A Successful Automated Search for Crouching Giants

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Abstract

Much effort has been expended during the last two decades on the search for Low Surface Brightness galaxies (LSBs), the galaxies Disney called "Crouching Giants," which may be a dominant mass repository in the universe. The difficulty in gathering information on a significant population of LSBs lies in the time-consuming nature of identifying LSB candidates. To date, all survey-based searches for LSBs have involved manual inspections of plate-based material or optical CCD observations.

We have conducted the first successful automated search for HI–rich galaxies (including LSBs) using the Minnesota Automated Plate Scanner (APS) Catalog of the POSS I. We identified HI–rich candidates by selecting galaxies located on the "blue edge" of an O–E vs. E color-magnitude diagram from the APS Catalog. Subsequent 21-cm observations on the upgraded Arecibo 305m dish showed that over 50% of our observed candidates were HI–rich with M_{HI}/ L_B ranging from 0.1 to 4.8 (in solar units). These M_{HI}/ L_B values are comparable to those of LSB candidates selected by manual means. Comparison of our candidate galaxies with known LSB galaxies shows that they have similar bivariate brightness distributions as well as other optical properties. Furthermore, examination of existing LSB catalogs shows that over 65% of LSBs are located on the "blue edge," whereas only 10% of the general APS galaxy population has O–E values this low. Known LSB galaxies on the O–E "blue edge" include several LSBs with red B–V colors from O'Neil, Bothun, and Schombert (2000), indicating our bandpasses are critical in the segregation of these LSB candidates from the general population.

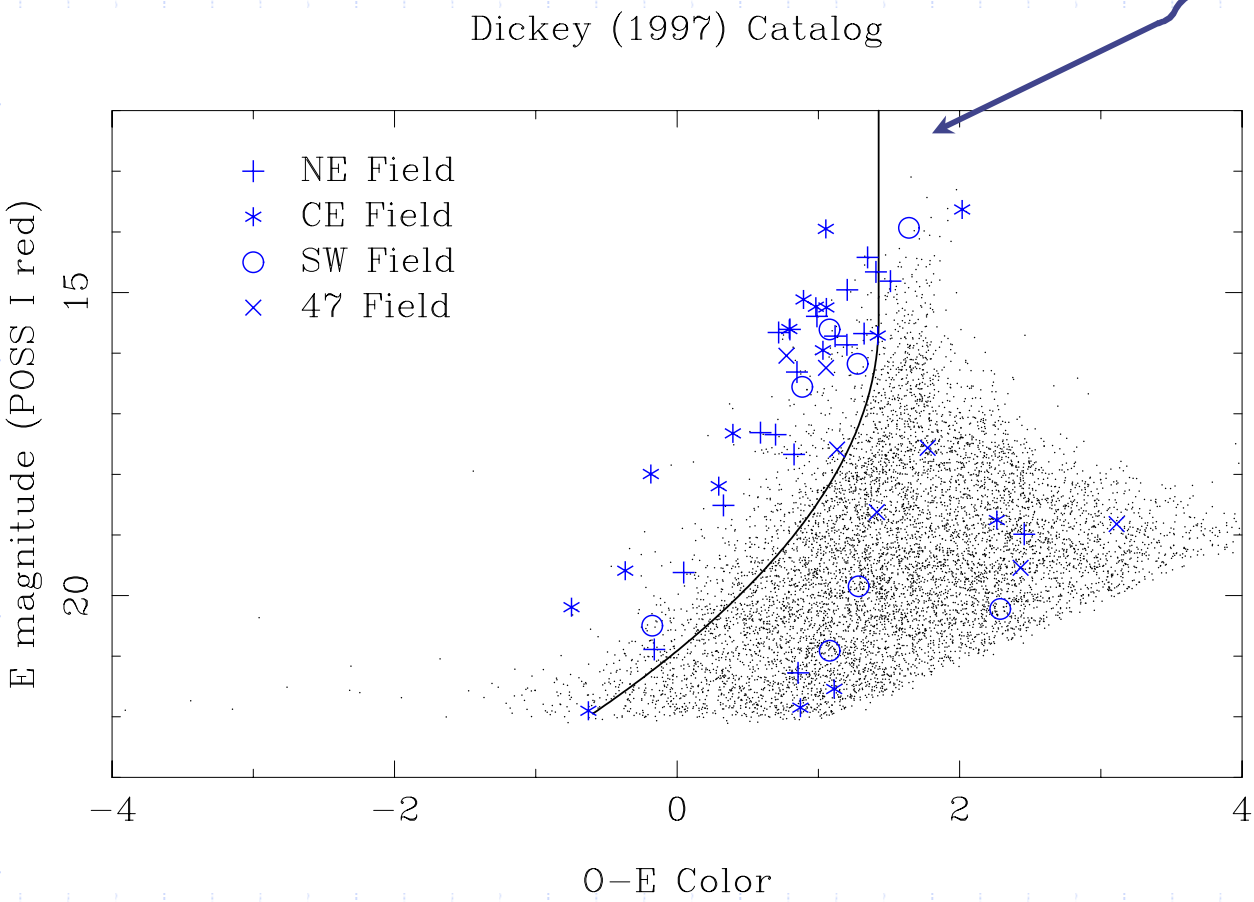
We have determined the physical basis for the success of these simple search criteria, which is tied to the low current star formation rate of LSBs. The details of the search algorithm and guidelines of how to apply it to other existing surveys, such as the SDSS, will be provided.

Project Goals

- Automated identification of HI-rich galaxy candidates.
- Explanation of why HI-rich galaxies lie on the “blue edge” of an O–E vs. E color-magnitude diagram.
- Outline a possible way for LSBs to be quickly segregated by Star Formation Rate.

