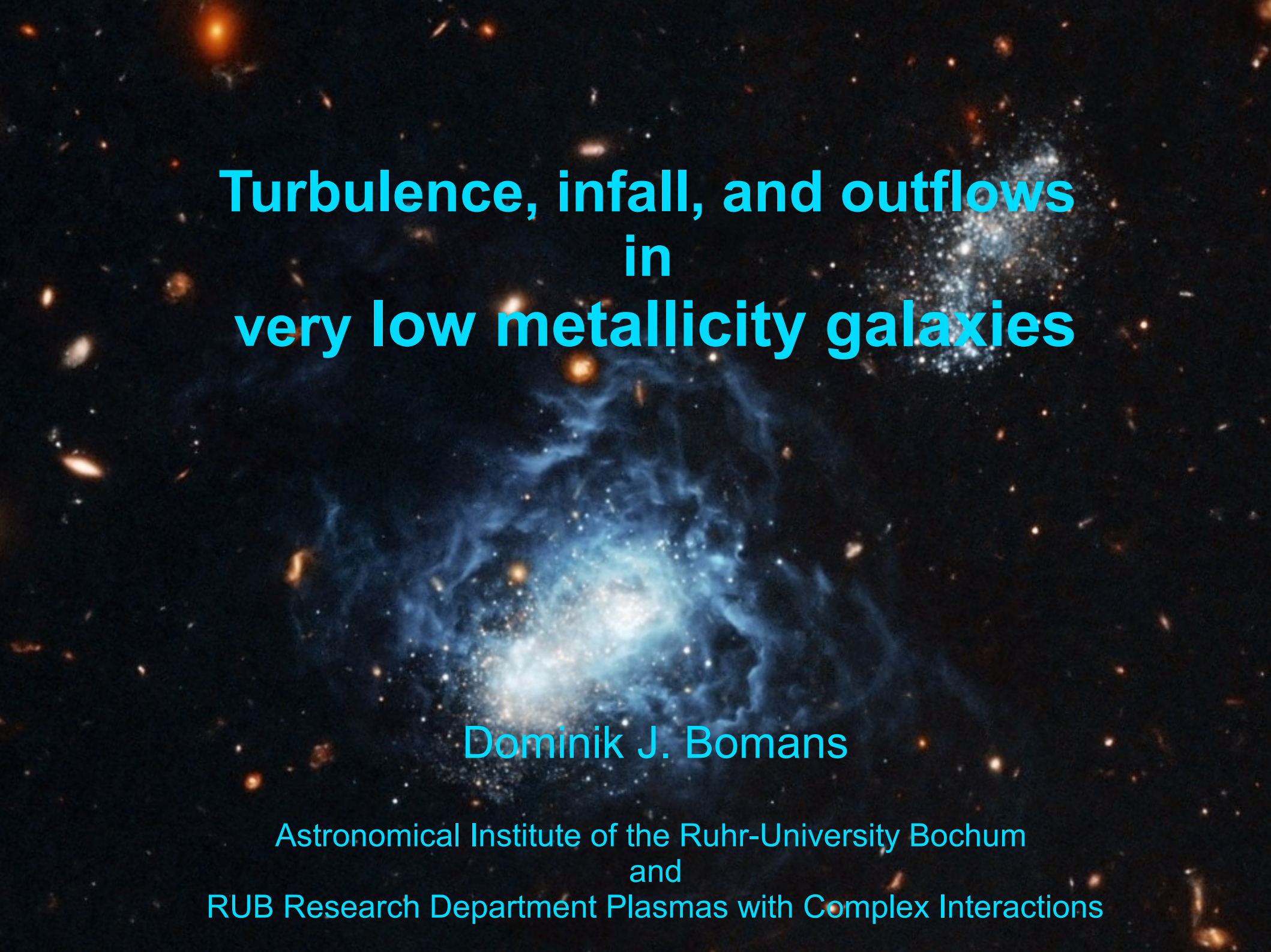

Turbulence, infall, and outflows in very low metallicity galaxies

Dominik J. Bomans

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and
RUB Research Department Plasmas with Complex Interactions

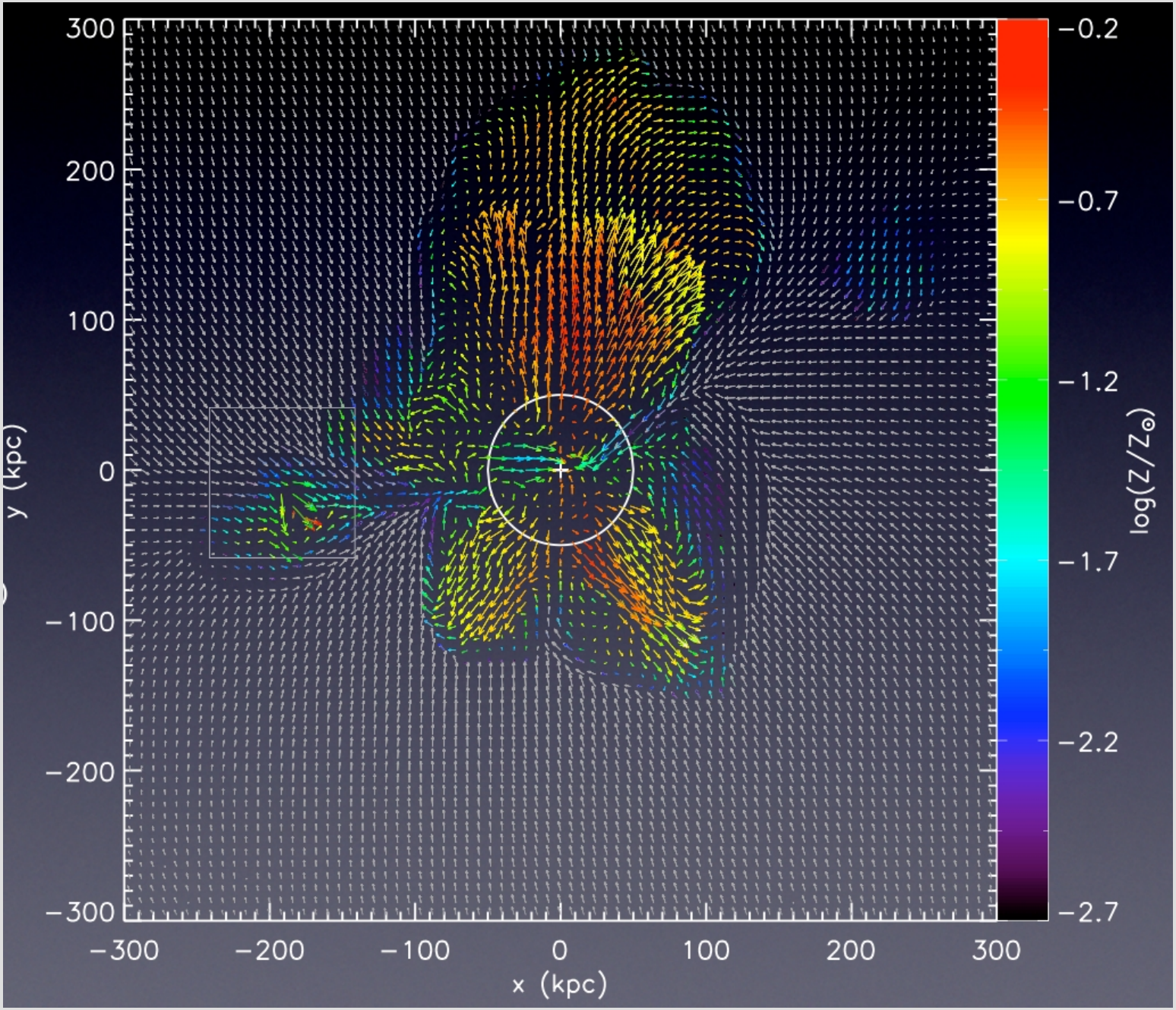
in collaboration with

Pierre Voigtländer, Marianne Langener,

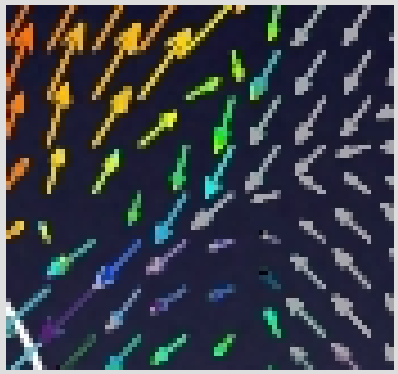
Marek Wezgowiec, Kerstin Weis,

Michel Marcelin, Alexei Moiseev, Simon Pustilnik

Galaxy formation and evolution



Cold streams
+
galactic outflows and winds
+
accretion of proto-galaxies



Shen et al. 2012

Why very low metallicity dwarf/proto-galaxies ?

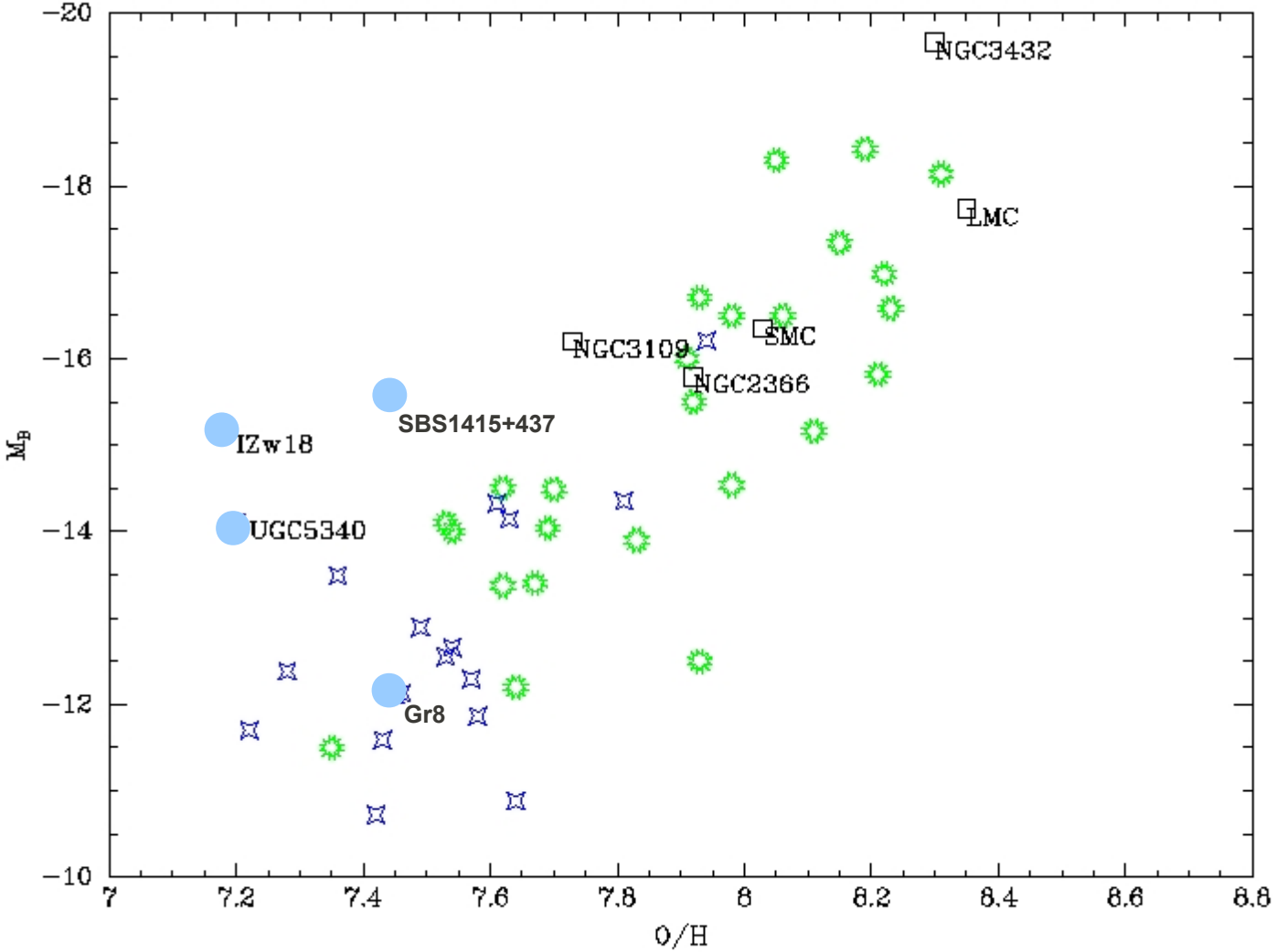
Conditions similar to high redshift universe

Many aspects are very Different in low-z environments:

- stellar winds
- stellar rotation
- late evolutionary phases
- SNe
- ISM heating / cooling
- magnetic fields
- dust properties
- environment
- .....

