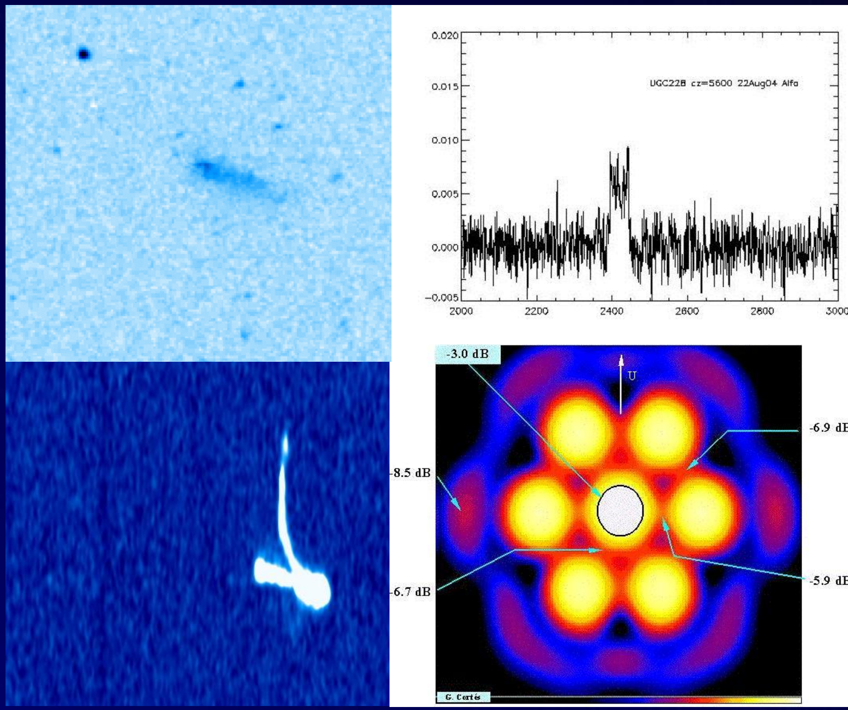


Introduction to LBW for ALFALFA followup

Martha Haynes
UAT13 13.01.14

ALFALFA source codes

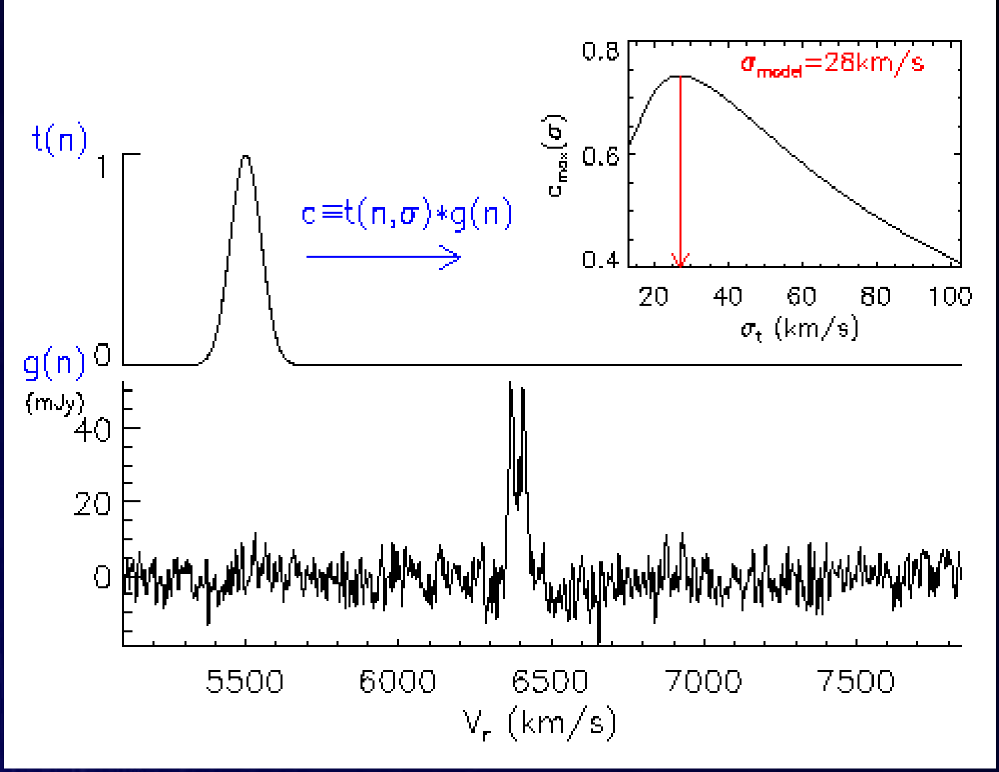
ALFALFA HI detections are coded according to:

Code 1	High quality sources, typically with S/N > 6.5
Code 2	Sources of lower S/N which are coincident with a probable OC of the same redshift (known from another source) => the "priors"
Code 3	Low S/N sources without identifiable OC
Code 4	Low S/N sources with a possible OC of unknown redshift
Code 5	Corresponding to Code 2, but of such low S/N or possible RFI contamination that they are untrustworthy
Code 6	Like OH megamasers at 0.16 < cz < 0.24

Signal Extractor -- Introduction

- The signals are extracted by cross-correlations of a template with the spectra. => "matched-filter algorithm

- More sensitive than peak-finding algorithms.
- Sensitive to total flux, not only peak flux
- Especially important for low mass systems
- Using FFT's, cross-correlations are computationally fast



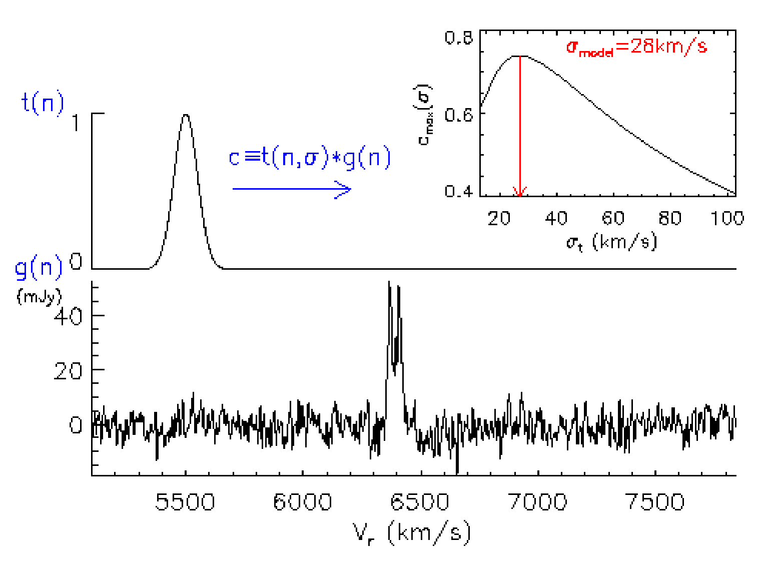
Saintonge 2007 AJ 133, 2087

Slide: Amelie Saintonge

ALFALFA

Signal Extractor -- Application(2)

Saintonge 2007
AJ
133, 2087



The process is :

- Repeat for a range of widths of the template
  - e.g. 10 km/s – 600km/s
- Choose the width for which the convolution is maximised --> position of the signal
- Calculate the amplitude of the signal from the width

