MUSE reveals metal-enriched absorbers in the circum-galactic medium (CGM) of a radio galaxy at z=2.9

Sthabile Kolwa
European Southern Observatory

In collaboration with: Carlos De Breuck, Joël Vernet, Montserrat Villar-Martìn, Andy Humphrey, Theresa Falkendal, Matthew Lehnert, Guillaume Drouart, Fabrizio Arrigoni-Battaia

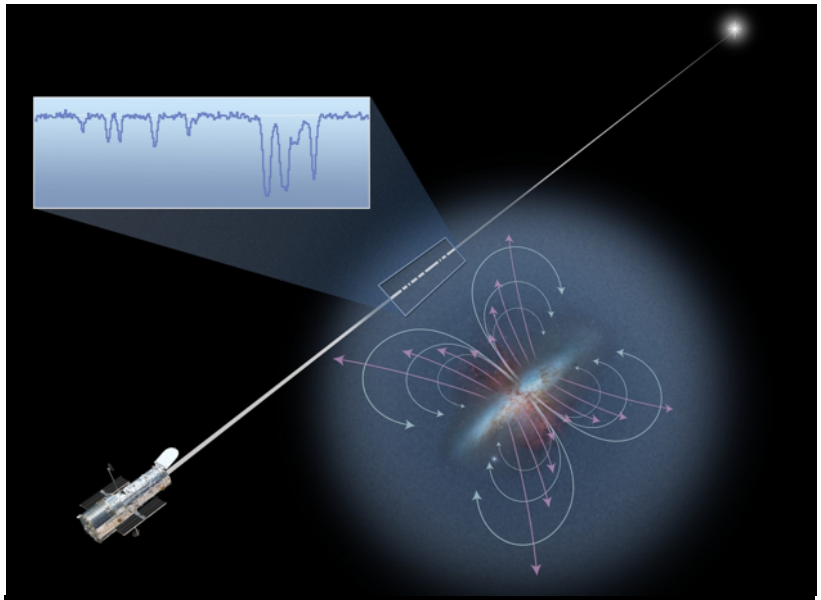
Topics of Discussion

- Absorption in quasars and radio galaxy spectrums
- Phenomenological case study: MRC 0943-242
- UVES and MUSE detections of Lyα absorption
- MUSE detections of metal absorption lines
- Ionization of absorbing gas
- HzRG vs quasar absorption
- Morphology of the CGM: MRC 0943-242

Absorption line spectrums

- In quasars
  - Weak quasar continuum
  - Absorption dominated
  - IGM and/or foreground galaxy CGM

- In radio galaxies
  - Strong continuum and emission
  - Absorption superimposed with bright emission lines
  - Mostly ISM and CGM



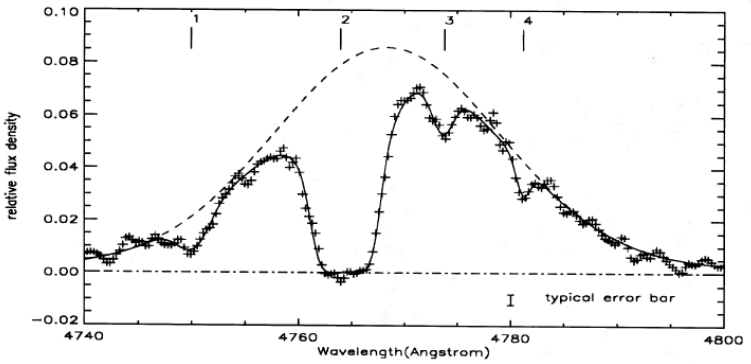
Courtesy of the HST-COS-HALOS Survey

Lyα absorption in the gaseous halo of MRC 0943-242

First detection of Lyα absorption:

Long-slit spectroscopy

AAT (Anglo Australian Telescope)
(Röttgering+1995)



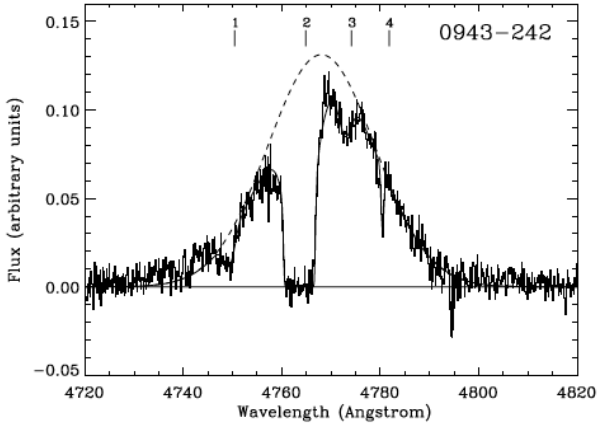
AAT: Lya line (Röttgering+1995)

First high-resolution spectral detections:

VLT/UVES

(Ultraviolet Echelle Spectrograph)

