Finding the smallest gas-rich galaxies

Betsey Adams
ASTRON / Kapteyn Astronomical Institute
Small Galaxies, Cosmic Questions 1 Aug 2019

John Cannon, Riccardo Giovanelli, Martha Haynes, Bill Janesh, Lilly Bralts-Kelly, Steven Janowiecki, Tom Oosterloo, Susie Paine, Kathy Rhode, John Salzer, Nick Smith

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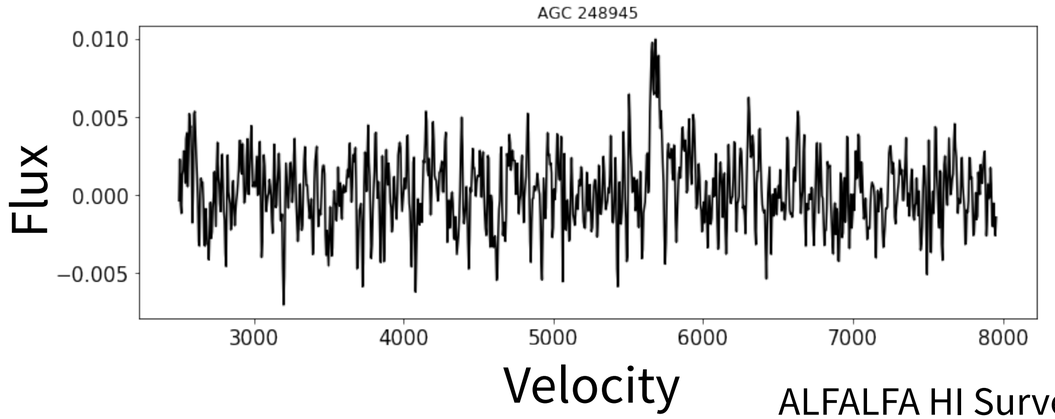
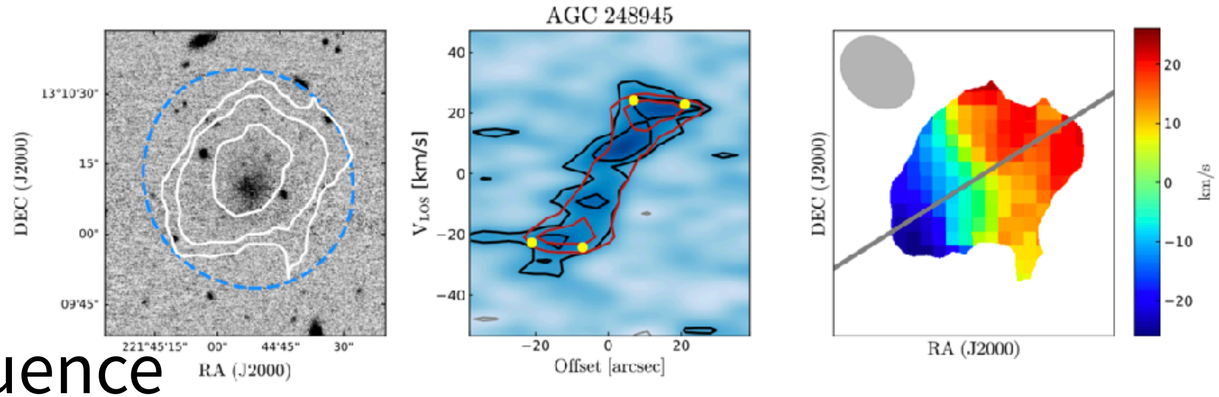
APERTIF
APERture Tile In Focus

The gas-rich (HI) Universe

- Observables:
  - Recessional velocity (distance)
  - Internal kinematics (total mass)
  - HI line flux -> HI mass
- Features:
  - Field galaxies: isolated, blue, star-forming
    - Disentangle environmental influence vs. intrinsic properties



ALFALFA HI Survey



Mancera-Piña+ submitted

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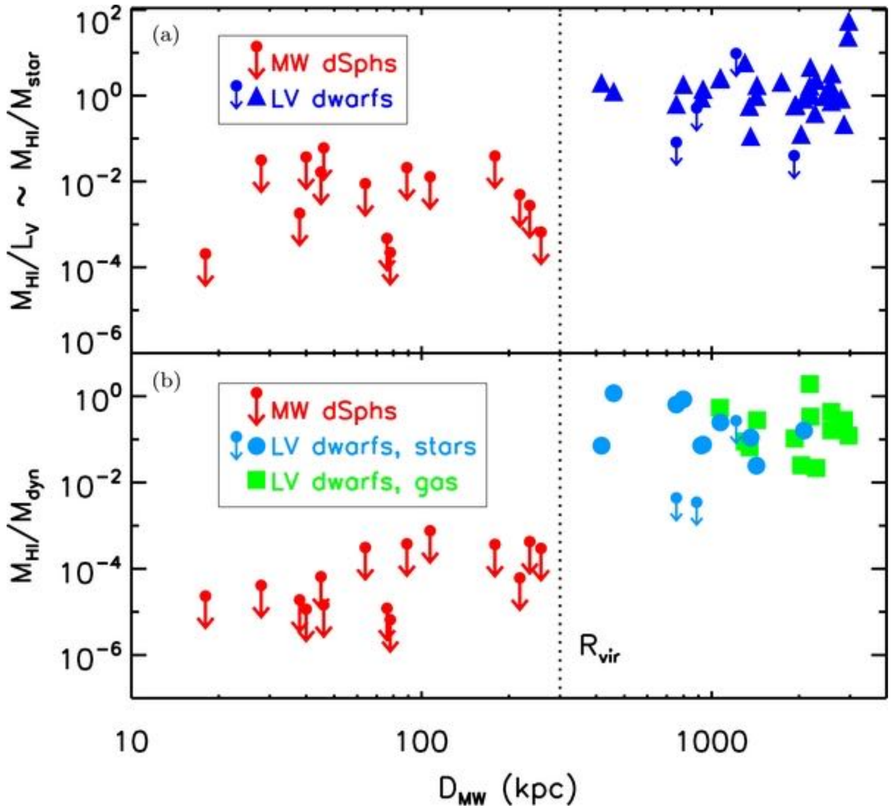

Spekkens+ 2014

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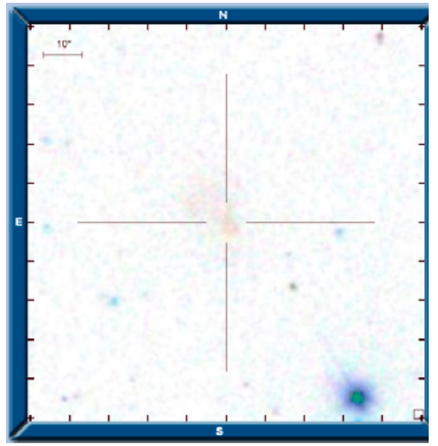
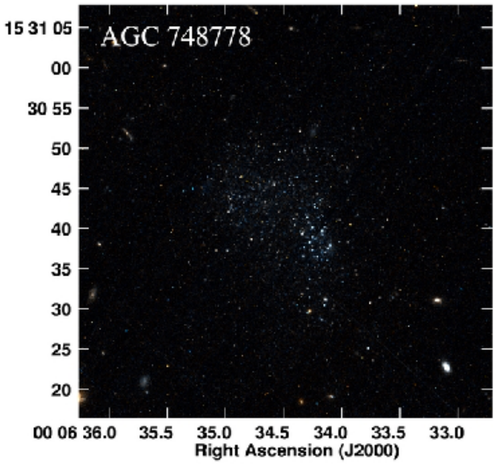
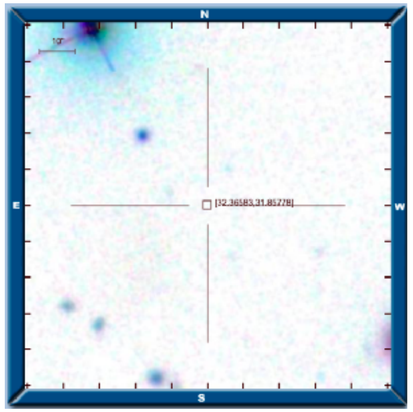
What dwarf galaxies do we see in HI?

