



Dark Cosmology Centre



Niels Bohr Institutet

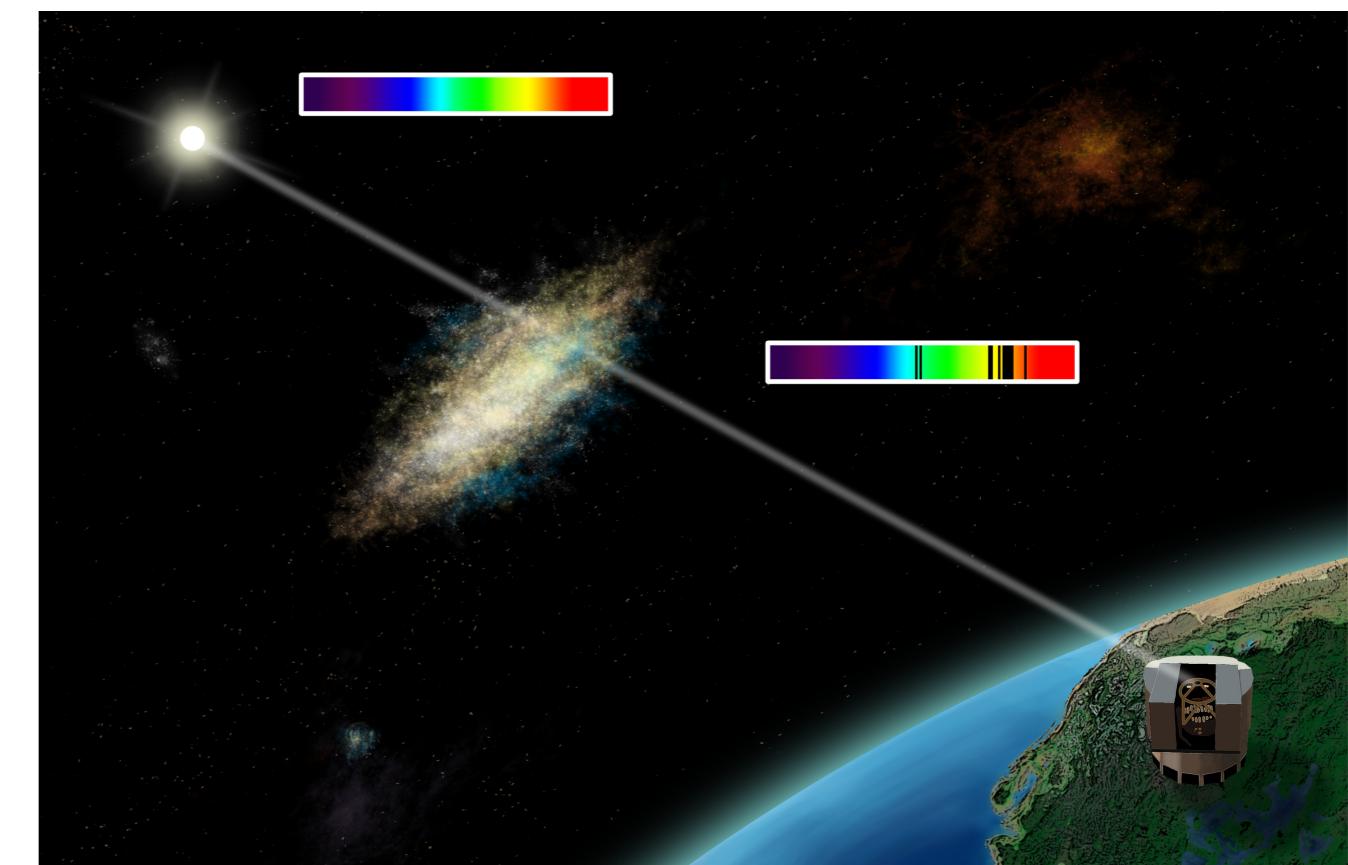
DAWN

ALMA observations of the environment of a metal-rich DLA at z=2.58

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Damped Lyman- α Absorbers (DLAs)

DLAs, QSO absorbers with neutral hydrogen column density $N_{\text{HI}} > 2 \times 10^{21} \text{ cm}^{-2}$, have taught us a lot about early galaxies since the first sample was published more than three decades ago (Wolfe et al. 1986, ApJS, 61, 249). The basic information from DLAs is 1) the total HI cross-section on the sky (several times higher than expected from local spirals), metallicities (from <1% solar to solar) and information about kinematics of the absorbing gas. However, for many years other fundamental properties normally coming from imaging studies like effective radii (big or small)?, dynamic and stellar masses (dwarfs or early stages of disks like the MW?), dynamics (rotationally supported or merging galaxy-sub-clumps?) of these galaxies remained in the dark. During the latest decade this situation has changed mainly thanks to the X-shooter spectrograph. Lately, we have started finding interesting results with ALMA. Here is an example of that.