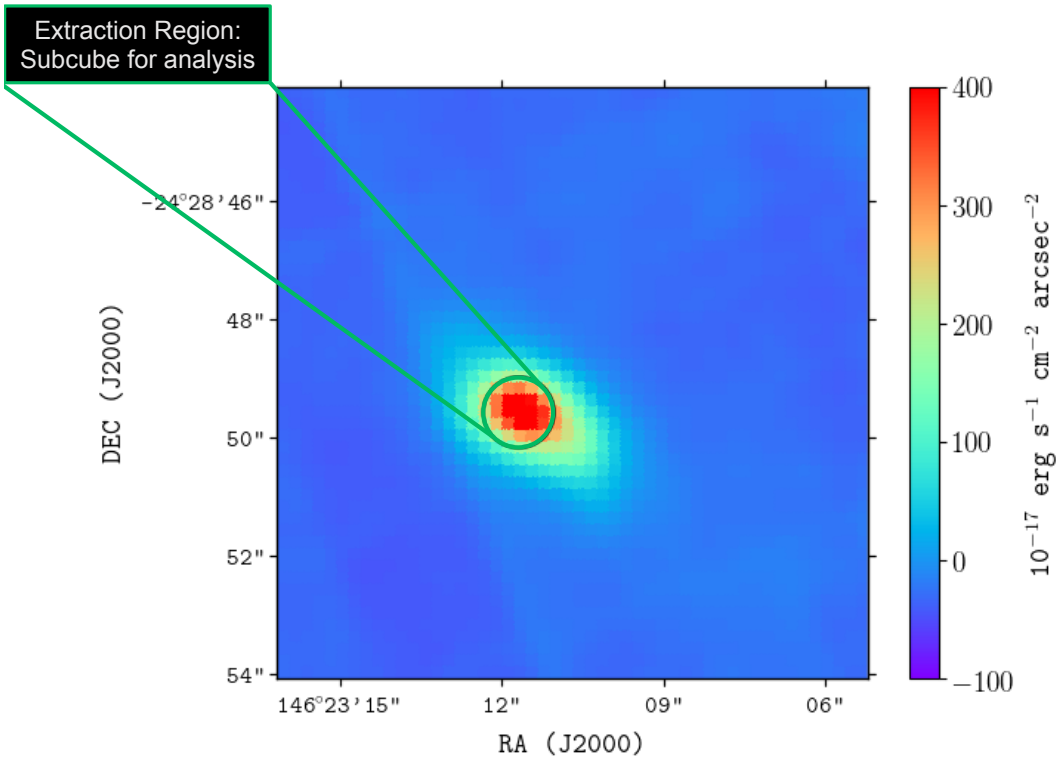
(Jarvis+2003, Wilman+2004)



UVES: Lya line (Jarvis+2003)

MUSE observation of Vgc0913-242

Name inspired by Norse mythology (see Gullberg+2016)



MUSE continuum (4600-9350 Å) image
4-h on-source time

MUSE (Multi-unit spectroscopic explorer) data:

