SHIELD: The Survey of HI in Extremely Low-mass Dwarfs

John M. Cannon
Macalester College
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SHIELD: Team Members

- PI: John M. Cannon (Macalester College)
- Macalester College (UAT stipend): Clara Thomann
- Cornell: Betsey Adams, Riccardo Giovanelli, Martha Haynes, Shan Huang
- Indiana: Steven Janowiecki, Angela Parker, John J. Salzer
- Minnesota: Kristy McQuinn, Evan D. Skillman
- MPE: Amélie Saintonge
- NRAO: Jürgen Ott
- Western Australia/ICRAR: Ed Elson
- Macalester College (minor): John Allan, Eric Engstrom, Grace Erny, Palmer Fliss, AnnaLeigh Smith
Outline

• Theoretical and observational importance of low-mass galaxies
• Studying *ALFALFA*-discovered low-mass galaxies with the *EVLA*
  – Brief interferometry interlude
  – Concept demonstration
  – SHIELD: overview and program goals
  – SHIELD: preliminary results
    – SHIELD: *HST* imaging
    – SHIELD: *Spitzer* imaging
• Future prospectus
On The Importance of Low-mass Galaxies

• The $\Lambda$CDM paradigm predicts more low-mass dark matter halos in the local universe than are observed
  – “Missing satellite problem”
  – Local low-mass systems are survivors of the structure formation process

• Changes in physical parameters and mechanisms are predicted in low-mass galaxies
  – Decreasing baryon fraction
  – Different relation between mass surface density and star formation rate than in massive galaxies

• Extreme and untested ISM conditions
  – Opportunities for leaps forward in our understanding of galaxy evolution
ALFALFA now has cataloged >400 galaxies with $M_{\text{HI}} < 10^8 \, M_\odot$ and a few dozen with $M_{\text{HI}} < 10^7 \, M_\odot$.

What is the nature of galaxies with $M_{\text{HI}} < 10^7 \, M_\odot$?

Martin et al. (2010)
What is the nature of galaxies with HI masses of $10^7 M_\odot$ and below?
Exploring New Frontiers

ALFALFA = new, low-mass galaxies

EVLAA follow-up

AGC 110482
Interferometry (Very Briefly)

- Small telescopes (large field of view)
- Separate these by large distances (improves spatial resolution)
- Correlate the signals from all antenna pairs (measures intensity at a specific location)
- Fourier transform these data into the image plane
SHIELD Concept Demonstration

\[ N_{\text{HI}} = (0.5, 1, 2, 4) \times 10^{20} \text{ cm}^{-2} \]

The Survey of HI in Extremely Low-mass Dwarfs

- 12 systems selected from > 20,000 ALFALFA sources
  - \( M_{HI} < 10^7 M_\odot \)
  - \( W_{50} < 65 \) km s\(^{-1}\)
  - Model distances < 8 Mpc

- Detectable stellar populations

- 15 hours per source with the EVLA (9/4/2 in B/C/D)
- 0.86 km s\(^{-1}\) ch\(^{-1}\)
- 5σ detection (per channel) of \( 10^{19} \) cm\(^{-2}\) (2.3\( \times 10^{20} \) cm\(^{-2}\)) columns at 40" (6") resolution
**SHIELD: Sample Overview**

- Median (estimated) HI mass = $4.7 \times 10^6 \, M_\odot$
- Distances uncertain: critical need for *HST*
• What properties change between mini-halos, very low-mass dwarfs, and more massive systems?
• What fraction of the mass in these low-mass dwarfs is baryonic?
• Is the character of the SF process different in very low-mass galaxies?
• Use SHIELD results to constrain models of galaxy evolution
An extremely low-mass, gas-rich satellite, within the virial radius of a relatively massive galaxy (c.f., Sawala et al. 2011)
SHIELD: Preliminary Results – AGC 749237

325-370 km s\(^{-1}\), 3 km s\(^{-1}\) intervals

\[ \text{M}_{\text{dyn}} \sim 1 \times 10^8 \text{ M}_{\odot} \]

\[ \frac{\text{M}_{\text{dyn}}}{\text{M}_{\text{baryon}}} \sim 11 \]

HI distributions are remarkably concentrated
• Most systems have coherent rotation
  – Some systems show incoherent motions and disrupted velocity fields
• 11 of 12 galaxies have WIYN 3.5m Hα imaging
  – 10 of 11 have active star formation
• Only 1 system with N_{HI} > 10^{21} cm^{-2} at 20″ resolution
  – The SHIELD galaxies are forming stars in conditions different from those seen in more massive systems
• Preliminary dynamical analyses reveal high mass-to-light ratios
• The SHIELD galaxies have retained baryons inside halos of total mass <10^8 M_☉
  – Among the lowest-mass gas-bearing halos known
SHIELD: Preliminary Results

- Are the SHIELD galaxies part of the population that will solve the missing satellite problem?
  - Number density of these systems (with stellar populations) appears too low
  - However, models predict a substantial population of halos of similar mass \textit{without} a stellar population
  - ALFALFA continues to search and find both

- The galaxy population to which the SHIELD members belong remains cosmologically critical
  - Most systems of this dynamical mass have been destroyed
  - How have the systems discovered to date survived?
SHIELD: The Next Steps – HST Imaging

AGC 174585

AGC 111977

AGC 748778
AGC 111977
Number of Stars: 5077

TRGB = distance
SHIELD: The Next Steps – HST Imaging

AGC 111977
Number of Stars: 5077

BHeB

MS

McQuinn et al. (2010)
SHIELD: The Next Steps – Spitzer Imaging
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SHIELD: The Next Steps

Thomann et al. 2012

AGC749237 Moment 1, 21"x21" beam

Thomann et al. 2012
SHIELD: The Next Steps

Thomann et al. 2012
SHIELD: Long-Term Prospectus

Large multiwavelength campaign now in progress

Well-studied

$M_{\text{HI}} (M_\odot)$

$M_{\text{dyn}} (M_\odot)$

$f_b \sim 0.01$  $10^5$  $10^6$  $10^7$  $10^8$  $10^9$  $10^{10}$  $f_b \sim 0.16$

$10^7$  $10^8$  $10^8$  $10^9$  $10^9$  $10^{10}$  $10^{11}$