REVEALING STAR FORMATION PROCESSES IN THE NEARBY UNIVERSE WITH THE NGVLA

STAR FORMATION AS A “WORK HORSE”

- Stellar light
- Stellar evolution
- Stellar feedback
- Stellar mass function

Star formation is one of the most important physical processes in the universe

ENVIRONMENTAL DEPENDENCE

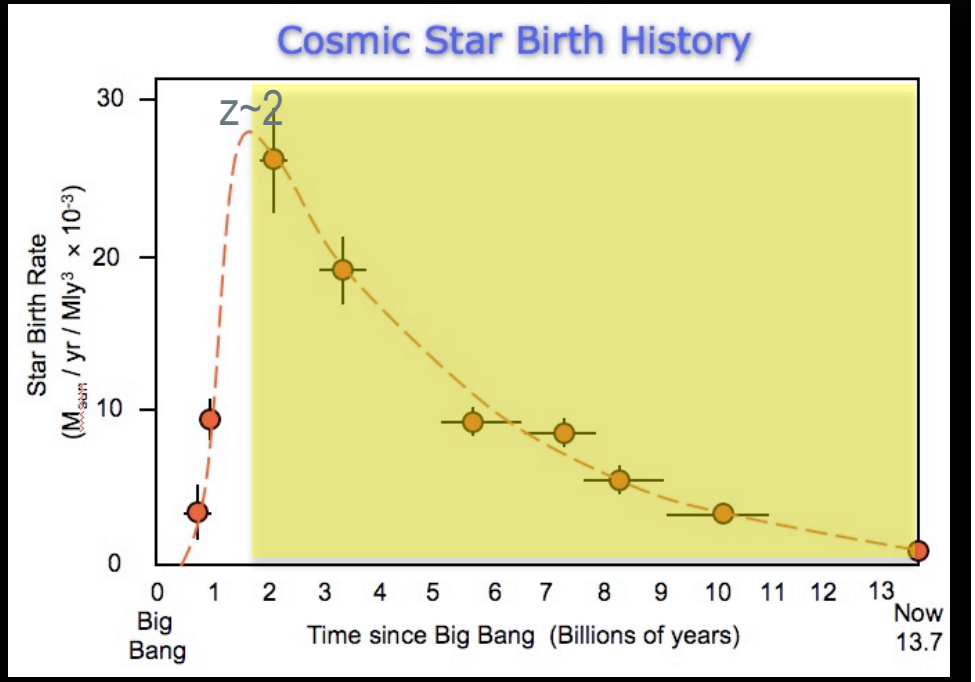
- Galactic Disks
- Nuclear Regions
- Spiral Arms
- Mergers
- “Quiescent” Ellipticals
- Outside of galaxies?

Images courtesy of STScI

We do not know how the properties of star formation depend on environment.

GOAL FOR THE NGVLA

Blue Skies Goal:
Determine the environmental dependencies of star formation from the “peak” of cosmic star formation (z~2) until today.



(courtesy of Mark Whittle)

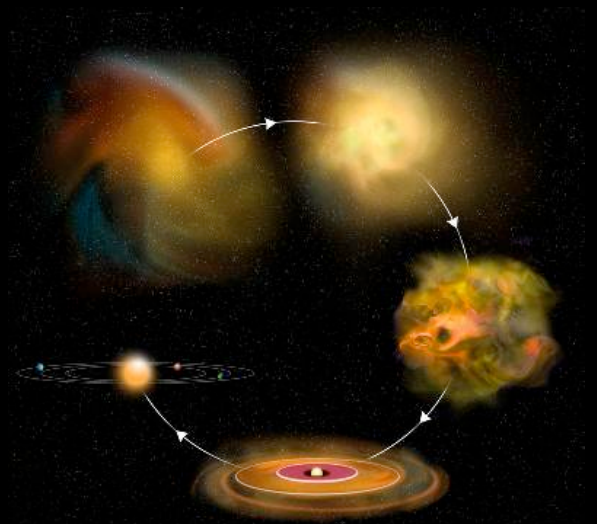
TOWARD A UNIVERSAL VIEW OF STAR FORMATION

1) Detect out to distance of significance (with high dynamic range)

2) Isolate physical scale of interest (core, cluster, complex, galaxy)

3) Apply tracers to determine physical properties

- Mass
- Density
- Temperature
- Dynamical structure
- Pressure
- Star formation rate
- Star formation efficiency



(Credit: Bill Saxton, NRAO)

CASE STUDY #1: ULTRA COMPACT HII REGIONS

Goal:

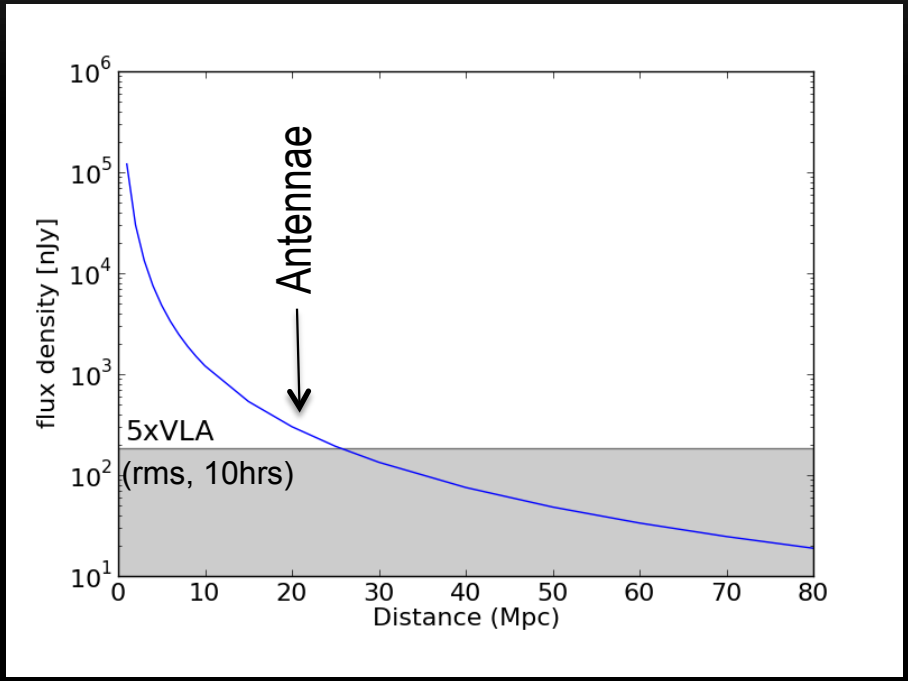
Detect and resolve the formation of individual stars in environments significantly different than our own galaxy.

DETECT UCHII REGIONS IN NEAREST MAJOR MERGER: ANTENNAE

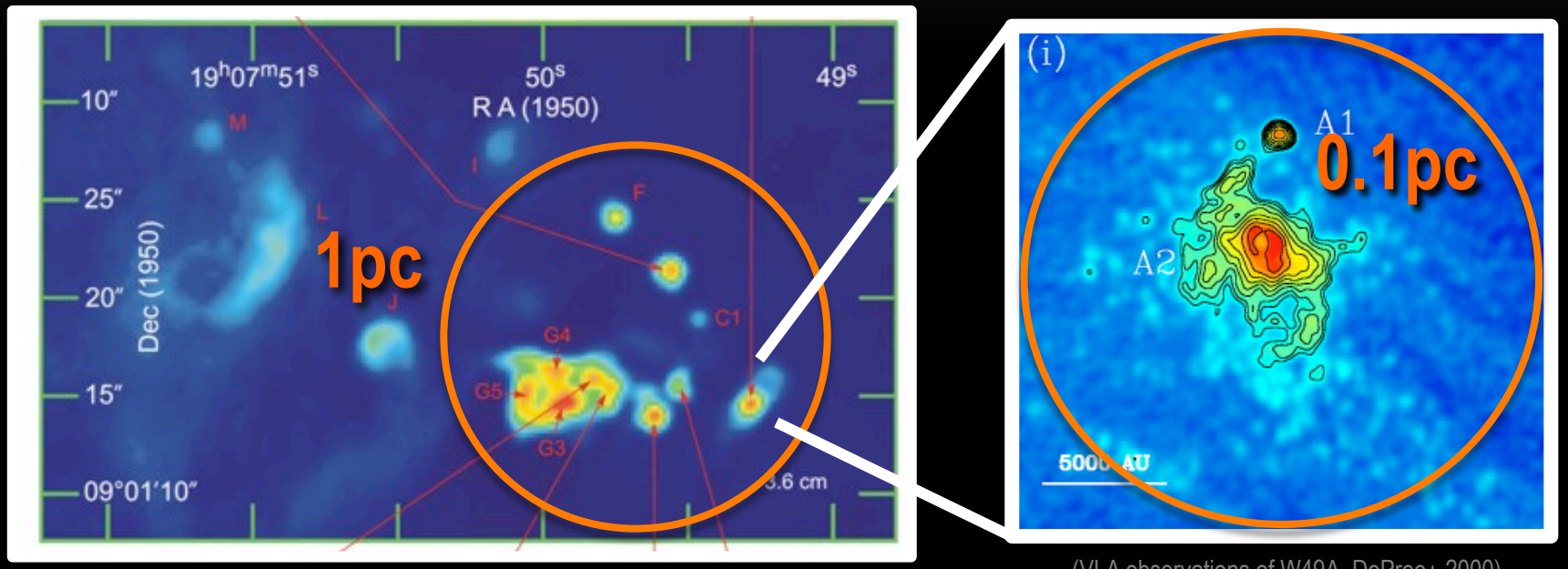
Do-able!