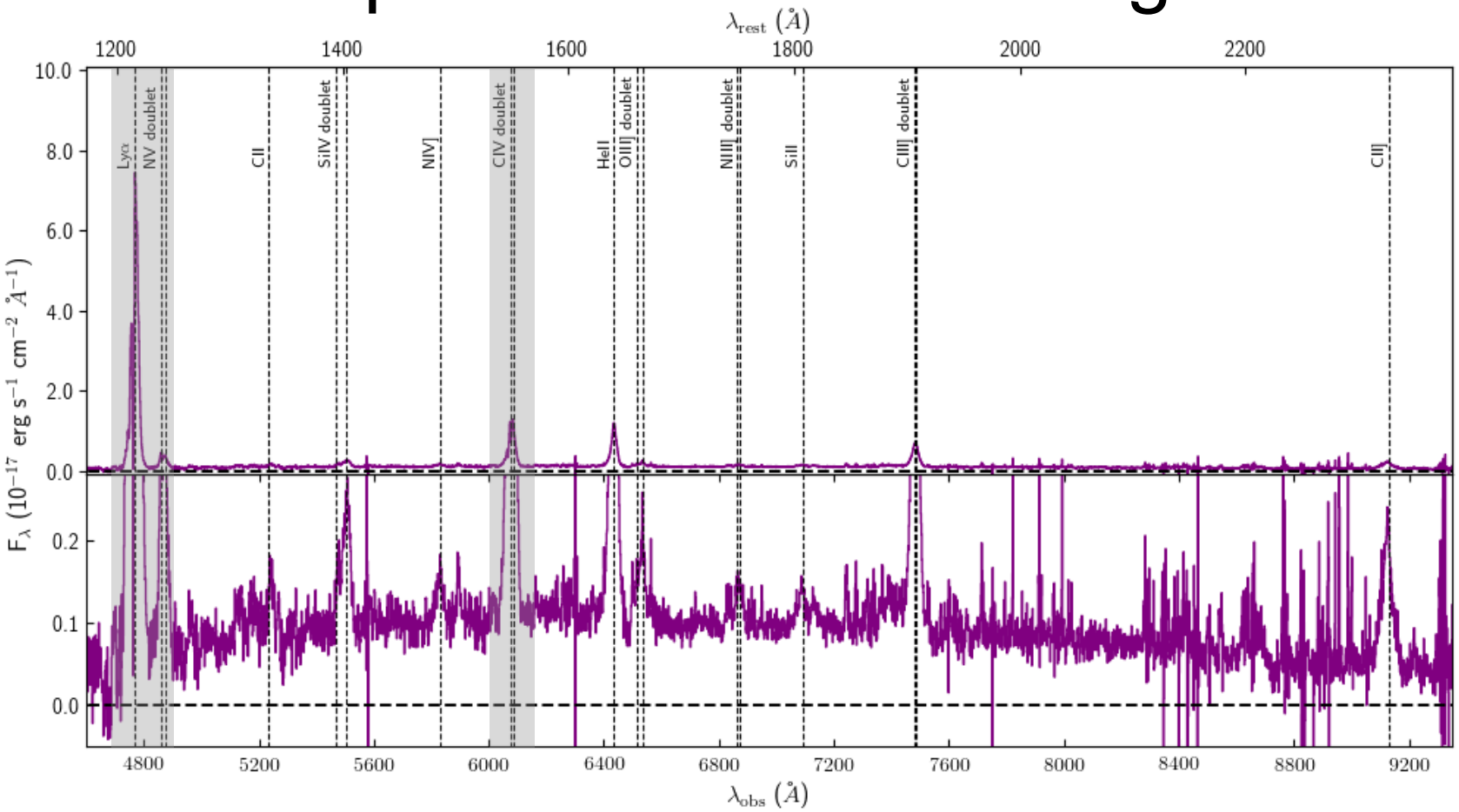
- Trace rest-frame UV-optical continuum

Choice of subcube

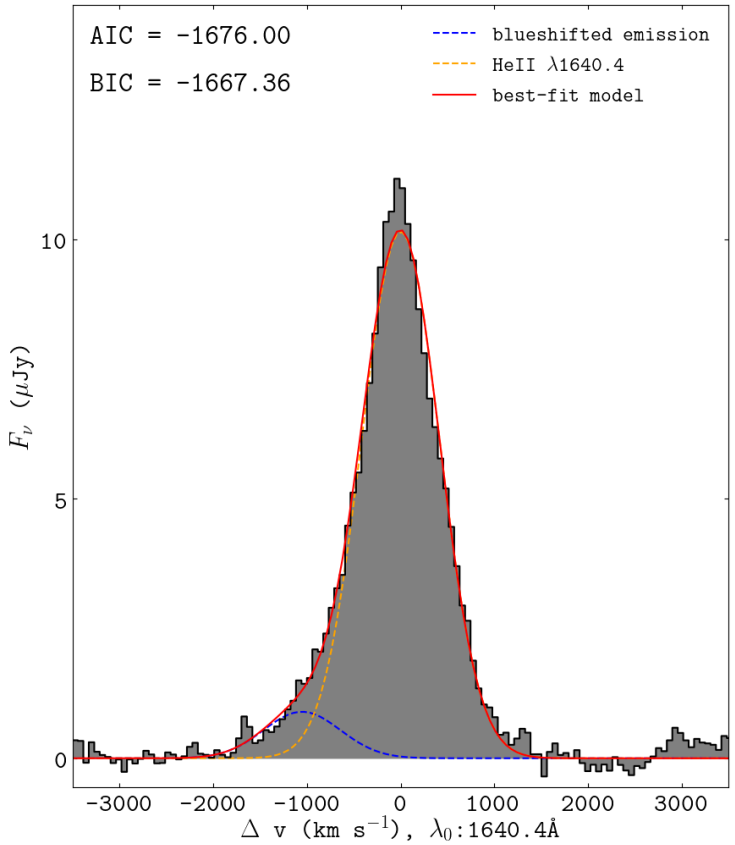
(R ~ 4.8 kpc aperture):

- Maximise S/N of lines
- Nuclear region

1D Spectrum of nuclear region



He II λ1640 double component fit



- Red and blue wing asymmetry
- Double component fit with two Gaussians
- Outflowing gas?
  - e.g. traced by OIII] λ5007 in quasars (Mullaney+2013)
  - e.g. radio galaxies (Villar-Martin+1999)

Update: Lyα absorption fit

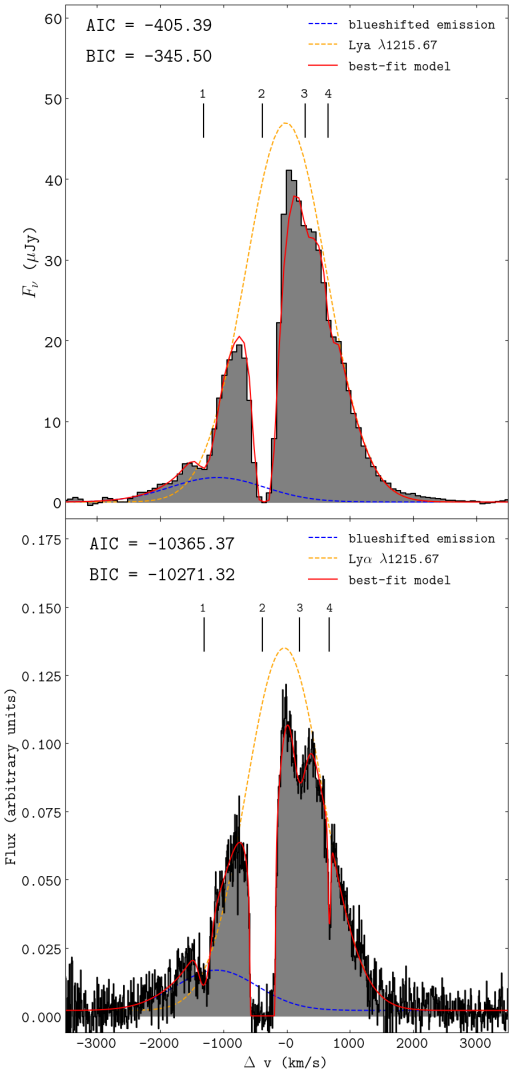
Four discrete Lyα absorbers

Additional emission component (blue)

