Quasar Absorption Lines -> Diffuse IGM and dense ISM

ESO Blues…

H2

Ly-β

Ly-α

C IV

Metals
The Universe through absorption lines

Intervening Objects:

The IGM
The ISM of high redshift galaxies
The interplay between galaxies and the IGM
Large scale structures traced by the gas

At the two ends:

The local universe
Winds from quasars

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Metals in the IGM

Association with galaxies

Metallicities and SF

Ly-α Forest

Metal Line Systems

Damped Systems

Intergalactic Medium

Reservoir of Baryons

Galaxies

Large Scale Structures

Density Field

Ionizing Flux

Metals

Winds
Simulations

Correlation in the IGM

+ metals and galaxies
Fifty years of history

1963: Identification of the redshift, Schmidt and Greenstein & Matthews

1965: Bahcall & Salpeter predict Absorption lines if redshifts are cosmological

1966: First detection of absorption lines in a QSO spectrum
Gamov, G. Nature, 216, 461 (1967) -> Due to intervening galaxies
Burbidge, G+M, Nature, 216, 1092, (1967) -> Associated to the quasar

Twenty years will be needed to definitely settle the problem
QSOAL studies at ESO: an answer

Shaver & Robertson 1983
Messenger 31, 28
IPCS on the 3.6m Telescope

Foreground quasar defined with the associated absorption has a smaller redshift

Bergeron 1986
A&A, 155, L8
EFOSC on the 3.6m Tel

Direct detection of a galaxy associated with a MgII system at z=0.4299
CASPEC at the 3.6mTelescope and EMMI at the NTT

ISM in M83 from SN1983
D’Odorico et al. (1986)

The Gunn-Peterson effect
Giallongo et al. (1994)
UVES 2000

- LP « Cosmic Evolution of the IGM » PI: J. Bergeron
  Best data on 21 QSOs at z<3 available to the community
  over the past ten years (SNR=40-80 at R>45,000)
- Metals in the IGM
- The ISM of high redshift galaxies: studies of DLAs
- Broad Absorption lines in quasars
- Constraints on the variations of fundamental constants (LP
  PI: P. Molaro)  -> M. Murphy talk
Flux power spectrum
Density power spectrum

Kim et al. (2003)
Large set of data of very good quality
-> S. Cristiani talk

Metals in the IGM (20% of the volume)
Stacking pixels

Aracil et al. (2004)
The blue
Spatial distribution of metals

Comparison of the spatial distribution of metals in simulations and the correlation function in the data

-> Massive halos (same for DLAs)

Scannapieco et al. (2006)
Damped Ly-α Systems: The ISM of high-z galaxies

HI :

Metals :
- Metalicities
- Dust content
- Kinematics

Star- Formation ?
Winds ?

Molecules H2 + CI, CI* :
- Density/Temperature
- UV flux (excitation)
Chemical evolution

Analytical Models of chemical evolution

Dessauges-Zavadsky et al. (2007)

Exact nature is still unclear

Molecules: Cold gas with small covering factor
ESO survey for H2: < 10% => most DLAs are warm
Presence of dust

- Correlation Depletion ([Zn/Fe]) vs Metallicity ([Zn/H])
- Presence of H2 related to the dust column density

(Ledoux et al. 2003, 2006, 2012)
Heating processes: Molecular excitation

Two temperatures
No velocity shift

Fluorescence -> UV flux
Collisions -> Tk, density
CI+ CI*

Doppler parameter increases with J

$n_H = 30-100 \text{ cm}^{-3}$ (3-10pc)  $T = 70-150 \text{ K}$
UV flux 10xGal
First detection of CO (elusive for 25 years) : Object selected amongst 10 000 QSOs
=> HD/2H2 = > The galaxy is formed with strong accretion of gas
HD/2H2 = 2.1x10^-5 Log(f) = -0.3 (highest in DLAs) ; CO/H2 = 3x10^-6

Excitation of CO: Redshift evolution of $T_{\text{CMB}}$

$\beta = 0.007\pm0.027$ (we’ve tried…)
Broad Absorption Lines – Quasar winds

Small scale to large scales?

Organised flow: small covering factor and line locking
Clouds are small and flow is radiatively driven

-> Variability

Srianand et al. (2002)
New claims for variations of constants

**UVES data**: All data: no significant variation

\[
\begin{align*}
&z < 1.8 \quad -0.06 \pm 0.16 \times 10^{-5} \\
&z \sim 1.5 \quad 0.01 \pm 0.15 \times 10^{-5} \quad \text{Srianand et al., 2007, PRL, 99, 239002}
\end{align*}
\]

The two groups agree

\[
\begin{align*}
&z > 1.8 \quad +0.61 \pm 0.20 \times 10^{-5} \quad 3\sigma \\
+ \quad \text{Keck} \quad -0.74 \pm 0.17 \times 10^{-5} \quad 4\sigma
\end{align*}
\]

Spatial Variations?

-> M. Murphy Talk
The Future: The questions

- IGM: Derive the power spectrum better (simulations)
  Metals at lower tauHI

- IGM: The acceleration of the universe from the Lya forest

- IGM: Correlations in pairs (or groups) of quasars
  (A. Smette et al. 1995)

- ISM: Physical conditions vs Z (need to go fainter at HR)

- Galaxy – IGM interactions
  <- <- <-

- Broad Absorption Lines and the AGN properties
  Variability and covering factors (several cases from H2)
The Future: The instruments

-> Xshooter:
   LP for 100 los at z>3  PI: S. Lopez: IGM properties and zQSO Legacy value

-> CUBES: Keep the blue with very high throughput
   R=10,000-20,000

-> Espresso: Very high resolution and precision but fixed set-up
   (variation of constants)

-> High resolution spectrograph on E-ELT obviously needed

   Boss will discover over 150,000 z>2 QSO at g=21!
A MOS on ELT

Large Scales: Direct reconstruction of the IGM at $z=3$

Correlation of HI Lyman-$\alpha$
$Z=2.5-3 \Rightarrow 4500\text{A}$
+ metals and galaxies
QSOs -> 100 / sqdeg not enough

With LBGs => Density field will be recovered
Inversion methods tested: density of sources:

- LBGs: about 900 sources/sq degree at $r=24.8$
- QSOs: only 100 sources/sq degree

Topology of the IGM (cosmological parameters; growth of structures)

Correlation IGM-galaxies: winds; metal enrichment; infall

Skeleton
Variability

And a lot of strange things!

The boomerang outflow
Thank you!

to all these people running the telescopes