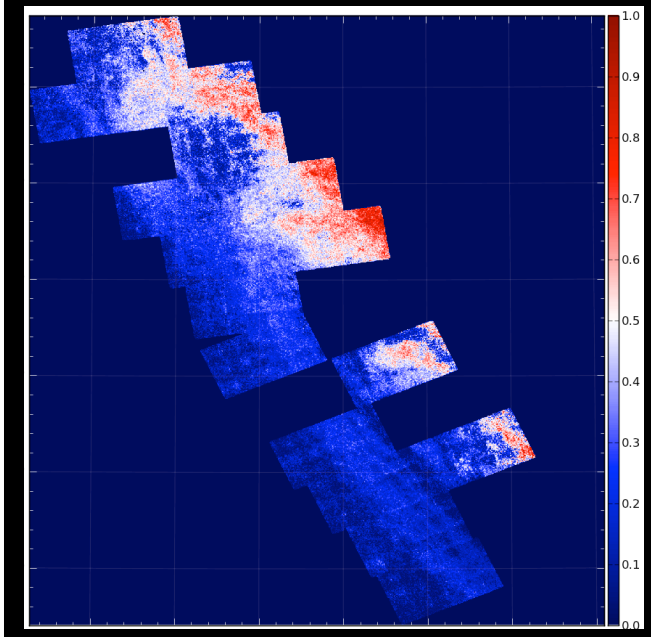


Median A_V

Residual structure: 1.5% flat fielding errors in WFC3/IR!

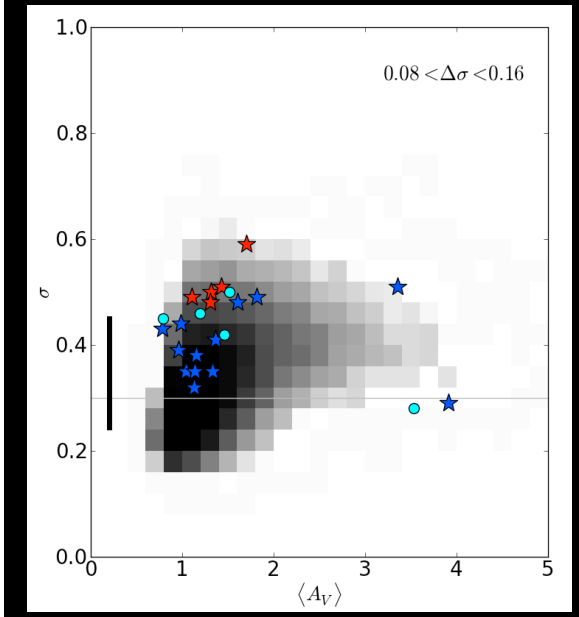

Optical
A_V(Extinction)
HI
A_V(Emission)
Wrong by factor >2!!!!

Fraction of Reddened Stars



Probes 3-dimensional structure of the stellar disk!

Width of Reddening Distribution



Grey: M31 Colored points: MW

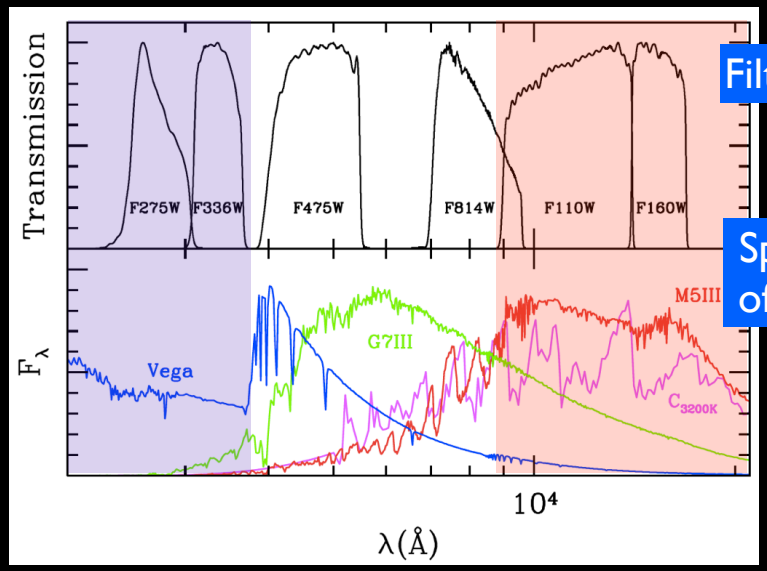
Probes statistics of interstellar turbulence!

