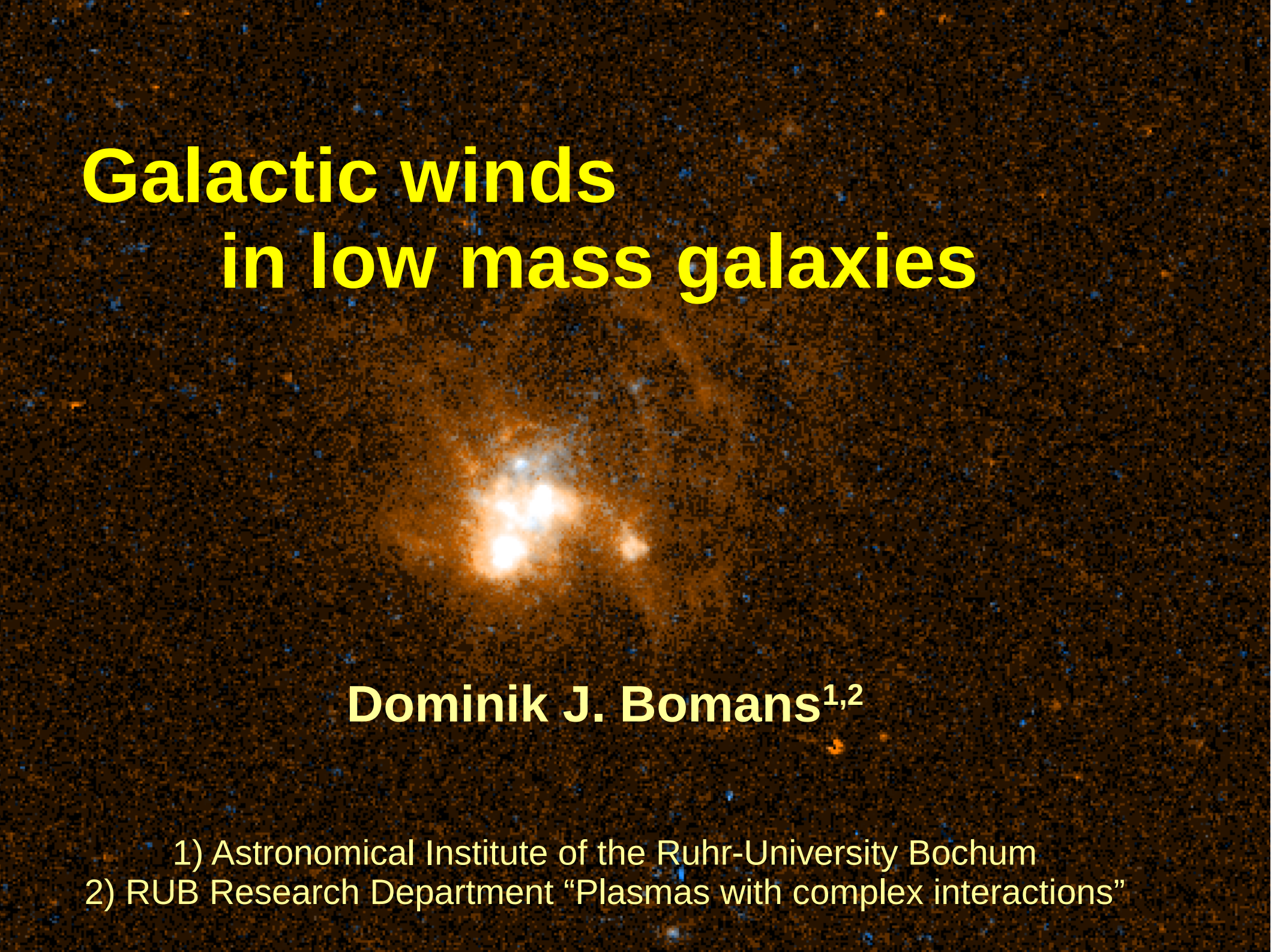
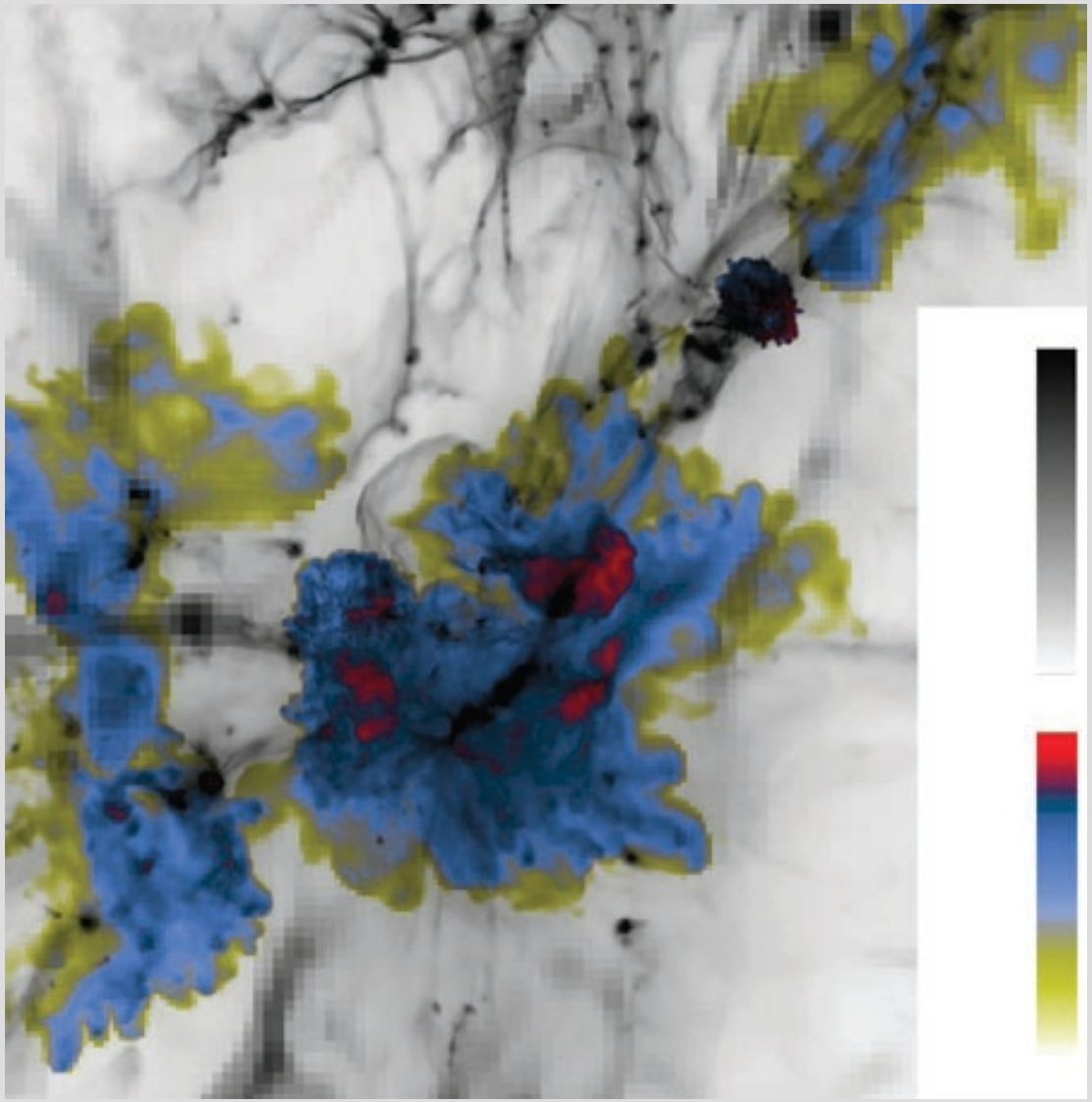


Galactic winds in low mass galaxies

Dominik J. Bomans[1,2]

1) Astronomical Institute of the Ruhr-University Bochum
2) RUB Research Department “Plasmas with complex interactions”

(proto-)galaxy formation



Feedback:
- Radiation
- Stellar winds
- Supernovae

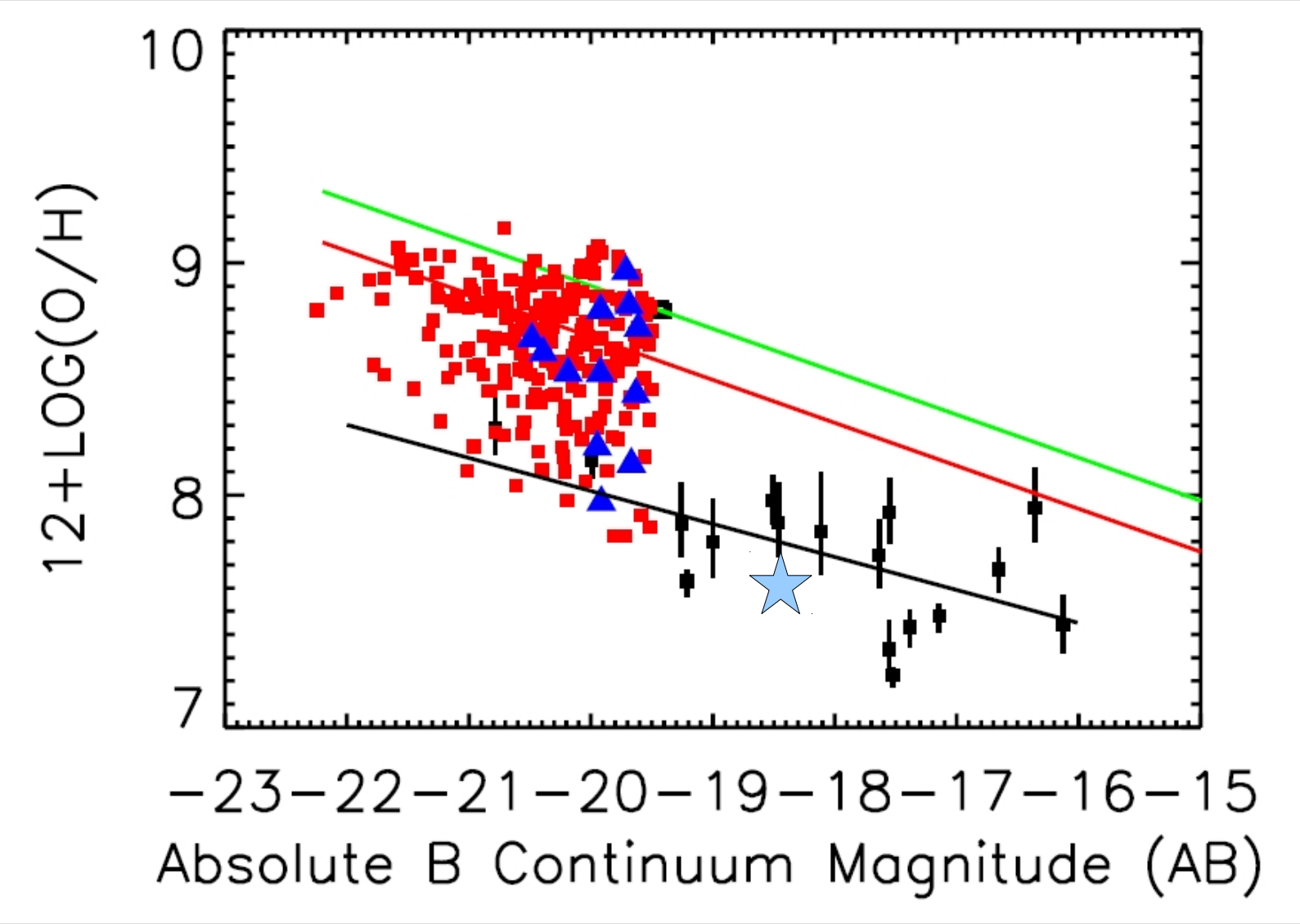
Log gas density [cm-3]