But how to observe it ?

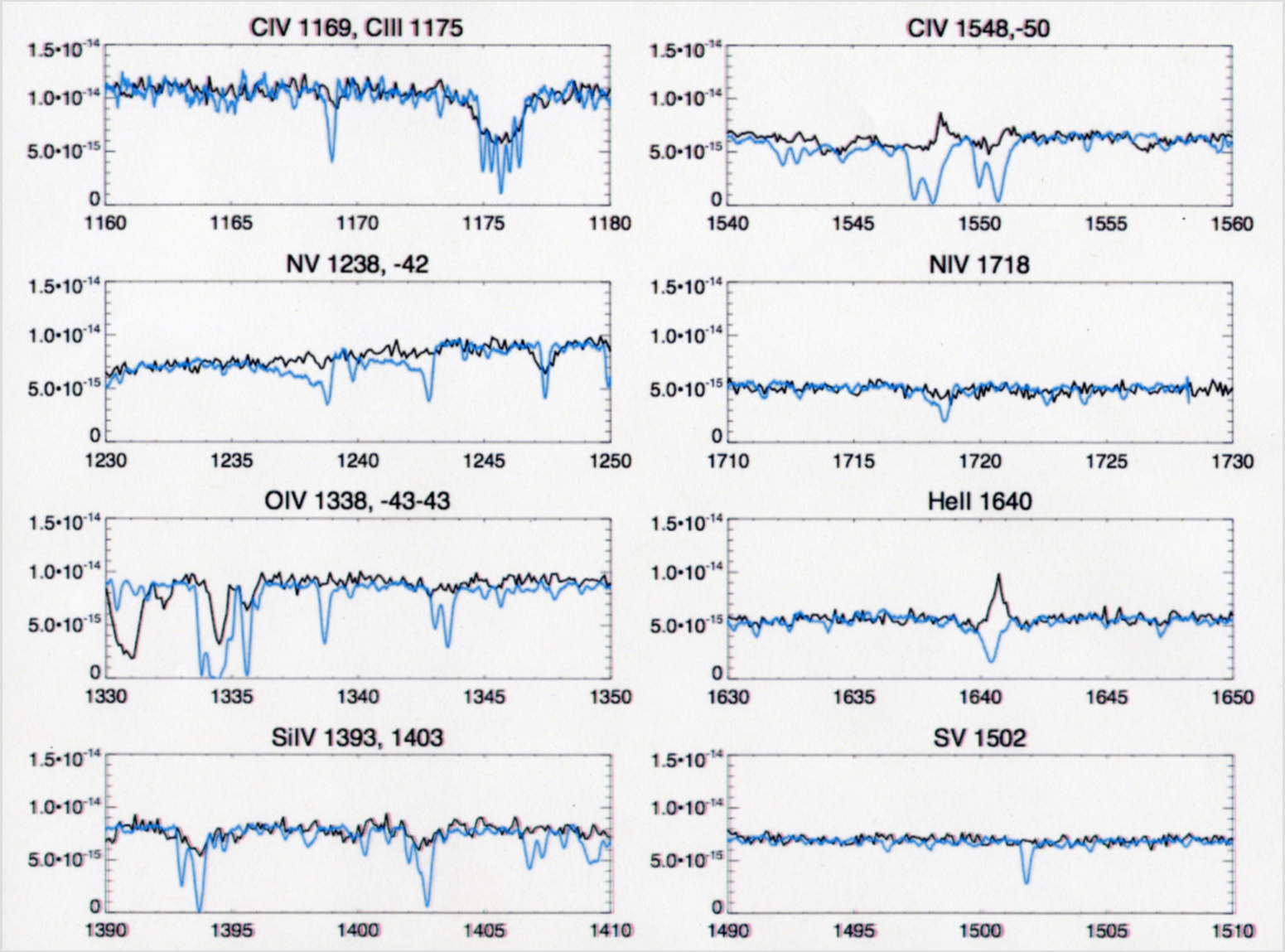
Nearby very low metallicity galaxies



I Zw 18

Aloisi et al.

What 1/30 of solar metallicity really means...

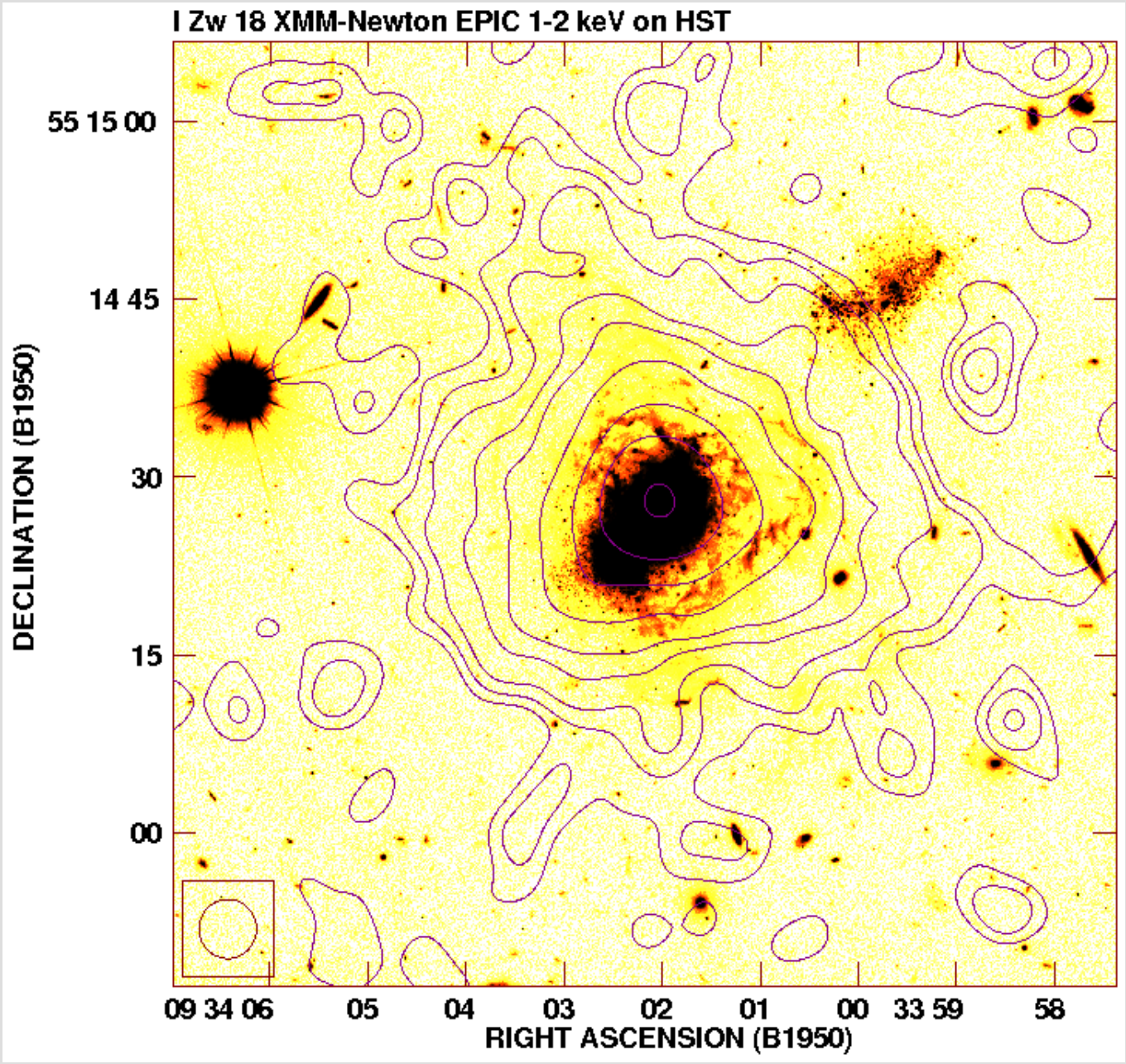


COS spectrum of I Zw 18 NW (black)

SMC O6I star NGC 346-113 (blue)

Heap et al. 2010

I Zw 18

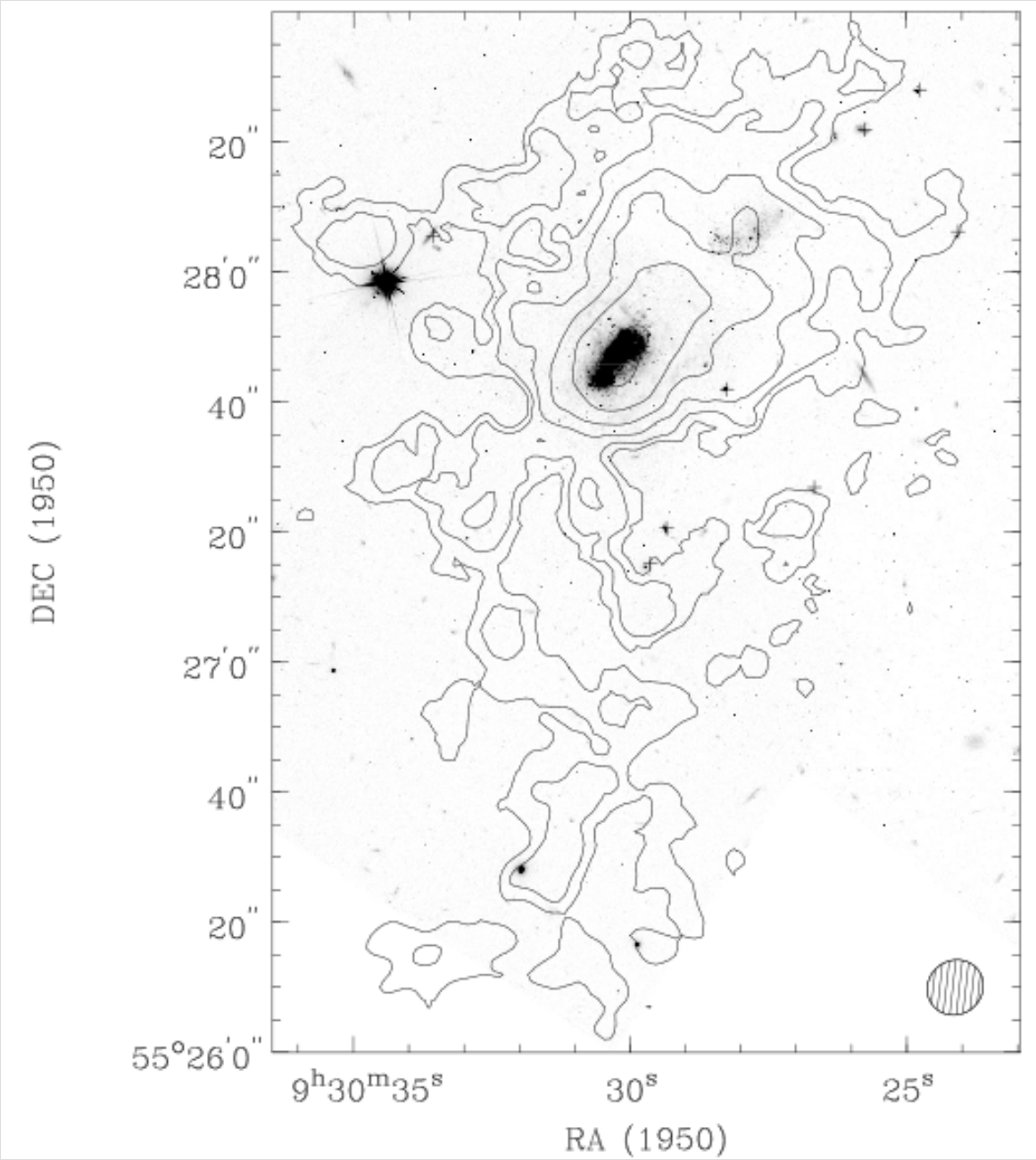


Warm and hot
Outflow / wind

Metal enrichted !