However…

- ➔ 0.1pc resolution
- ➔ Baselines of ~1000km
- ➔ Intermediate between NGVLA and VLBA



IMPORTANCE OF SPATIAL RESOLUTION: W49A



(VLA observations of W49A, DePree+ 2000)

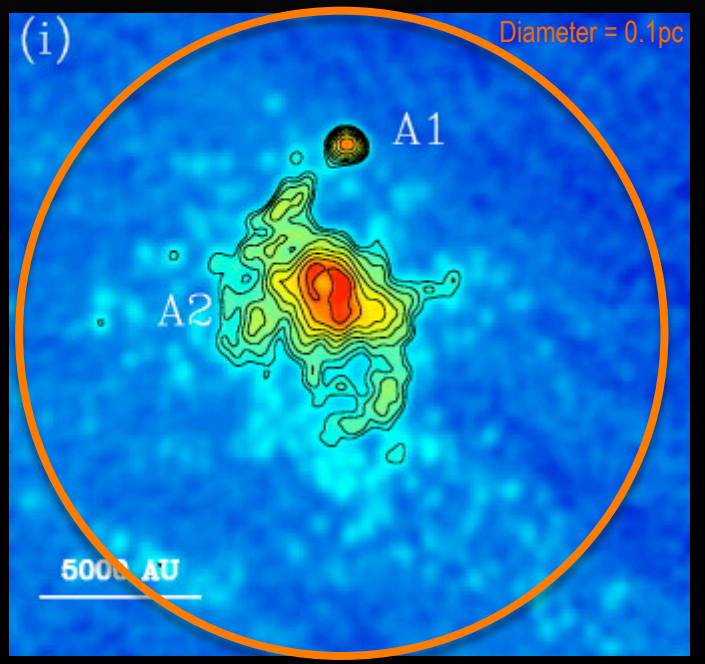
RESOLVE INDIVIDUAL UCHII REGIONS IN NEAREST STARBURST: M82

- Require resolution ≈ 0.1pc
- Achievable to ~3.5 Mpc with θ = 0.”006

➔ Includes entire local group

\+ NGC253, IC4662, Maffei 1, Maffei 2, NGC4214, IC342, NGC1569, Holmberg II

~ M81, M82 (requires 0.”0055)



(VLA 7mm observations of W49A, DePree+ 2000)

CASE STUDY #2:
FORMATION OF GLOBULAR CLUSTERS

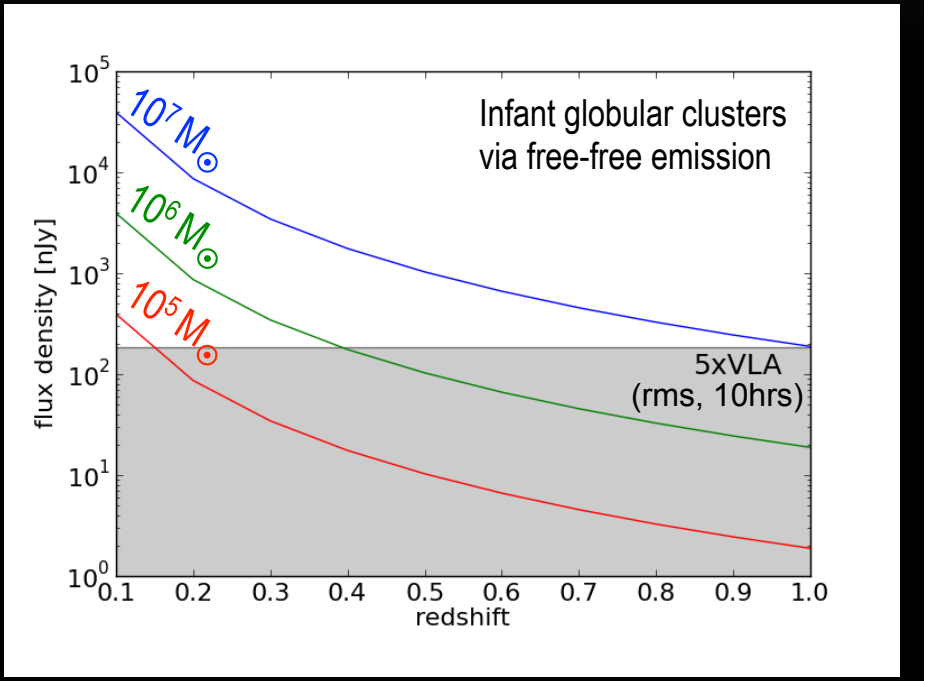
Goal:

Detect and resolve infant super star clusters in environments common during the peak of cosmic star formation.

