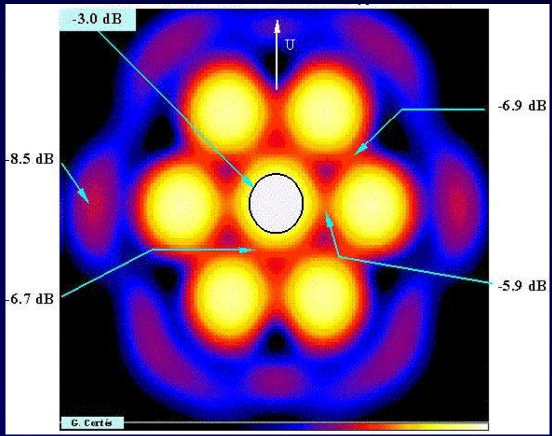

ALFALFA

The Arecibo Legacy Fast ALFA Extragalactic Survey

(An Exploration of the z~0 HI Universe)

Riccardo Giovanelli (Cornell University)
for the ALFALFA team

Spineto June 07

ALFALFA

ALFALFA, a Legacy Survey

ALFALFA

The Arecibo Legacy Fast ALFA Survey

Main People Science Schedule Data Documentation Links Publications Undergrads Non-experts News/Events Observing/Data Team

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Overview

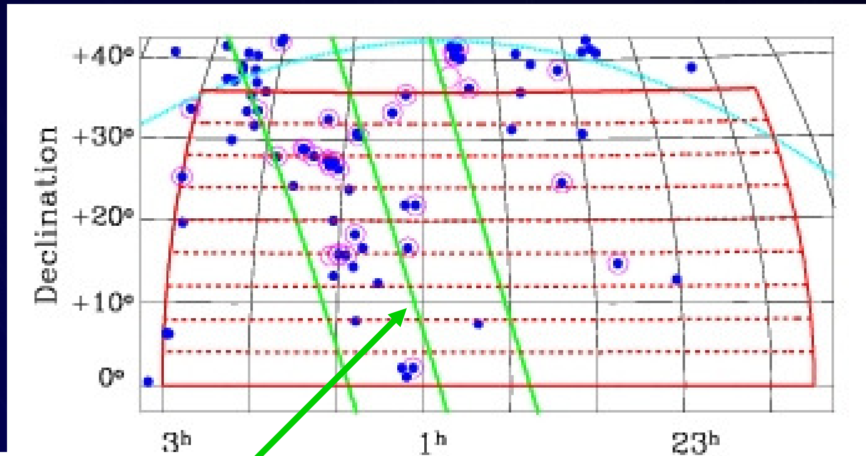
Arecibo is the world's most sensitive radio telescope at L-band. In addition to that all-important sensitivity advantage, Arecibo equipped with ALFA offers important and significant improvements in angular and spectral resolution over the available major wide area extragalactic HI line surveys such as HIPASS and HIJASS. To break ground into new science areas, extragalactic HI surveys with ALFA must exploit those capabilities to explore larger volumes with greater sensitivity than have the previous surveys. The lowest mass objects will only be detected nearby; wide areal coverage is the most efficient means of increasing the volume sampled locally. An extragalactic survey covering the high galactic latitude sky visible from Arecibo will produce an extensive database of HI spectra that will be of use to a broad community of investigators, including many interested in the correlative mining of multiwavelength datasets; we thus dub this program the *Arecibo Legacy Fast ALFA* survey: ALFALFA. A comparison

http://egg.astro.cornell.edu/alfalfa

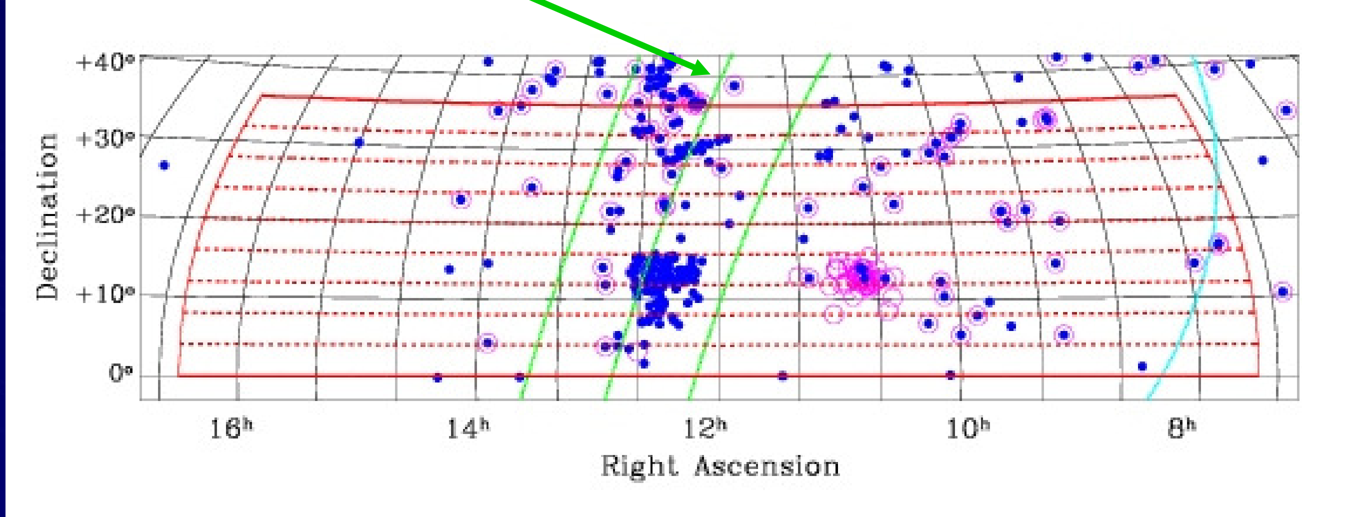
ALFALFA

ALFALFA Survey

High galactic latitude sky visible from AO



Supergalactic plane



ALFALFA

The minimun integration time in sec , to detect an HI mass M_{HI} at the distance D_{Mpc} with ALFA, is

$$t_s \approx 0.25\left(\frac{M_{HI}}{10^6 M_{sun}}\right)^2 D_{Mpc}^4 \left(\frac{W_{kms}}{100}\right)^{3/2}$$

i.e. the Depth of the survey increases only as

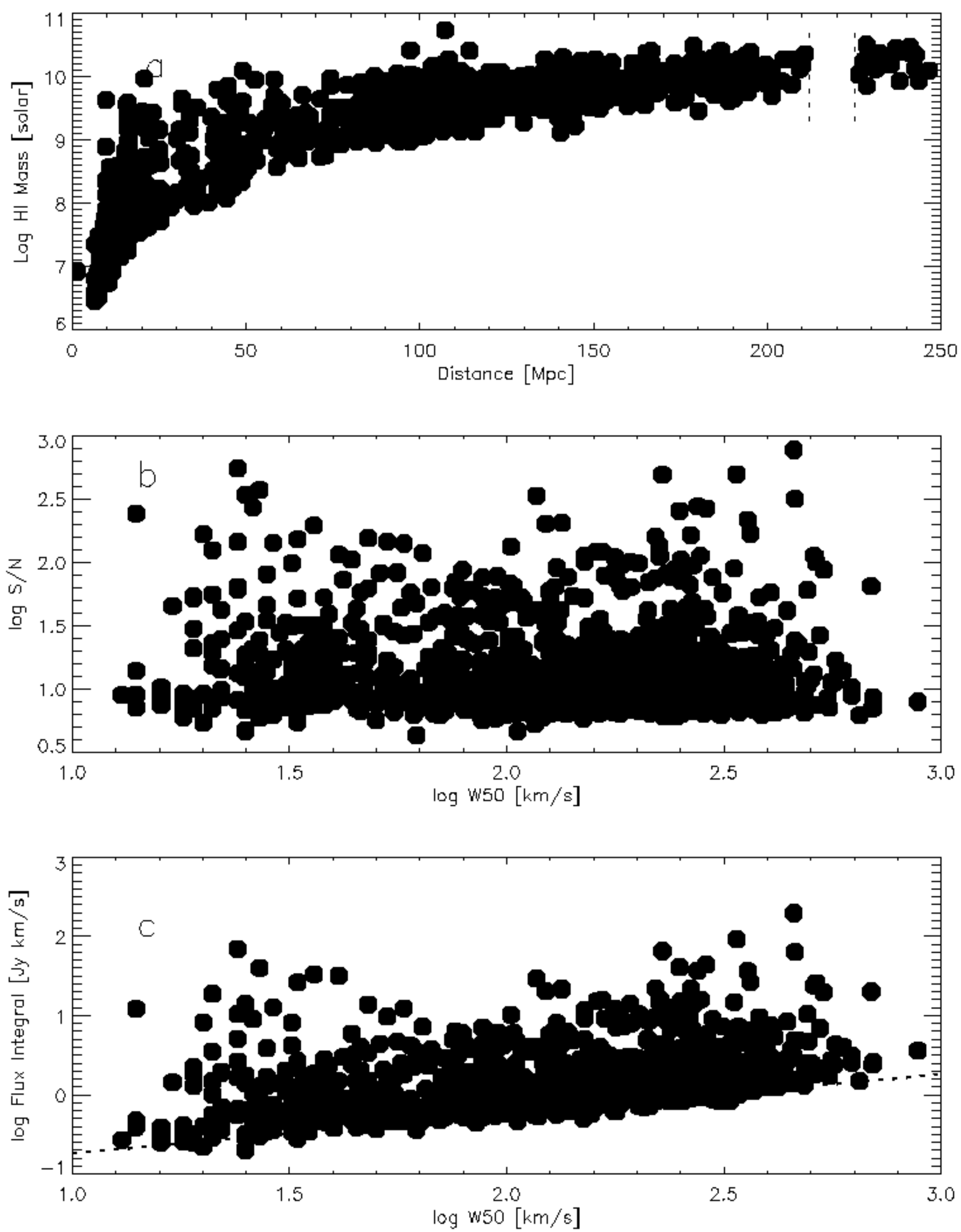
$$D_{Mpc} \propto t_s^{1/4}$$

➔ *You're better off increasing Ω_{survey} than increasing t_s*

Alternatively

$$\left(\frac{M_{HI}}{10^7 M_{sun}}\right) \approx 2.0\left(\frac{t_s}{40\sec}\right)^{-1/2}\left(\frac{D_{Mpc}}{16.7}\right)^2\left(\frac{W_{kms}}{25}\right)^{3/4}$$

ALFALFA



a
Log HI Mass [solar]
11
10
9
8
7
6
0
50
100
150
200
250
Distance [Mpc]
b
log S/N
3.0
2.5
2.0
1.5
1.0
0.5
1.0
1.5
2.0
2.5
3.0
log W50 [km/s]
c
log Flux Integral [Jy km/s]
3
2
1
0
−1
1.0
1.5
2.0
2.5
3.0
log W50 [km/s]

Who is ALFALFA?

ALFALFA is an open collaboration: anybody with a valid scientific interest can join.

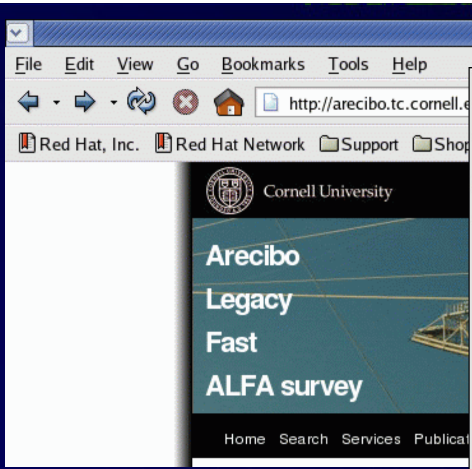
For participation guidelines, see:
http://egg.astro.cornell.edu/alfalfa/joining.php

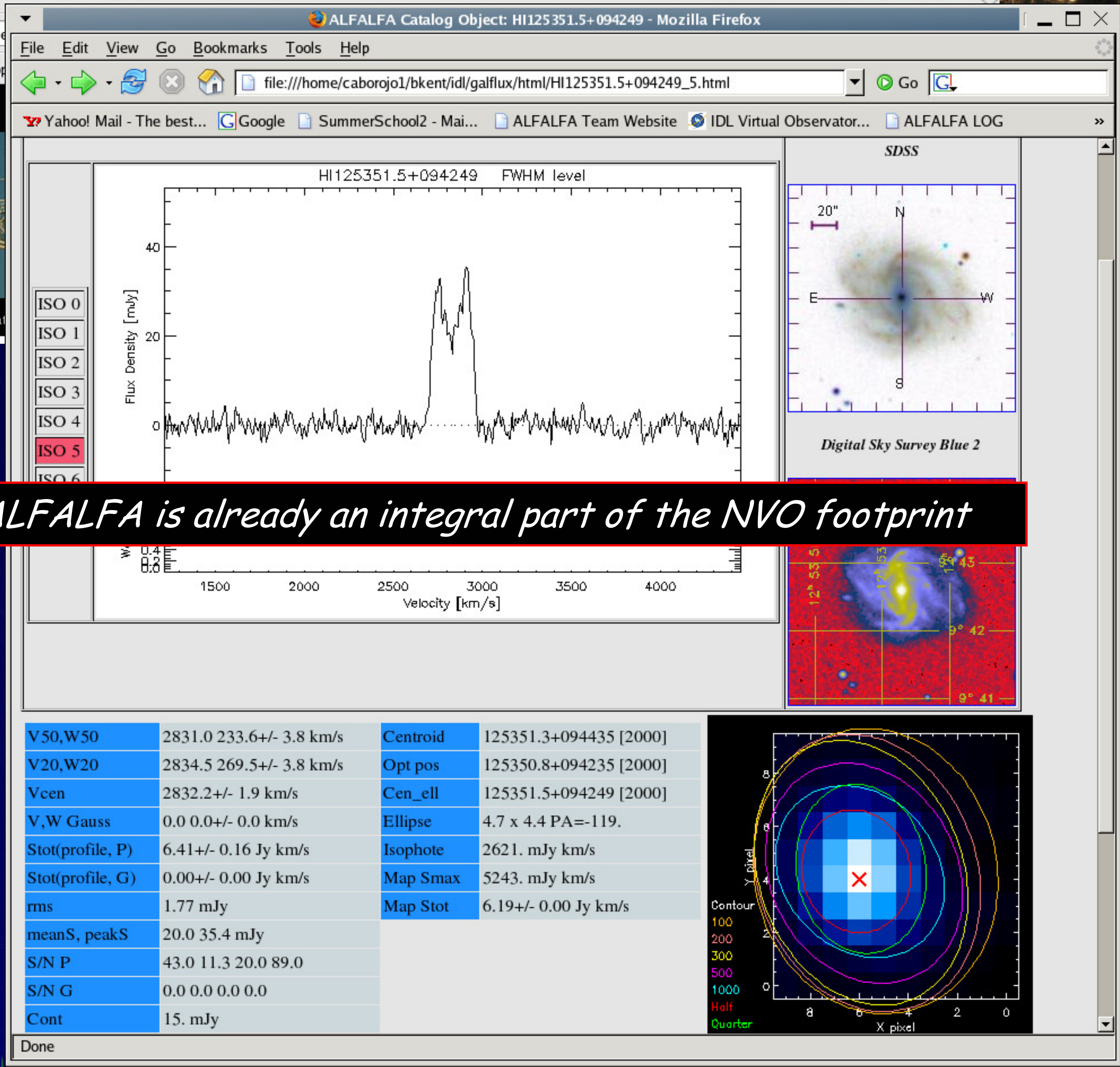
Recommended guidelines for authorship can be found at:
http://egg.astro.cornell.edu/alfalfa/projects/authorshipguidelines.php

Project Guidelines:
http://egg.astro.cornell.edu/alfalfa/projects/projectguidelines.php

Projects (Team/PhD/undergrad):
http://egg.astro.cornell.edu/alfalfa/projects/projects.php

ALFALFA





ALFALFA is already an integral part of the NVO footprint

ALFALFA data products can be accessed through the web using robust, NVO-compatible software tools, developed by our students, thanks to an NSF/NVO development grant and the archival support of the Cornell Theory Center.

ALFALFA

Science Goals to Be Addressed by ALFALFA:

1 Determination & environmental variation of the faint end of the HI Mass Function and the cosmic abundance of low mass halos

2 Global properties of HI-selected galaxy samples

3 The LSS of HI sources, the "void problem" & metallicity

4 Blind Survey for HI tidal remnants & "cold accretion"

5 HI Diameter Function

6 The low HI Column density environment of galaxies

7 The nature of HVC's around the MW (and beyond?)

8 HI absorbers and the link to Lyman α absorbers

9 OH Megamasers at intermediate redshift

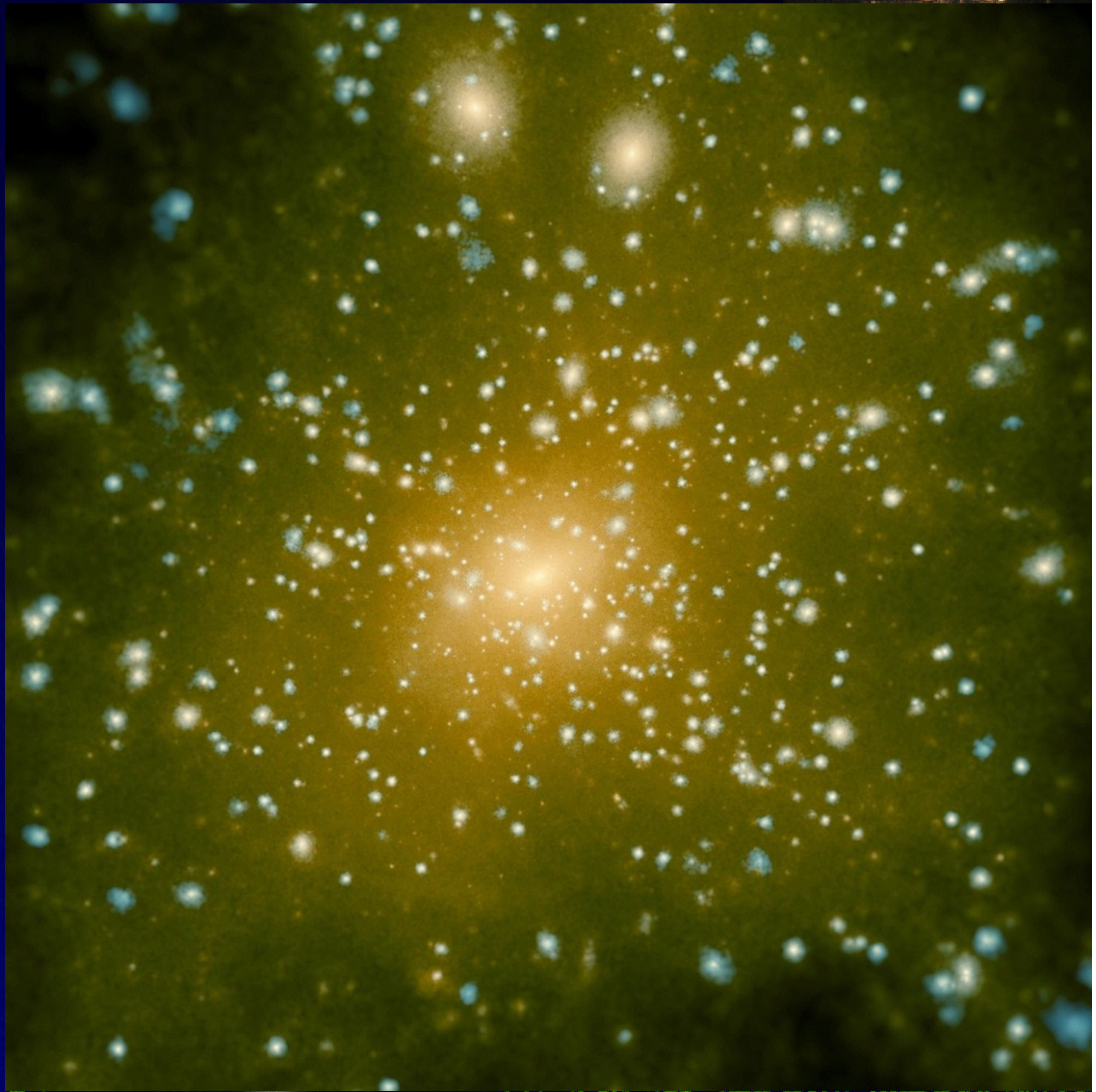
ALFALFA

How and when do galaxies form?

Numerical simulations predict the existence of lots of low mass halos, but so far, we have not found very many of them.

Do they exist?

