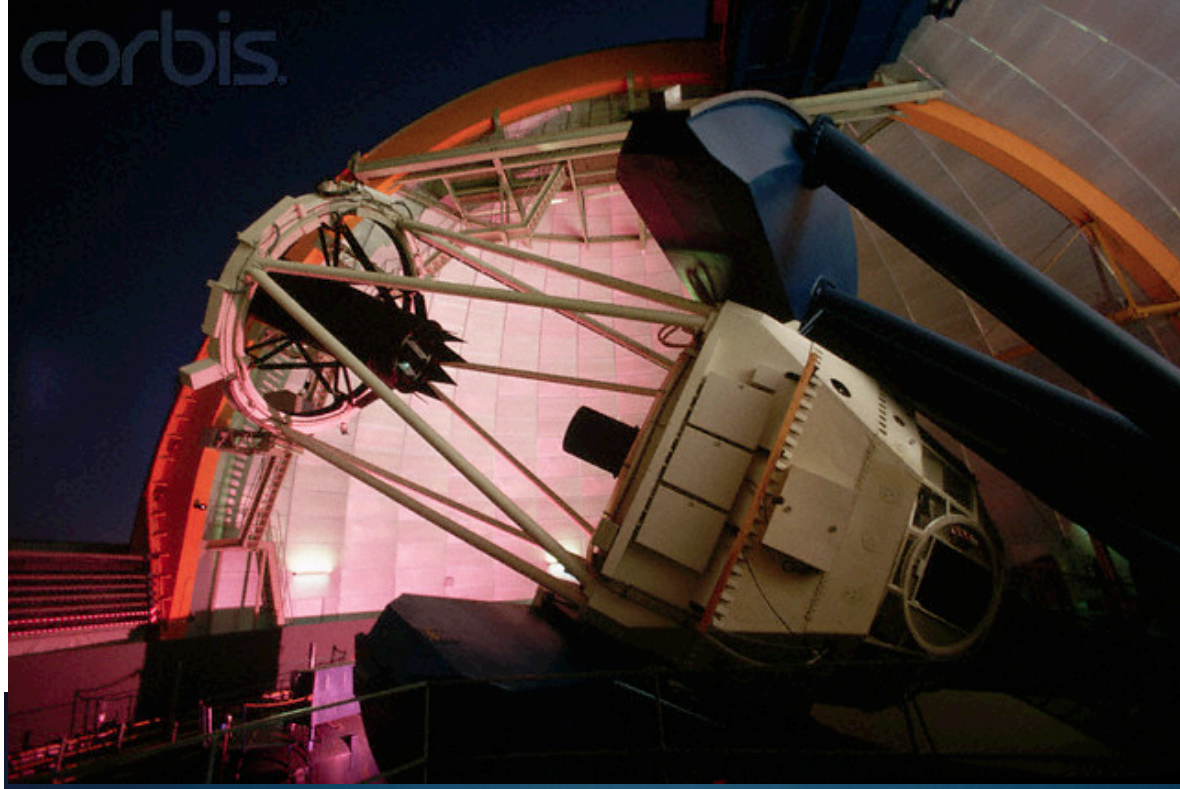
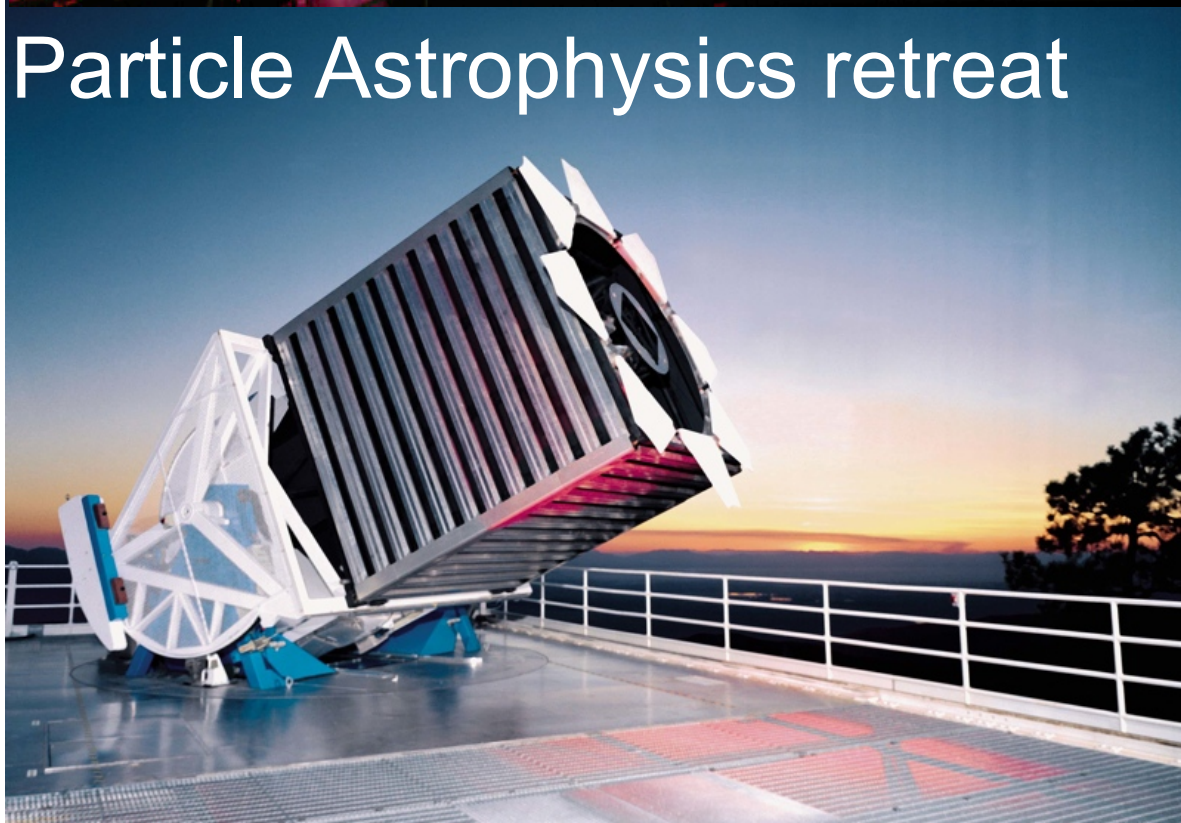
Cosmic Surveys

Rich Kron

17 April 2009

Fermilab Center for Particle Astrophysics retreat





outline:

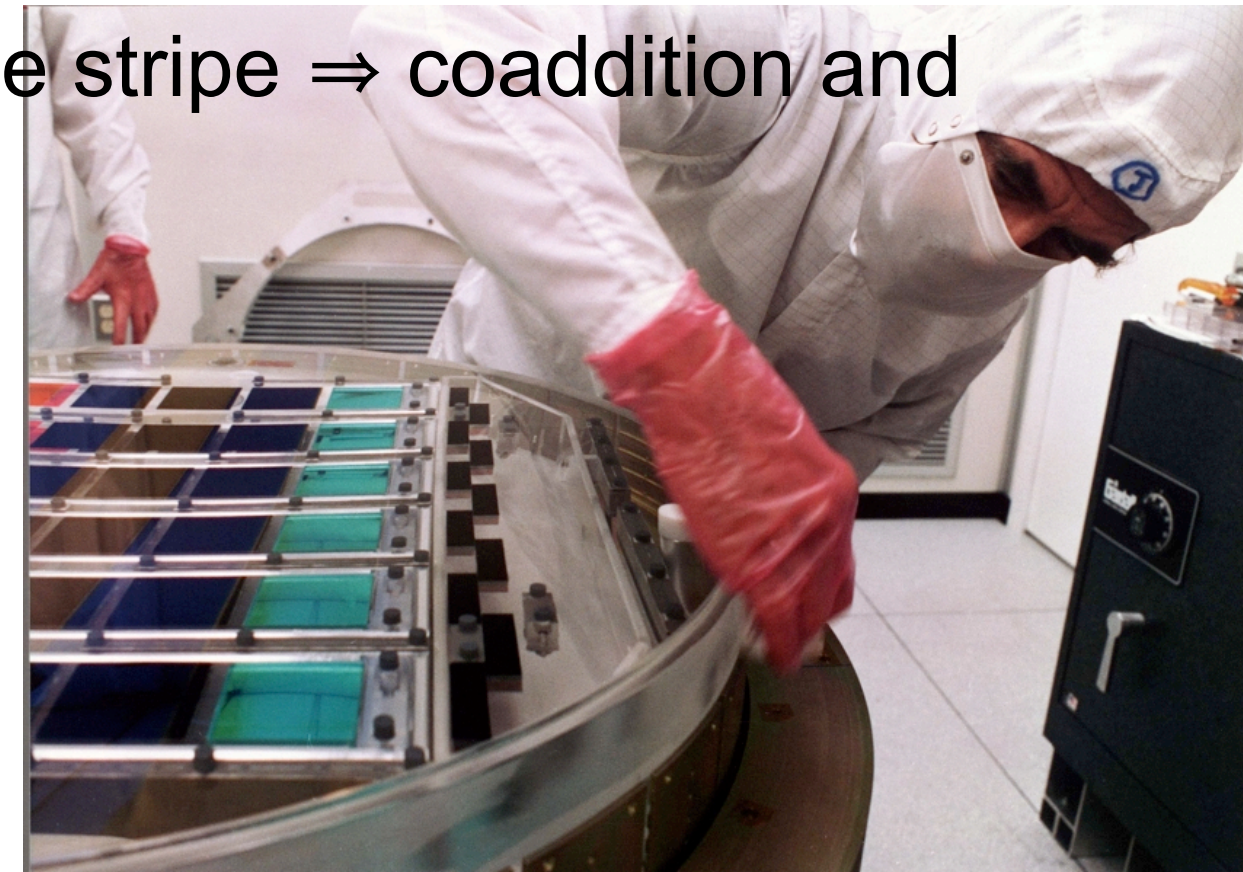
SDSS (I, II, & III)

DES

Original SDSS scientific goals: map large-scale structure using galaxies and quasars as tracers, both imaging and spectroscopy

in 5 years: π steradians, u g r i z, 10^6 galaxy redshifts, 10^5 quasar redshifts

multiple scans on one stripe ⇒ coaddition and variables



Madrid & Macchetto arXiv:0901.4552v1 analyzed the 200 most-cited papers published in 2006 and found that SDSS was “once again the telescope with the highest impact in astronomy.”

