ALFALFA 2005: Results and Plan

Martha Haynes, Cornell University
2005 ALFALFA Undergraduate Workshop

We already have 1 TB of data, and will start again in August to undertake the Fall A2010 program!

- Observing at Arecibo* and remotely
- Data reduction and analysis
- Correlative studies with other databases, e.g., SDSS
- Followup observations with other telescopes
- Modeling/simulation of interactions, processes

* A lot more fun; especially recommended in winter

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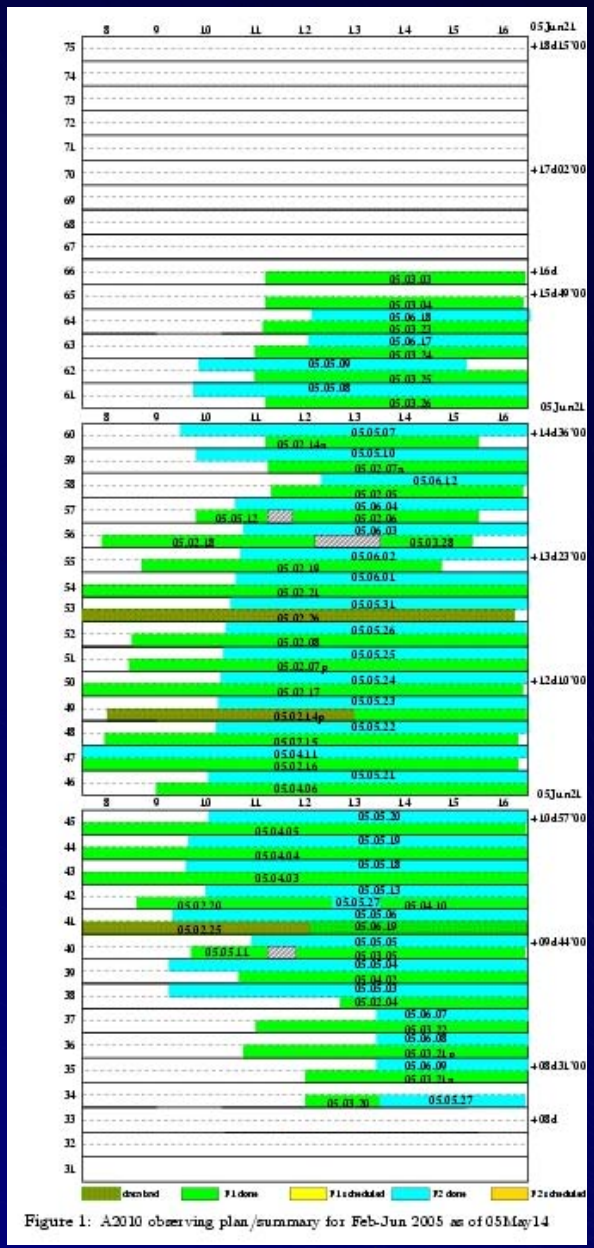

Figure 1: A2010 observing plan/summary for Feb-Jun 2005 as of 05May14

Status

- Started 1st pass Feb 4
- Started 2nd pass Apr 11
- Allocation ended Jun 12
  (Have picked up 4 more slots on short notice due to cancellation of other programs)
- Coverage incomplete in RA
- Almost complete in Decl.
- Except for hardware failures, 97% of assigned time is used for science

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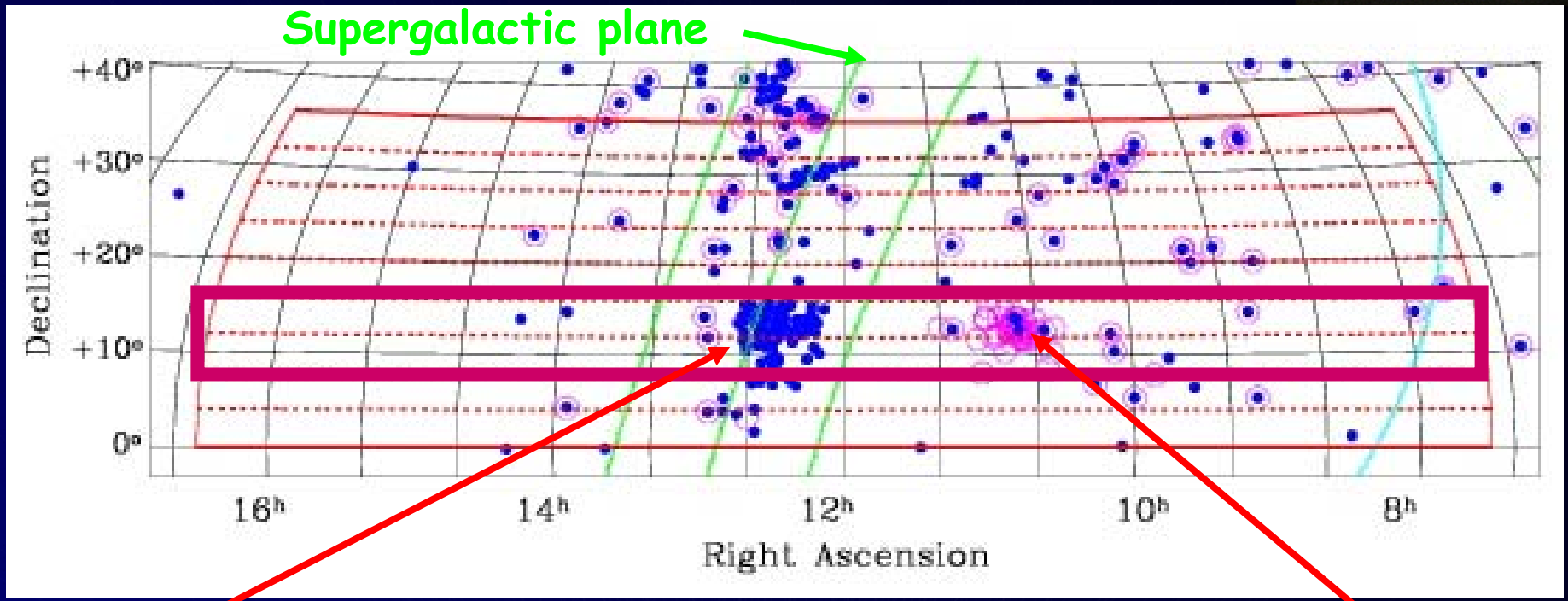
ALFALFA: Spring Sky



Virgo cluster
D=16.7 Mpc

2005: Tiles at +10° and +14°
- **Leo to Virgo region**
- **Leo Group**
- **Virgo cluster core**

Leo I group
D=10 Mpc

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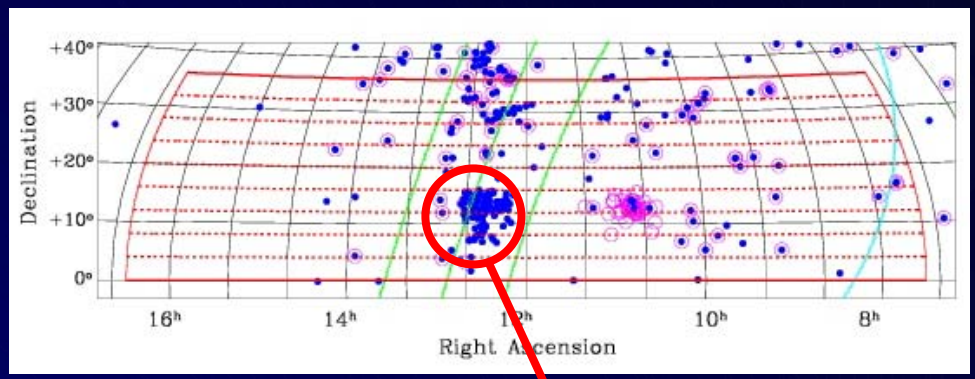
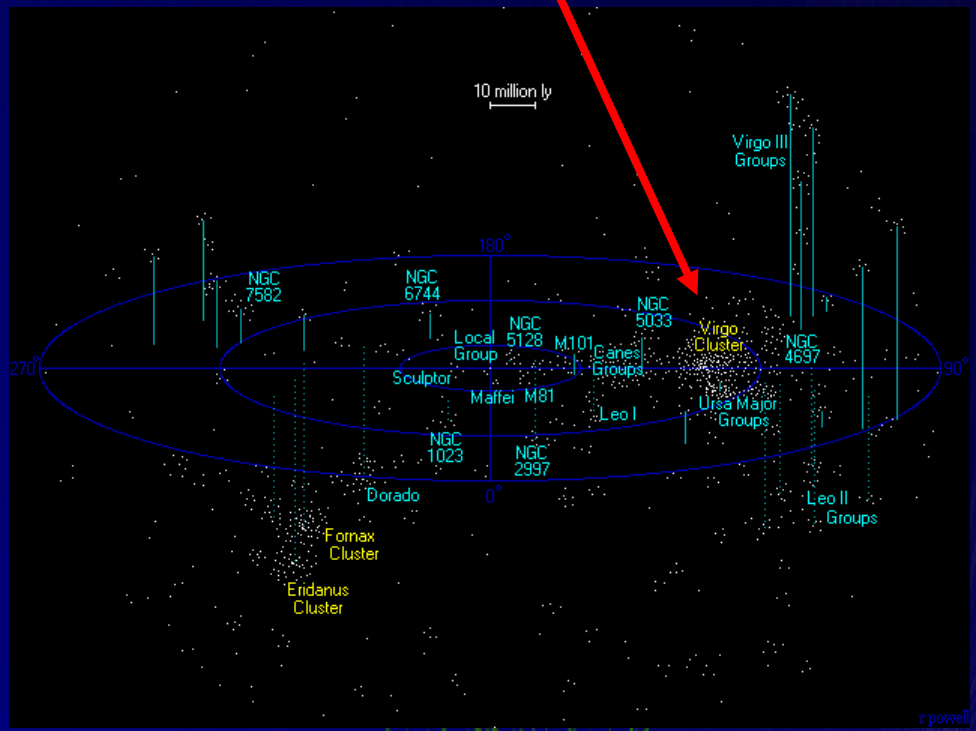
ALFALFA Spring 2005

- While coverage is not ideal, we have a lot of data!
- Observations cover the Leo to Virgo area, perpendicular to the supergalactic plane.
  - Leo Group at 10 Mpc, RA ~10 hr, Dec +8° to +16°
  - Virgo Cluster at 16 Mpc, RA ~12h, Dec +12°
- Many other interesting groups, interacting galaxies, starbursting dwarf galaxies, very high HI mass galaxies, very nearby low mass galaxies, etc.
- Surprises?!

The easy stuff has already been done…
By us, when we were students…
But it wasn't easy when we did it!
If it were easy, it wouldn't be nearly as much fun!

The Virgo Cluster





- The Spring 2005 ALFALFA dataset includes a 7 degree wide band across the center of the Virgo cluster.
- Much of this region is also included in the SDSS (DR4).
- The nearest rich cluster, Virgo is dynamically young.