Color-Magnitude Diagrams: HI-rich Galaxies vs. the Rest

- Cross-identification of Dickey HI catalog of Hercules Region (Dickey 1997) with APS Catalog of POSS I led to this surprising result



- **Most HI galaxies' optical counterparts lie on the "blue edge" of an O–E vs. E color-magnitude diagram.**
- Could this be characteristic of HI-rich galaxies in general?

Probing the "Blue Edge"

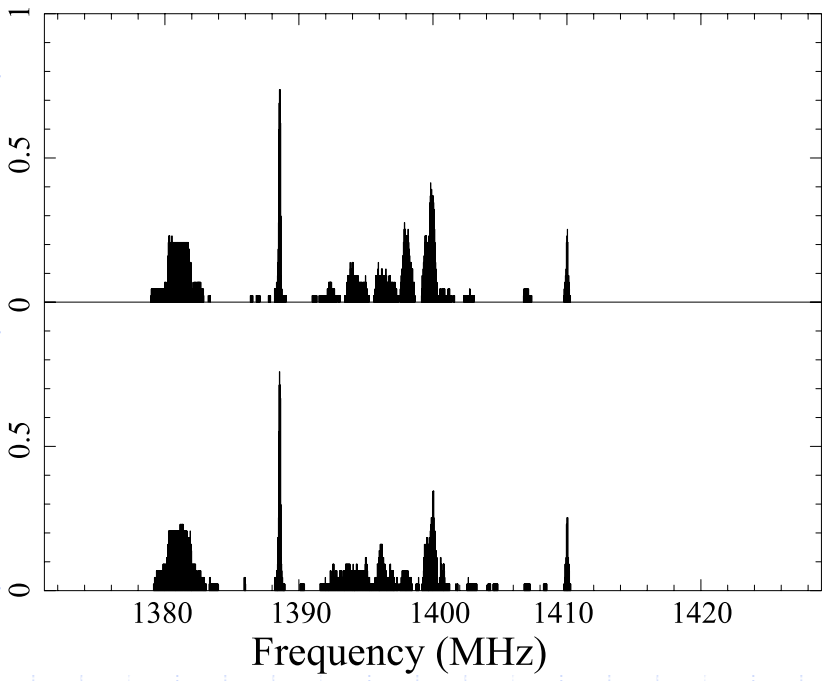
- Test hypothesis that "blue edge" of APS Catalog also HI-rich edge.
  - Select galaxies on the "blue edge" of O–E vs. E diagram from the APS Catalog
  - Search for them in HI.
- Selection of HI Candidates
  - Focused on the Pisces-Perseus field (known supercluster at ~5000 km/s).
  - Galaxies within 2˚ of Supercluster Ridge.
  - Selected Bluest (lowest O–E) objects with m_O~16 to 21.
  - After initial automated selection, manual inspection of images gave us 75 candidates.

Arecibo Observations

- Observed 31 galaxies in Pisces-Perseus field.
- 14 nights between August 6 and 20, 1998.
- New Gregorian Feed used with narrow L band receiver.
- 21cm line spectra using staggered 25MHz bands overlapping 5MHz centered on cz = 5000km/s.
  - Final Coverage: cz = 0–10,000 km/s
- Typical integration: 8 minutes on + 8 minutes off
  - Some candidates observations repeated to confirm tentative signal or overcome RFI.

Managing Radio Frequency Interference

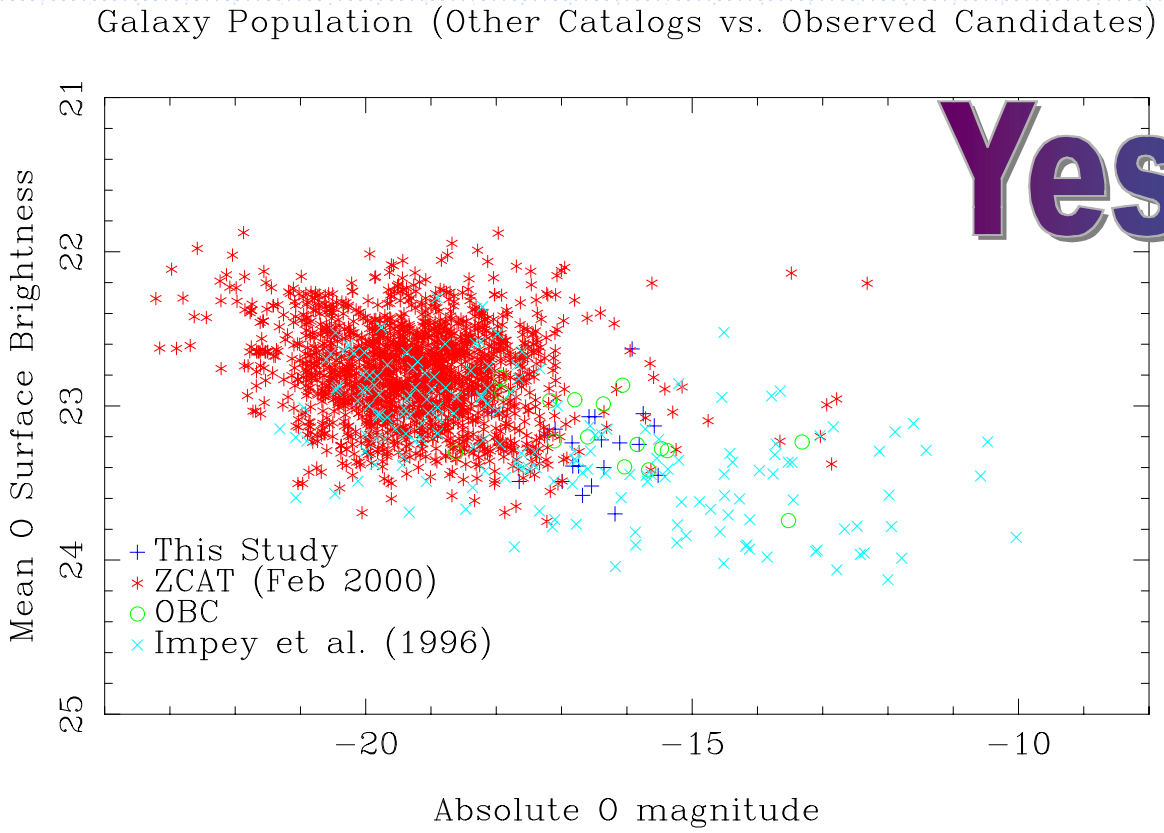
- RFI was identified by looking at both polarizations separated.
  - **RFI is generally polarized**, so signals that are different in the two polarizations were identified as likely RFI.
- RFI was a consistent problem at certain frequencies (see figure below)
  - galaxies at cz = 6865 to 6910 km/s and 8300 to 8800 km/s would rarely have been detectable.