TABLE 1

HIGH-IMPACT OBSERVATORIES

Rank	Facility	Citations	Participation
1	SDSS	1892	14.3%
2	Swift	1523	11.5%
3	HST	1078	8.2%
4	ESO	813	6.1%
5	Keck	572	4.3%
6	CFHT	521	3.9%
7	Spitzer	469	3.5%
8	Chandra	381	2.9%
9	Boomerang	376	2.8%
10	HESS	297	2.2%

This high impact is due to several factors:

freely accessible database (dr7: arXiv 0812.0649)
processing and calibrations: science-ready data
uniform and high-quality data
large footprint on the sky
overlap with other major surveys (2MASS, GALEX)
data useful across many fields of astronomy

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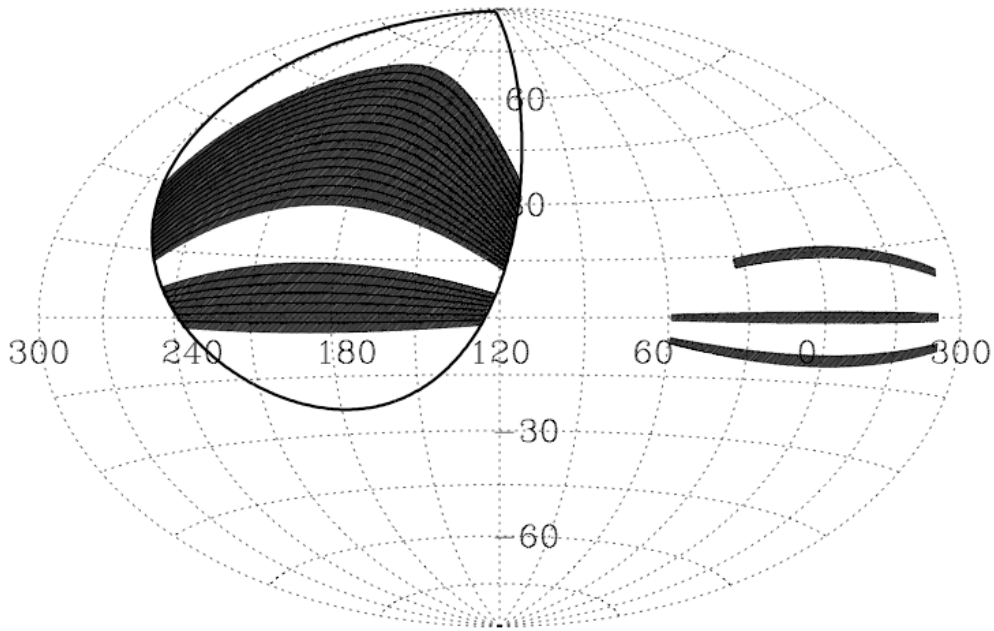
way the telescope is used
SDSS Collaboration as a scientific team

SDSS-II (2005 - 2008) extension survey: same instrumentation, same target-selection for Legacy, improvements to processing software for Legacy.



Legacy required 1/3 of the total time to “fill the gap.” The other 1/3 and 1/3 were for:

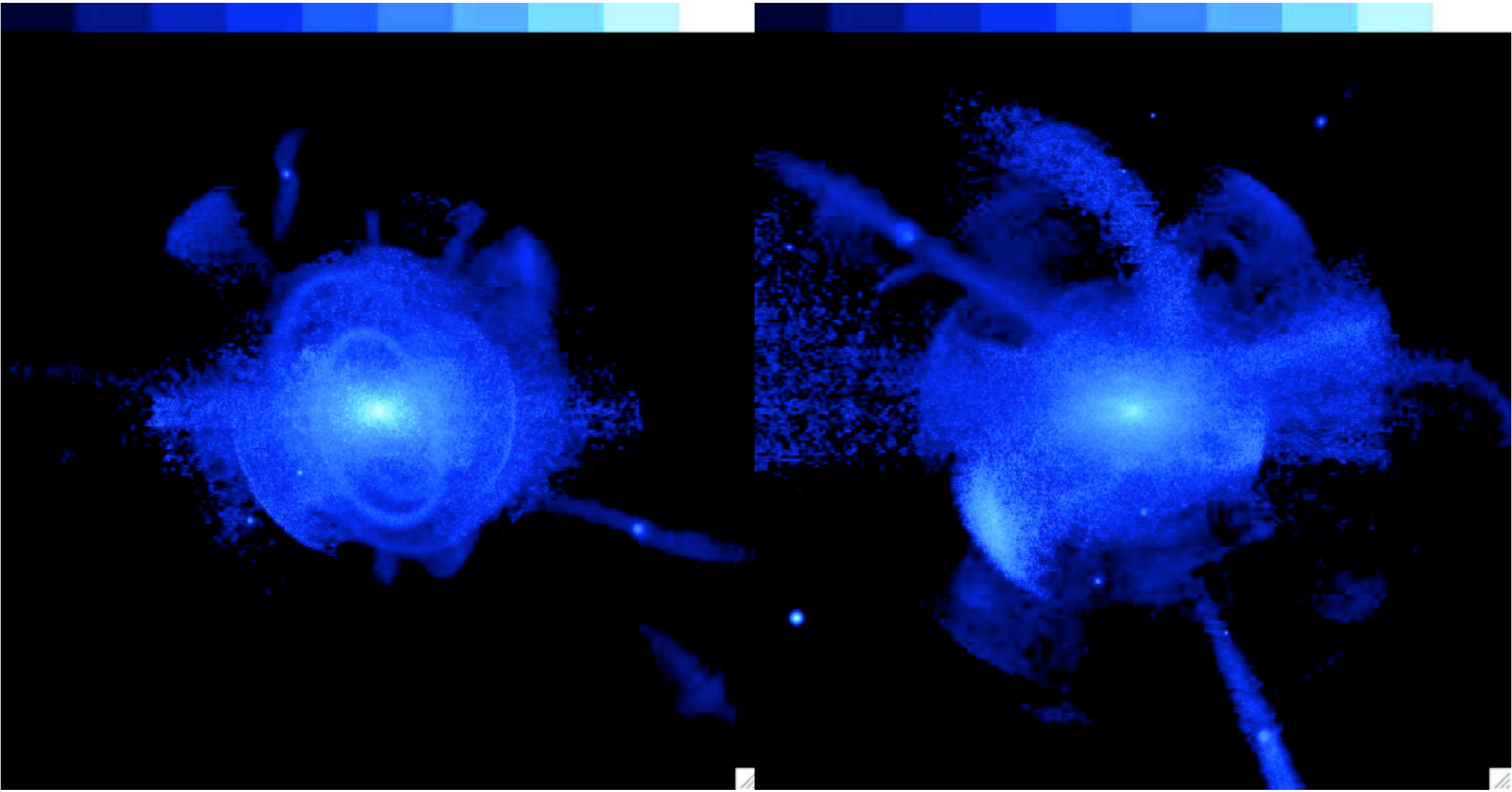
SEGUE (Sloan Extension for Galactic Understanding and Exploration):

Deliberate spectroscopic targeting of stars.

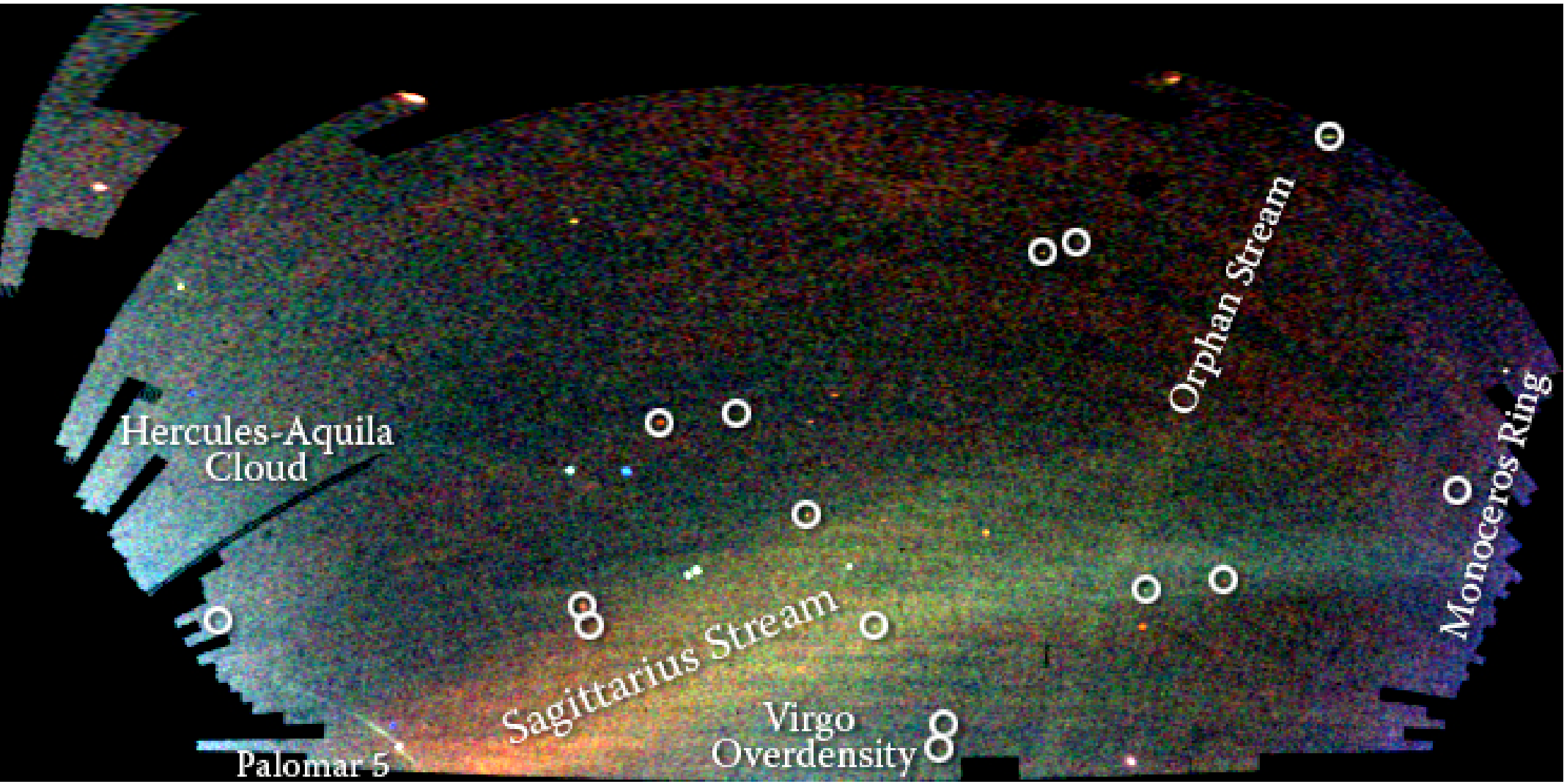
Development of new code for extraction of T_{eff}, log g, [Fe/H], and higher-precision radial velocities (5 km sec^{-1} for brighter stars).