RA = 12^h, Dec = +12°
<V> = 1035 km/s

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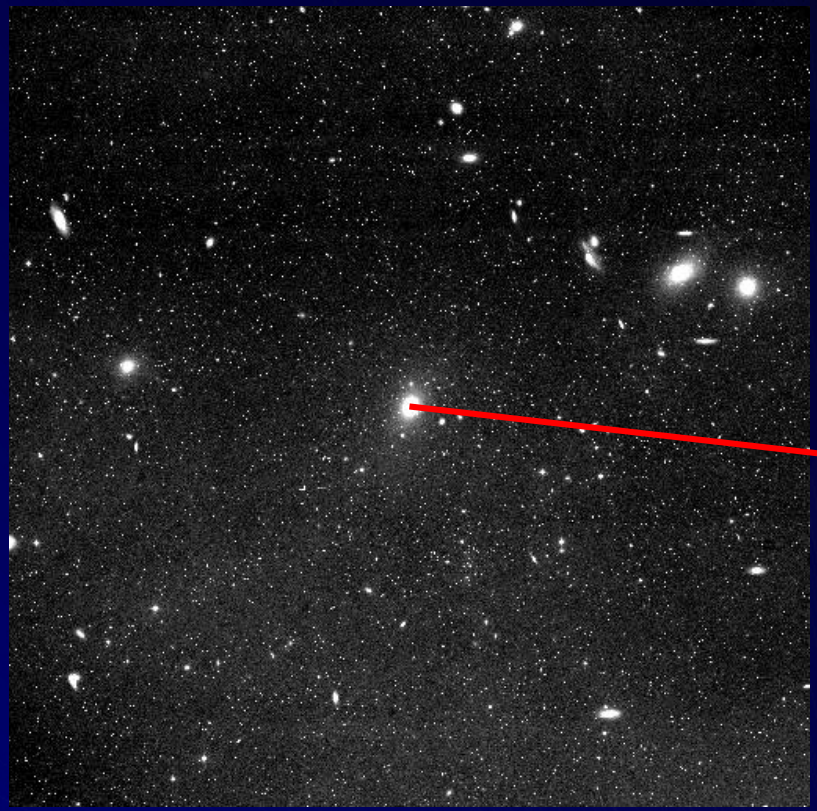
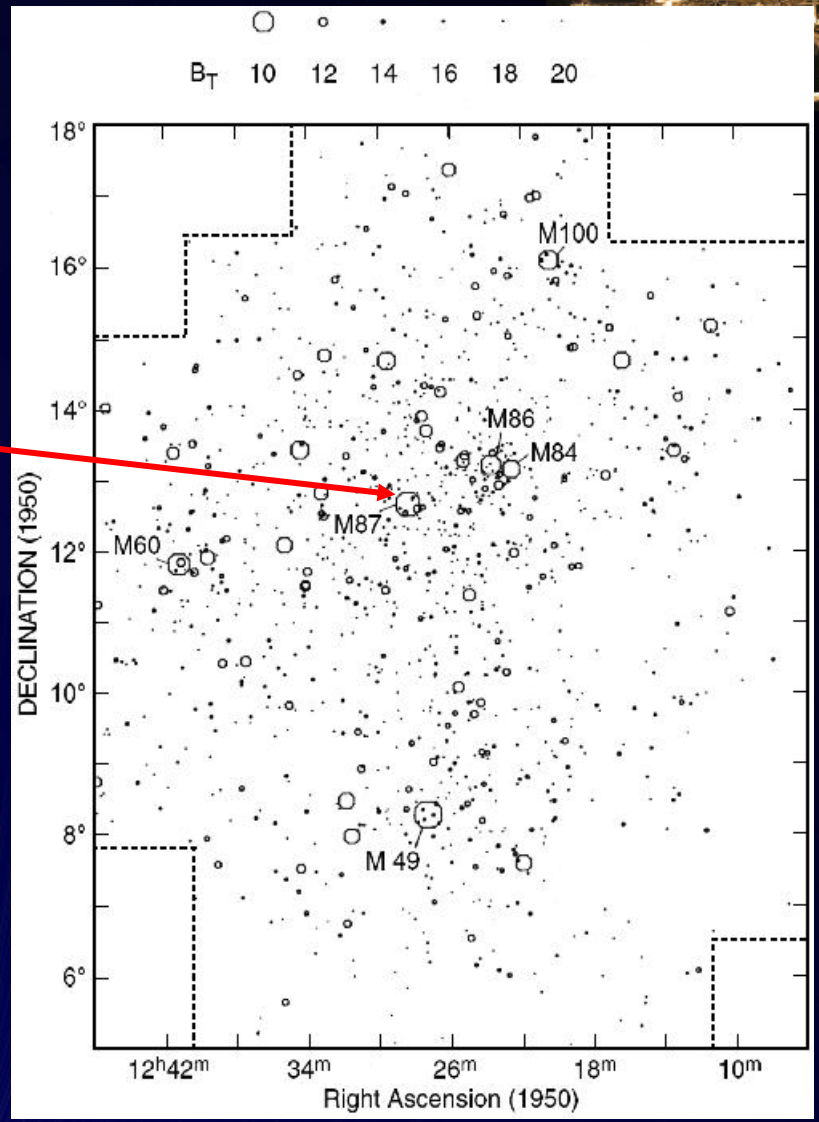
The Virgo Cluster





- Virgo Cluster Catalog (BST85)
- ~2000 objects
- Based on morphological appearance
- Largely confirmed by redshift measurements

Binggeli, Sandage & Tammann 1985, AJ 90, 1681

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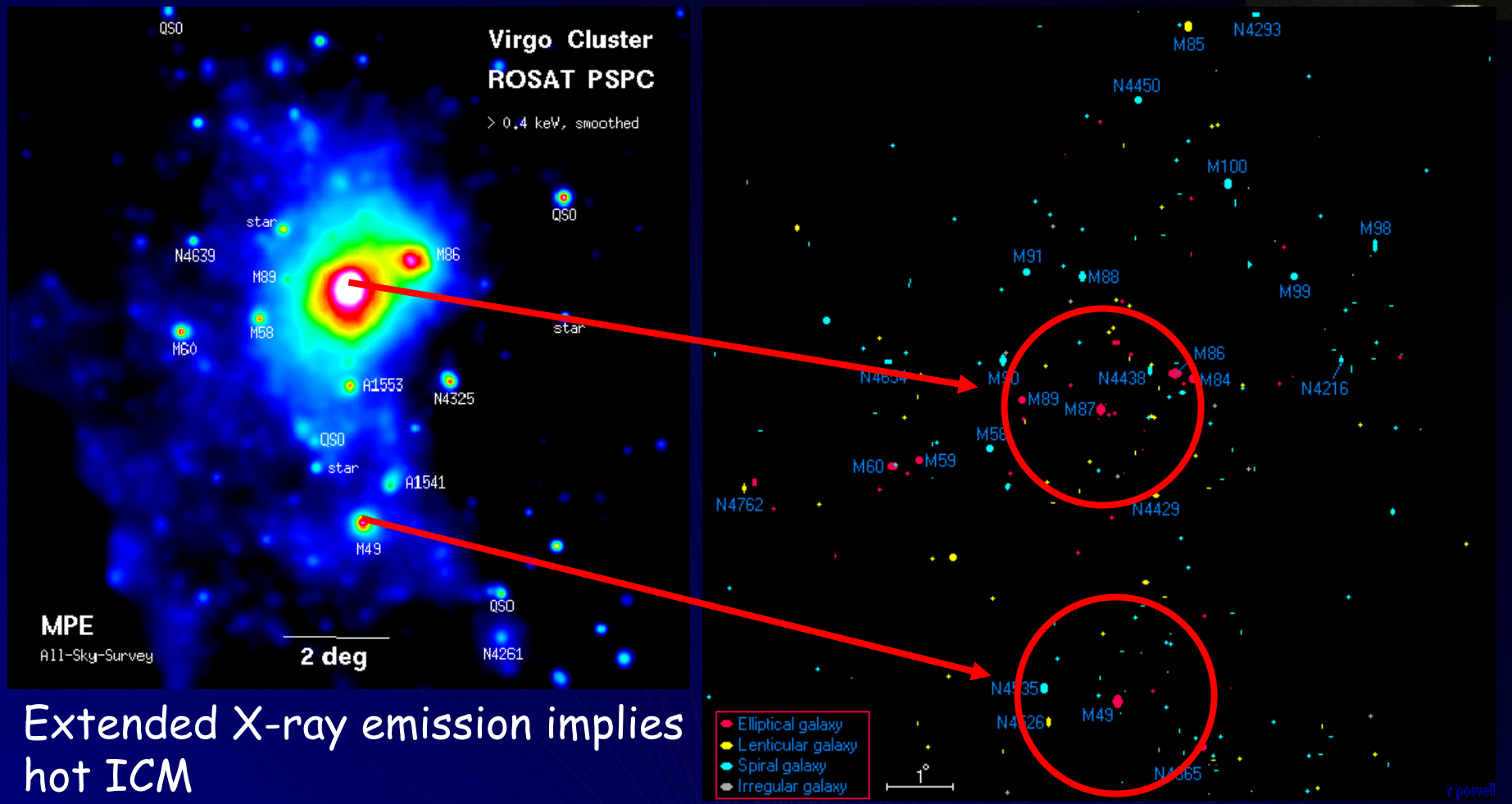
Structure in the Virgo Cluster



- Extended X-ray emission implies hot ICM
- Redshift distribution implies substructure including main cluster around M87, secondary one around M49, plus infalling spiral groups

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Distances in the Virgo Region

- Galaxies in the Virgo Cluster orbit its center with speeds up to 1500 km/s.
  - $V_{obs} = V_{Hub} + V_{orb}$
- In the Virgo region, the redshift is NOT a good indicator of distance.
- Redshift-independent distances are available to some galaxies in Virgo, with more soon to come from the HST/ACS Virgo survey.

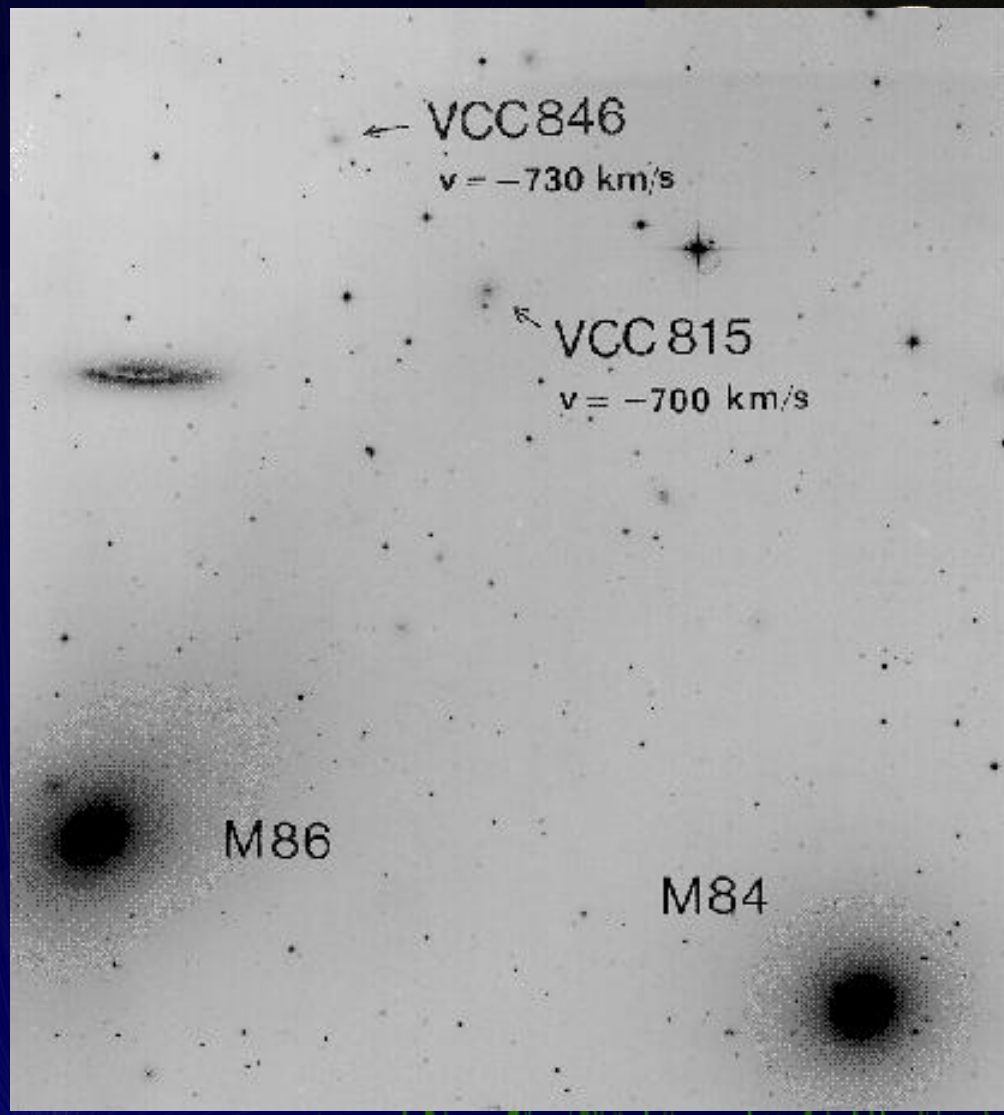
Use known groupings in Virgo and known redshift-independent distances to study Virgo structure so that we can estimate distances to ALFALFA galaxies better.

Dwarf galaxies in Virgo

- BST in the VCC identified some 1000 dwarfs in Virgo
- 90% are dE's
- The remainder are dIs and BCDs

dEs are the dominant population in Virgo
Some of them rotate!

How are they like/unlike dwarfs in the Local Group?



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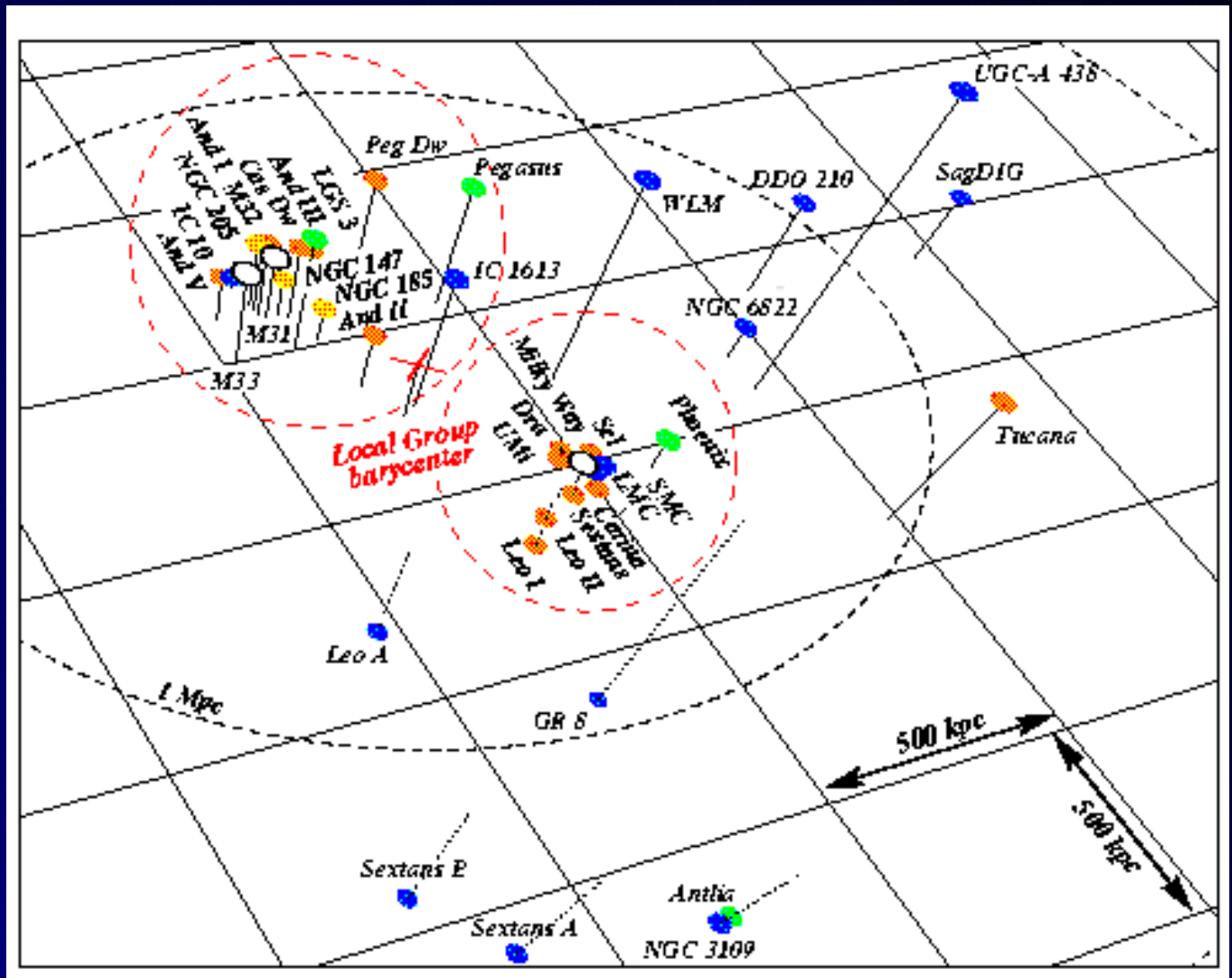
Segregation in the Local Group