HI Results

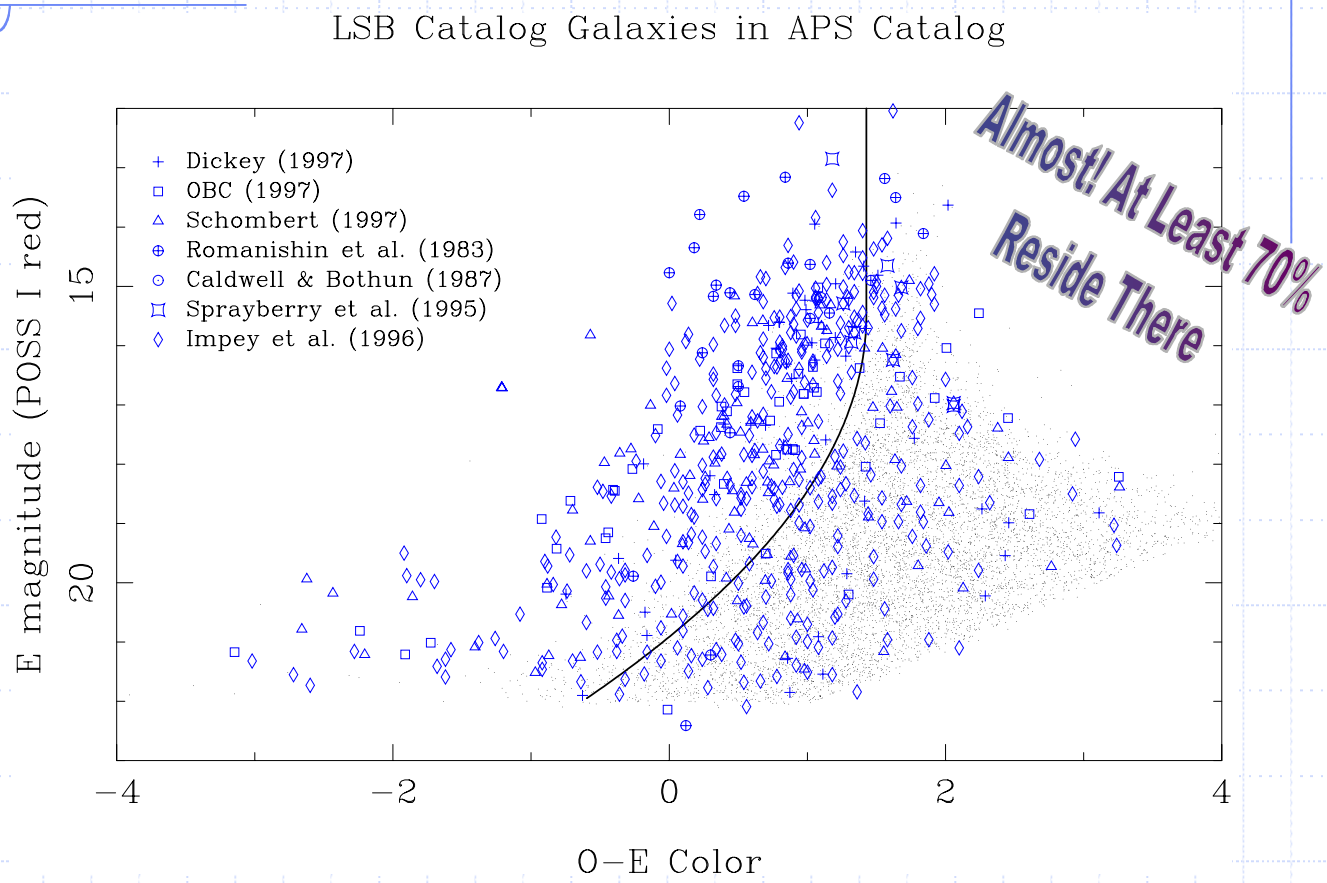
- Of 31 galaxies observed:
  - 16 (52%) were detected.
  - 4 more tentatively detected.
  - 3 off-beam detections.
  - **See Review of Images & Spectra**
- HI masses ranging from 2.7×10^8 $M_\odot$ to 3.6×10^9 $M_\odot$.
- M_{HI}/L_O from 0.09 to 3.73 $M_\odot/L_\odot$
  - Much higher than “normal” galaxies, but typical of LSBs.
- No extreme Malin 1 like objects discovered, but plenty of HI-rich galaxies recovered.

The “Blue Edge”: Is It A Distinct Population?



- Bivariate brightness distribution of our sample vs ZCAT & LSBs (with APS magnitudes & colors).
  - **Our galaxies are a distinct population** separate from ZCAT (mostly high surface brightness galaxies) and nested within the LSB population of O’Neil, Bothun, & Cornell (1997)and Impey et al. (1998).