Log metallicity [Z/H]

Simulation snapshot of dwarf/proto-galaxy at z=17
Box size 8.6x8.6 kpc

Wise & Abel (2008)
Version adapted by Bromm & Yoshida 2011

Evolution in [O/H] – L plane ?

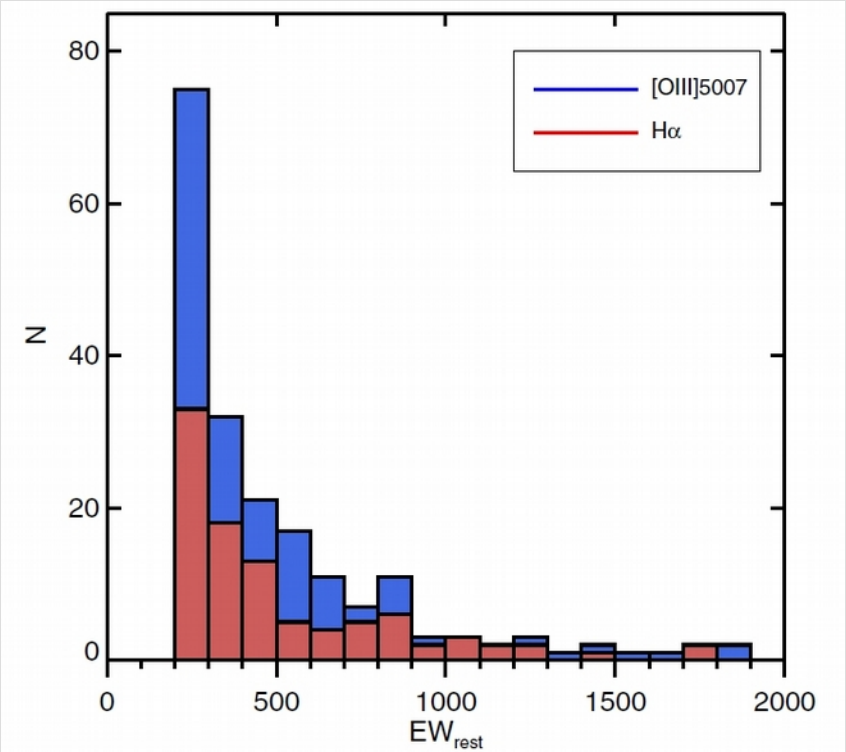


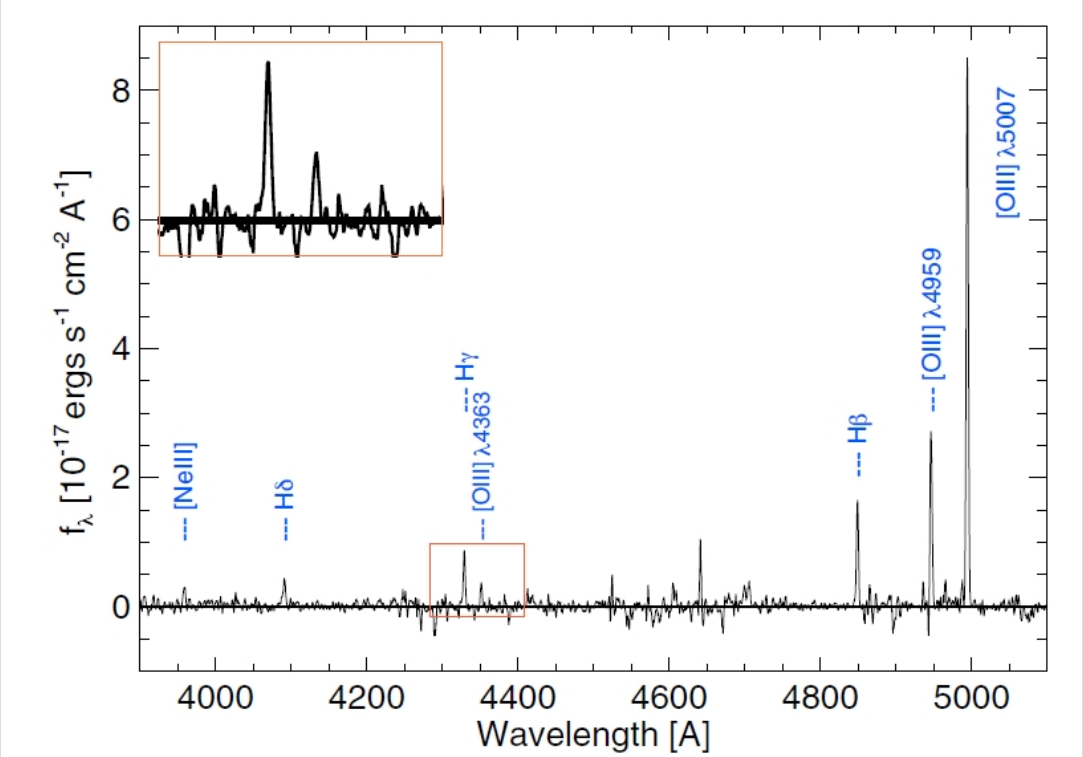
Adapted from Hu et al. (2009)

Langener, Bomans et al. 2014

Extreme emission line galaxies

Ultra Strong Emission line galaxies (USELs) (Kakazu et al. 2007, Hu et al. 2009) z~0.5
Green Pea (Cardamone et al. 2009) z~0.05
Very Stong Emission line galaxies (Atek et al. 2012, van der Wel et al. 2012) z~1.7
…

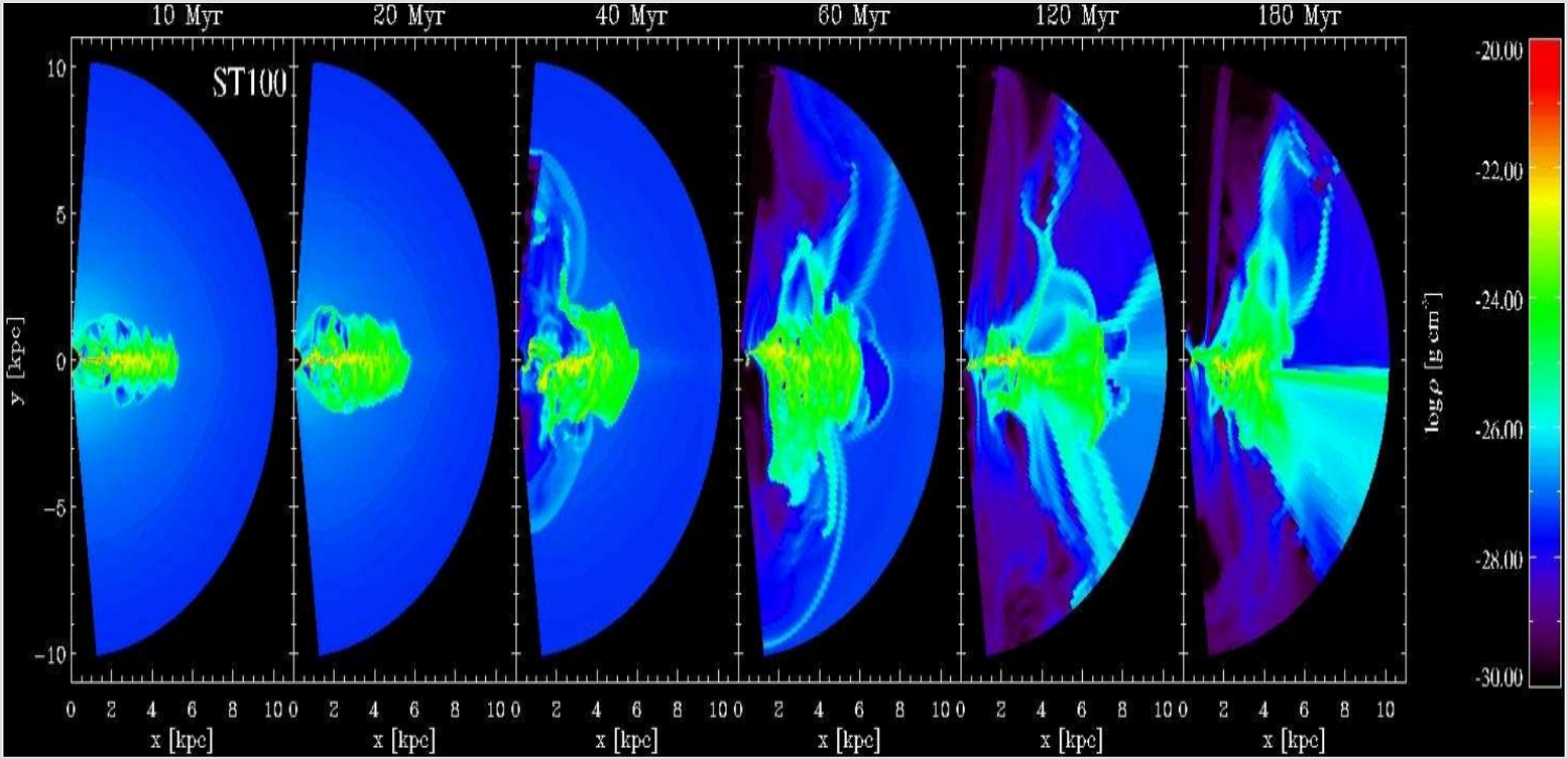




Atek et al. (2012)