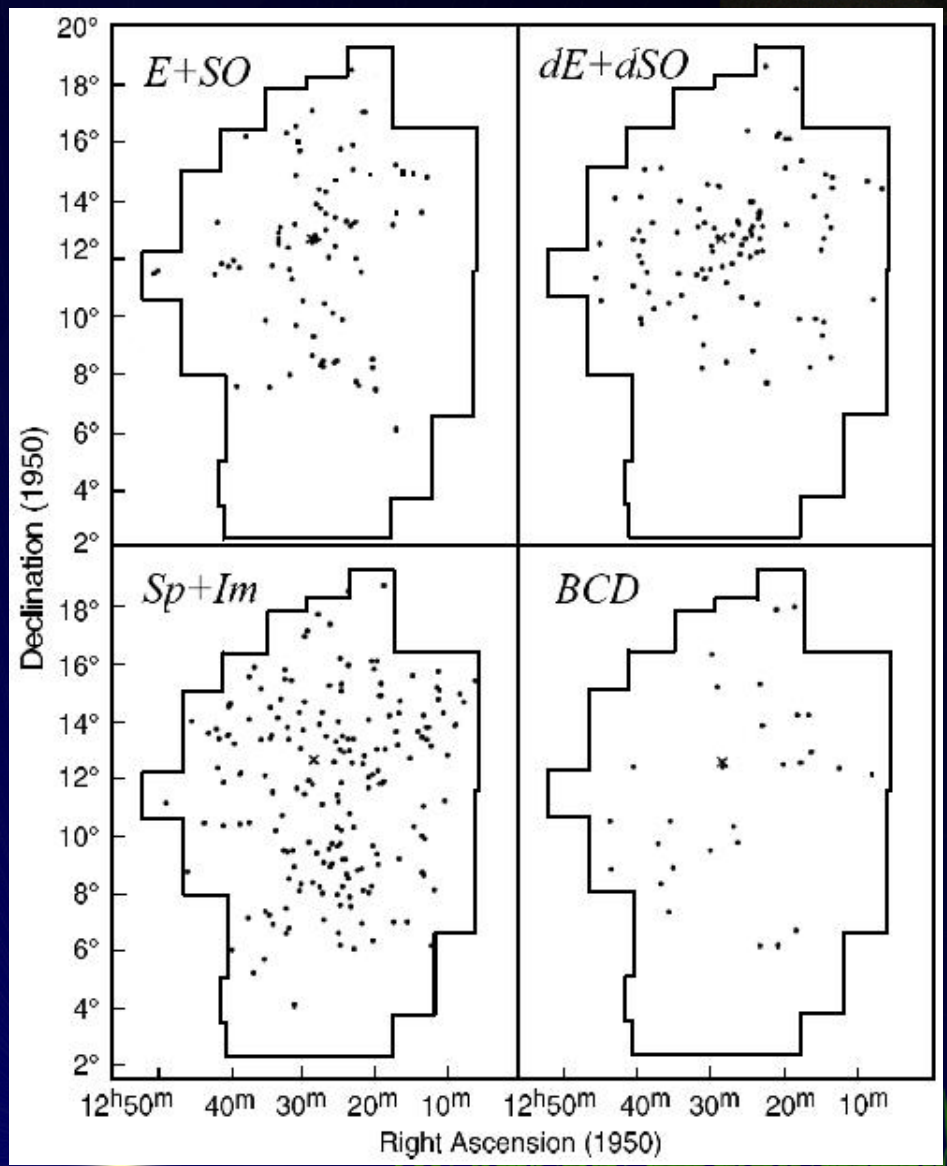
- dE/dSph swarm around M31 and MW
- dI found throughout Local Group

Credit: Sarah Maddison

dIs in Virgo

- dIs form a widely dispersed population
- dIs not preferentially stripped as might be expected due to shallower potential wells

Hoffman et al. 1987, 1989



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Sloan Digital Sky Survey

www.sdss.org

University of Chicago, Fermi National Accelerator Laboratory, Institute for Advanced Study, Japan Participation Group, John Hopkins University, Los Alamos National Laboratory, Max-Planck-Institute for Astronomy/Heidelberg, Max-Planck-Institute for Astrophysics/Garching, New Mexico State University, University of Pittsburgh, Princeton University, United States Naval Observatory, University of Washington

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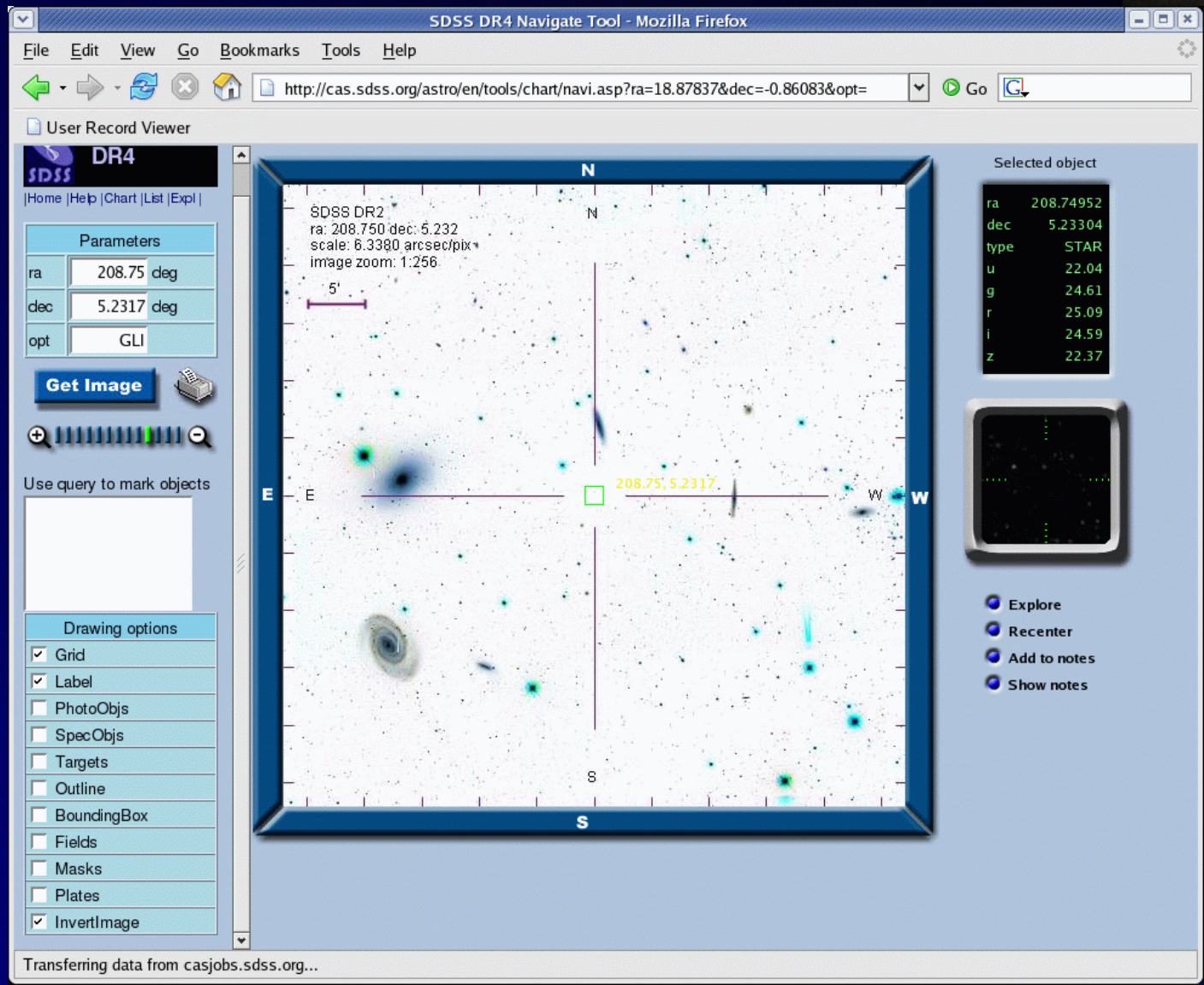
SDSS



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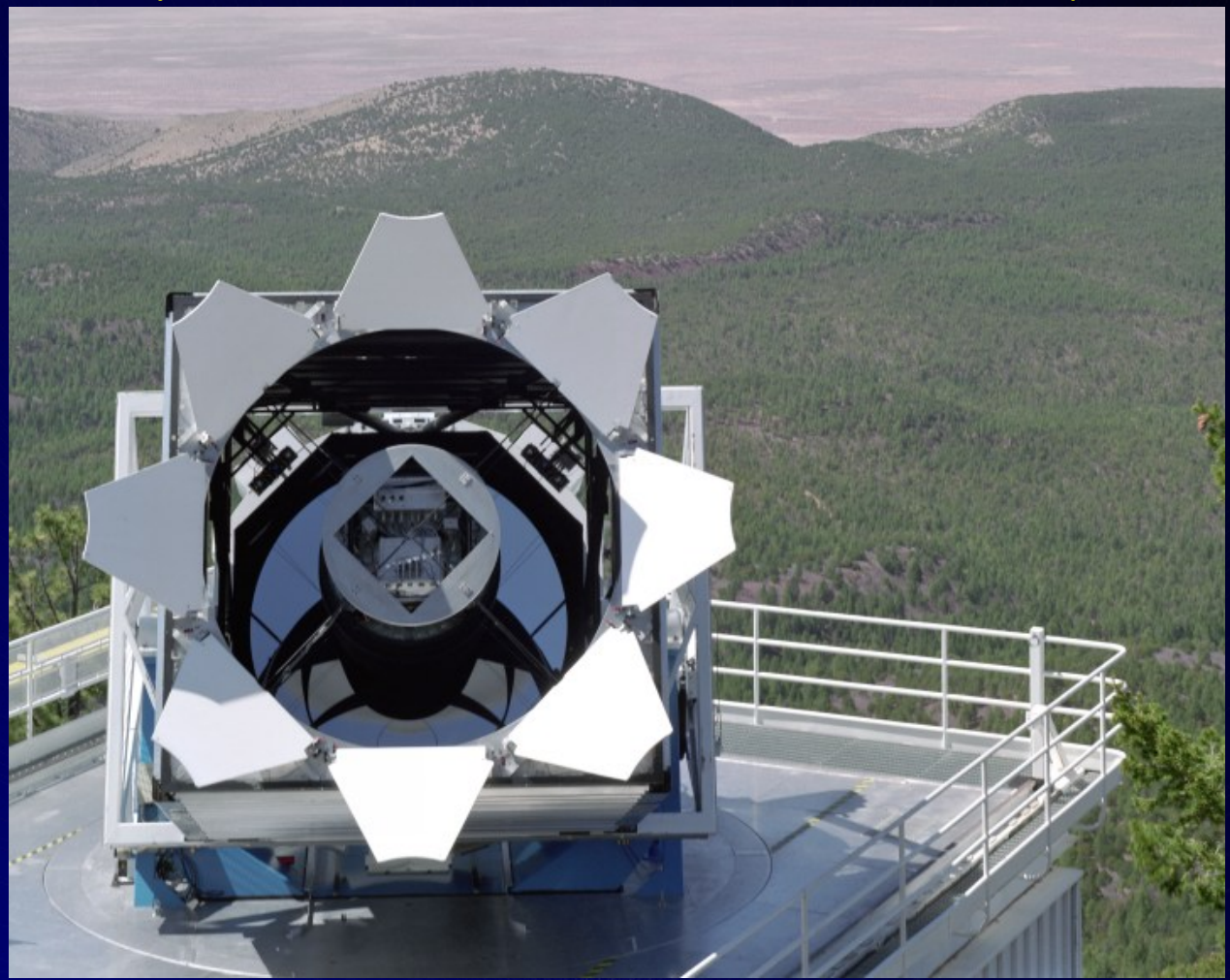
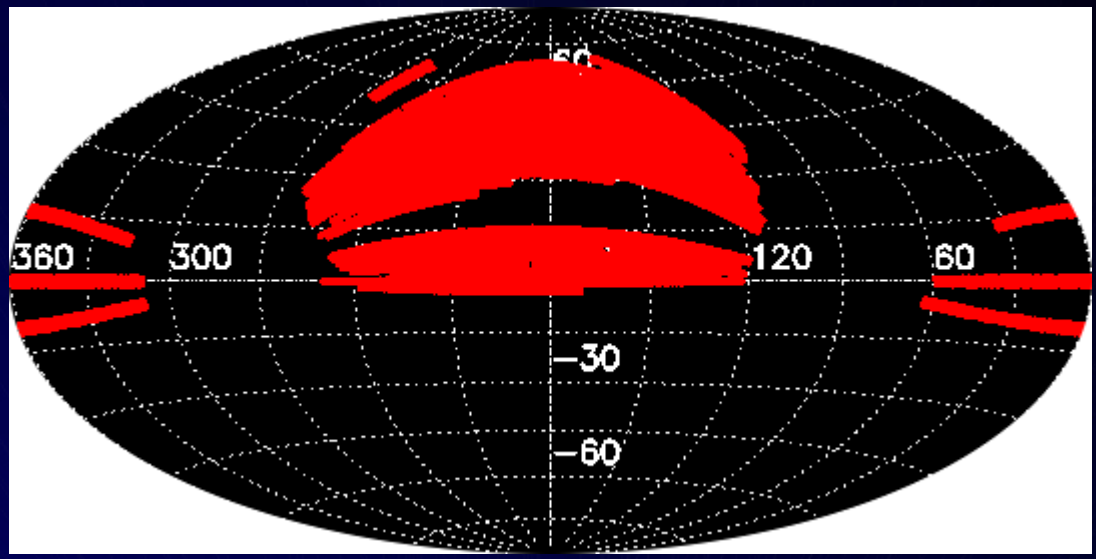
SDSS Telescope, Apache Point Observatory