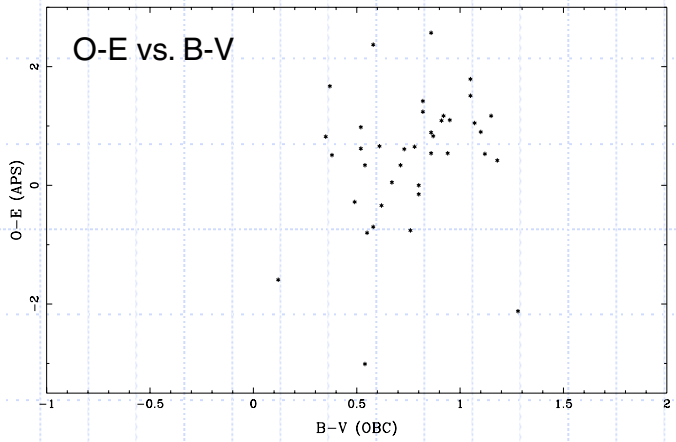
The “Blue Edge”: Do All LSBs Reside There?

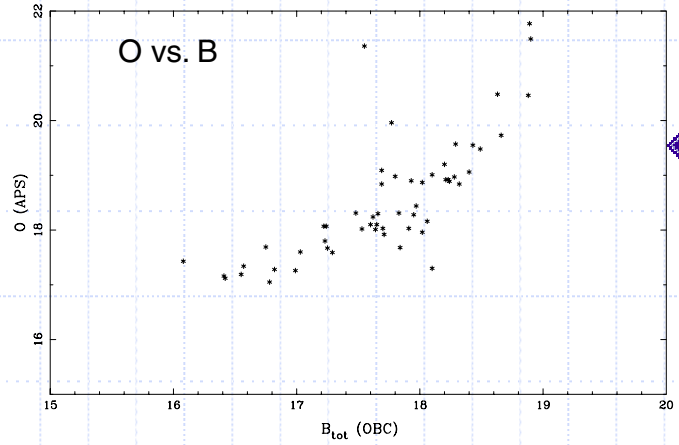


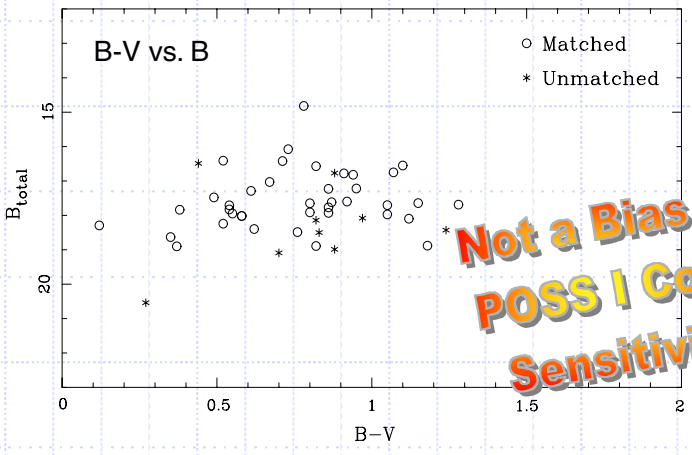
- “Blue Edge” also prominent in LSB catalogs, **even the “red” (B-V) galaxies from O’Neil, Bothun, & Cornell (1997) are Blue on POSS I.**
- Over 70% of LSBs are blueward of the bluest 10% of “normal” APS galaxies (marked by the dark curving vertical line).

The "Blue Edge": Is It Due to High Current Star Formation?

O'Neil, Bothun, & Cornell (1997) in the APS Catalog of the POSS I







Not a Bias in POSS I Color Sensitivity.

Examination of O'Neil, Bothun, and Cornell (1997) LSBs in APS Catalog shows:

- O-E not well correlated with B-V, but O strongly correlated with B.
- This suggests it is the POSS E magnitudes that are dimmer than expected. **Less light in the E bandpass is causing the observed blue O-E colors.**

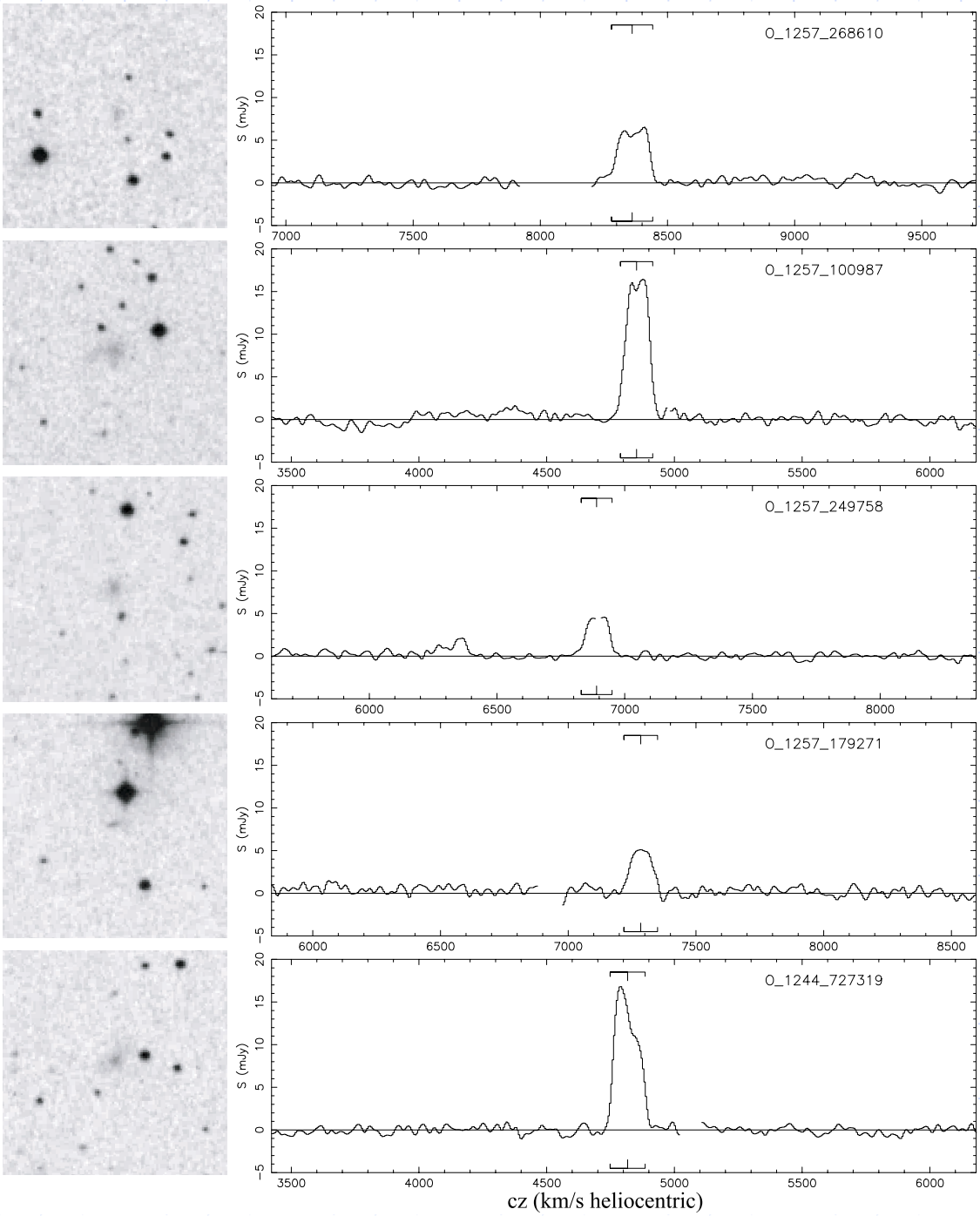
A Connection to Current Star Formation Rates?