DETECT INFANT GLOBULAR CLUSTERS OUT TO z=1

- Can detect most massive out to z=1
- Can only resolve scales of ~10pc out to distances of ~300 Mpc with 180km baselines.

@ z=1, 1” ~ 8kpc
➔ Need θ ~ 0.”001
➔ Baselines ~1000 km

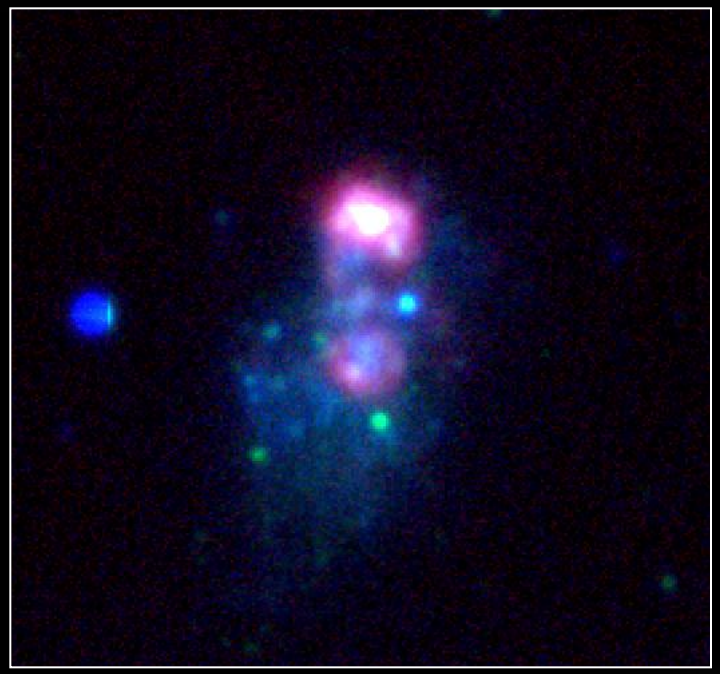


CASE STUDY #3:
STAR FORMATION AT ULTRA-LOW METALLICITY

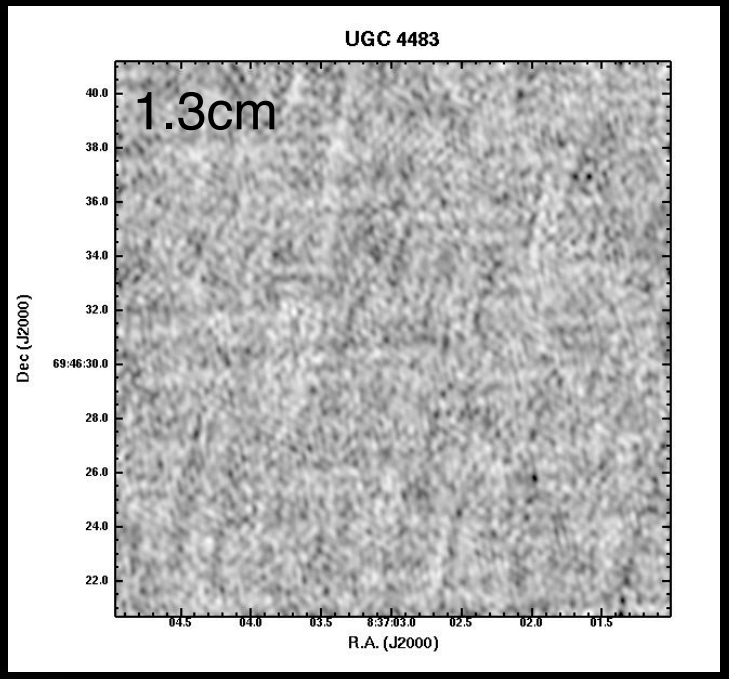
Goal:

Observationally determine the impact of ultra-low metallicity (< 1/15 $Z_{\odot}$) on star formation.