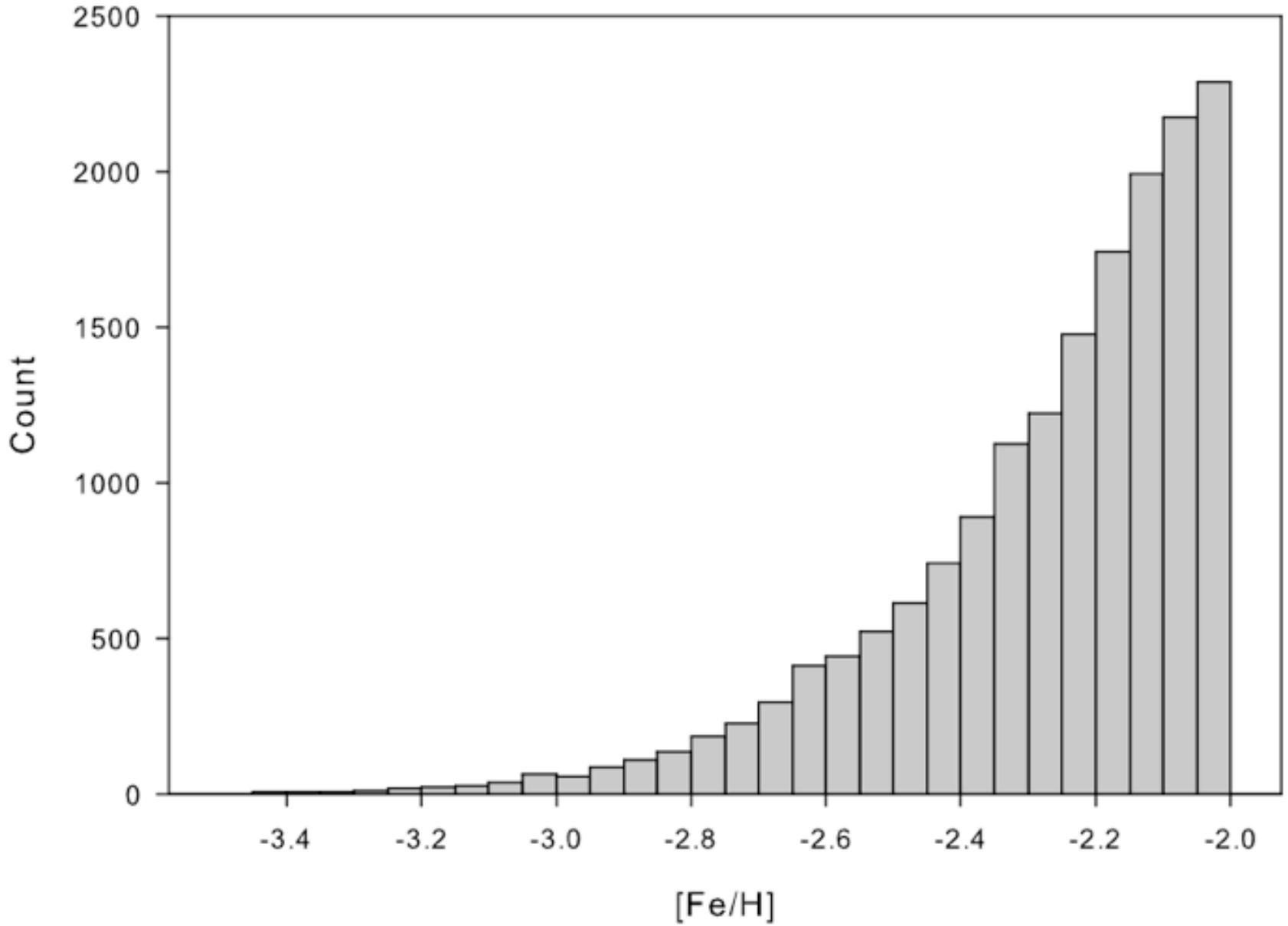
New code for stellar photometry in crowded fields.

237,000 stellar spectra, 3500 deg^2 new imaging

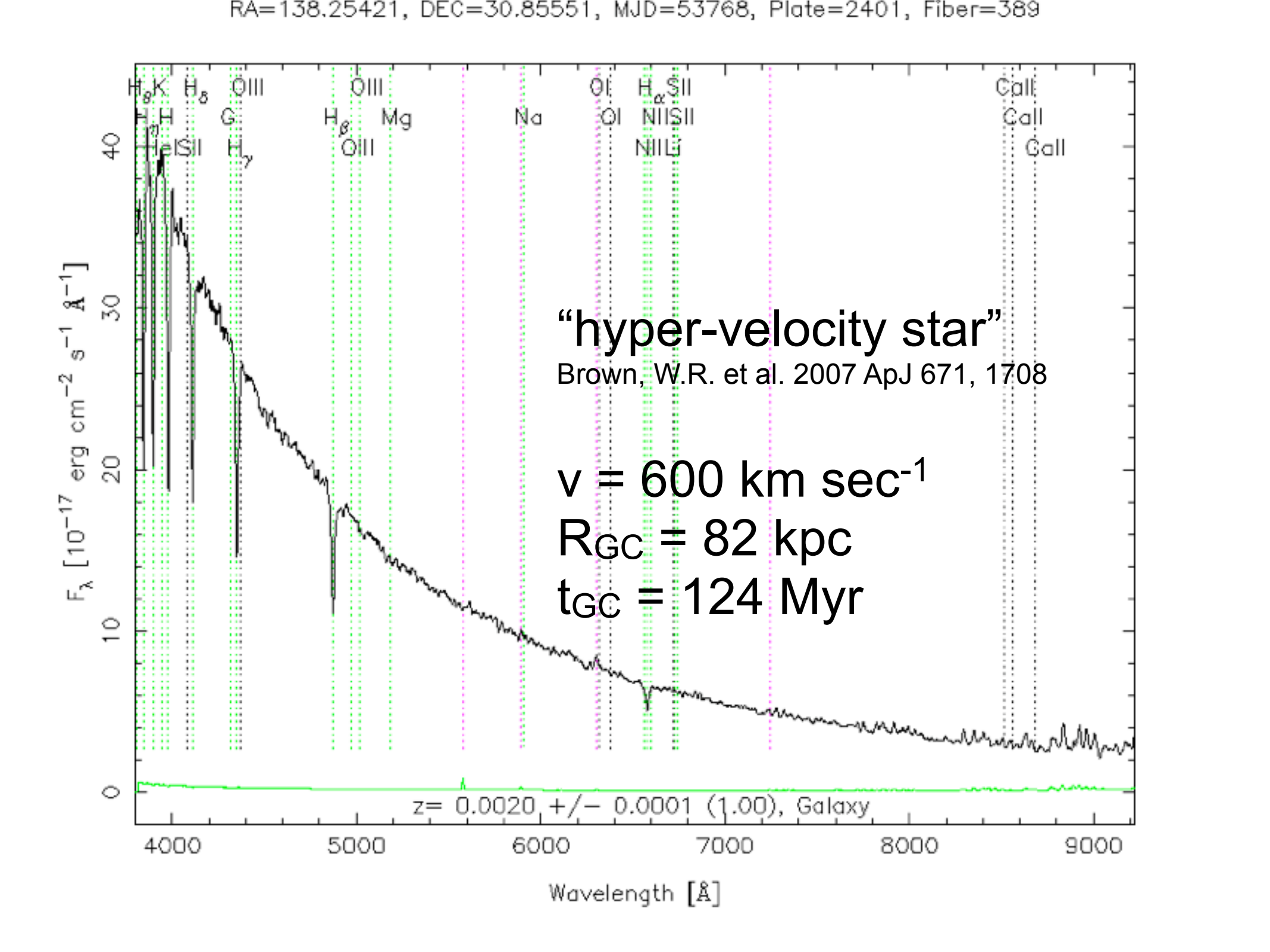


Bullock, J. & Johnston, K. 2005 ApJ 635, 931


Hercules-Aquila
Cloud
Orphan Stream
Monoceros Ring
Sagittarius Stream
Virgo
Overdensity
Palomar 5



Metallicity Distribution Function of over 16000 F-G-K stars from SDSS/SEGUE

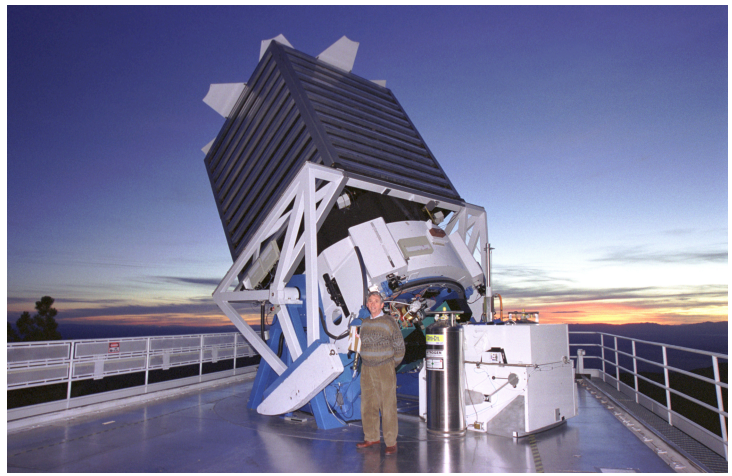

RA=138.25421, DEC=30.85551, MJD=53768, Plate=2401, Fiber=389
"hyper-velocity star"
Brown, W.R. et al. 2007 ApJ 671, 1708
v = 600 km sec-1
RGC = 82 kpc
tGC = 124 Myr
z= 0.0020 +/- 0.0001 (1.00), Galaxy
Wavelength [Å]
Fλ [10-17 erg cm-2 s-1 Å-1]