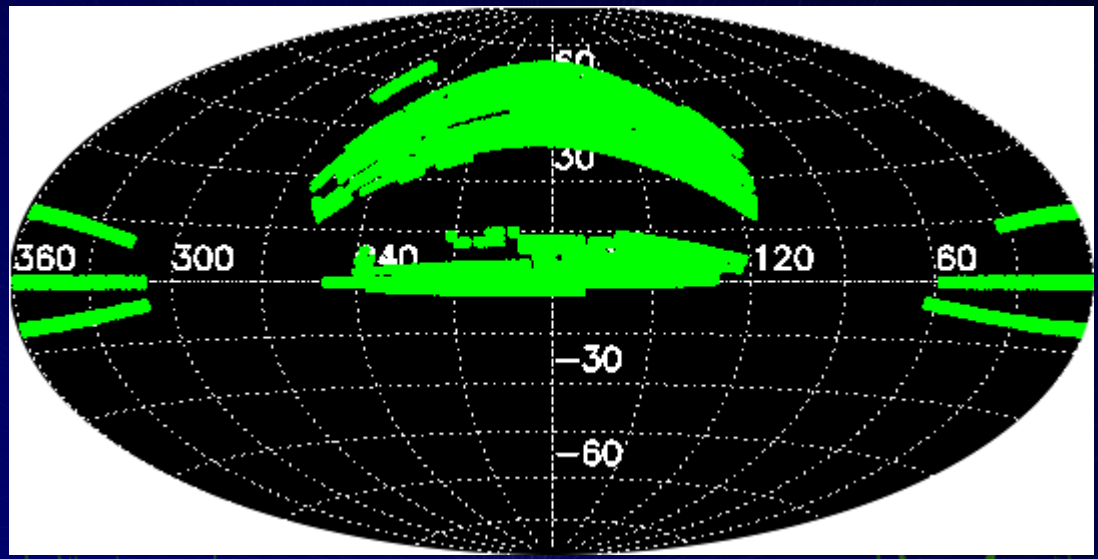


SDSS - DR4 (July 2005)

Photometric Survey DR4



Spectroscopic Survey DR4



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ALFALFA & SDSS

ALFALFA: positions, redshifts, HI fluxes, rotational widths
- Cool HI; future star formation potential

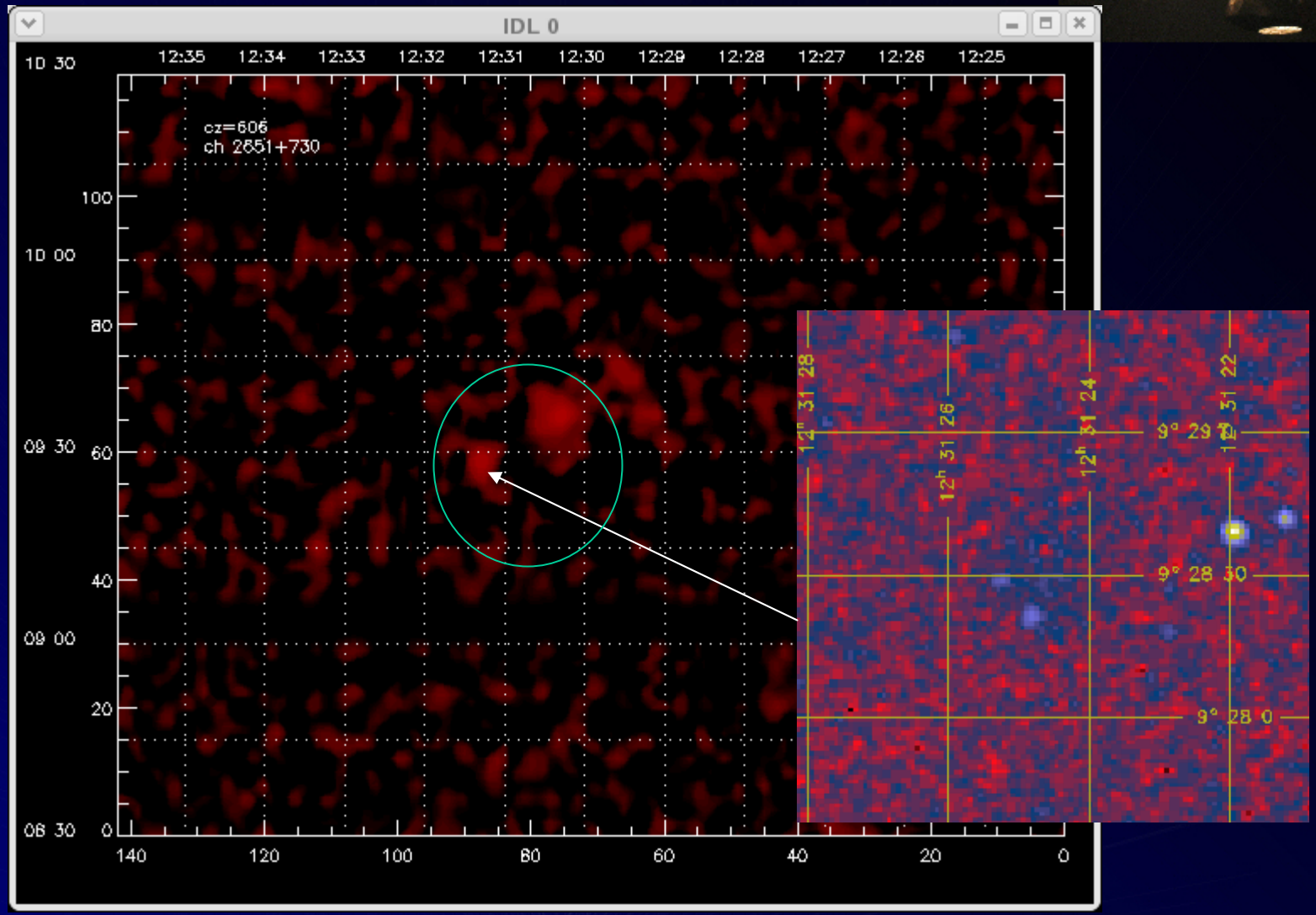
SDSS: positions, morphologies, colors, spectra of stars
- Stellar population, nuclear star formation/AGN

What are the stellar components of the galaxies detected both by ALFALFA and by SDSS like?

What are the objects identified only by ALFALFA?

What are the objects identified only by SDSS?

We may also undertake new optical imaging, e.g. Halpha



VCC1357
0.2x0.1
I?
603 km/s

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Morphological Alterations

Morphological segregation:

- Spirals avoid cluster cores; Ellipticals favor cores.
- Spirals in Virgo core are HI deficient.
- In loose groups, tidal tails can be traced by HI where galaxies have interacted in the recent past.
- The ratio of the number of dwarfs to the number of giants seems to vary from place to place.
- Dwarfs around MW and M31 are dE/dSph; dI's are widely dispersed in Local Group.

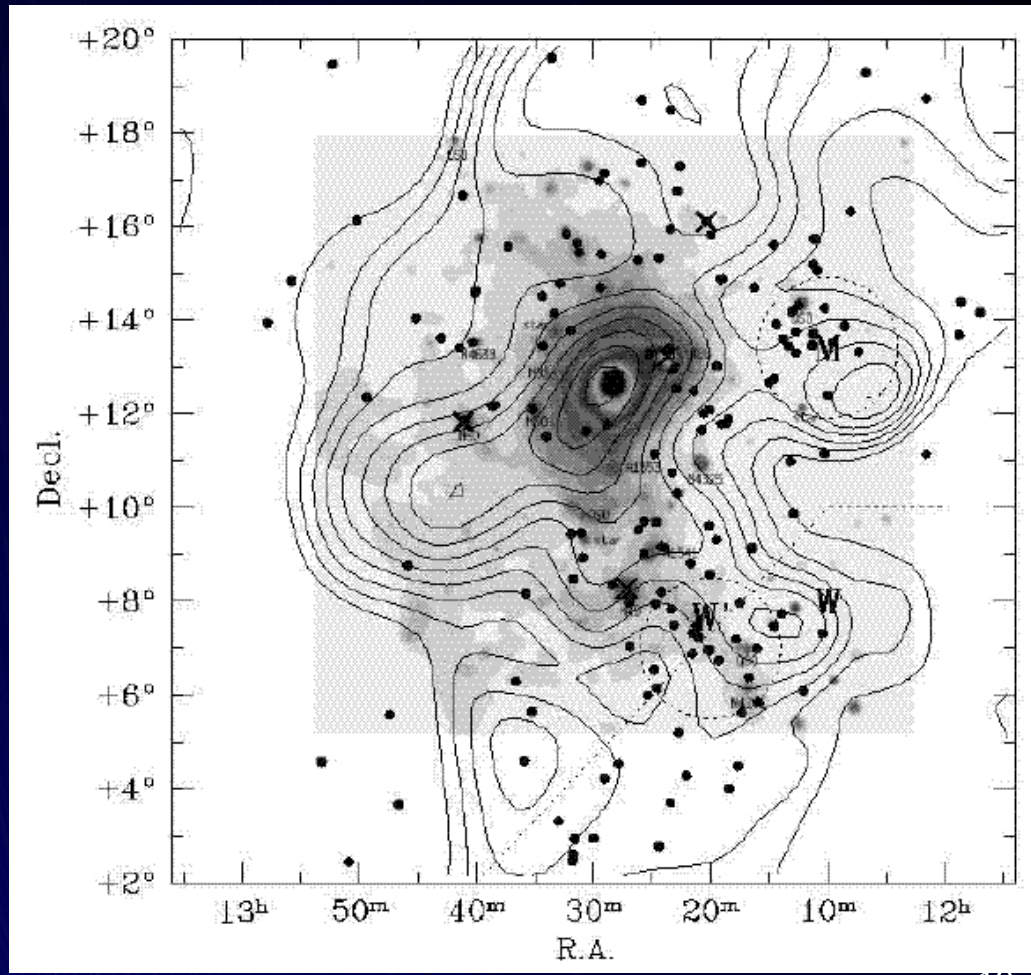
HI deficiency in Virgo

Galaxies embedded in the hot X-ray gas are deficient in their HI relative to isolated galaxies of the same size and morphology.