- The POSS E bandpass is very narrow, centered on Hα.
- Hα flux correlated with star formation rate.
- **Our "Blue Edge" appears to be a reflection of a low star formation rate (and thus low Hα flux).**
- About 30% of known LSBs lie redward of "Blue Edge," $\Rightarrow$ LSBs with ongoing star formation?

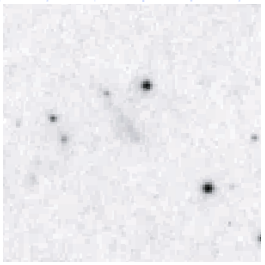
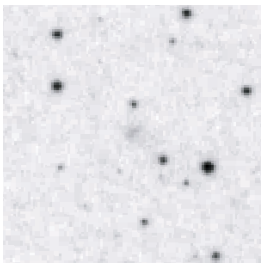
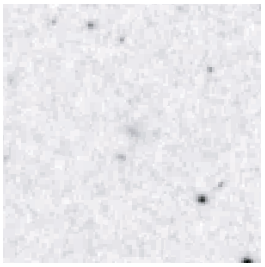
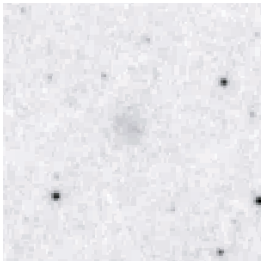
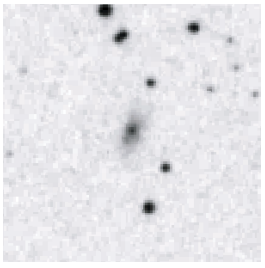
Conclusions & Future Directions

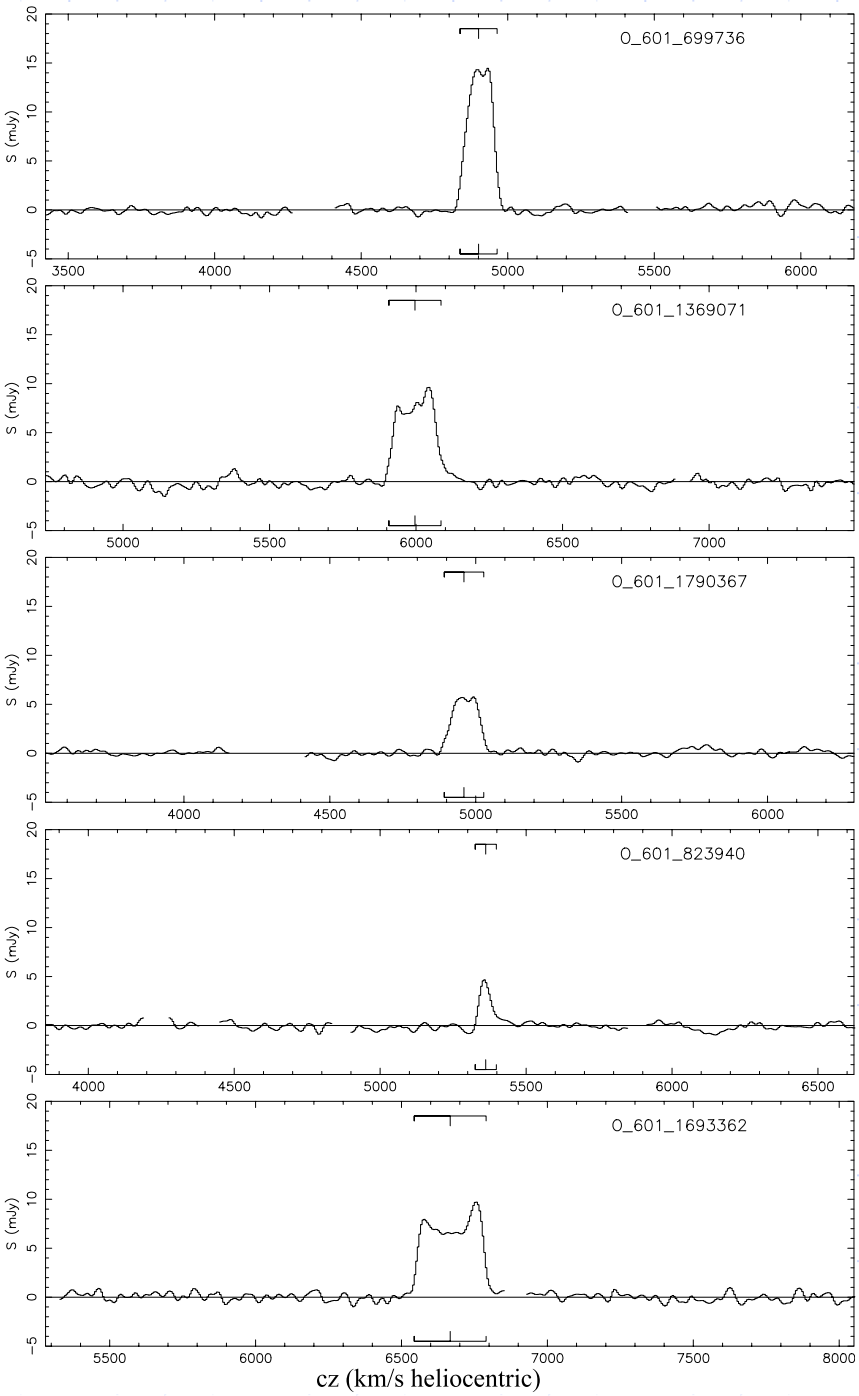
- **We have developed a successful method for selecting HI galaxies from an optical catalog.**
- **We believe the "Blue Edge" is a reflection of the current low star formation rate in LSBs.**
  - This may offer a quick way of segregating known LSBs by varying SFR.
- **Future Directions**
  - Multi-bandpass CCD observations may provide useful followup.
  - B–Hα vs. Hα should show the "Blue Edge" tied to current SFR.
  - SDSS: Could look for "blue edge" in g'-r' vs. r', but r' is much wider than E, may not be sensitive to this effect. But if effect visible on SDSS, than B-R vs. R should also show it.