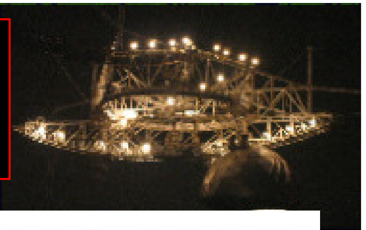
- *Are baryons in small Dark Matter halos fried at the epoch of reionization?*
- *Are they blown away by the first generation of stars?*
- *Are they retained but unable to make stars?*
- *Is that more likely in cosmic voids?*



Credit: Virgo collaboration (MPIfAp)

ALFALFA

The HI Mass Function (HIMF)

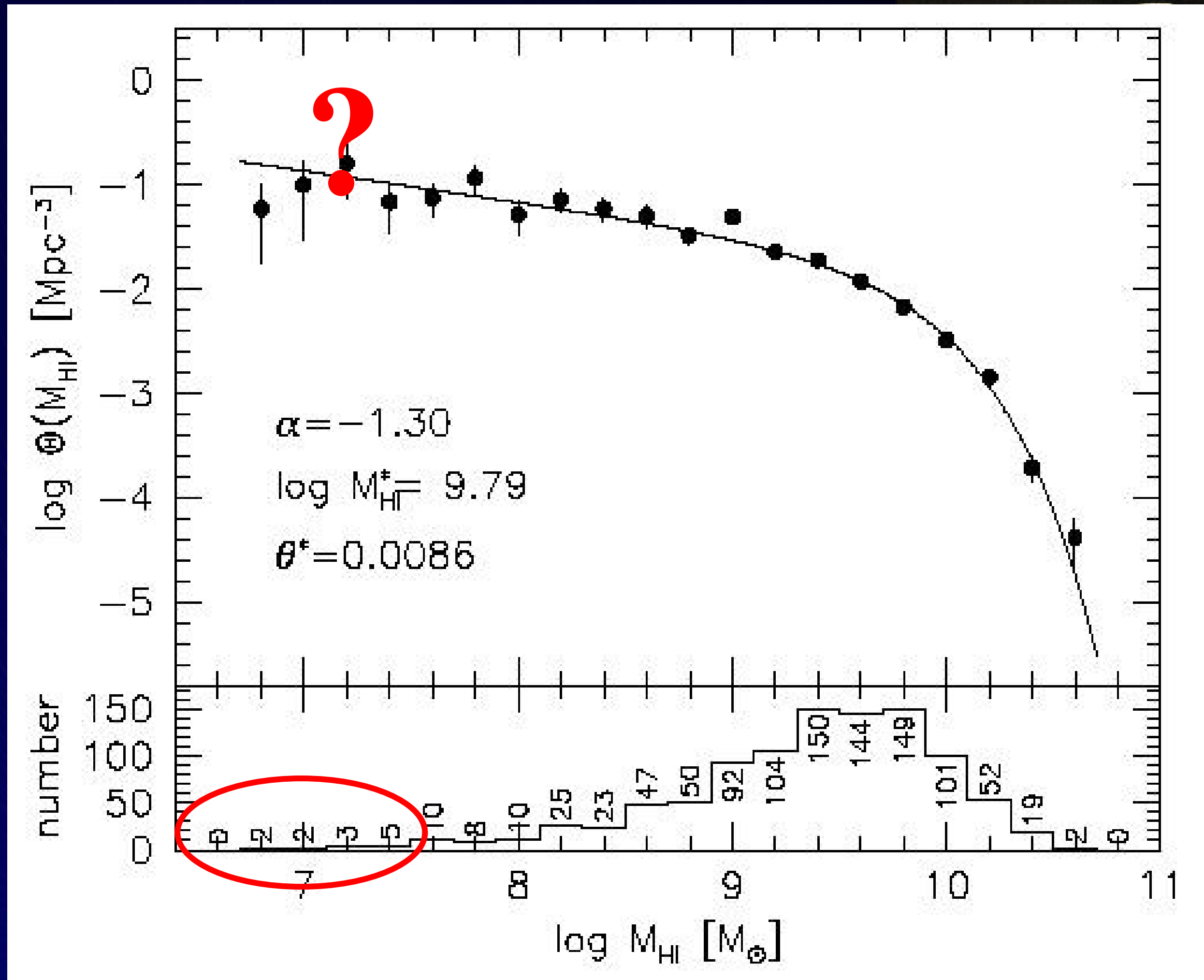


- Previous surveys have detected few (if any) objects with low HI.
- At low mass end, HIMF estimates differ by >10X:

  Rosenberg & Schneider (2000)

  versus

  Zwaan et al. (1997)



Parkes HIPASS survey: Zwaan et al. 2003

ALFALFA

ALFALFA: First Catalog Release

RA: 11:44h to 14:00h
Dec: 12deg to 16deg
Solid Angle: 132 sq deg
(1.9% of survey)

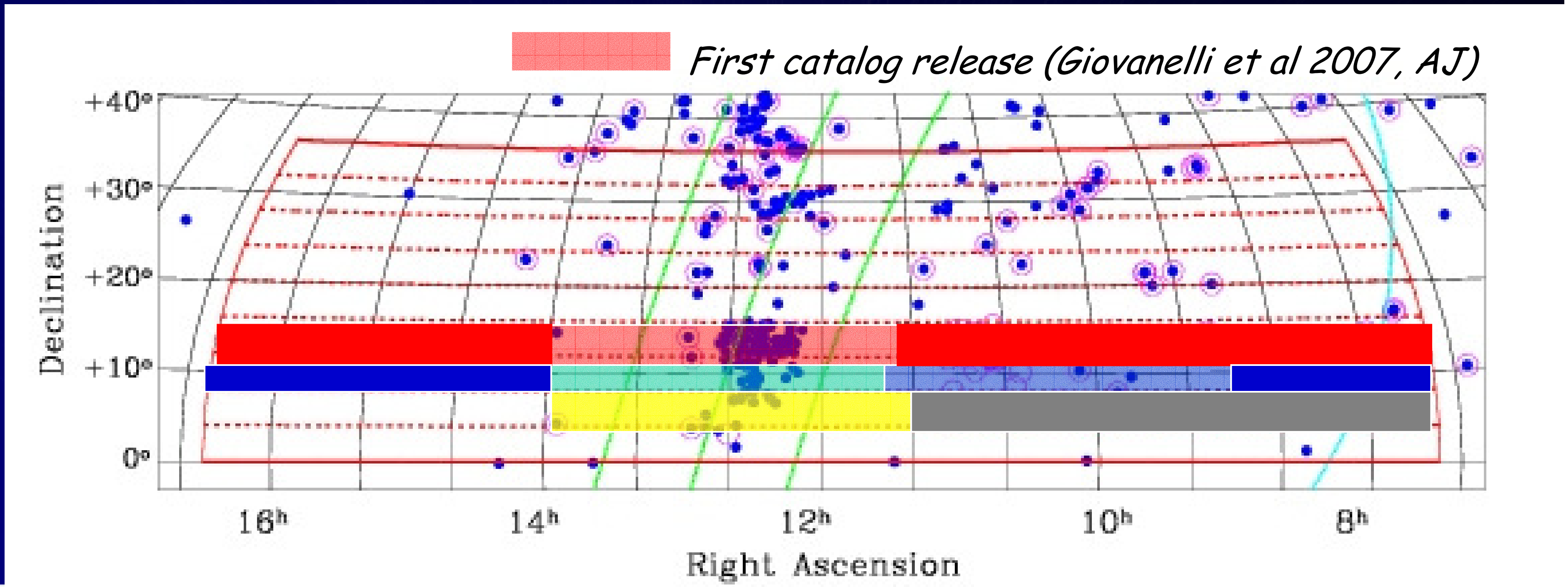
Catalogs in preparation :

- Brian Kent et al.
- Sabrina Stierwalt et al.
- R. Koopmann et al.
- M. Haynes et al.
- R. Giovanelli et al.
- J. Dowell et al.

Saintonge et al. 2007 (AJ, Fall sky)

For public access see:

http://arecibo.tc.cornell.edu/hiarchive/alfalfa



A Comparison with HIPASS

Over the 132 sq. deg. including the northern part of Virgo, i.e. RA=[11:44-14:00], Dec=[14.-16.0] :

➔ *ALFALFA detects 730 sources, HIPASS 40 (2 unconfirmed)*

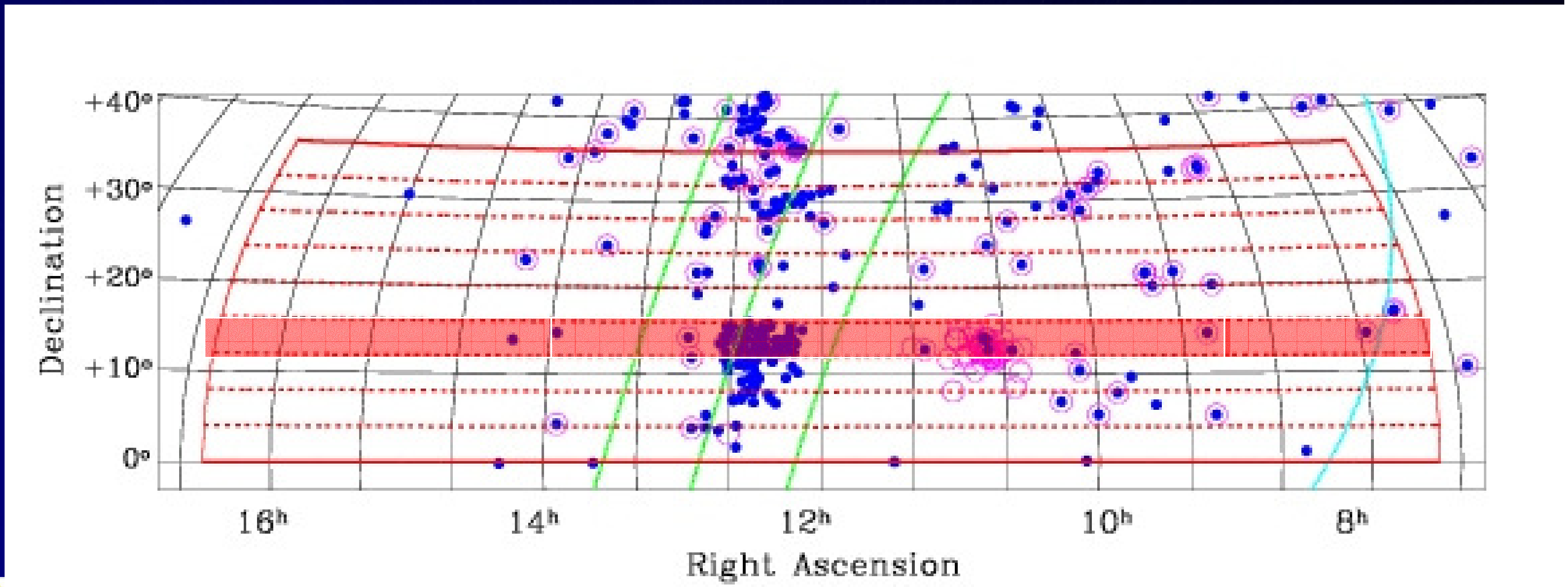
➔ *While this region is perhaps the most intensively studied in the local Universe, at all wavelength bands (including HI, using optically selected samples),*

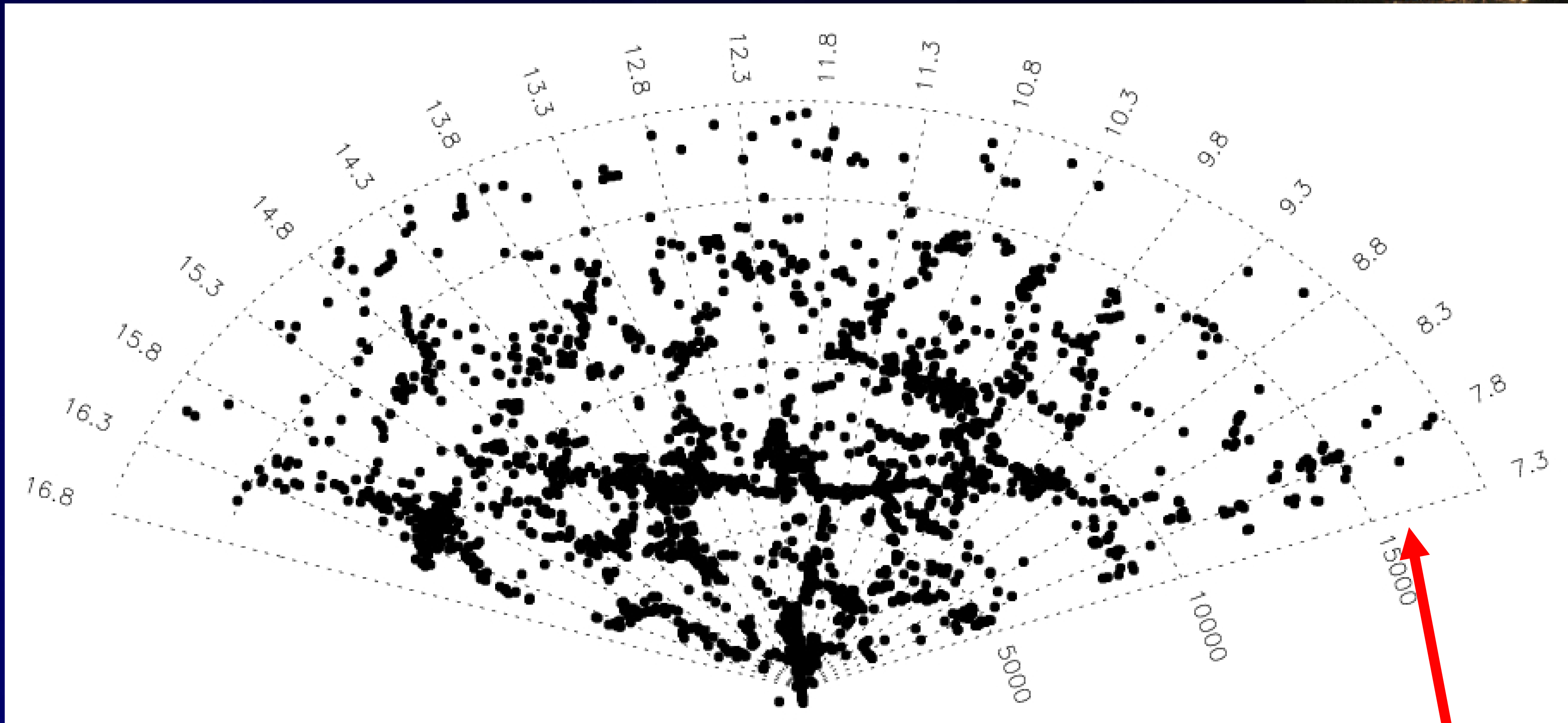
- ➔ *69% of ALFALFA detections are new (the conventional wisdom on which optical targets would turn out to be HI-rich appears to have been limited)*

ALFALFA

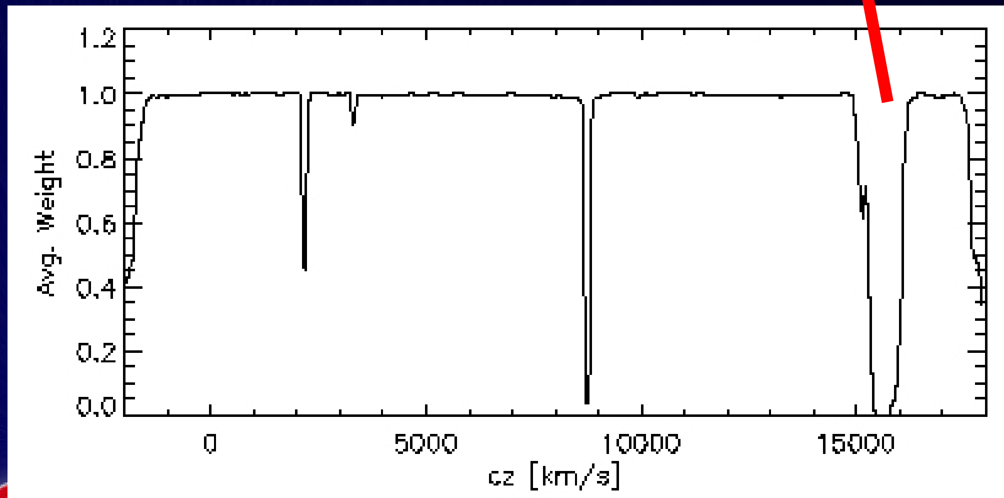
ALFALFA: Preliminary Results from a strip through Virgo

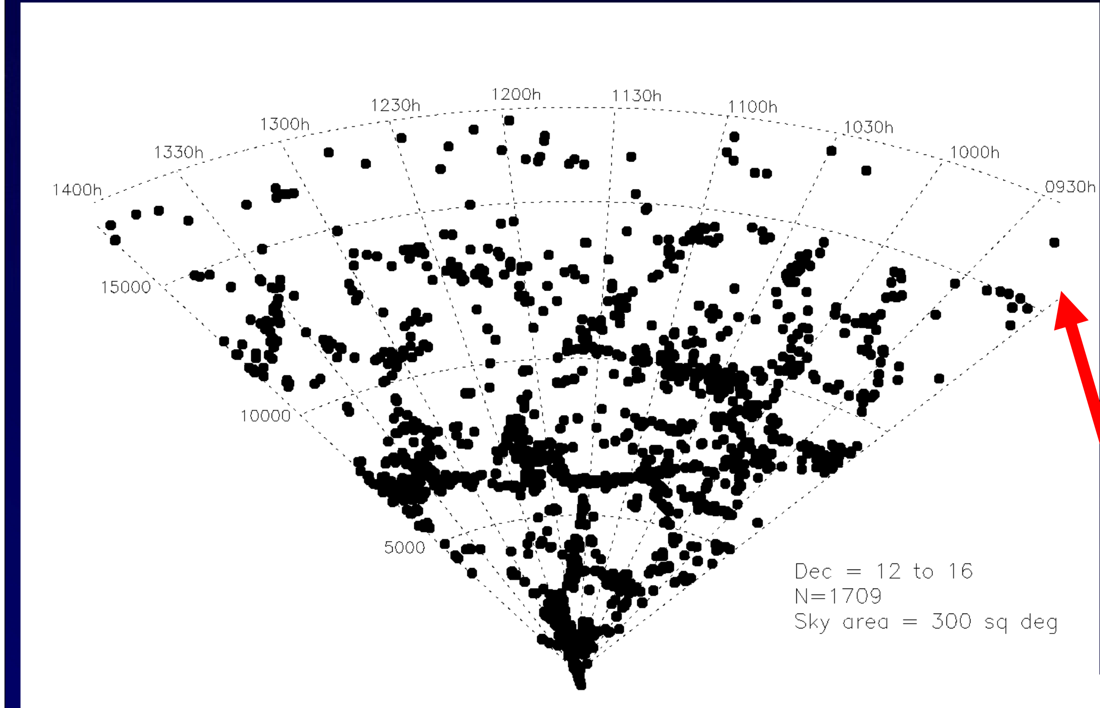
RA: 07:40h to 16:30h
Dec: 12deg to 16deg
Solid Angle: 524 sq deg
(7.5% of survey)



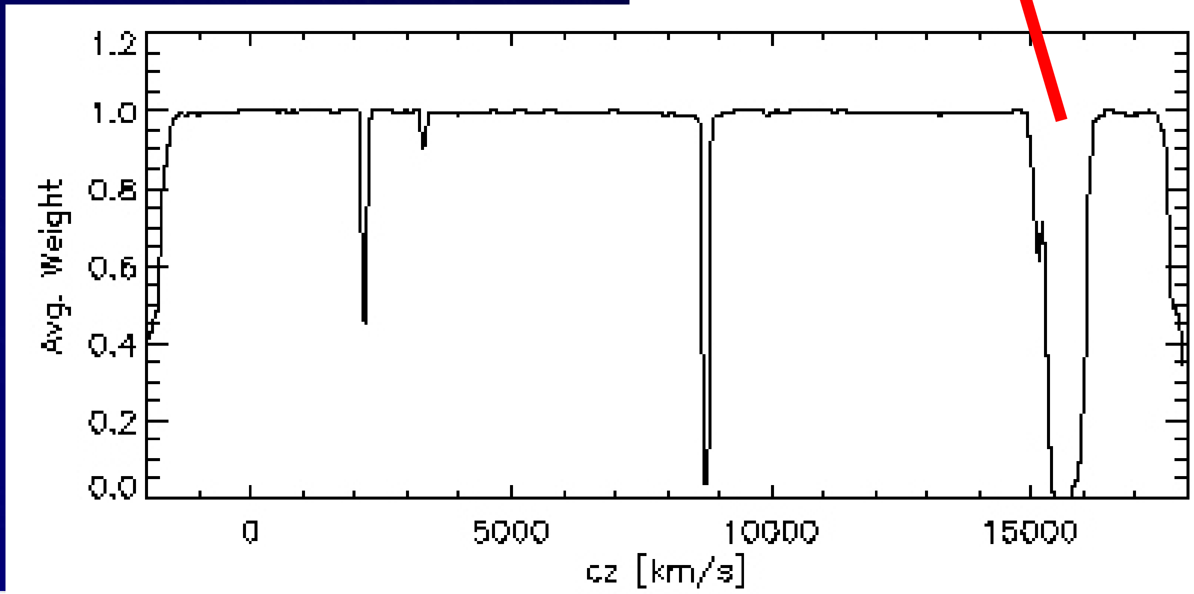


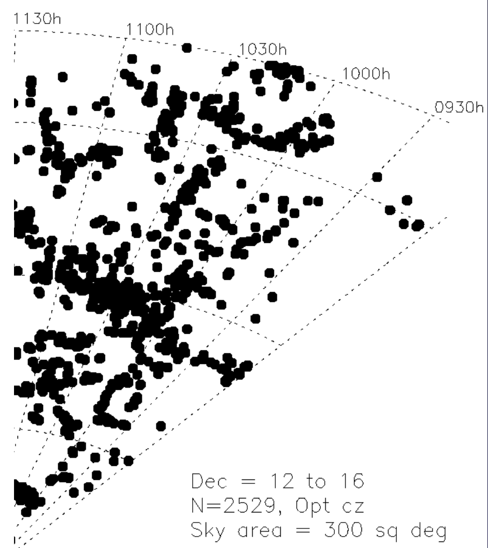
N = 2657
RA= 7.5 to 16.5 hrs
Dec = 12 to 16 deg
7.5% of survey solid angle