See talk by
Marek Wezgowiec

I Zw 18 in HI envelope



embedded into HI halo / filament

van Zee et al. 1998

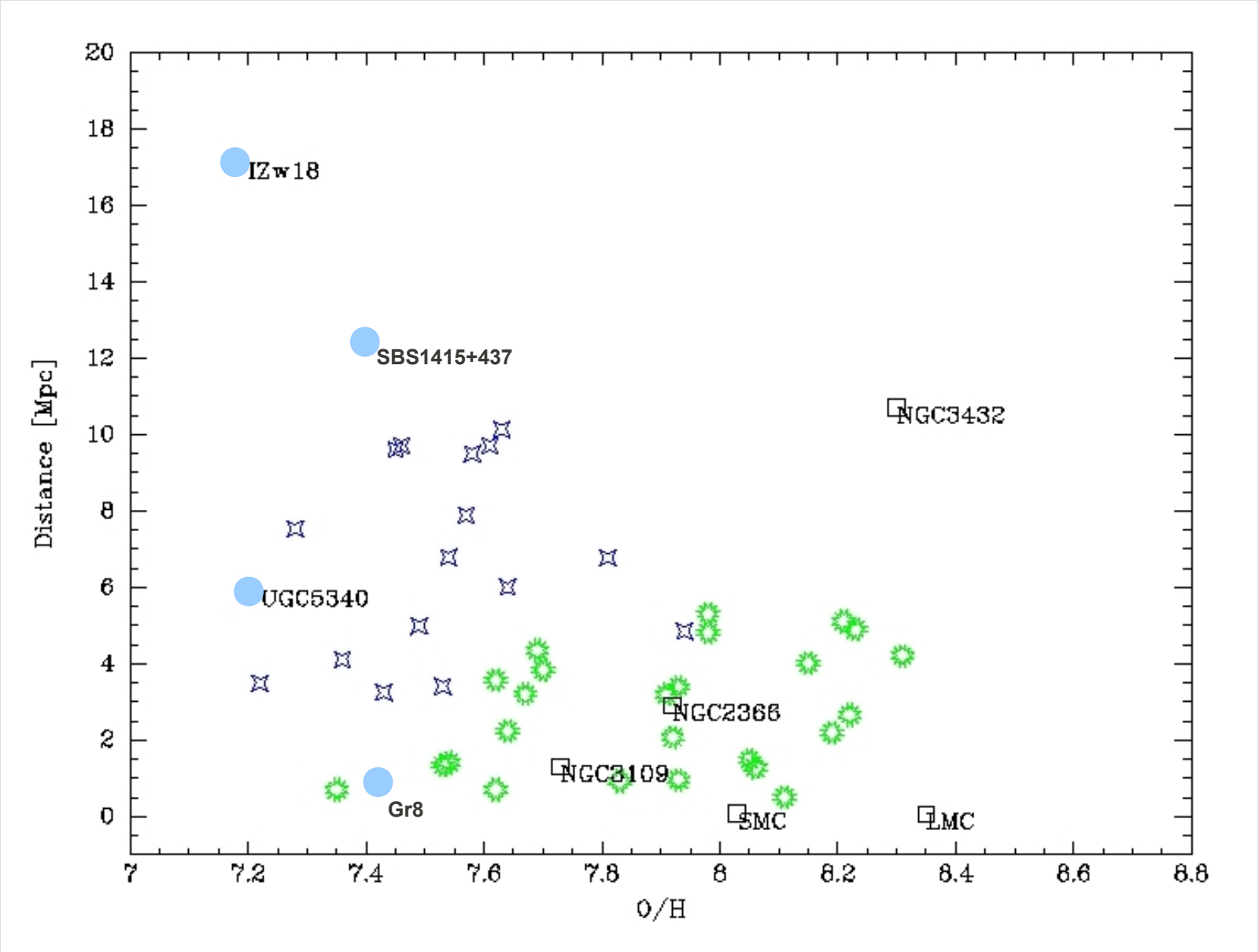
Great, but where is the problem?

I Zw 8 has now a securely determined distance of 18 Mpc.
(Aloisi et al. 2007, Fiorentino et al. 2010)

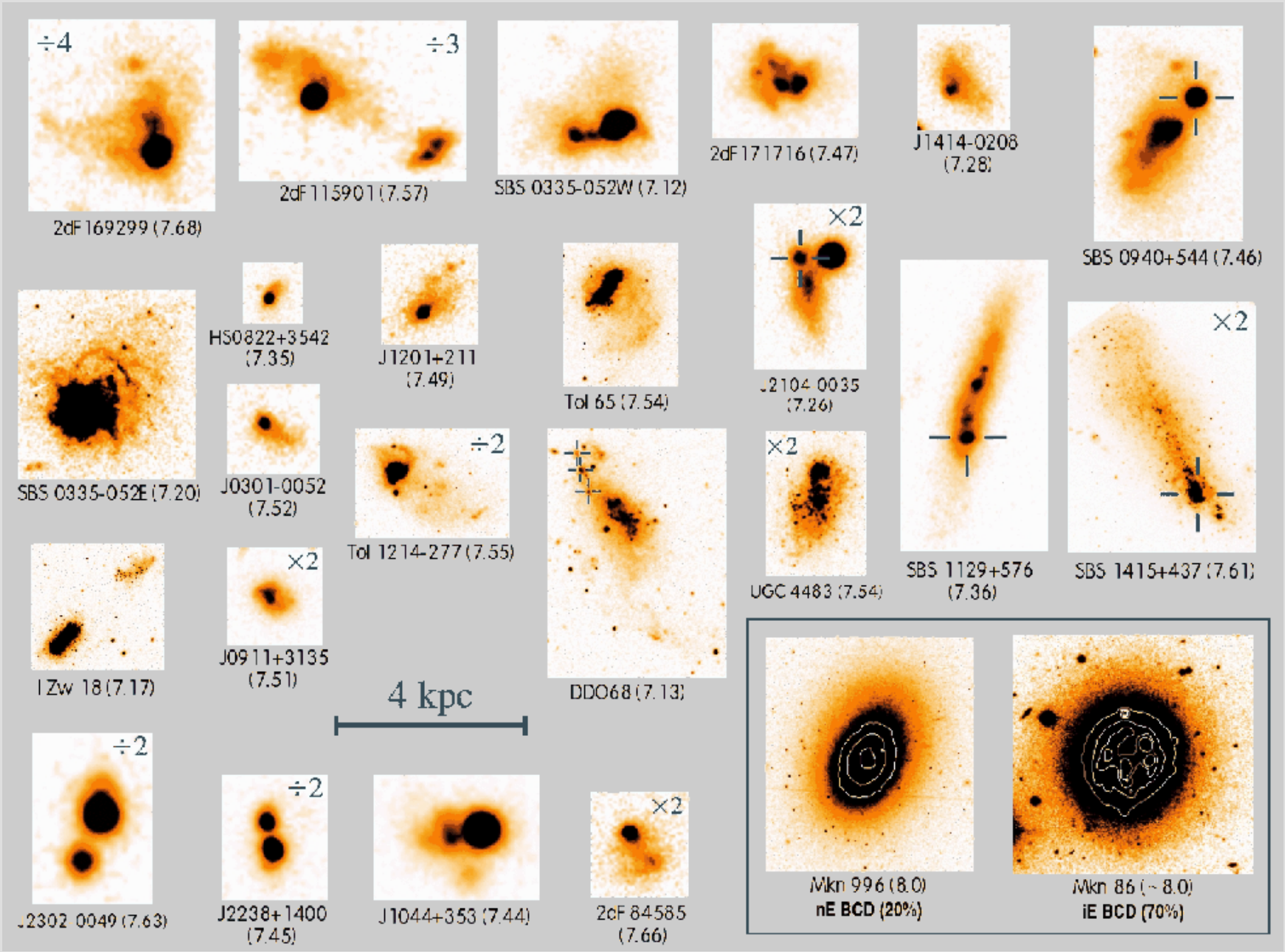
Even HST-based studies are difficult!
(crowding, high and variable background, faintness of targets, spatial resolution, ...)

What about the more local universe?

