# Probing Thermal Gas Conditions in Extragalactic Star-Forming Regions Using Radio Recombination Lines


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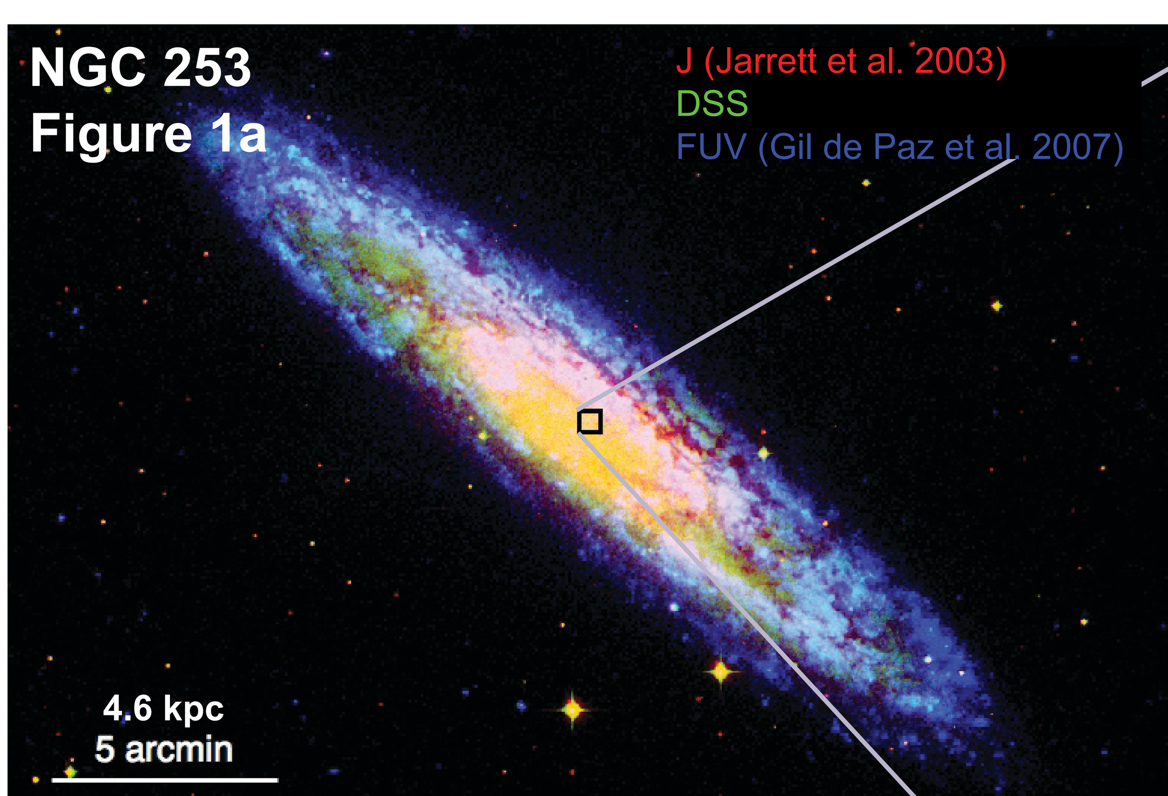
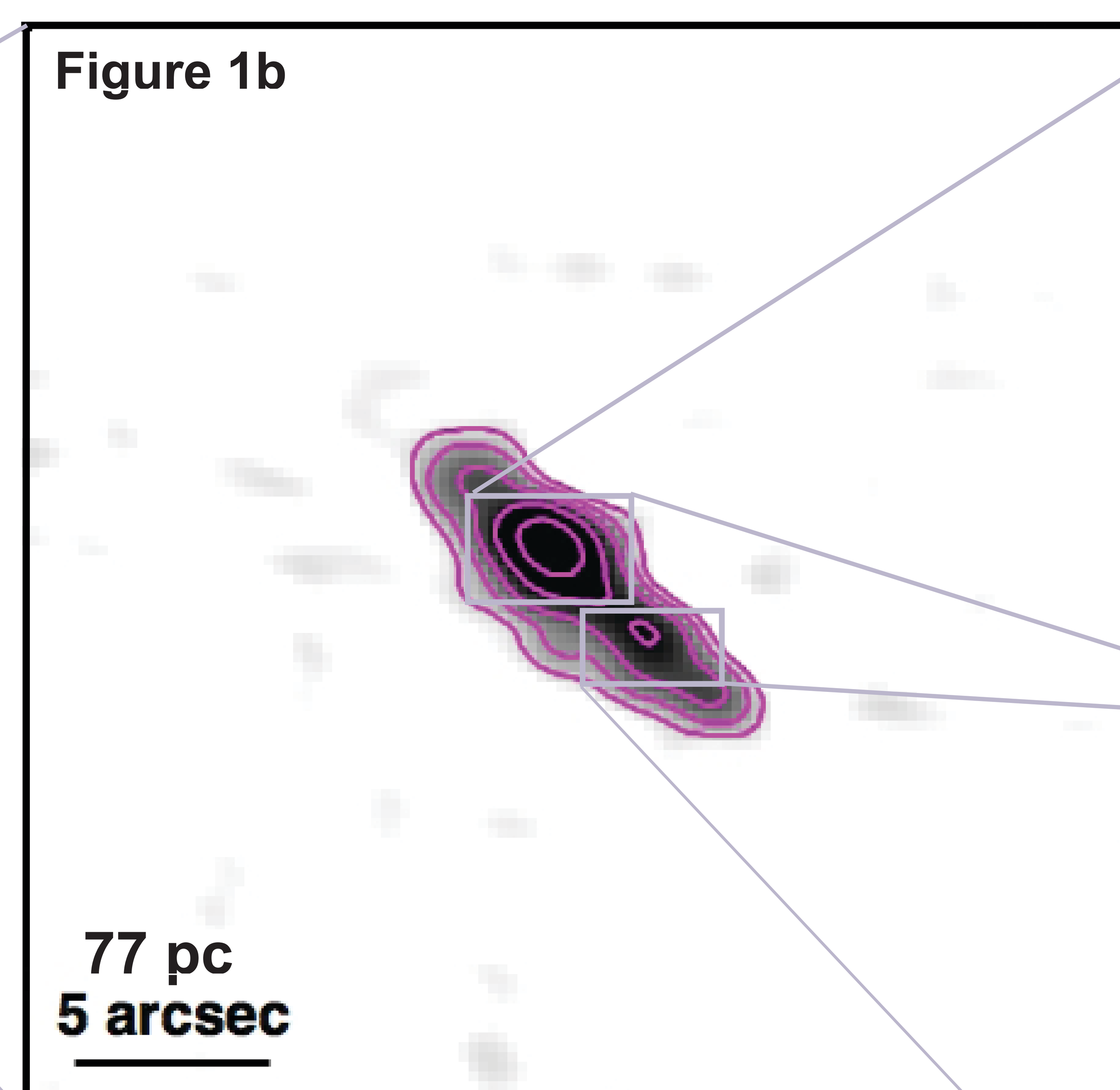
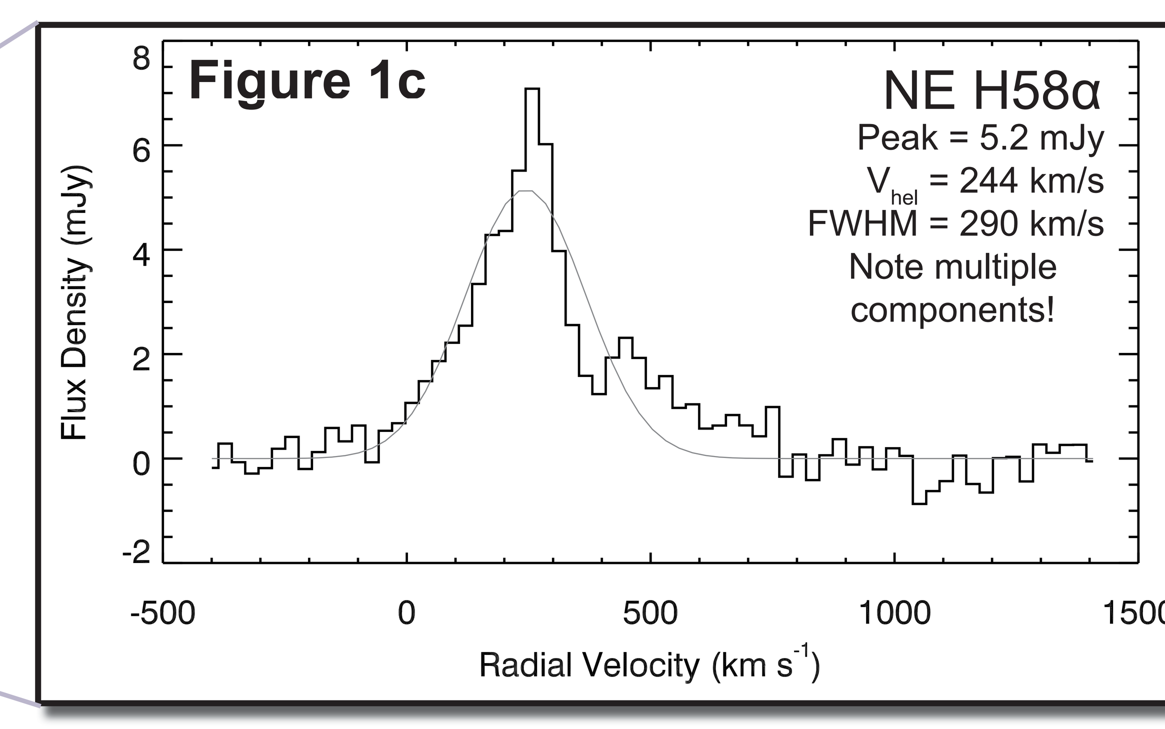
## Introduction

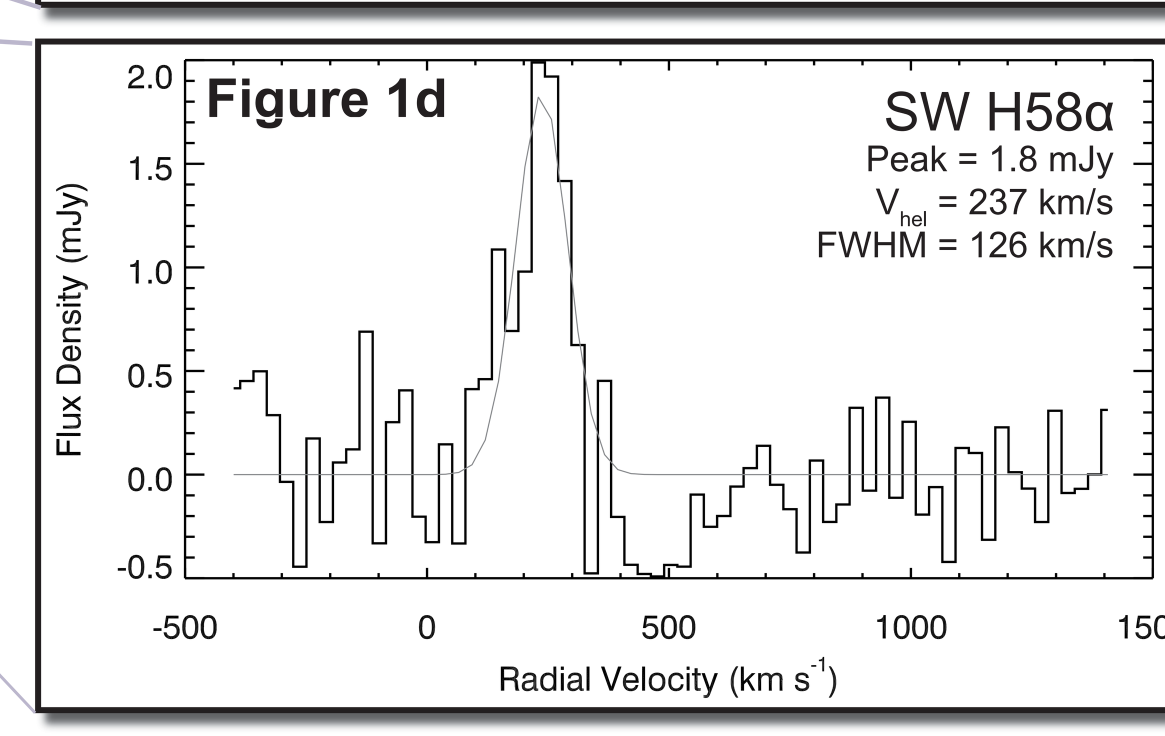
How stars are formed, especially in environments different from those in the Milky Way, is one of the great unsolved mysteries in astronomy today. The physical conditions in the thermal gas ionized