- Seen in UVES and MUSE Lyα lines

Red and blue wing asymmetry

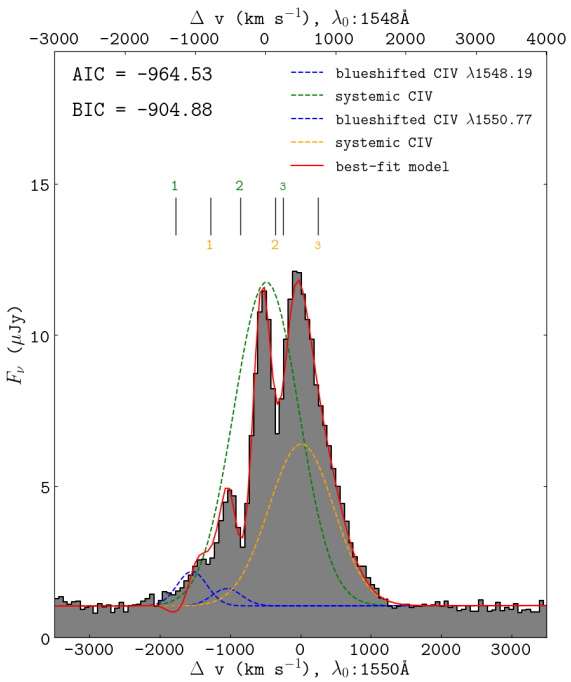
- Radiative transfer effects
- Outflow as in He II λ1640



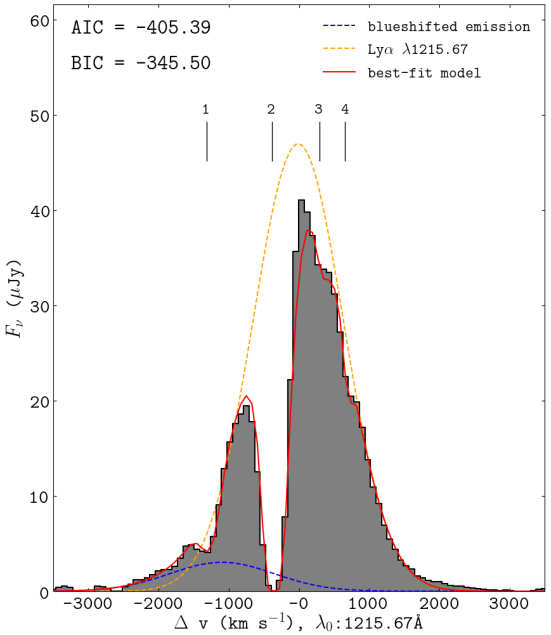
MUSE Lyα

UVES Lyα

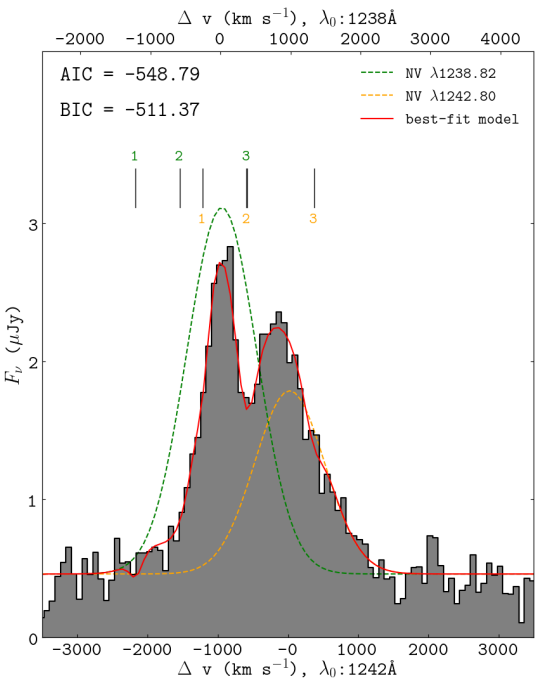
Absorption lines in metal ions: C IV and N V



N1 < 3.8 x 10^{14} cm^{-2}
N2 < 4.5 x 10^{14} cm^{-2}
N3 < 6.0 x 10^{14} cm^{-2}

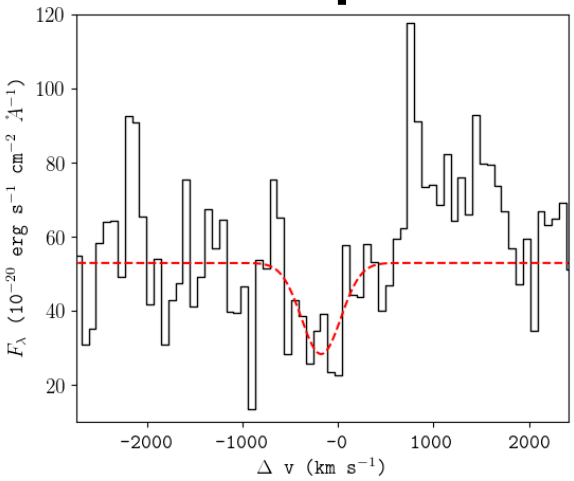


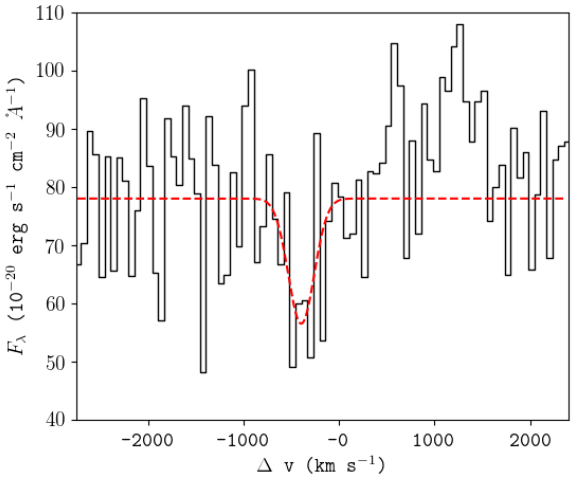
N1 = (1.6 ± 0.5) x 10^{14} cm^{-2}
N2 = (1.6 ± 0.5) x 10^{19} cm^{-2}
N3 = (2.1 ± 1.5) x 10^{14} cm^{-2}
N4 = (2.1 ± 1.2) x 10^{13} cm^{-2}