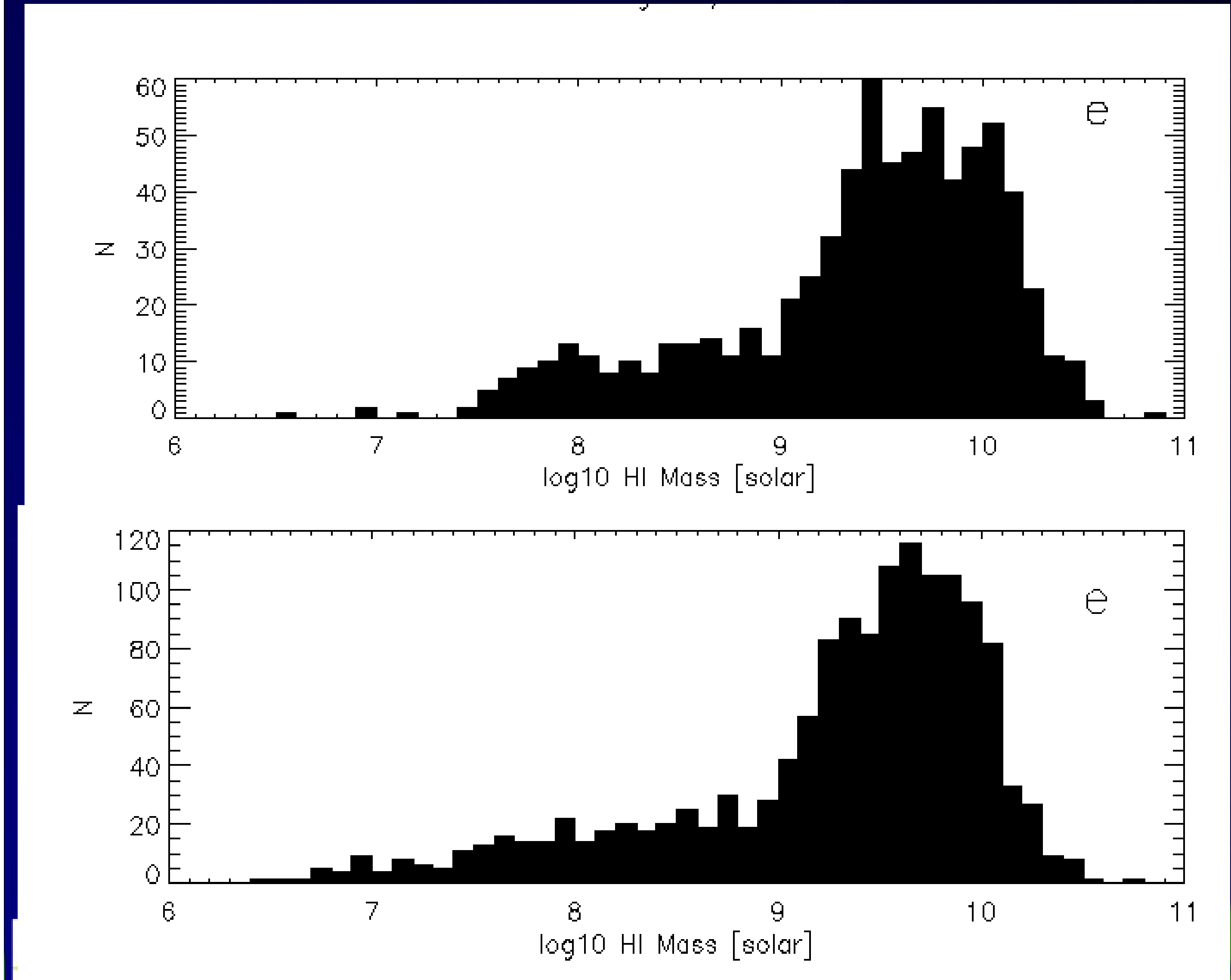
←HI (ALFALFA)
N=1709





ALFALFA

Problem with Virgo/foreground Distances



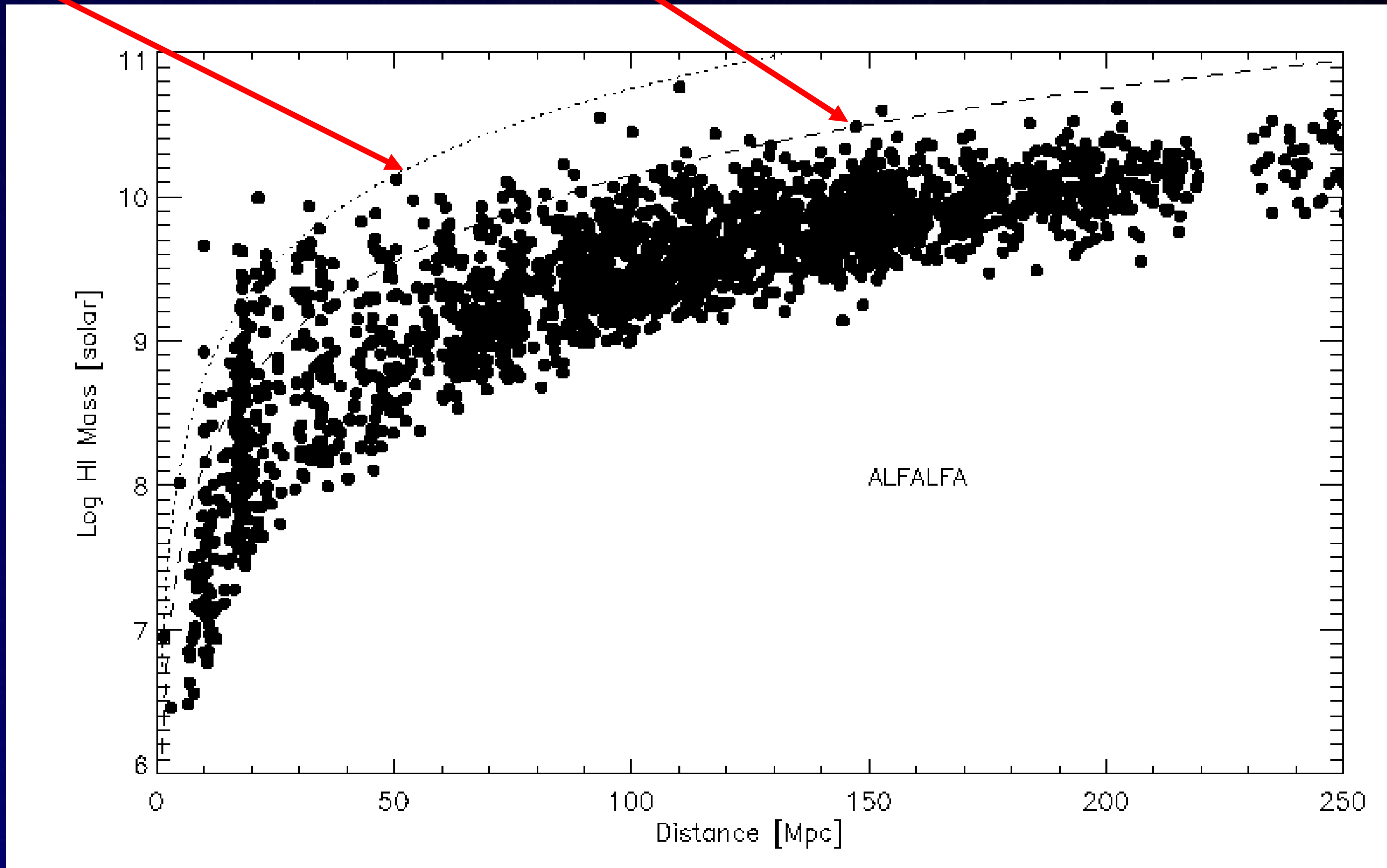
RA Range:

1144 – 1400 (largely Virgo)

0900 - 1400

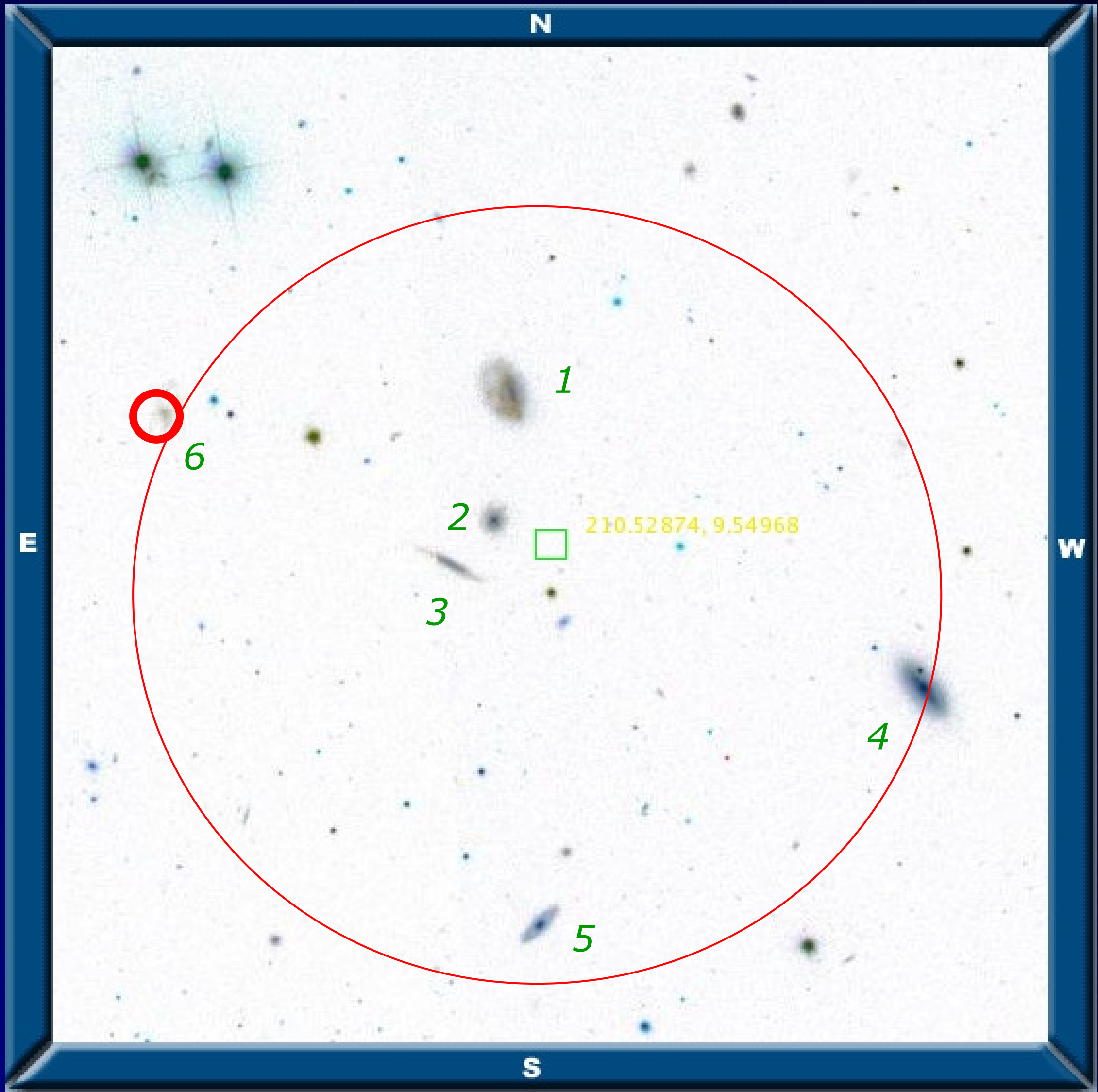
HIPASS Completeness Limit

HIPASS Limit



Source extraction and identification of counterparts at other wavelength regimes can be a painful experience…

...source centroiding as accurately as possible is thus highly desirable



Centroiding accuracy goes roughly as

HPFW(PSF)/(S/N)

Suppose HIPASS detects a source at S/N~6 near 3000 km/s in this field. The position error box will have a radius of ~2.5′.

The opt counterpart could be gal #1, 2, 3, 4, 5 or 6.

ALFALFA will detect the same source with S/N~50

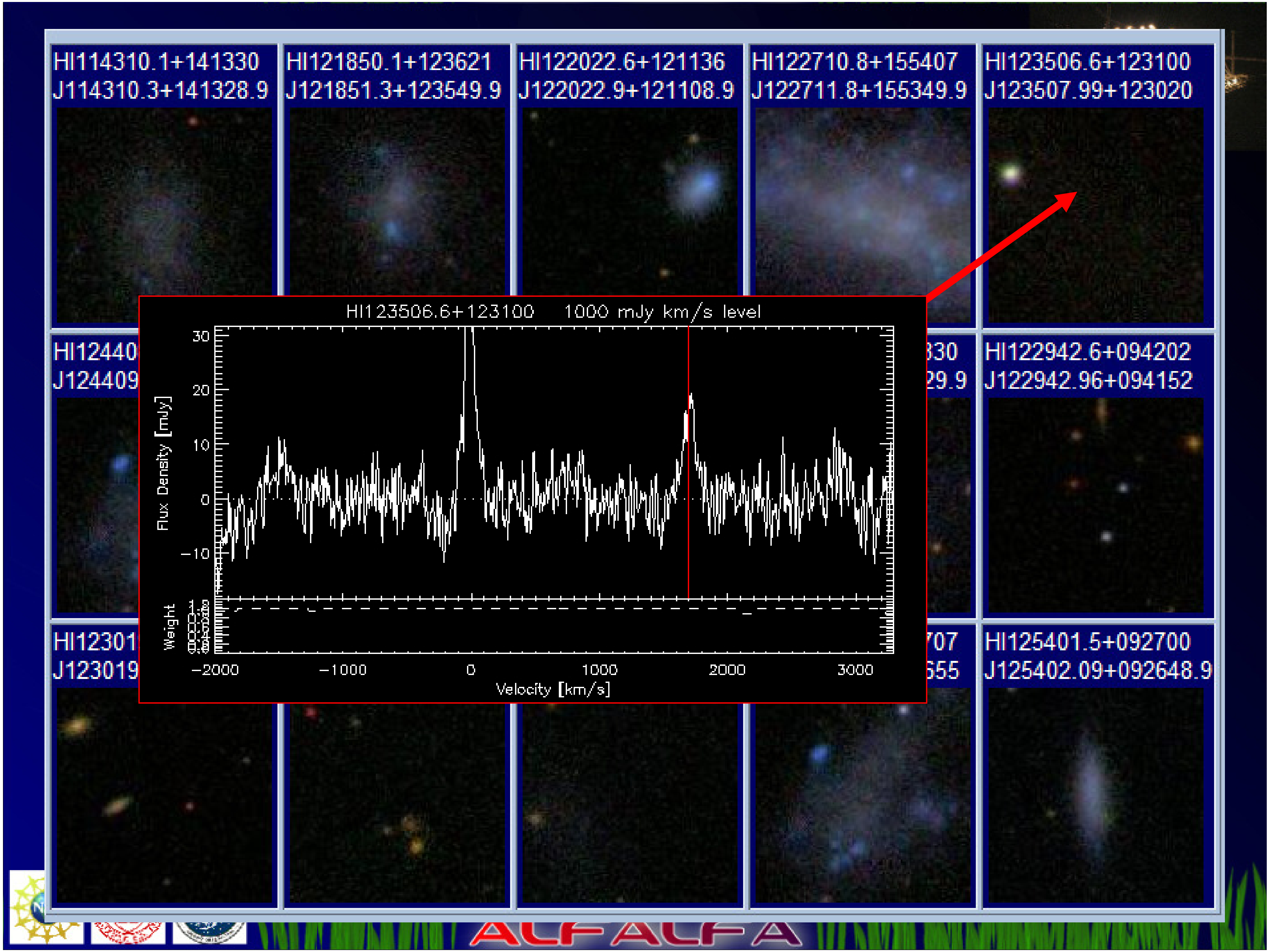
and the Arecibo beam is ¼ as wide as the Parkes one

➔ *The same source will have an ALFALFA position error of ~ 0.1′*

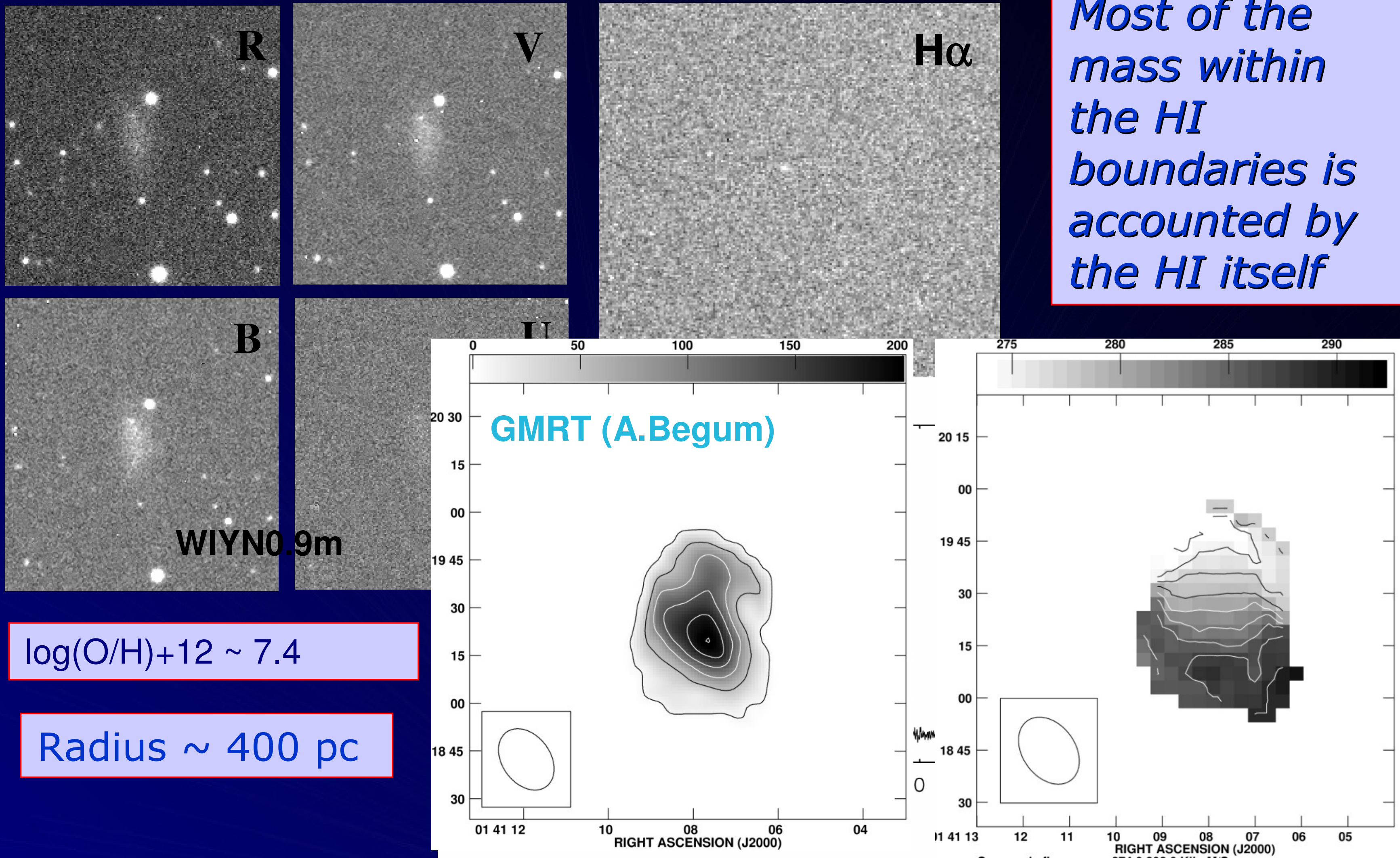
ALFALFA

So what do we find?


HI114310.1+141330
J114310.3+141328.9
HI121850.1+123621
J121851.3+123549.9
HI122022.6+121136
J122022.9+121108.9
HI122710.8+155407
J122711.8+155349.9
HI123506.6+123100
J123507.99+123020
HI124408.7+120707
J124409.59+120655
HI125602.2+120800
J125603.1+120759
HI122441.1+083007
J122439.59+083010
HI122650.7+113330
J122650.4+113329.9
HI122942.6+094202
J122942.96+094152
HI123019.2+093526
J123019.43+093516
HI123025.7+092809
J123025.92+092759
HI124316.2+085700
J124319.69+085710
HI124408.6+120707
J124409.59+120655
HI125401.5+092700
J125402.09+092648.9
ALFALFA


HI114310.1+141330
J114310.3+141328.9
HI121850.1+123621
J121851.3+123549.9
HI122022.6+121136
J122022.9+121108.9
HI122710.8+155407
J122711.8+155349.9
HI123506.6+123100
J123507.99+123020
HI122942.6+094202
J122942.96+094152
HI125401.5+092700
J125402.09+092648.9
HI123506.6+123100 1000 mJy km/s level
Flux Density [mJy]
30
20
10
0
−10
Weight
−2000
−1000
0
1000
2000
3000
Velocity [km/s]
ALFALFA