Nearby low metallicity malaxies



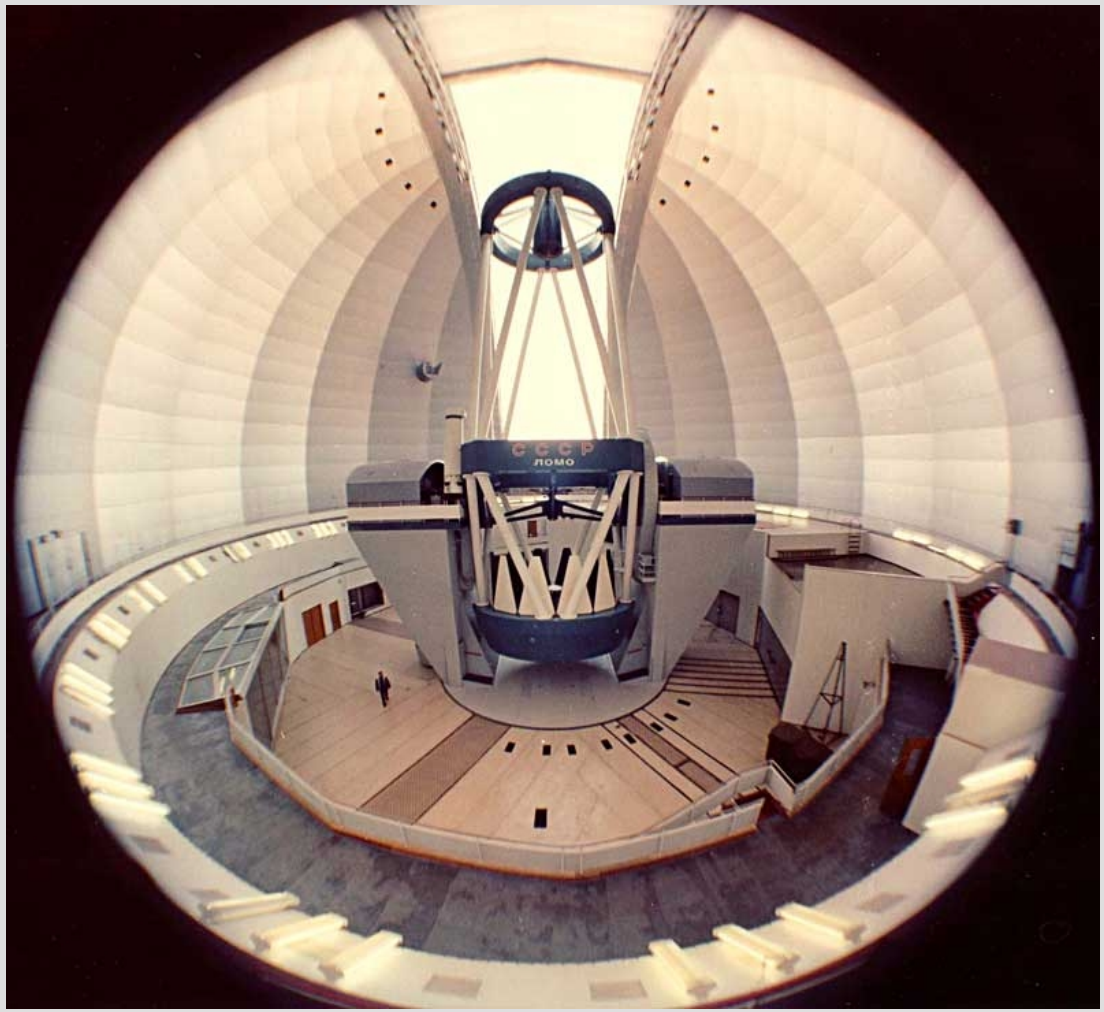
Extremely metal-poor galaxies



Papaderos et al. 2008

Hα Fabry-Perot Observations

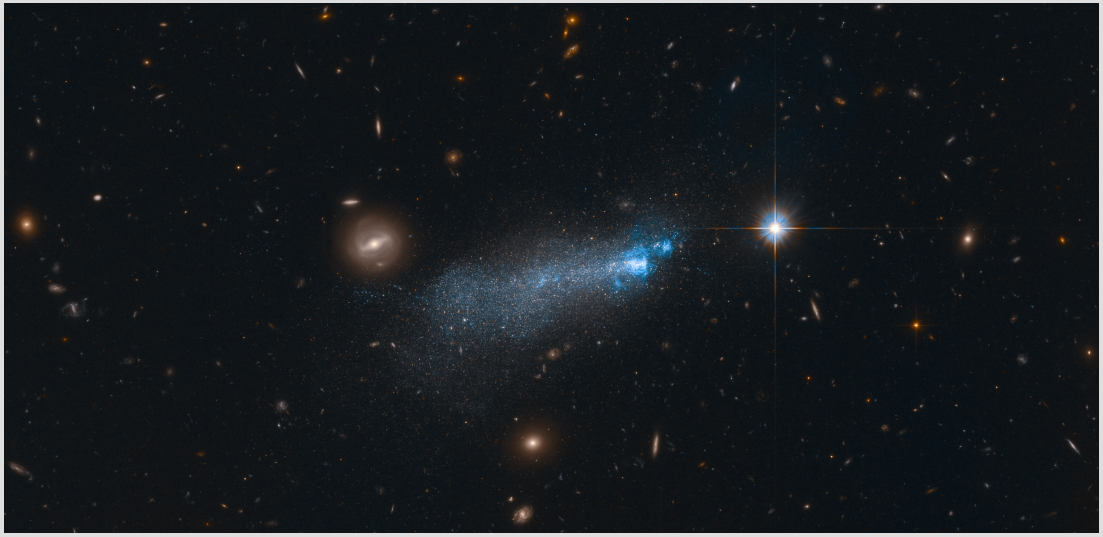
OHP 1.93m & CIGALE



SAO 6m & SCORPIO

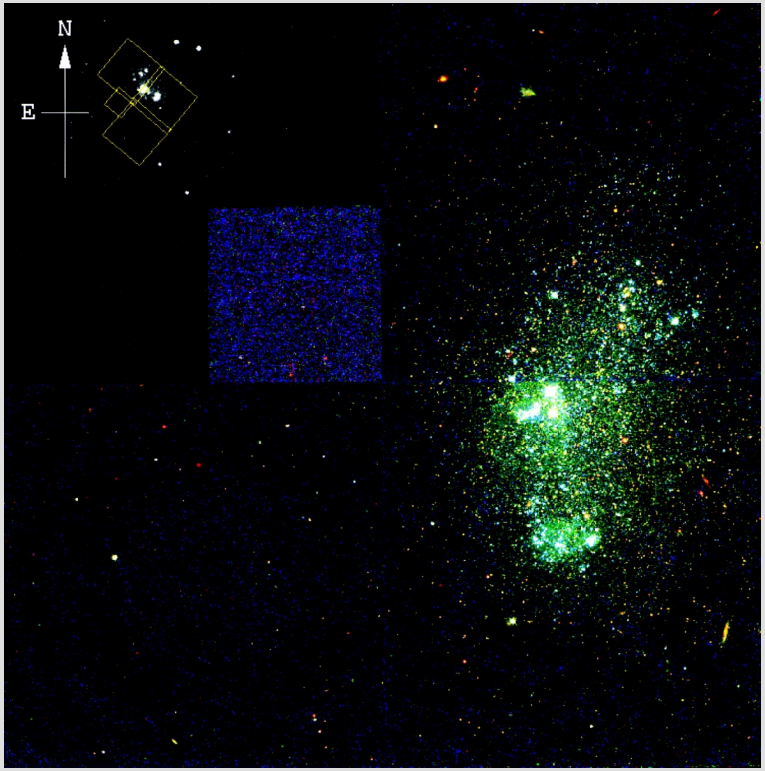
FOV ~ 6'x6'
spectral resolution R~12000 at Hα