DLAs are galaxies lying along the line of sight to background light sources (typically QSOs). Absorption lines in the QSO spectrum probe the ISM of the DLAs.

The line-of-sight towards Q0918+1636

The z=2.583 DLA towards Q0918+1636 is interesting as it is as metal-rich as the sun (despite a lookback time of 11.3 Gyr). **The quasar spectrum is shown in Fig. 1.** In [1] and [2] we found that:

- The galaxy giving rise to the DLA is located 16.2 kpc from the quasar line-of-sight (los)
- It is strongly star-forming (about $30 M_{\odot}/\text{yr}$)
- The stellar light is compact (less than 1 kpc), yet the galaxy contains lots of neutral gas, metals, dust, and molecules 16 kpc from its center.

In 2017 we observed the field with ALMA (PI Prochaska, paper submitted [3]) with the objective to detect the absorbing galaxy in CO(3-2) molecular emission. **Somewhat to our surprise we detected another strongly star-forming galaxy 117 kpc from the quasar los and redshifted by 131 km/s relative to the DLA. We detected no CO-emission from the DLA galaxy (Fig. 2 and Fig. 3).**

Interestingly, **at the redshift of CO-emitting galaxy we detect weak absorption from low-ionization lines and strong absorption from high-ionization lines in the quasar spectrum (Fig. 4).** It is plausible that this absorption is caused by a galactic wind from the CO-emitting galaxy.

Interpretation:

We think we here see a galaxy group where the intragroup medium is being enriched with metals, dust and molecules from several strongly star-forming galaxies. Multiple galaxies could contribute to the metal line kinematics for DLAs.

Other recent advances from observing DLAs with ALMA can be seen in [4-7].

Refs:

- [1] Fynbo et al. 2011, MNRAS, 413, 2481
- [2] Fynbo et al. 2013, MNRAS, 436, 361
- [3] Fynbo et al. 2018, submitted to MNRAS (let me know if you would like a preprint)
- [4] Neeleman et al. 2016, ApJ Letters, 820, L39
- [5] Møller et al. 2018, MNRAS, 474, 4039
- [6] Neeleman et al. 2018, ApJ Letters, 856, L12
- [7] Kanekar et al. 2018, ApJ Letters, 856, L23