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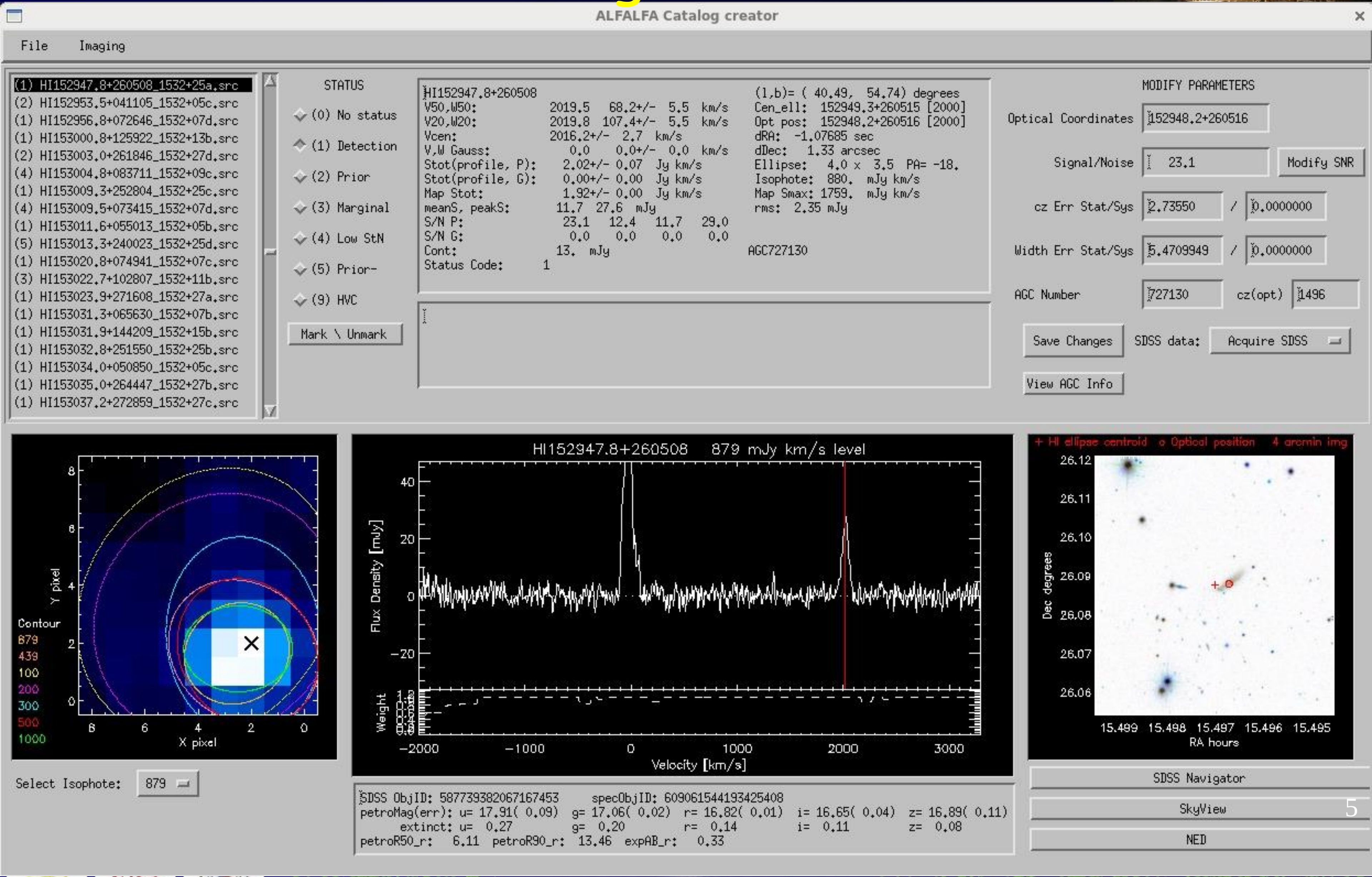
Slide: Amelie Saintonge

High S/N



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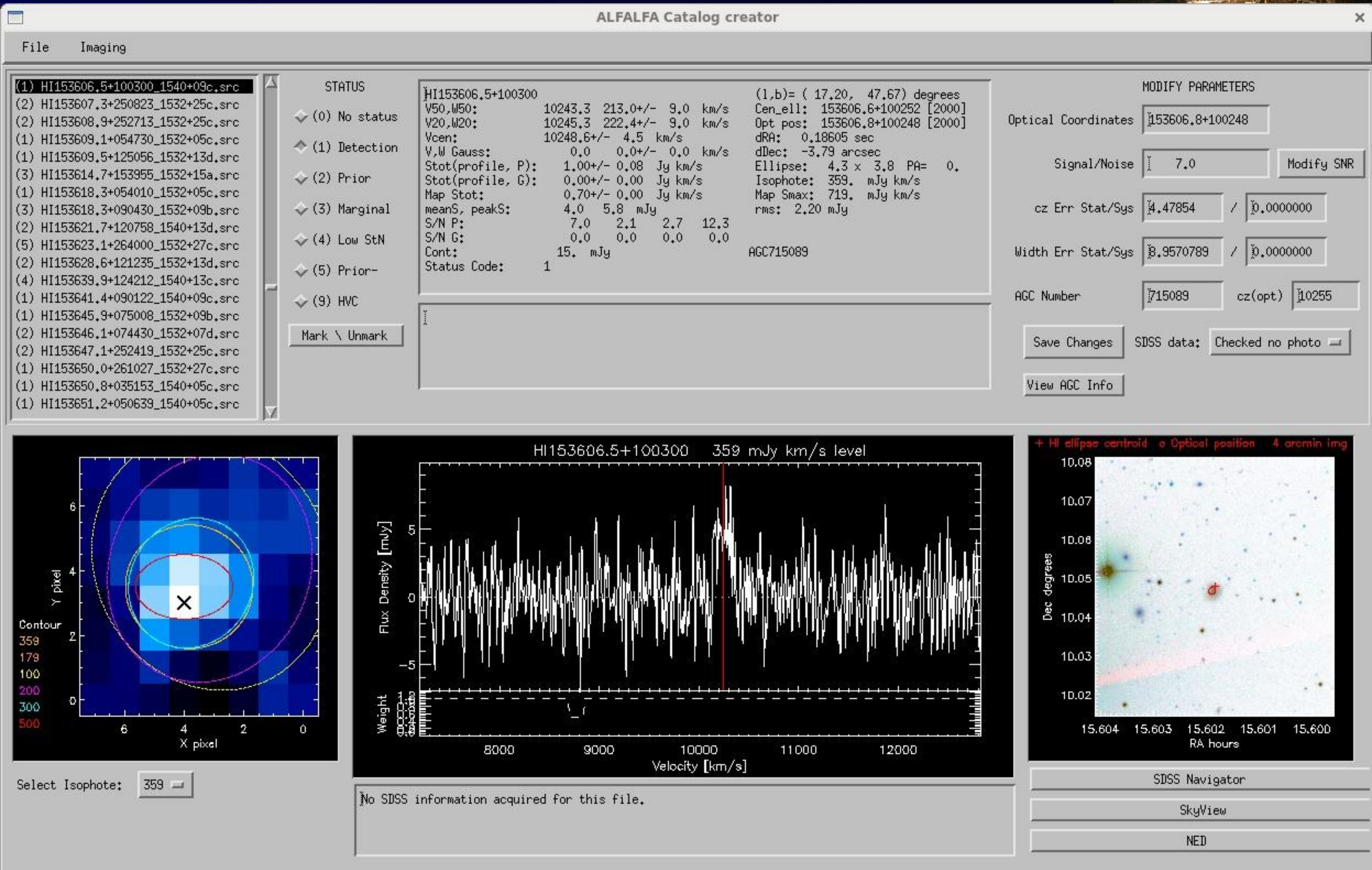
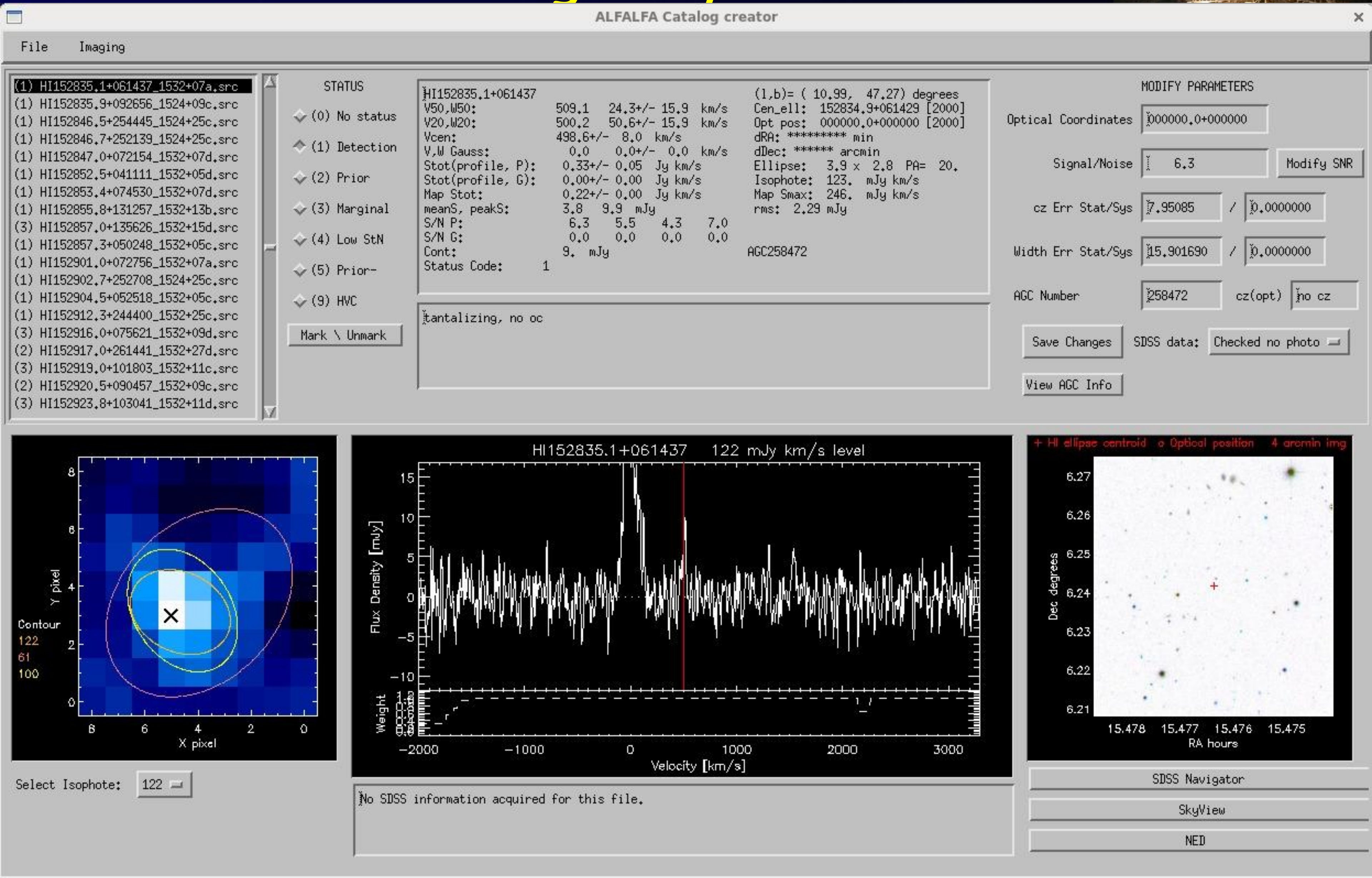
Low S/N