Dots: galaxies w/ measured HI

Contours: HI deficiency

Grey map: ROSAT 0.4-2.4 keV



Solanes et al. 2002

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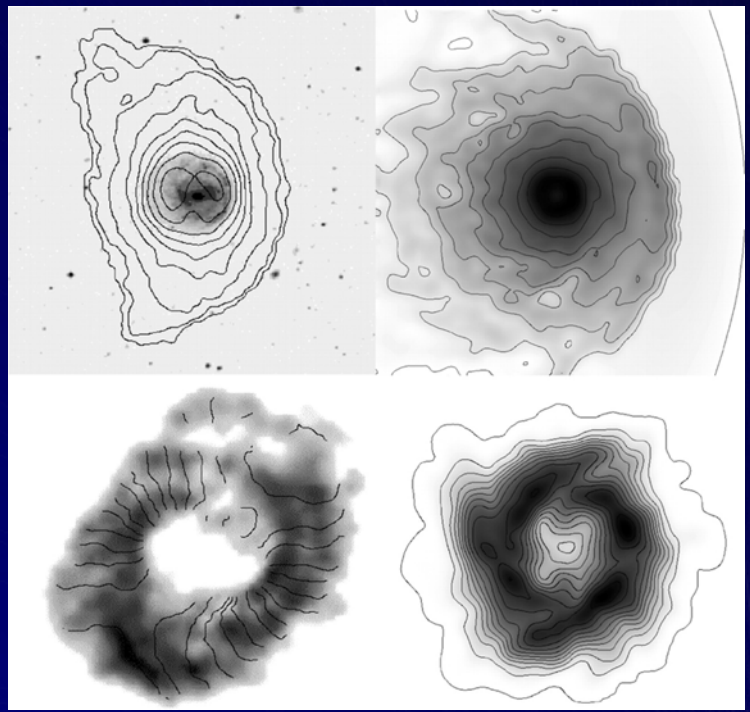
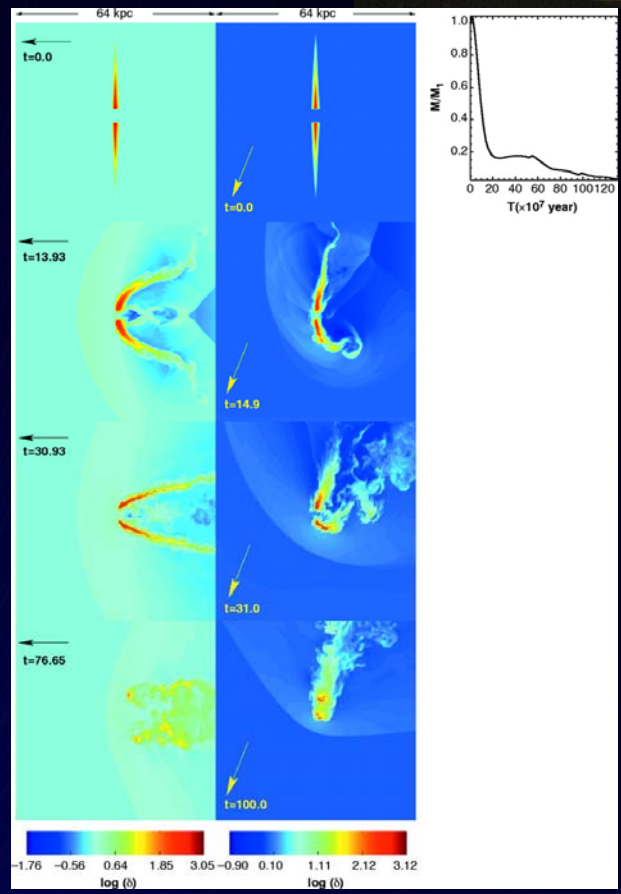
Ram pressure sweeping

- Spirals in Virgo are HI deficient.
- Hydrodynamical simulations show effectiveness of ram pressure stripping





Vollmer et al. 2001

Stripping in Groups/Clusters

ALFALFA clues:

- Asymmetric/peculiar HI distribution
- No HI in optically "gassy" galaxy

Better definition of group/cluster structure and substructure.

What is the X-ray environment in groups/clusters?

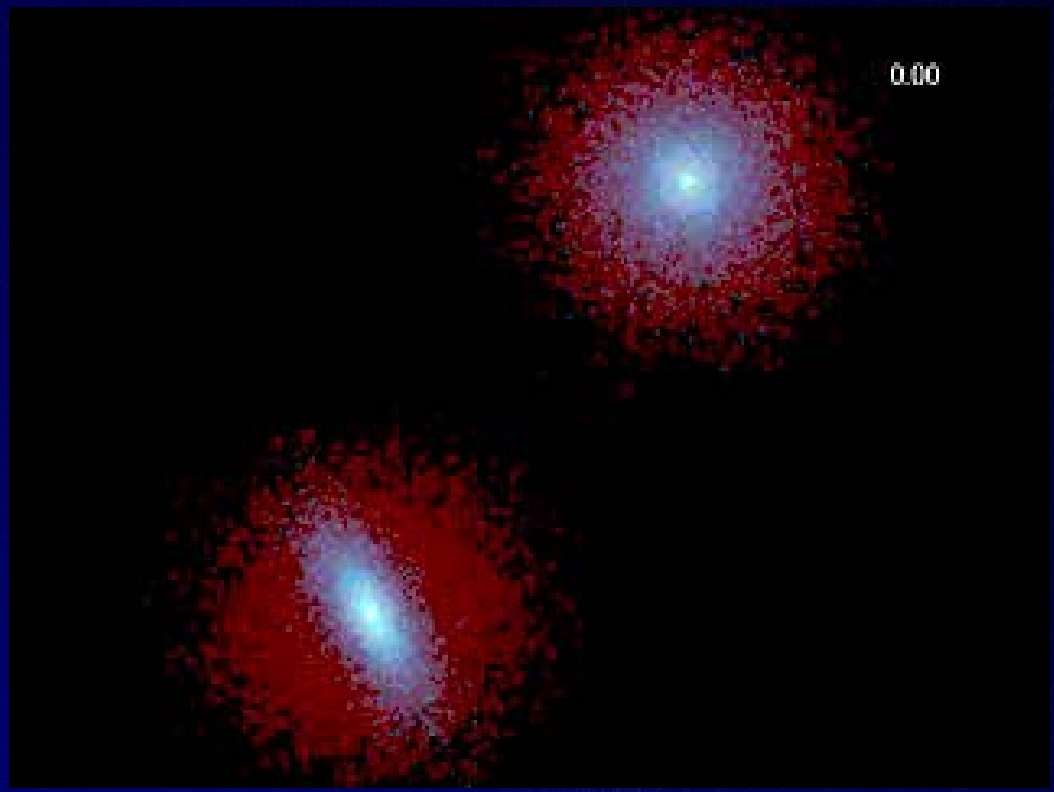
- Chandra data (archival and new)

Other evidence for interactions?

- Active nuclei
- Star burst indicators
- Radio continuum emission

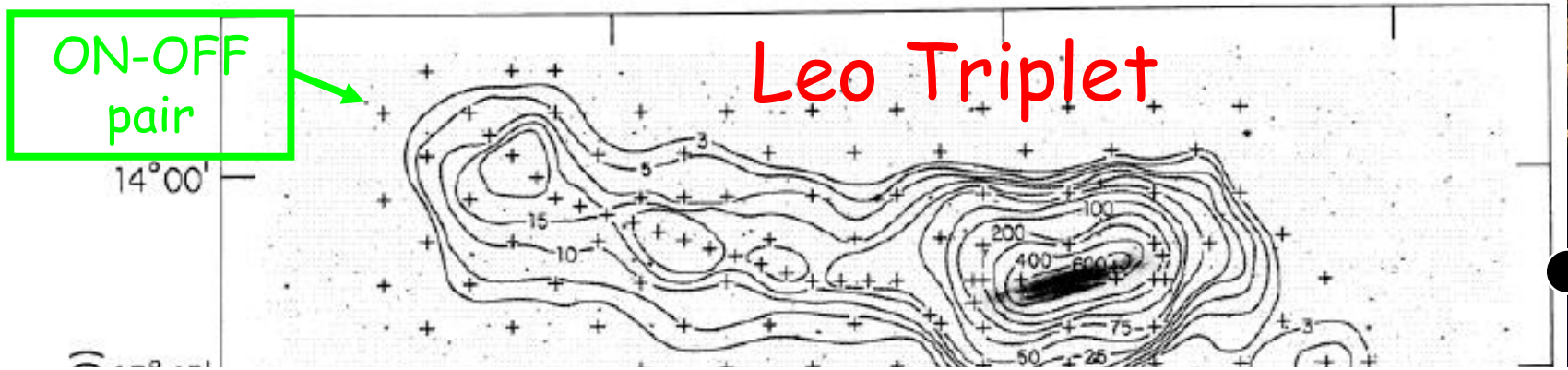
Blind search for tidal remnants

In loose groups, slow tidal encounters lead to disruption of disks and the formation of bridges and tails.



ON-OFF pair

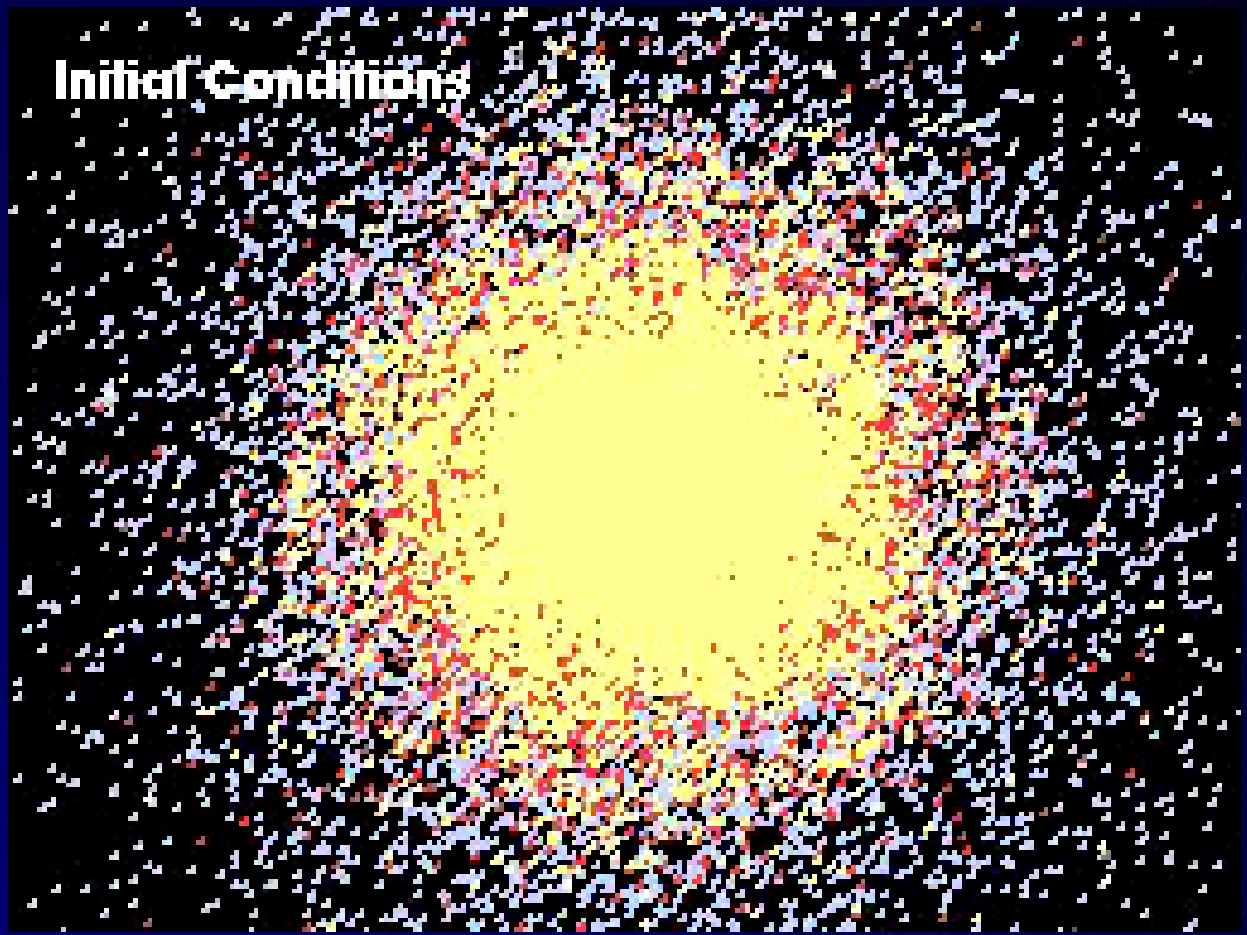
Leo Triplet



← Right Ascension

Single ALFALFA drift

Galaxy harassment

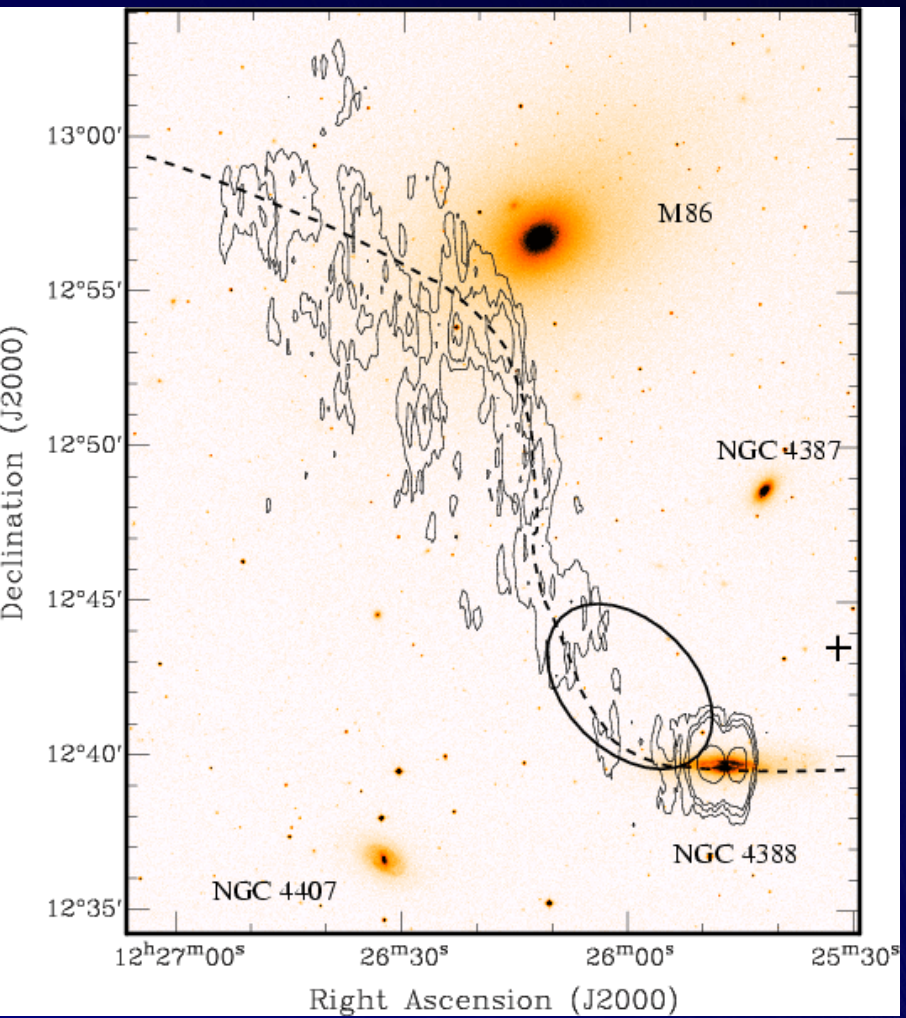


Multiple rapid encounters in a cluster may also seriously impact galaxy evolution.