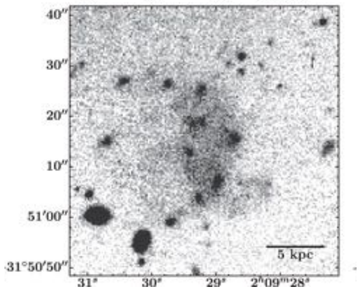
- SHIELD: Nearby, bonafide low-mass dwarf galaxies
  - Distances ~ 5 -12 Mpc
  - M_{HI} ~ 3-50 x 10^6 M_{sun}
  - M_{star} ~ 3-50 x 10^6 M_{sun}
- HI-bearing ultra-diffuse galaxies: distant, low surface brightness dwarfs
  - Distances ~50-100 Mpc
  - M_{HI} ~ 10^8 - 10^9 M_{sun}
  - M_{star} ~ 10^7 - 10^8 M_{sun}





McQuinn+ 2014





Leisman+ 2017

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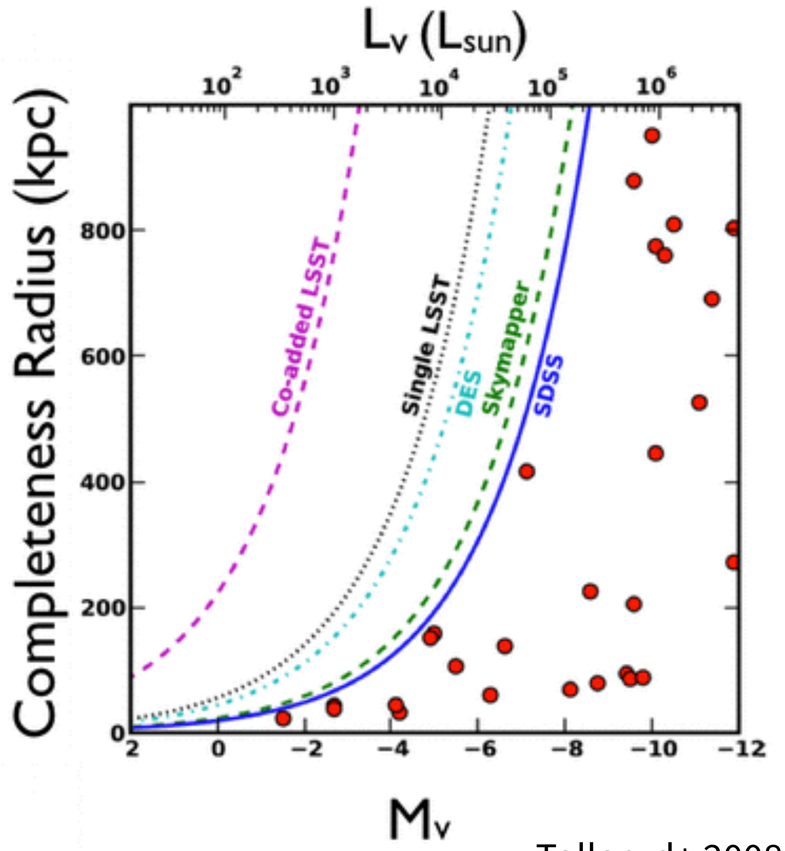
What about the ultra-faint regime?

- Leo T
  - Most distant UFD
  - Only one that is gas-rich
    - $M_{star} \sim 2 \times 10^5 M_{sun}$
    - $M_{HI} \sim 4 \times 10^5 M_{sun}$
- Fill out parameter space pre-LSST?



Tollerud+ 2008

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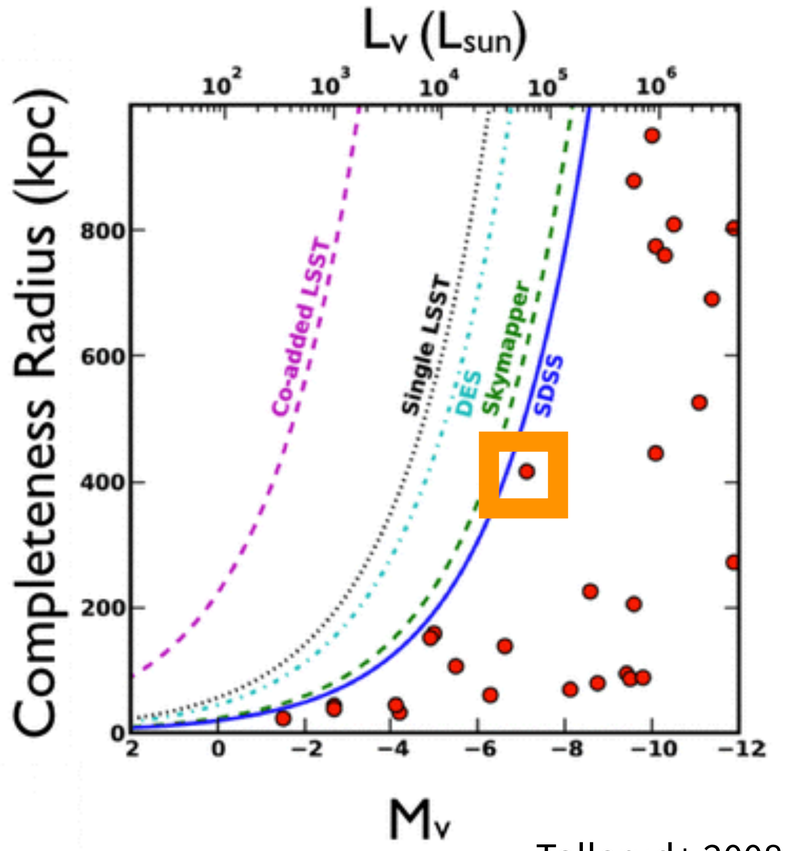

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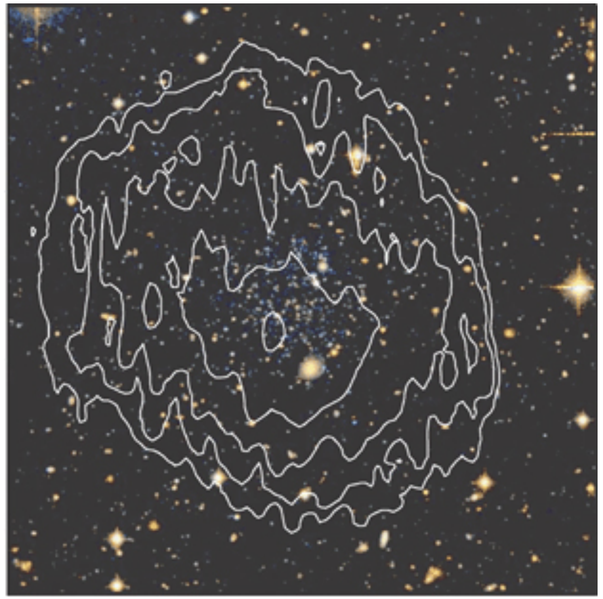
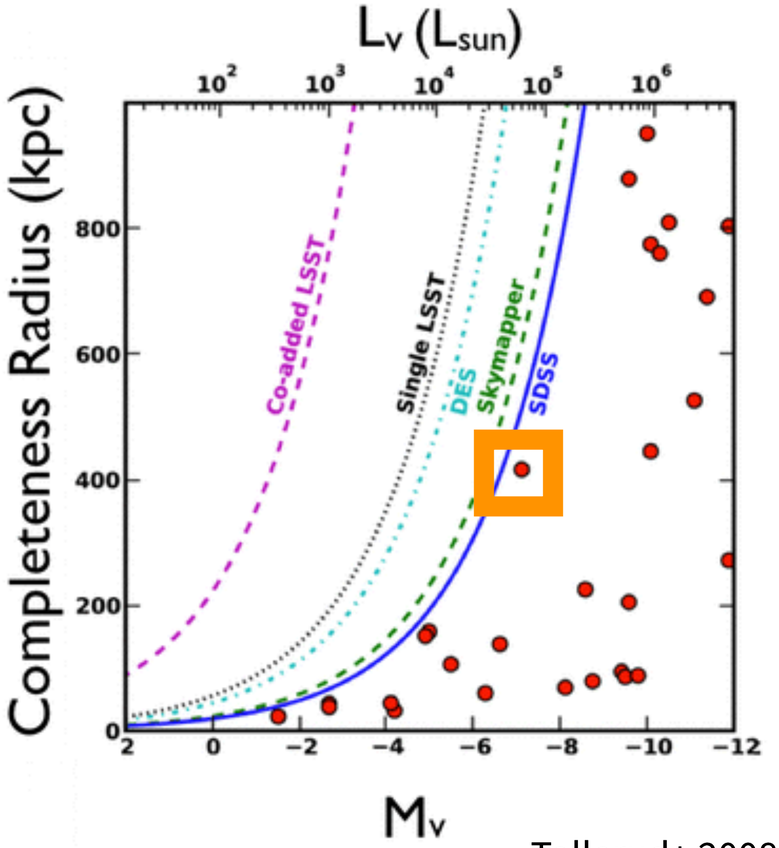