ALFALFA Catalog creator
File
Imaging
(1) HI153606.5+100300_1540+09c.src
(2) HI153607.3+250823_1532+25c.src
(2) HI153608.9+252713_1532+25c.src
(1) HI153609.1+054730_1532+05c.src
(1) HI153609.5+125056_1532+13d.src
(3) HI153614.7+153955_1532+15a.src
(1) HI153618.3+054010_1532+05c.src
(3) HI153618.3+090430_1532+09b.src
(2) HI153621.7+120758_1540+13d.src
(5) HI153623.1+264000_1532+27c.src
(2) HI153628.6+121235_1532+13d.src
(4) HI153639.9+124212_1540+13c.src
(1) HI153641.4+090122_1540+09c.src
(1) HI153645.9+075008_1532+09b.src
(2) HI153646.1+074430_1532+07d.src
(2) HI153647.1+252419_1532+25c.src
(1) HI153650.0+261027_1532+27c.src
(1) HI153650.8+035153_1540+05c.src
(1) HI153651.2+050639_1540+05c.src
STATUS
(0) No status
(1) Detection
(2) Prior
(3) Marginal
(4) Low StN
(5) Prior-
(9) HVC
Mark \ Unmark
HI153606.5+100300
V50,W50: 10243.3 213.0+/- 9.0 km/s
V20,W20: 10245.3 222.4+/- 9.0 km/s
Vcen: 10248.6+/- 4.5 km/s
V,W Gauss: 0.0 0.0+/- 0.0 km/s
Stot(profile, P): 1.00+/- 0.08 Jy km/s
Stot(profile, G): 0.00+/- 0.00 Jy km/s
Map Stot: 0.70+/- 0.00 Jy km/s
meanS, peakS: 4.0 5.8 mJy
S/N P: 7.0 2.1 2.7 12.3
S/N G: 0.0 0.0 0.0 0.0
Cont: 15. mJy
Status Code: 1
(l,b)= (17.20, 47.67) degrees
Cen_ell: 153606.6+100252 [2000]
Opt pos: 153606.8+100248 [2000]
dRA: 0.18605 sec
dDec: -3.79 arcsec
Ellipse: 4.3 x 3.8 PA= 0.
Isophote: 359. mJy km/s
Map Smax: 719. mJy km/s
rms: 2.20 mJy
AGC715089
MODIFY PARAMETERS
Optical Coordinates 153606.8+100248
Signal/Noise 7.0
Modify SNR
cz Err Stat/Sys 4.47854 / 0.0000000
Width Err Stat/Sys 8.9570789 / 0.0000000
AGC Number 715089
cz(opt) 10255
Save Changes
SDSS data: Checked no photo
View AGC Info
Contour
359
179
100
200
300
500
Y pixel
X pixel
HI153606.5+100300 359 mJy km/s level
Flux Density [mJy]
Weight
Velocity [km/s]
8000
9000
10000
11000
12000
Dec degrees
RA hours
15.604
15.603
15.602
15.601
15.600
Select Isophote: 359
No SDSS information acquired for this file.
SDSS Navigator
SkyView
NED

“Dark” galaxy candidate



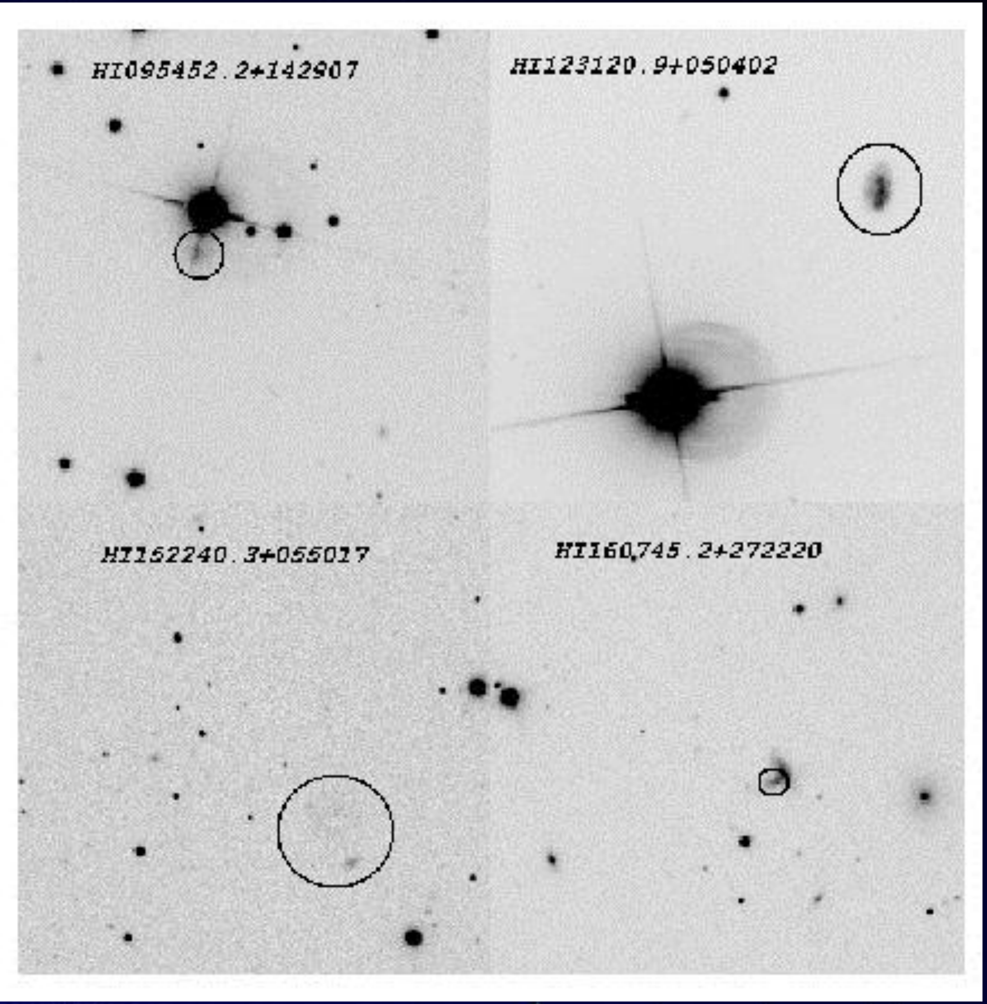
ALFALFA

Identifying Optical Counterparts

ALFALFA source centroids good to ~18" (depends on S/N)

ALFALFA catalogs include:

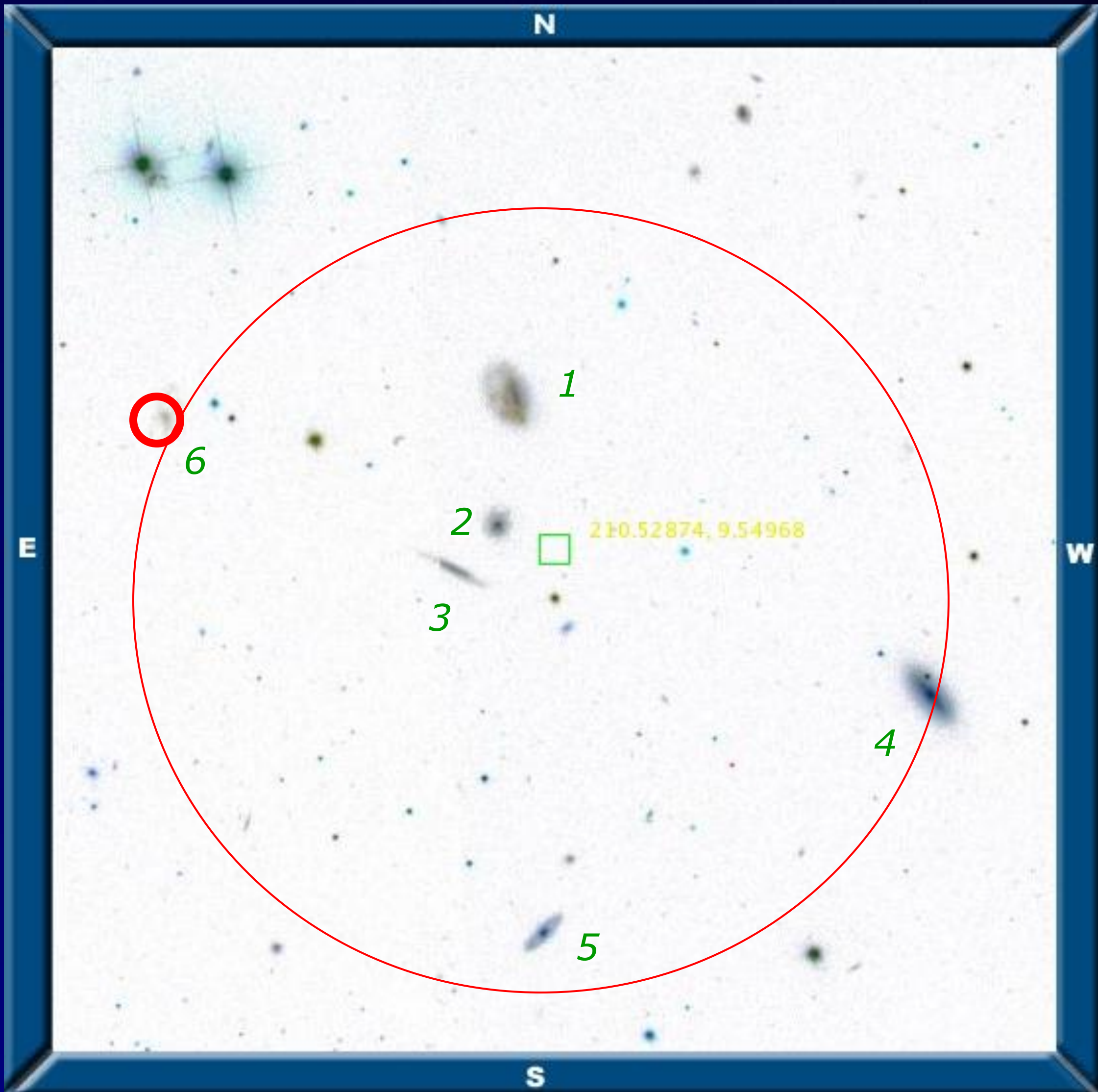
- the HI centroid position
- the position of the most probable OC
- OC's SDSS PhotoObjID and SpecObjID (where applicable)



