Gas absorbers in the Andromeda halo: a possible Stream connection

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Emmy Noether group "Galactic halos"

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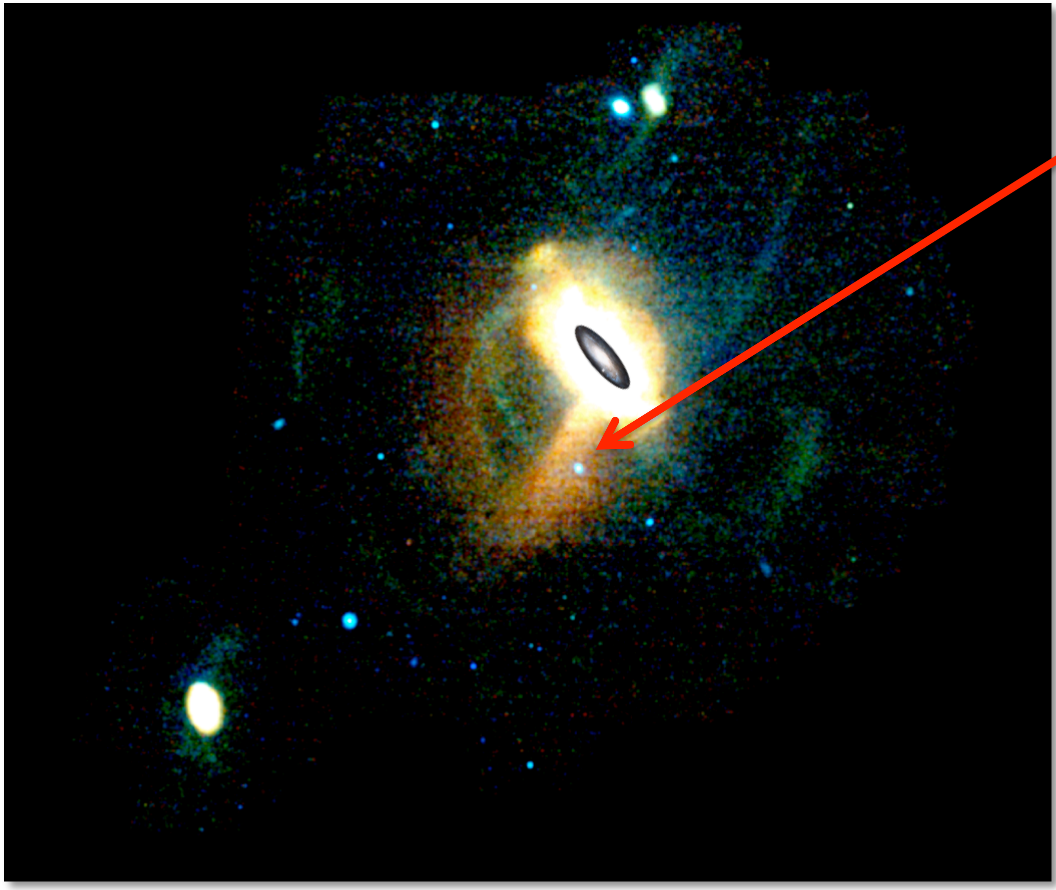
"Baryons at low densities: the stellar halos around galaxies", ESO/Garching, Feb. 24, 2015

Accretions in the M31's halo



Giant Stellar Stream
(Ibata et al. 2001):

- ~140 kpc full extent
- HST-CMDs indisting-uishable from halo (Brown et al. 2006)
- Progenitor: M ~ $3x10^8$ – $5x10^9$ $M_\odot$; yet little known

PAndAS map (McConnachie et al. 2009)