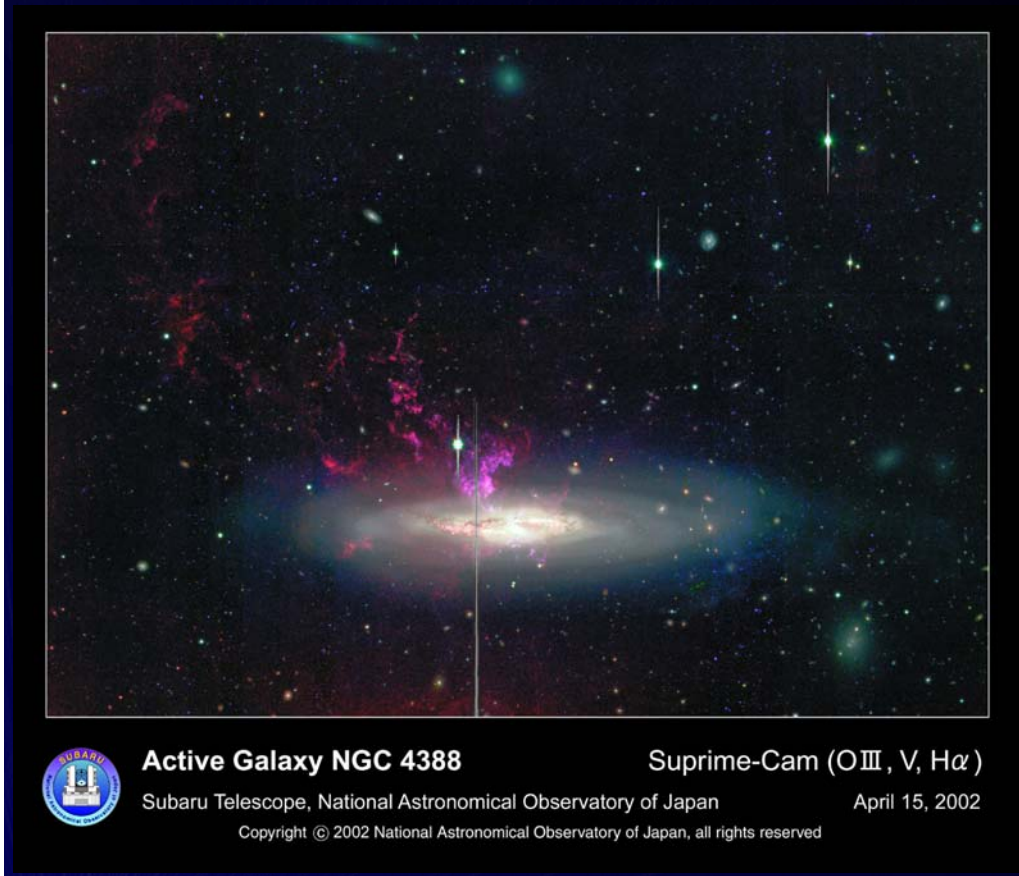
Animation courtesy of G. Lake

NGC 4388

Oosterloo & van Gorkom 2005



APOD



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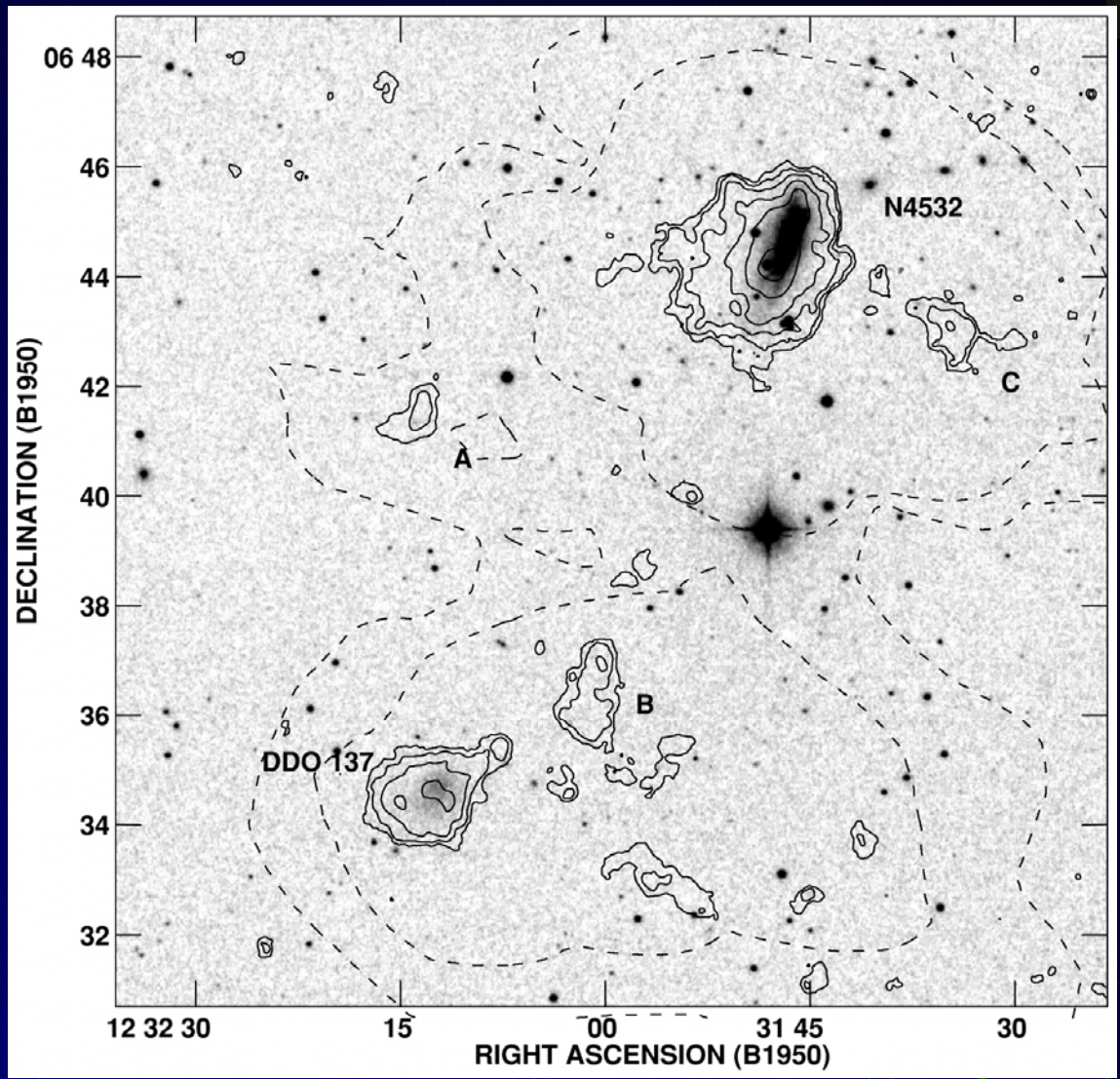
N4532+DDO 137

Hoffman et al. (1989) Giant HI cloud around a pair of dwarf galaxies



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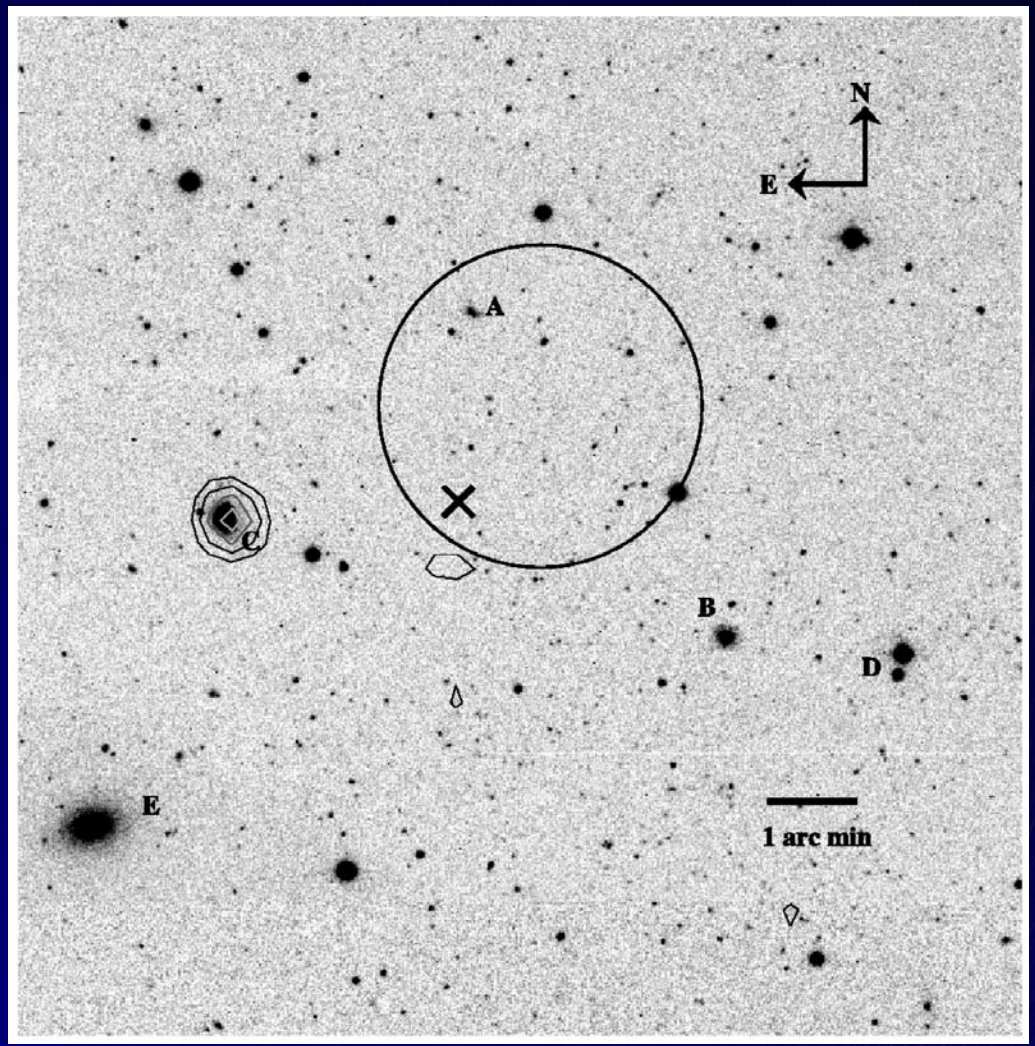
A "dark cloud" in Virgo?



Davies et al 2004
Minchin et al 2005

ALFALFA: object is much bigger than this AND indicates interaction with lopsided galaxy NGC4254

HI debris in Virgo

There are already several examples of intriguing HI debris/clouds in Virgo:

- HI plume of NGC 4388 (Oosterloo & van Gorkom)
- Giant HI envelope around NGC4532/DDO134 (Hoffman et al. 1989)
- The "dark cloud" of Davies et al. 2004; Minchin et al. 2005 … but is it really a separate bound " dark galaxy"????
- The new ALFALFA cloud…

Lots more to find????
Are there isolated dark galaxies?