N1 < 10^{14} cm^{-2}
N2 < 9.4 x 10^{14} cm^{-2}
N3 < 1.6 x 10^{14} cm^{-2}

Absorption lines in metal ions: Si II

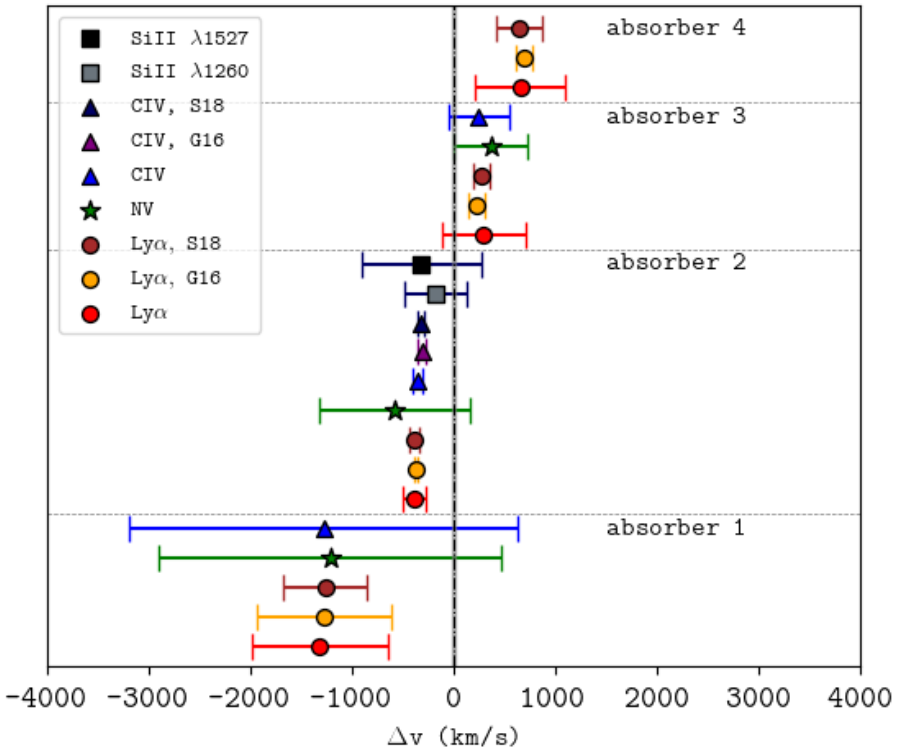




- Si II λ1260
- $N_{Si\ II} \sim 1.8 \times 10^{12}$ cm^{-2}
- $\Delta v \sim -175 \pm 295$ km s^{-1}

- Si II λ1526
- $N_{Si\ II} \sim 6.0 \times 10^{12}$ cm^{-2}
- $\Delta v \sim -397 \pm 461$ km s^{-1}

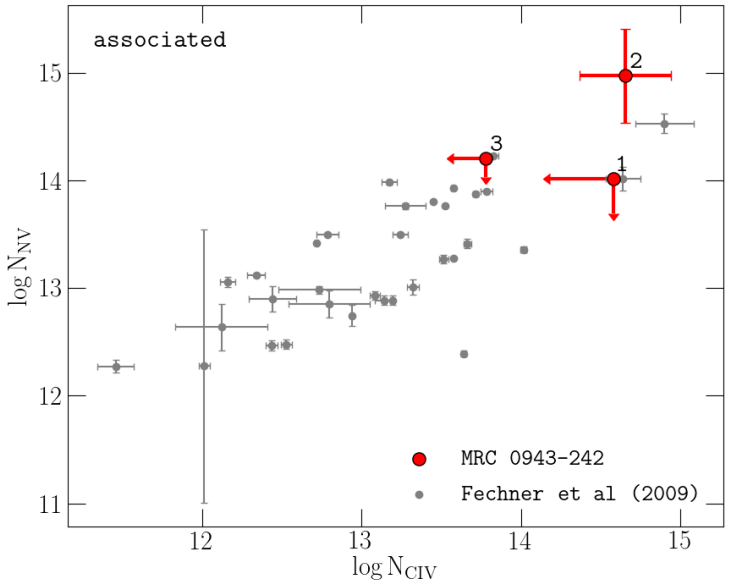
Absorption lines in metal ions: C IV, N V and Si II

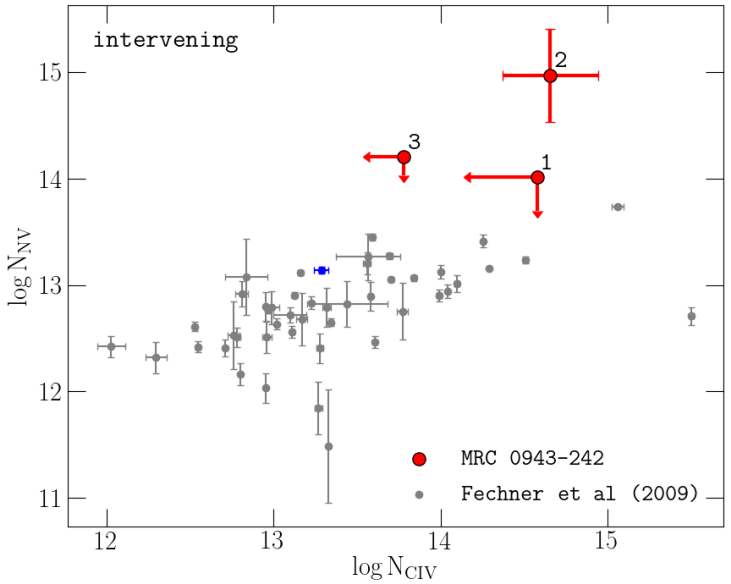


Velocity alignment of absorbers with Lyα λ1216, C IV λ1548,1551 and N V λ1238,1243 and Si II λ1260, λ1527