Extremely metal-poor galaxies



Most of the mass within the HI boundaries is accounted by the HI itself

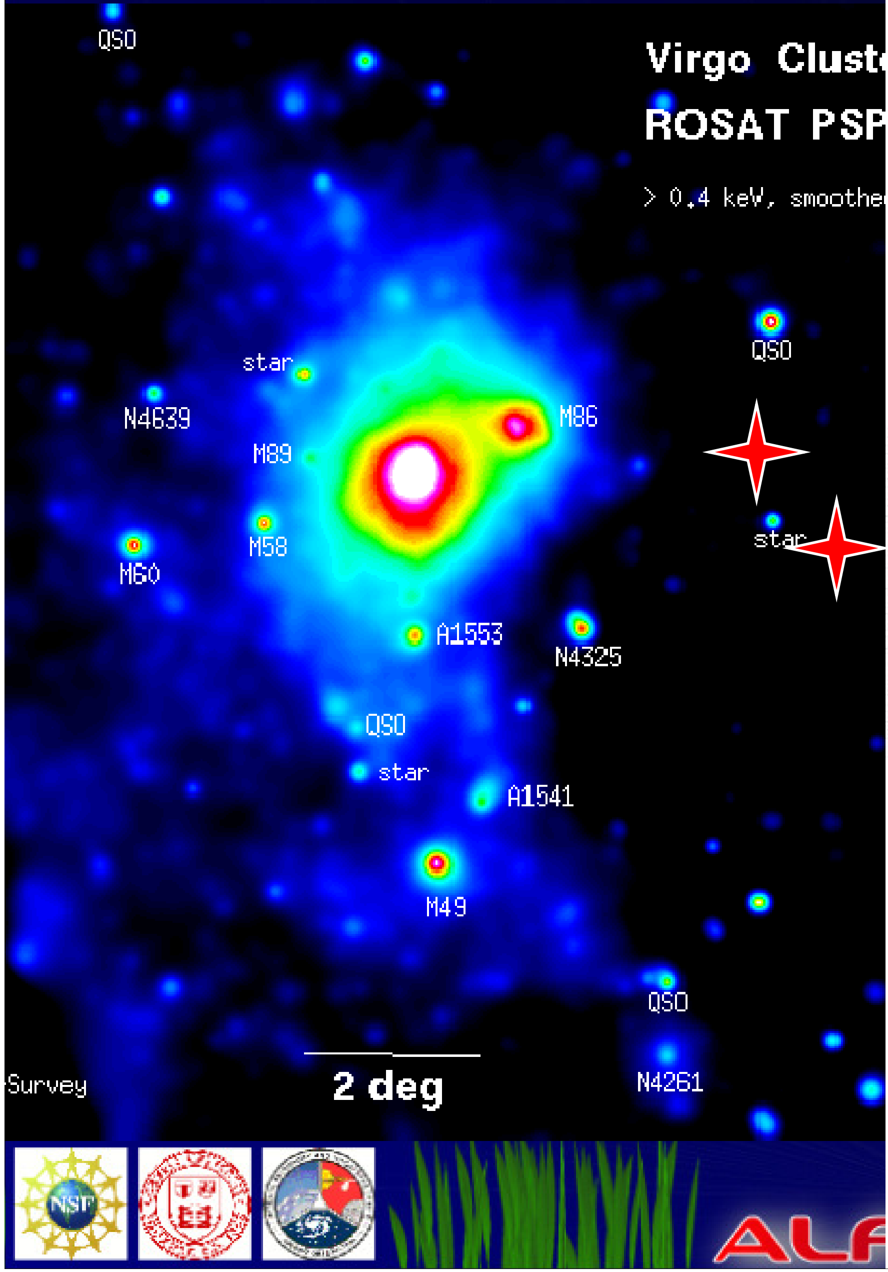
log(O/H)+12 ~ 7.4

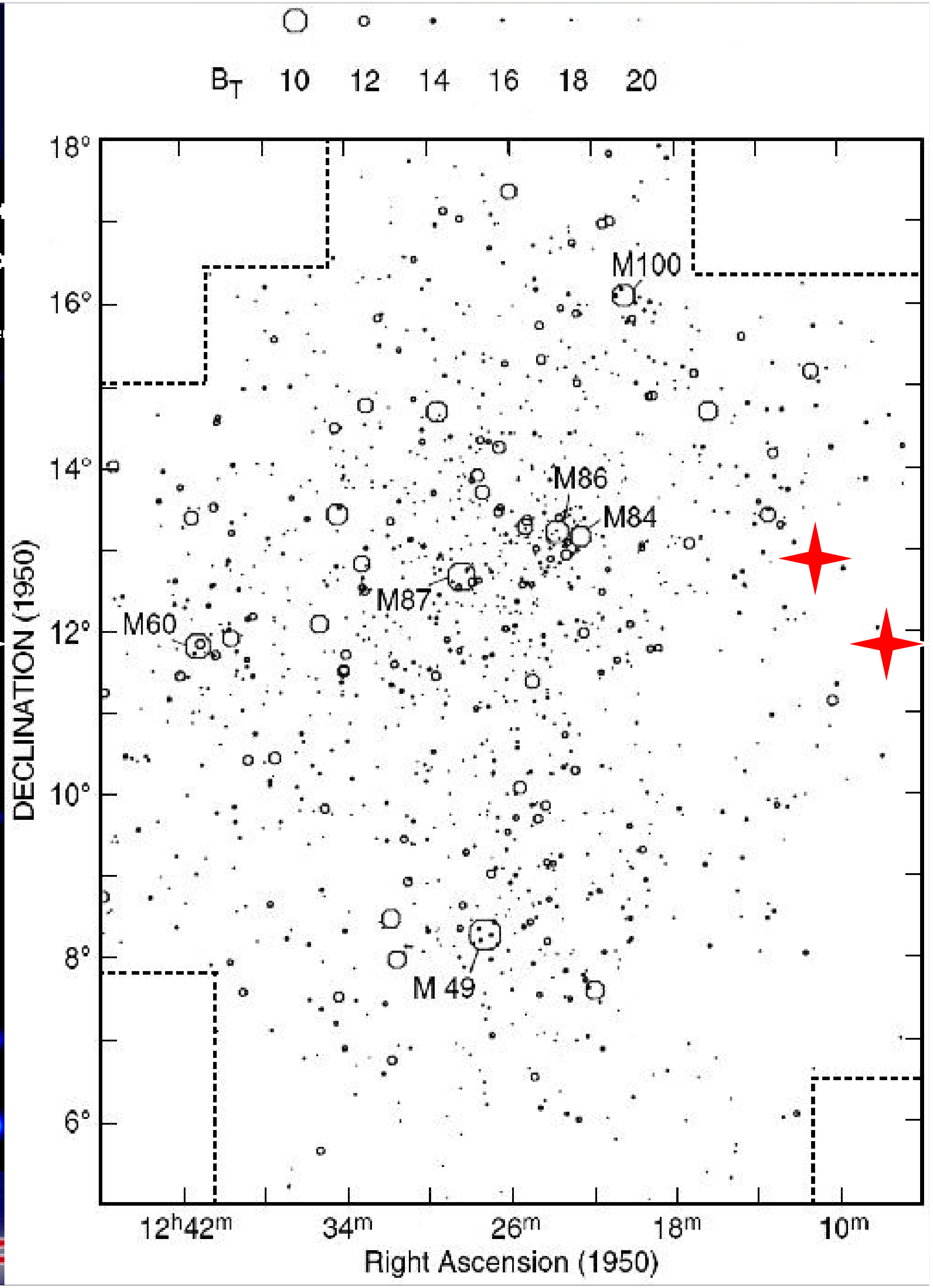
Radius ~ 400 pc

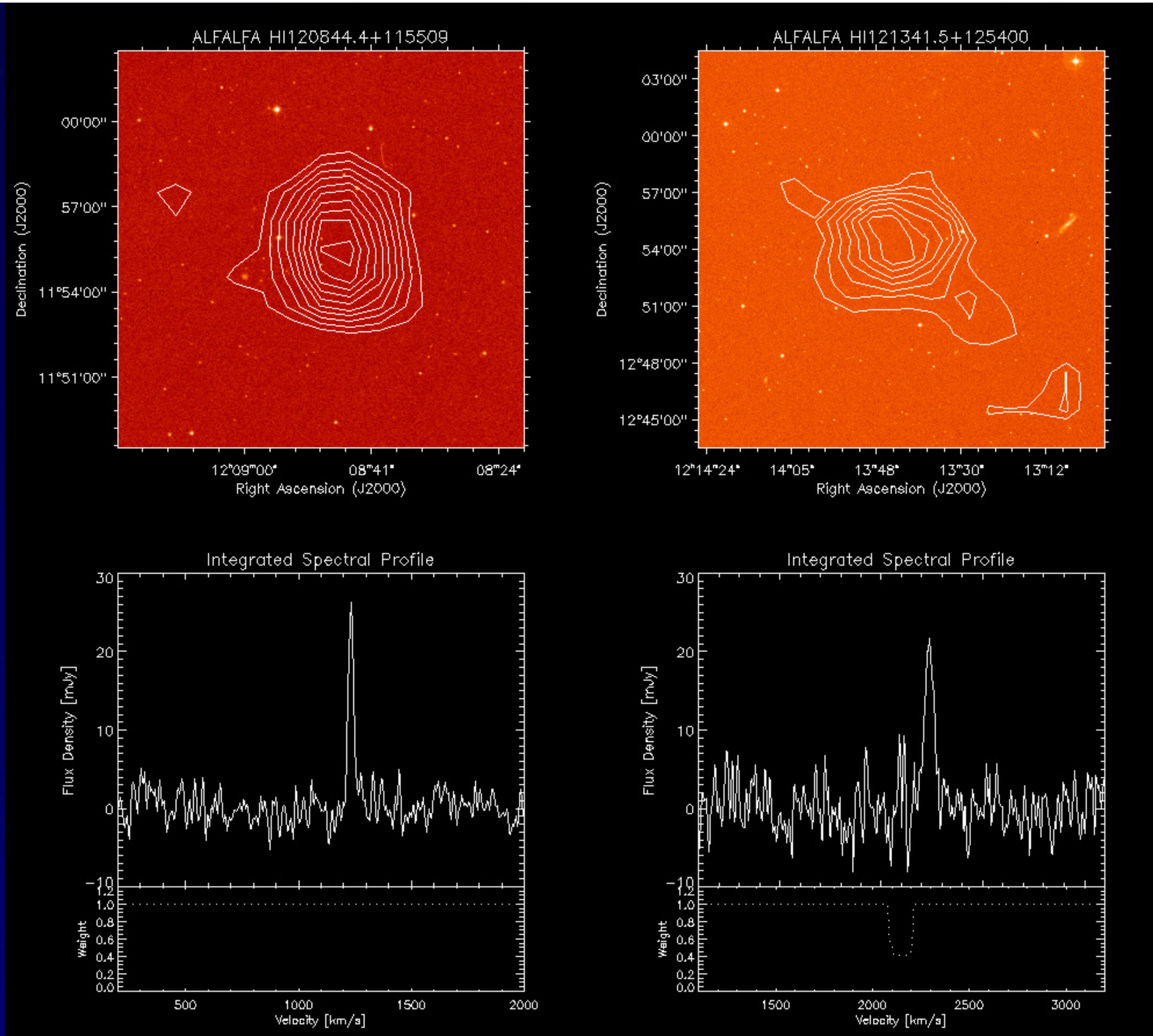
HI0141+27, a metal-poor galaxy : Saintonge, Begum et al. (*in prep*)

A few goodies near Virgo
(an HI cloud cemetery? …)

Two "stray" clouds





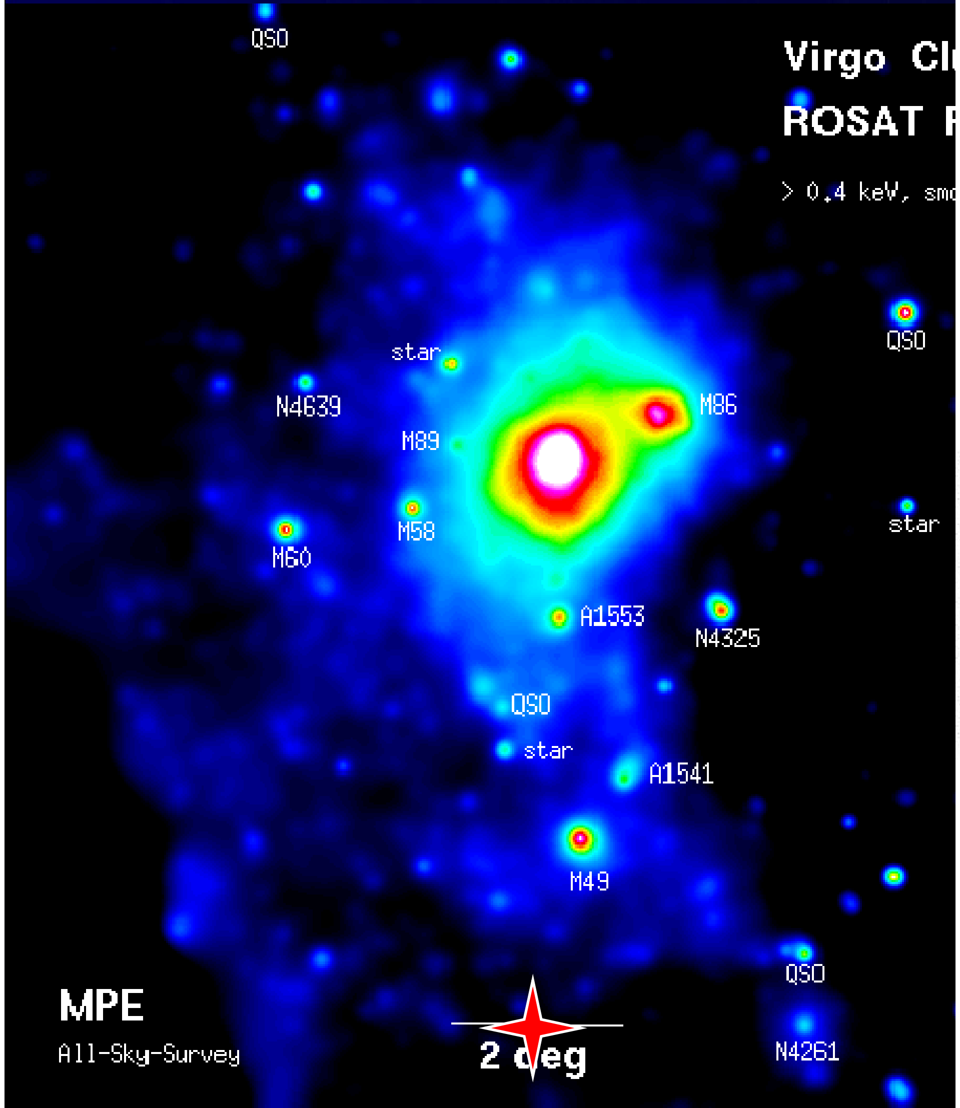


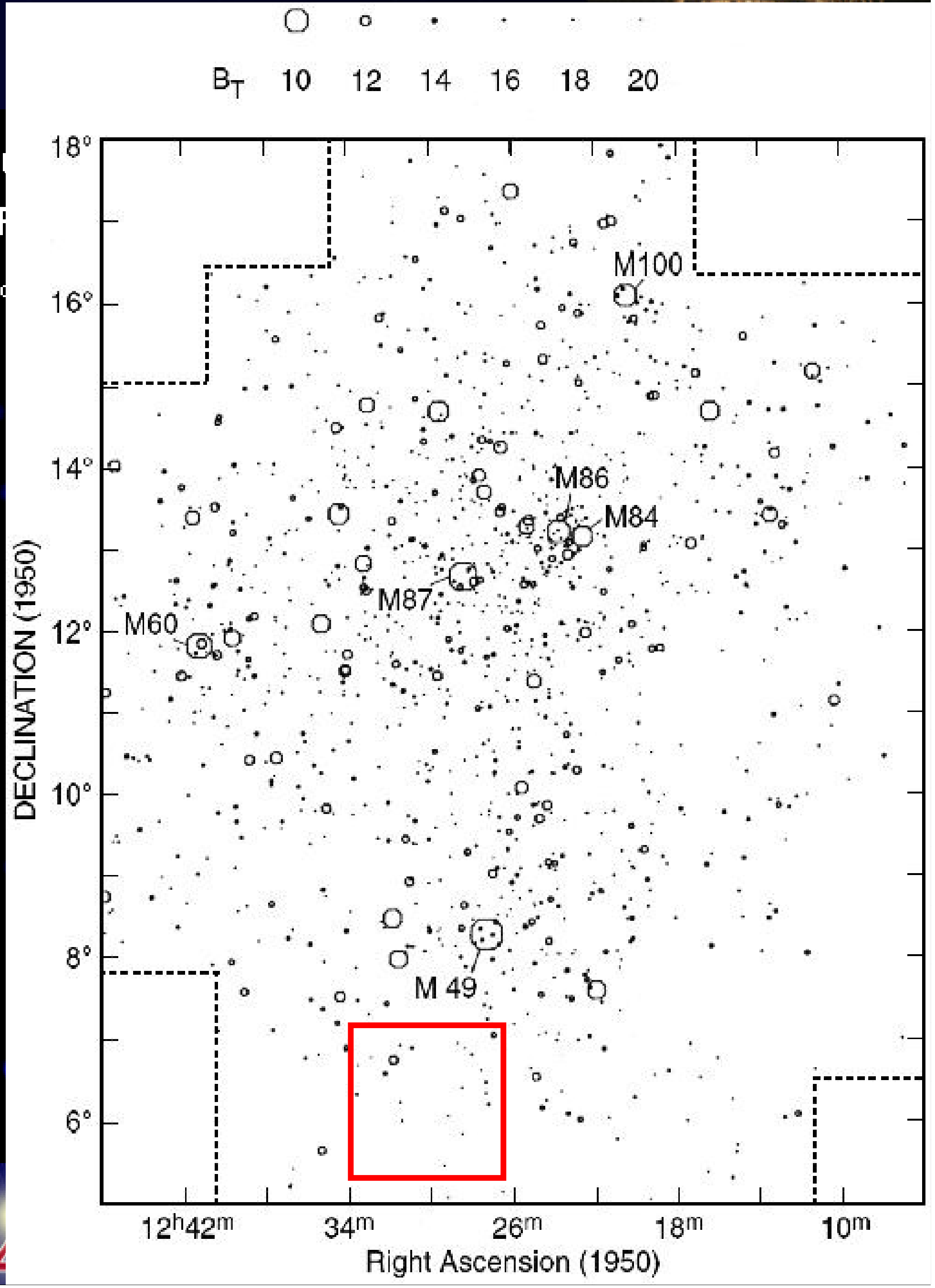
4.76 x 10^7 $M_\odot$

7.29 x 10^7 $M_\odot$

Brian Kent et al.
(2007 ApJL submitted)

A recent discovery in the ALFALFA data by Becky Koopmann…





NGC4532

DDO137

Hoffman et al 1993 AJ 106,39

Arecibo HI

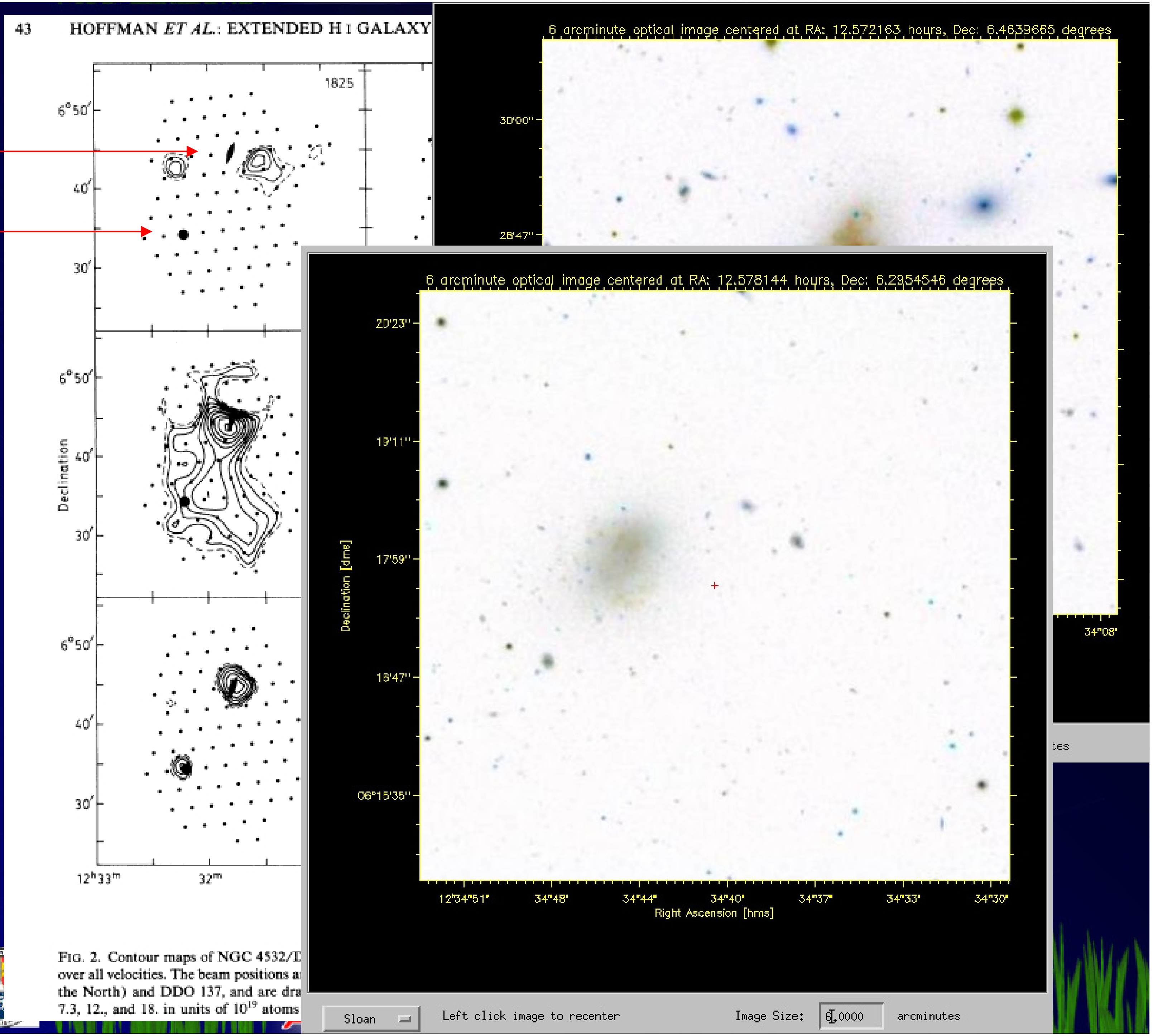
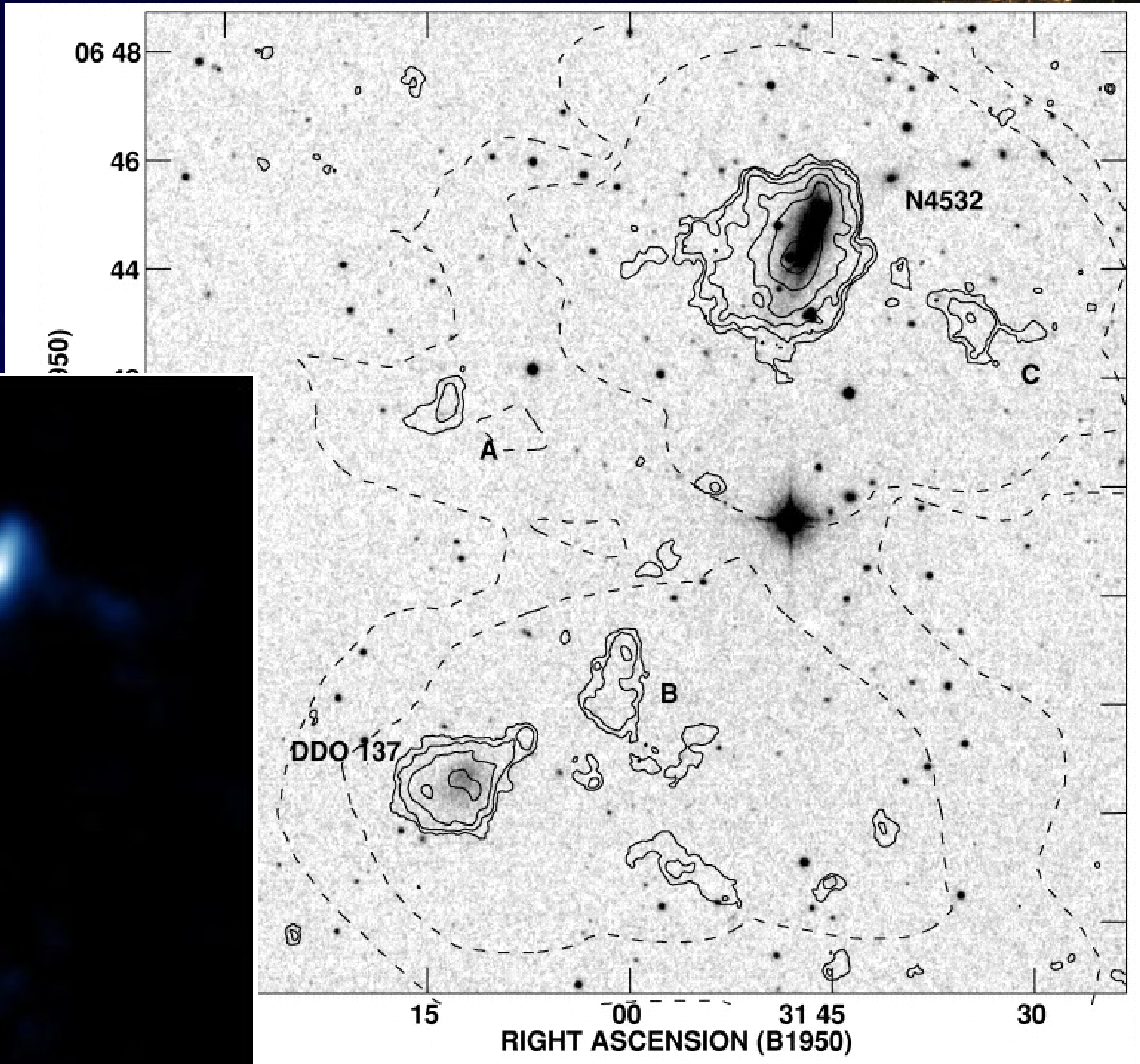