UGC 4483:
12 + LOG(O/H) = 7.53 (~1/23 $Z_\odot$)
D=5.1Mpc

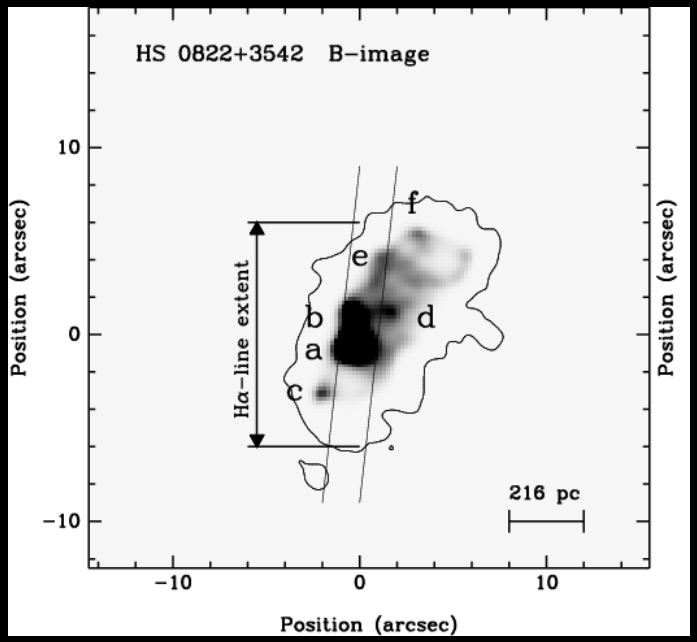


(B, R, Ha from Gil de Paz et al. 03)

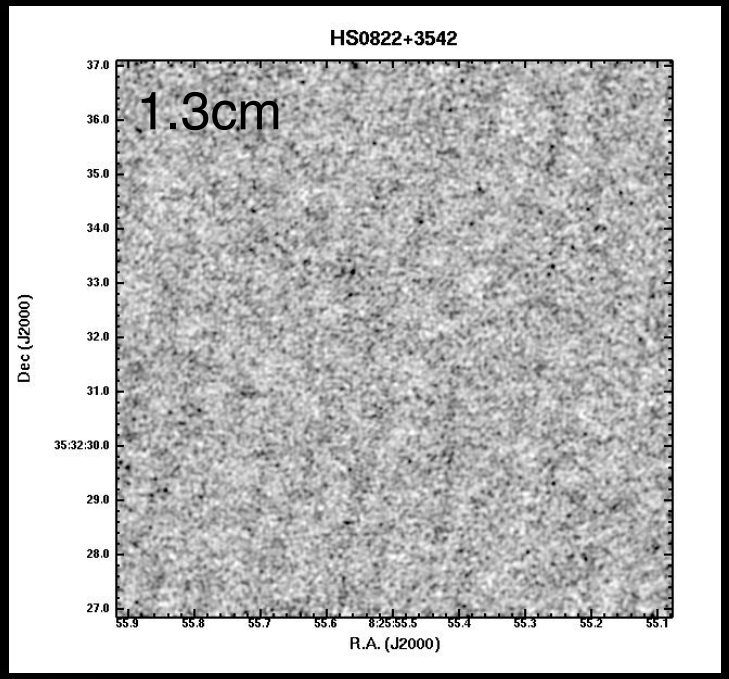


$M_{cluster} < 8 \times 10^3 M_\odot$

HS 0822+3542:
12 + LOG(O/H) = 7.4 (~1/32 $Z_\odot$)
D = 12.5 Mpc



(Pustilnik et al. 03)