Current sample

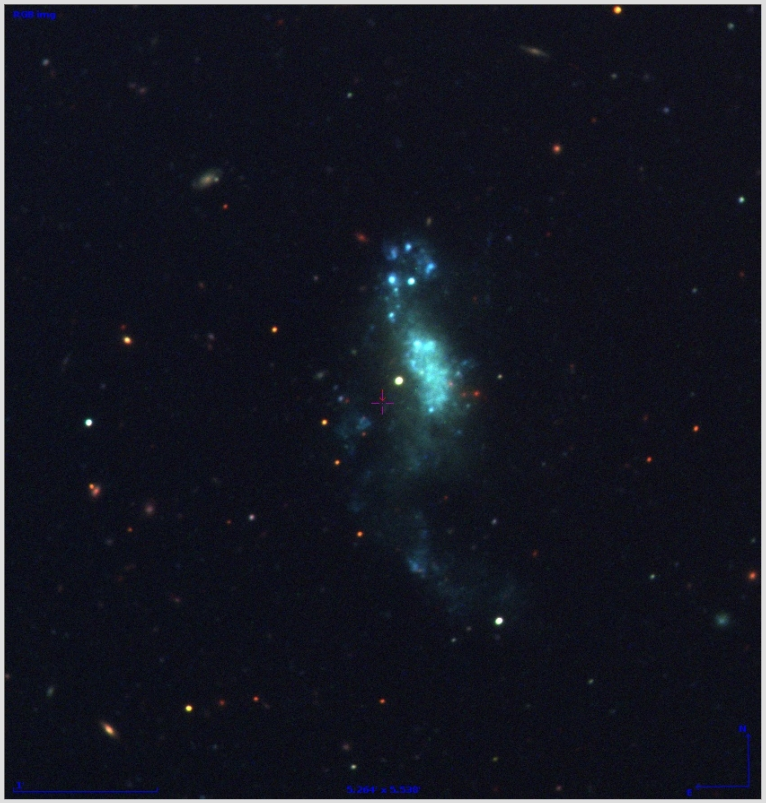


SBS 1415+437

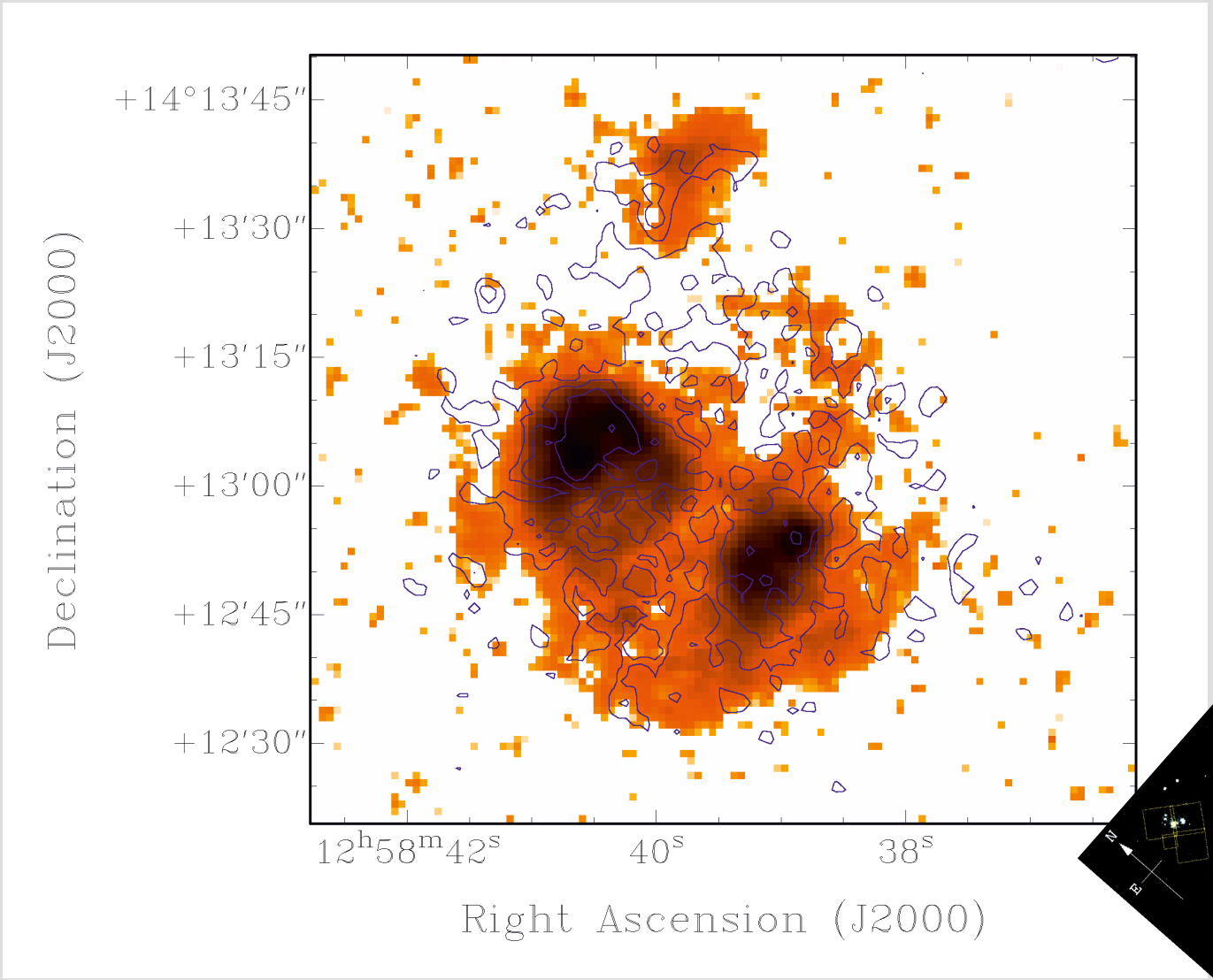
UGC 5340



GR 8



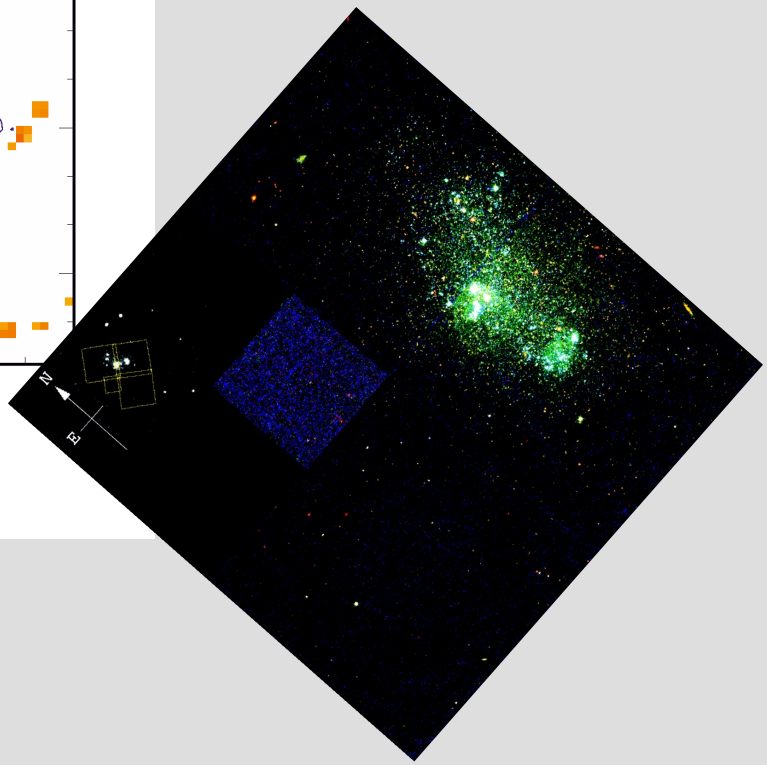
Gr 8



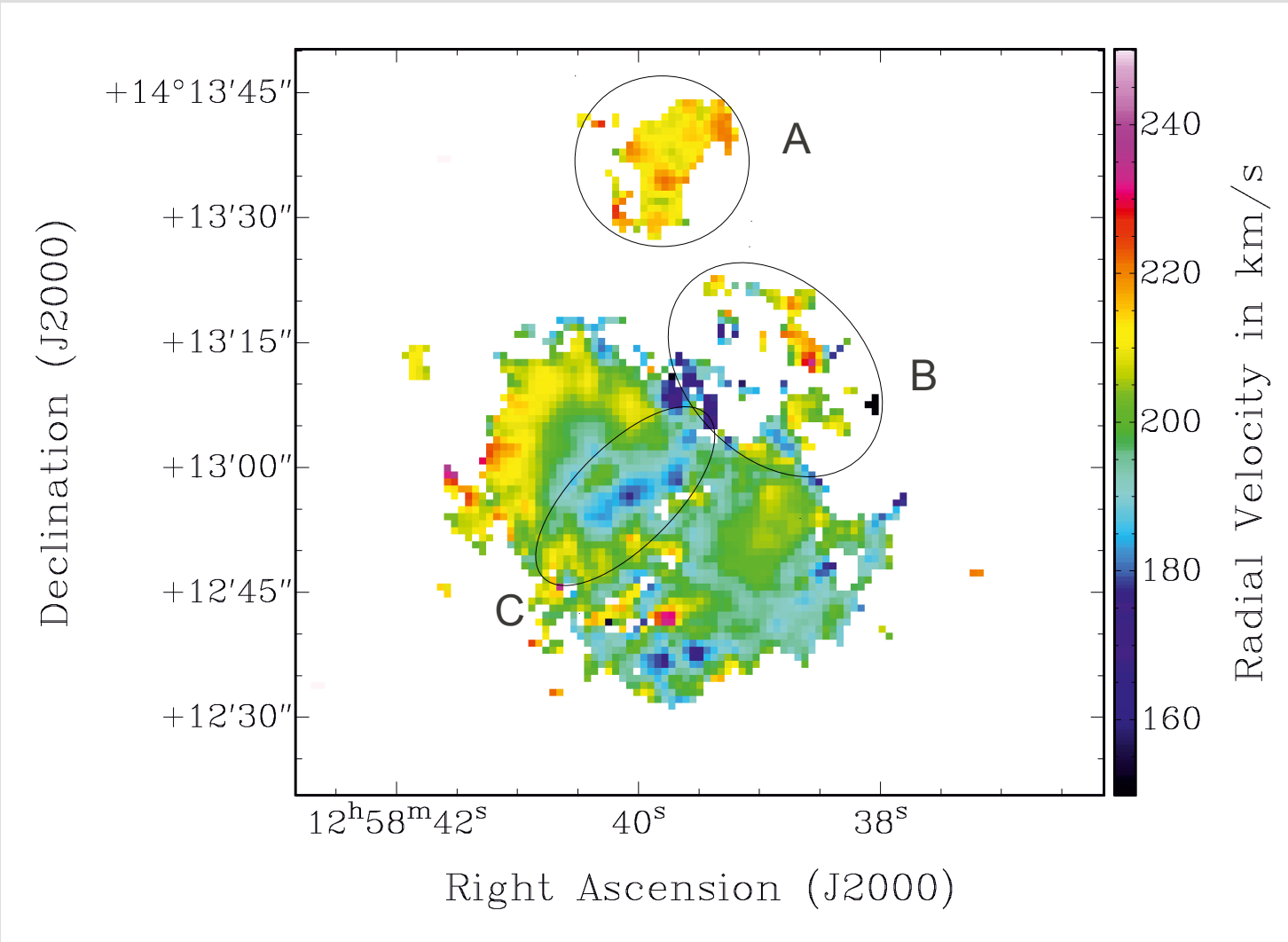
$M_B \sim -12$

$Z \sim 1/20$ solar

SFR ~ 0.004 M_{sol}/yr

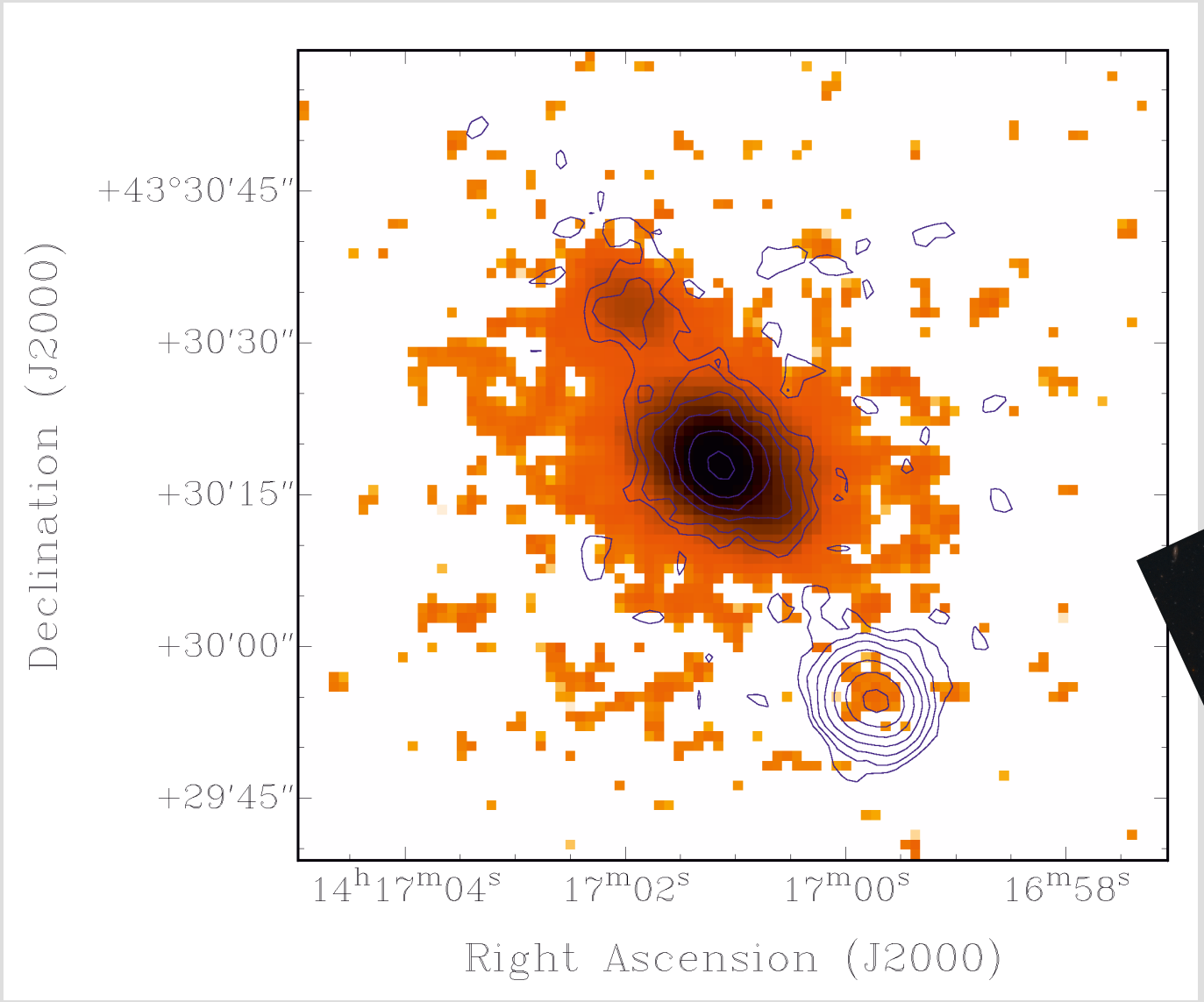


Pure Hα image with continuum in contours



region A: homogenous emission region in the north → Infall?
region B: medium scale outflow (~0.25 kpc)
region C: area with 30-40 km/s lower velocity between two bubble-like emission regions → expanding superbubble?