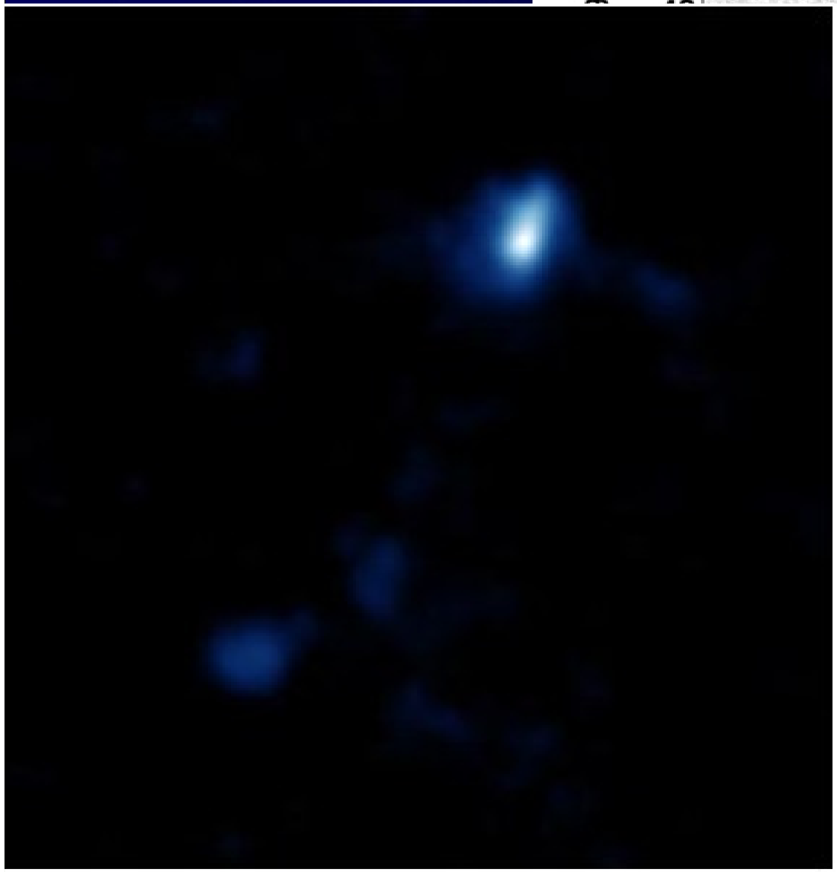
FIG. 2. Contour maps of NGC 4532/D
over all velocities. The beam positions a
the North) and DDO 137, and are dra
7.3, 12., and 18. in units of 10^{19} atoms

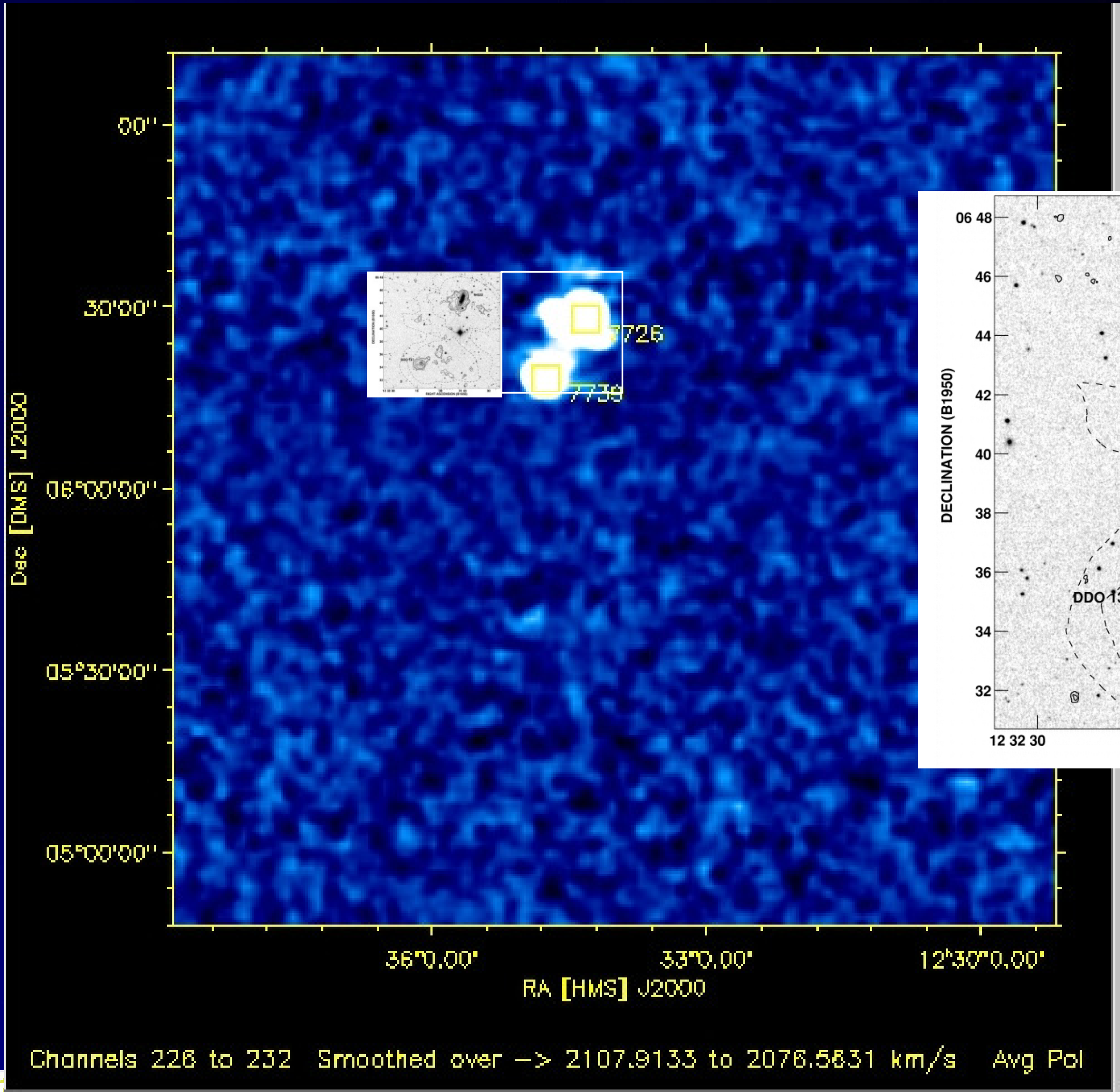
Hoffman et al. 1999
AJ 117, 811

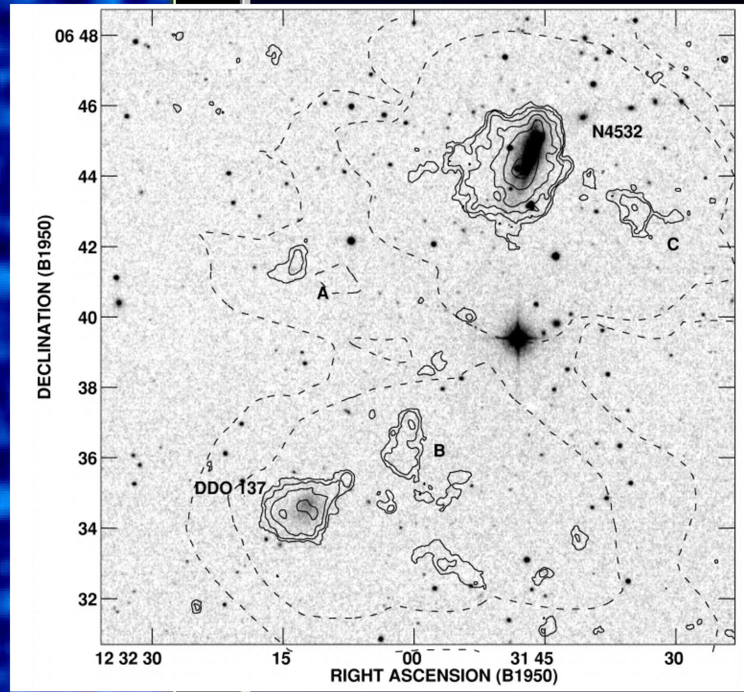


VLA Data

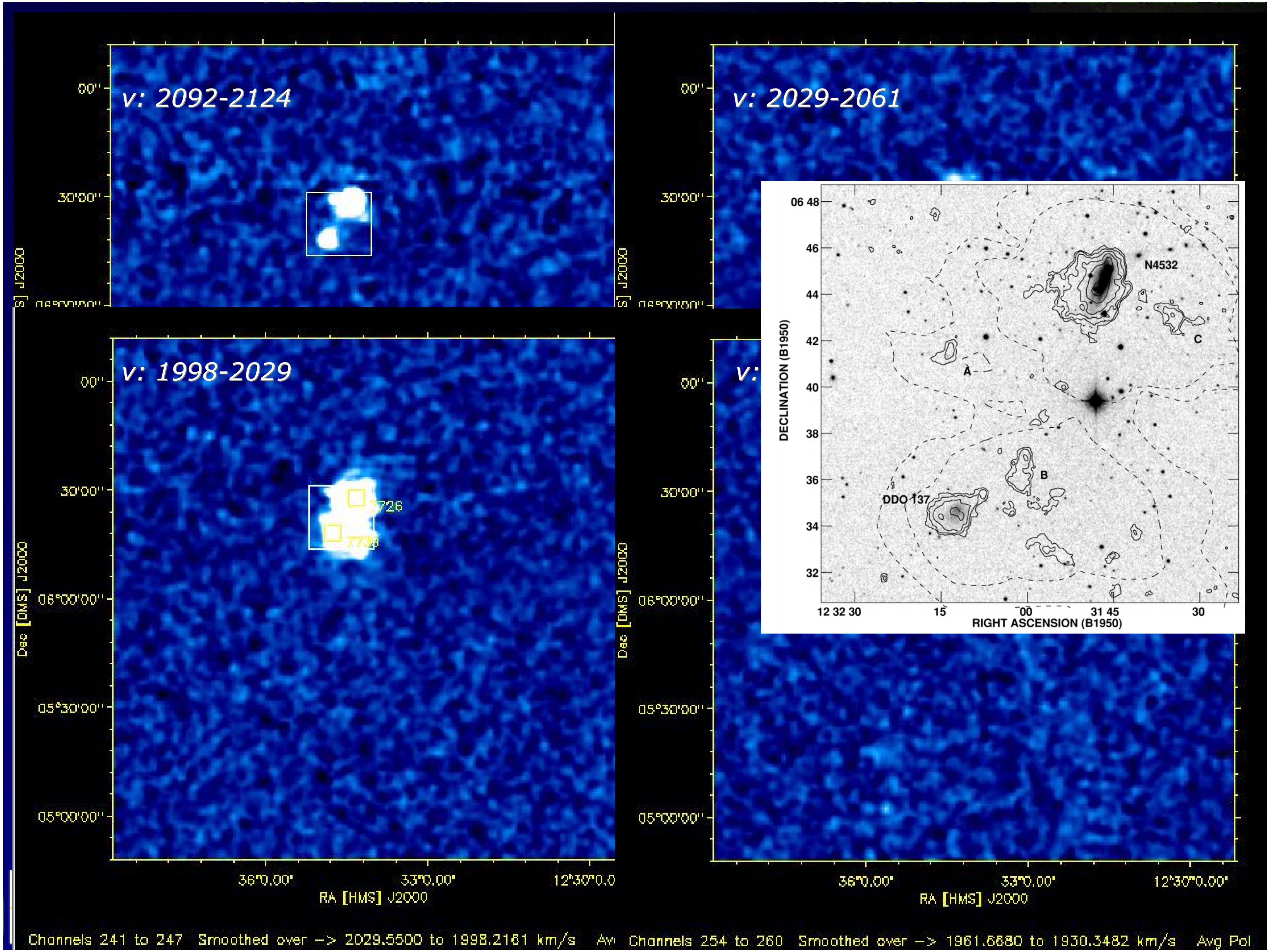
VIVA (Kenney et al)

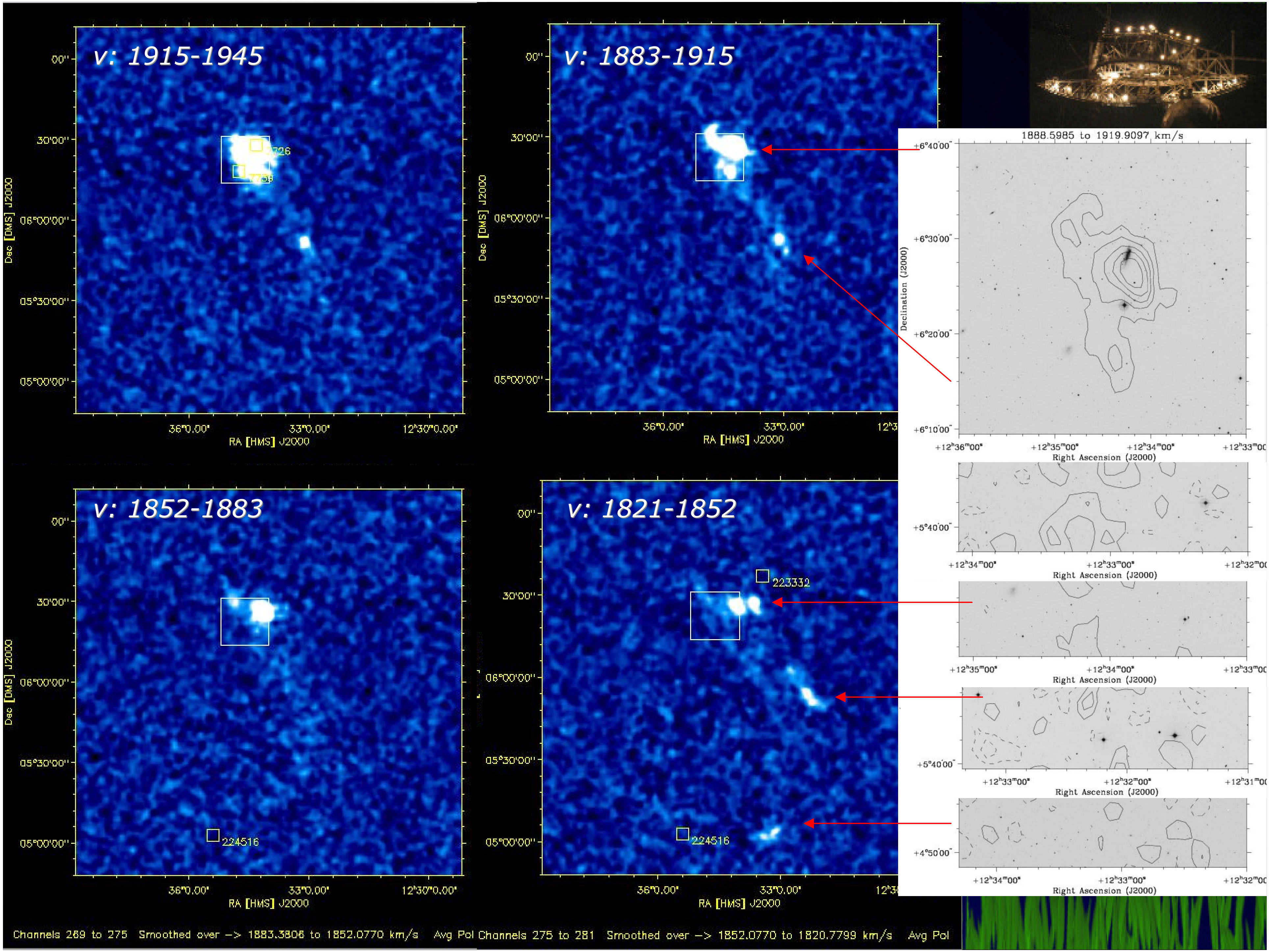



00''
30'00''
06°00'00''
05°30'00''
05°00'00''
Dec [DMS] J2000
7726
7739
36m0.00s
33m0.00s
12h30m0.00s
RA [HMS] J2000
Channels 226 to 232 Smoothed over -> 2107.9133 to 2076.5831 km/s Avg Pol


06 48
46
44
42
40
38
36
34
32
DECLINATION (B1950)
N4532
C
A
B
DDO 137
12 32 30
15
00
31 45
30
RIGHT ASCENSION (B1950)