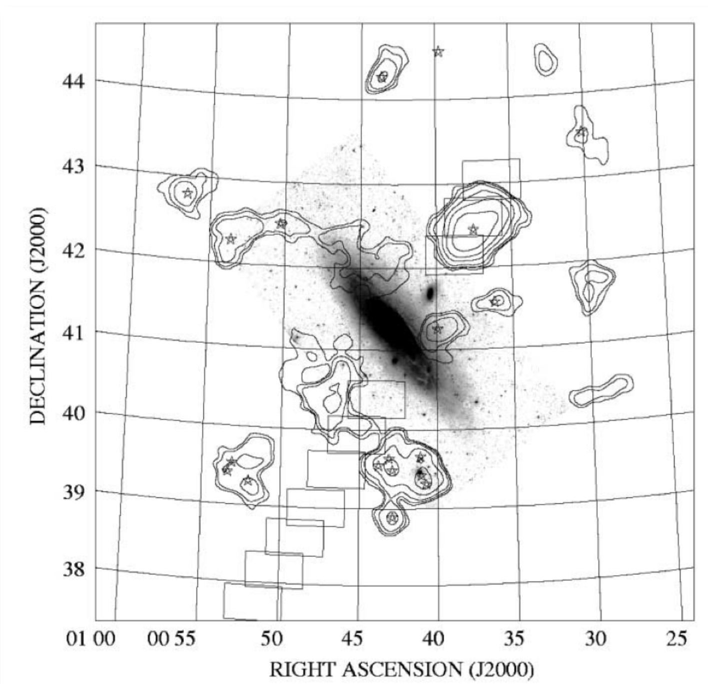
Many spatial and kinematic substructures (Ibata et al. 20NN); Ferguson et al. 2002; Irwin et al. 2005; ...) argue against *one* stream progenitor polluting the entire halo. Indication of a large scale, accreted halo, and interactions with M33. (→Poster #6; Matthias Frank)

Gas in the M31 system

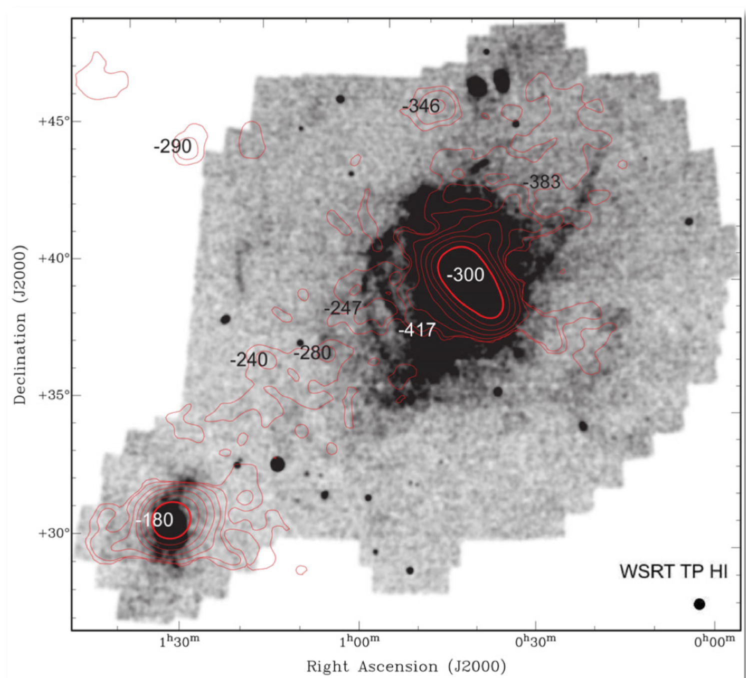
H I surveys detected many gas clouds at M31 velocities.

There is neutral gas, "bridging" M31 and M33 (sim. to the Magellanic Stream). Cf. "lack of spatial correlation between gas and stars on all scales". (e.g., Lewis et al. 2013)**.**

None of this is obviously associated with the Stream.



(Braun & Thilker 2004)



Quasar absorption

Use distant background quasars to trace line-of sight halo gas in absorption.