Leo I: An interesting region

- Quite nearby: D=10Mpc
- Leo I is dominated by early types
- Velocity dispersion is very small ~112 km/s
- Leo I contains the "Leo ring" of HI

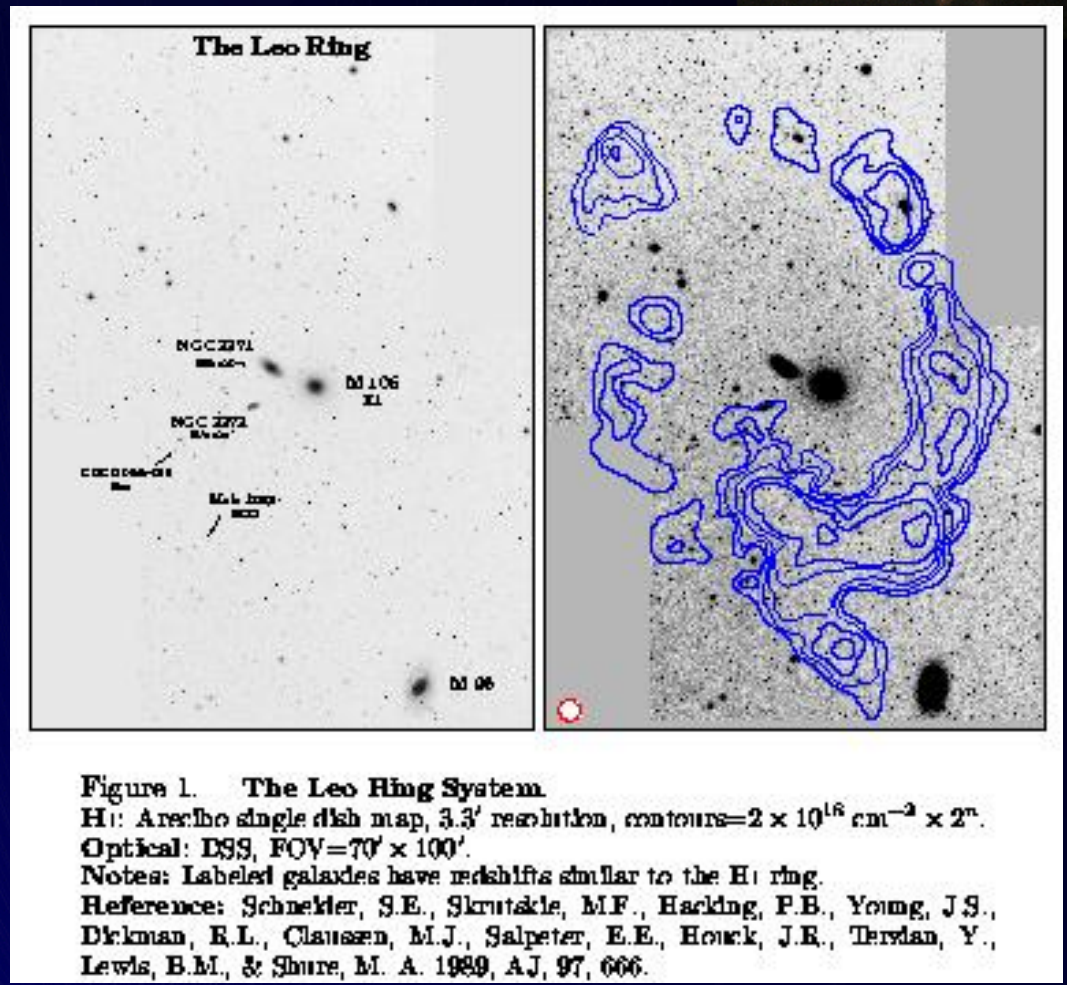


Figure 1. **The Leo Ring System.**
H I: Arecibo single dish map, 3.3′ resolution, contours=2×10^{18} cm$^{-2} \times 2^n$.
Optical: DSS, FOV=70′ × 100′.
Notes: Labeled galaxies have redshifts similar to the H I ring.
Reference: Schneider, S.E., Skrutskie, M.F., Hacking, P.B., Young, J.S., Dickman, R.L., Claussen, M.J., Salpeter, E.E., Houck, J.R., Terzian, Y., Lewis, B.M., & Shure, M. A. 1989, AJ, 97, 666.

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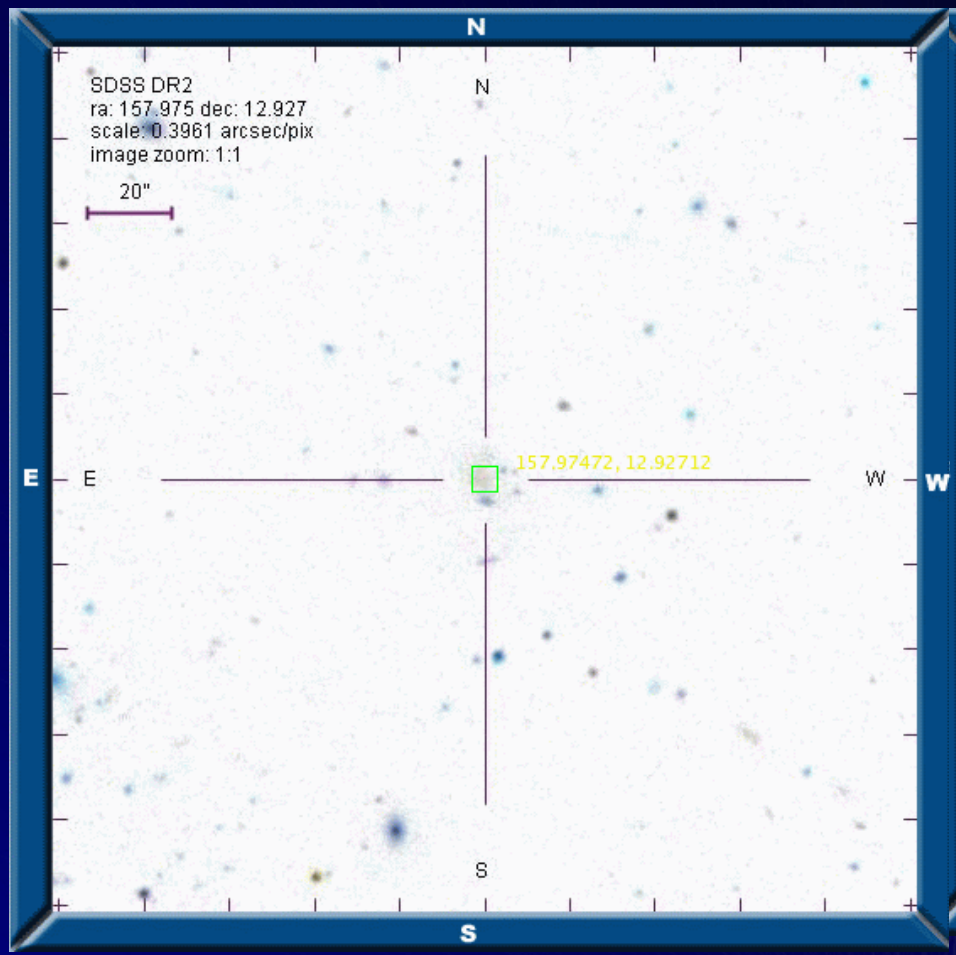
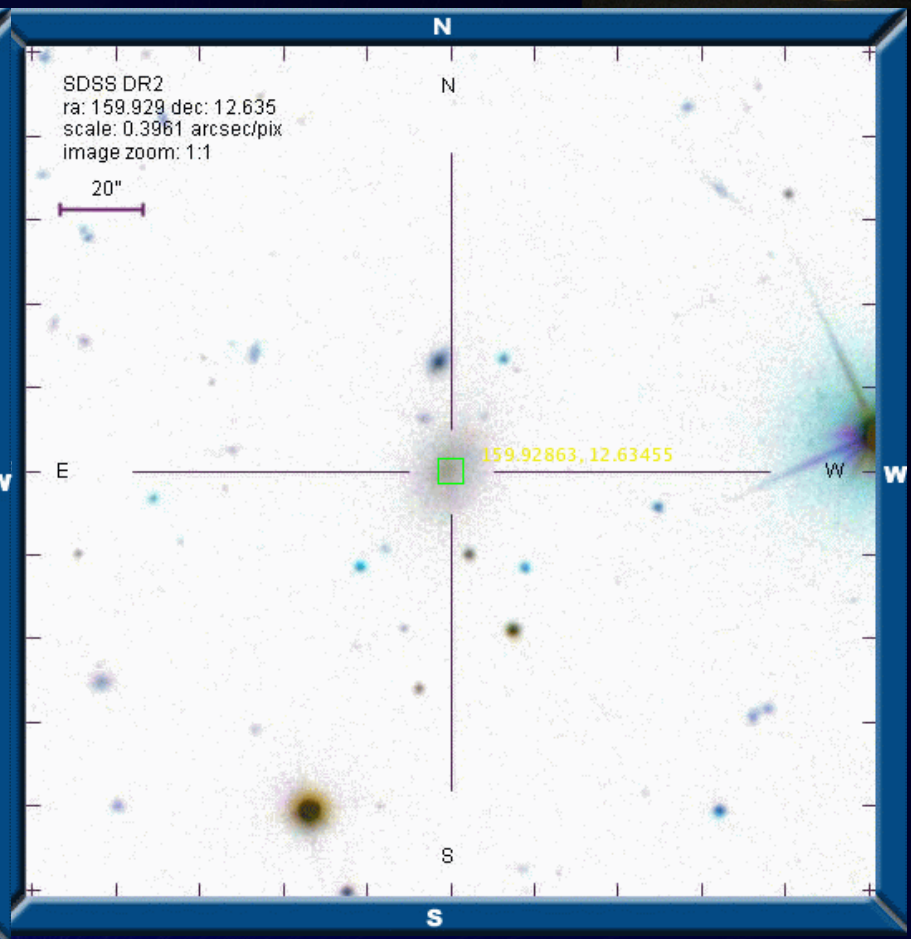
Leo I: Comparison with Virgo





Dwarf galaxy candidates identified optically by Karachentsev & Karachentseva

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Plus more….

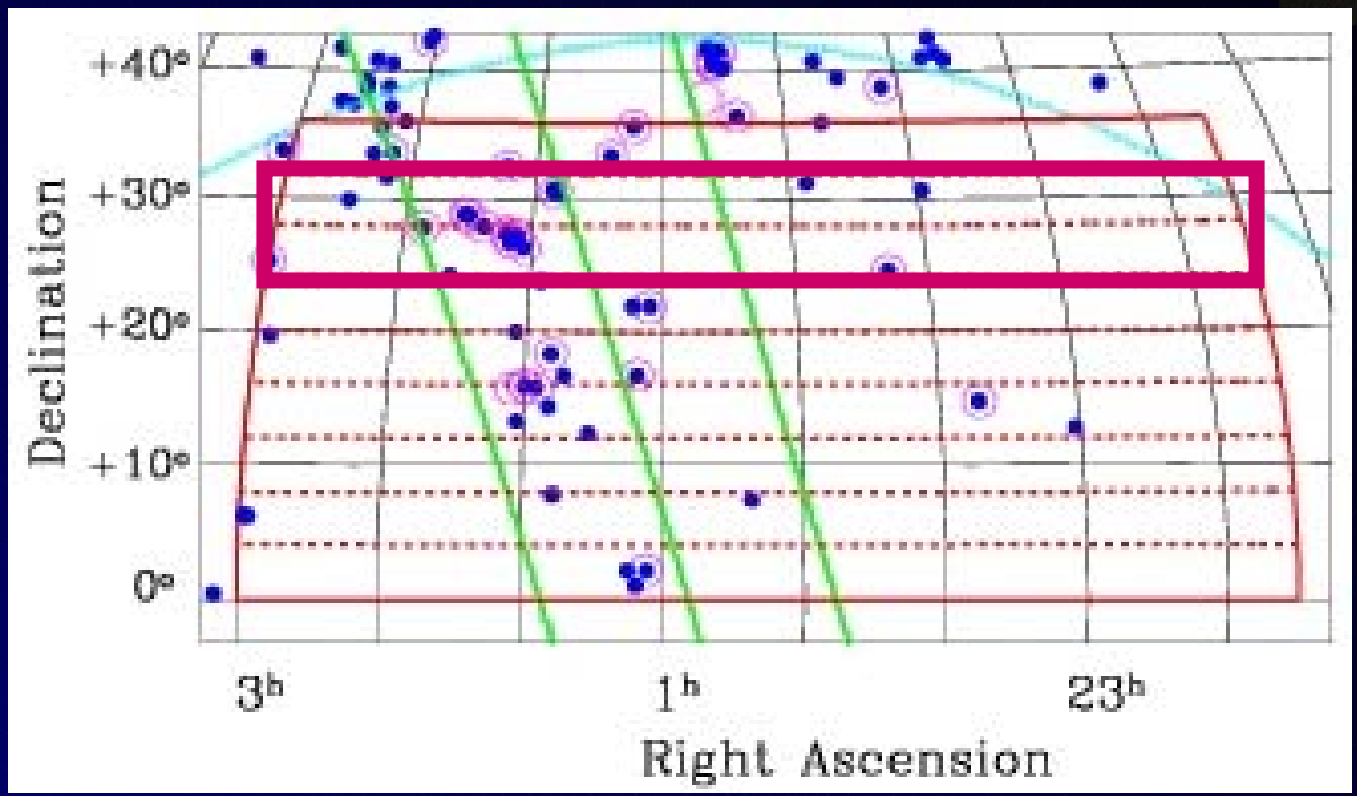
Those are just some of the things we know about….

Even more exciting will be the unexpected things…!

… like the NGC 5364 group…..