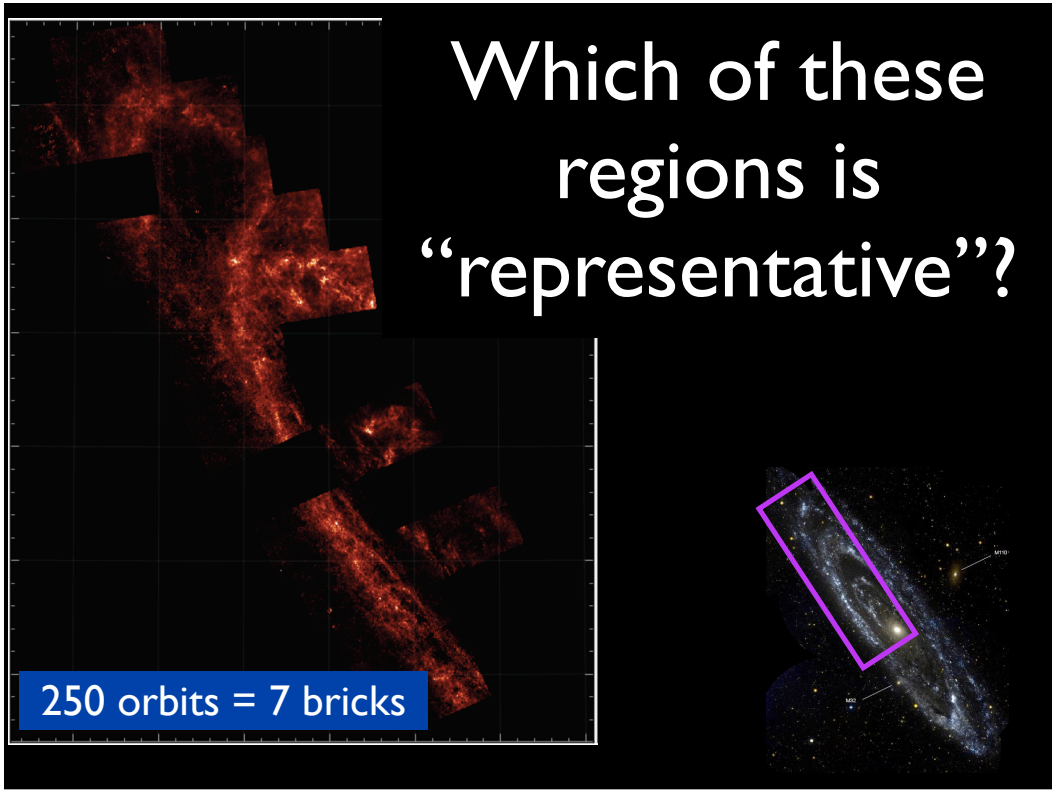
"How much of the science produced by your program could have been achieved through a standard 150-250 orbit HST program? Is there a qualitative difference in the science that you could tackle because of the scale of the program - are there topics where you have a result where a smaller program would simply have given tantalizing hints?"

"Would ~250 Orbits have been ok?"

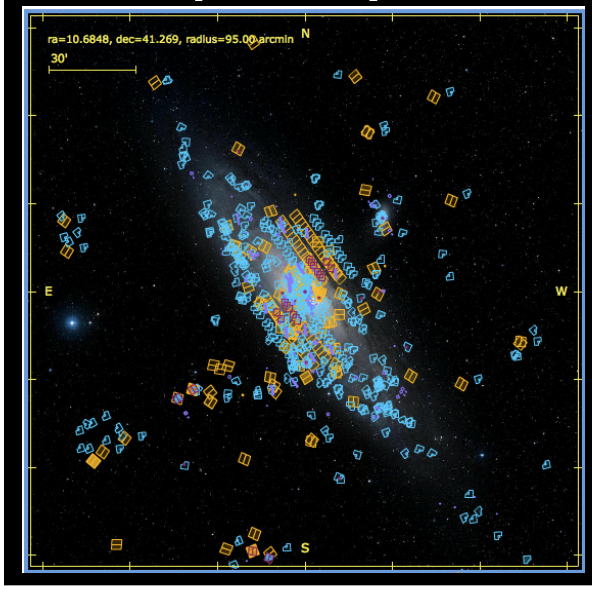
NO!