Confirmation of metal-enrichment in absorbing gas with new elements detected

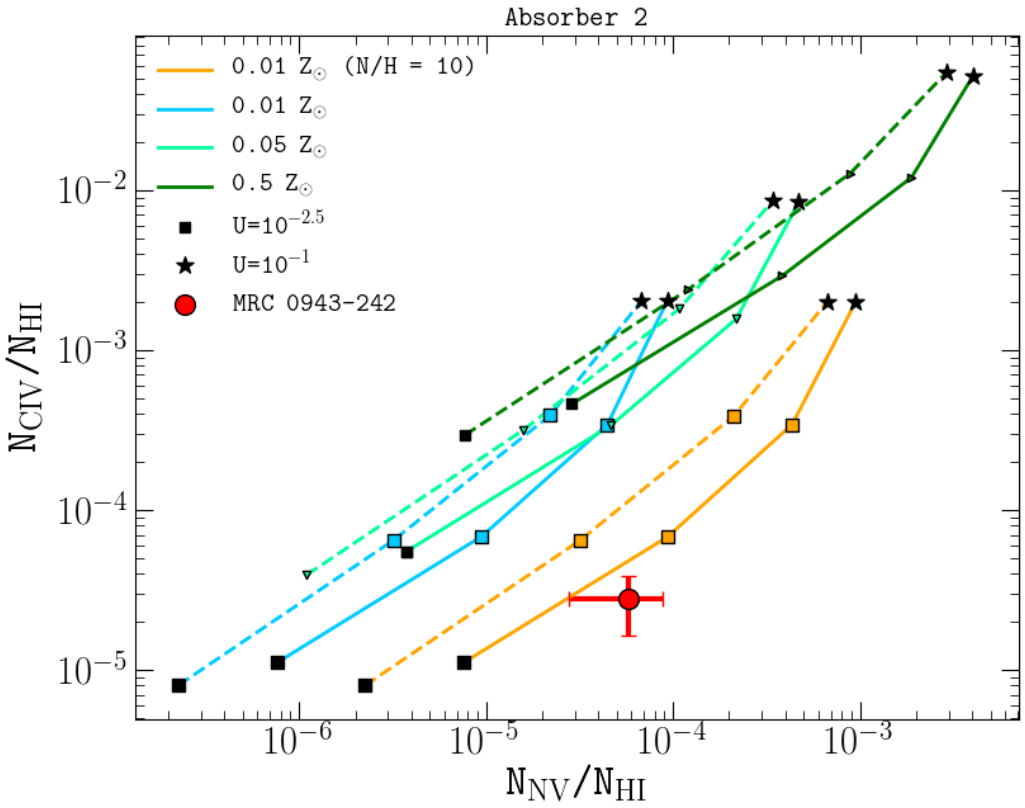
HzRG and quasar absorbers, compared





N V and C IV quasar absorbers (Fechner+2009):
Intervening: $\Delta v > 5000$ km s^{-1}
Associated: $\Delta v < 5000$ km s^{-1}
Assuming quasar and HzRG absorbers are from same parent population

Simulated abundances, CLOUDY grid: absorber 2



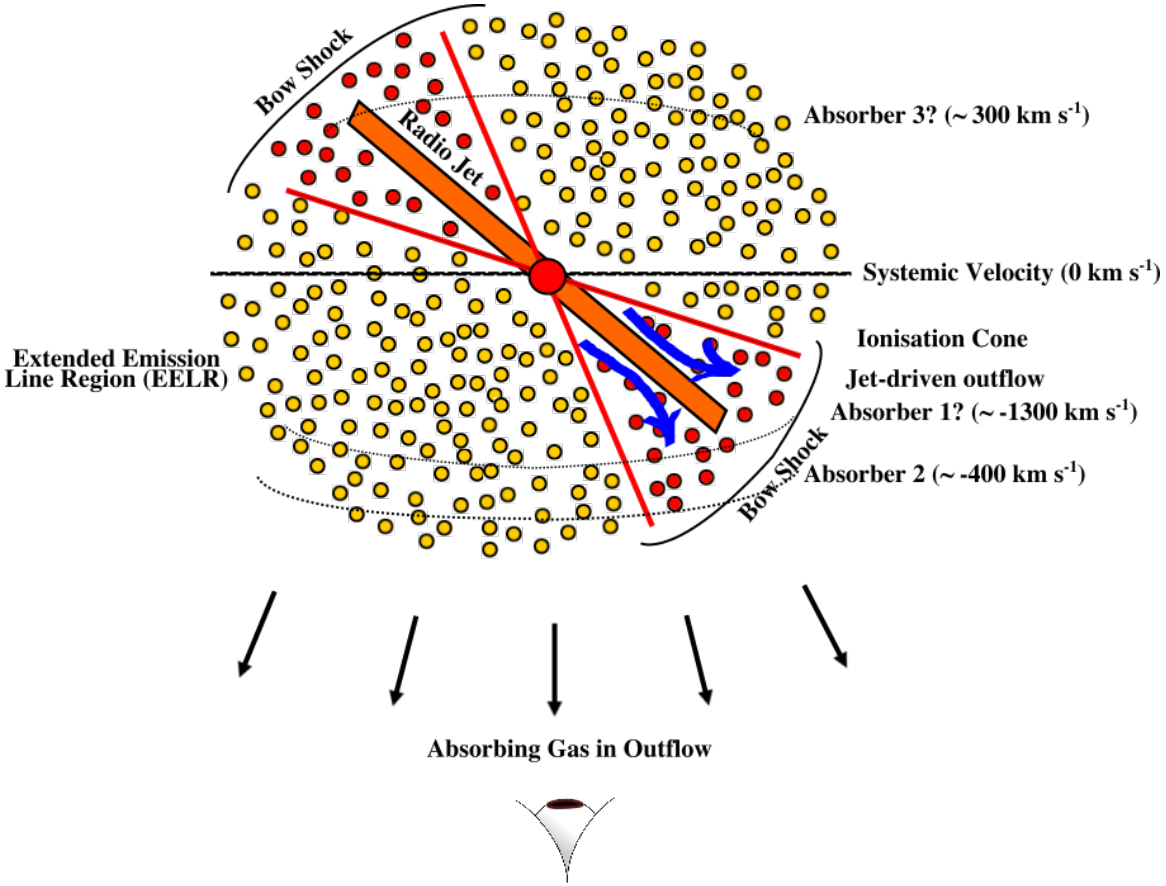
CLOUDY grid:
AGN photoionization ($S_\nu \propto \nu^\alpha$)