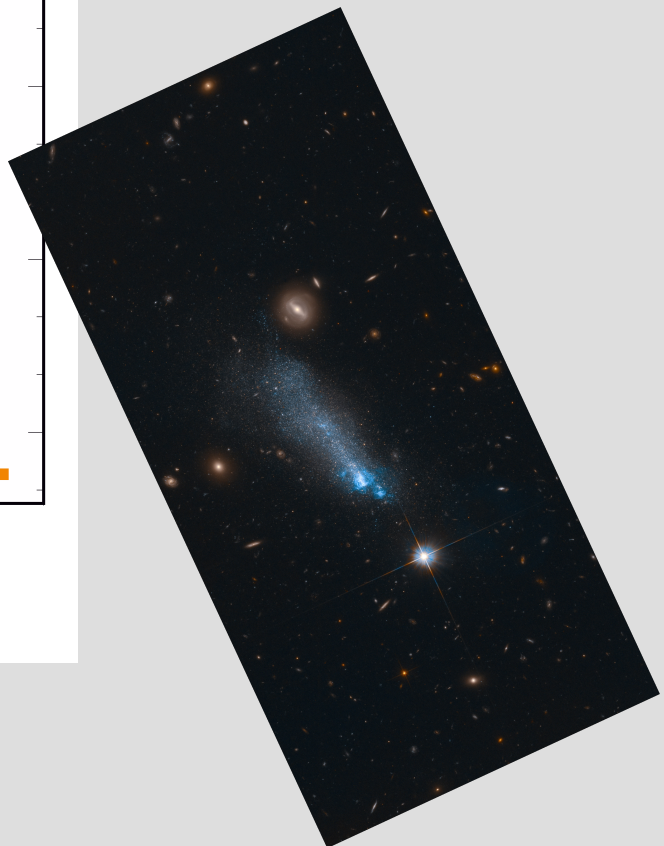
SBS 1415+437



$M_B \sim -15$

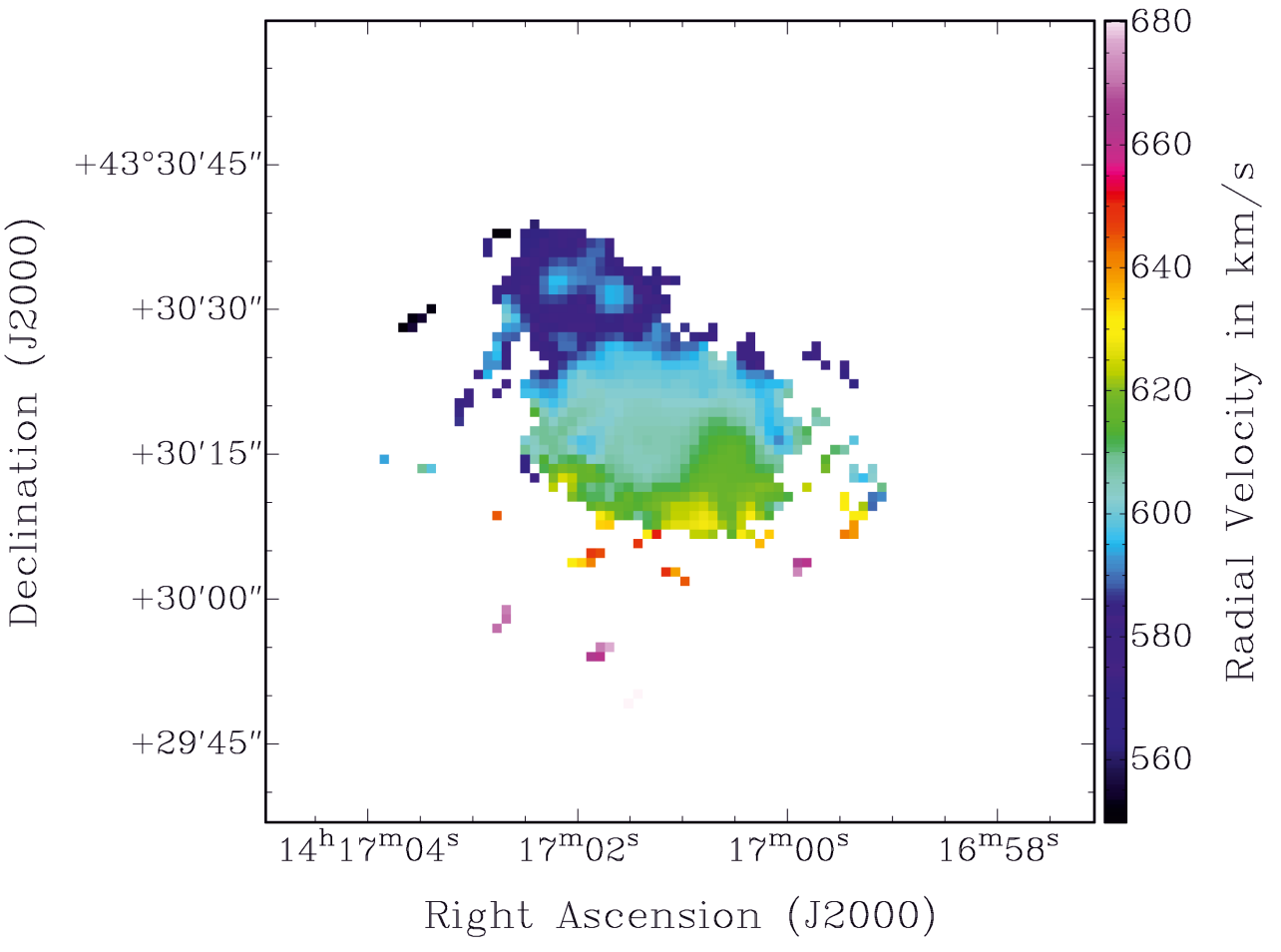
$Z \sim 1/20$ solar

$SFR \sim 0.2\ M_{sol}/yr$



Pure Hα image with continuum in contours

SBS 1415+437



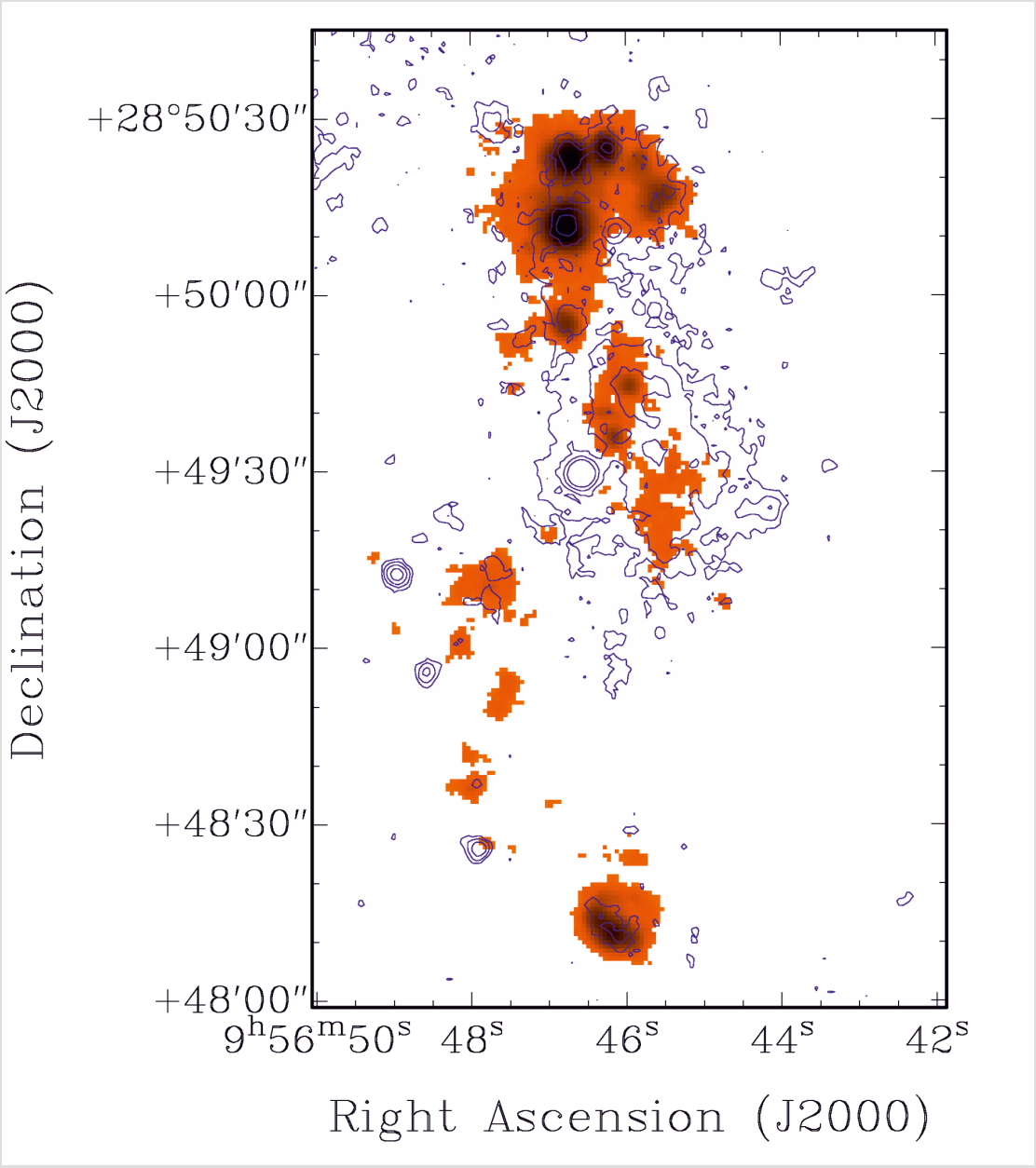
Well defined rotation Curve in area of stellar disk