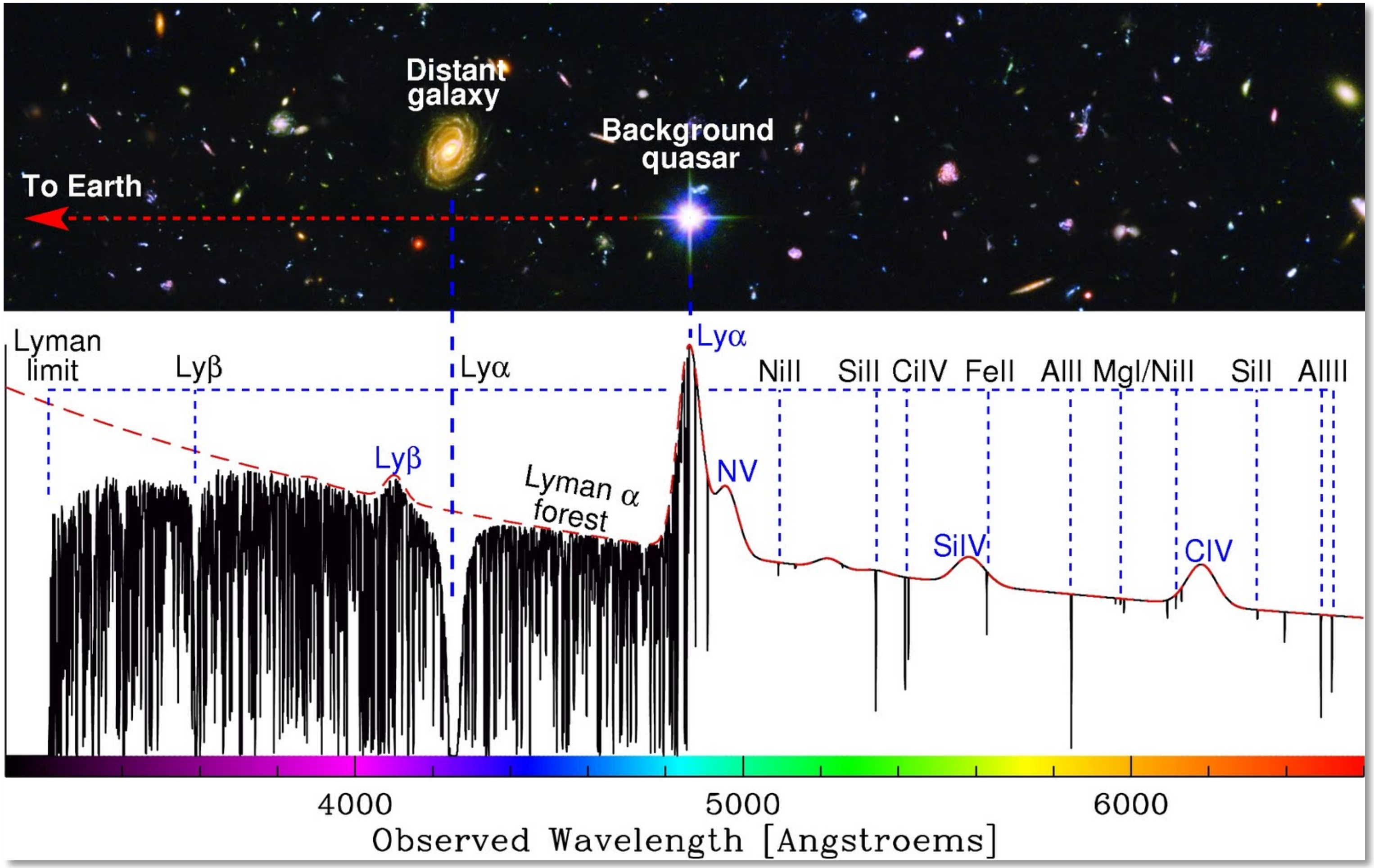