Of 15855 sources in α.40:

- 1013 have no OC
- 844 of those could be HVCs (or LG minihalos)
- 199 (<2%) extragalactic
- Of those, <50 are "isolated"

ALFALFA advantage for finding the OC



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

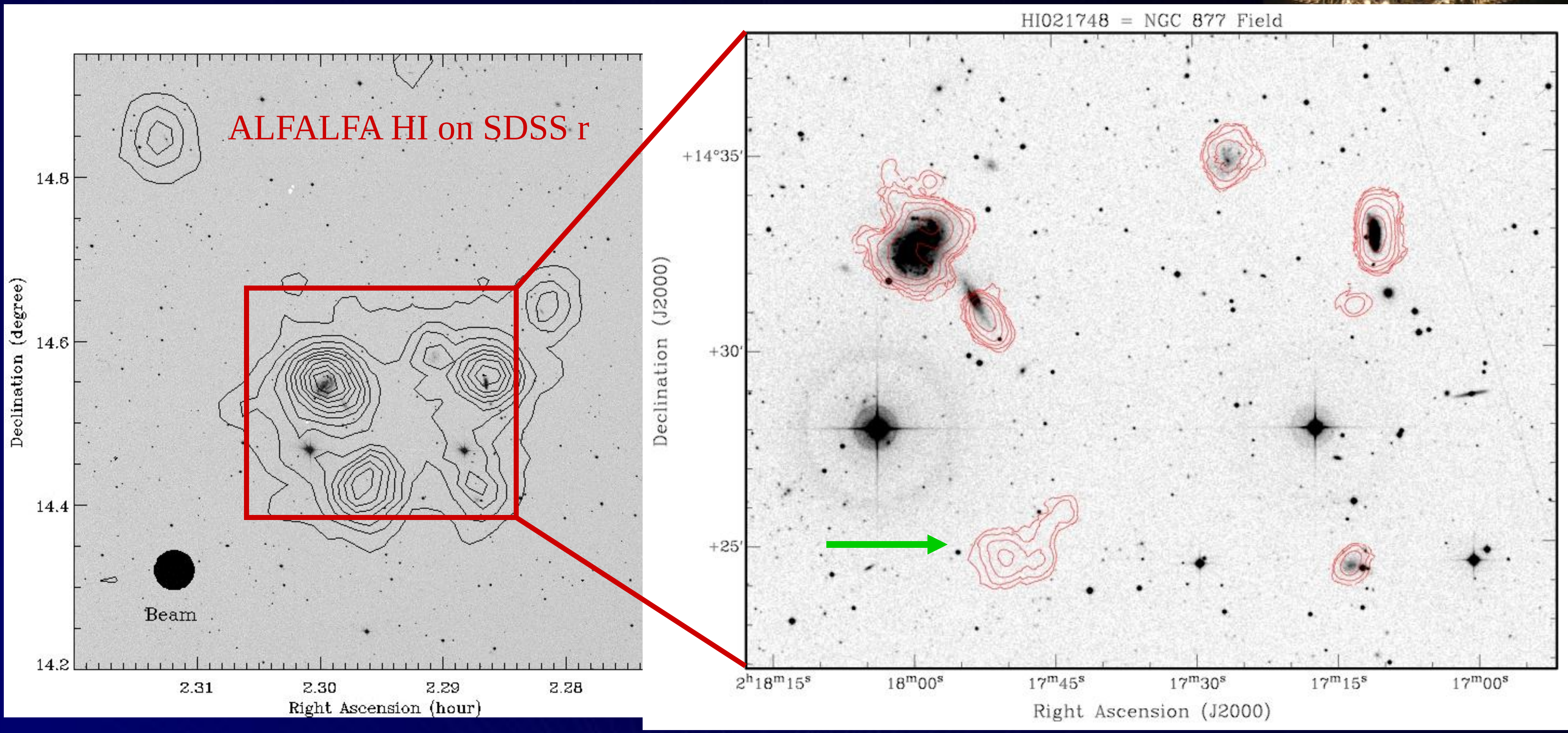
➔ The same source will have an ALFALFA position error of ~ 0.1′

ALFALFA

Dark galaxies

- In agreement with previous results, ALFALFA finds that fewer that 2% of (clearly extragalactic) HI sources cannot be identified with an optical counterpart.
- The majority of objects without OC's are found near to galaxies with similar redshifts.
- There are few interesting cases to be confirmed (work in progress).

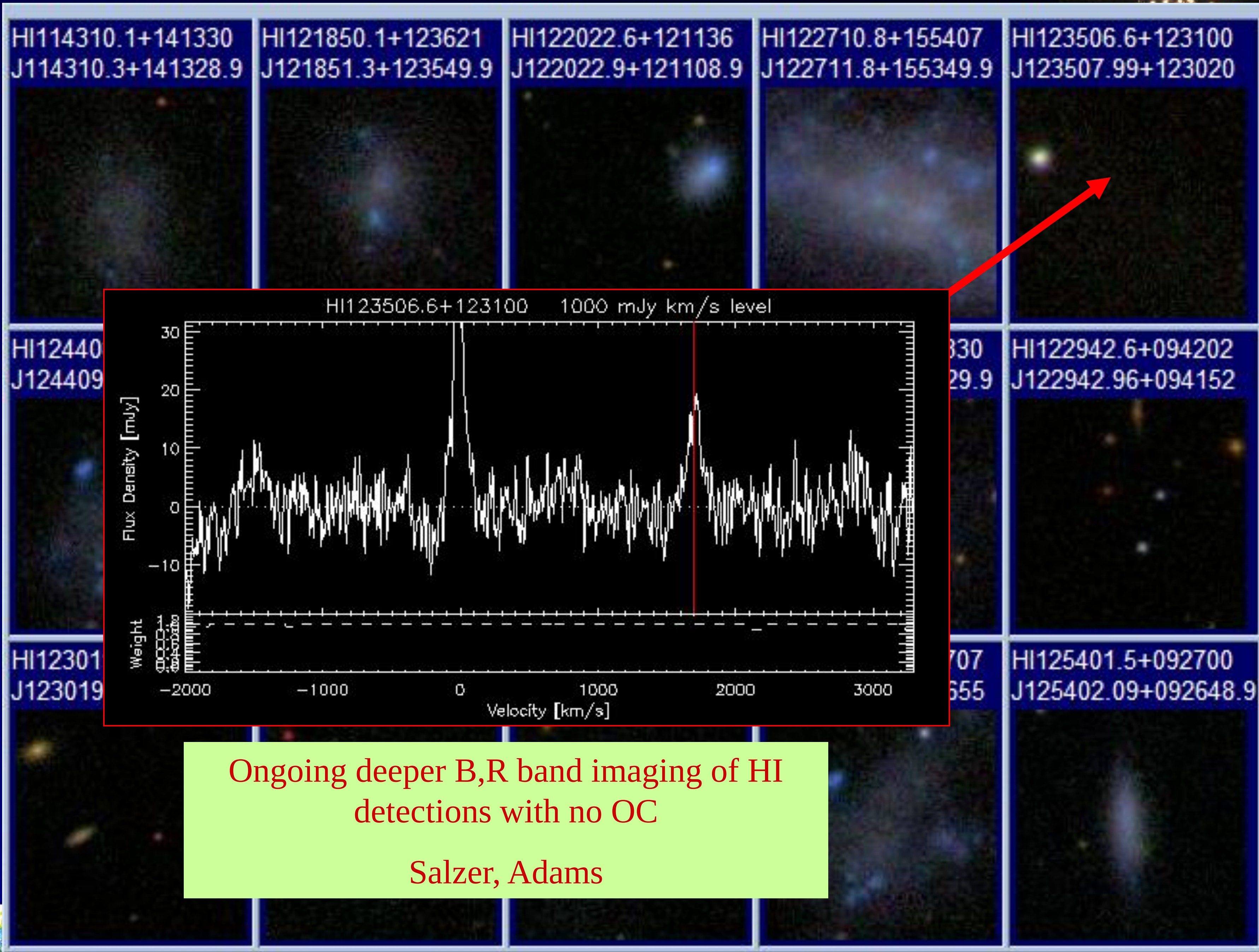
"Dark" object in a group



HI peak with no optical/marginal UV: almost dark?