Review of Detected Galaxies 1

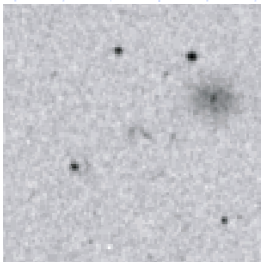


Review of Detected Galaxies 2

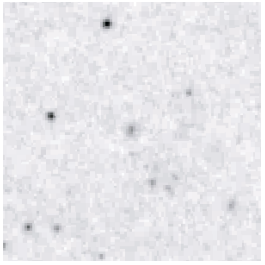






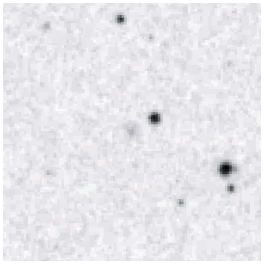


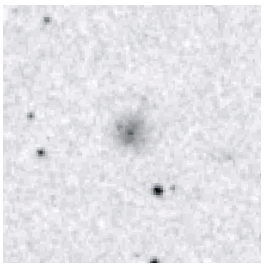
Review of Detected Galaxies 3

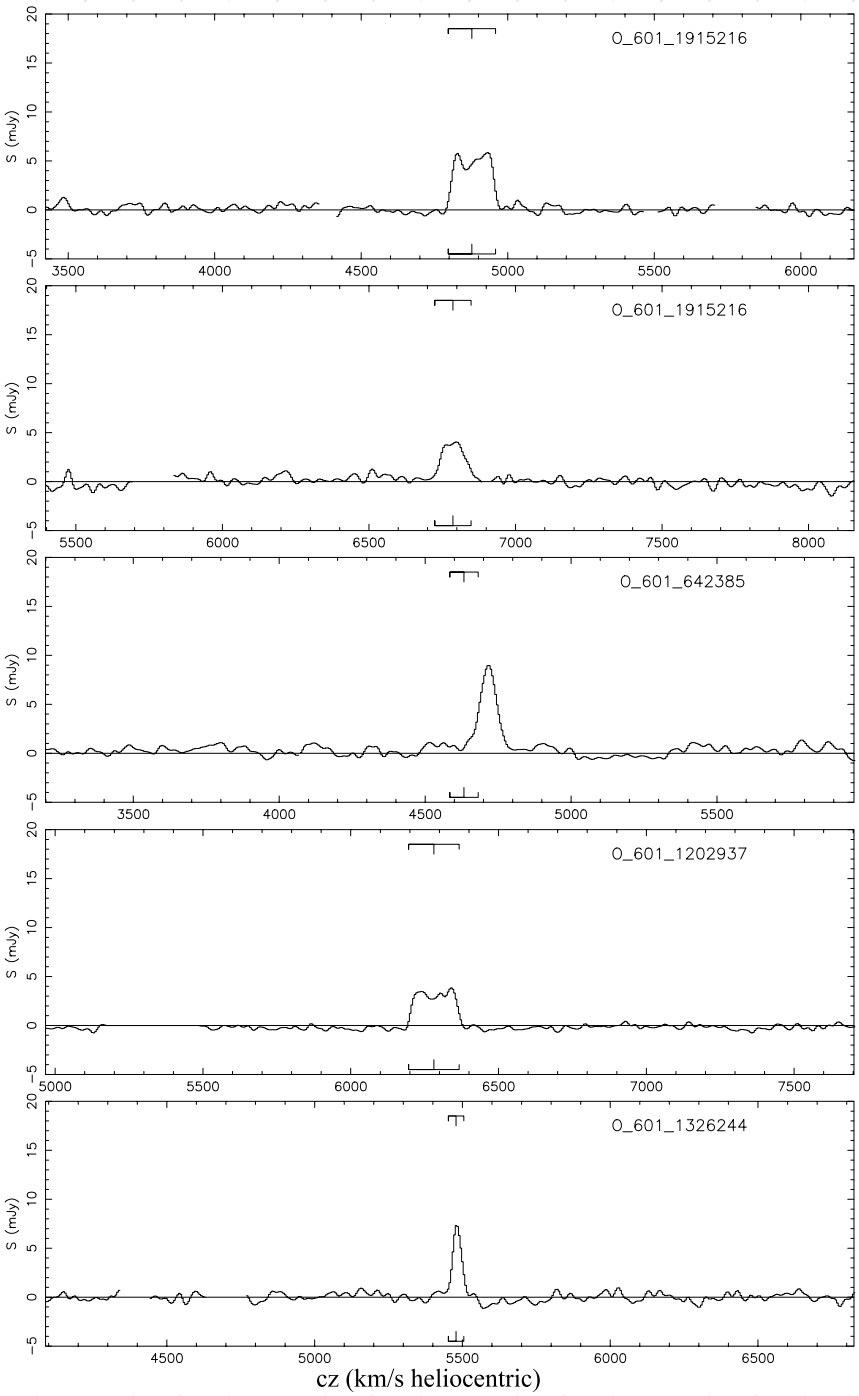


NOTE: UGC 630 is in the center right of this field and has a systemic velocity of 4884 km/s. O_601_1915216 is spectra to right.