Which filters are not needed?




Which of these regions is "representative"?
250 orbits = 7 bricks

Resulting data set: *Infinitely* more versatile



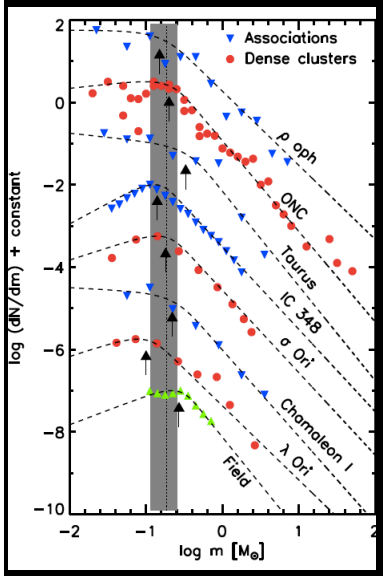
Hubble Legacy Archive, Pre-PHAT

Lots of orbits already invested, but limited use as a legacy!

“Would ~250 Orbits have been ok?”

Consider the Stellar Initial Mass Function....

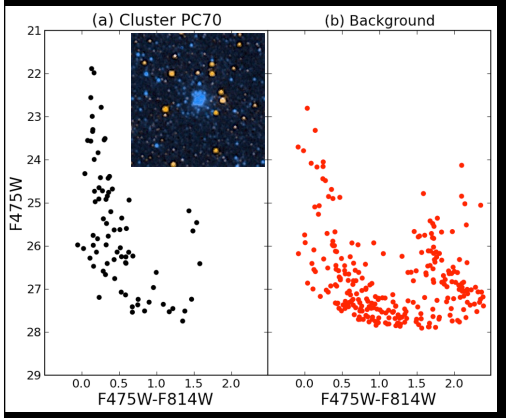
Traditional:

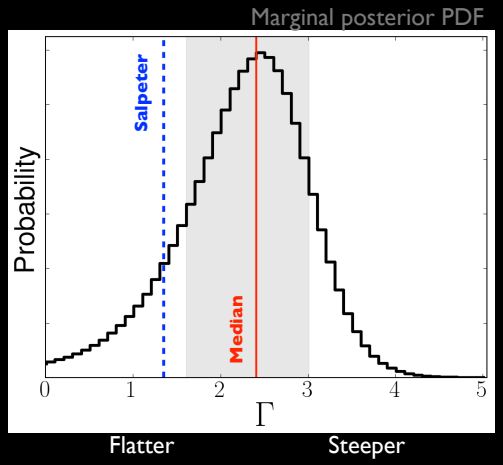


Bastian et al 2010

- Find a young cluster
- Convert luminosity to stellar mass
- Fit histogram to binned mass distribution

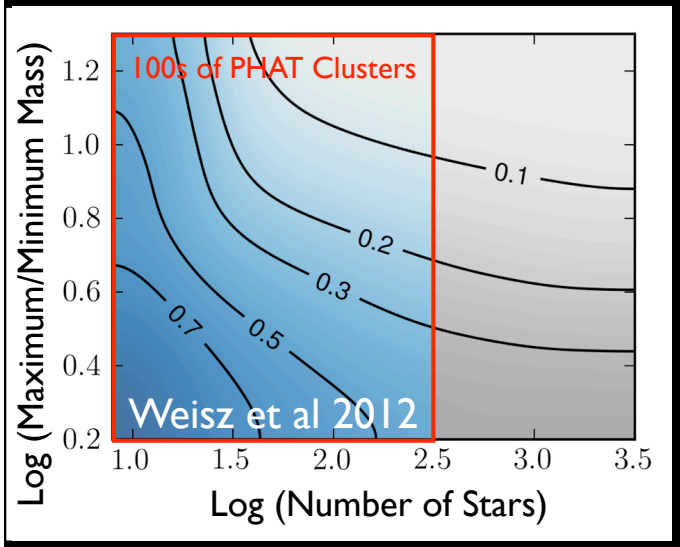
Initial Mass Function is uncertain for single clusters