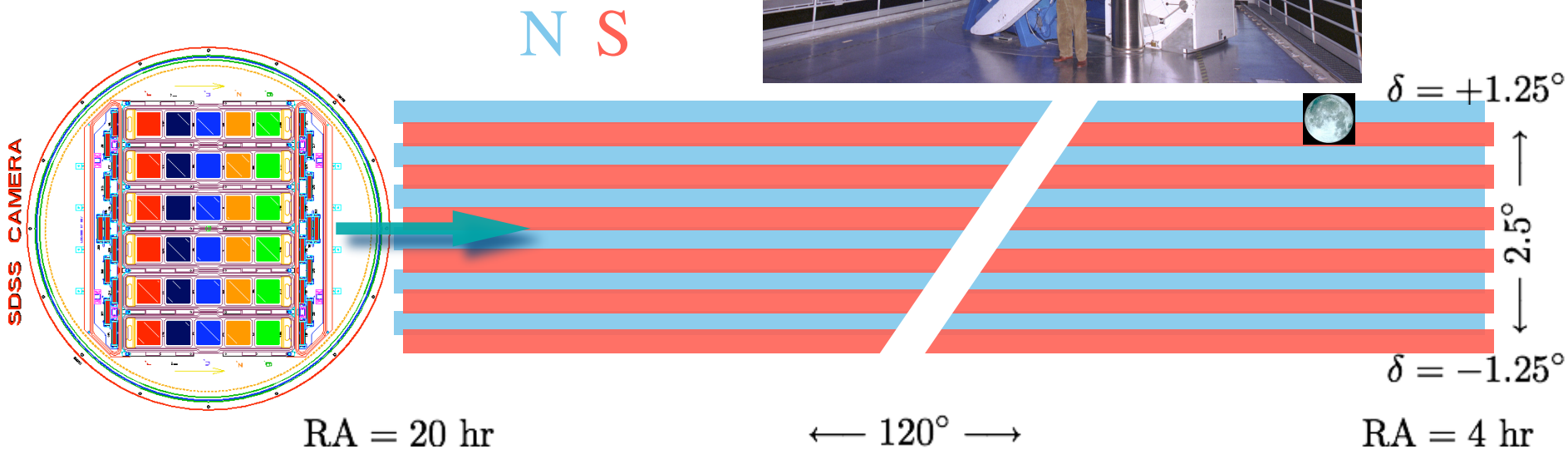
Supernova: light curves for Type Ia supernovae with $0.05 < z < 0.35$. This redshift range is natural for SDSS capabilities and complements other surveys.

Spectroscopic follow-up (to confirm type and to obtain redshifts) requires other telescopes.

Development of on-the-mountain processing for rapid identification of candidates; code development for precision photometry.

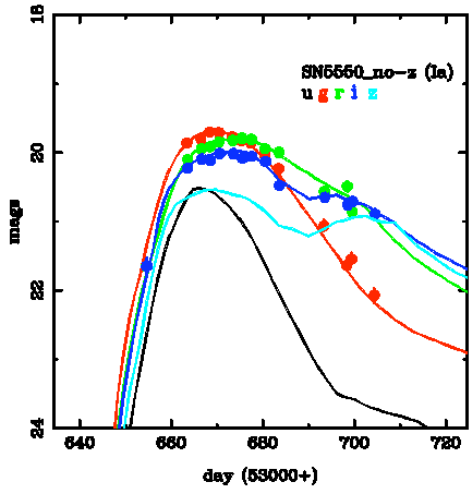
SNe Survey





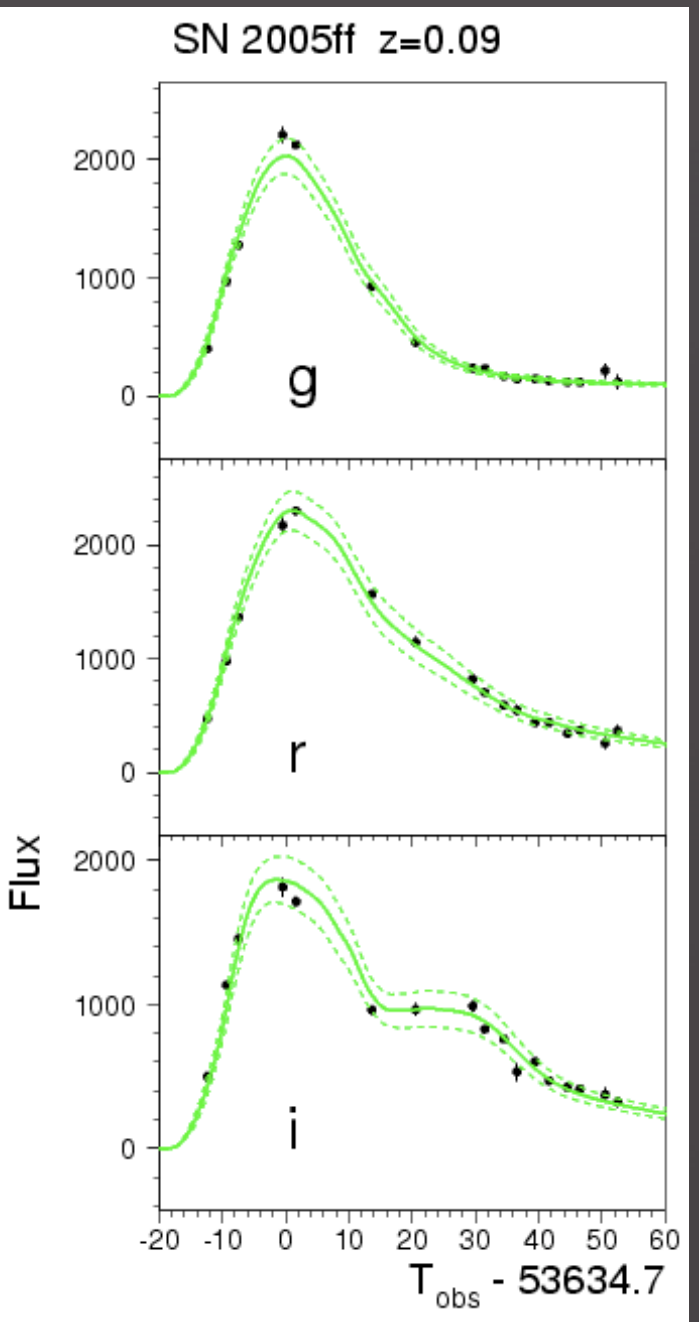
Use the SDSS 2.5m telescope

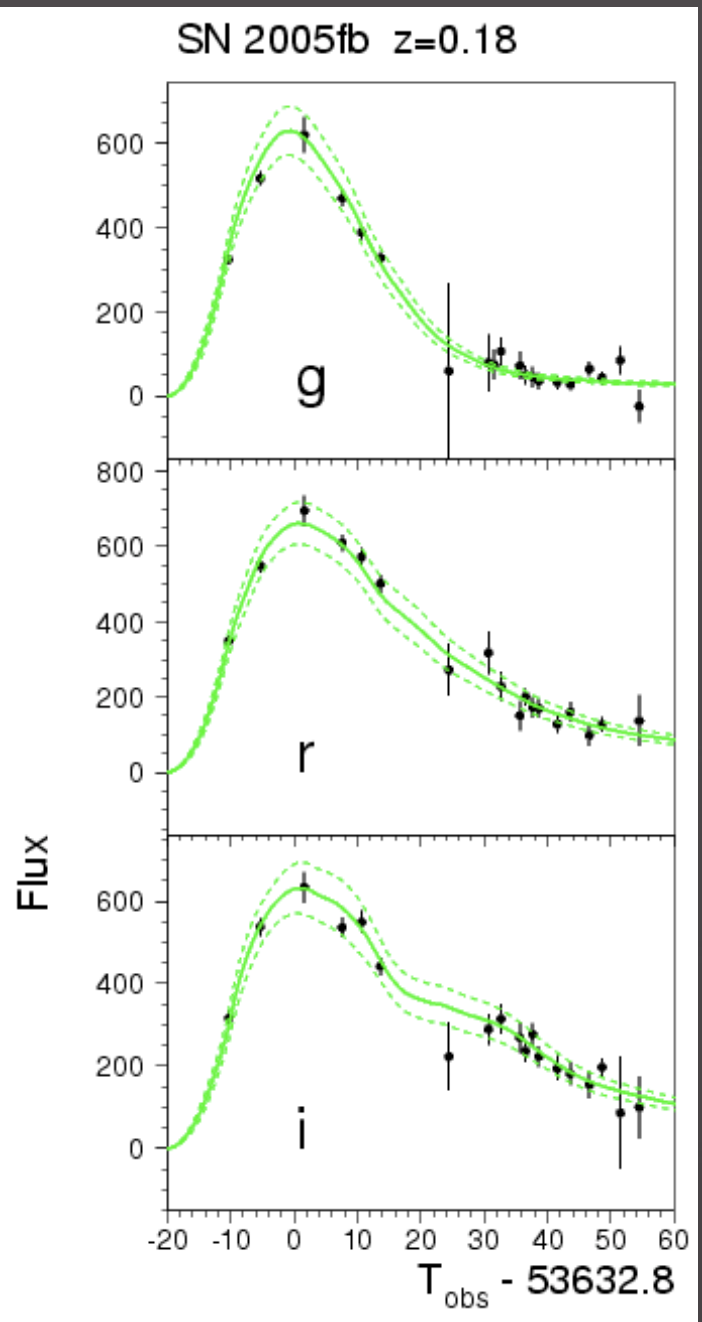
- September 1 - November 30 of 2005-2007
- Scan 300 square degrees every 2 days
- Obtain multi-color light curves
- >90% efficiency after ~2 - 4 epochs