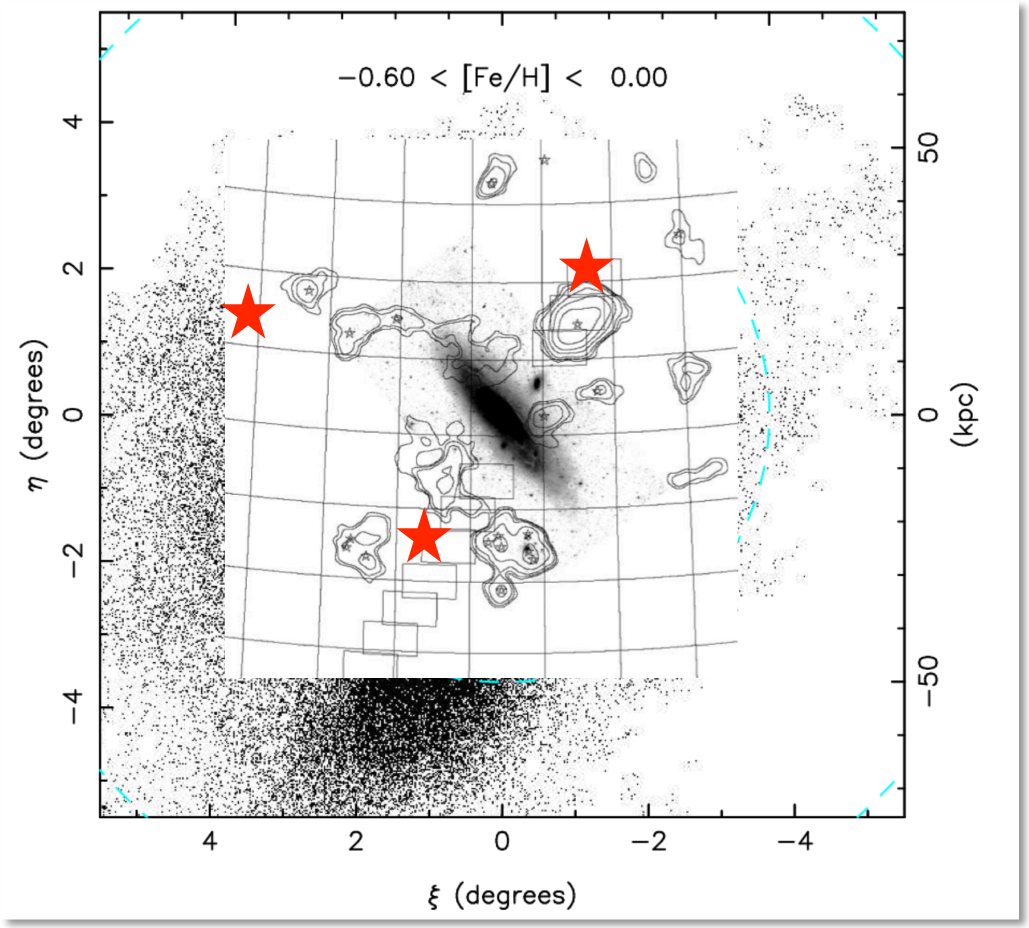