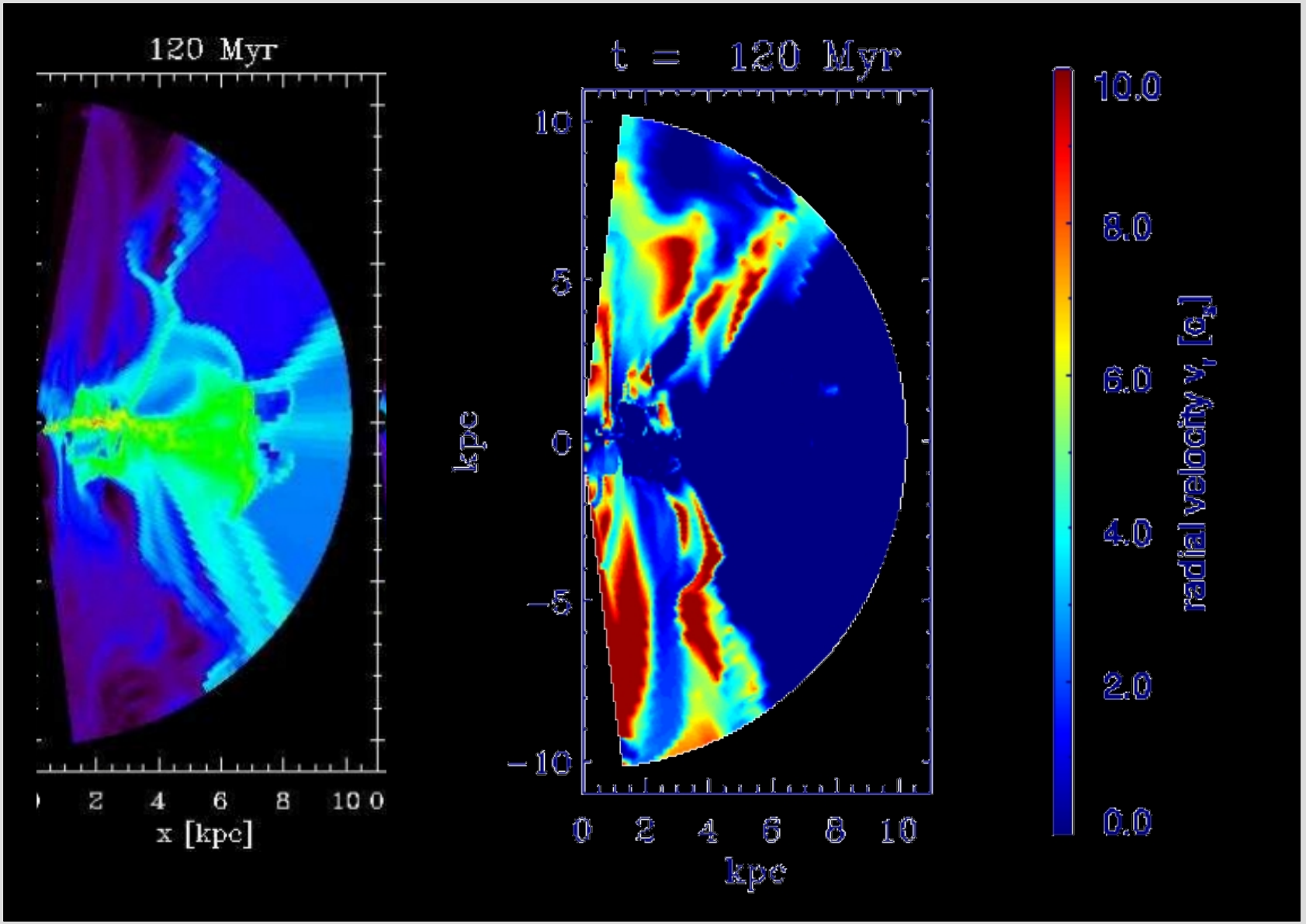
→ strong bursts in small, partly metal-poor galaxies

Galactic winds



Density at different time steps with a setup for Lyman Break galaxies
Thermal and mechanical feedback included