- α = -1.5 (dashed) and -1.0 (solid)
- -2.5 < log U < -1
- Solar abundances
- Modified abundance of nitrogen
- n_{HI} = 100 cm^{-3}

- Metal-poor gas cloud
  - N/H ~ 10
  - Nitrogen enrichment from feedback event?

- d ~ 51 kpc
  - assuming log U = -2 and n_{HI} = 100 cm^{-3}

Picture of MRC 0943-242 Halo?



A cross-section schematic of the halo (as seen from the “top”)

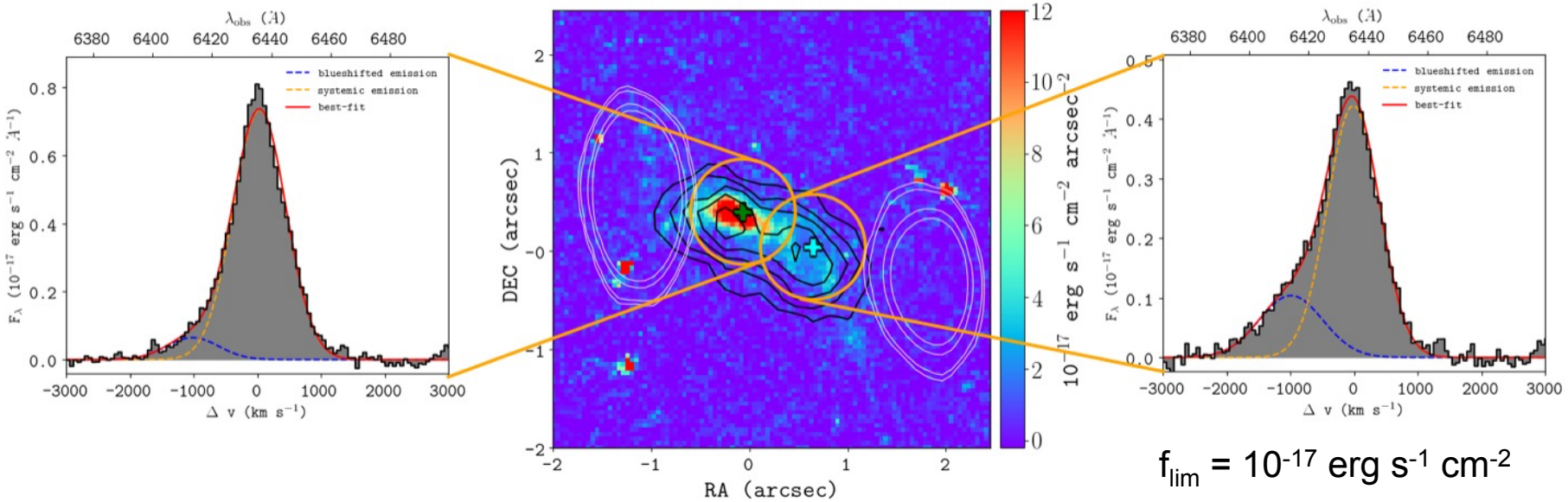
Current Conclusions

- Discrete absorbers in the galaxy halo (ISM or CGM) are metal enriched
- First detection N V absorption in the gaseous nebula of a radio galaxy
- N V detection proves enrichment (good metallicity tracer)
- Si II also detected at velocity of strong absorber (not matter-bounded)
- Strong absorber: metal-poor gas shell with nitrogen enrichment from feedback event
- Absorbers likely to be associated with the galaxy
- Radio axis inclined to projected plane (from He II and Lyα kinematics)
- Absorber 1 and 3 fragmented gas shells