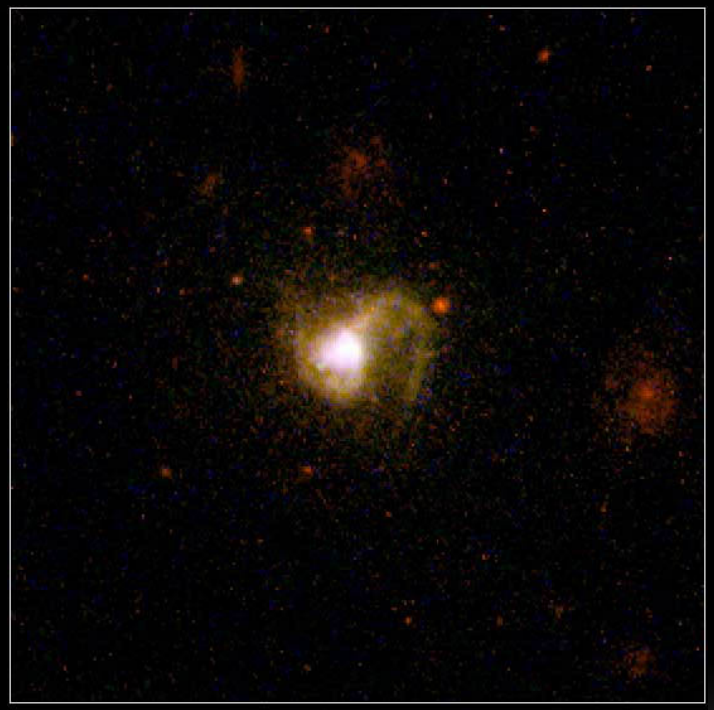


$M_{cluster} < 2 \times 10^4 M_\odot$

POX 186

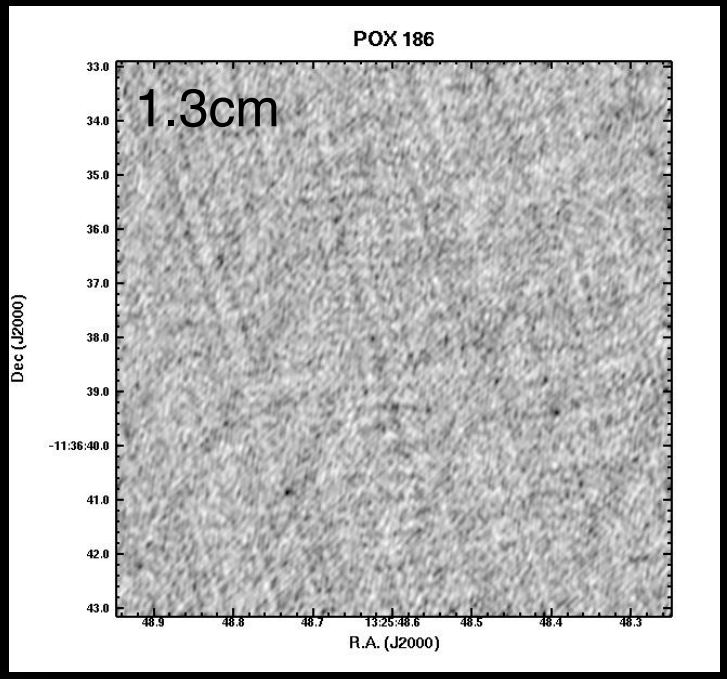
12 + LOG(O/H) = 7.72 (~1/15 $Z_\odot$)