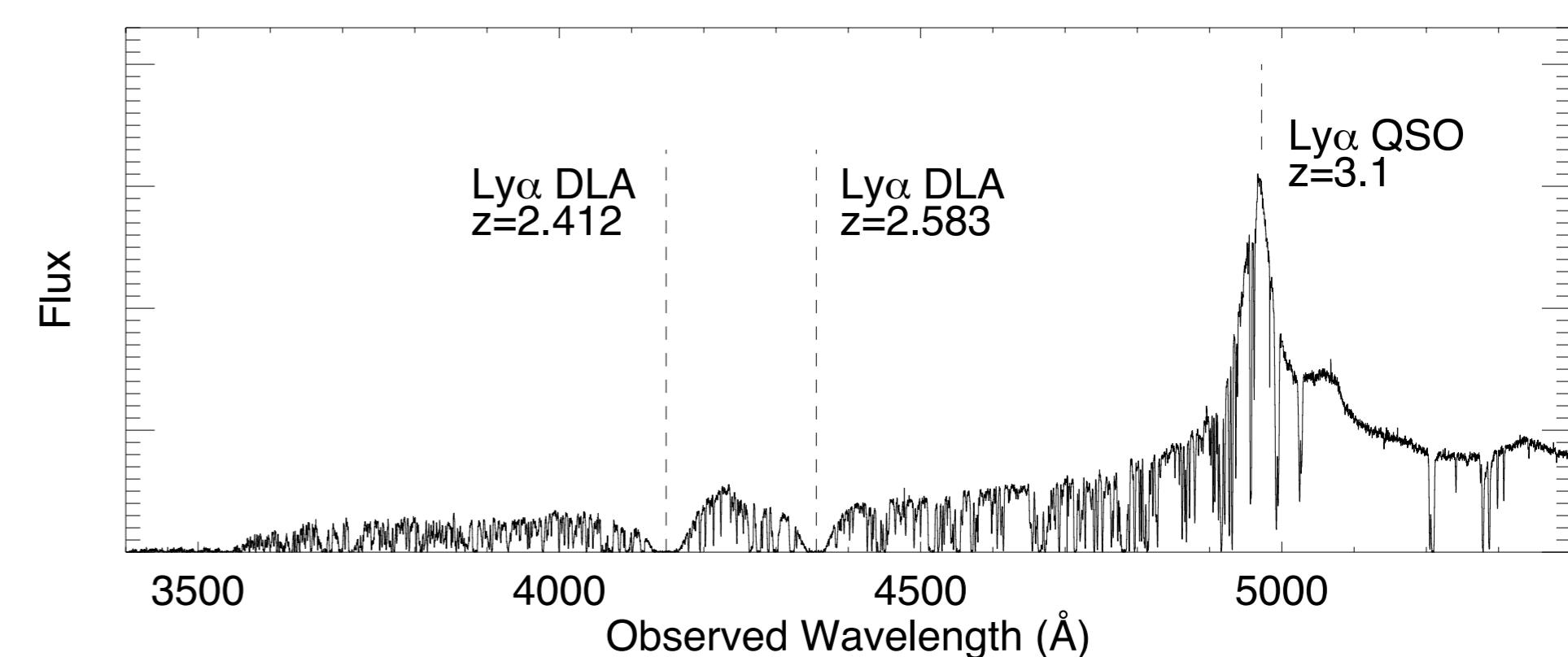


Fig. 1: The UVB spectrum of the background quasars. Two DLAs are found along the line-of-sight. The z=2.583 DLA has solar metallicity.