MH, RG (CU), Cannon (Macalester), Salzer (Indiana), Karen Lee-Waddell, K. Spekkens (RMCC/Queens)

ALFALFA

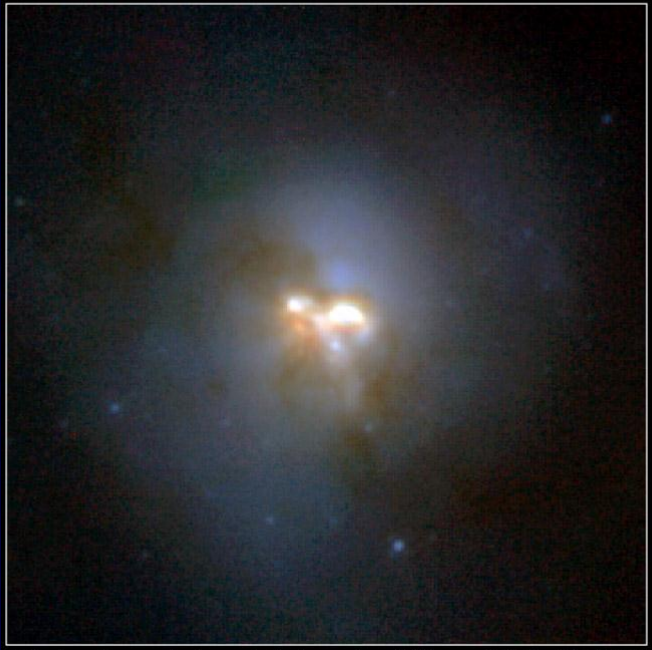


Ongoing deeper B,R band imaging of HI detections with no OC

Salzer, Adams

OH Megamasers: OHMs

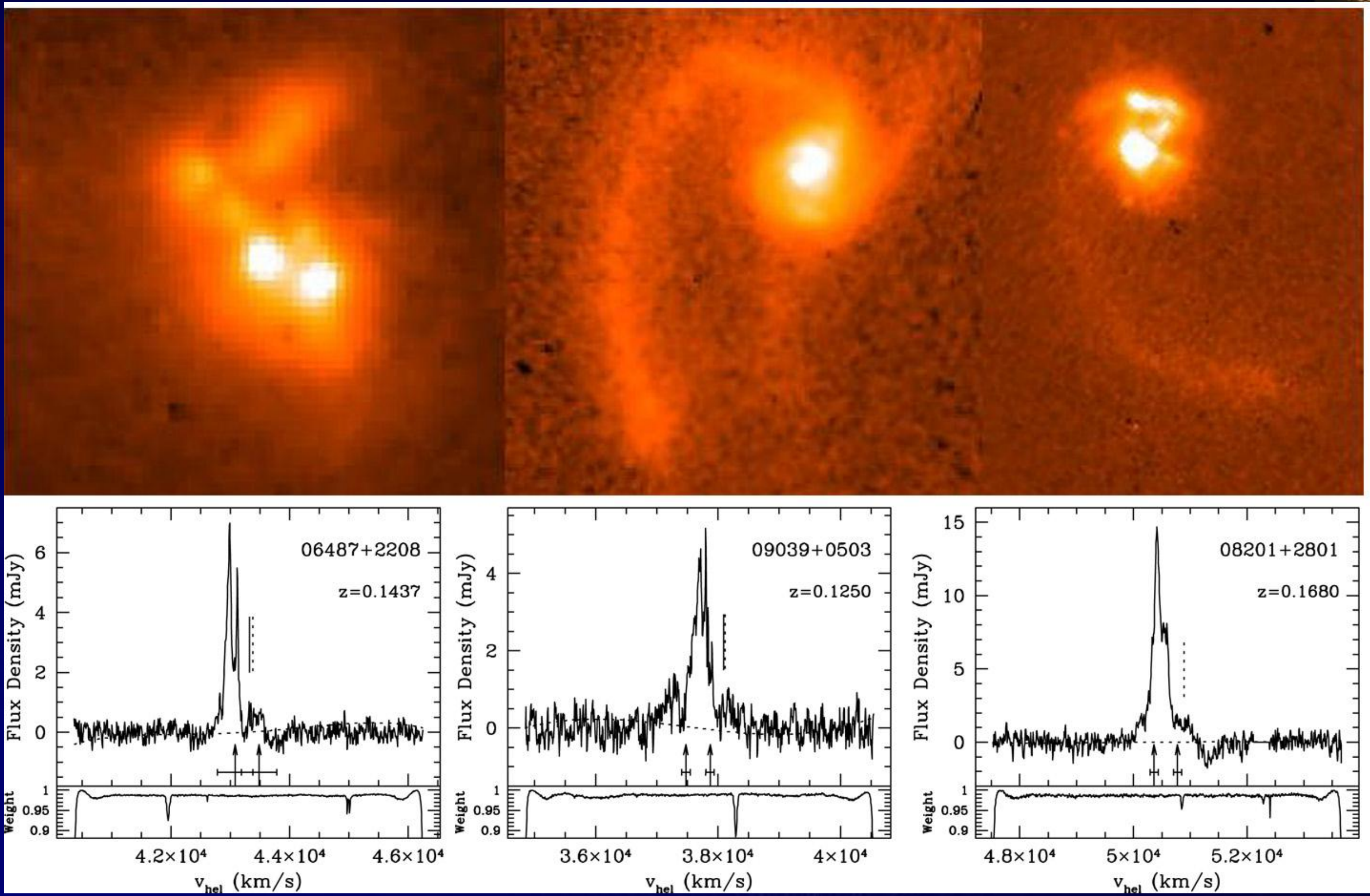
- Arise in interacting/merging galaxy systems.
  - When galaxies merge, gas clouds close to their nuclei are shocked and heated by the collision, and the emission from certain molecules especially OH is strongly amplified.
- Since this stimulated emission is like the more familiar laser but occurs in the microwave region of the electromagnetic spectrum, it is called a "maser".
- When galaxies collide, the emission is millions of times stronger than in normal galaxies, hence the term "megamaser".
- Such objects are also typically (ultra) luminous in the far-infrared.



Ultraluminous Infrared Galaxy Arp 220 HST • NICMOS
PRC97-17 • ST ScI OPO • June 9, 1997
R. Thompson (University of Arizona),
N. Scoville (California Institute of Technology) and NASA

ALFALFA

18 cm OHMs



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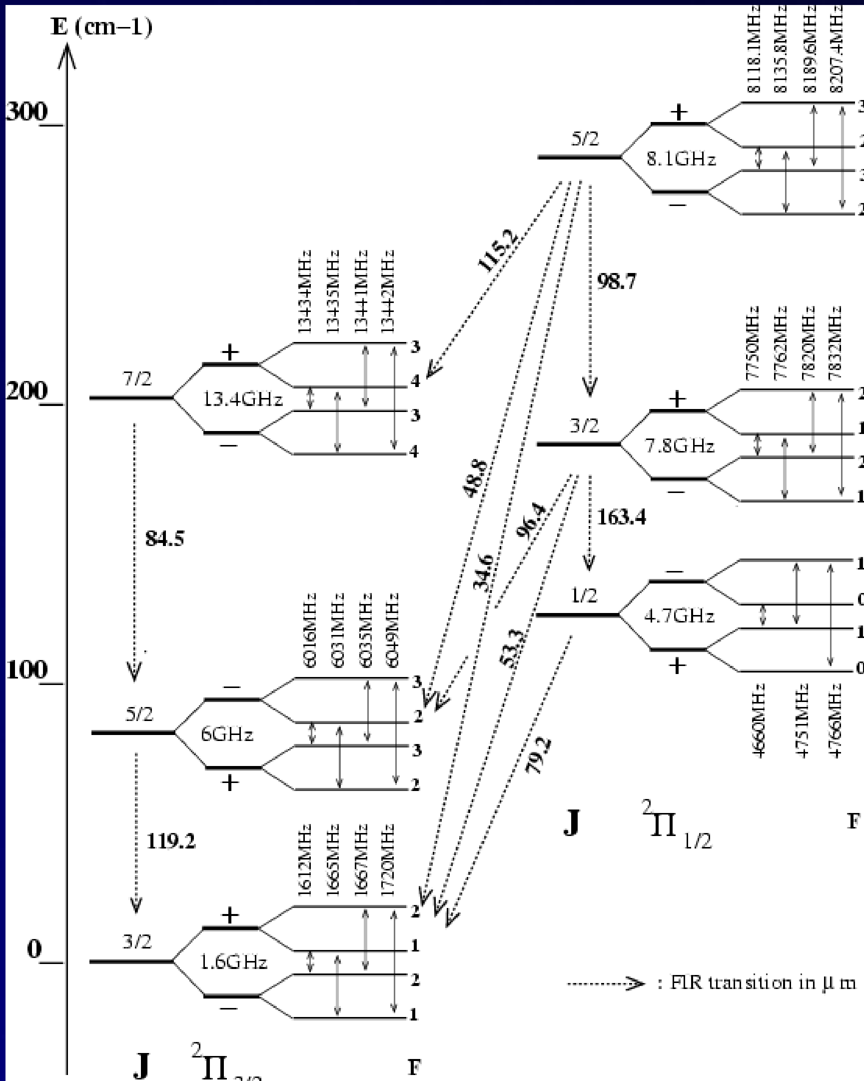
18 cm OH lines