D=18.1Mpc



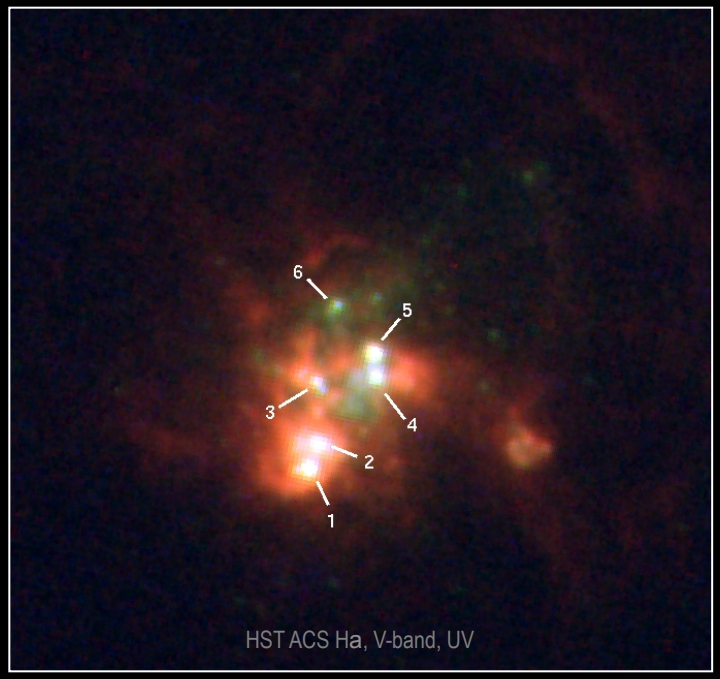
Galaxy POX 186 HST ◆ WFPC2

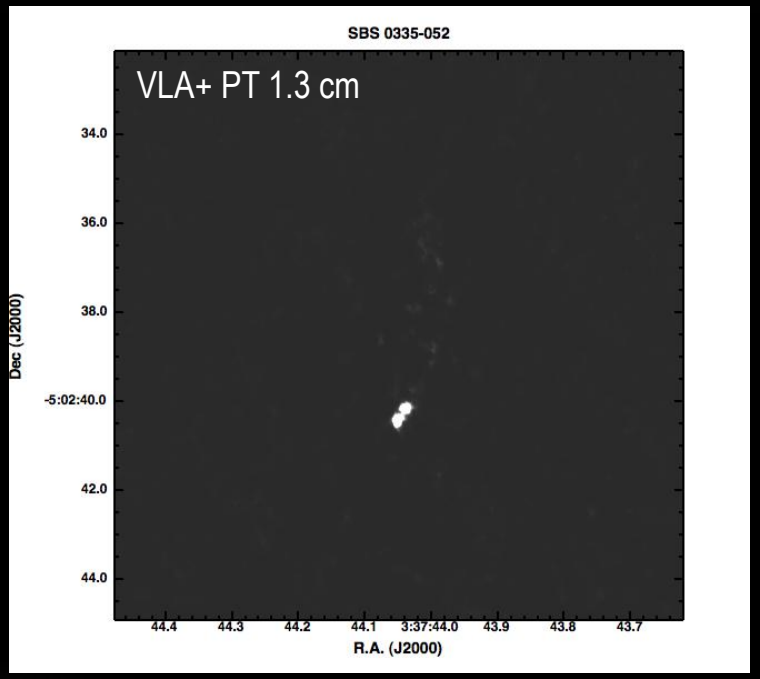
NASA and M. Corbin (CSC/STScI) STScI-PRC02-16



$M_{cluster} < 4 \times 10^4 M_\odot$

SBS0335-052:
12 + LOG(O/H) = 7.3 (~1/40 $Z_{\odot}$)
D=56Mpc



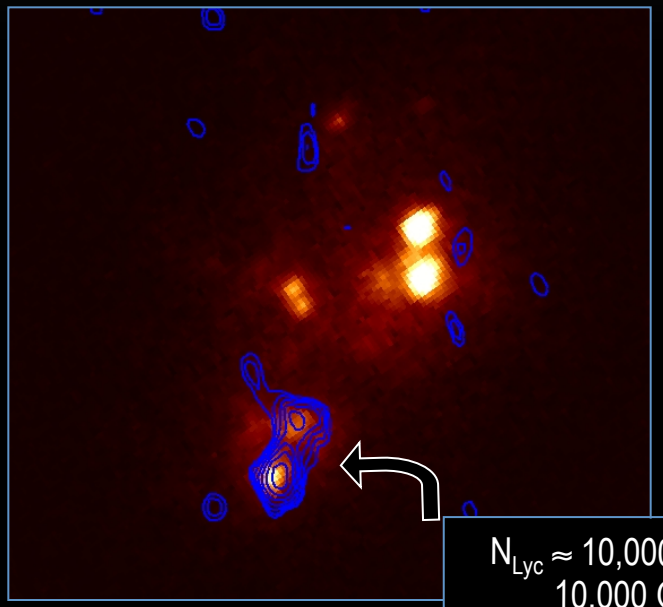


(Johnson+ 09)

SBS0335-052:
12 + LOG(O/H) = 7.3 (~1/40 $Z_\odot$)
D=56Mpc

- D = 56 Mpc (~275 pc / ")
- Resolution w/ PT ~0."25 (~70pc)

➔ Need θ < 0."03 to disentangle individual star clusters



$N_{Lyc} \approx 10{,}000 \times 10^{49}\ s^{-1} \approx$ 10,000 O7* stars

Contours: VLA + Pie Town X-band (Johnson, Hunt , & Reines 09)