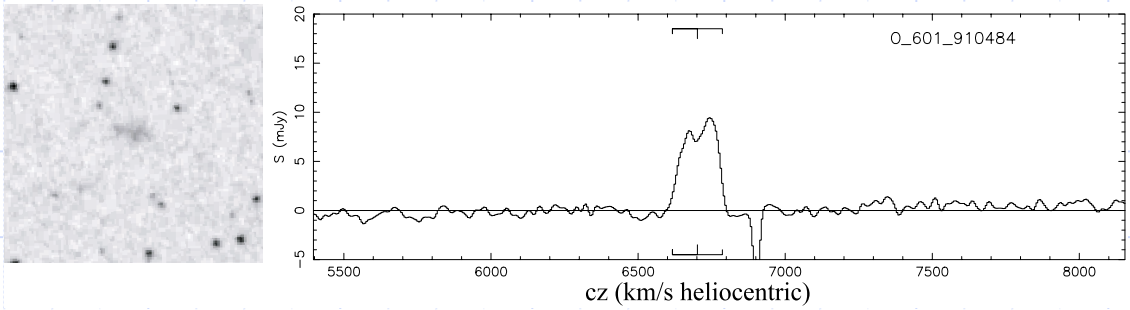


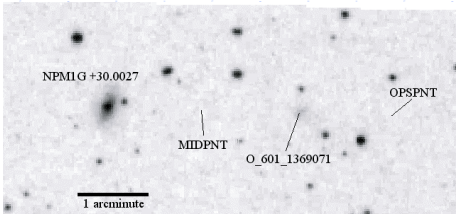


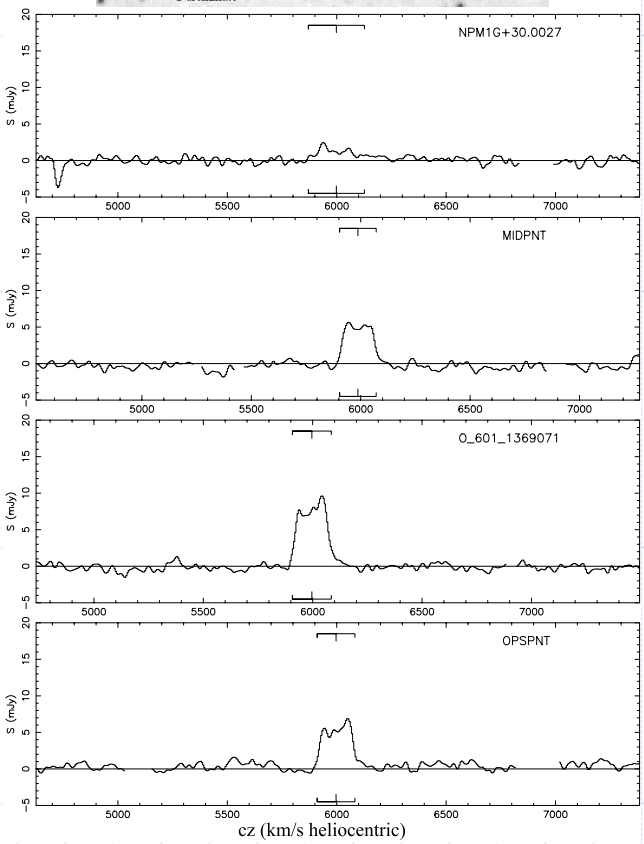




Review of Detected Galaxies 4

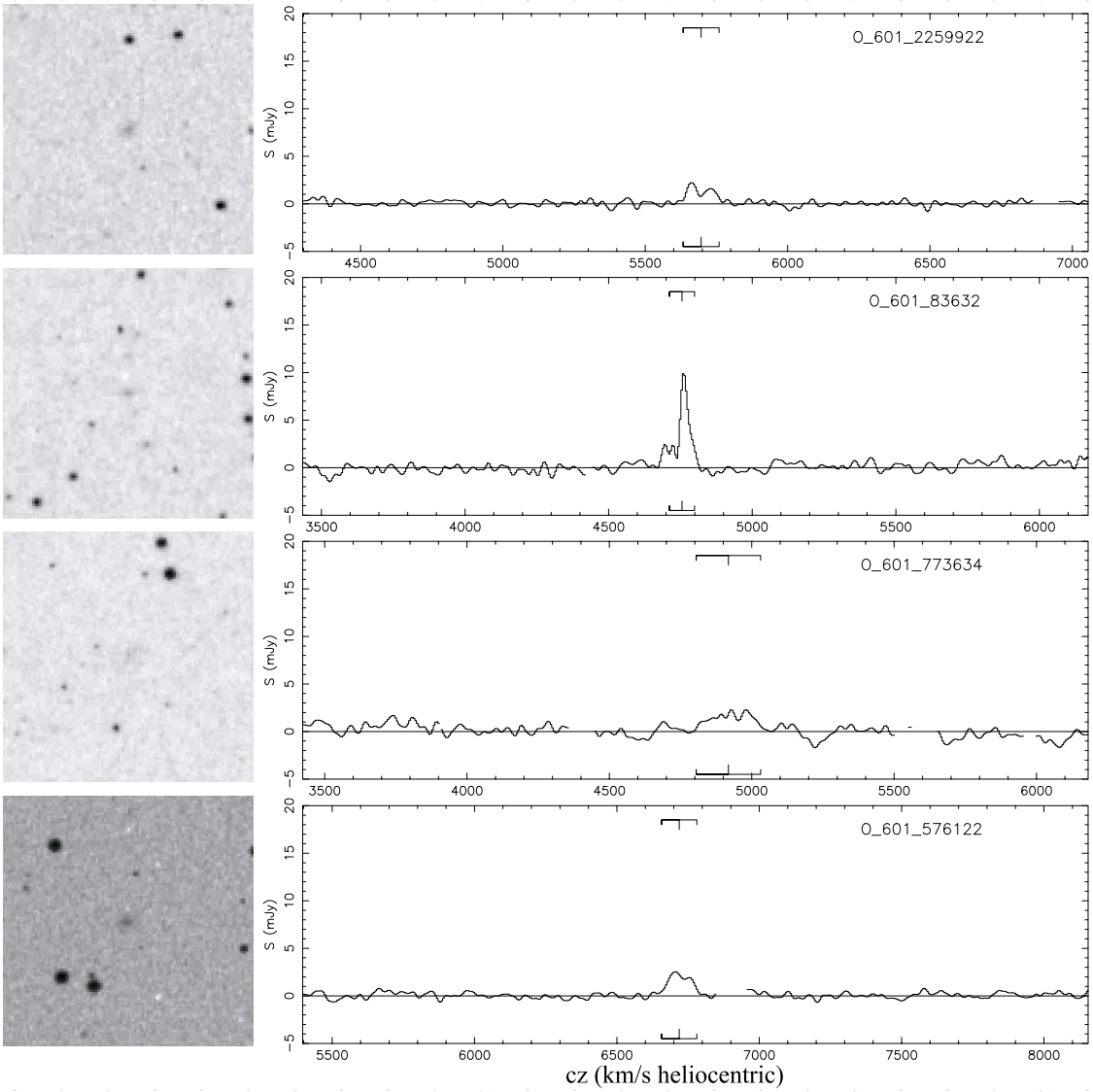




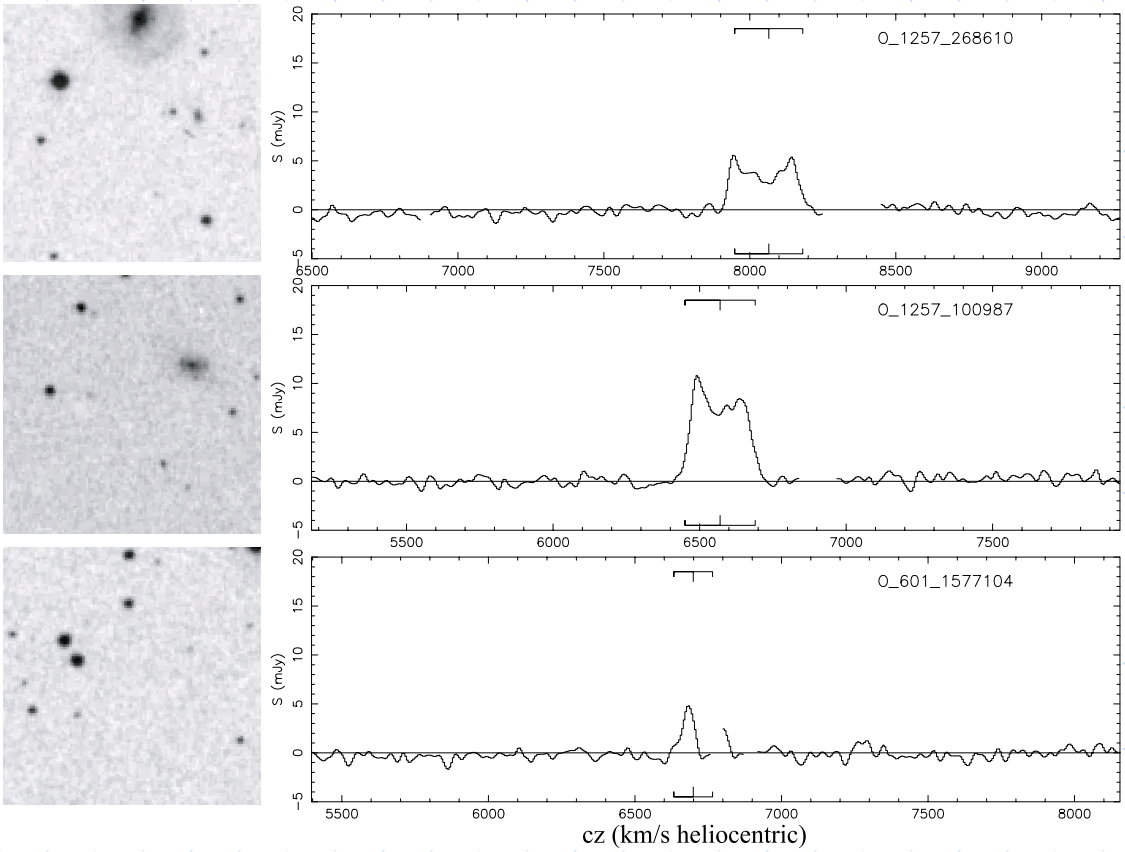


O_601_1369071 was in a crowded field, so multiple pointings used to confirm HI detection centered on that galaxy.

Review of Tentative Detections



Review of Serendipitous Detections



These 3 galaxies were all detected in the off-beam.