Ryan-Weber+ 2008



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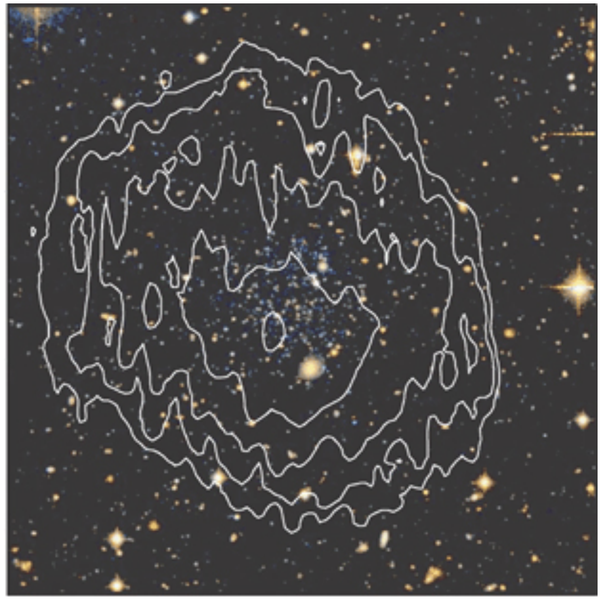

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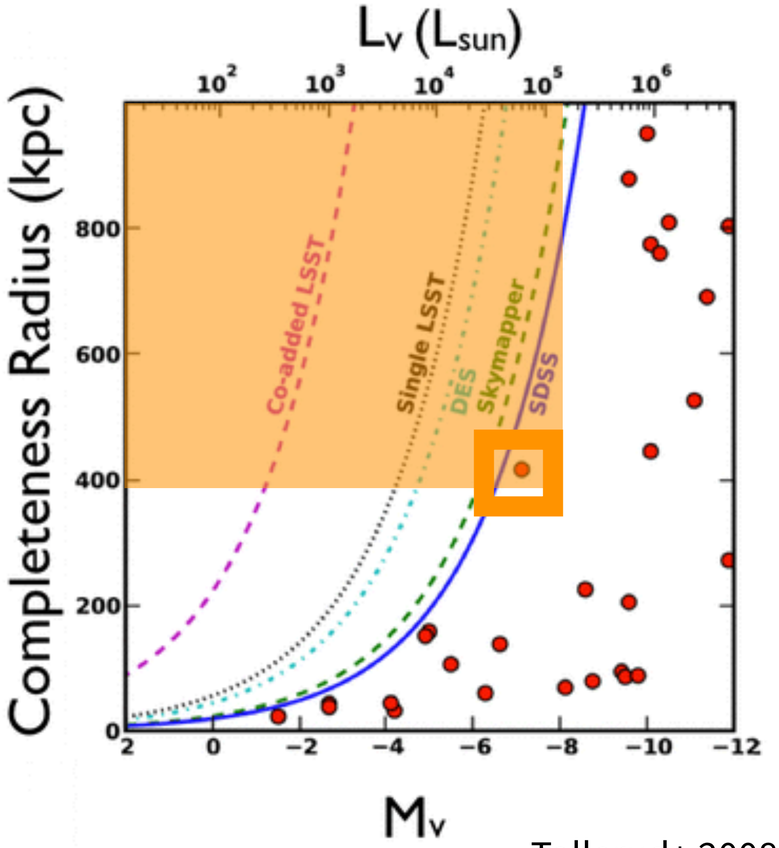

Tollerud+ 2008

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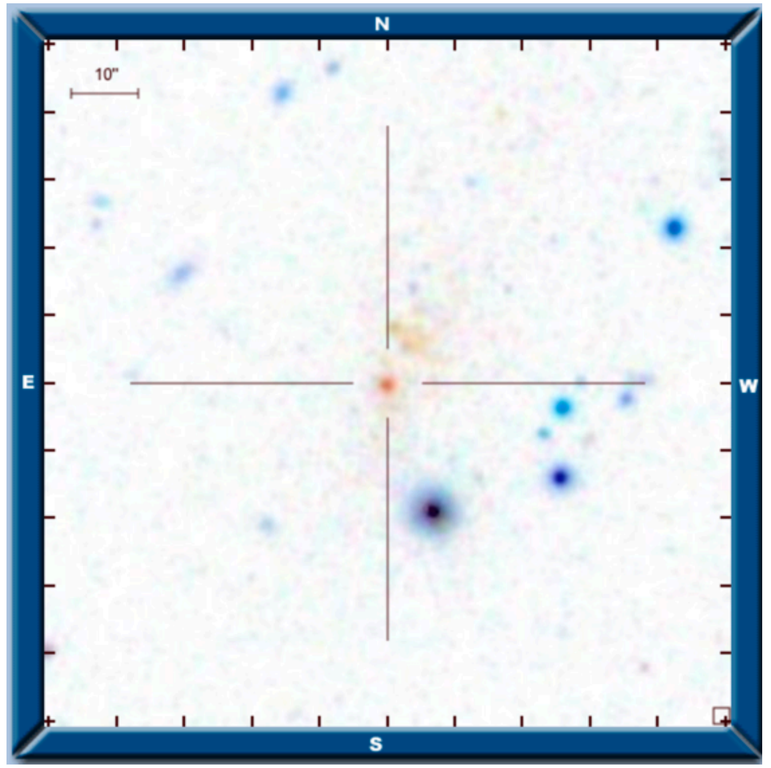
Leo P: Pushing to the field UFD limit

- Extreme, nearby galaxy discovered as an HI source in ALFALFA
  - D=1.62 Mpc
  - $M_{HI} = 8.1 \times 10^5 M_{sun}$
  - $M_{star} = 5.6 \times 10^5 M_{sun}$
  - $v_{rot} = 15$ km/s
  - 12 + log[O/H] = 7.17 (~3% solar)
  - Single star-formation region



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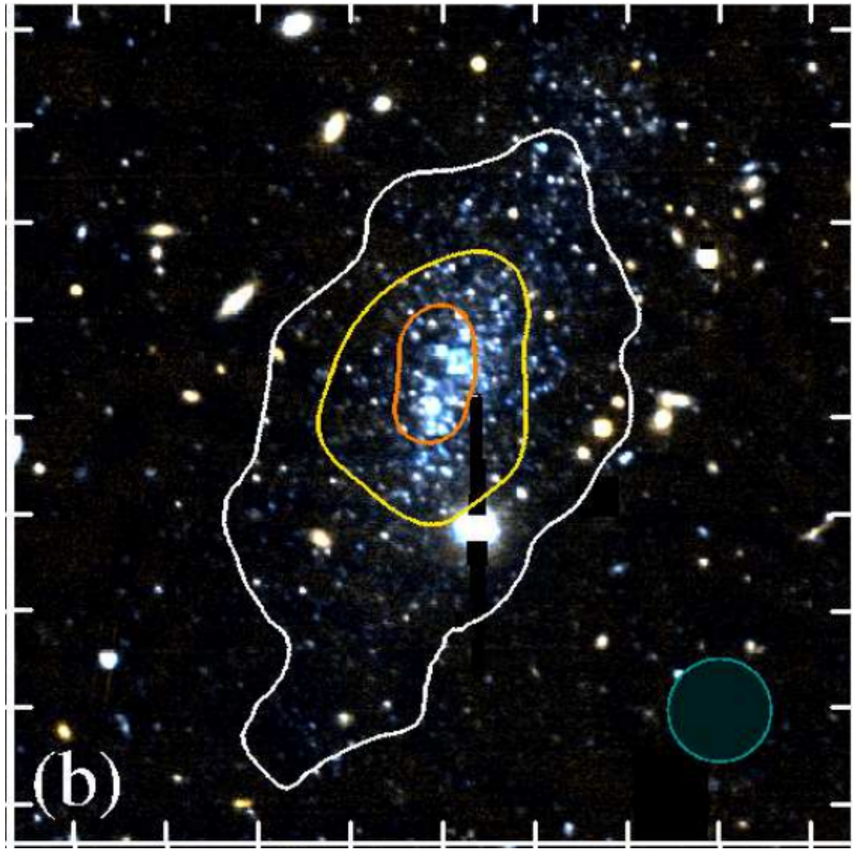