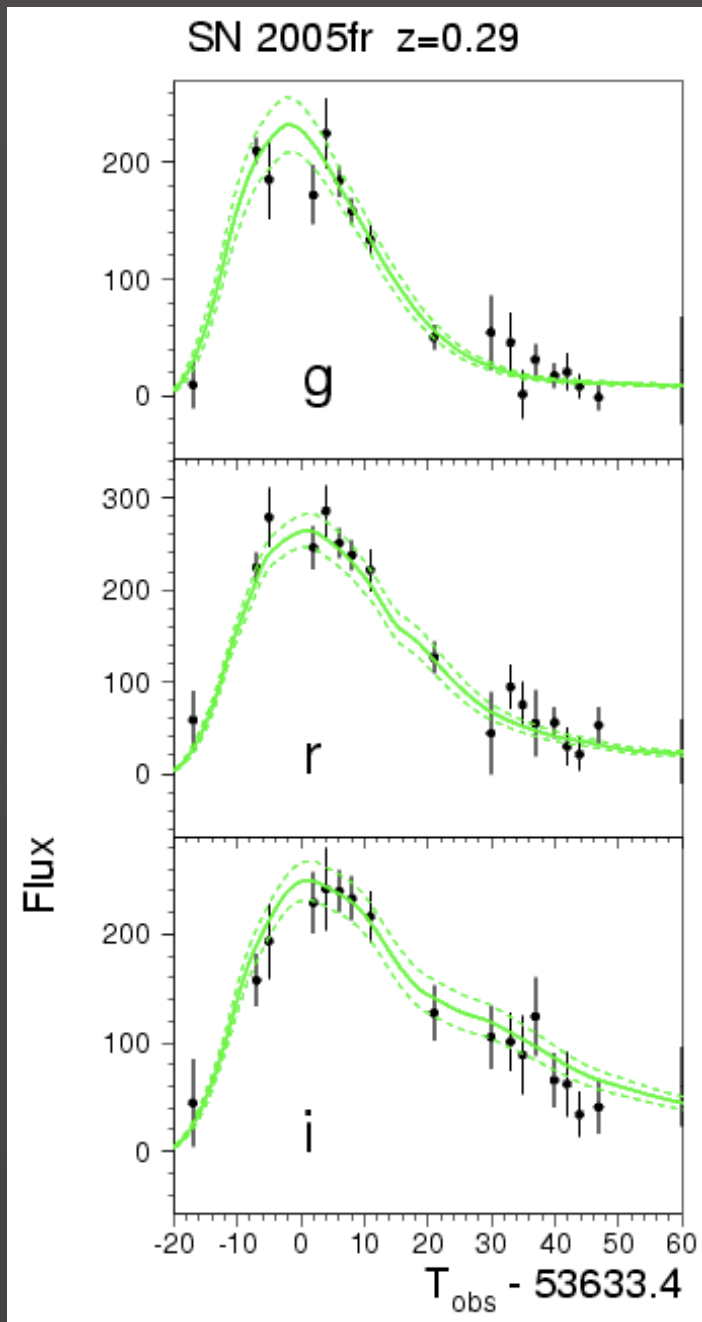


SDSS SN Photometry

Holtzman etal (2008)



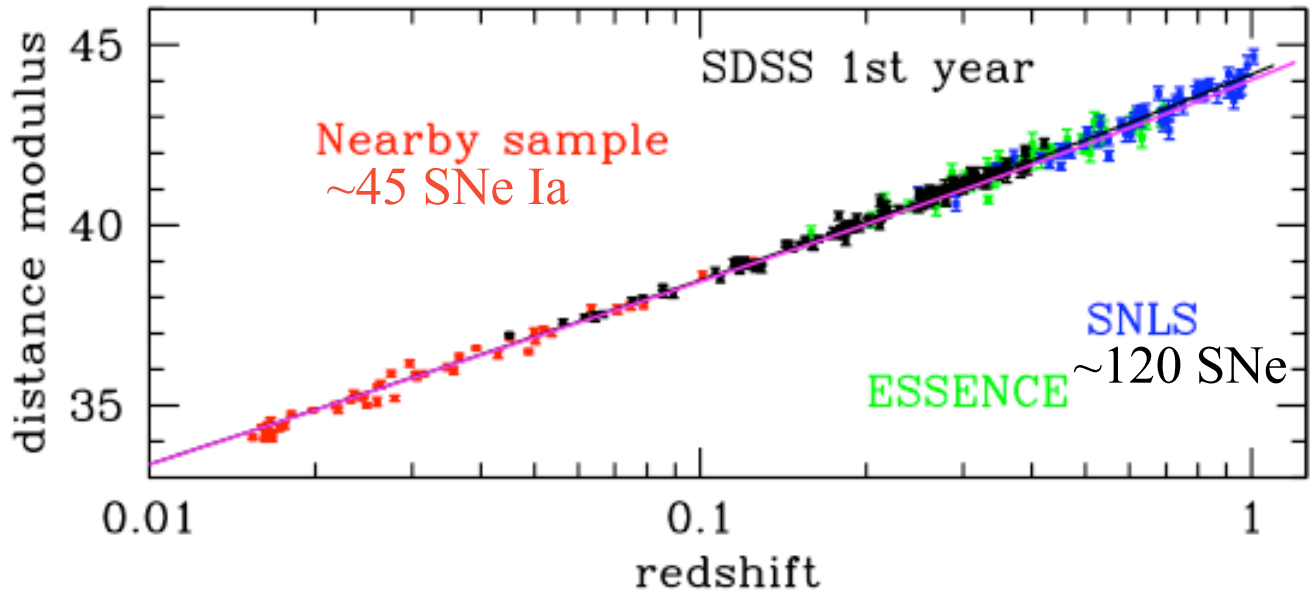


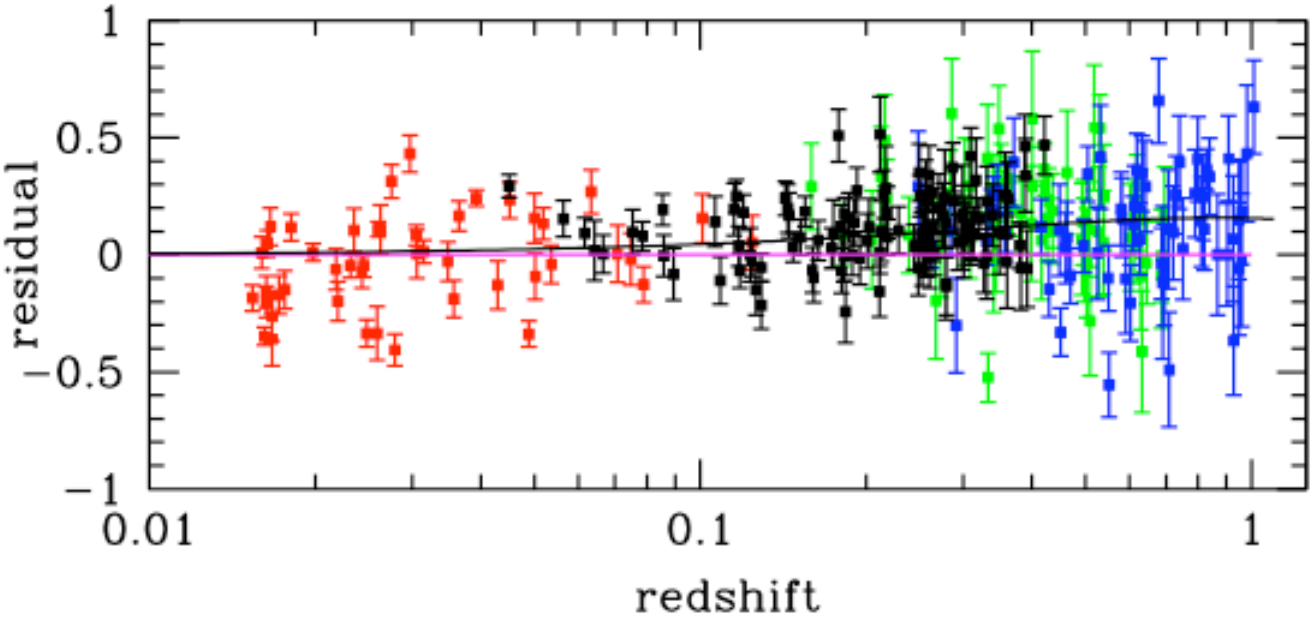


Hubble Diagram with SDSS SNe

103 SNe Ia from first season

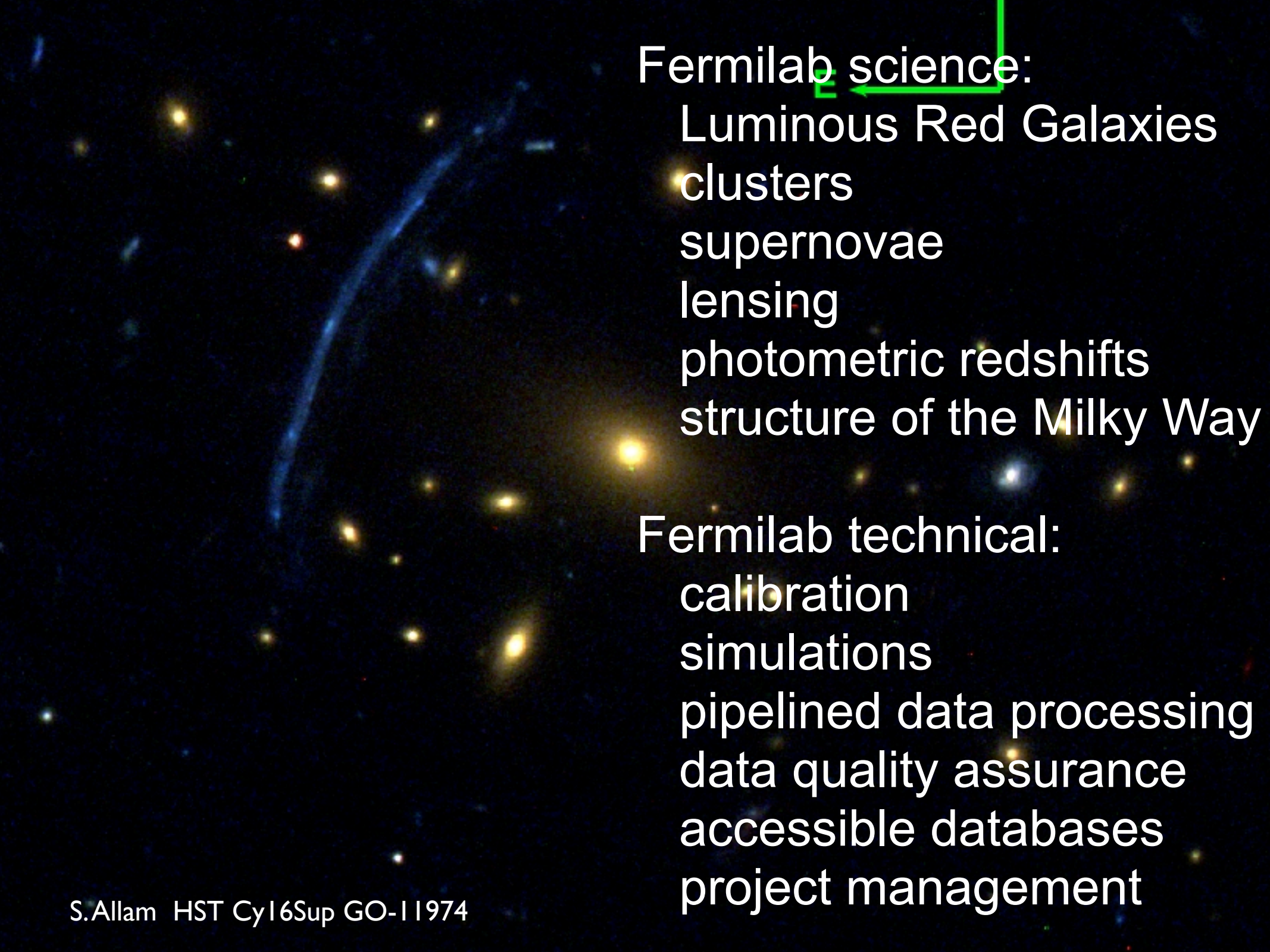
Kessler etal (2009)
Lampeitl etal (2009)
Sollerman etal (2009)





SDSS-II had 25 institutional partners, including:

Fermi National Accelerator Laboratory
Los Alamos National Laboratory
Joint Institute for Nuclear Astrophysics
Kavli Institute for Particle Astrophys & Cosmology



Fermilab science:

- Luminous Red Galaxies
- clusters
- supernovae
- lensing
- photometric redshifts
- structure of the Milky Way

Fermilab technical:

- calibration
- simulations
- pipelined data processing
- data quality assurance
- accessible databases
- project management

S. Allam HST Cy16Sup GO-11974

SDSS-III: baryon acoustic oscillations discovered in SDSS spectroscopic data: error in length scale from 2005 data ~ 4% at z = 0.35.