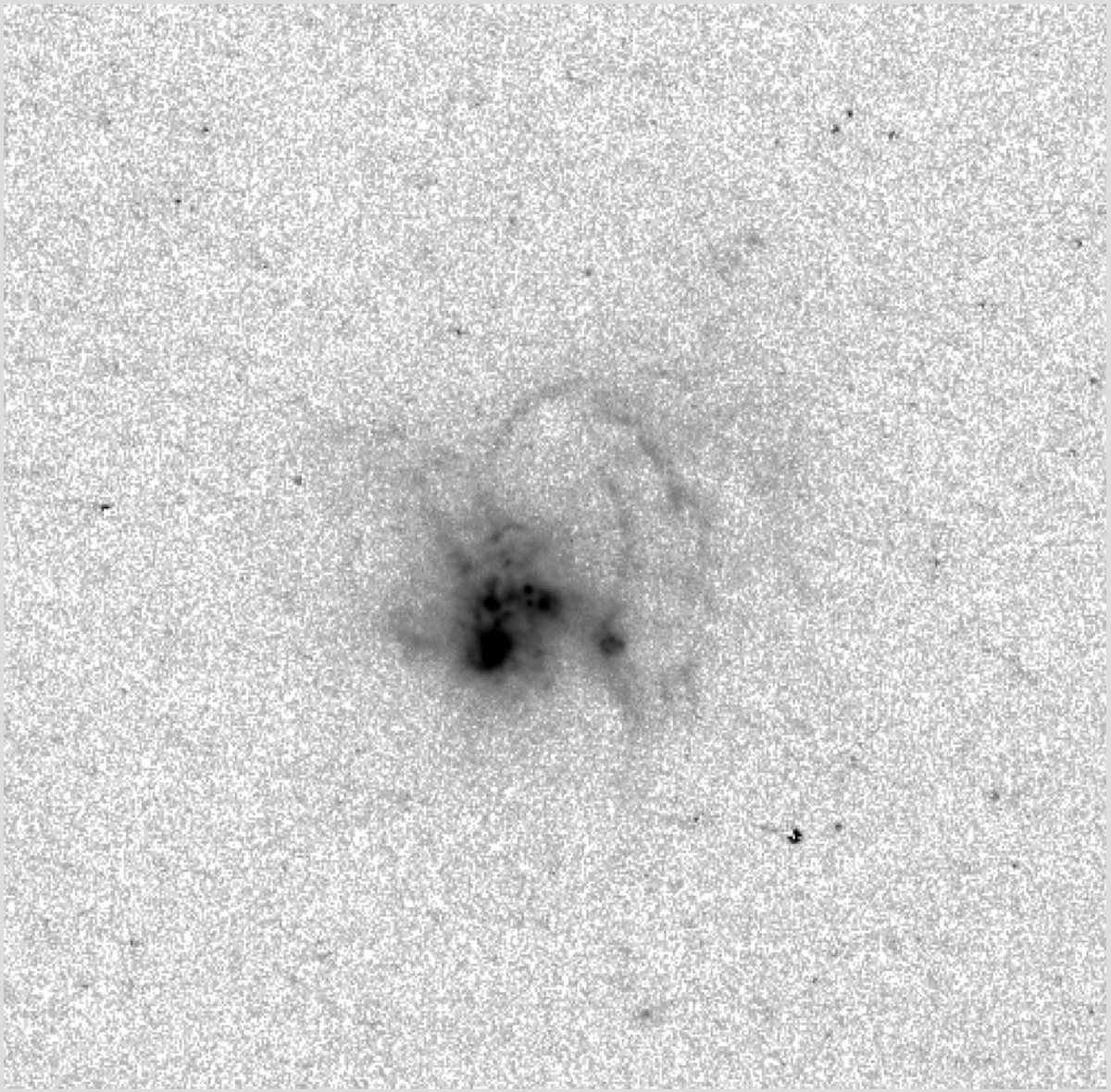
von Glasov, Krause et al. 2013



Velocity of the flow in units of local sound speed

von Glasov, Krause et al. 2013

Nature is likely more complicated



HST Hα image of
SBS 0335-052
Distance ~ 90 Mpc

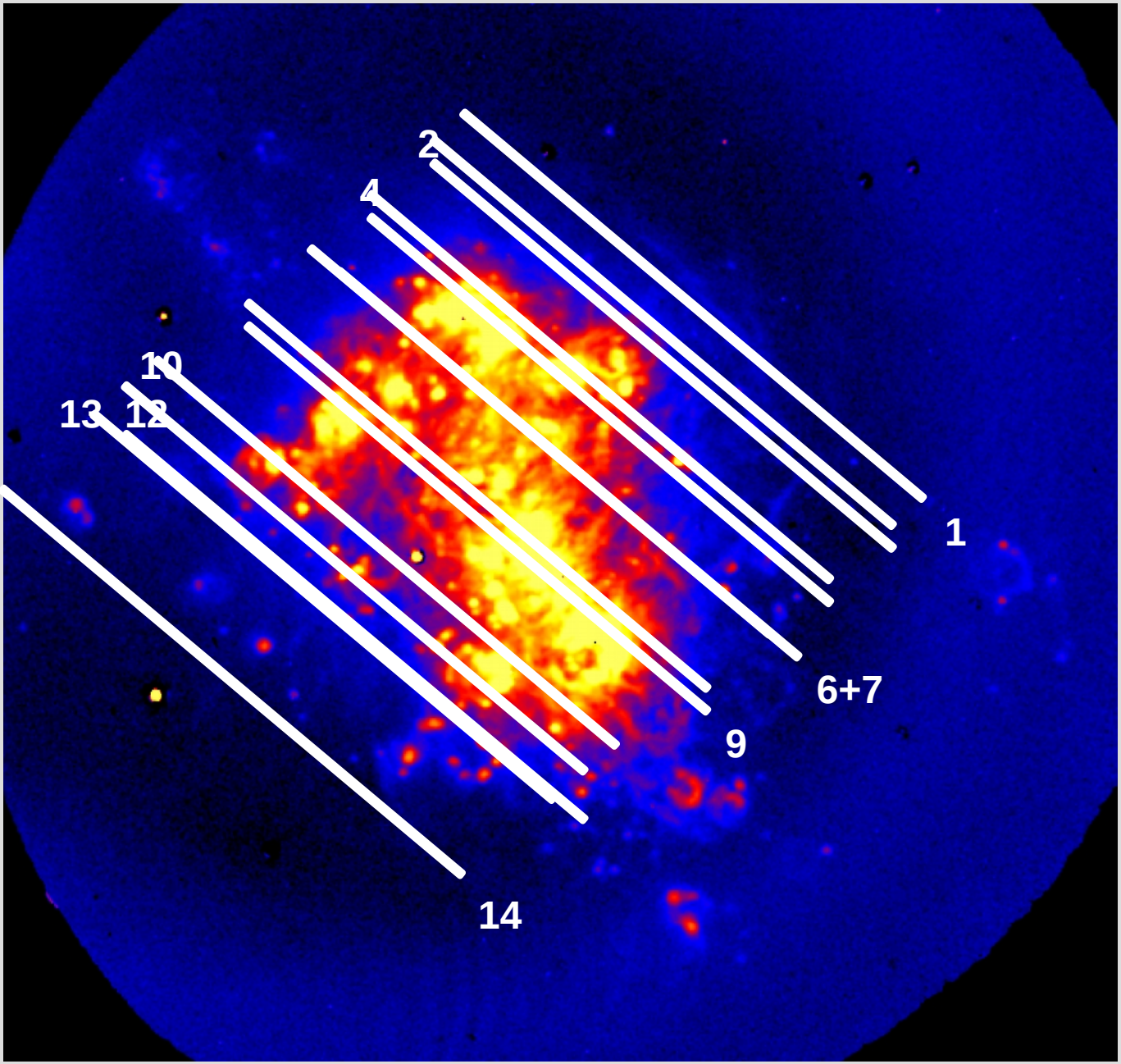
Arc sinh color scale

→ note the very faint narrow shell structures!

Lesson #1

High sensitivity for extended emission
together with
high spatial resolution
are important

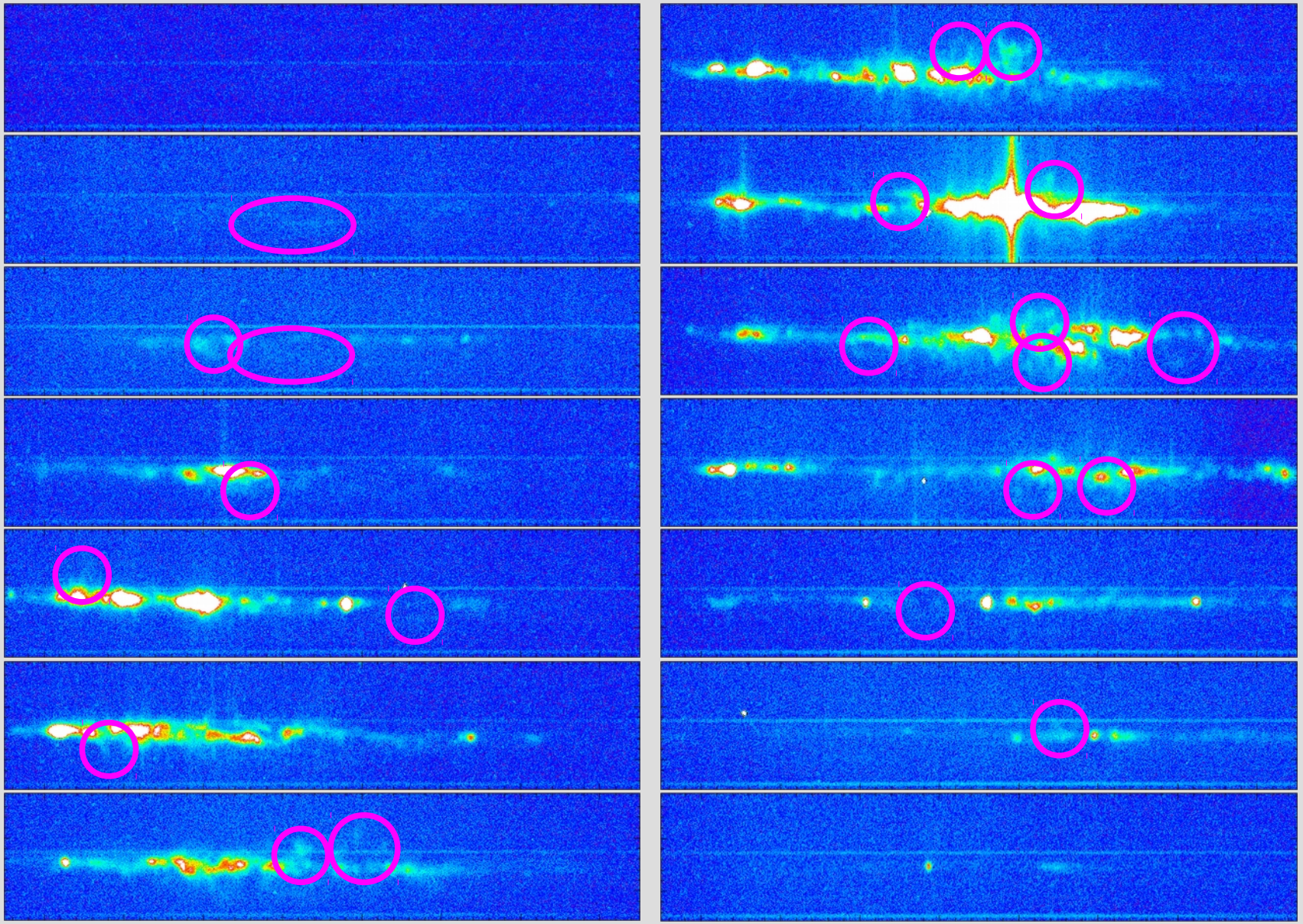
Long-slit echelle data



NGC 4449

Bomans & Weis 2014

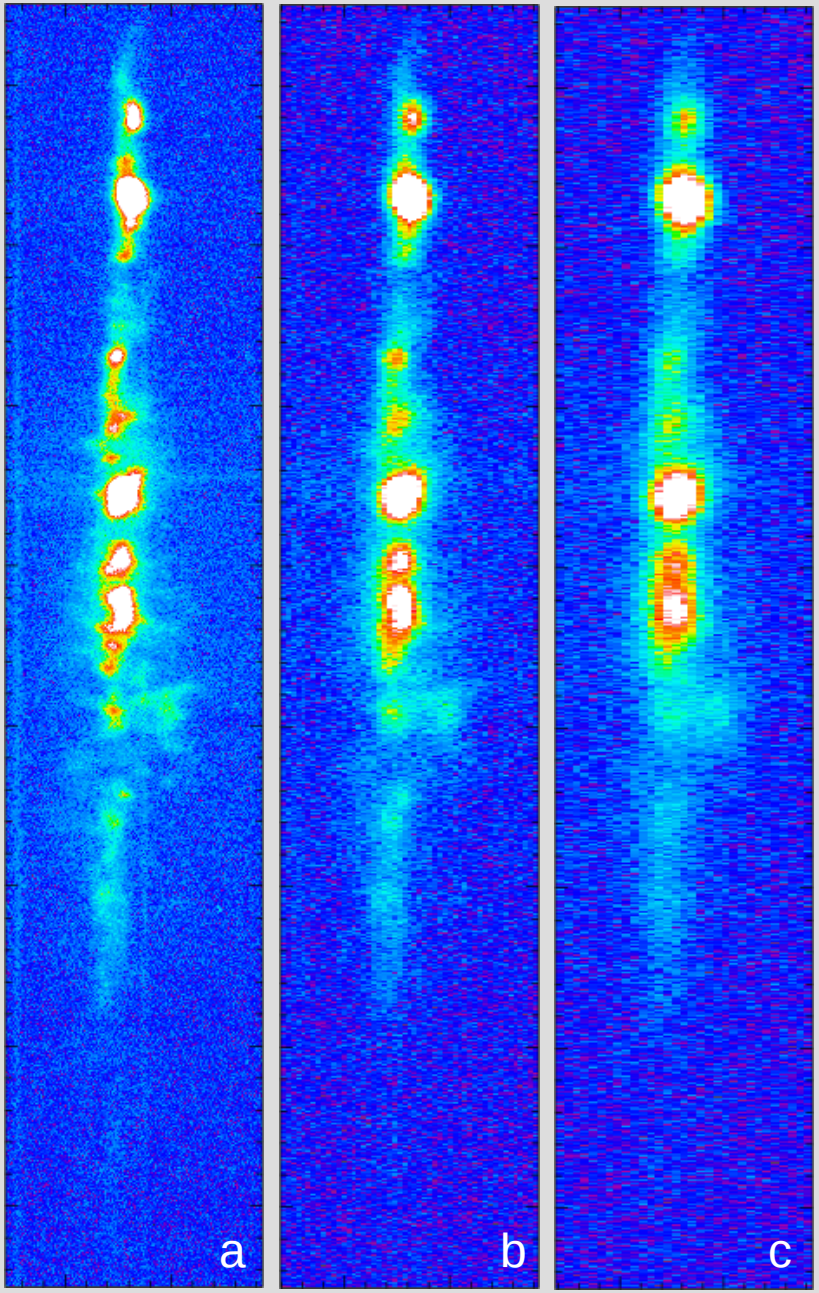
Echellograms



Echellograms (R~22500) are 3.5' long (~ 3.7 kpc) and 540 km s^{-1} wide
→ many bright and especially faint features with offsets of > 100 km s^{-1}

Bomans & Weis 2014

Impact of low spectral resolution



Echellogram #8:
a) in full spectral resolution of 13 kms^{-1} (R~22500);
b) gaussian smoothed to a spectral resolution of 42 kms^{-1} (R~7000);
c) smoothed to 70 kms^{-1} (R~4200).