Large Hα extend beyond Disk

deviating from rotation curve and high velocity clumps

→ outflow / wind

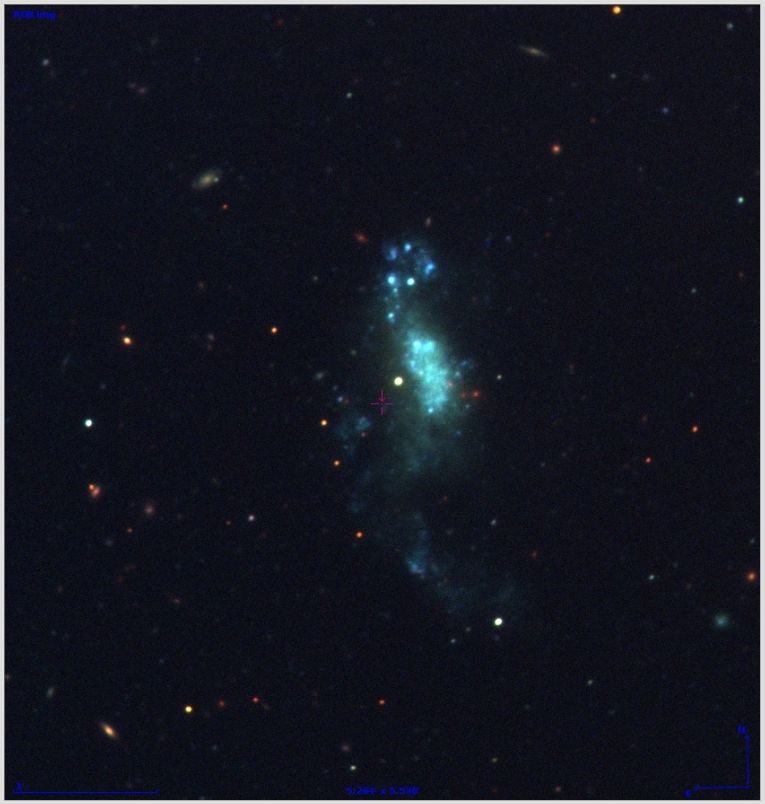
UGC 5340



$M_B \sim -14$

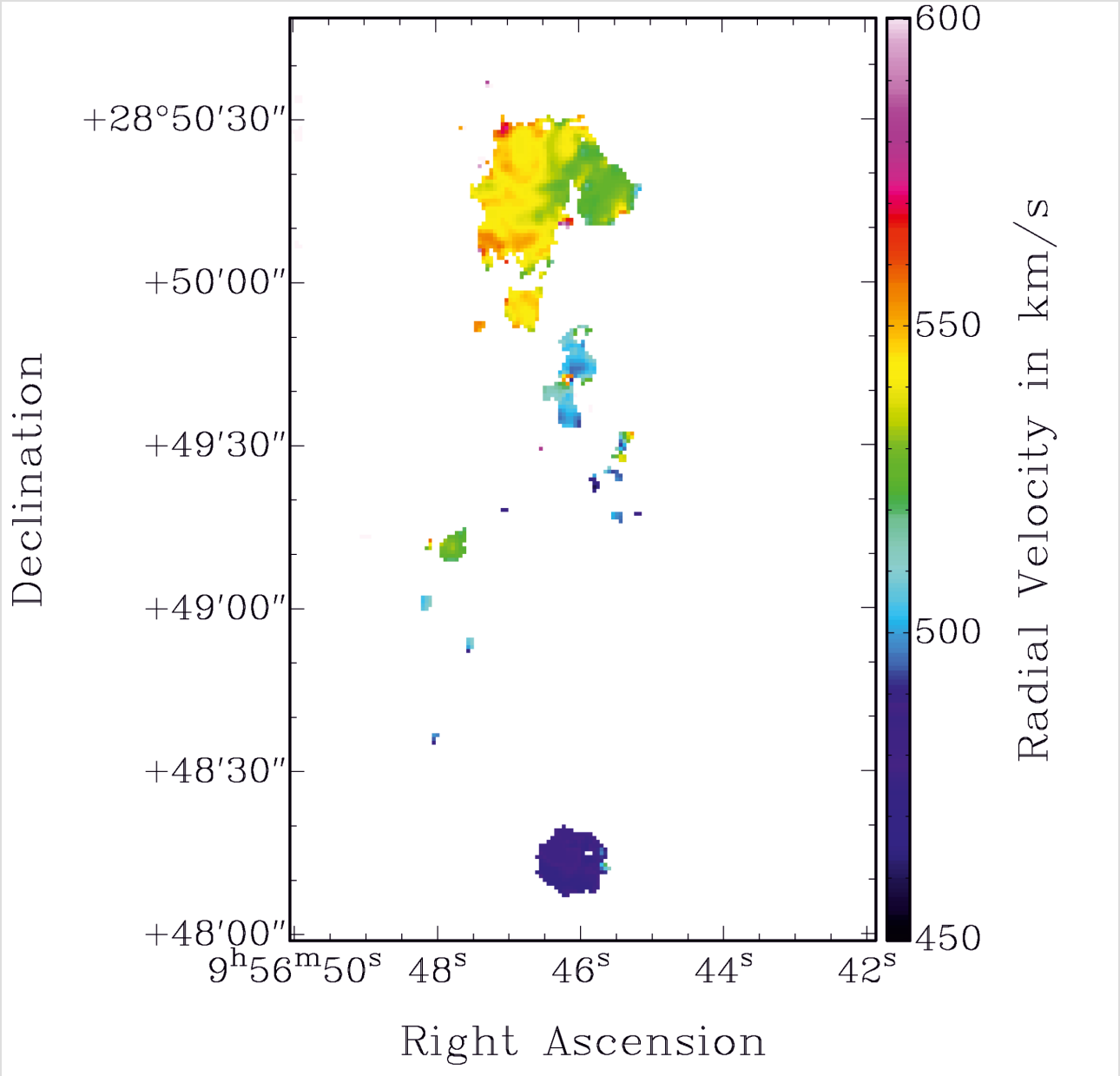
Z ~ 1/30 solar

SFR ~ 0.002 M_{sol}/yr



Pure Hα image with continuum in contours

UGC 5340



Complex velocity field

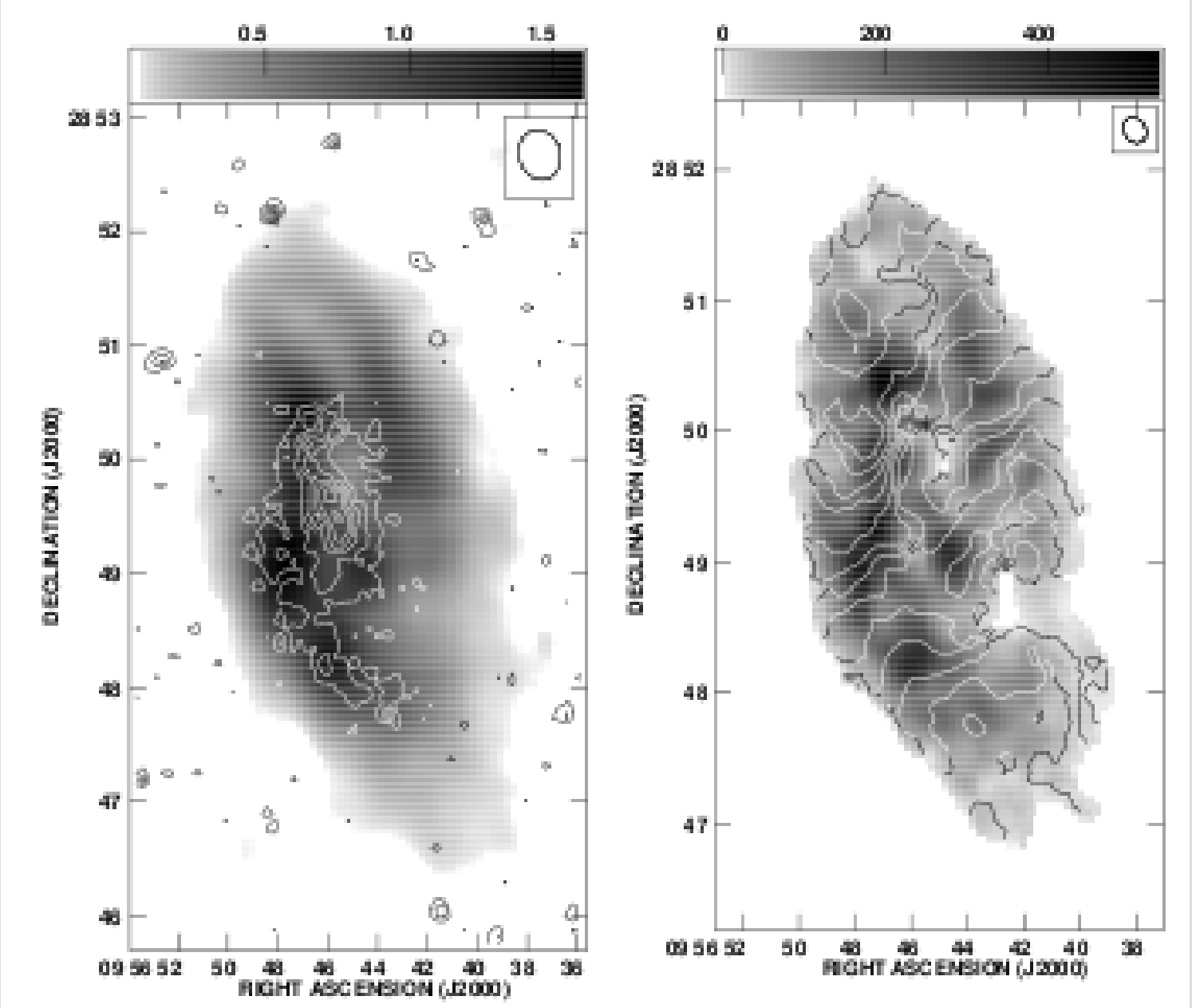
many kinematical distinct knots along a chain

multiple merger or infall along filament

possible proxy for proto-galaxy

weak signs for outflows

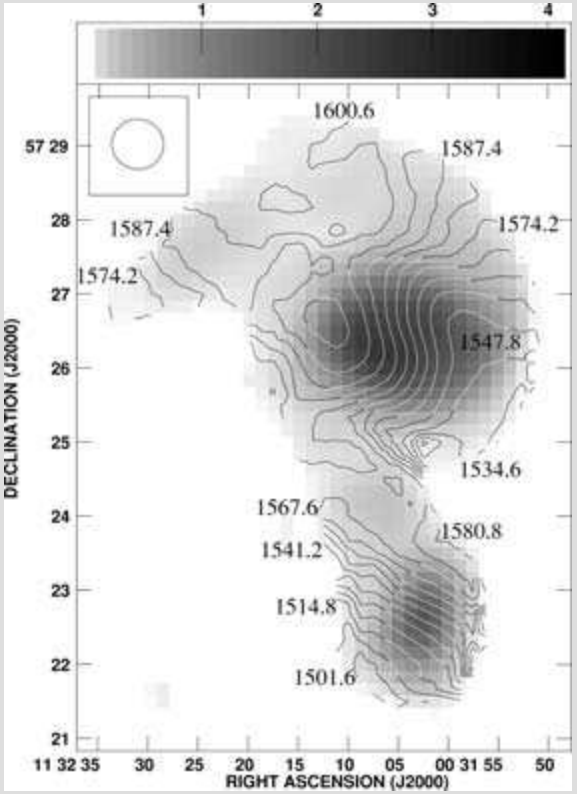
UGC 5340



and again embedded in an HI envelope with complex kinematics

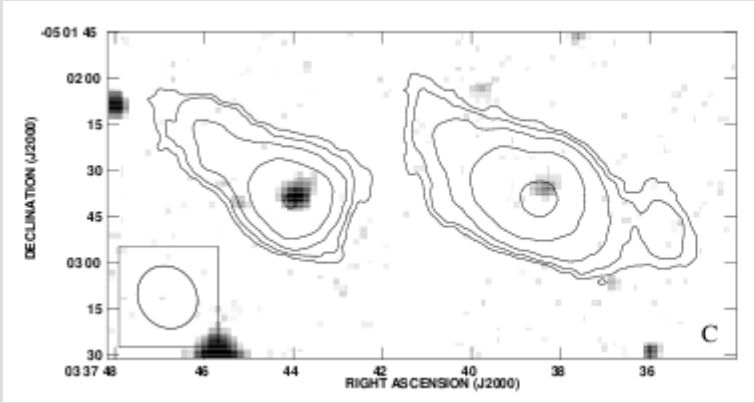
Ekta et al. 2008

HI in extremely metal-poor galaxies



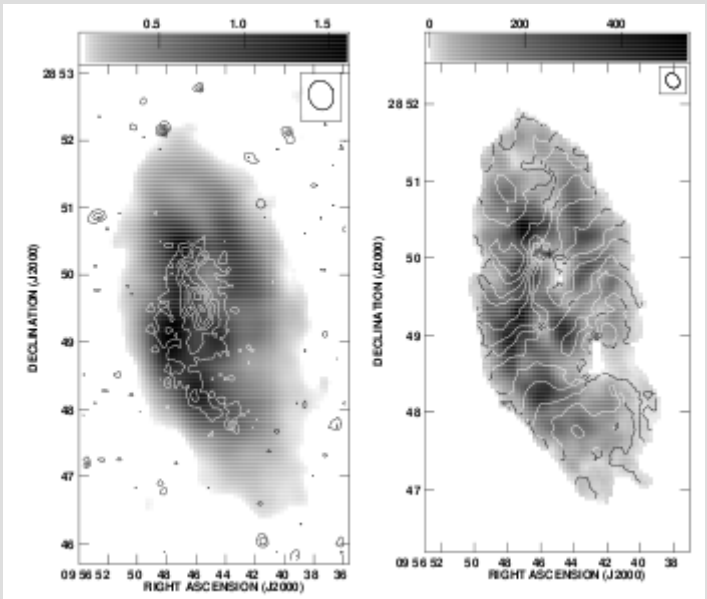
SBS1129+576

Ekta et al. 2006

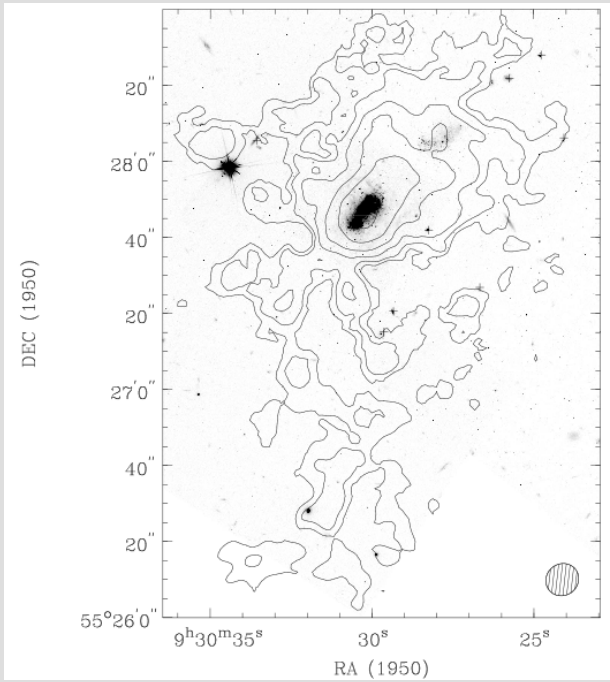


SBS 0335-053 Ekta et al. 2009

UGC 5340



Ekta et al. 2008

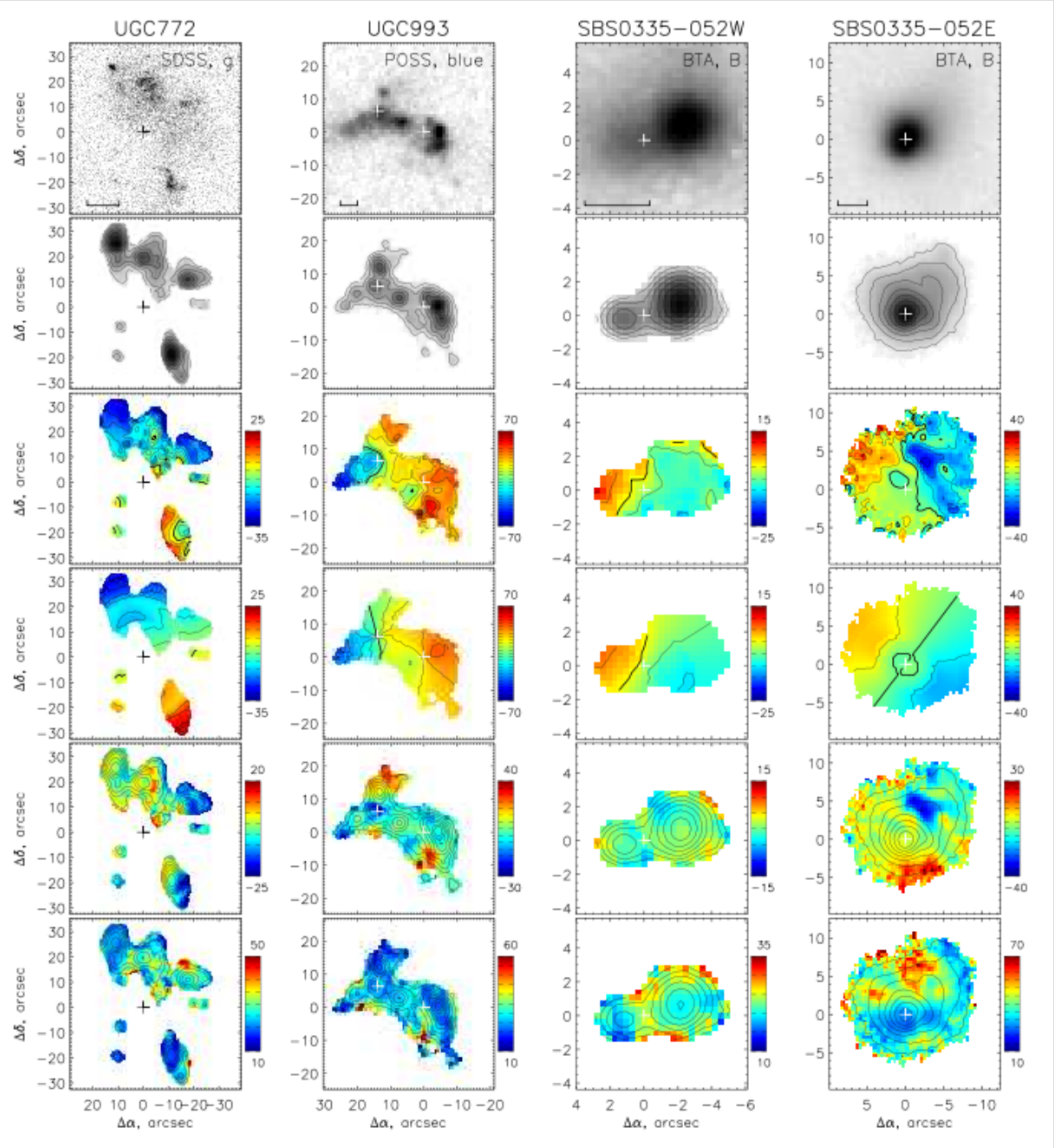


I Zw 18

van Zee et al. 1998

(see also Lelli et al. 2012)

Mergers and complex knots...