Can get 7x SDSS volume with a new survey with upgraded hardware (smaller fibers, more fibers, and extended red sensitivity). 1.5×10^6 galaxies, 1% error on length scale at z = 0.6.

Also look for BAO in Lyman α forest using a denser network of quasars enabled by better blue CCD's. 160,000 quasars, 1.5% error on length scale at z = 2.2.

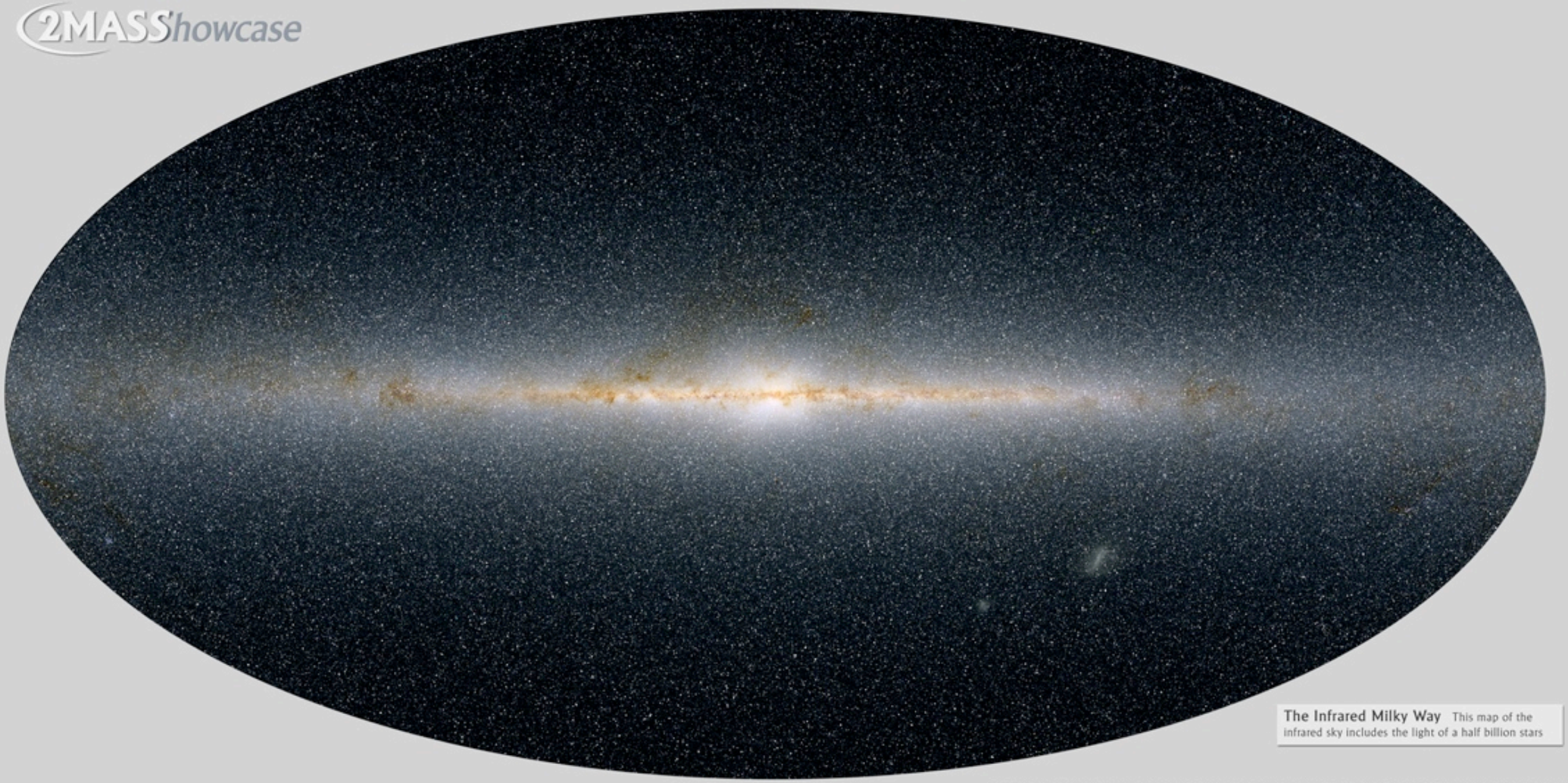
Bright time can be well used with a new bench-mounted spectrograph (APOGEE).

300 fibers
H band
R = 22,000

100,000 stars (e.g. K giants selected via 2MASS photometry)

science is to establish abundance patterns & kinematics across the disk of the Milky Way

2MASS showcase



The Infrared Milky Way This map of the infrared sky includes the light of a half billion stars

Two Micron All Sky Survey Image Mosaic: Infrared Processing and Analysis Center/Caltech & University of Massachusetts

6-year survey, observations starting September 2008. Operations proposal to DoE positively reviewed but allocation still not known; partner contributions (29+) higher than projected.

While instrument upgrades are in process, continue with more imaging of the Southern Galactic Cap, plus SEGUE-2.

MOU with Fermilab enables four scientists to participate (in addition to JP and RK) in science analysis. This gives Fermilab some access to spectroscopy of LRG's and quasars.

The Dark Energy Survey

- Study Dark Energy using

  4 complementary* techniques:

  I. Cluster Counts

  II. Weak Lensing

  III. Baryon Acoustic Oscillations

  IV. Supernovae

- Two multiband surveys:

  5000 deg^2 *g, r, i, z,Y*

  smaller area repeat (SNe)

- Build new 3 deg^2 camera

  and Data management sytem

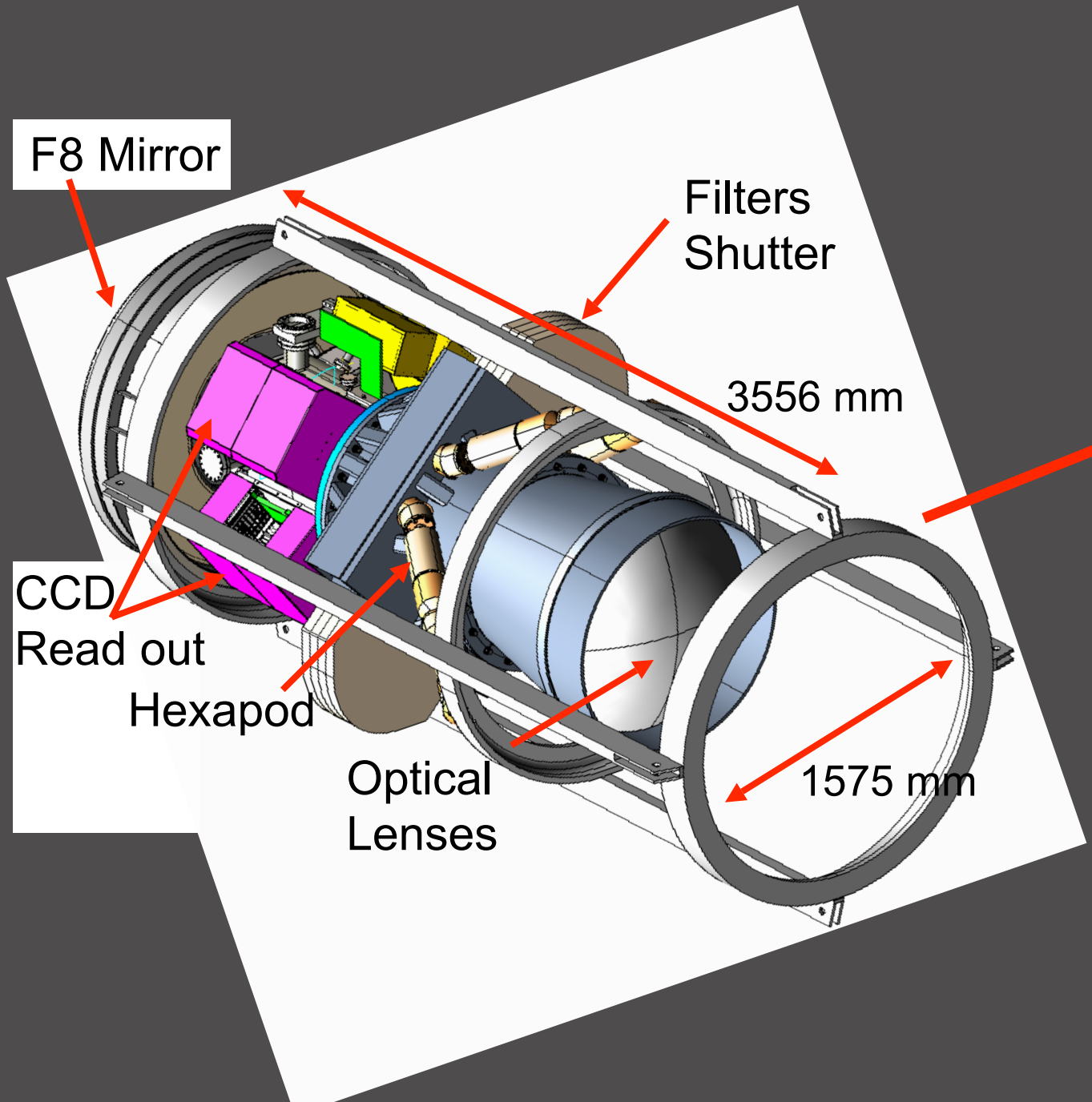
  Survey 2011-2016 (525 nights)