And we have only just begun…

ALFALFA: Fall Sky



2005: Tiles at +26° and +30°

- Region around M33
- NGC 672 group
- NGC 784 "group of dwarfs"

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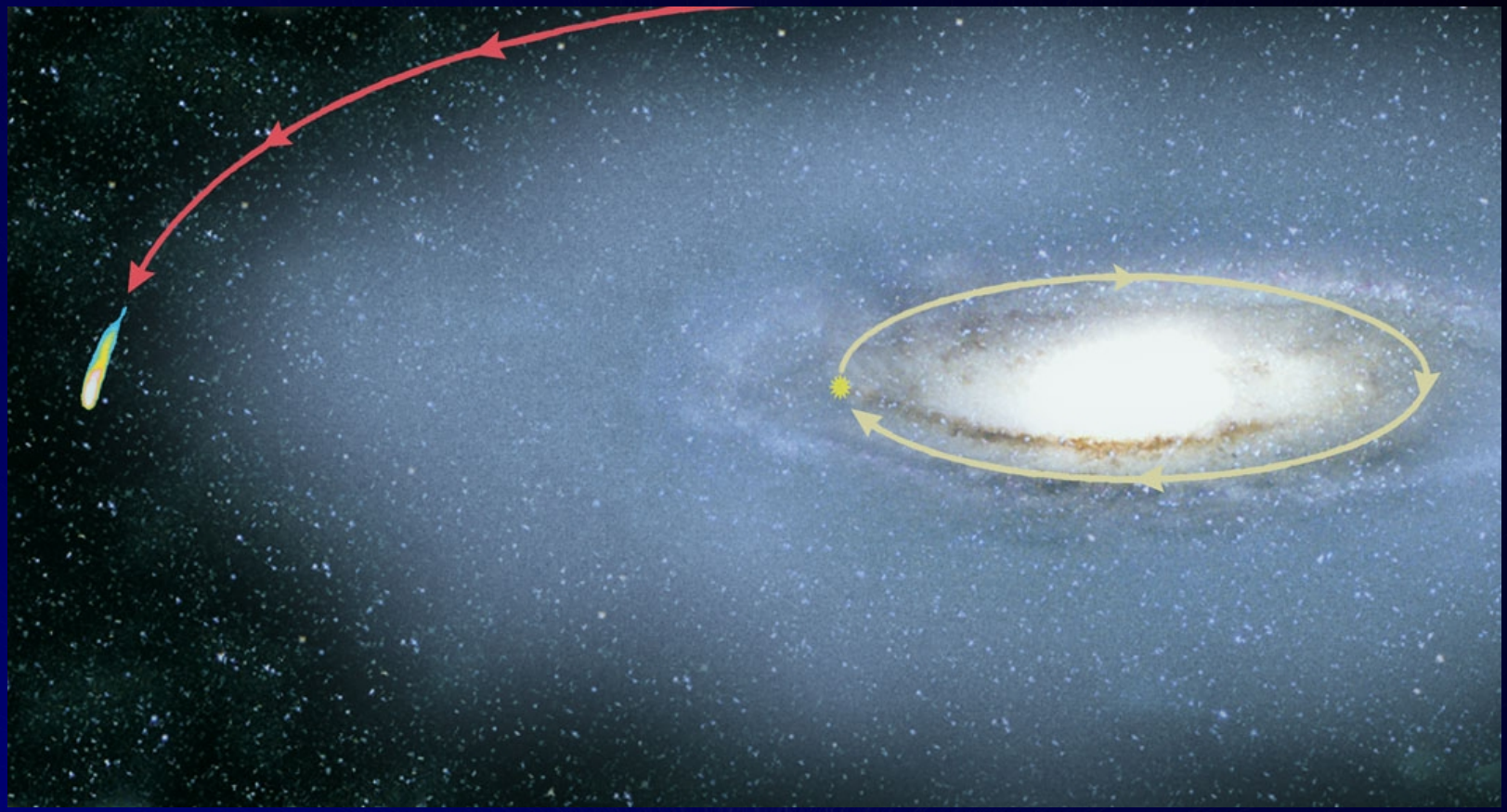
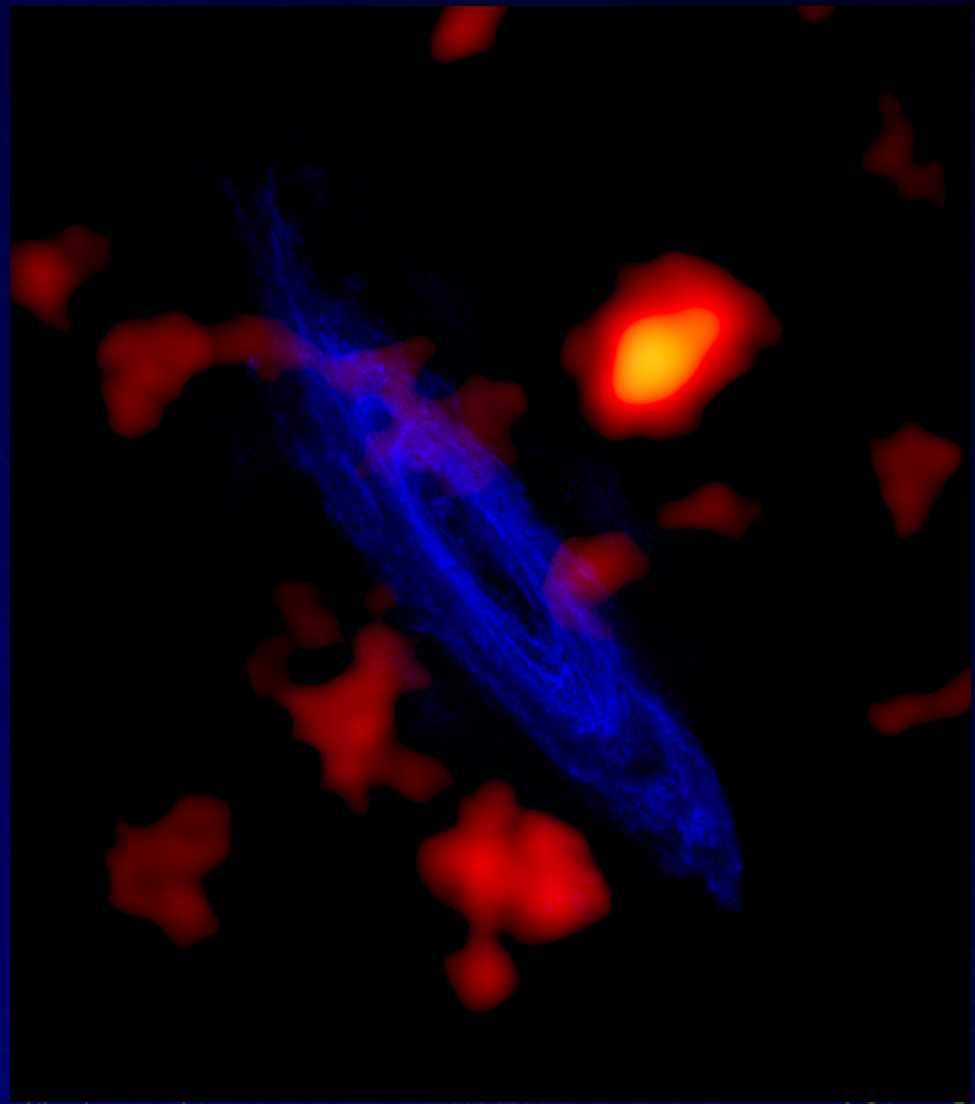
"Complex H" : A Relic Stream



A trail of atomic hydrogen is the relic of a dwarf galaxy that was tidally disrupted by the bigger Milky Way.

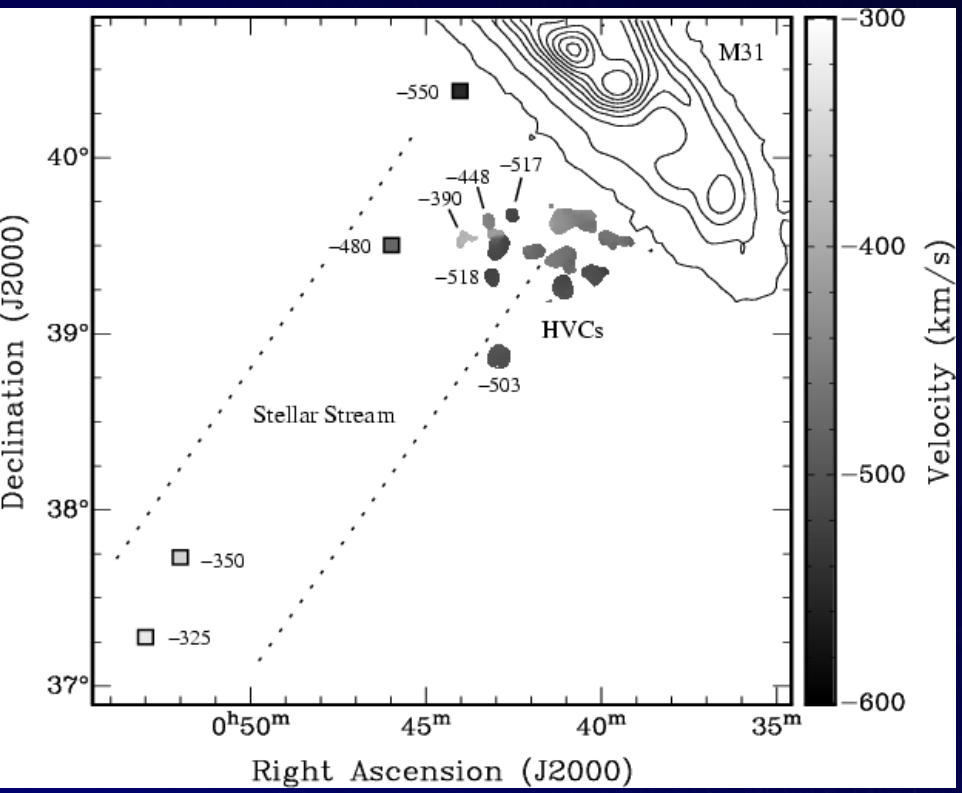
HI around M31

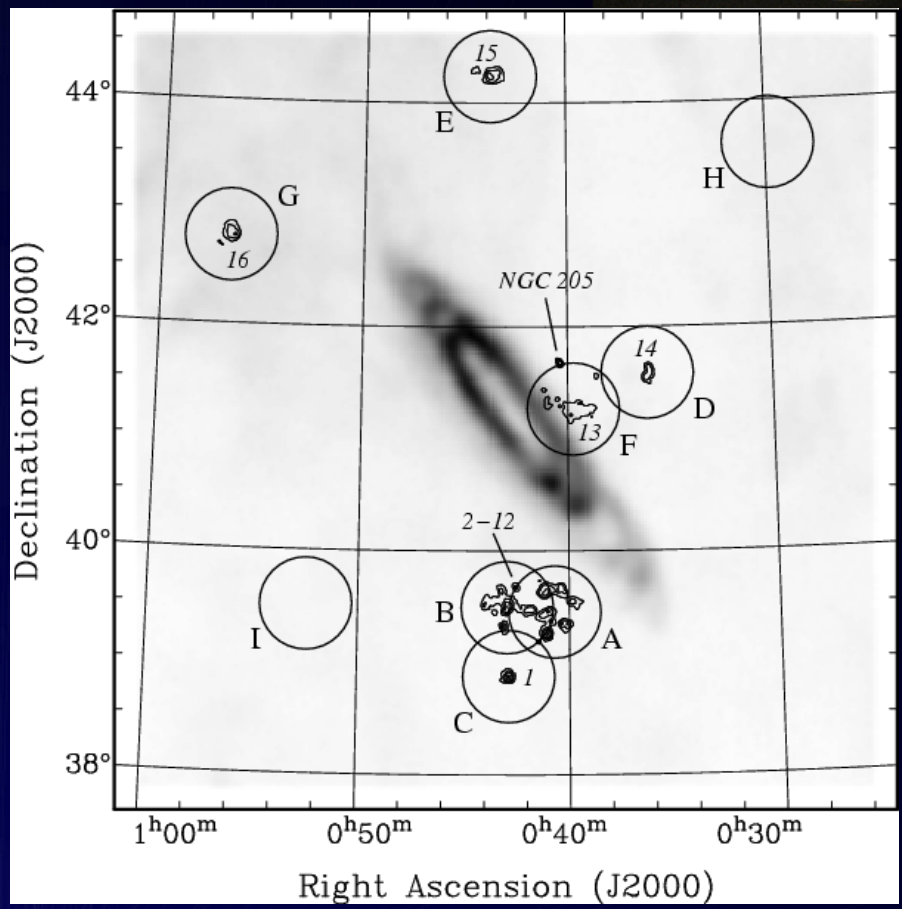
M31 lies too far north!



NRAO image gallery & D.J. Thilker

Clouds around M31





M33 sits at
01^h34^m, +30°

Westmeier et al 2005

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ALFALFA in the Fall

Lots of observing (we hope)!

Lots more data

- M33 region
- Anti-Virgo region = nearby void
- Pisces-Perseus supercluster ridge

Possible 2006 Request

Similar to 2005 request:

- 2 "spring" tiles (2 x 33 sessions of 9+ hours)
- 2 "fall" tiles (2 x 33 sessions of 5+ hours)

Possible coverage:

- **Spring**
  - +06° : includes SMUDGES strip
  - [+20° : A1367, NGC 2903 (not in SDSS yet)]
  - +30°: Coma (mostly in SDSS)
- **Fall**
  - +14° : NGC 628 group
  - +34° : Complete M31-M33 region; high ZA
  - [+06°: includes SMUDGES strip]

05.07.06 d22p1

13h31m to 15h02m centered at +05°13′54″

1. The NGC 5364 group field (~1350+0514)
   - Catalog of HI detections in field
   - HI detection of SDSS spectroscopic objects
   - SDSS identification of ALFALFA detections
   - HI absorption in NGC5363
   - Are the HI disks of the galaxies "normal"?
   - Structure of the group and its place in the Local Supercluster
   - Any surprises?
2. The rest of the drift – What's there? What's not?

You now have an ALFALFA dataset!
What do you want to do with it?
Who/what/when/where/how?