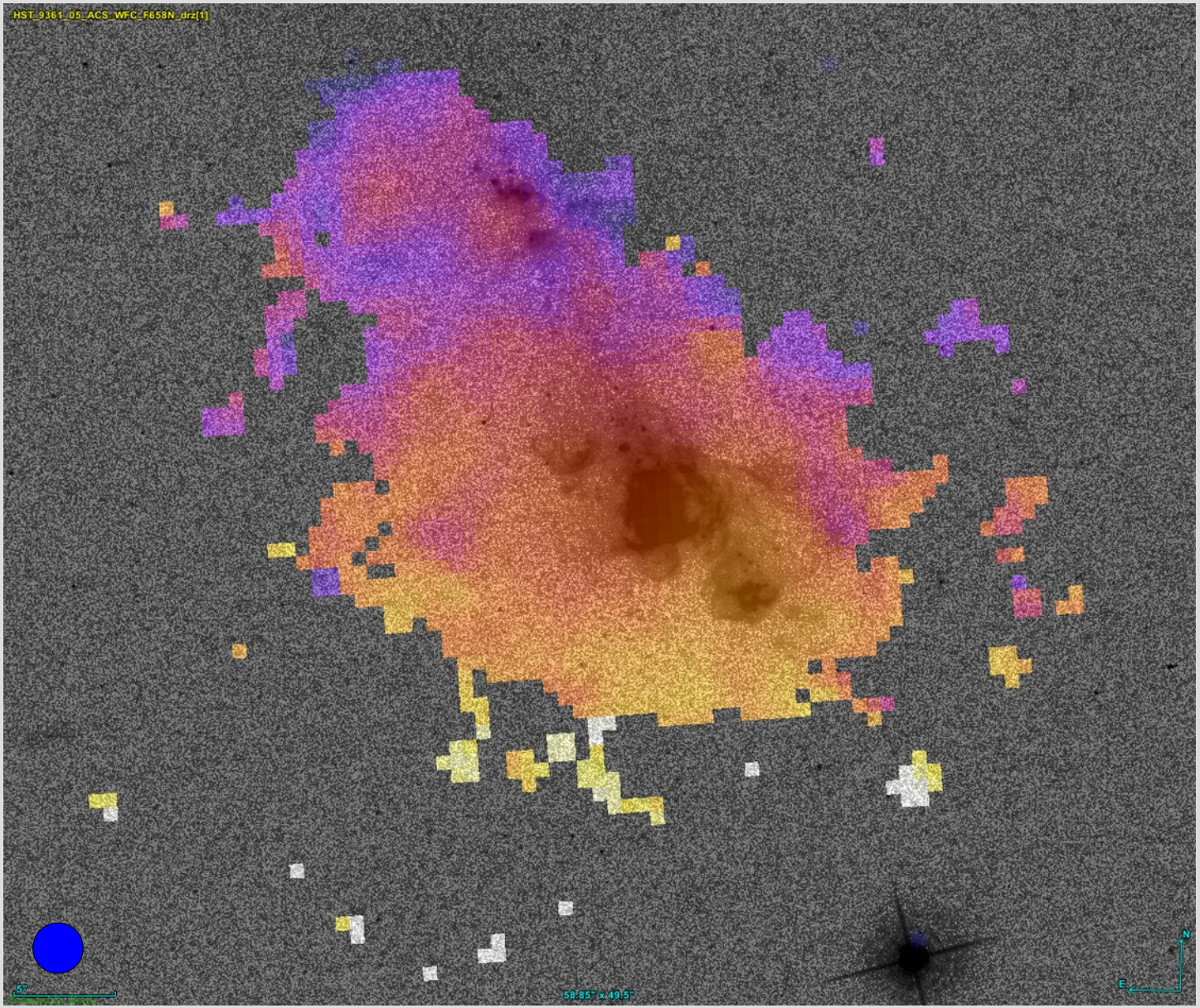
c) and c)
noise was added to the synthetic echellograms using the IRAF mknoise task to reach similar S/N level as in the original one.

Bomans & Weis 2014

Lesson #2

High spectral resolution is essential !

Example: Fabry-Perot of SBS1415+437



HST Hα image
plus
Color map of the Fabry-Perot based velocity field
(dark blue ~ 550 km s^{-1}
white ~ 700 km s^{-1})
Effective spatial resolution = 2”
(see dark blue dot)

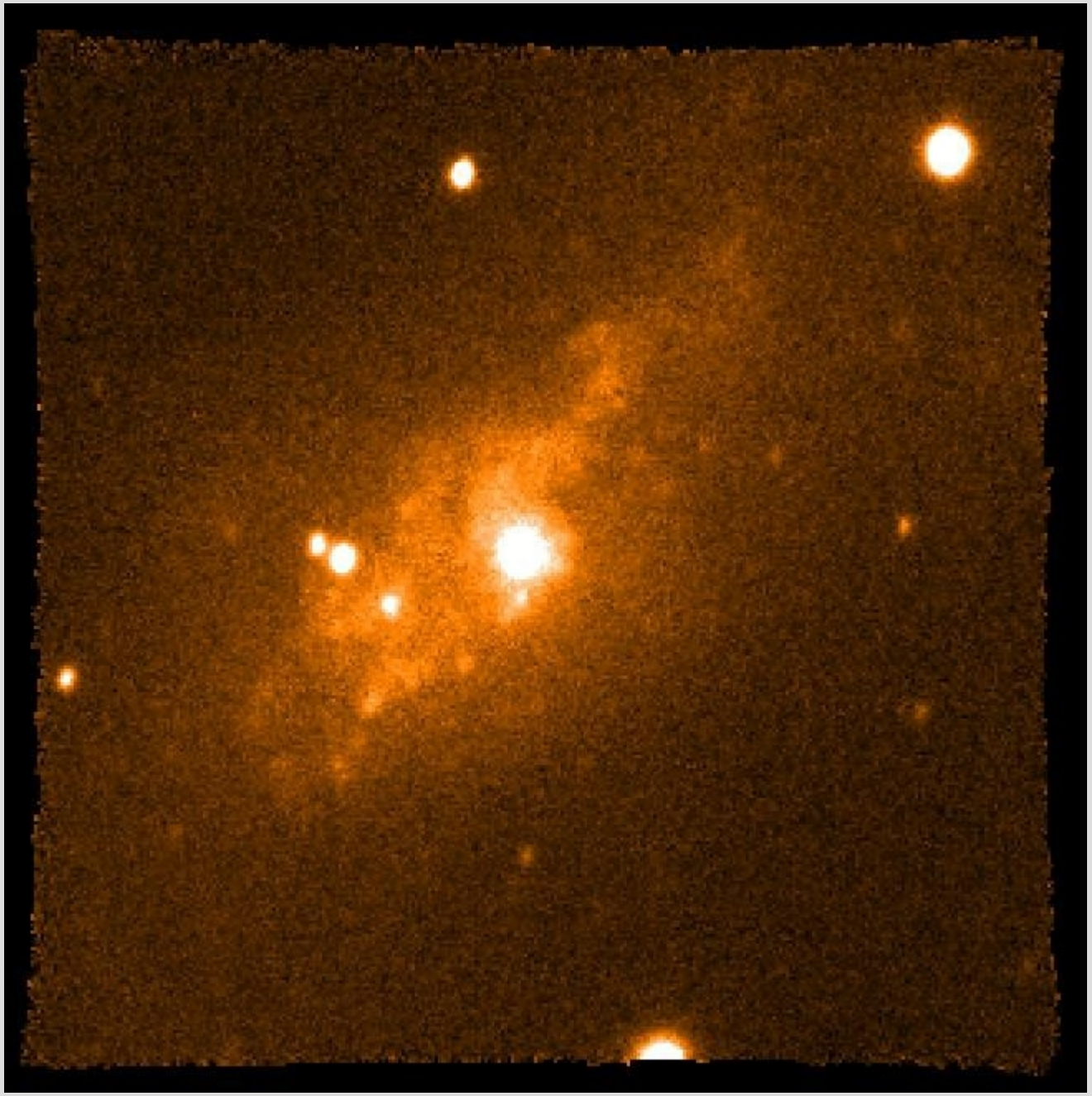
Note the large extend of the detected Hα and the large deviation from rotation outside the major axis

Bomans & Marcelin 2015, in prep.