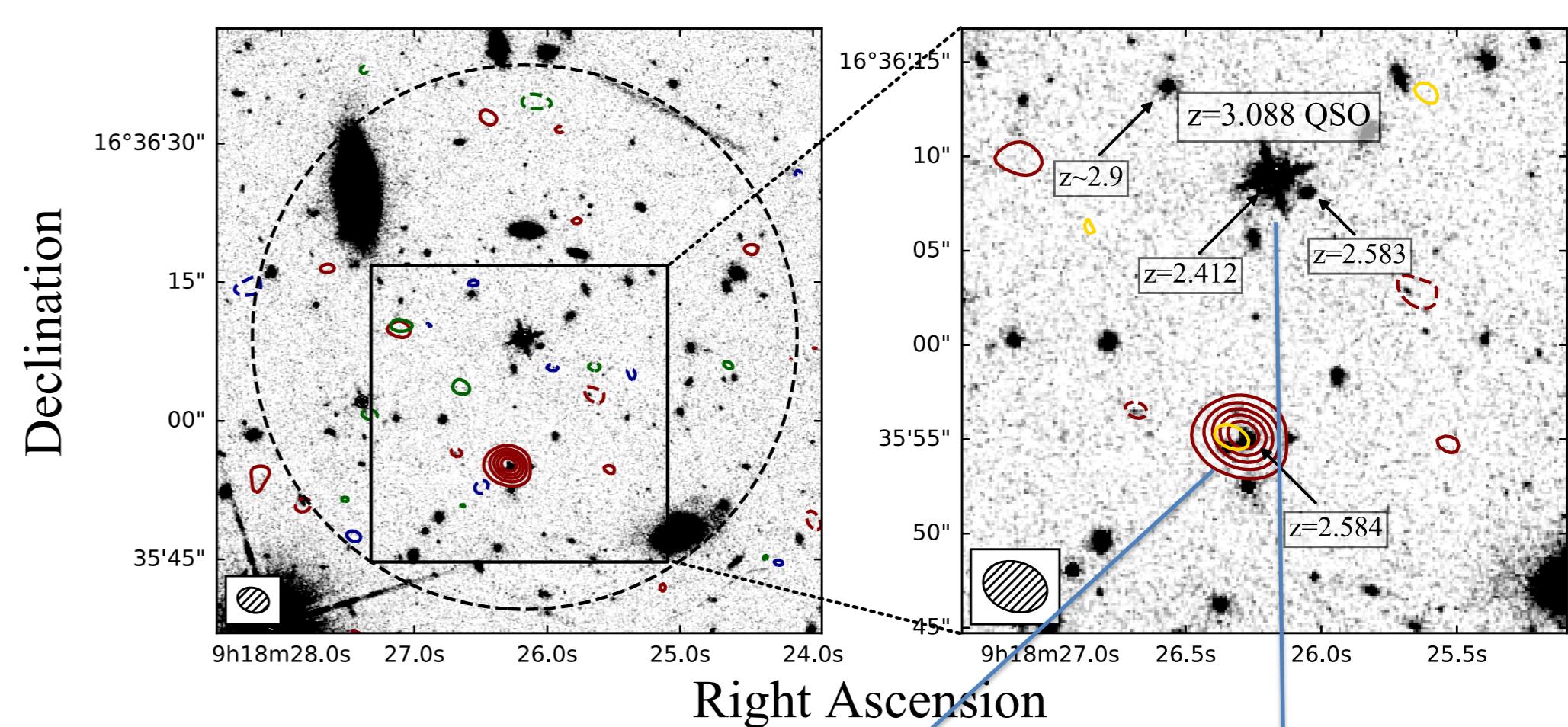


Fig. 2: ALMA and HST imaging of the field. The most important objects here are: the background quasar ($z=3.088$), a $z=2.583$ DLA, the galaxy giving rise to the DLA (16 kpc from los, blueshifted by 35 km/s), a CO emitter (117 kpc from los, redshifted by 131 km/s relative to the DLA).

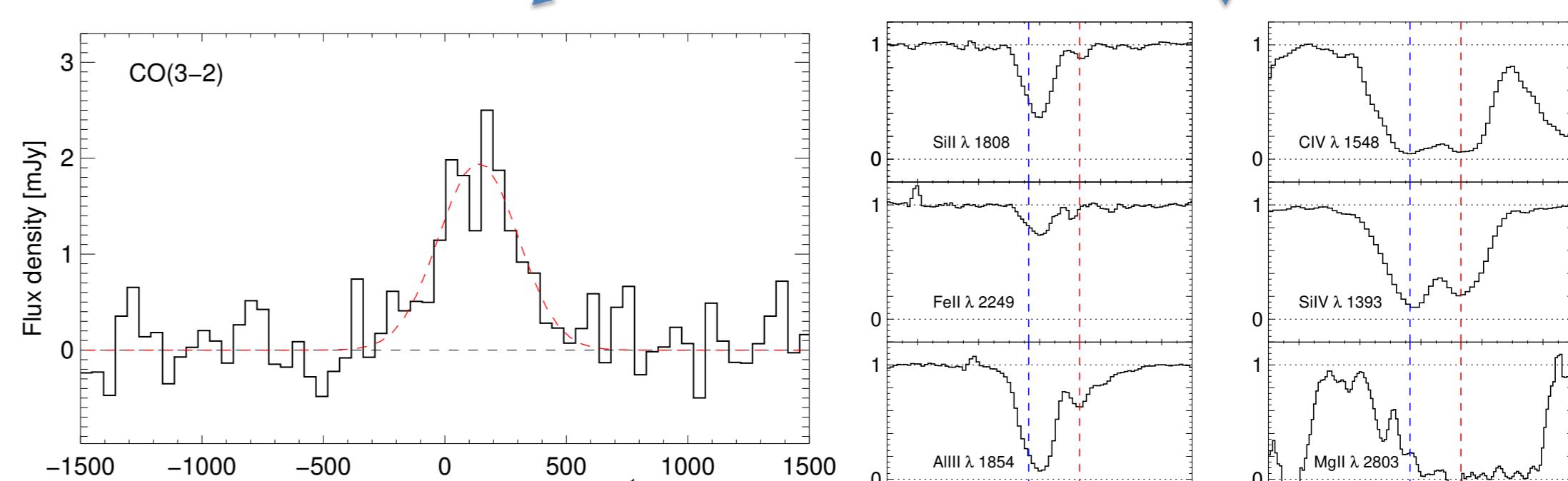


Fig. 3: ALMA CO(3-2) spectrum of the galaxy 117 kpc from the quasar los.

Fig. 4: metal-lines in the quasar spectrum.
Blue: Galaxy counterpart.
Red: CO-emitting galaxy.