Bernstein-Cooper+ 2014

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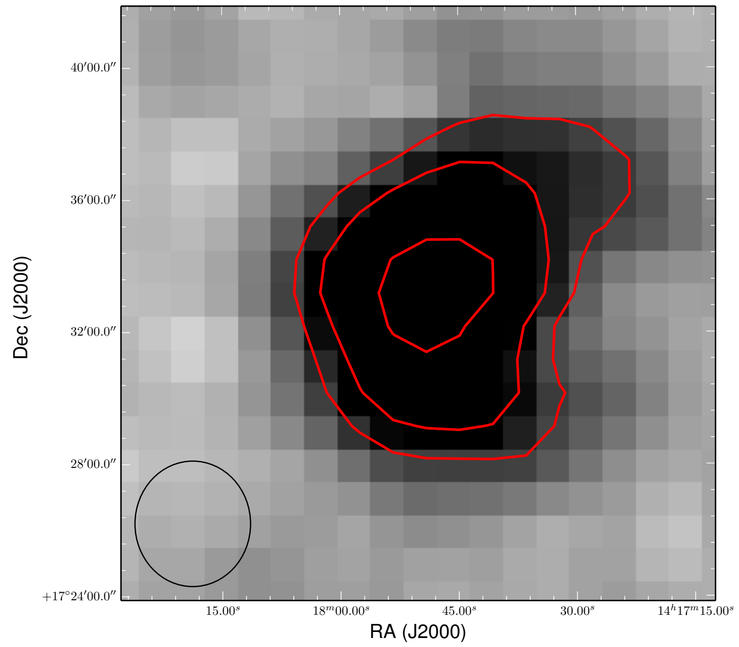
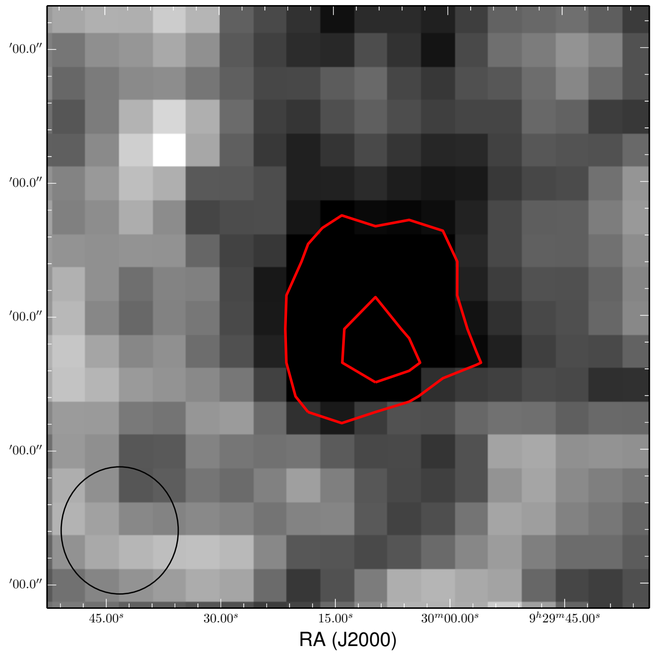
Isolated HI clouds as candidate LG galaxies

By design: No apparent optical counterpart in SDSS data

Feature: Confusion with Galactic HI halo cloud population

Higher resolution HI to discriminate





E. A. K. Adams+ 2013

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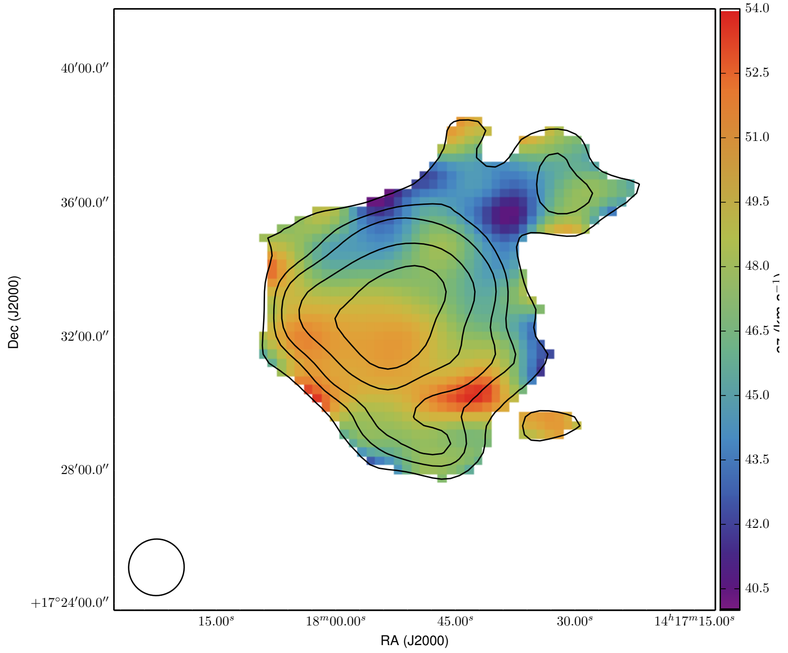
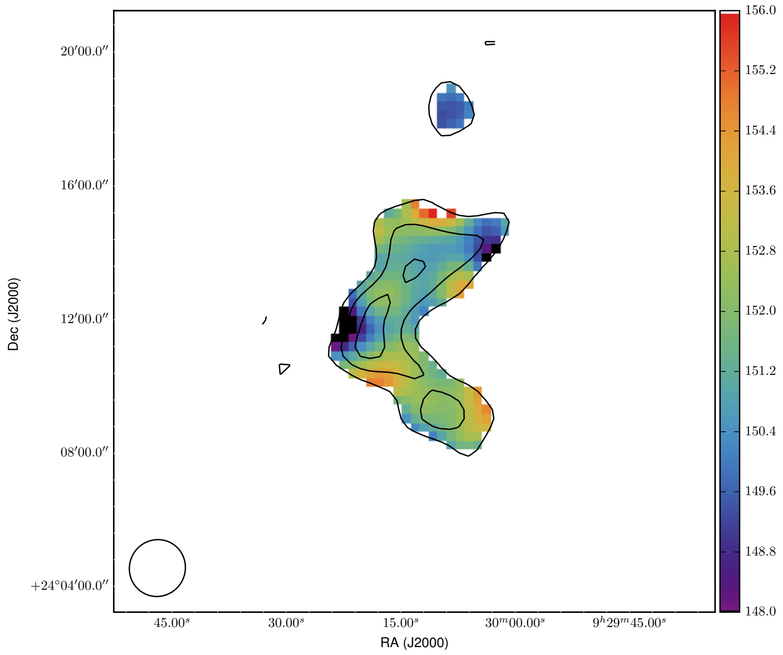