Lesson 3

High spectral resolution can somewhat compensate
for lower than dieal spatial resolution
if there are enough photons

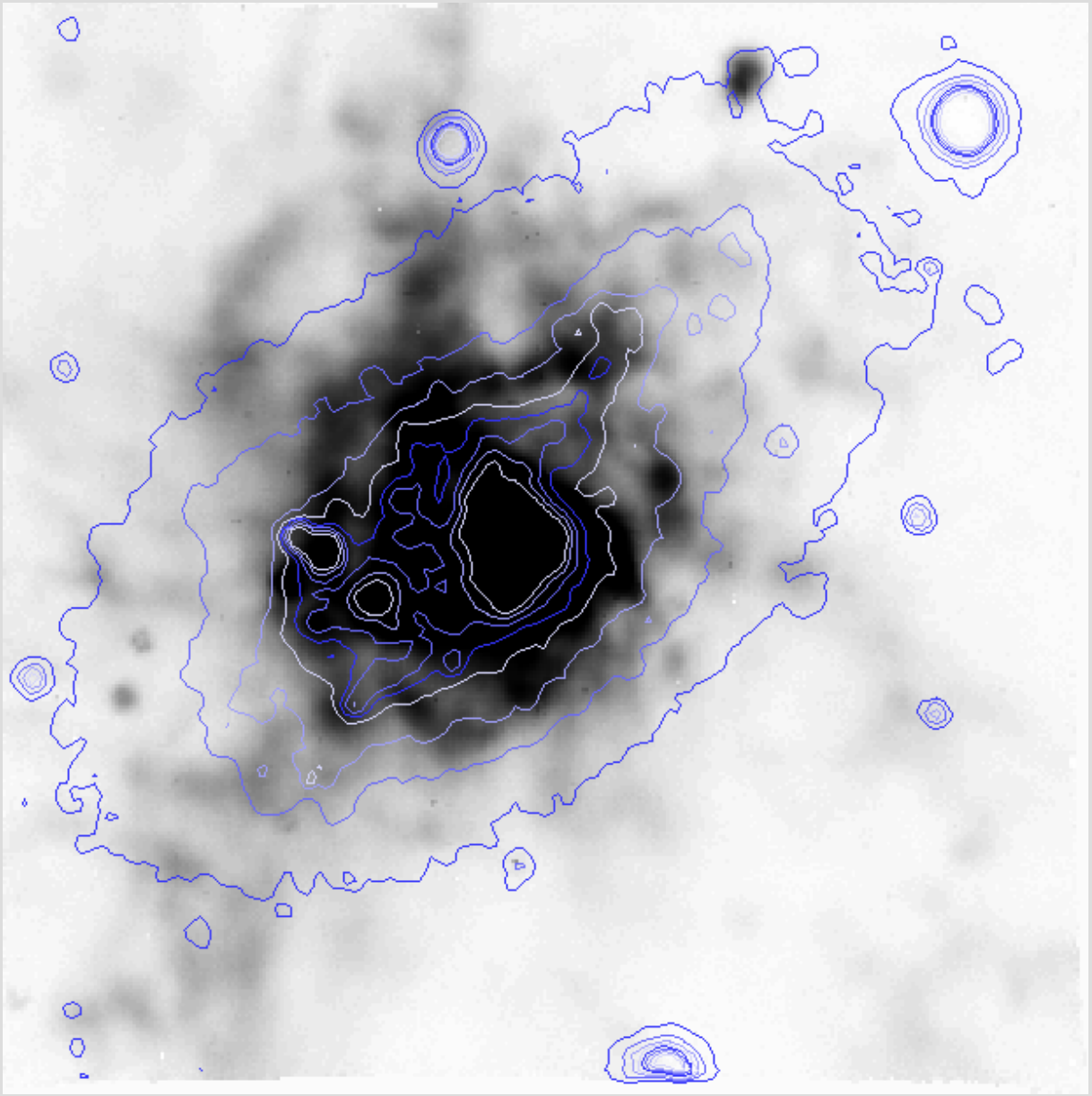
Example: VLT Muse view of IC 4870



Reconstructed blue continuum image from current version of the reduced data cube

Bomans, Kleemann et al.

Galactic Outflow

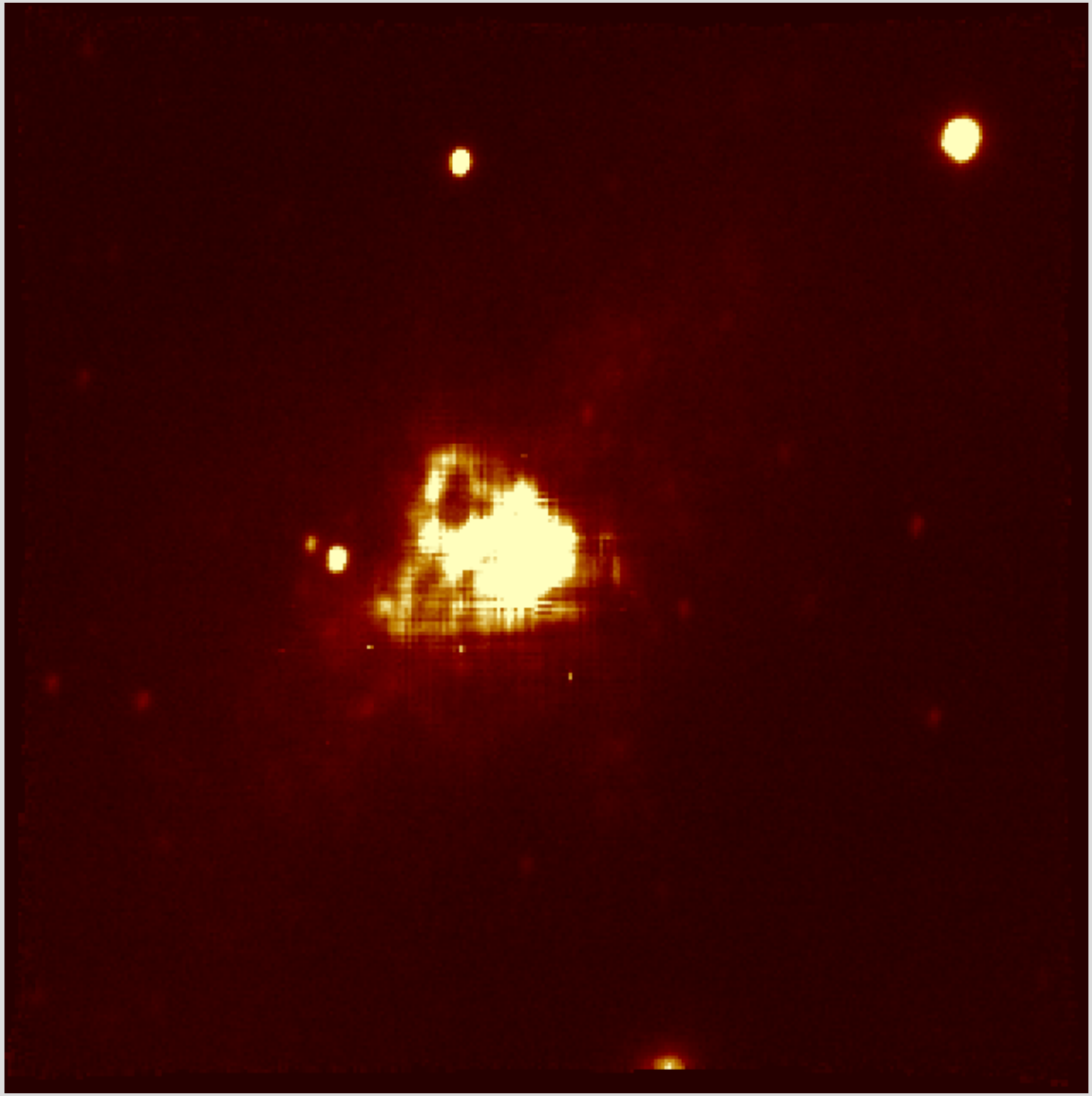


Stellar feedback of central
Region drives bipolar outflow
out to rim of FOV
R > 1.6 kpc

Continuum subtracted Hα image and contours of blue continuum
Image generated from MUSE data cube

Bomans, Kleemann et al.

Galactic Outflow



Movie of the Hα line

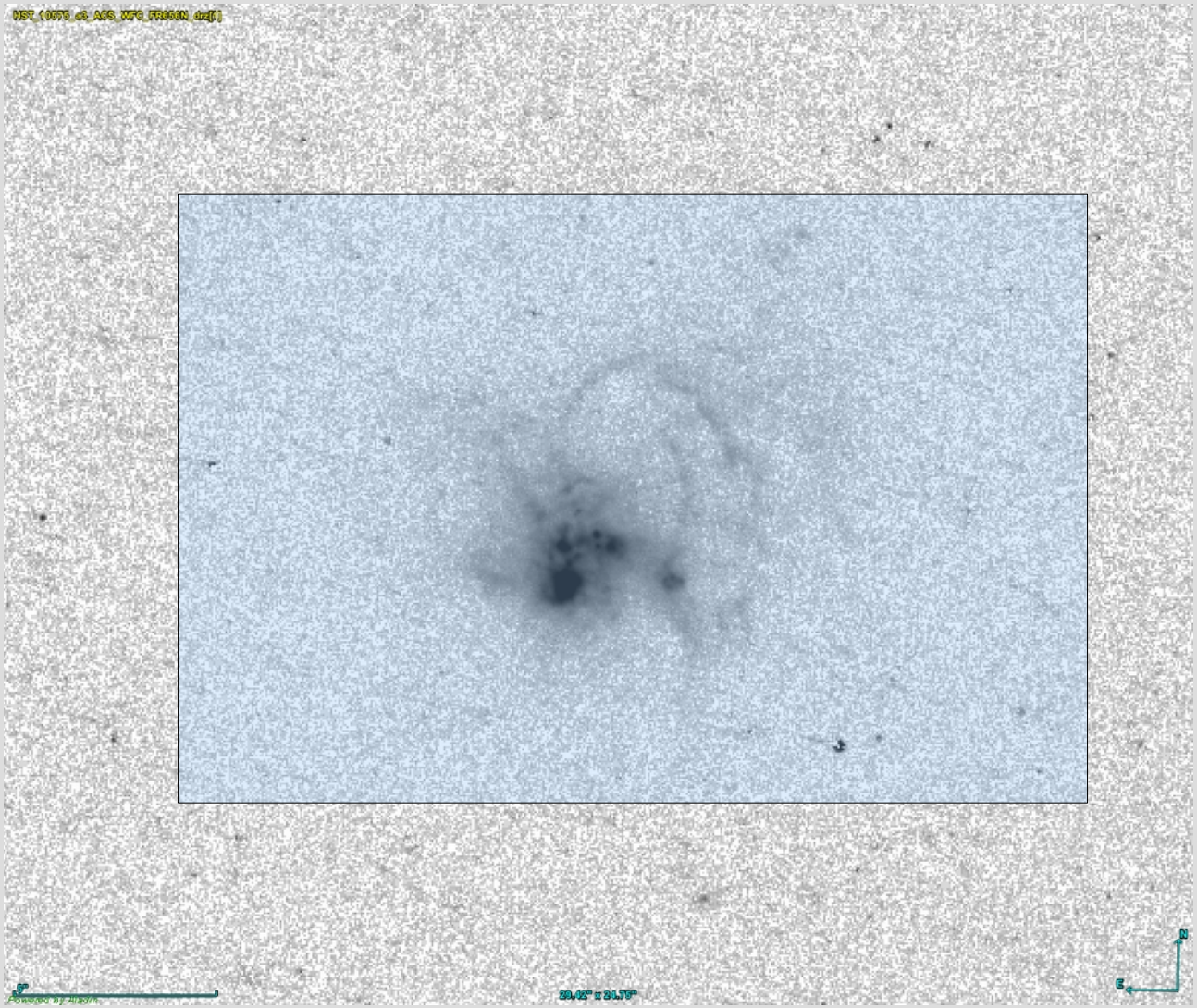
Clearly the northern lobes
Only show up in the last
Channels
→ outflow speed > 150 km/s