- First molecular lines detected in radio.
- 18 cm lines formed by "lambda doubling" hyperfine structure
- 1612, 1665, 1667 and 1720 MHz

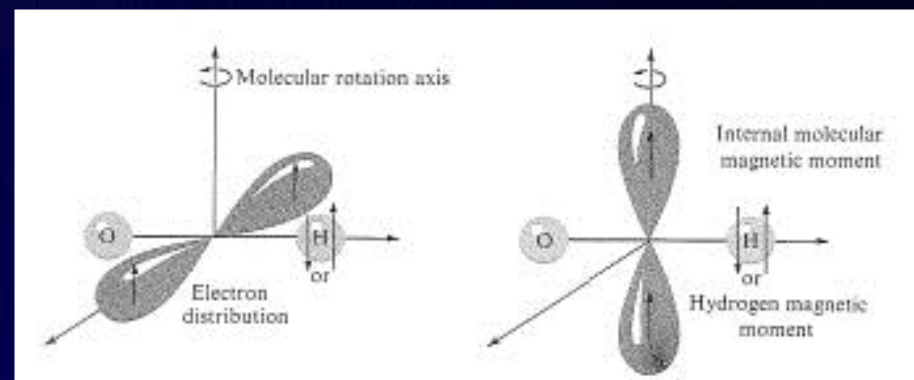
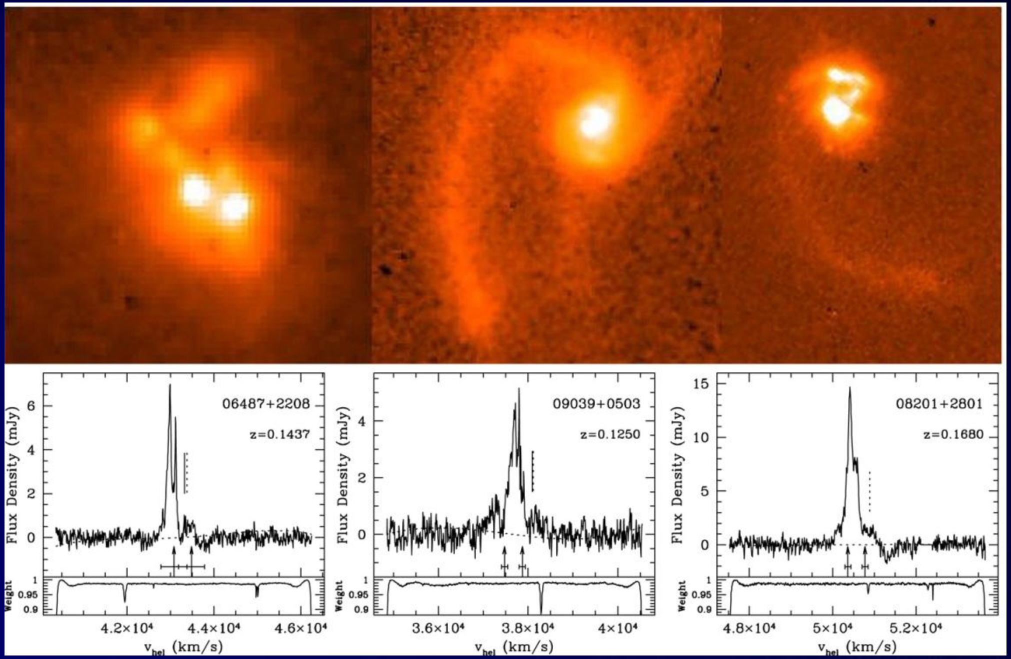


Fig. 8.2 The two different orientations of the electron distribution in the OH molecule leading to Λ-doubling.

Pacholczyk, *Radio Astrophysics*

ALFALFA

Redshifted 18 cm OHMs in ALFALFA



- $f_5 = 1665.4018$
- $f_7 = 1667.3590$

In OHMs, $S(f_7) > S(f_5)$

$f_{obs} = f_{rest} / (1+z)$

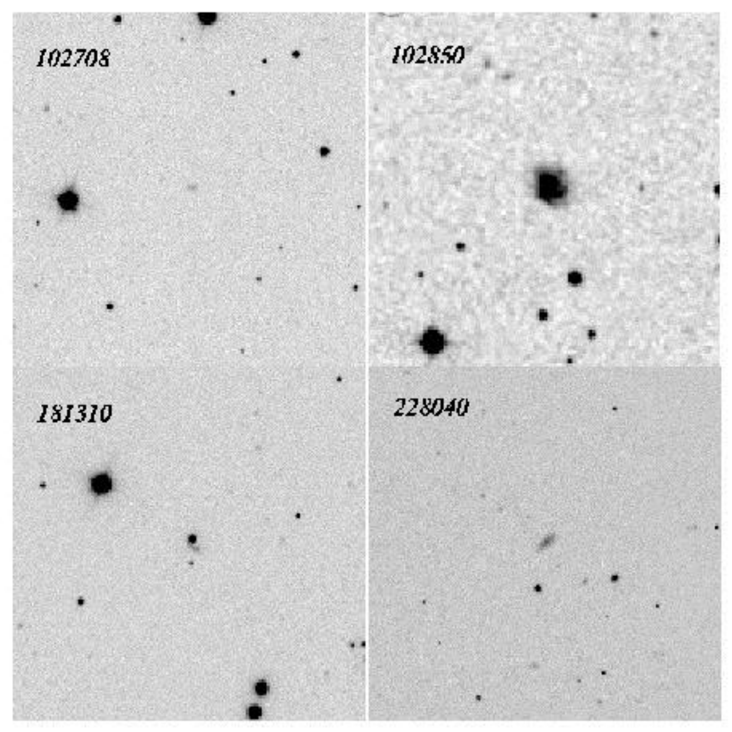
ALFALFA: 1340-1430 MHz, corresponding, for OH, to $0.166 < z < 0.244$

- Emission at $f > 1422$ MHz (blueshifted if HI)
- Emission associated with OC in $0.1666 < cz < 0.244$
- Emission with no OC

OHM candidates in α.40

Table 4
OH Megamaser Candidates

AGC (1)	OHM Coords (J2000) (hh mm ss.s+dd mm ss) (2)	Opt. Coords (J2000) (hh mm ss.s+dd mm ss) (3)	z_{opt} (4)	z_{OH} (5)	cz_{21} (km s^{-1}) (6)	F_{OH} (Jy km s^{-1}) (7)	S/N (8)	rms (mJy) (9)
102708	000337.0+253215	000336.1+253204		0.169	−1335	0.91	5.7	2.33
102850	002958.8+305739	002958.2+305832		0.172	−596	0.46	6.7	2.09
181310	082311.7+275157	082312.7+275138	0.16783	0.168	−1551	2.17	15.9	2.18
228040	124540.5+070337	124545.7+070347		0.172	−624	0.33	5.1	2.11