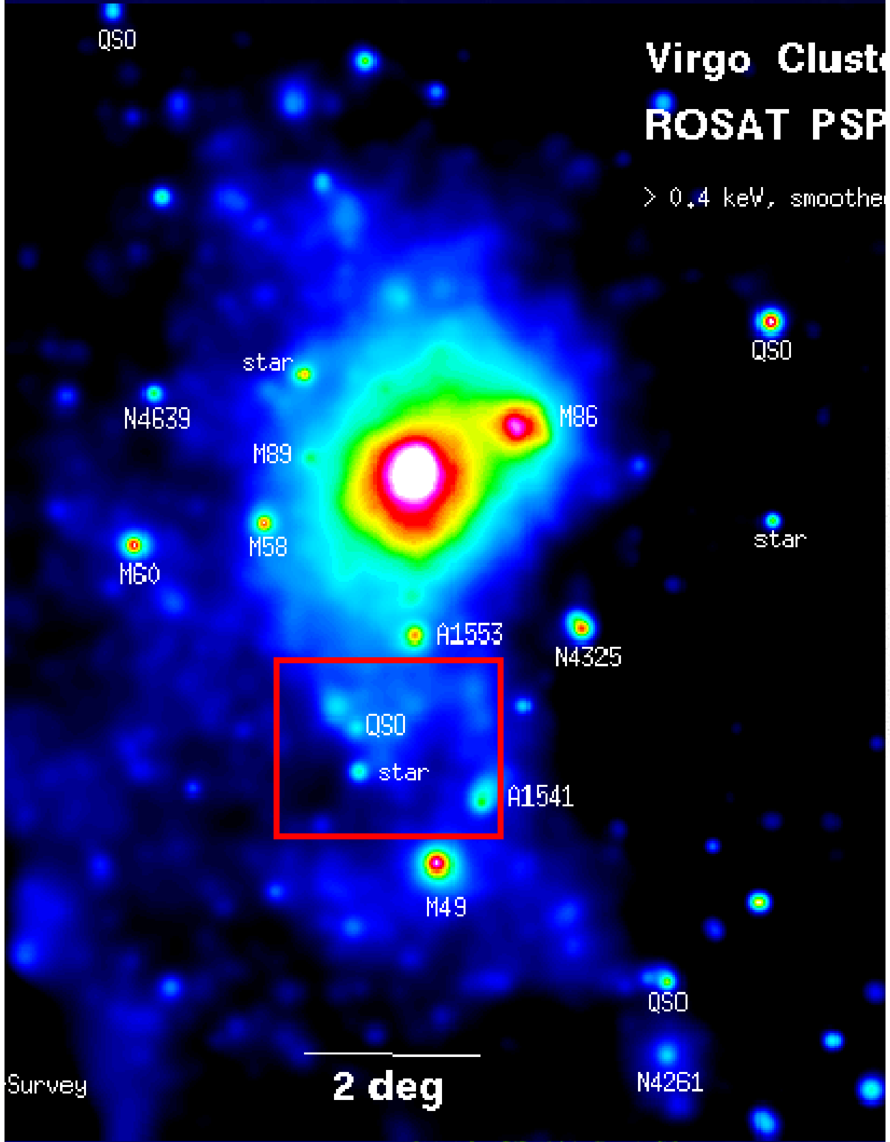
ALFALFA

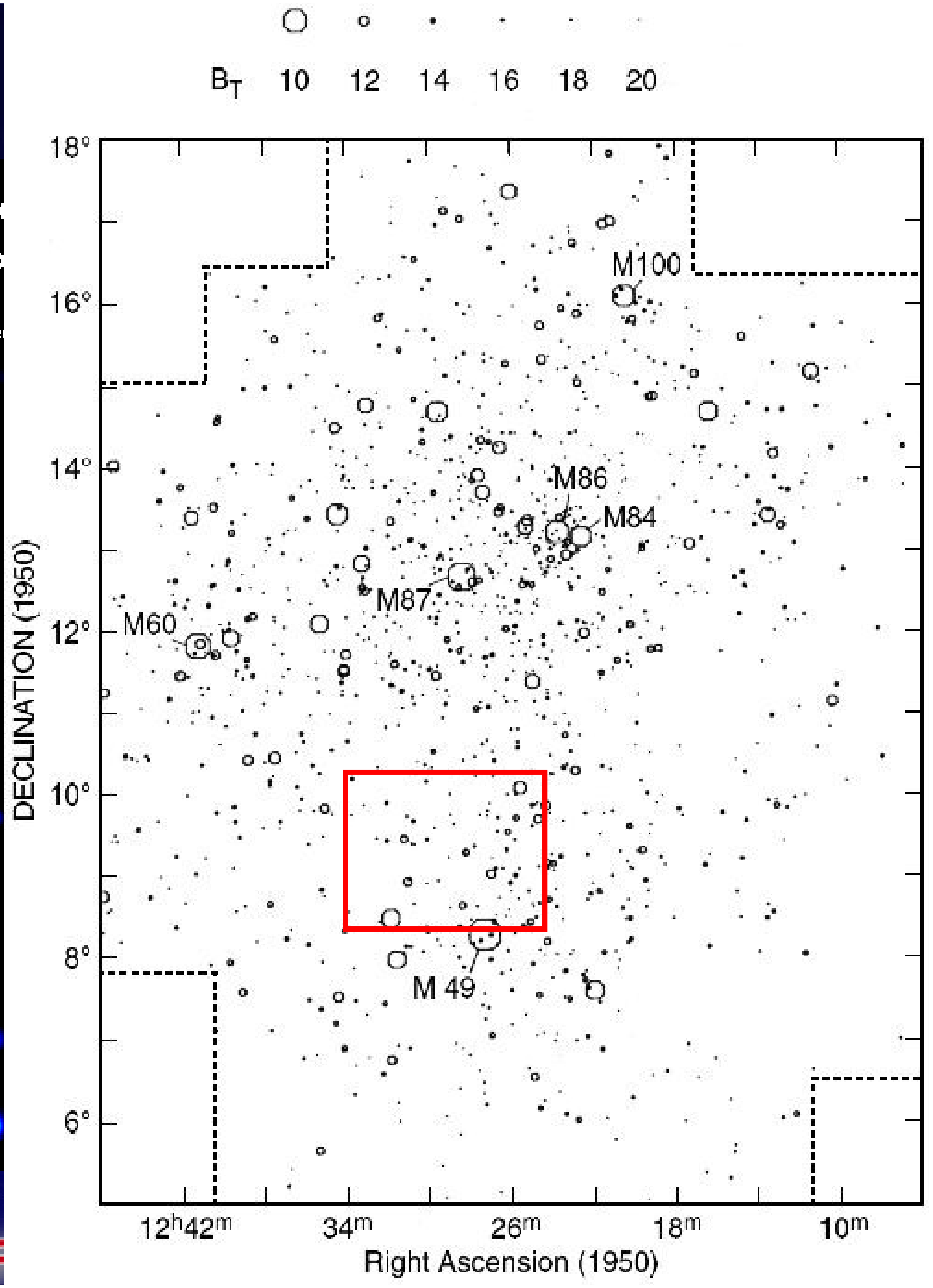

v: 2092-2124
v: 2029-2061
v: 1998-2029
v:
7726
7728
N4532
A
B
C
DDO 137
DECLINATION (B1950)
RIGHT ASCENSION (B1950)
12 32 30
15
00
31 45
30
06 48
46
44
42
40
38
36
34
32
Dec [DMS] J2000
RA [HMS] J2000
36m0.00s
33m0.00s
12h30m0.00s
06°00'00"
05°30'00"
05°00'00"
30'00"
00"
Channels 241 to 247 Smoothed over -> 2029.5500 to 1998.2161 km/s
Channels 254 to 260 Smoothed over -> 1961.6880 to 1930.3482 km/s Avg Pol

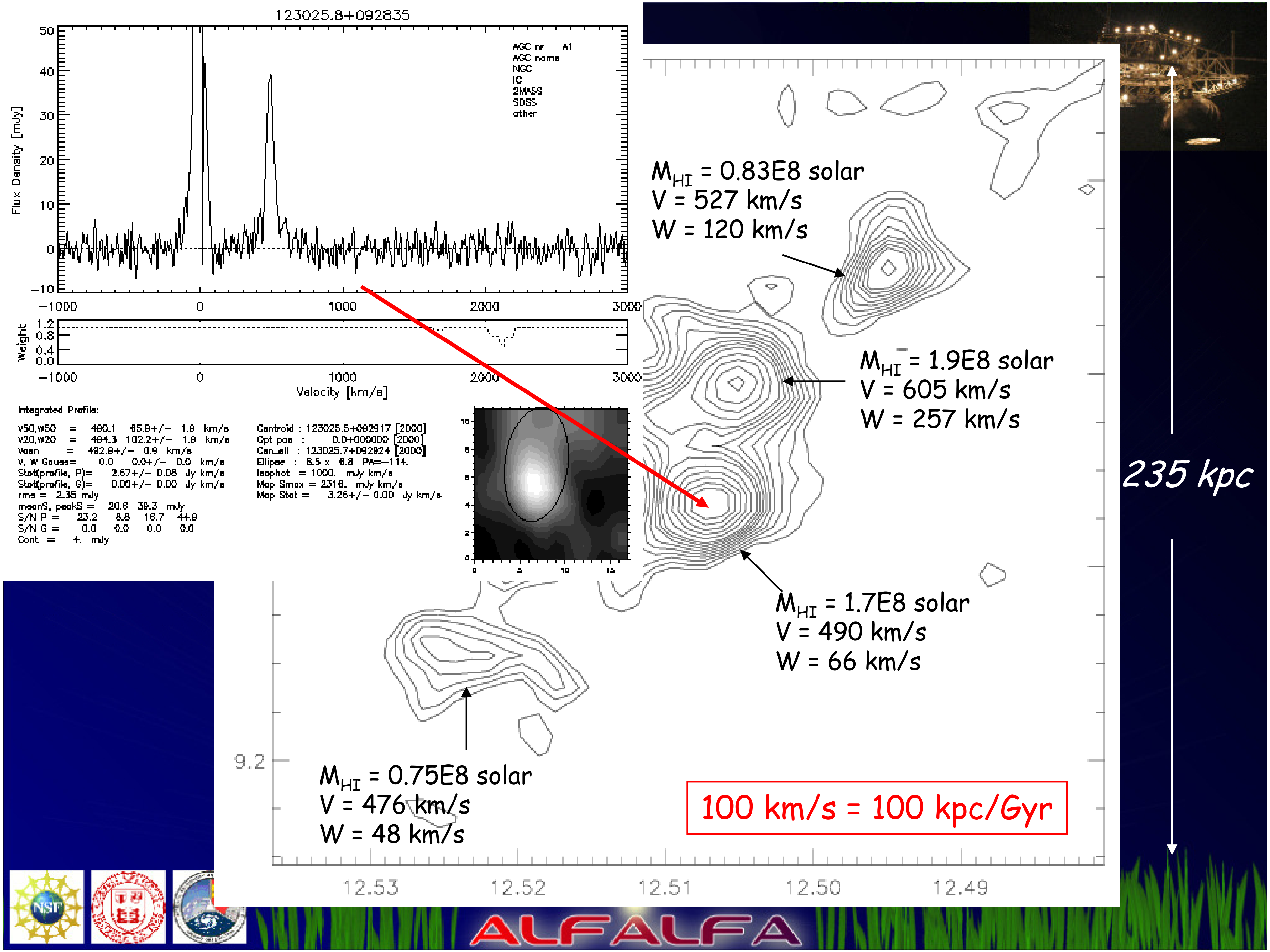


v: 1915-1945
v: 1883-1915
v: 1852-1883
v: 1821-1852
7726
7738
223332
224516
224516
RA [HMS] J2000
Dec [DMS] J2000
1888.5985 to 1919.9097 km/s
Declination (J2000)
Right Ascension (J2000)
Channels 269 to 275 Smoothed over -> 1883.3806 to 1852.0770 km/s Avg Pol
Channels 275 to 281 Smoothed over -> 1852.0770 to 1820.7799 km/s Avg Pol

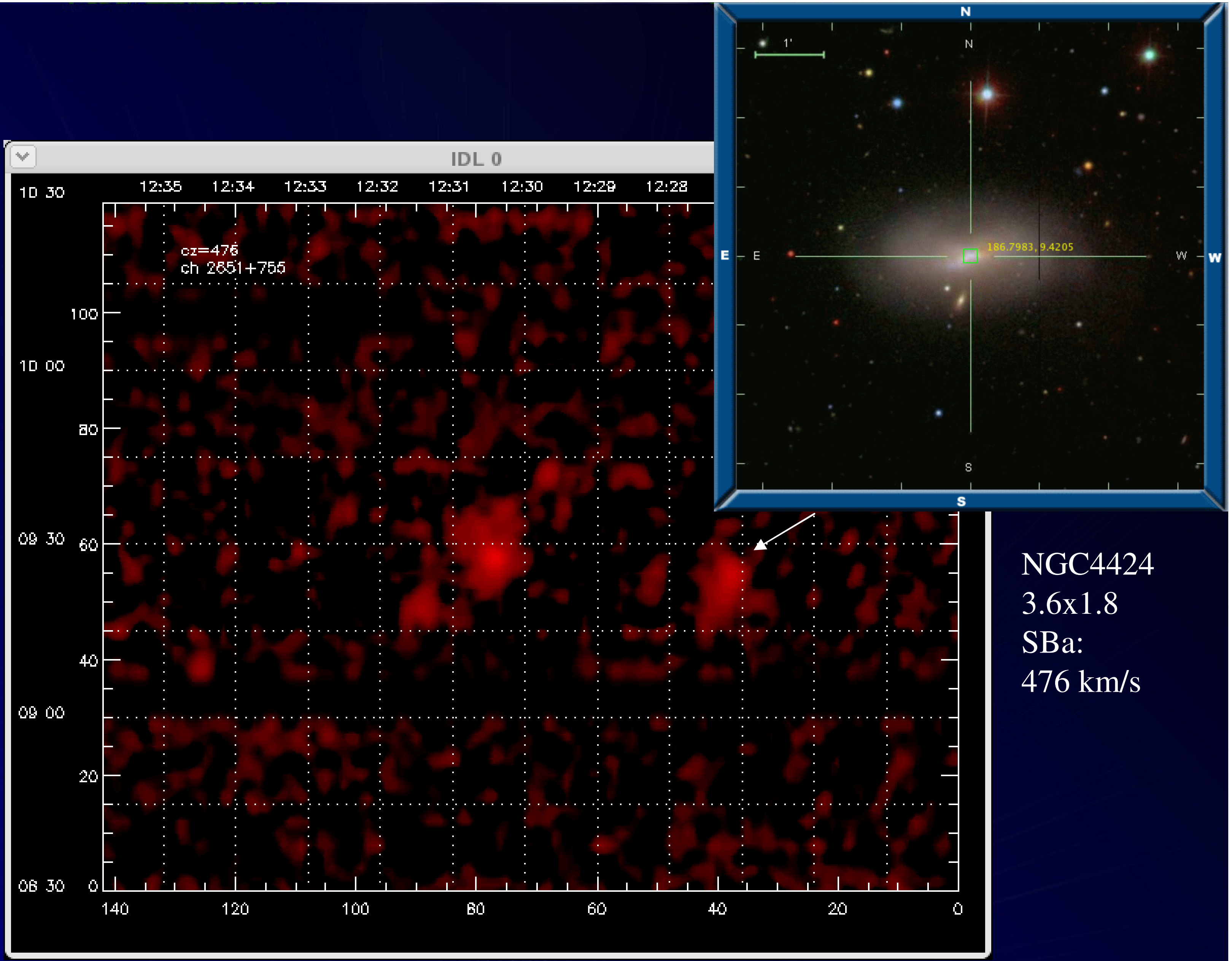
A cloud complex







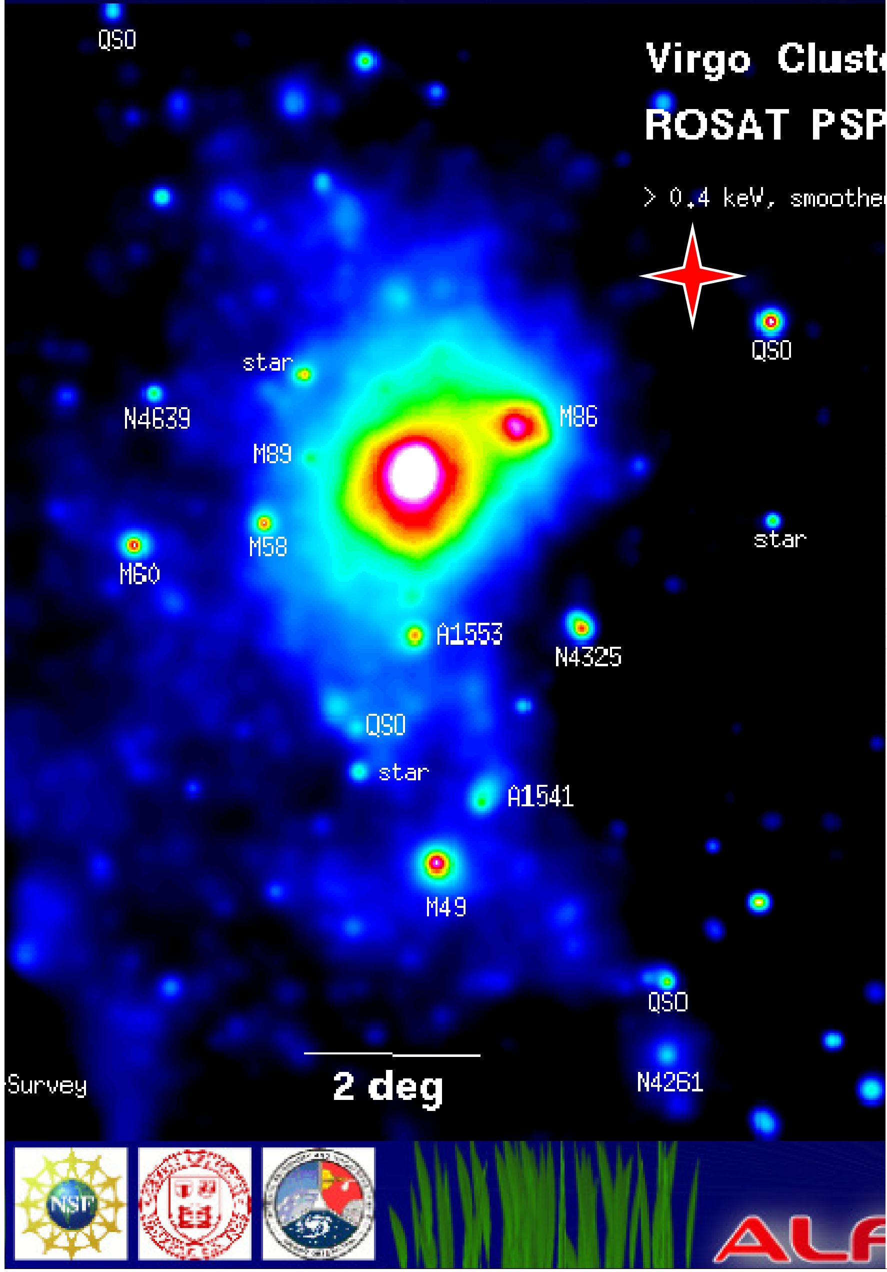
123025.8+092835
Flux Density [mJy]
Velocity [km/s]
Weight
AGC nr A1
AGC name
NGC
IC
2MASS
SDSS
other
Integrated Profile:
M_HI = 0.83E8 solar
V = 527 km/s
W = 120 km/s
M_HI = 1.9E8 solar
V = 605 km/s
W = 257 km/s
M_HI = 1.7E8 solar
V = 490 km/s
W = 66 km/s
M_HI = 0.75E8 solar
V = 476 km/s
W = 48 km/s
235 kpc
100 km/s = 100 kpc/Gyr
9.2
12.53
12.52
12.51
12.50
12.49
ALFALFA