Jet-gas interactions traced by He II λ1640

FWHM (blue) ~ 970 km s^{-1}
Flux ~ 1.43 f_{lim}

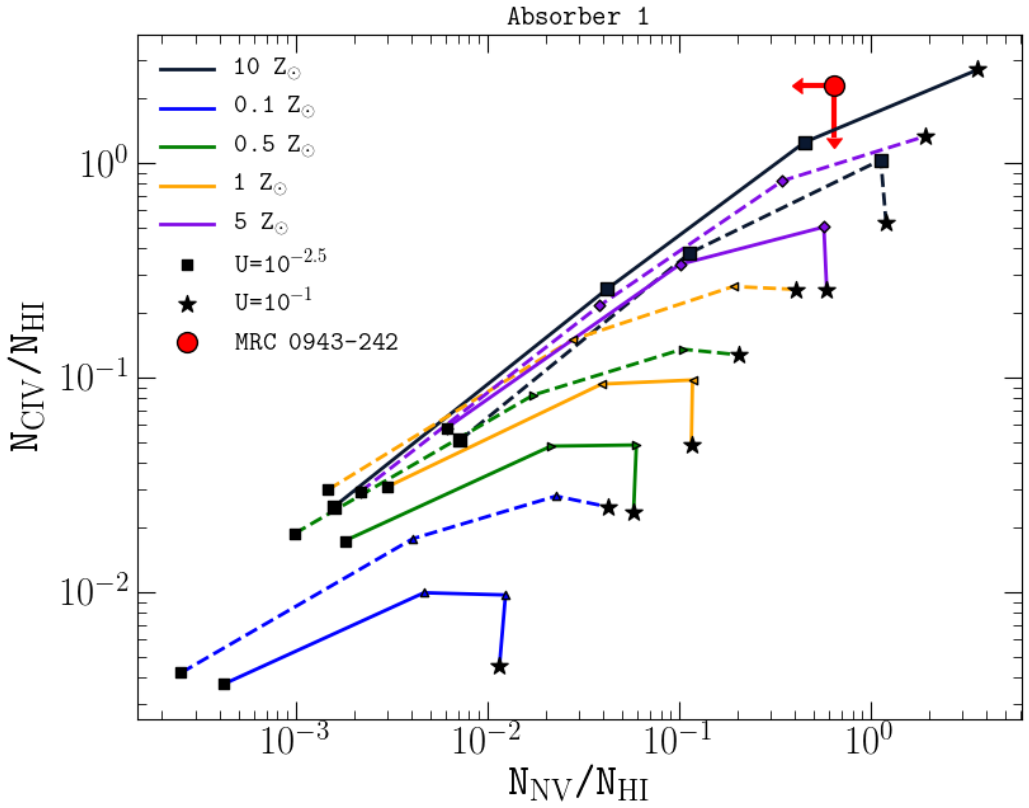
FWHM (blue) ~ 1134 km s^{-1}
Flux ~ 2.69 f_{lim}



f_{lim} = 10^{-17} erg s^{-1} cm^{-2}

e.g. Humphrey+2006, Nesvadba+2017
Perturbed kinematics accelerated by jets (compressed and heated)
Radio jet orientation can be inferred: blueshift and tilt of radio axis

Simulated abundances, CLOUDY grid: absorber 1

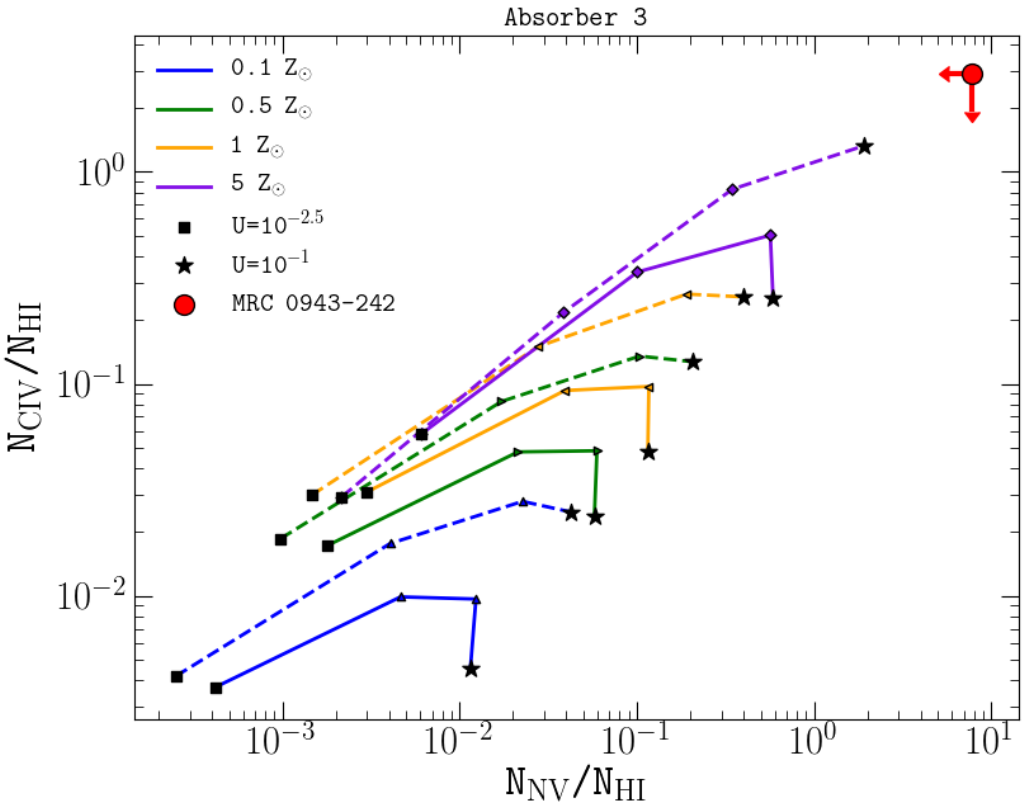


CLOUDY grid:
AGN photoionization ($S_\nu \propto \nu^\alpha$)

- α = -1.5 (dashed) and -1.0 (solid)
- -2.5 < log U < -1
- Solar abundances
- n_{HI} = 100 cm^{-3}

- U ?
- Distance ?

Simulated abundances, CLOUDY grid: absorber 3



CLOUDY grid:
AGN photoionization ($S_\nu \propto \nu^\alpha$)

- α = -1.5 (dashed) and -1.0 (solid)
- -2.5 < log U < -1
- Solar abundances
- n_{HI} = 100 cm^{-3}

- U ?
- Distance ?