Probabilistic fit the Age, Reddening, Mass and IMF of a cluster using SED fits to individual stars (Weisz+ *in prep*)

Power in Numbers

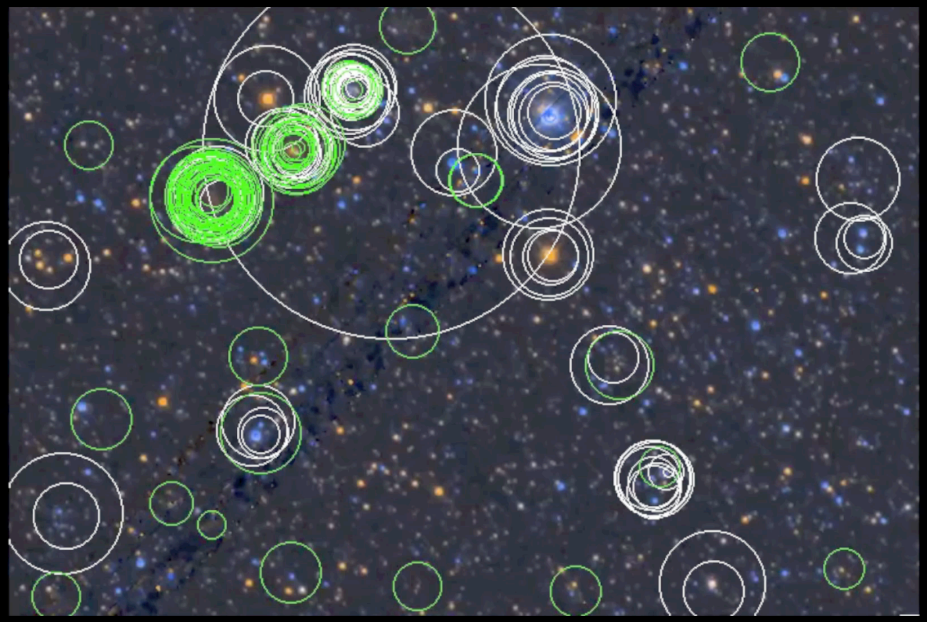


Contours: Precision on high mass slope of IMF

Either:

- Find rarest, richest, youngest clusters
- Jointly analyze 100's of clusters

“The Andromeda Project”: Citizen Science



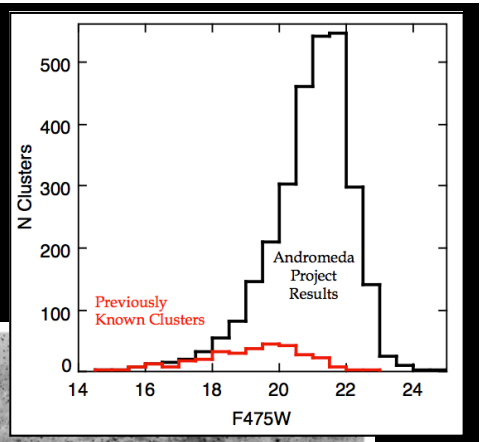
Video by Matt Wallace, white=clusters, green=galaxies

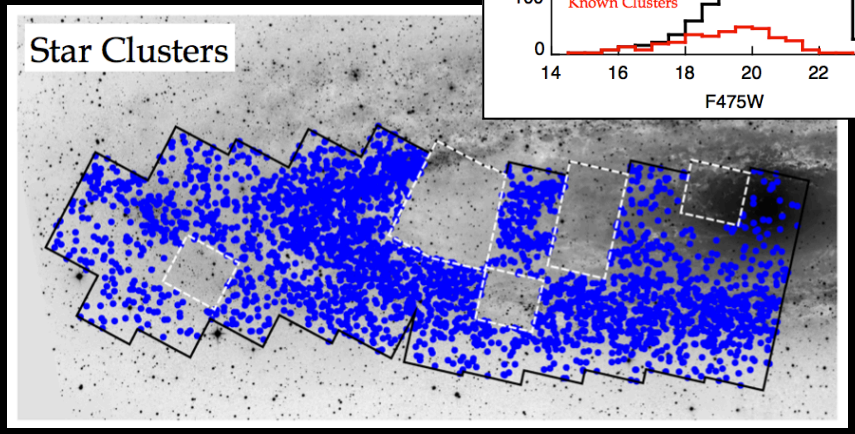
http://www.youtube.com/watch?v=w5VyYTO_vNk