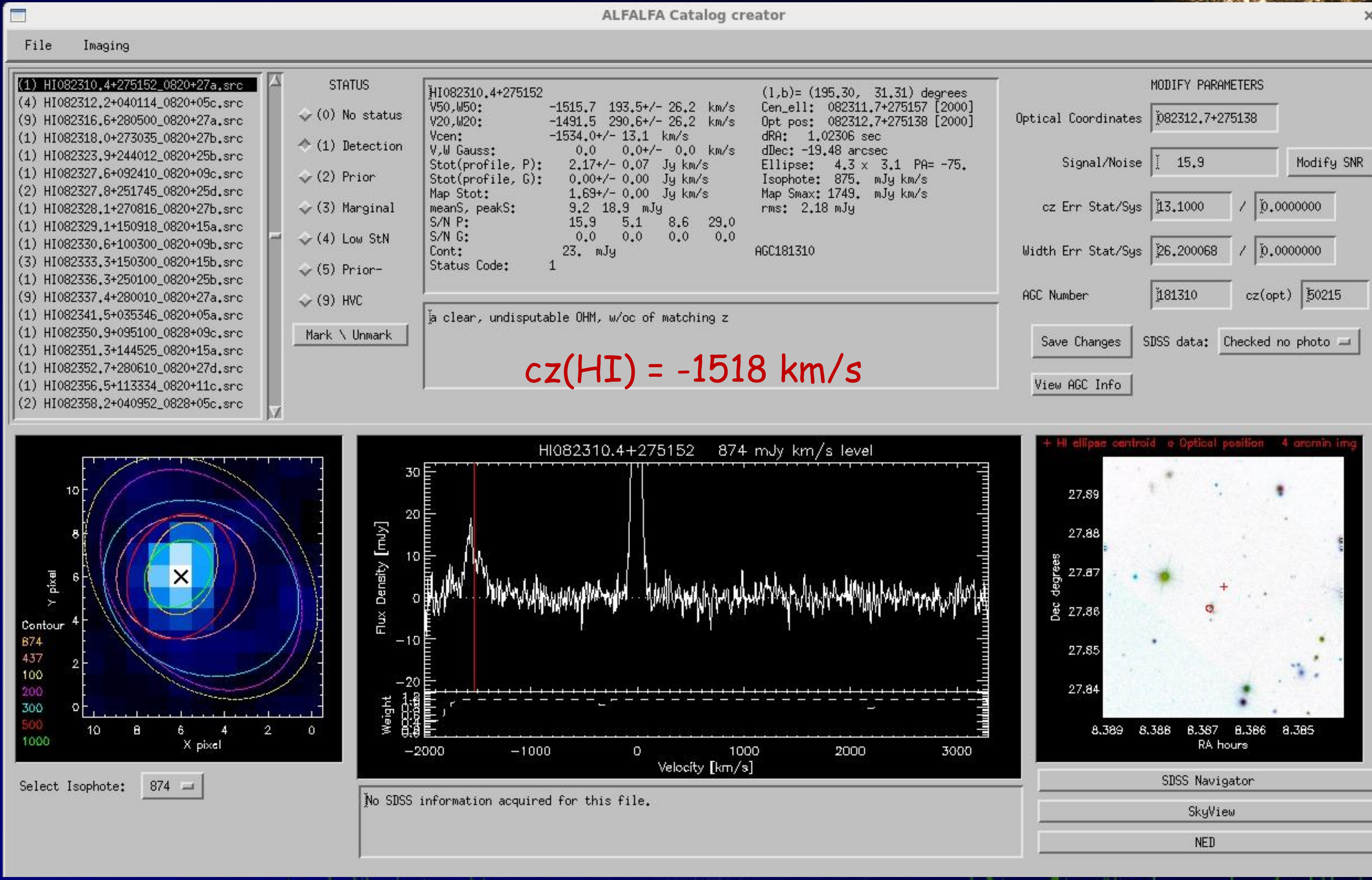
AGC 181310:

- Previously discovered OHM by Darling & Giovanelli (2001)
- Coincides with SDSS J083212.61+275139.8 at z=0.167830
- Also IRAS 08201+2801 and 5C 07.206

We need to confirm the others, and a few more low SNR sources.

ALFALFA

AGC 181310: confirmed OHM



ALFALFA

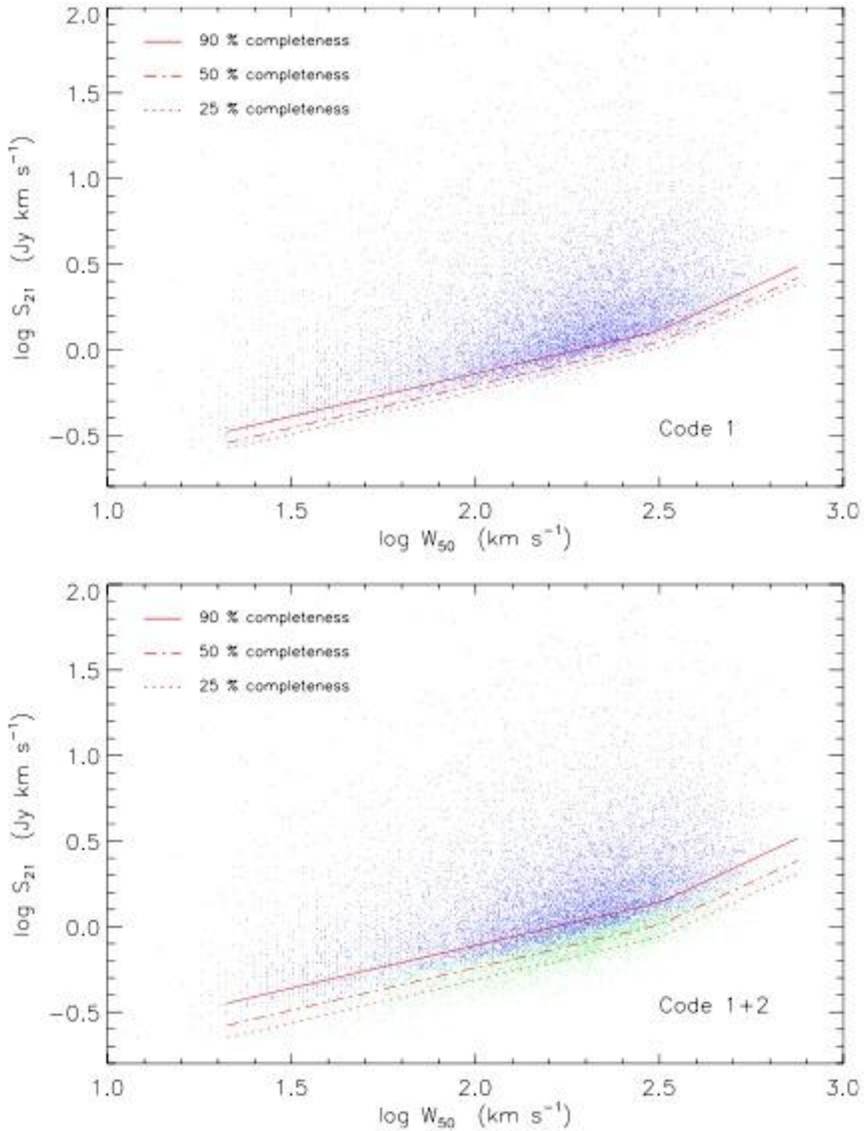


Figure 12. Distribution of α.40 extragalactic sources in the profile width vs. integrated flux density ($\log W_{50} - \log S_{21}$) plane. The upper panel shows the distribution of Code 1 detections only, while the lower panel shows the same for the whole α.40 catalog, including Code 1 (blue symbols) and Code 2 (green symbols) detections. In both panels, the solid red line corresponds to the 90% completeness limit, while the red dash-dotted line corresponds to the 50% ("sensitivity limit") and the red dotted line to the 25% ("detection limit") completeness limits. See Section 6 for the analytical expressions for the plotted limits, as well as for an explanation of the derivation method.

ALFALFA sensitivity & completeness

- We want to integrate longer on the low S/N sources.
- Even on high S/N sources, we want to verify they are real.
- Point at OC if there is one or the HI centroid if not
  "Targeted observations"

- LBW has a single horn ("pixel") but higher gain and lower T_{sys} than ALFA

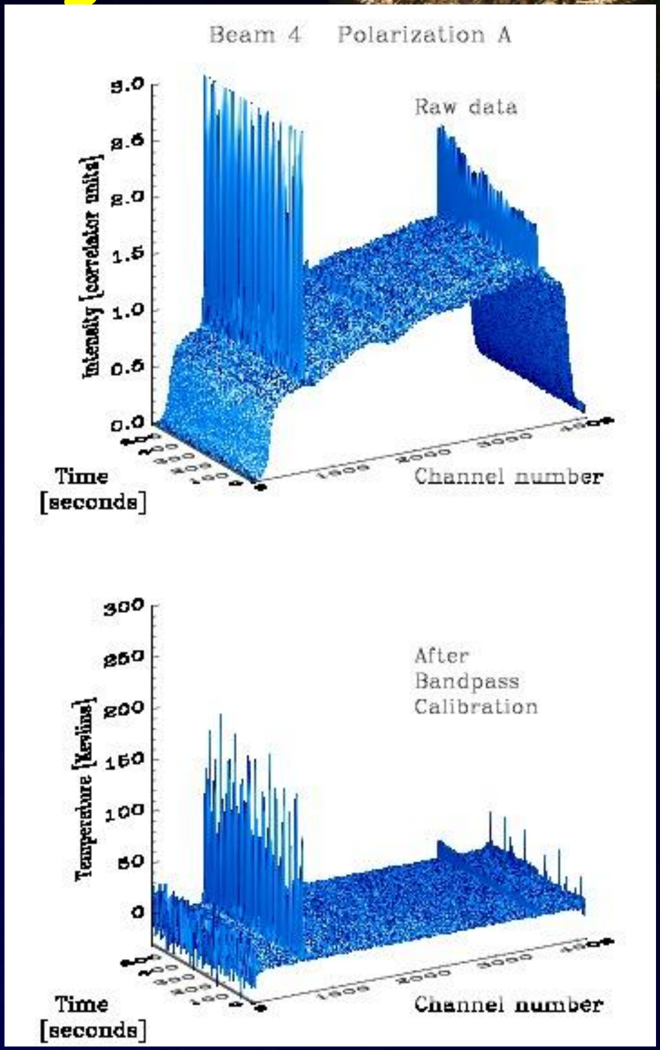
Position-switched observing

The signals we are trying to take are billions of times weaker than the radio noise contributed by the receiver, electronics, antenna, cosmic microwave background and the sky overall.