$N_{HI,peak}$ ~ 5 x 10^{19} atoms cm^{-2}



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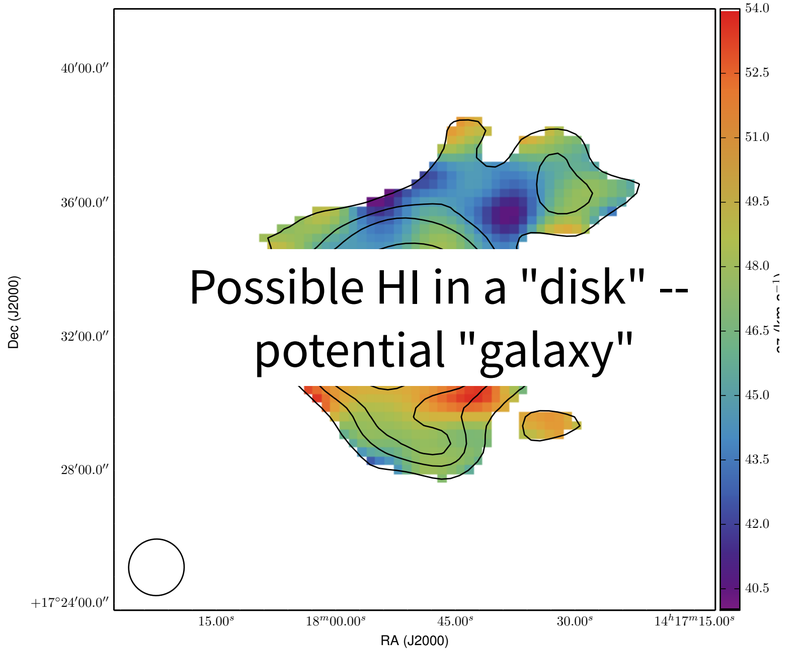

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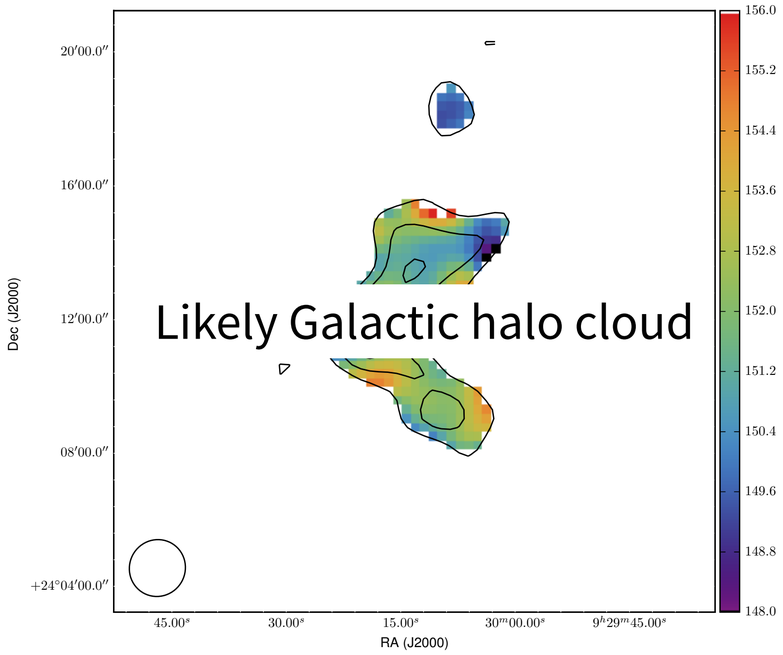

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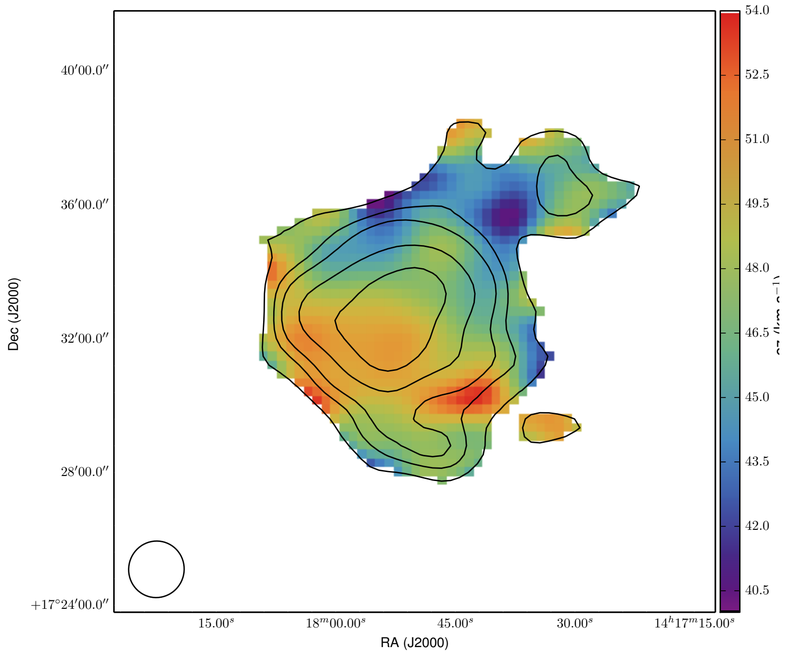

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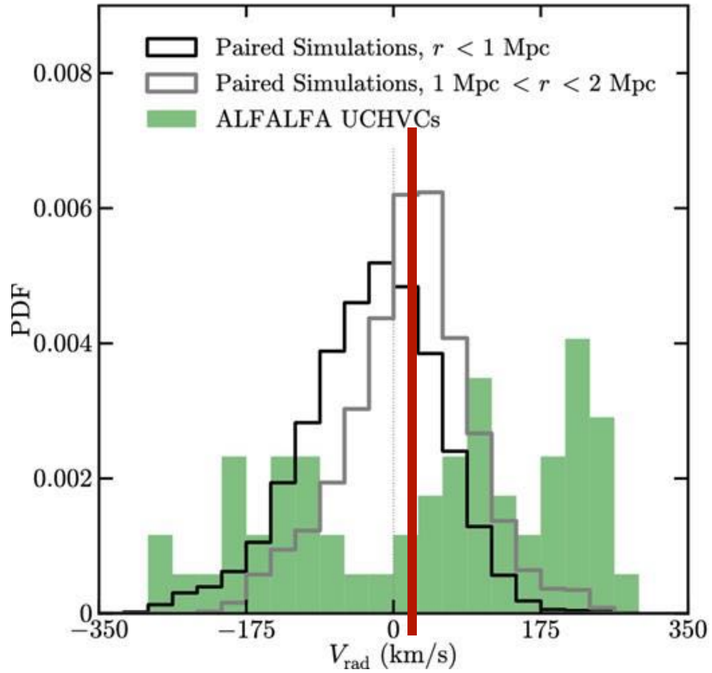

Garrison-Kimmel+ 2014

E. A. K. Adams+ 2016

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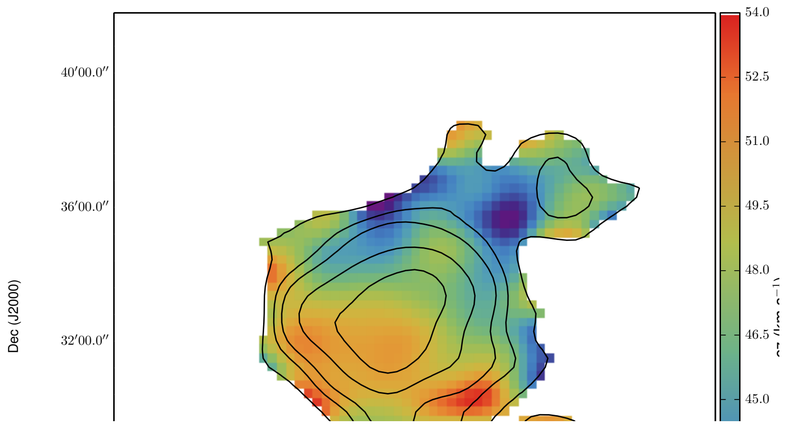