Bomans, Kleemann et al.

Lesson 4

High signal to noise ratio can somewhat compensate for lower than ideal spectral resolution

Projections for HARMONI



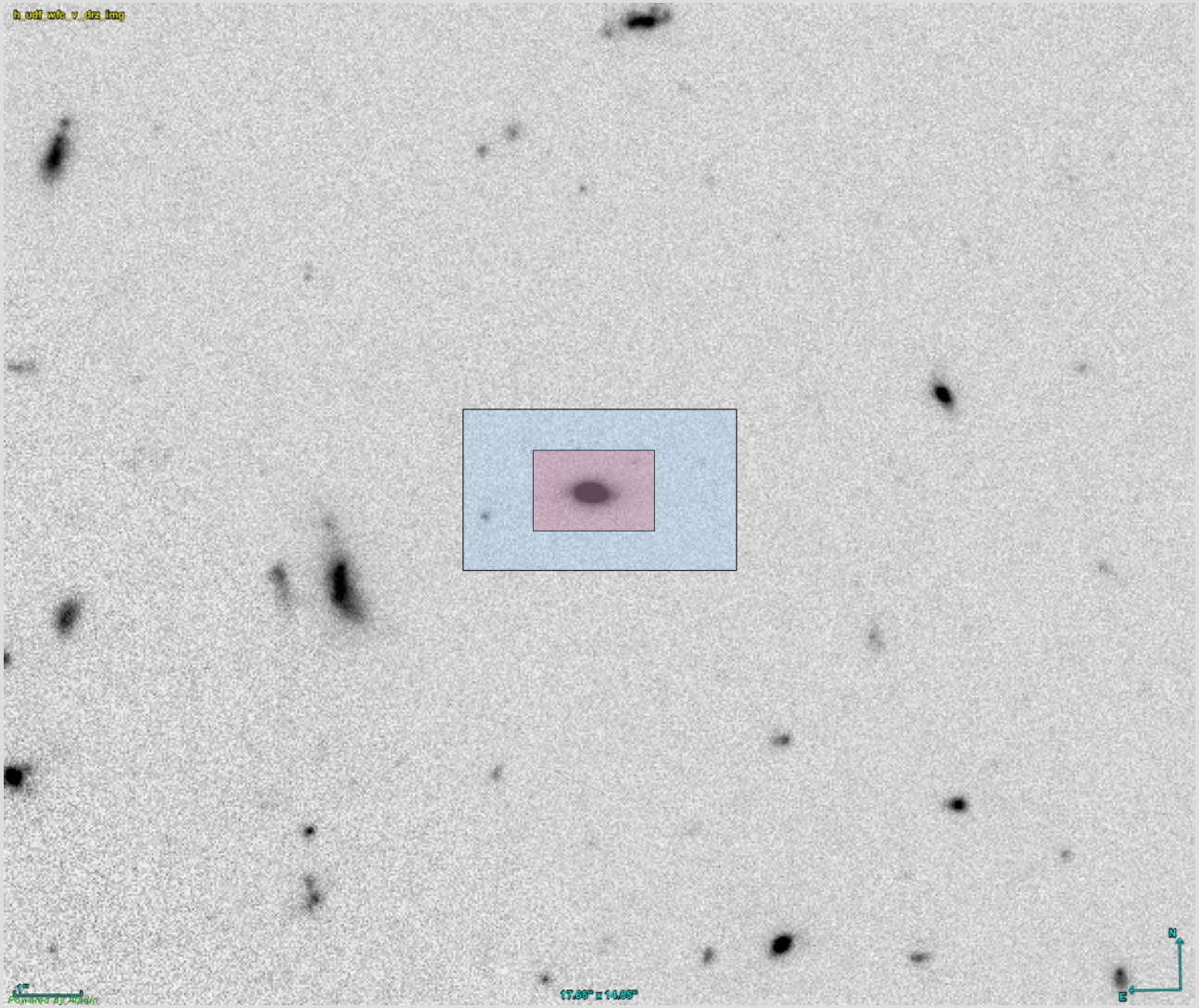
“Nearby” metal poor dwarf starbursts

Blue IFU 40mas scale

R: 20000

SBS 0335-052 scaled to z=0.05
R_{rest} = -16.5 R ~ 21.2

Projections for HARMONI

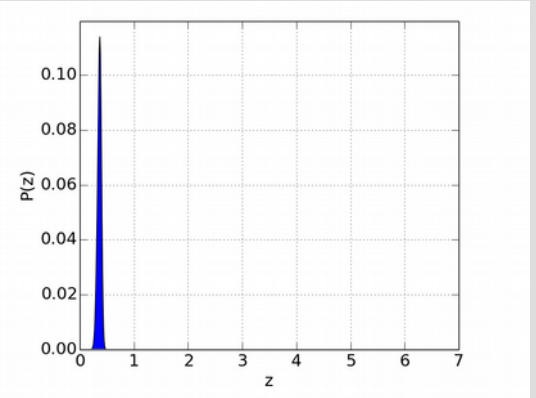


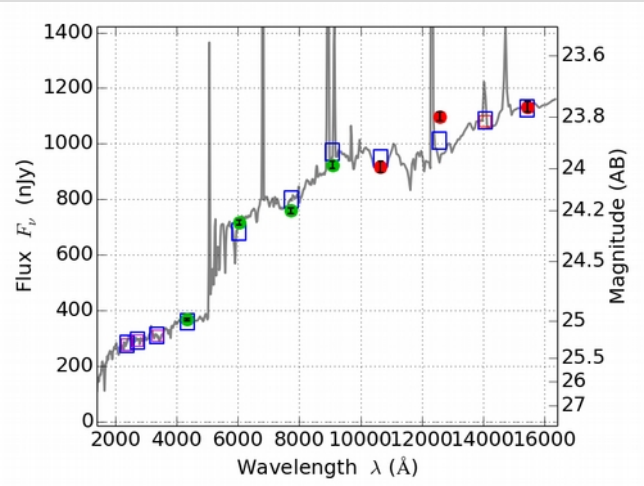
uv_udf #06025 z=0.36 R_{rest}=-17.17 F606W=24.263