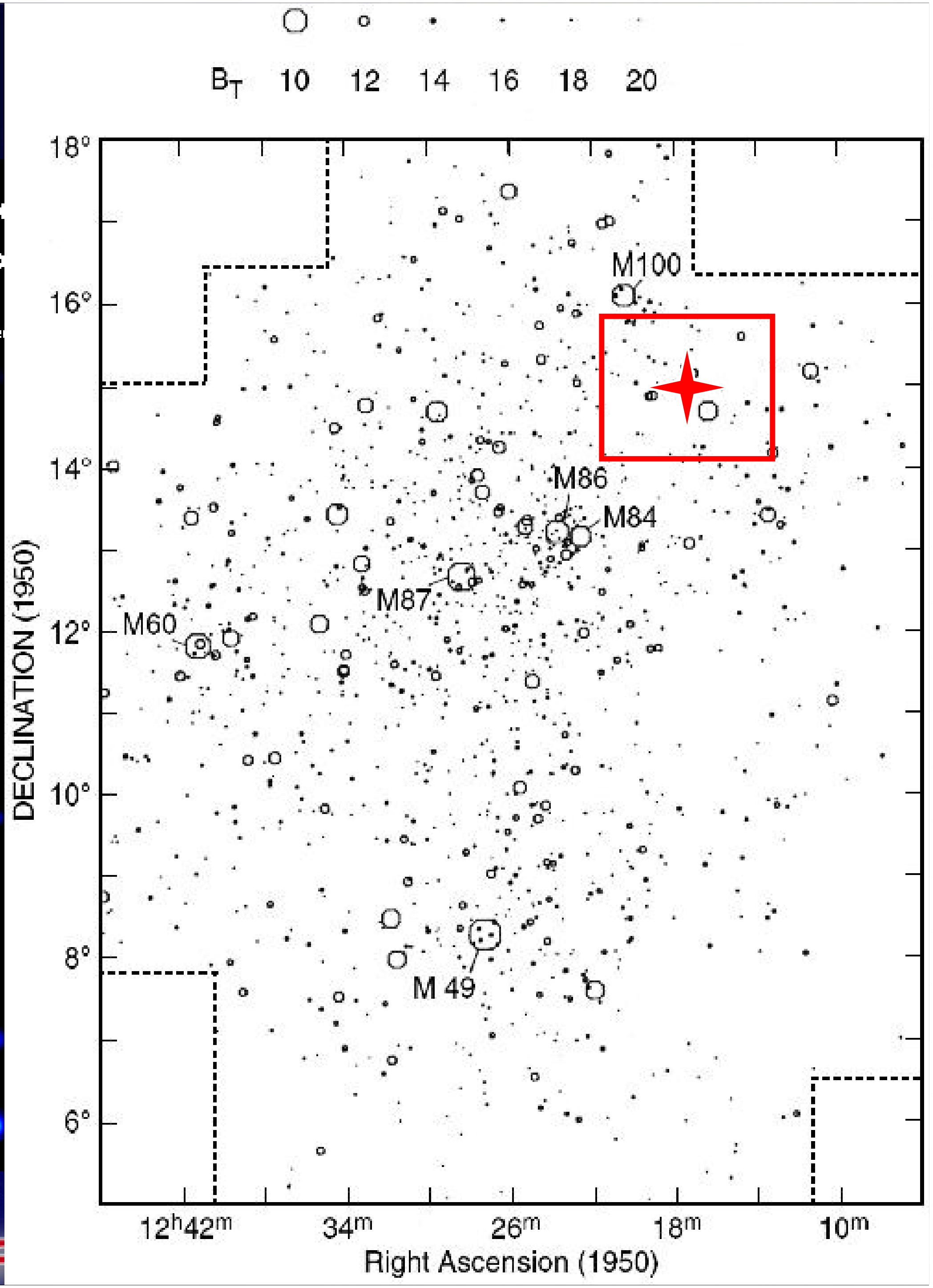


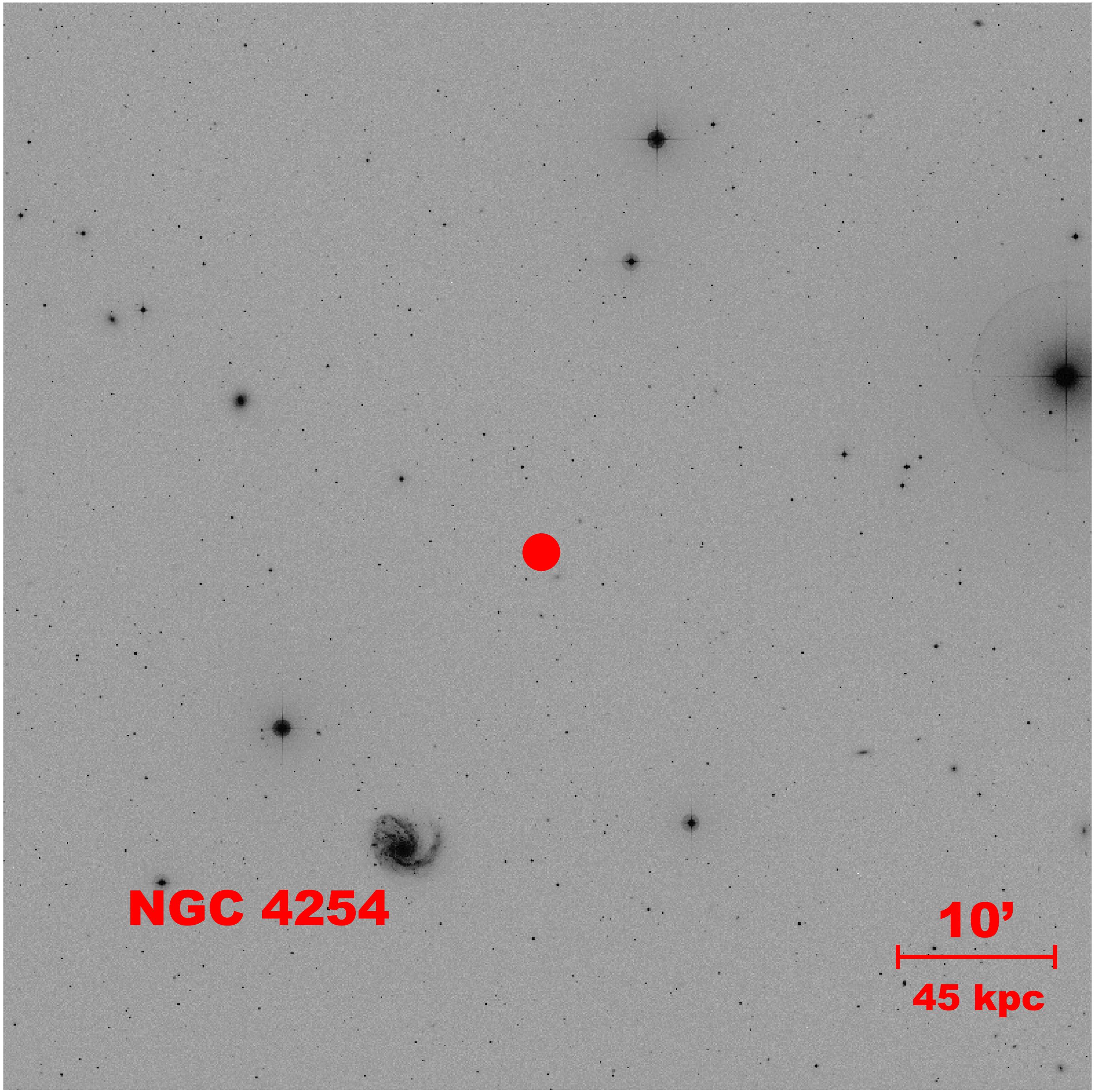
NGC4424
3.6x1.8
SBa:
476 km/s

ALFALFA

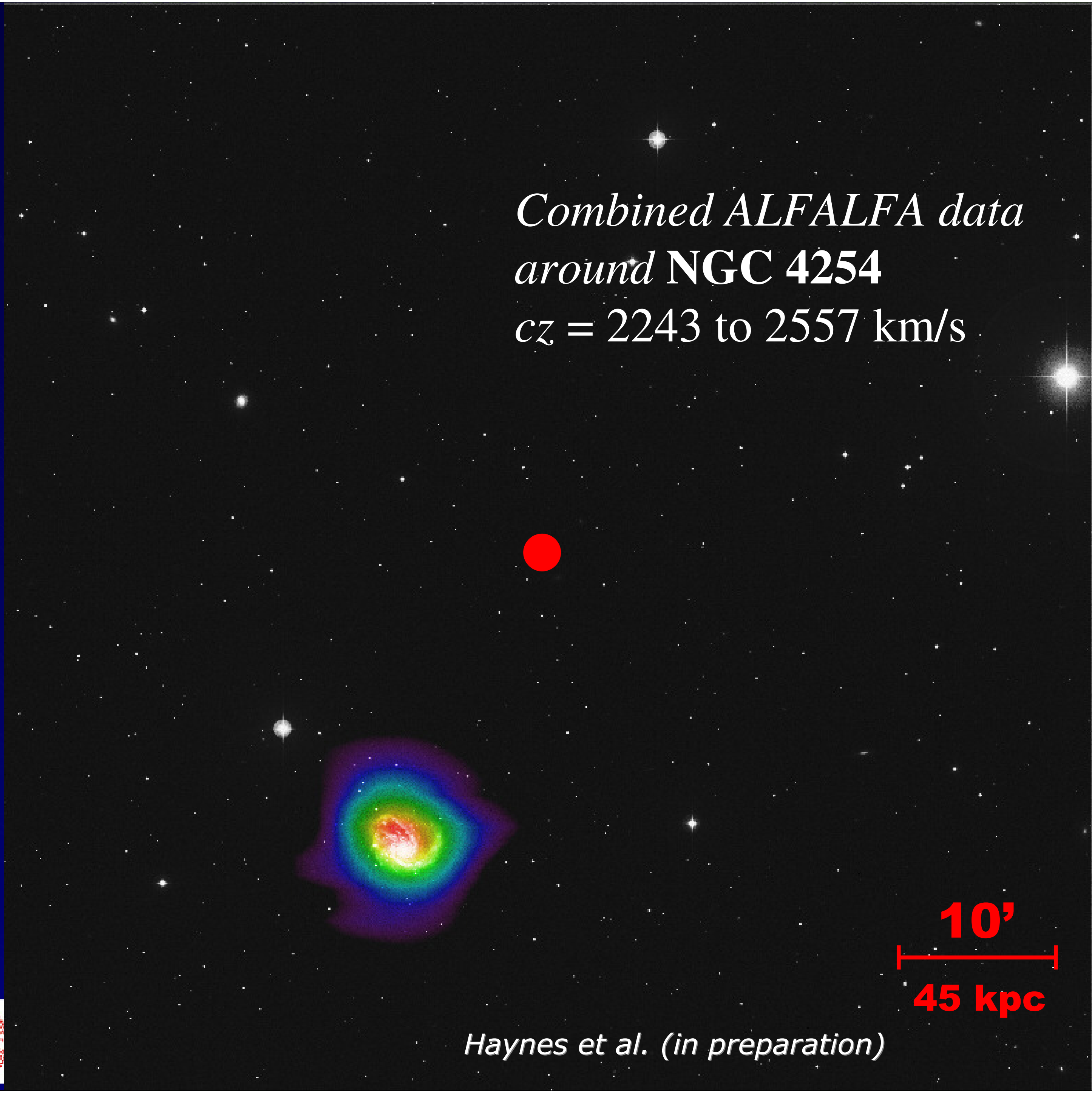
The Cardiff "Dark Galaxy"



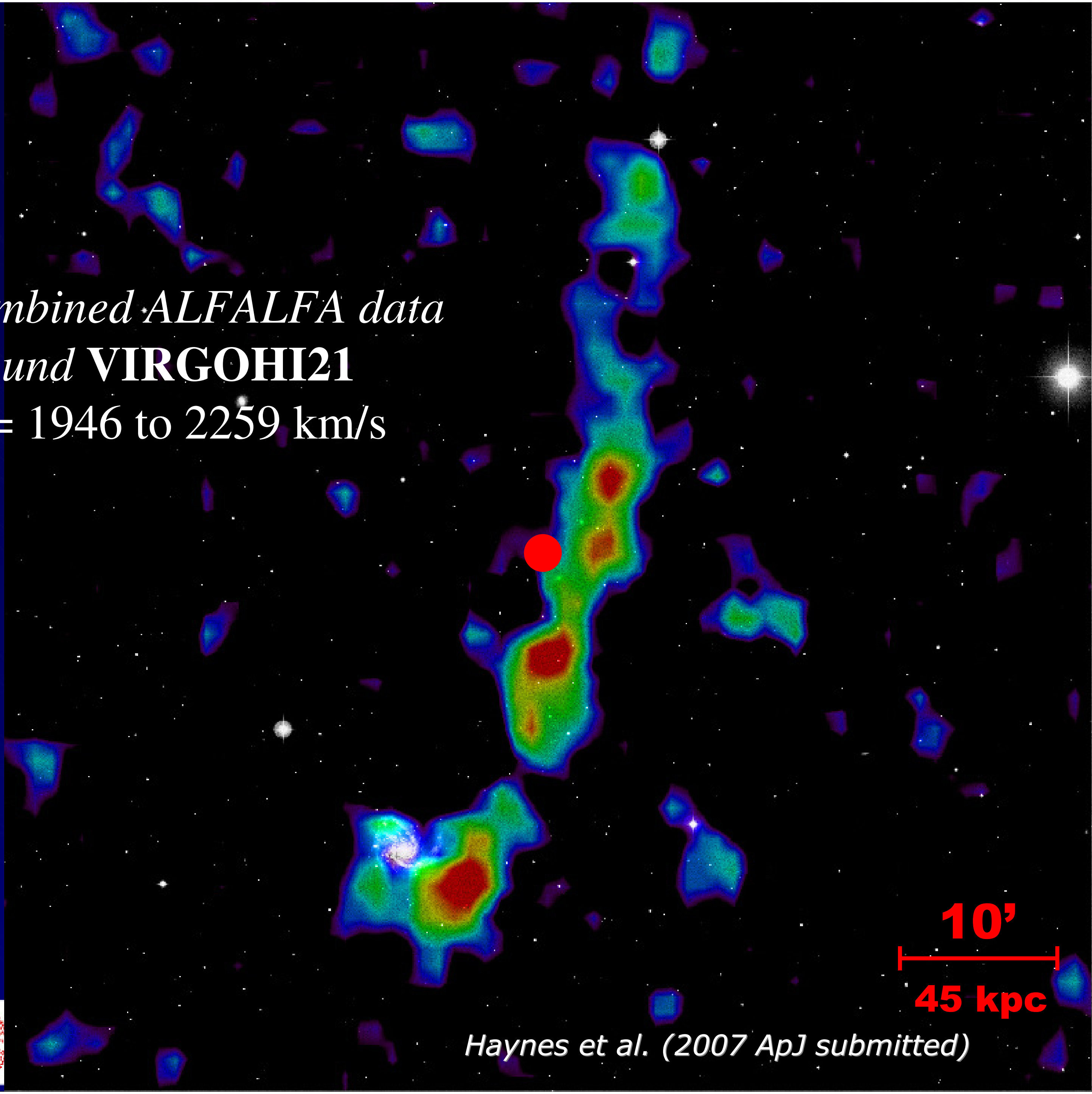


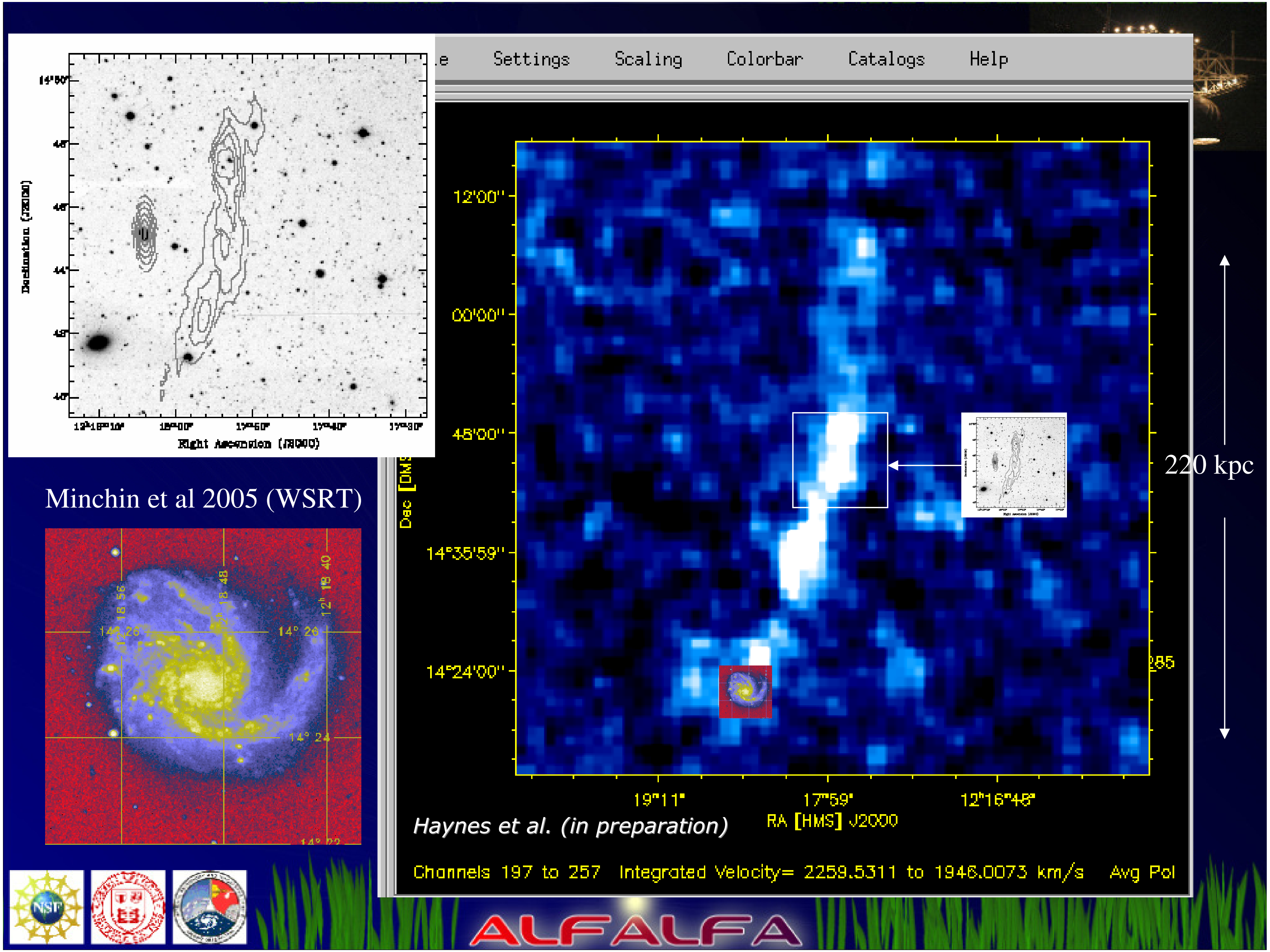


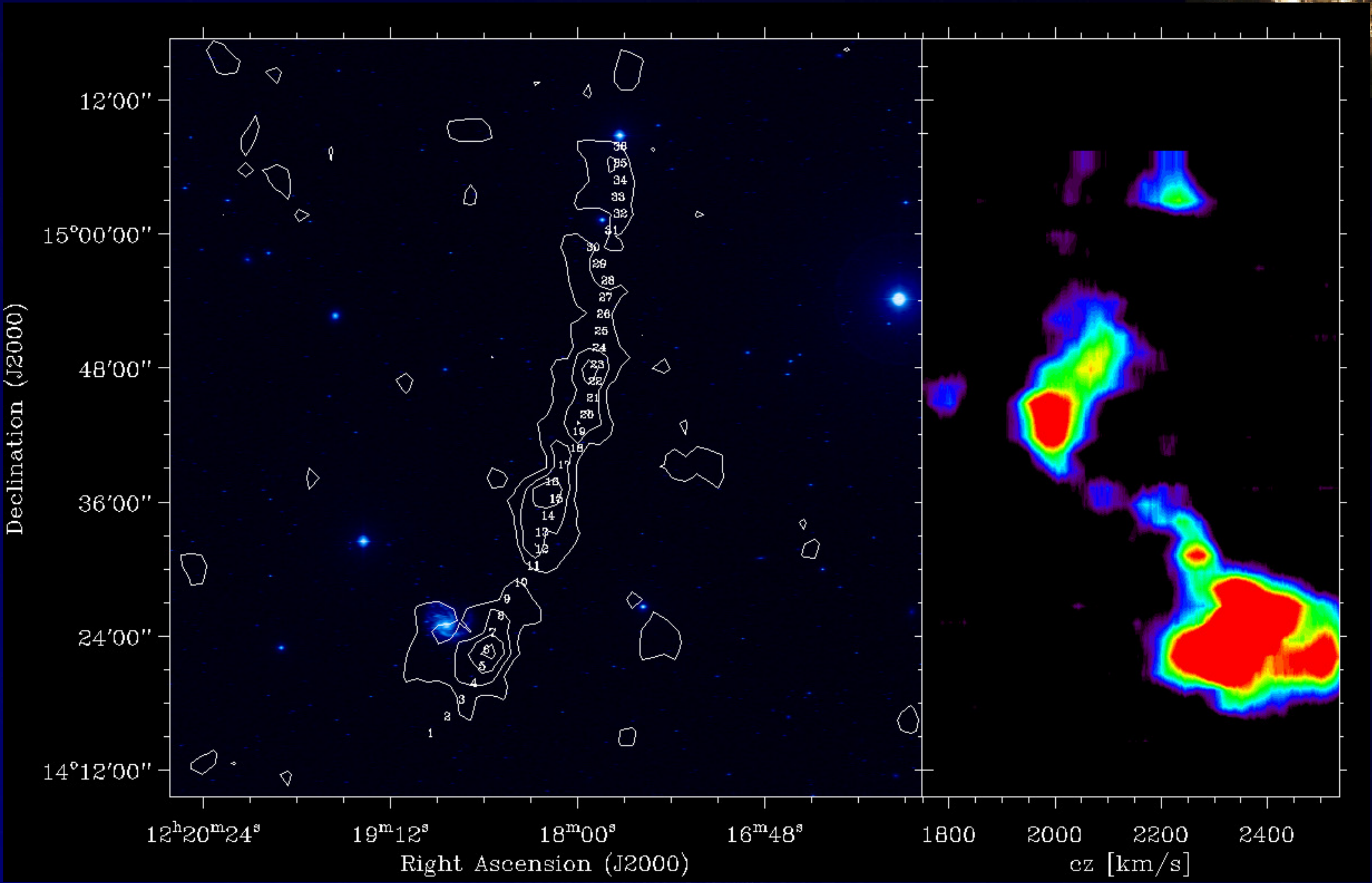
DSS2
Blue


Combined ALFALFA data
around NGC 4254
cz = 2243 to 2557 km/s
10’
45 kpc
Haynes et al. (in preparation)

Combined ALFALFA data
around **VIRGOHI21**
cz = 1946 to 2259 km/s



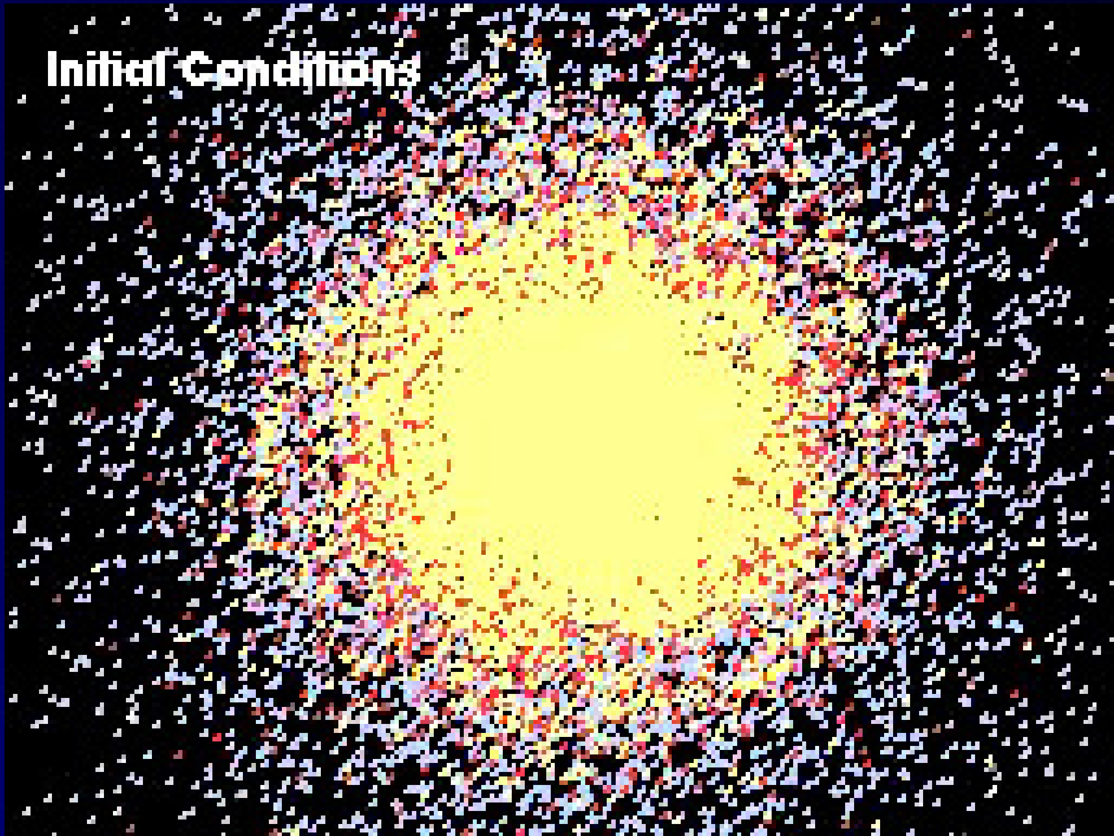

Minchin et al 2005 (WSRT)
Right Ascension (J2000)
Declination (J2000)
Settings
Scaling
Colorbar
Catalogs
Help
12'00''
00'00''
48'00''
14°35'59''
14°24'00''
Dec
19m11s
17m59s
12h16m45s
RA [HMS] J2000
220 kpc
Haynes et al. (in preparation)
Channels 197 to 257 Integrated Velocity= 2259.5311 to 1946.0073 km/s Avg Pol
14° 26
14° 24
ALFALFA



Haynes, Giovanelli & Kent 2007, ApJ submitted

ALFALFA

Galaxy harassment?



High velocity, - but long-lasting - encounters in a cluster can drastically impact galaxy evolution.