by massive stars in still obscured (and thus young) star-forming regions provide important clues about the end products of star formation, i.e., the young massive stars. Radio recombination lines (RRLs) are a sensitive and extinction-free probe of the density and filling factor of this gas. They occur when electrons make transitions between the outer levels in a highly excited atom. Unfortunately, RRLs are broad and weak, making them difficult to detect. Past extragalactic use of RRLs was limited to about a dozen galaxies. Today the extraordinary power of the Expanded Very Large Array (EVLA) is ushering in a new era for extragalactic RRL measurements. In addition to the improved sensitivity of the EVLA receivers, the vastly increased EVLA bandwidth allows simultaneous measurement of the line and continuum flux densities at high frequencies, which is needed to model the dense gas. Furthermore, the excellent spectral line capabilities of the Green Bank Telescope (GBT) have made low-resolution RRL surveys feasible. Here we present early results of new RRL observations with the EVLA and GBT.

## Initial High-Resolution RRL Data from the EVLA



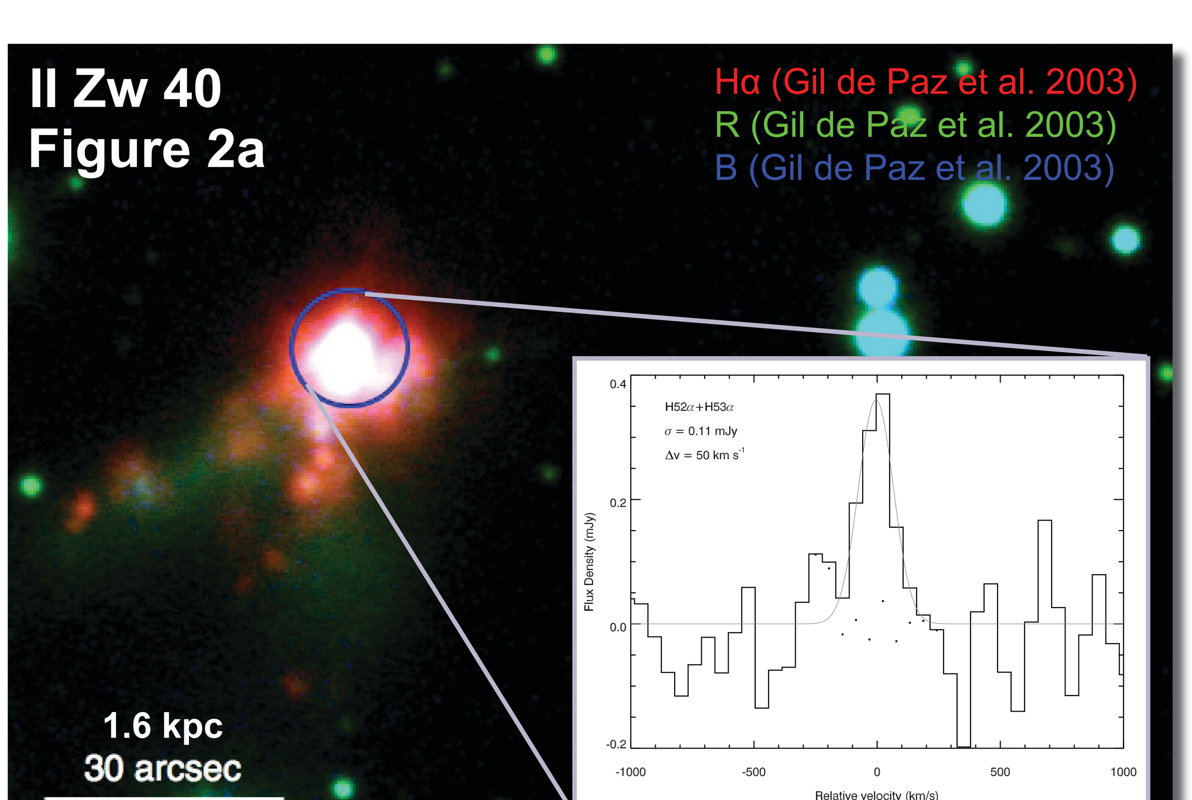



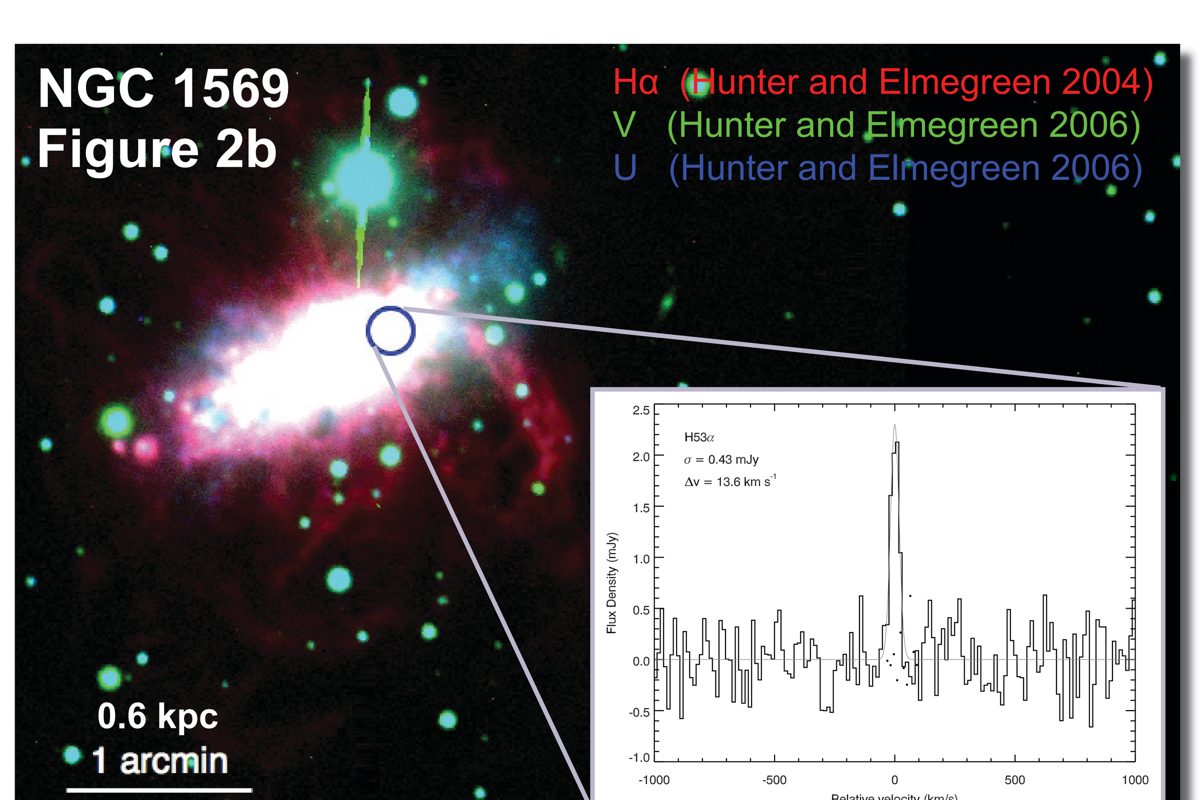



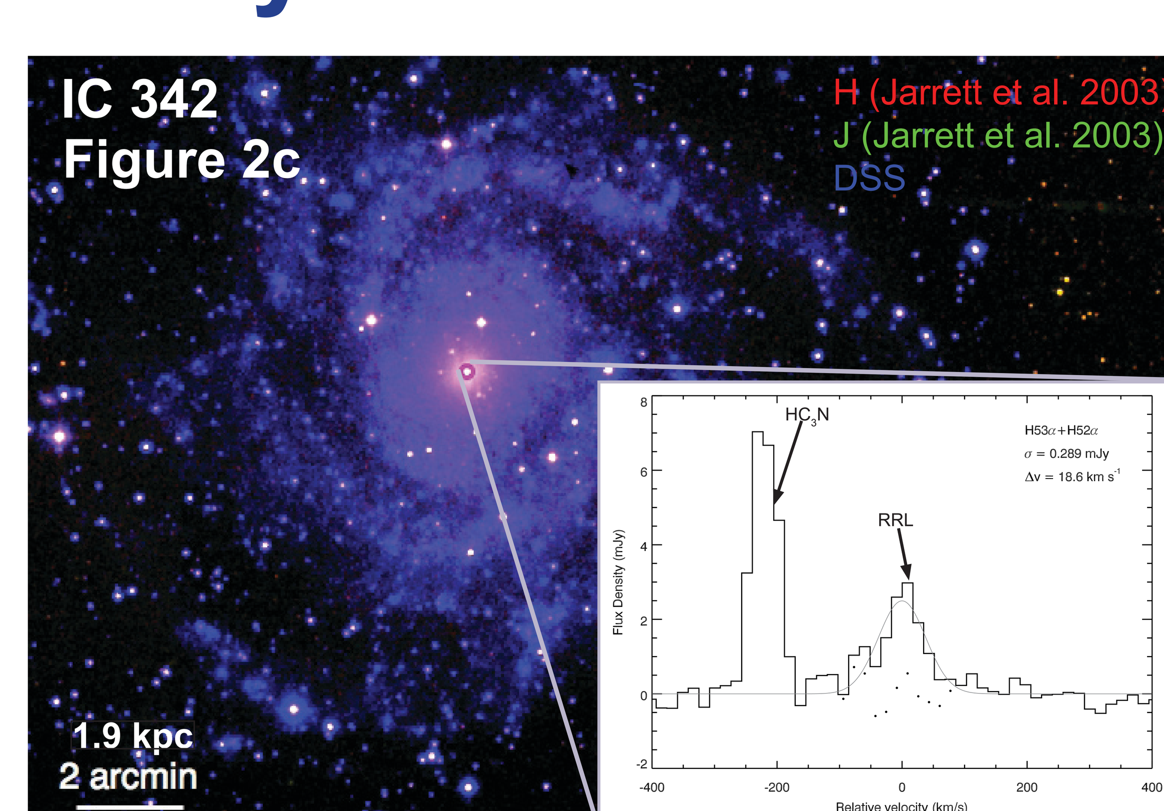




In **Figure 1a**, we show an optical image of the starburst galaxy NGC 253. We observed the boxed region with the EVLA in DnC configuration for 16.5h as part of the Resident Observer Shared Risk Program in September 2010. The correlator was configured to provide two 1GHz IFs centered on the H58α (32.852 GHz) and H59α (31.223 GHz) RRLs with 9 km/s resolution. **Figure 1b** shows our continuum image and **Figures 1c and 1d** show our detection of the H58α RRL in two regions. The peak line flux density, the line width, and the line velocity agree well with previous detections of the H53α line by Rodríguez-Rico et al. (2006).

## Initial Results from GBT RRL Survey




To increase the number of galaxies with RRL detections, we have selected a sample of galaxies with a wide range of metallicities, stellar masses, and star formation rates for an RRL survey with the GBT. After measuring the continuum flux density for each galaxy between 26 and 40 GHz with the Caltech Continuum Backend, we searched the five brightest galaxies (12 - 25 mJy) for the H52α (45.453 GHz) and H53α (42.951 GHz) RRLs. The backend was set up to provide two 800 MHz IFs with 2.6 km/s resolution. **Figures 2a, b, and c** shows our three new detections. We will apply for time on the EVLA to obtain the high-resolution measurements necessary for detailed modeling of the properties of the thermal gas.