~2,900 Star Clusters

294 Previously Known

Largest catalog of star clusters in *any* galaxy





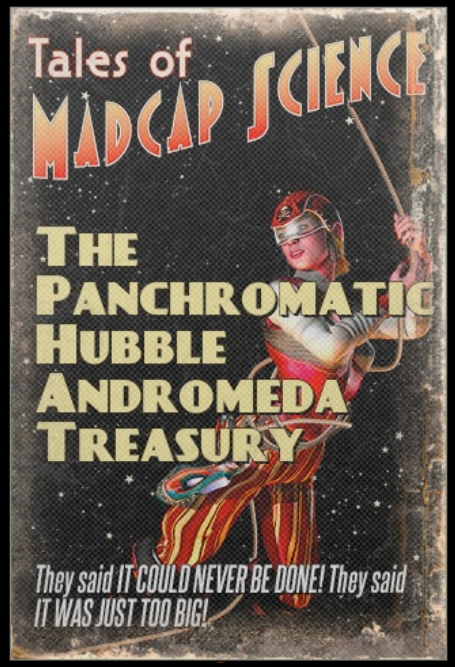
L. Cliff Johnson, Anil Seth et al 2012, 2014

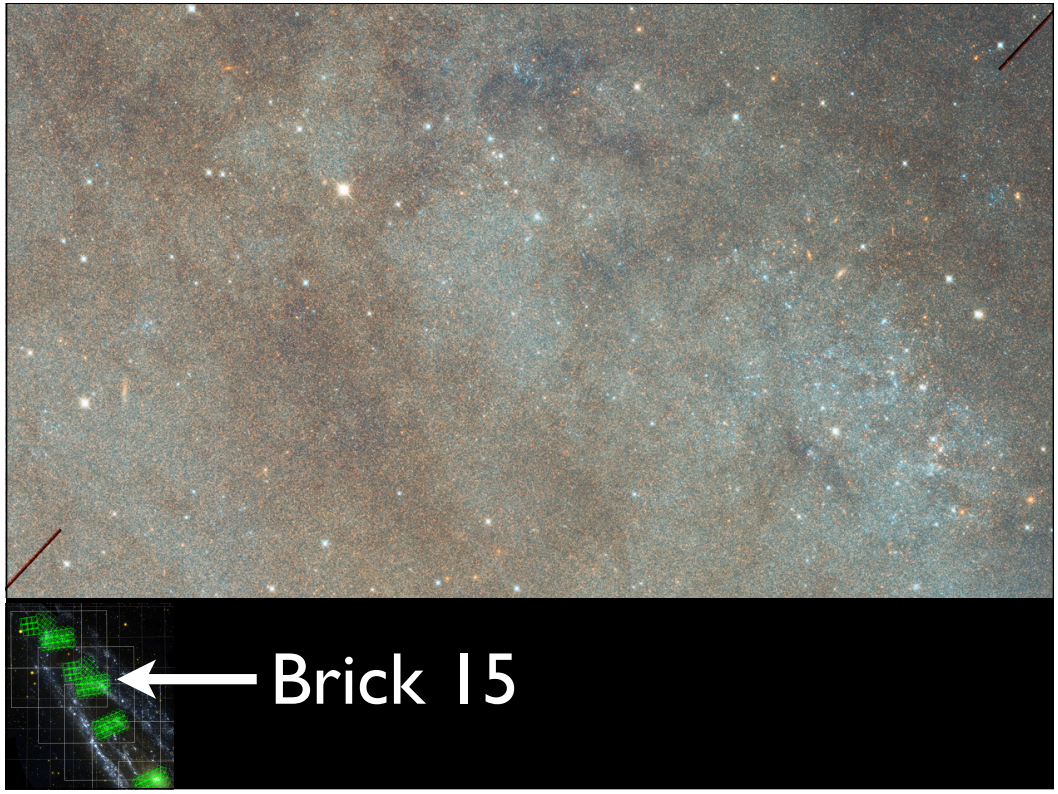
In summary

"Je ne regrette rien" -- E. Piaf

Still believe strongly in the long term legacy of this program

Huge thanks to the many people who have made it possible!




Brick 15