RELHICs - column density corresponds to halo mass of ~few x 10^9 M_{sun}

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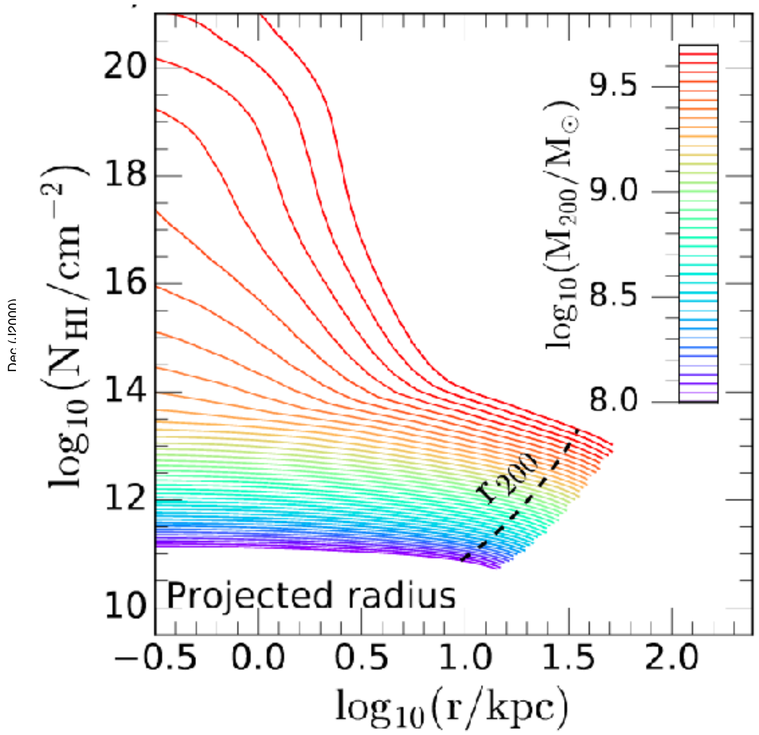

Benítez-Llambay+ 2017

E. A. K. Adams+ 2016

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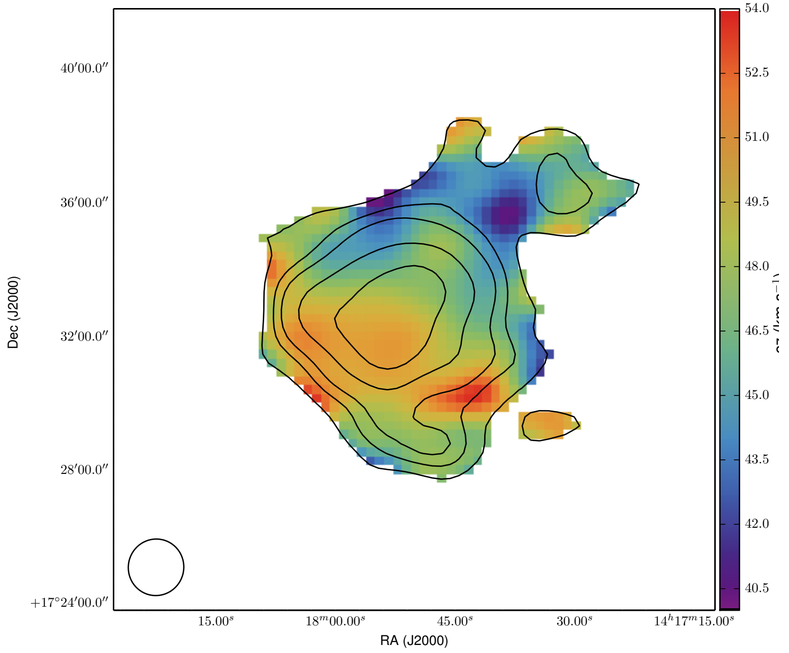
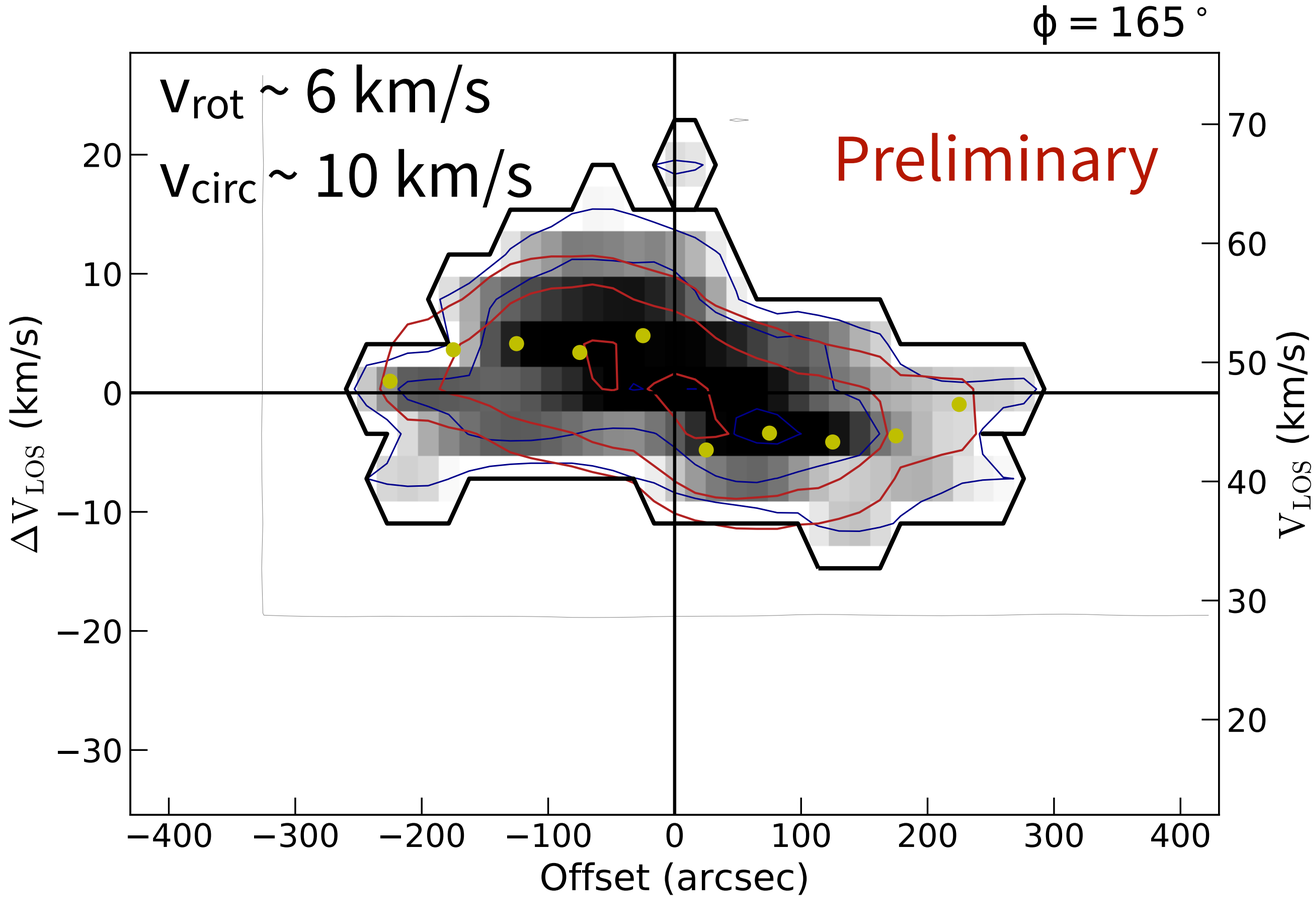
Kinematics of galaxy candidates