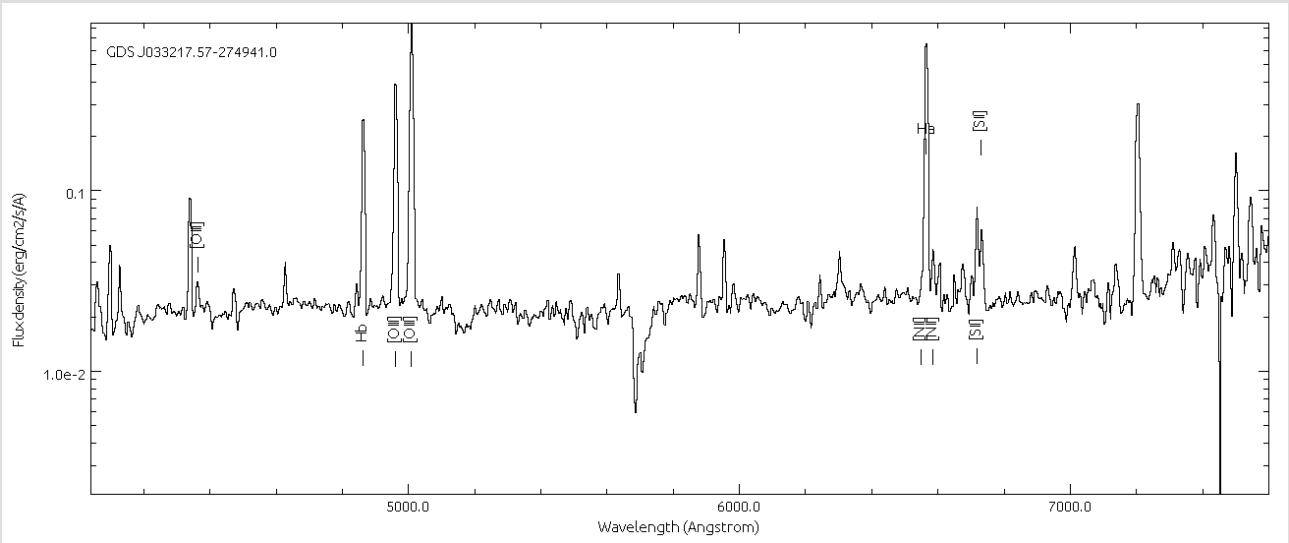
Complex kinematics:
Merger,
Infall,
outflow

Moiseev et al, 2010

Intermediate redshifts

For candidates extemely low metallicity dwarfs at intermediate redshifts:

see poster by Marianne Langener



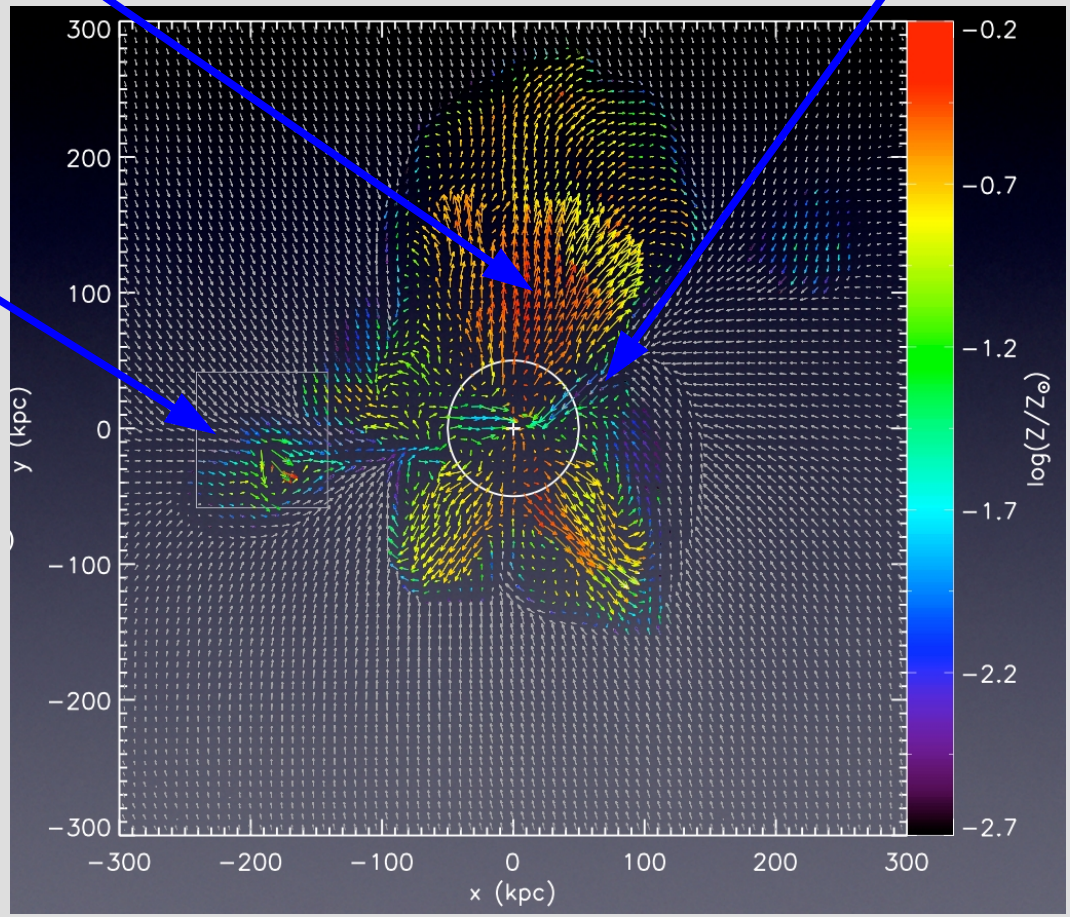
Local very metal-poor galaxies

We have observed:

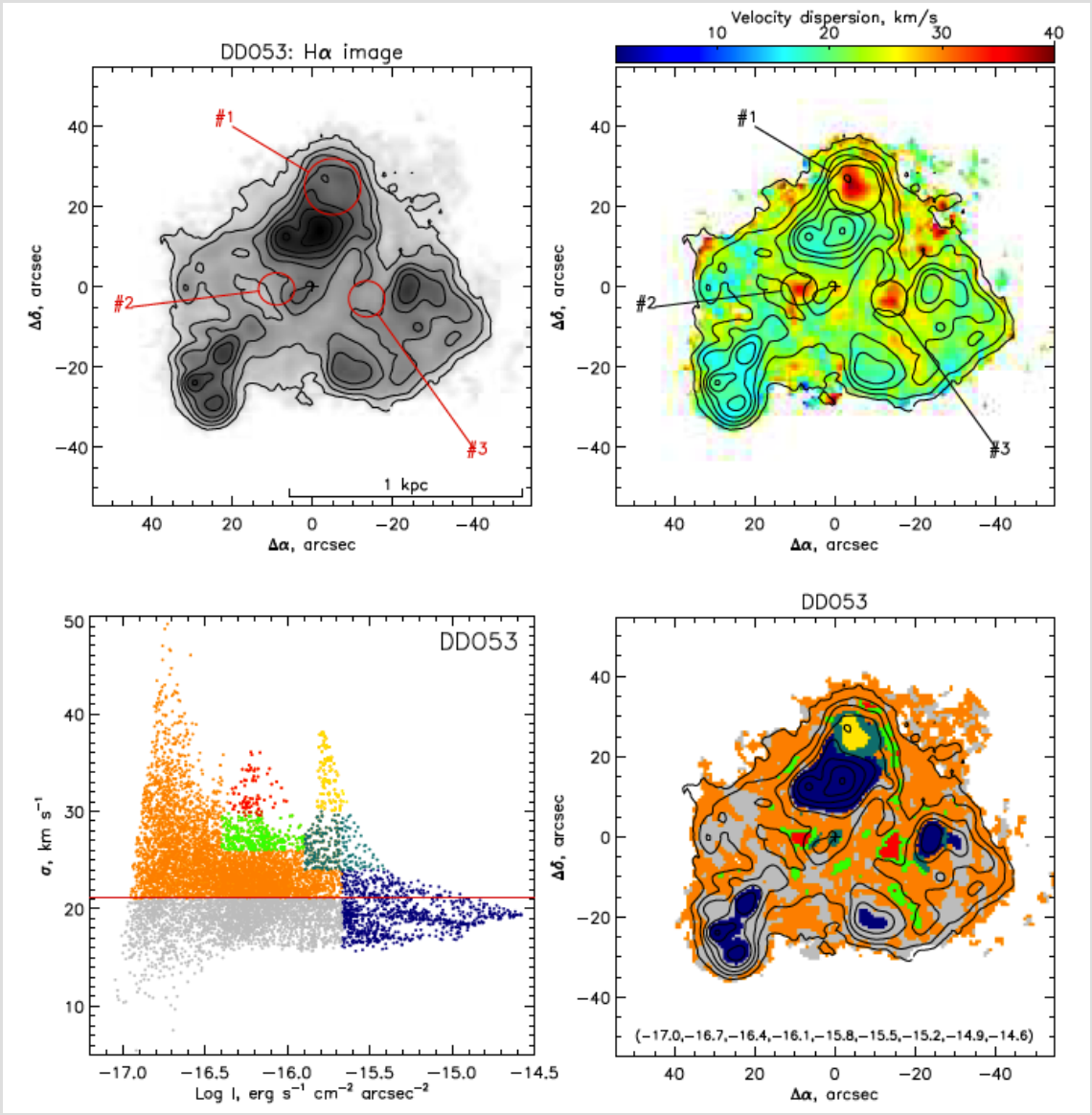
Metal-enriched outflows

Infall of neutral and ionized gas

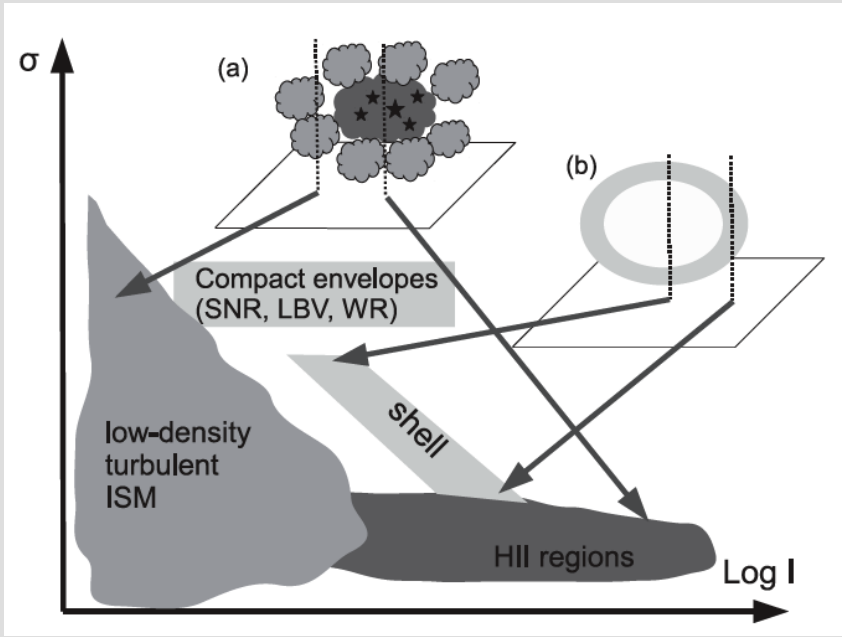
merging dwarf



Turbulence



I-σ diagnostics:
Munoz-Tunon et al. 1996
Martinez-Delgado et al. 2007
Moiseev & Lozinskaya 2012



Turbulence

SF drives velocity dispersion in ionized gas:
- stellar winds
- SNe
- expanding bubbles and superbubbles

Different timescales imply different regions in l-σ diagram

Galaxy merging and infall of gas add complications to the picture

For circumstellar bubbles see
poster by Kerstin Weis

Conclusions

- Very low metallicity dwarf galaxies are the best proxies for high redshift proto-galaxies
- Optical broad band show disturbed morphology, sometimes implying a merger of dwarf galaxies
- Fabry-Perot based sensitive line intensity maps and kinematics show complex and diverse properties
- At high star formation rate, galactic outflows dominate
- Lower star formation objects show signs of infall or multiple knot structure along a filament
- Several objects are embedded in large scale HI structures reminiscent of filmanets
- Turbulence in the dwarfs is not only locally due to star formation, but also due to large scale expanding bubbles and maybe infalling clouds


Thank you for your attention !