Somehow, we have to subtract off all those unwanted contributions to find our signal.

We assume that a random position in the sky does not contain an HI line source at the exact same velocity as our target source.

We observe such a position, but track it over the exact same Az, ZA as our observations of the target source. => ON-OFF pair



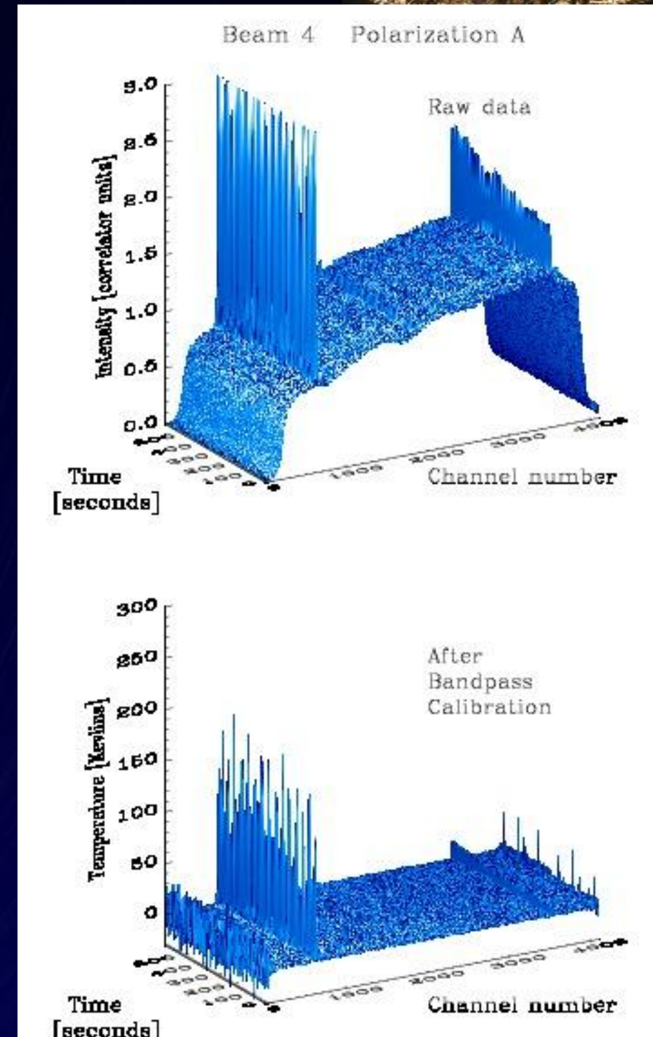
ALFALFA

Position-switched observing

- Position telescope on target source
- Track ON-source for 3 minutes
- Move to same Az,ZA as at start of ON-source track but 4 mins from now; this is the OFF-source position.
- Track OFF-source for 3 minutes.
- Record noise with “CAL” (noise diode) – ON for 10 secs; then record noise for 10 sec with CAL-OFF.

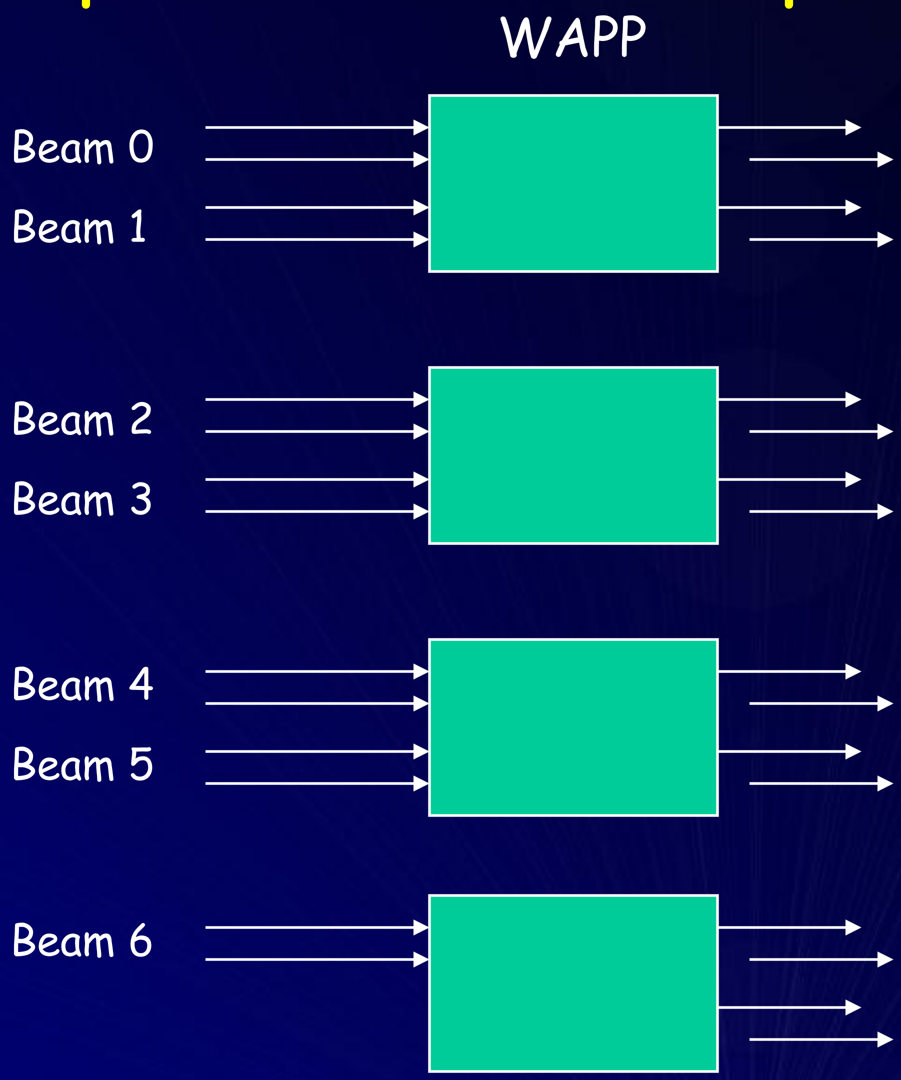
- Go to next target.
- Repeat ON-OFF-CAL ON/OFF sequence

This is what the “command file” (for a set of sources for the whole night) does.



ALFALFA

Spectrometer setup for LBW



ALFA spectra:

16 x 4096 frequency channels (2 not used)

7 beams X 2 polarizations/beam

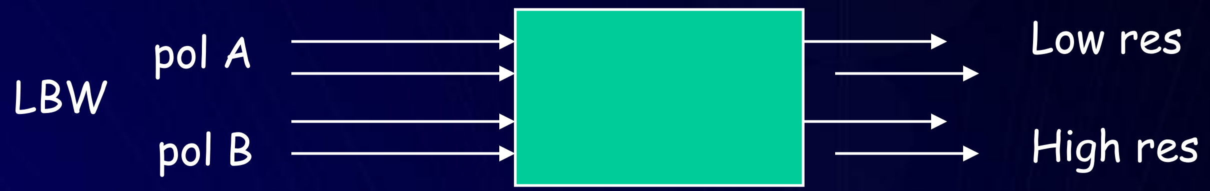
100 MHz wide

Centered at 1385 MHz

So resolution is 100 MHz/4096 channels

Spectrometer setup for LBW

Interim Correlator



So resolution is

Low res: 25 MHz/2048 channels

High res: 6.25 MHz/2048 channels

LBW spectra:

4 x 2048 frequency channels

1 beam X 2 polarizations/beam

Low res/high res

25 MHz / 6.25 MH

Centered at doppler velocity of target

Estimating how long we integrate

The radiometer equation for our observations

$$S_{\rm rms} = \frac{(T_{\rm sys}/G)}{\sqrt{2\Delta f_{\rm ch} t_s f_t}},$$

For LBW,
T~ 30K
G ~ 11 K/Jy

Δf : is the bandwidth per channel
t_s : is the effective integration time, in secs
f_t : accounts for the degree of smoothing, the technique applied for bandpass subtraction, clipping losses, etc.
The factor of 2 under the square root comes from the fact that we average the two independent polarizations.

See Giovanelli + 2005, AJ 130, 2598

ALFALFA

A2669/A2707 LBW followup

Targeted LBW observations of selected ALFALFA sources:

1. "Dark" galaxy candidates: high quality (Code 1) detections with no OC and not associated with known tidal debris fields
2. OH megamaser (OHMs) candidates: either at large blueshift or coincident (within centroiding accuracy) of OC of appropriate cz.
3. "Low mass dwarf candidates": low signal-to-noise ratio sources at low cz (< 1000 km/s)
4. Statistical samples of low S/N signals possibly associated with optical galaxies (A2669 only)

ALFALFA: effective integration time of 40 seconds/beam
LBW: 3 minutes ON-source

ALFALFA

Scavenger Hunt #1

Next: 15 min break

Then: Work on SH #1
Work in your groups
ASK questions!

15:15: Remote observing demo