Image Credit: M.Murphy

Quasar absorption towards M 31

Here: three QSOs behind the halo of M 31 (z = 0.12 – 0.19).
Spectroscopy with HST's Cosmic Origin Spectrograph



Rao et al. (2013):

M31 does *not* possess a large gaseous X-section (along the major axis)

Lehner et al. (2015):

gaseous corona

Map of metal-rich stars
(Ibata et al. in prep.)

COS QSOs
26 – 51 kpc from M31

AK, Danforth, Rich, et al. 2015 (ApJ, submitted)

Metal absorbers towards M31

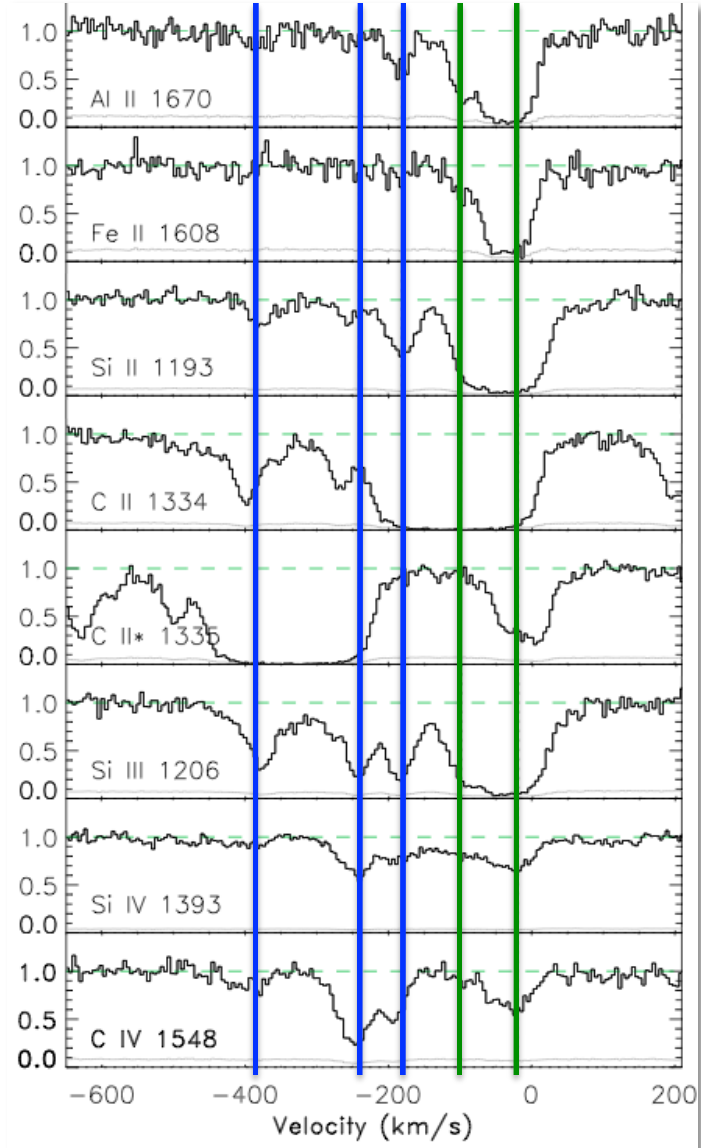
Detection of significant gas-absorption in all three sight-lines.

(C II, C IV, OI, Al II, Si I, Si II, Si III, Si IV, Fe II)

Partly MW clouds (v = 0, -100 km/s)

Towards the Stream:
at v = -385, -230, -170 km/s.

NB: M31's systemic velocity
<v> = -300 km/s
σ = 85 km/s

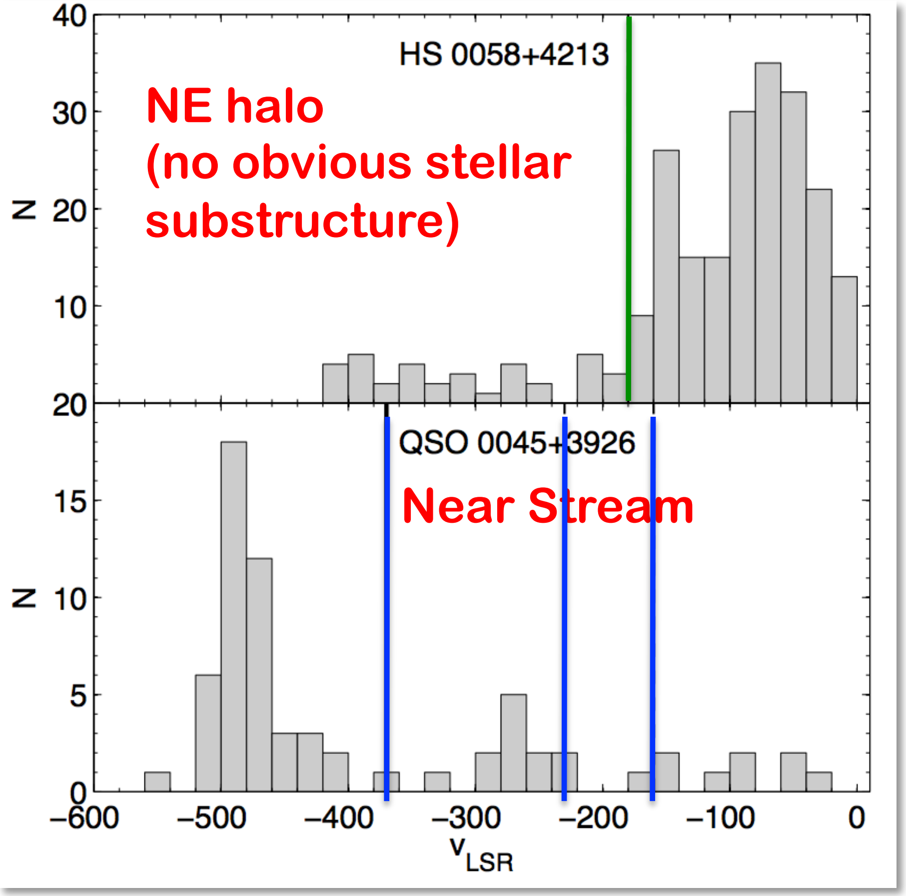


AK, Danforth, Rich, et al. 2015 (subm.)