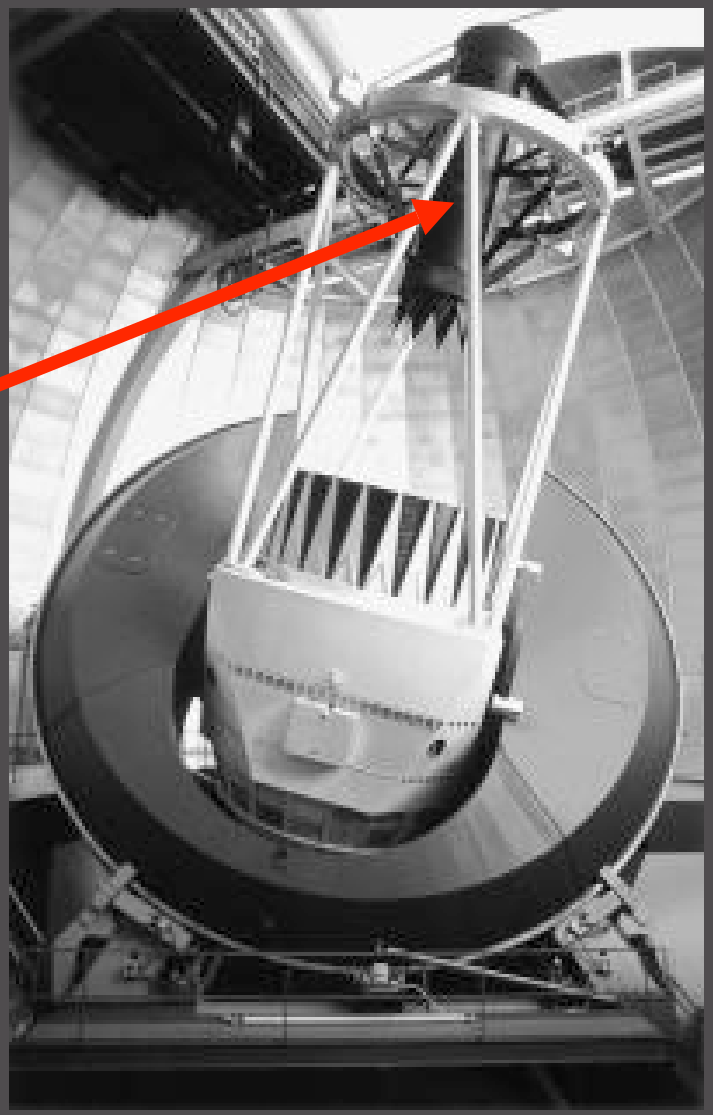
Blanco 4-meter at CTIO

*in systematics & in cosmological parameter degeneracies

*geometric+structure growth: test Dark Energy vs. Gravity

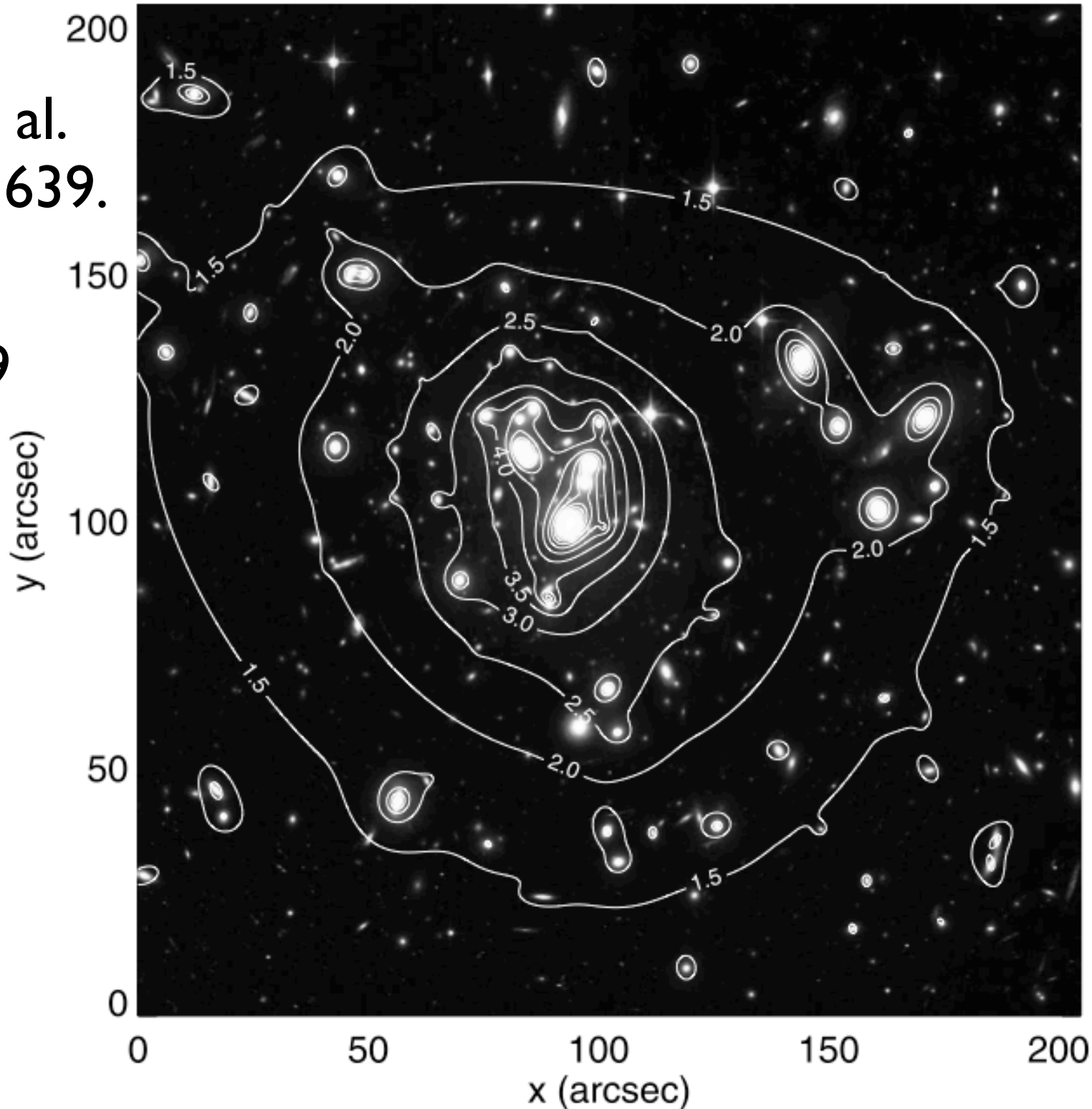
DECam

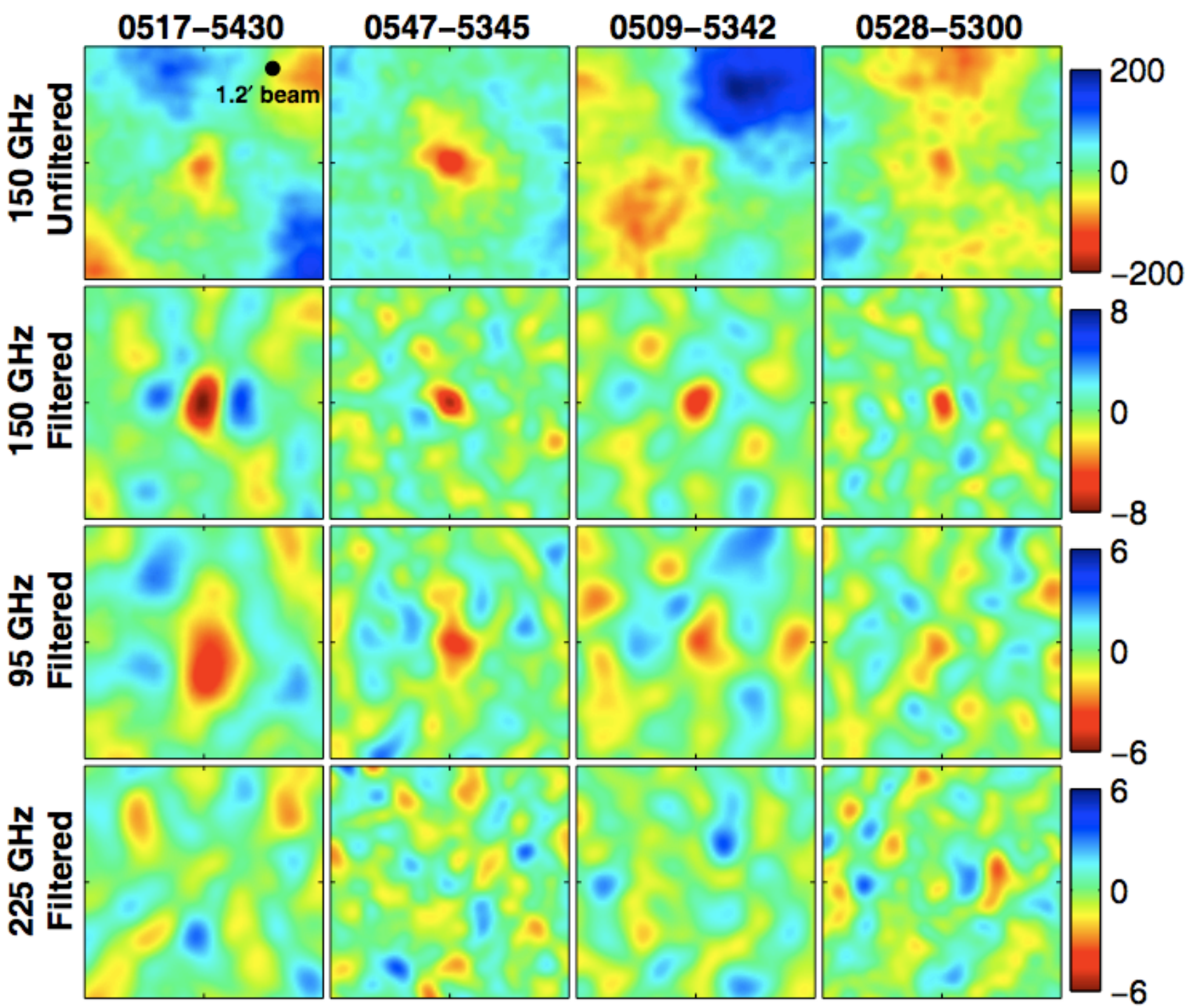

F8 Mirror
Filters
Shutter
3556 mm
CCD
Read out
Hexapod
Optical
Lenses
1575 mm



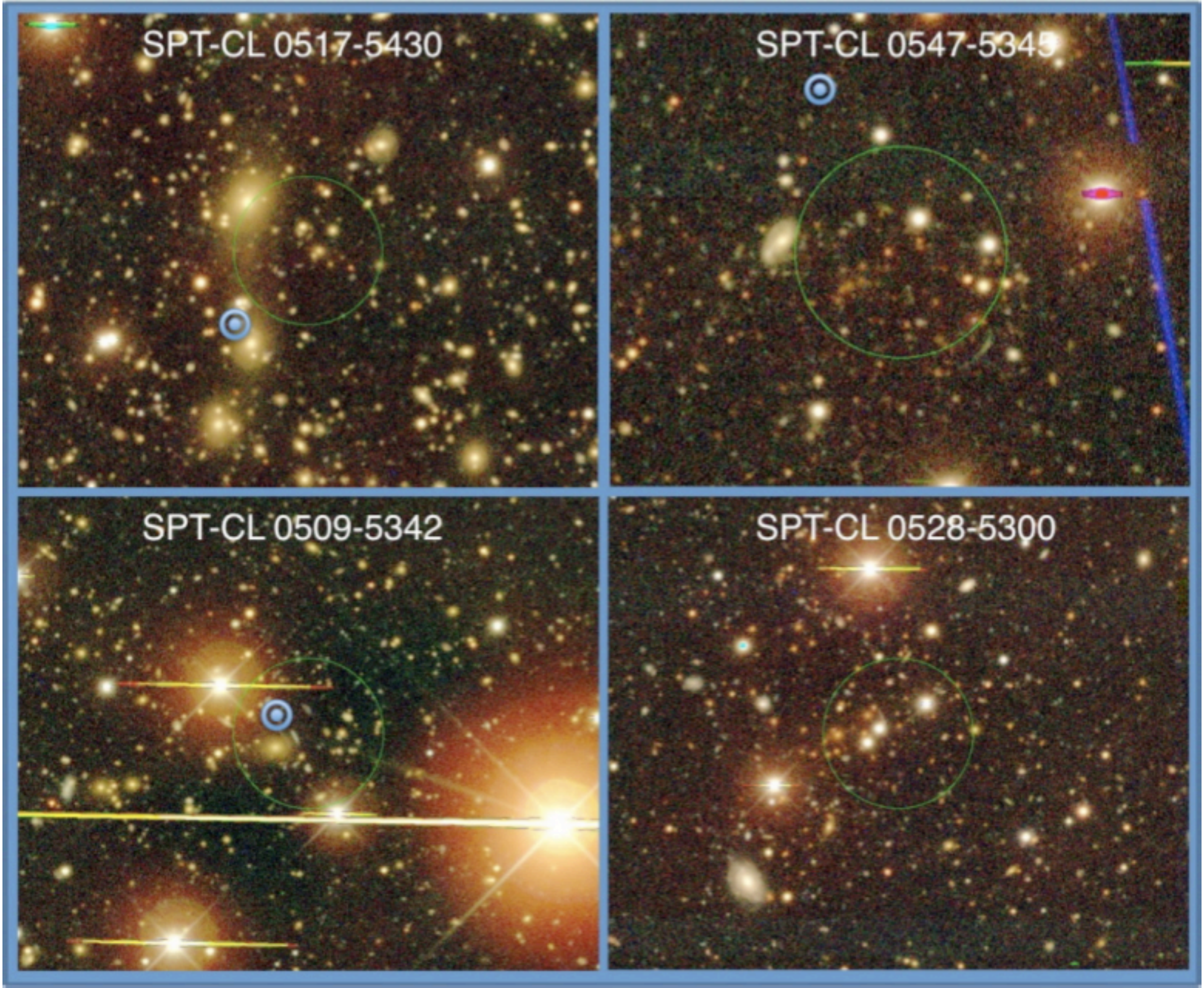
Zekser, K. et al.
2006 ApJ 640, 639.

Abell 1689





Staniszewski, Z. et al. arXiv 0810.1578v1


SPT-CL 0517-5430
SPT-CL 0547-5345
SPT-CL 0509-5342
SPT-CL 0528-5300

Fermilab is the host institution for the project.

DECam: CD3a/b approval October 2008

outcomes are:

1) the science from the data

2) a facility instrument, with data processing pipeline, available for public use

A collaboration perspective of The DES Organization

DARK ENERGY SURVEY

Dark Energy Survey Projects

The Council
P. Oddone, FNAL
T. Dunning, NCSA
D. Silva, NOAO

DES Project
J. Peoples, Director
Management Committee
J. Annis, DES Scientist
D. Tucker, Calibration Scientist
D. Finley, Designated Hitter

DECam
B. Flaugher, PM
D. DePoy, PS
T. Abbott, W. Merritt, DPMs

CFIP
A. Walker, CTIO director
T. Abbott, PM

DES-DM Project
J. Mohr, PL
C. Beldica PM

Science Committee
J. Frieman
O. Lahav

Fermilab
UIUC/NCSA
The University of Chicago
Lawrence Berkeley National Laboratory
The National Optical Astronomy Observatory
Spain DES Collaboration
United Kingdom DES Collaboration
The University of Michigan
DES-Brazil Consortium
The University of Pennsylvania
Argonne National Laboratory
Ohio State University
Santa Cruz-SLAC-Stanford DES Consortium

Fermilab also has significant involvement on the science side. Science Committee chaired by J. Frieman and O. Lahav.