NGC 1705 like galaxy

Blue IFU 20mas scale
Red: IFU 10mas scale

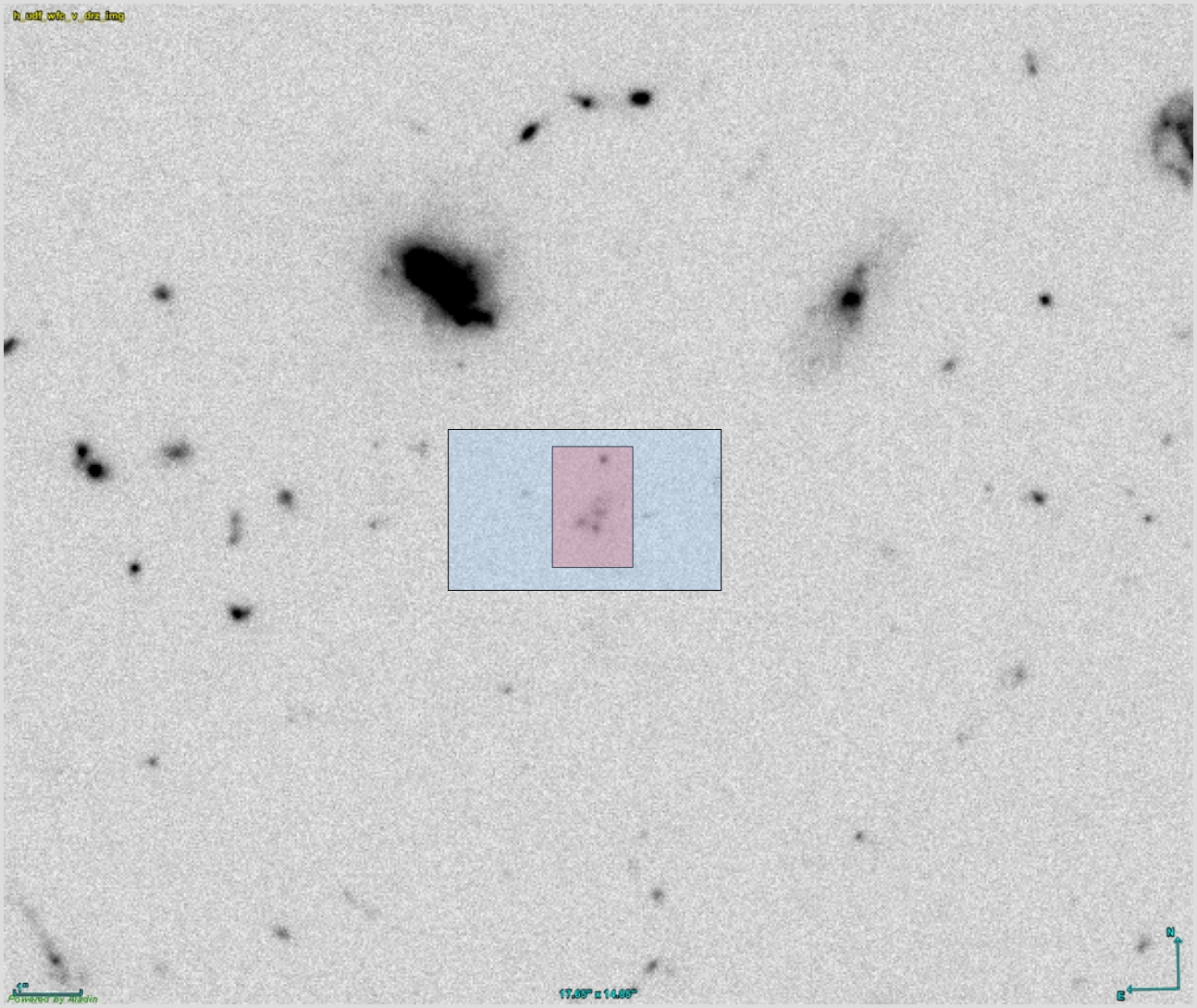
R: 10000 or 20000





SED fit by Rafelski et al. 2015

Projections for HARMONI

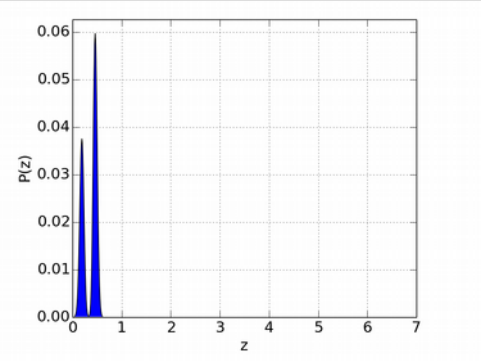


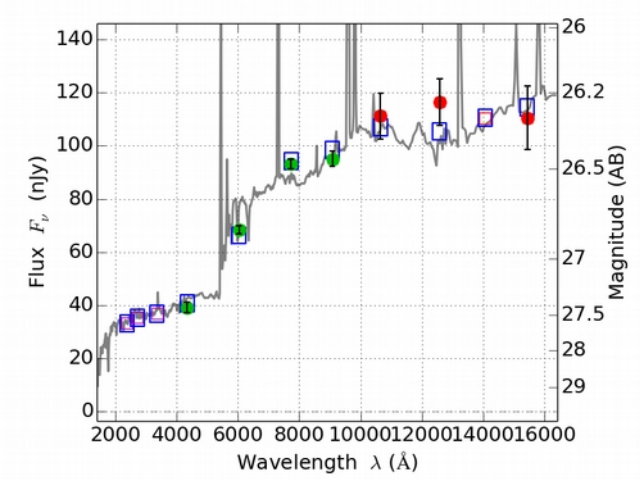
uv_udf #04919 z=0.46 R_{rest}=-15.26 F606W=26.811

SBS 1415+437 like

Blue IFU 20mas scale
Red: IFU 10mas scale

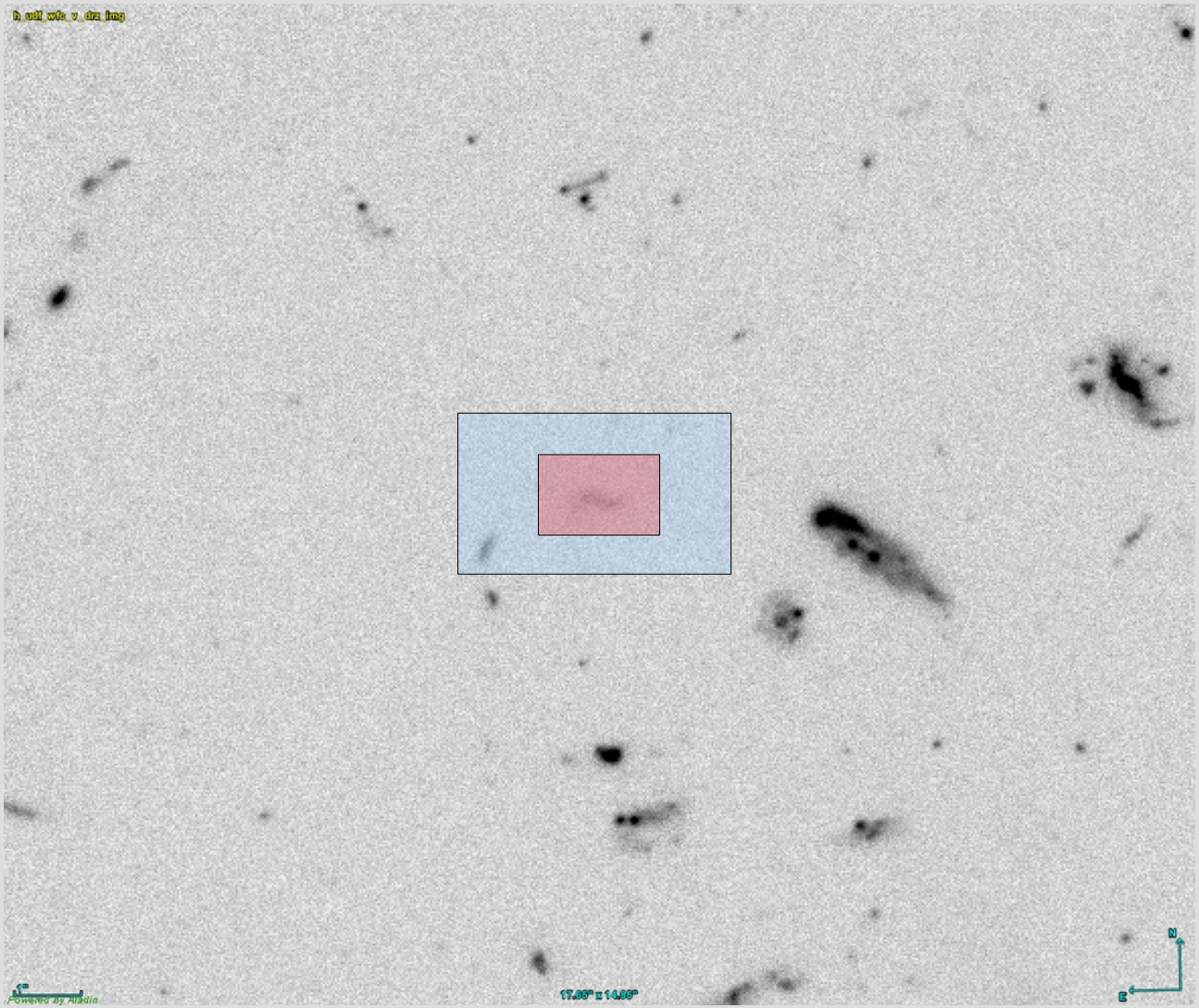
R: 20000





SED fit by Rafelski et al. 2015

Projections for HARMONI

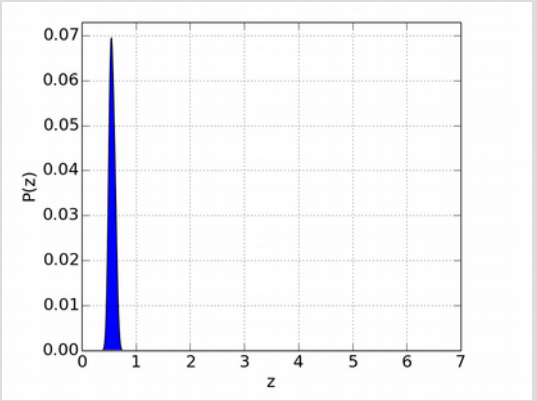


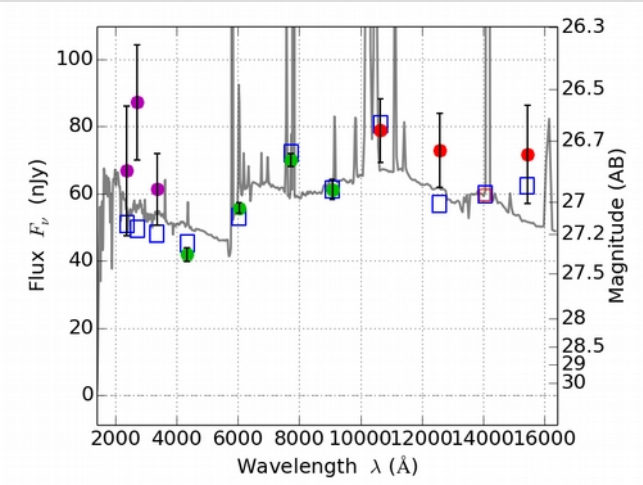
uv_udf #10182 z=0.56 R_{rest}=-15.55 F606W=27.036

Candidate for Pop III stars ?!

Blue IFU 20mas scale
Red: IFU 10mas scale

R: 20000 (10000 ?)





SED fit by Rafelski et al. 2015

Conclusions

- Galactic outflow and winds are complicated multi-scale, multi-phase phenomena

- For the study of feedback during galaxy formation and evolution, dwarf galaxies, especially strong emission line objects at intermediate redshifts are excellent proxies

- To do this observationally, 4 points are essential:
  - High sensitivity for extended structures and high spatial resolution
  - High spectral resolution: R~20000 is close to ideal
  - High spectral resolution can compensate for less than optimal spatial resolution
  - High S/N can compensate only partly for lower than ideal spectral resolution

- **HARMONI brings intermediate redshift dwarf galaxies in reach**

- Use of gravitationally lensed galaxies can even extend observational window to higher redshift and/or even lower luminosity dwarfs