Lily Bralts-Kelly, in progress

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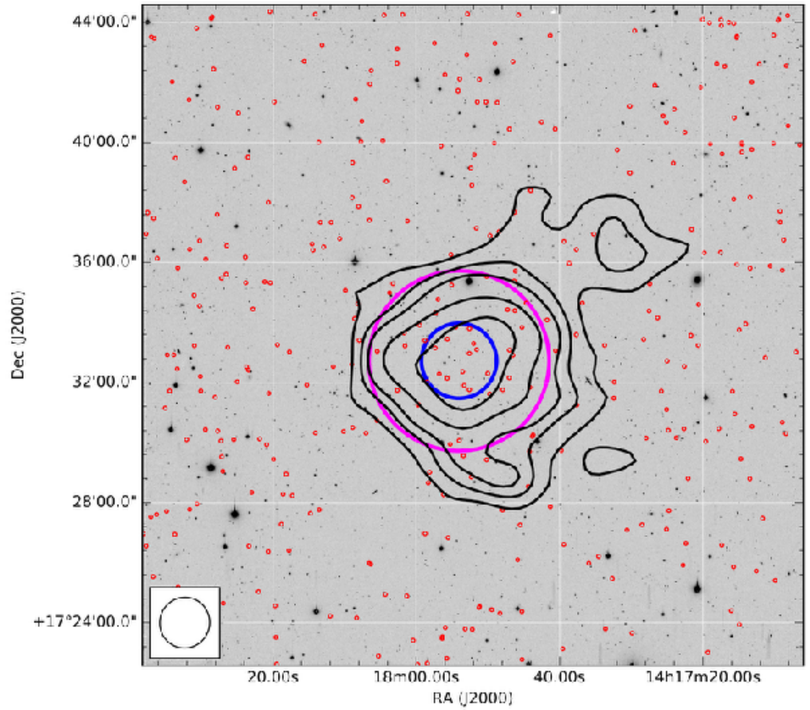
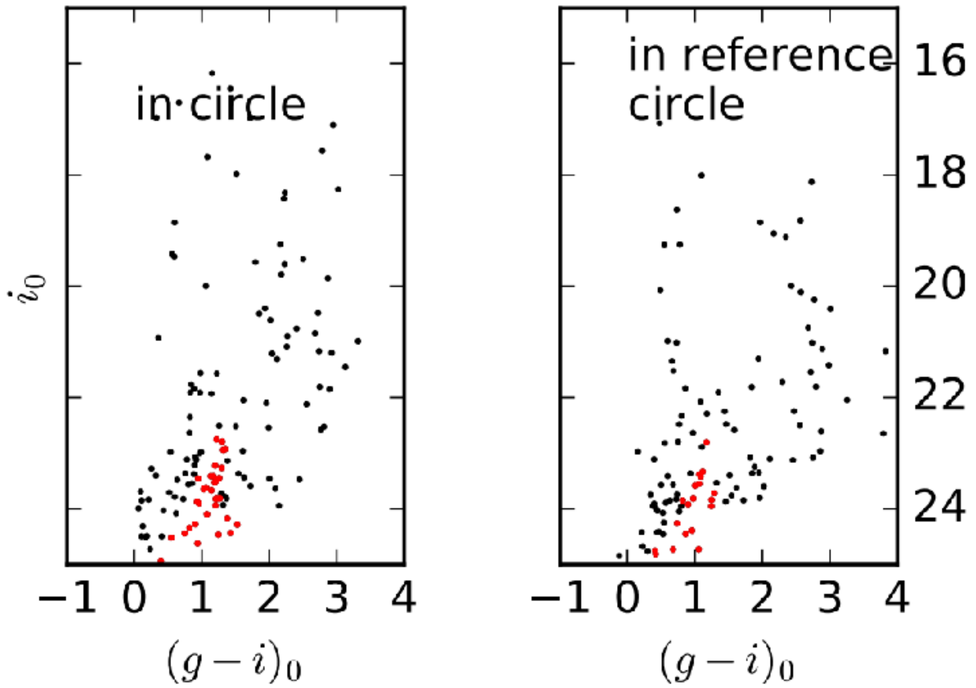
Distances to candidate galaxies

Deep optical imaging with WIYN/pODI reveals potential stellar component





Janesh+ 2017

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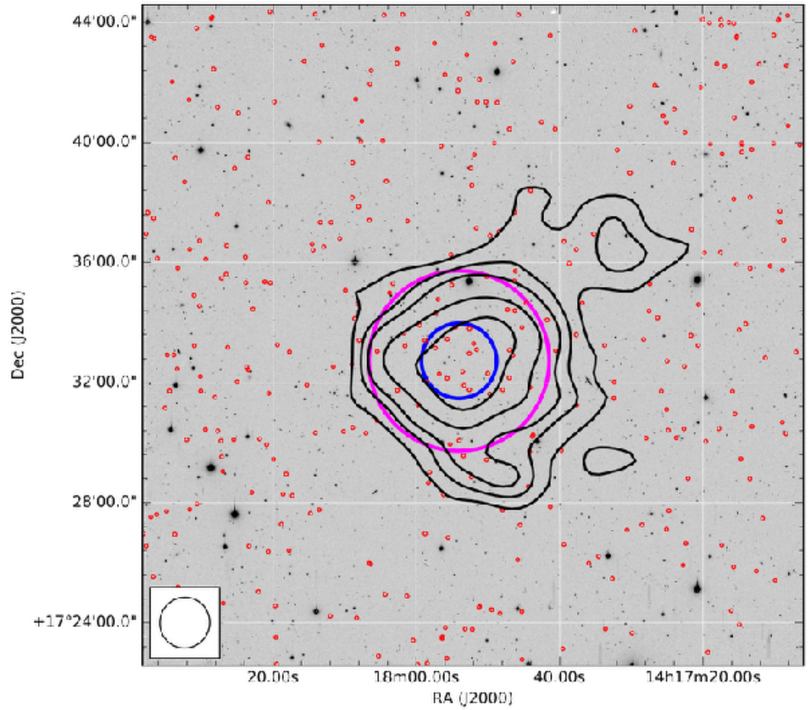
Properties of candidate galaxies

Deep optical imaging with WIYN/pODI reveals potential stellar component



Janesh+ 2017

AGC 249525

- 98% significance
- D = 1.64 Mpc
- M_{star} ~ 0.2 - 4 x10^5 M_{sun}
- M_{HI} = 3 x 10^6 M_{sun}
- D_{HI} ~ 4 kpc
- M_{dyn} ~ 10^8 M_{sun}

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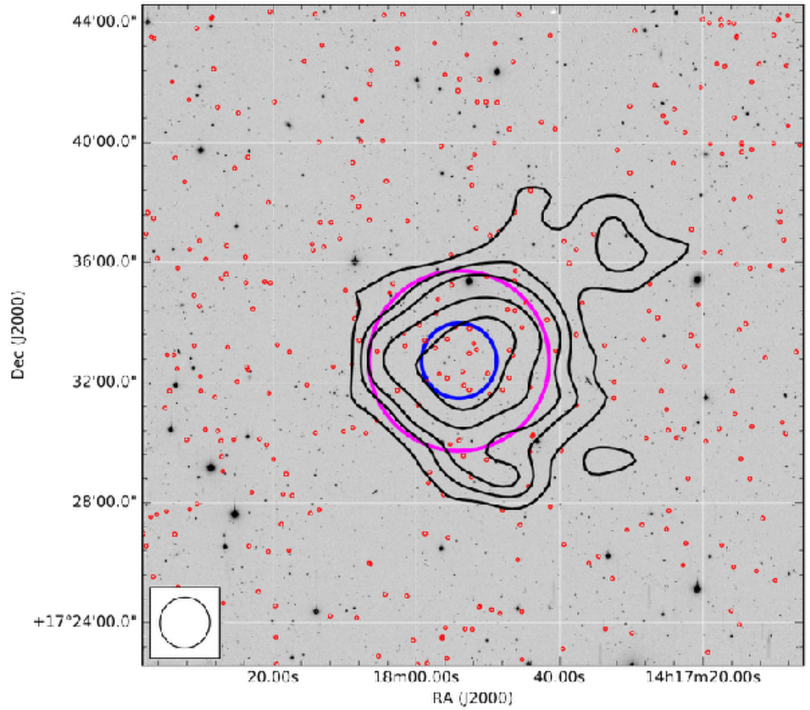