CASE STUDY #4: RADIO RECOMBINATION LINES

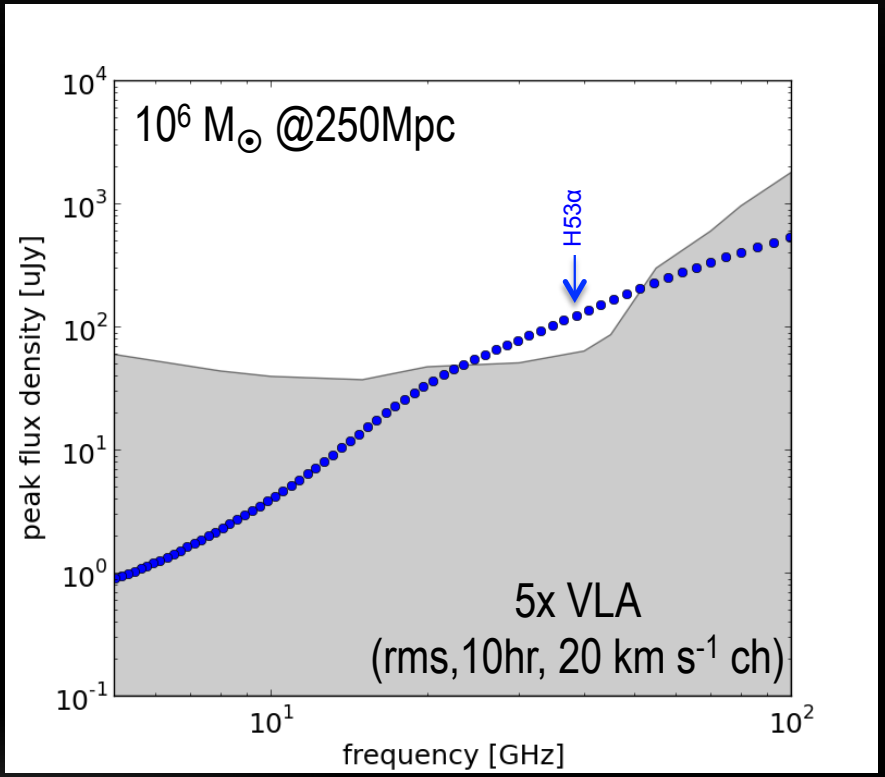
Goal:

Use RRLs to infer physical conditions, including:

- Electron temp
- Electron density
- Virial mass
- Dynamics
- Filling factors
- Ionizing flux
- Stellar mass
- Star formation rate

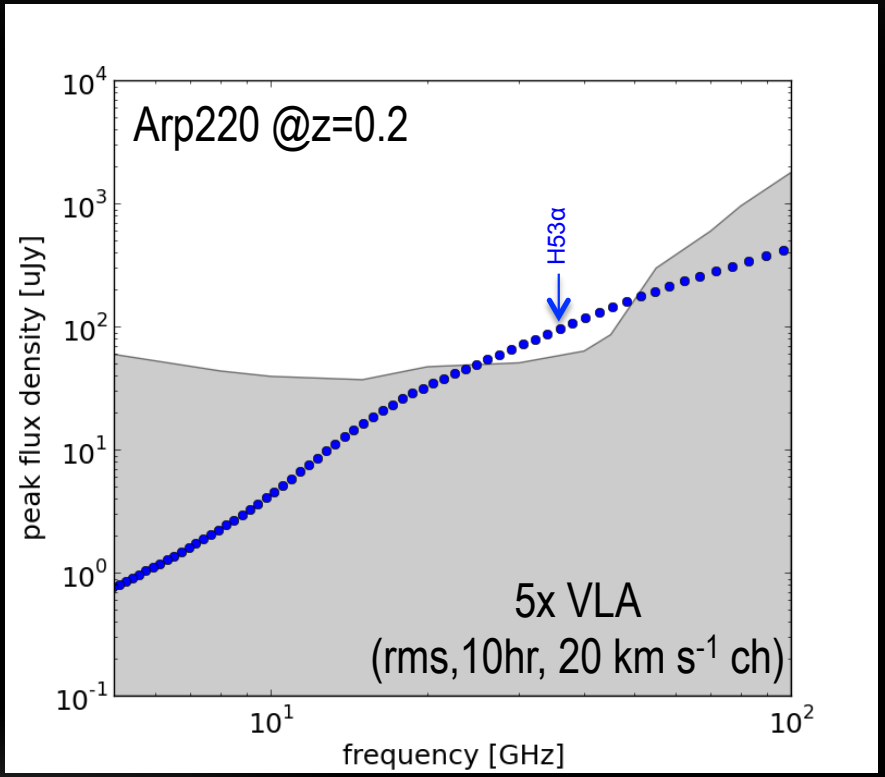
DETERMINE CONDITIONS OF SUPER STAR CLUSTERS IN 10 NEAREST ULIRGS

- Detectable out to ~250 Mpc with spatial resolution of <10pc for 180km baselines



MEASURE IONIZED GAS DIRECTLY WITH RADIO RECOMB LINES

- UV & FIR light are subject to assumptions about extinction and reprocessing of light
- Radio recombination lines provide a direct measure of the ionized gas



MAIN POINTS

- Star formation is important
- Need to *both* detect *and* resolve scales of interest

  ➔ For case studies presented here, resolution (and dynamic range) will be limiting step
- Case studies

  1) Detect and resolve UCHIIs in range of galactic environments

  2) Identify and study infant globular clusters at the peak of cosmic star formation

  3) Determine the impact of ultra-low metallicity of star formation

  4) Measure physical conditions in star-forming regions using RRLs

+++ LOTS OF OTHER LINES:

(CO shifts to 100GHz at z=0.2, NH3, CS, masers, etc)