Working Groups:

Large-Scale Structure (E. Gaztanaga, W. Percival)
Clusters (T. McKay, J. Mohr)
Supernovae (J. Marriner, R. Nichol)
Weak Lensing (B. Jain, S. Bridle)
Simulations (A. Evrard, A. Kravtsov)
Photo-z's (H. Lin, F. Castander)

Study Groups:

Theory/Combined Methods (W. Hu, J. Weller)

Strong Lensing (L. Buckley, M. Makler)

Quasars (R. McMahon, P. Martini)

Galaxy Evolution (R. Wechsler, D. Thomas)

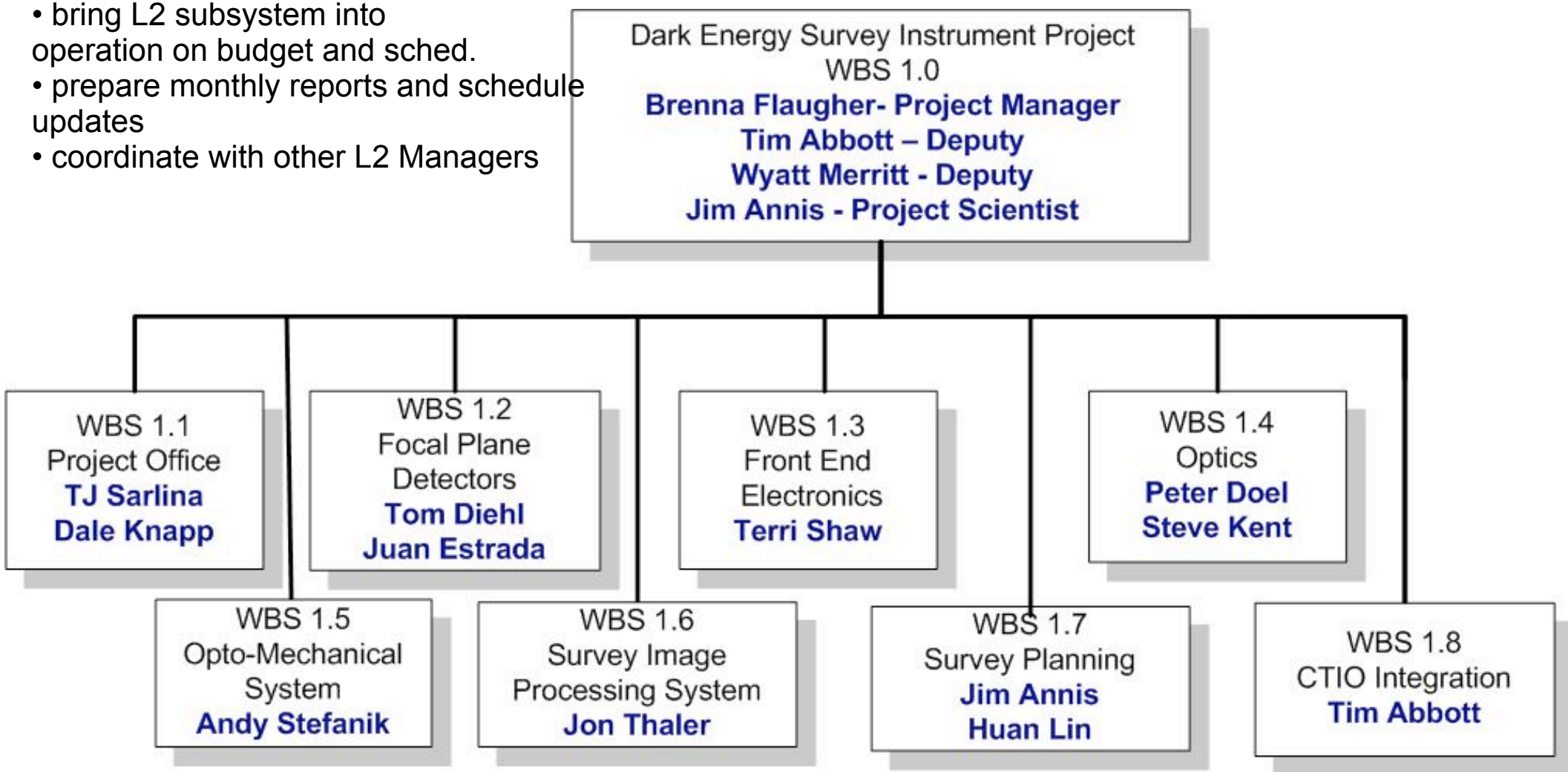
Milky Way Structure (B. Yanny, B. Santiago)

DECam Work Breakdown Structure

DARK ENERGY SURVEY

Level 2 Managers:

- bring L2 subsystem into operation on budget and sched.
- prepare monthly reports and schedule updates
- coordinate with other L2 Managers



SDSS and DES imaging comparison

pixel size	0.40 arcsec	0.27 arcsec
solid angle	1.55 deg^2	3.0 deg^2
aperture	2.5 meters	4.0 meters
PSF	1.4 arcsec	0.8 arcsec
exposure	54 seconds	320 seconds
point-source detection	$f_{lim} = 1$	$f_{lim} \sim 1/7$, or 2 mag

in addition, DES has much more sensitive z band, plus the Y band (but no u band)

conclusions:

SDSS and DES have established a track record for FNAL leadership in building and conducting cosmic surveys (science and technical).

We have experience in building data processing, database, and archive systems; building a working multi-institutional scientific collaboration; and building a focal plane.

We have developed internal scientific expertise in key areas related to cosmology, and can help catalyze broader participation to advance the field.

Connecting surveys is natural, e.g. DES + VISTA + SPT + SkyMapper.

All of this means we are well placed for the next survey!