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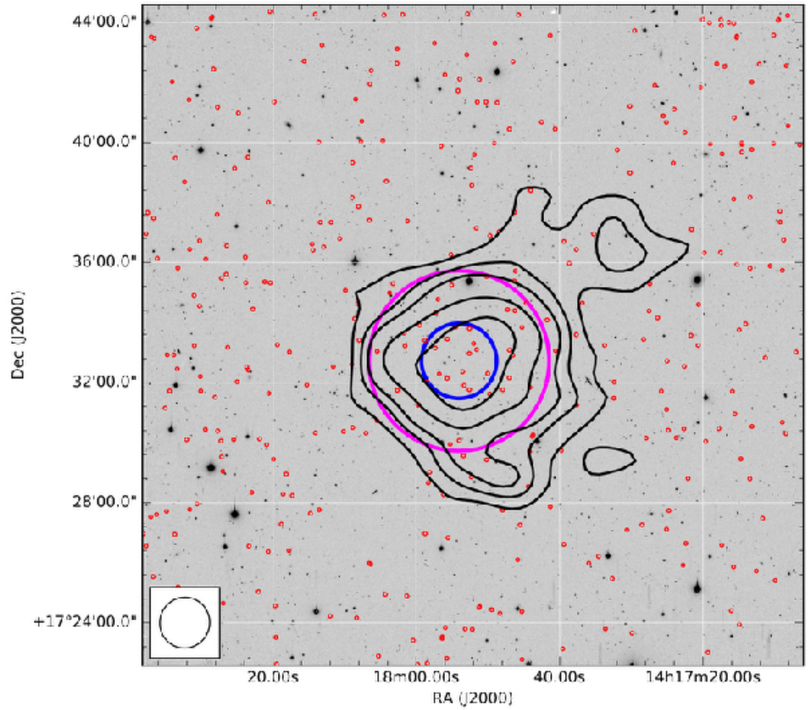

Janesh+ 2017

5/29 detections in total (Janesh+ 2019)

- D = .35 - 1.6 Mpc
- M_{HI} ~ 0.2 - 30 x10^5 M_{sun}
- M_{star} ~ 0.04 - 40 x 10^4 M_{sun}
- Only old stellar populations

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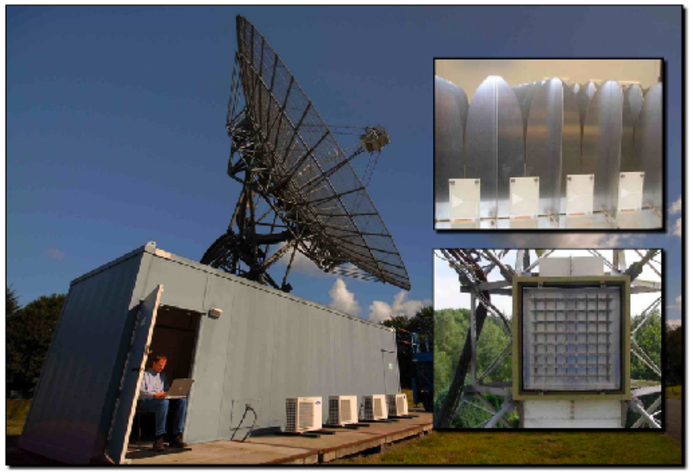
Looking to the future



Apertif: Phased-array feed on WSRT

MeerKAT: sensitive single-pixel feeds

ASKAP: Phased-array feed

FAST, Arecibo w/ ALPACA (40 beams)

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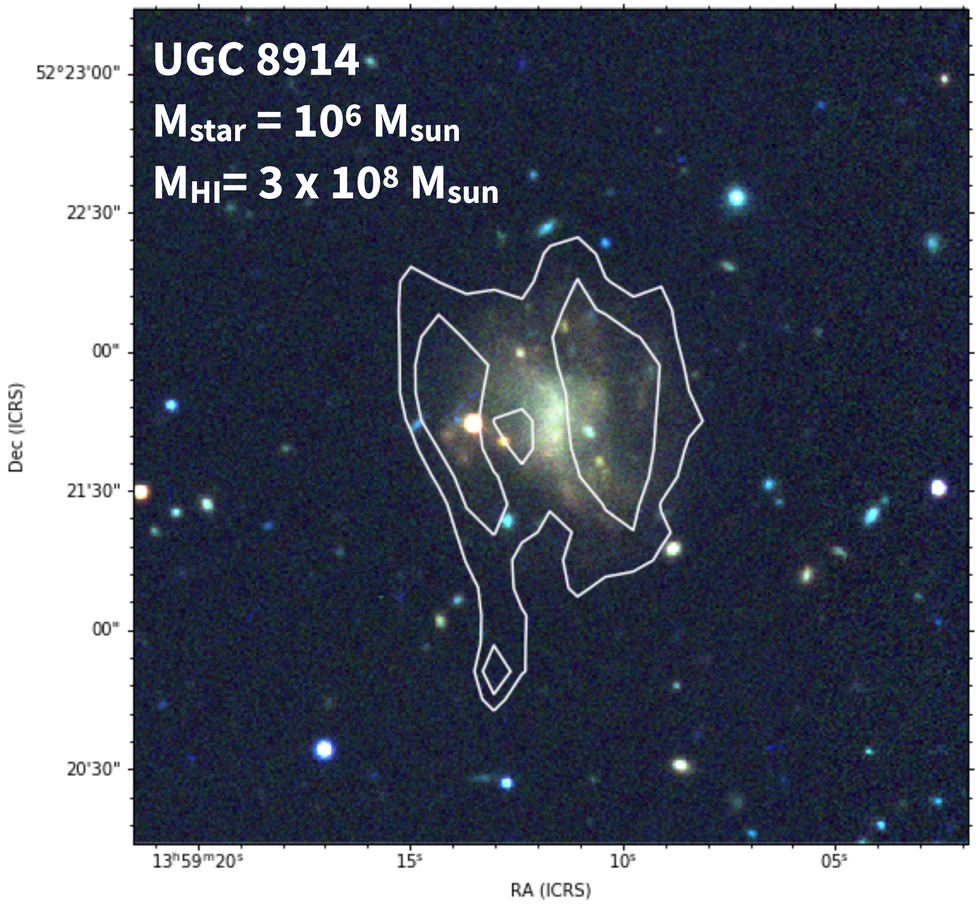
The data is flowing

Apertif Early Science Data



Apertif Imaging Team

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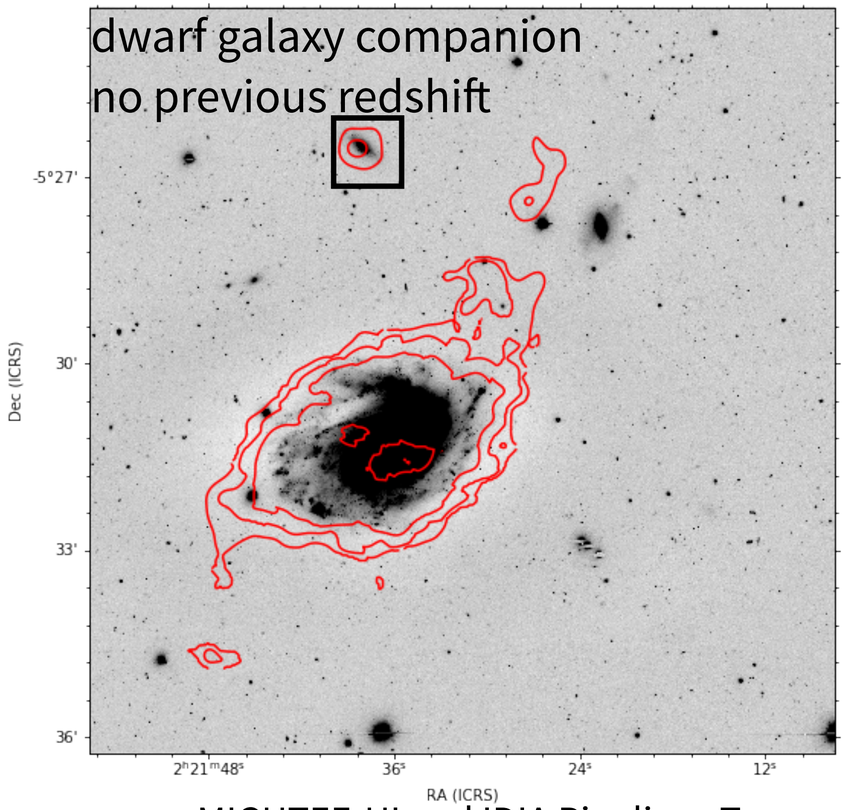
MIGHTEE (MeerKAT) Early Science Data



MIGHTEE-HI and IDIA Pipelines Team

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Take-away messages

- HI offers an important perspective on dwarf galaxies
- HI surveys offer possibility of finding gas-bearing field ultra-faint dwarf galaxies
  - Have found several (~2-5) potential candidates in ALFALFA
    - AGC 249525 is an excellent candiate with promising HI properties and a potential stellar counterpart
- Exciting times ahead with SKA pathfinders coming online