Animation by G. Lake

ALFALFA

- *The LSS characteristics of HI-selected galaxies are the same as those optically-selected*
- *ALFALFA does not detect a population of high mass (say > 10^{10} solar), optically unseen systems (e.g. Cardiff "dark galaxy")*
- *ALFALFA detects a numerically conspicuous pop of HI-rich, optically faint, low mass systems: dynamics within the boundaries of the HI appear dominated by the HI mass*
- *Virgo: an HI cloud cemetery:*

➔ *A number of optically unseen systems are detected; of both hydro and tidal origin*

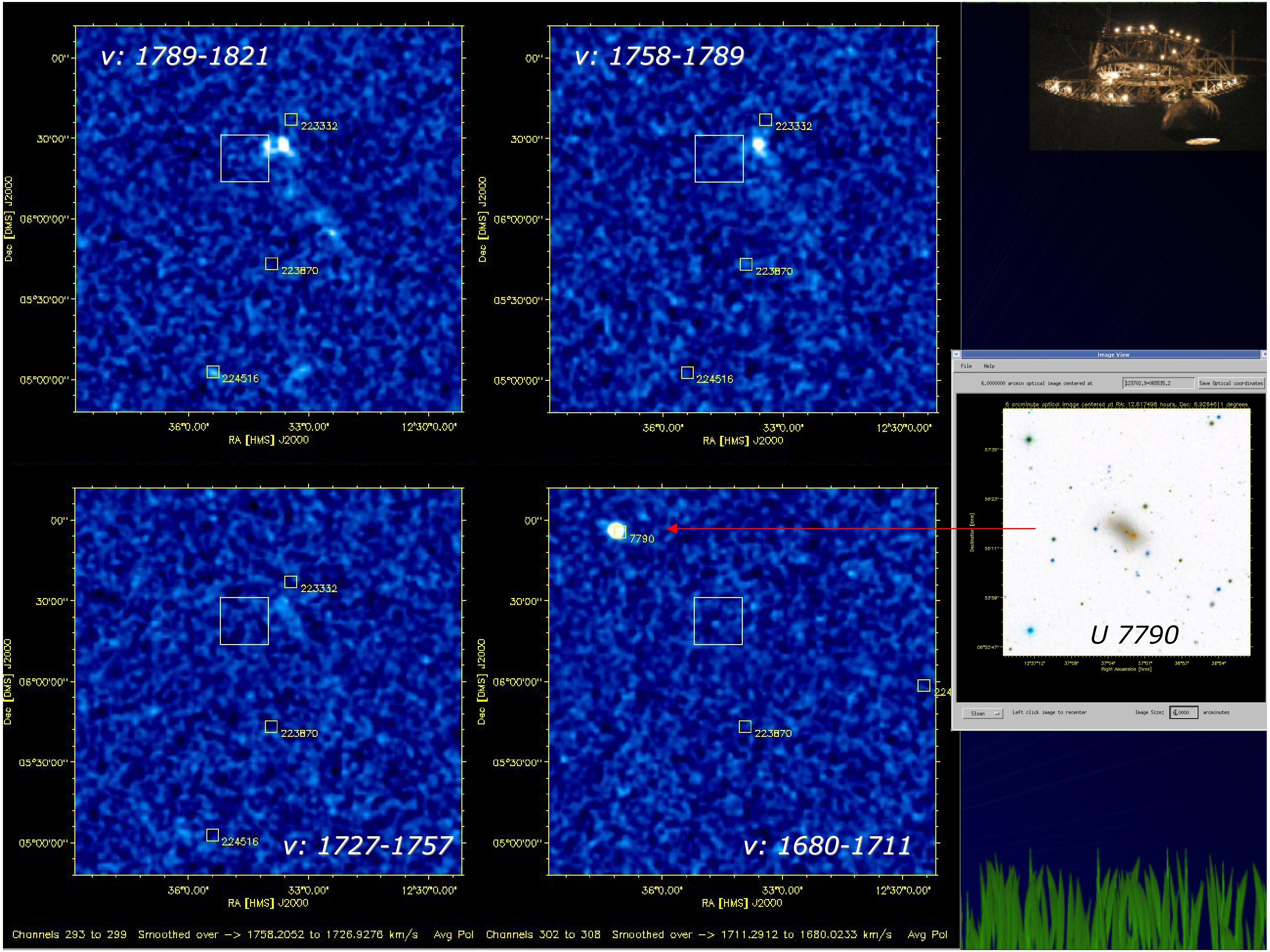
- *A population of HVCs with positive velocities (cz>150 km/s) near the NGP are found: related to nearby, low mass galaxies?...*

We're just getting started.

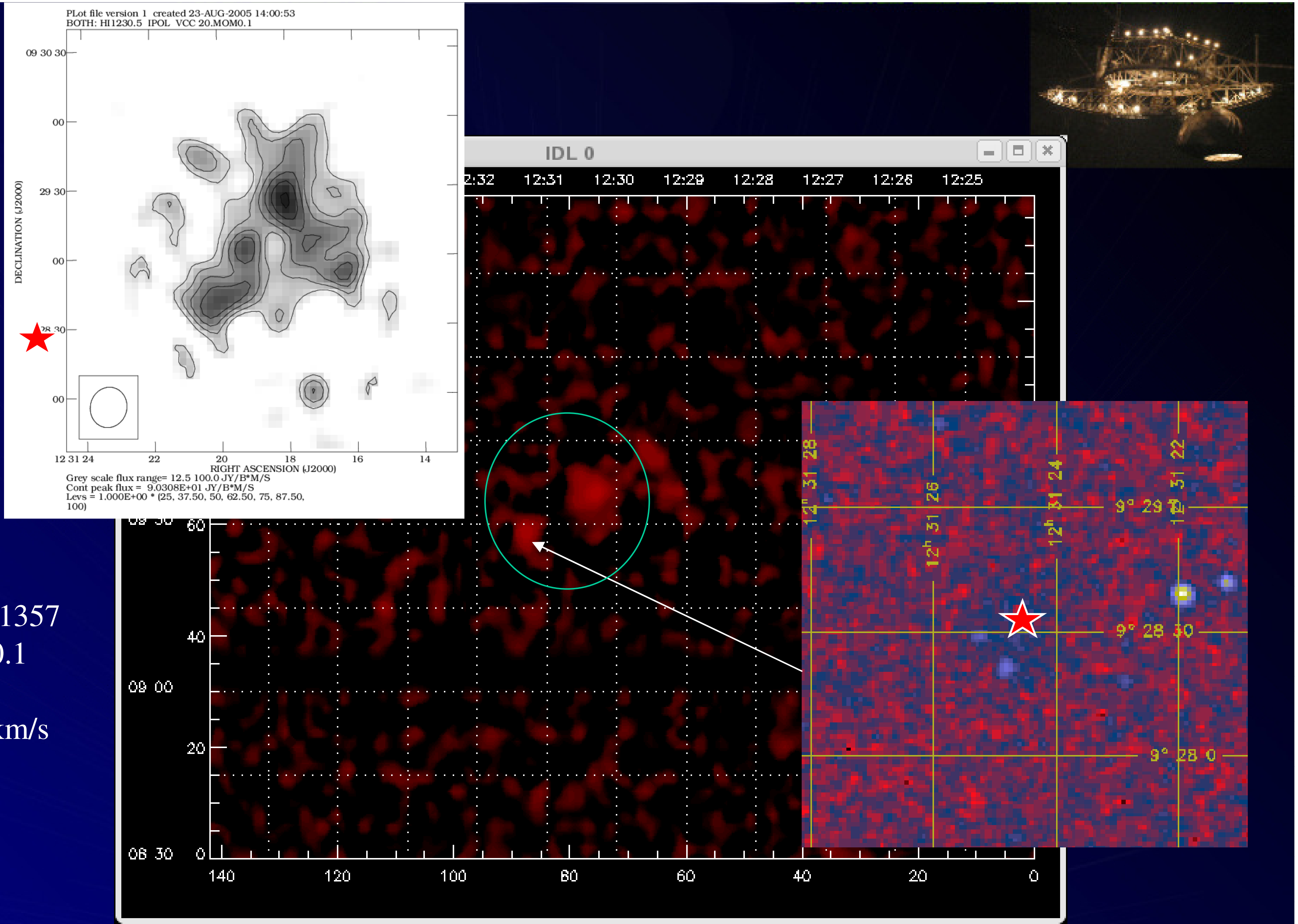
Stay tuned

ALFALFA

Extra slides…



v: 1789-1821
v: 1758-1789
v: 1727-1757
v: 1680-1711
223332
223870
224516
7790
U 7790
Dec [DMS] J2000
RA [HMS] J2000
00''
30'00''
06°00'00''
05°30'00''
05°00'00''
36'0.00''
33'0.00''
12h30'0.00''
Image View
File
Help
Save Optical coordinates
Sloan
Left click image to recenter
Image Size:
arcminutes
Channels 293 to 299 Smoothed over -> 1758.2052 to 1726.9276 km/s Avg Pol
Channels 302 to 308 Smoothed over -> 1711.2912 to 1680.0233 km/s Avg Pol



VCC1357
0.2x0.1
I?
603 km/s

ALFALFA

- *Cloud complex is in Virgo cluster*
- *Complex is not gravitationally bound*
- *Cloud-to-cloud Δv ~ 100 km/s, Δr ~ 100 kpc*
  - ➔ *mean cloud separation will double in 1 Gyr*
  - ➔ *cloud complex is transient phenomenon, at first pass through the cluster*
- *If individual clouds are bound their individual total masses average 1-2 x 10^9 solar*

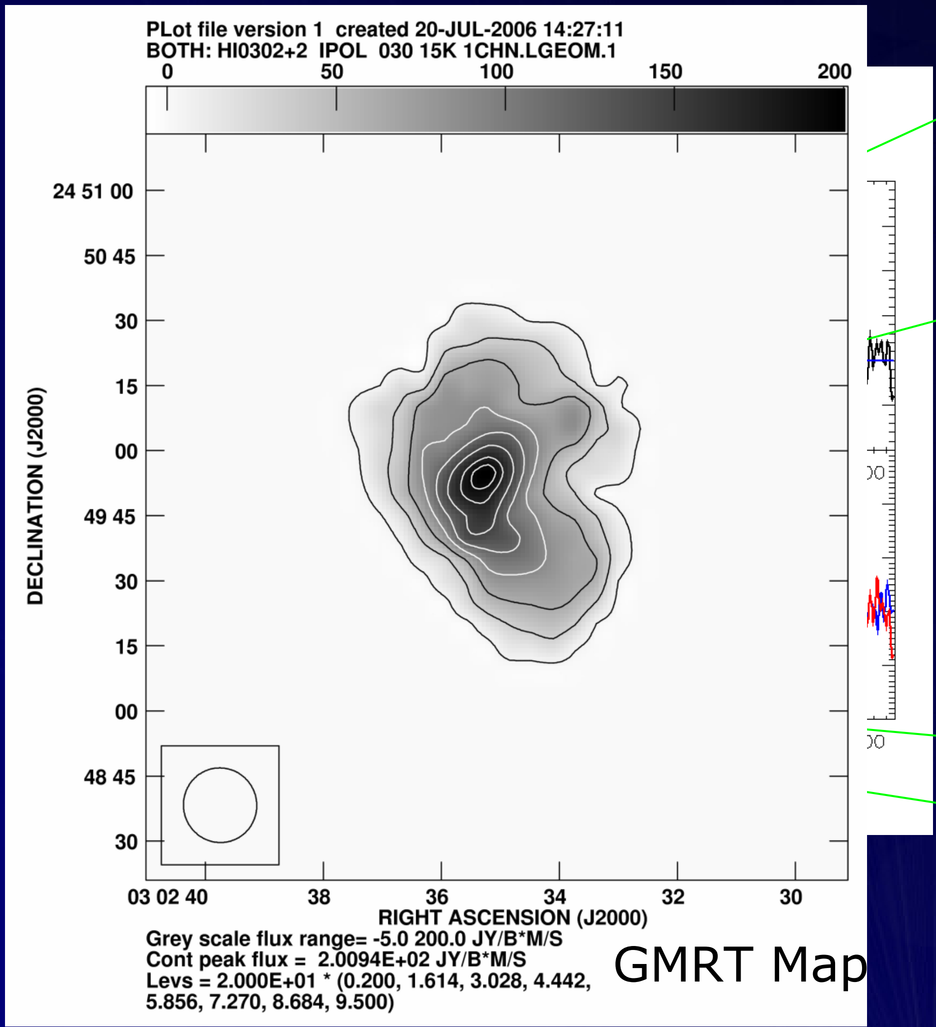
Possible Origin:

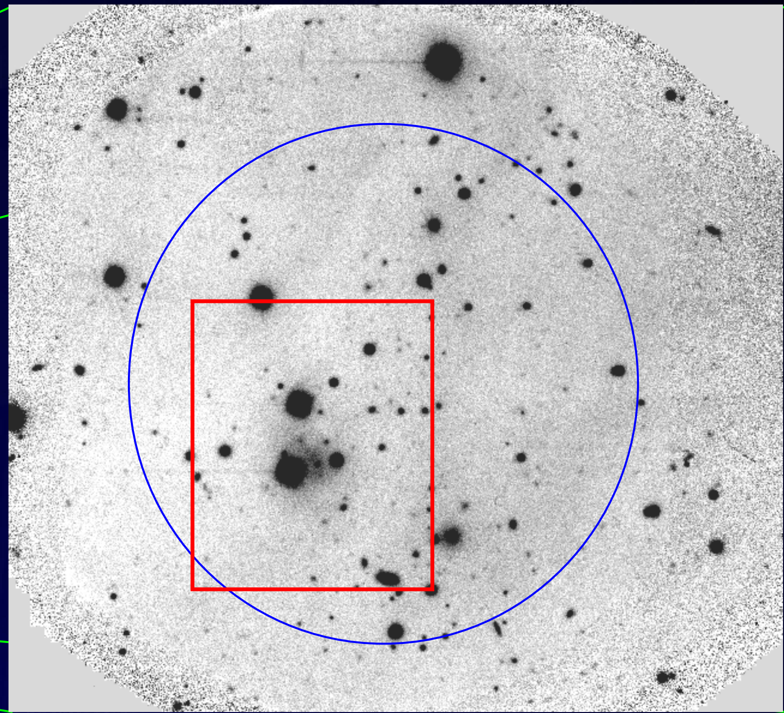
- *Group of mini-halos falling in cluster for first time*
- *Separated outskirts from single spiral galaxy*
- *Satellites separated from main galaxy in group*

HYDRO (Ram Pressure)?   TIDAL (gravi)?

ALFALFA

A Void Dweller





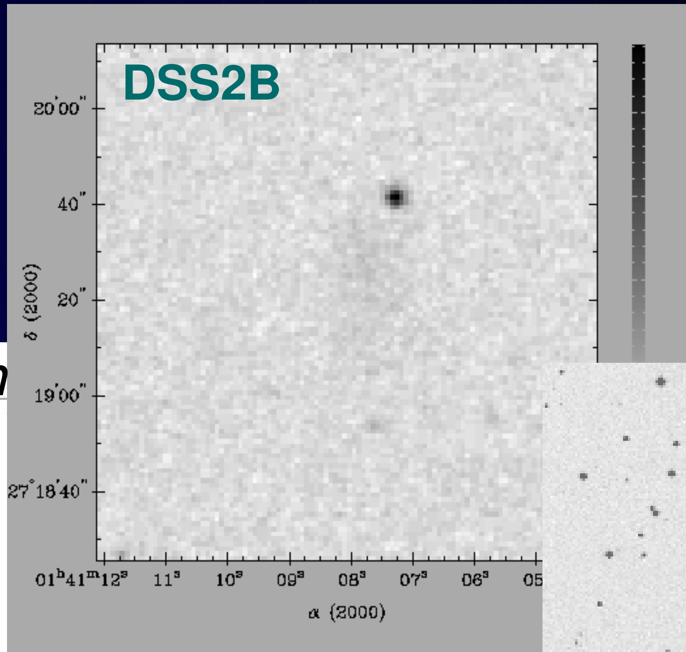
Amelie Saintonge et al. (2007, *in prep*)

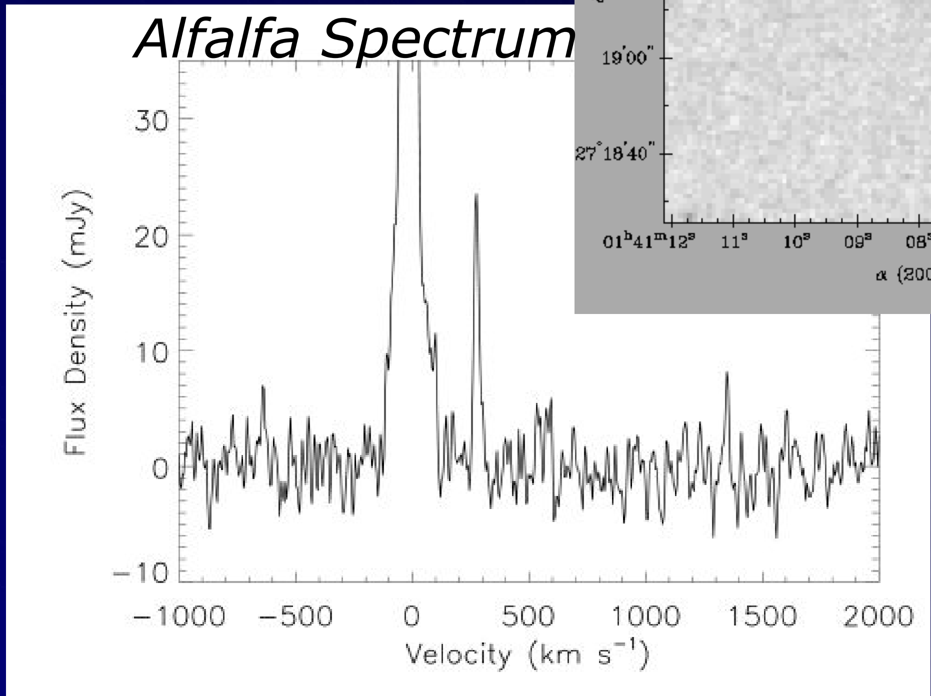
Most of the mass within the HI boundaries is accounted by the HI itself

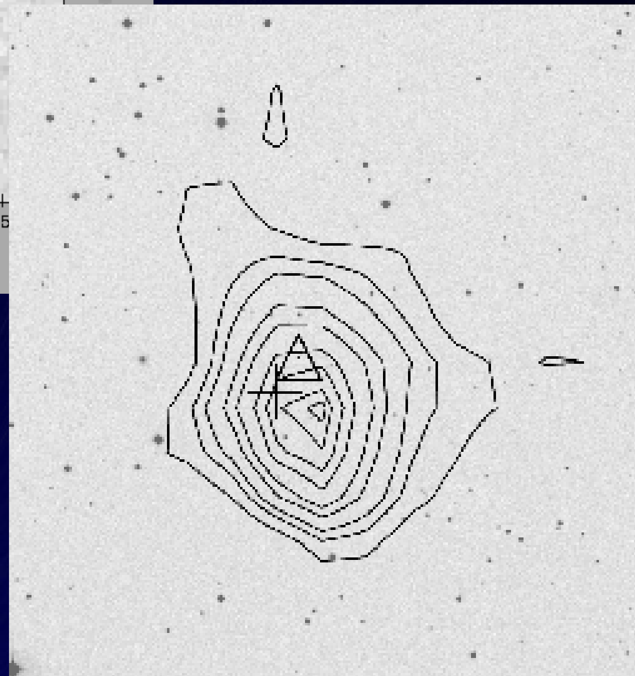
ALFALFA

Extremely metal-poor galaxy

cz	280 km/s
W	27 km/s
F	0.64 Jy km/s
D	6.3 Mpc
$\log(M_{HI})$	6.77



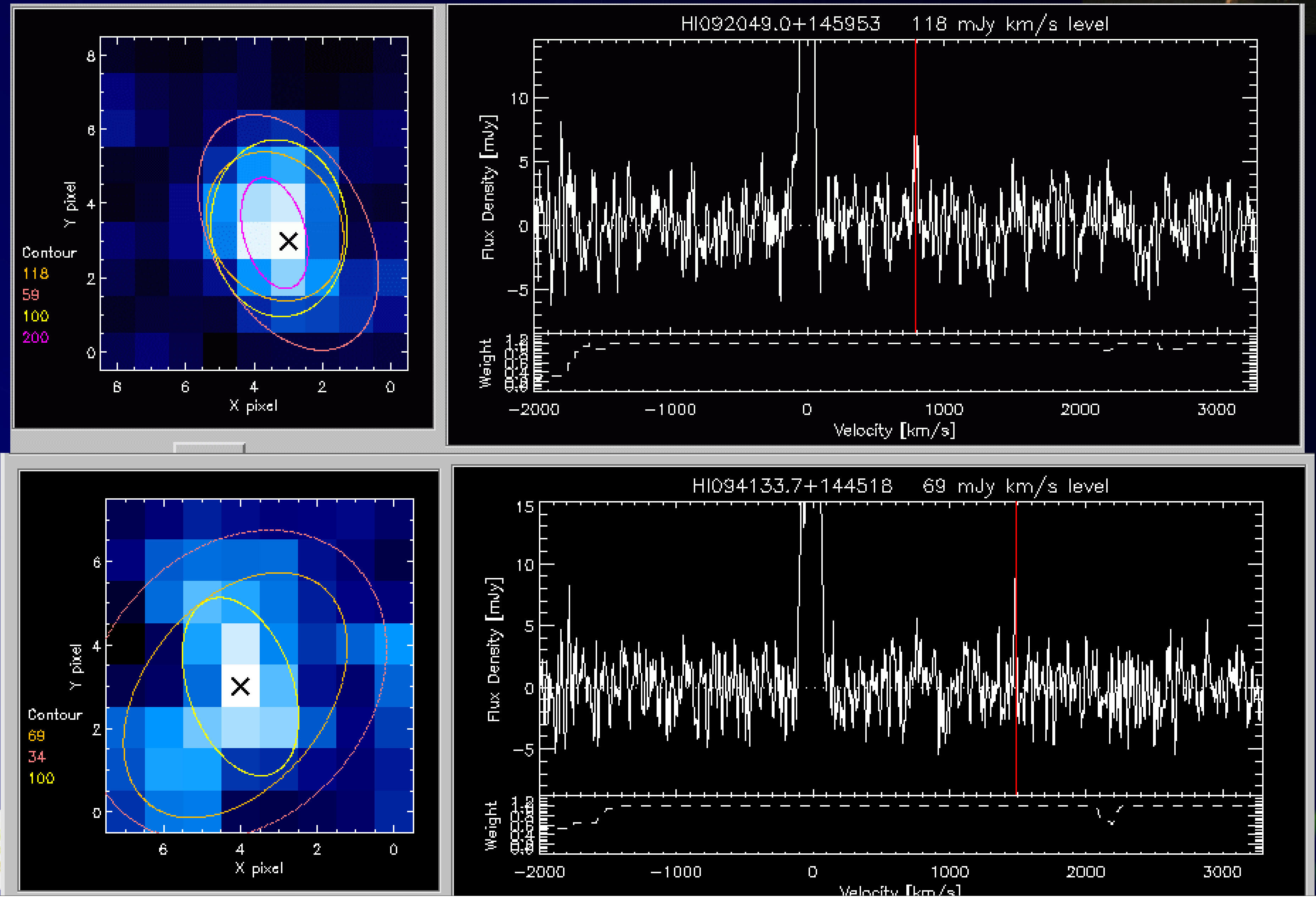




HI0141+27, a metal-poor galaxy : Saintonge et al. (*in prep*)

ALFALFA

And then there are lots of narrow features, near the noise, with no optical counterpart: they'll be chased one by one



… some more credible than others…