Connections with the Stream?

Comparison with observed, stellar velocities within 5 kpc of the Stream (Calcium Triplet low-resolution spectra)

(Koch et al. 2008; Ibata et al. in prep.)



More positive velocities could be related to MW HVCs.

Stellar Stream velocities are more negative than the gas;

but mind possible, larger σ of the Stream, rotation, or un-accounted dynamical effects.

Also, QSO is at the edge of the Stream → spatial variations?

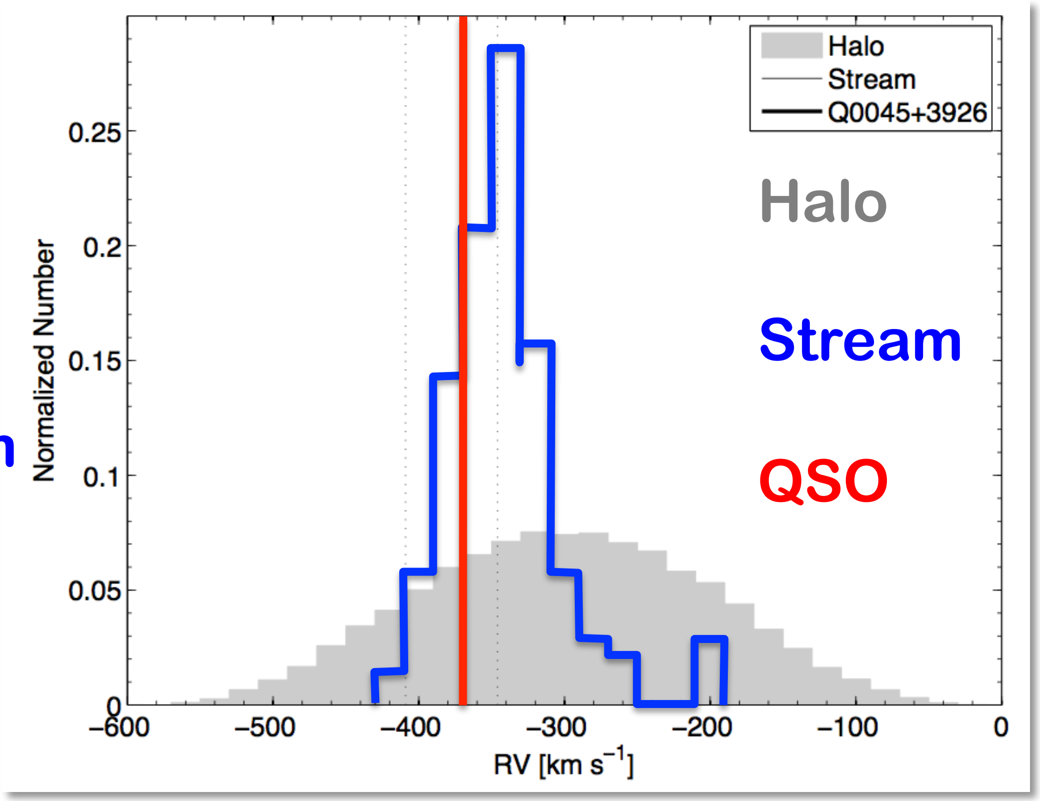
Models of Stream formation

Comparison with a model of Stream formation by minor merger (~3 – 5 x $10^9 M_\odot$), ~0.8 Gyr ago (Mori & Rich 2008).

NB: simulations were tailored to reproduce Stream *morphology*.

Coincidence of gas absorption with velocities of Stream particles within 5 kpc.

Connection with Stream is dynamically plausible.



Absorber characteristics

From CLOUDY models and line strengths:

→ Stream gas is similar to MW halo gas (e.g., in terms of ionization, log U = -3).

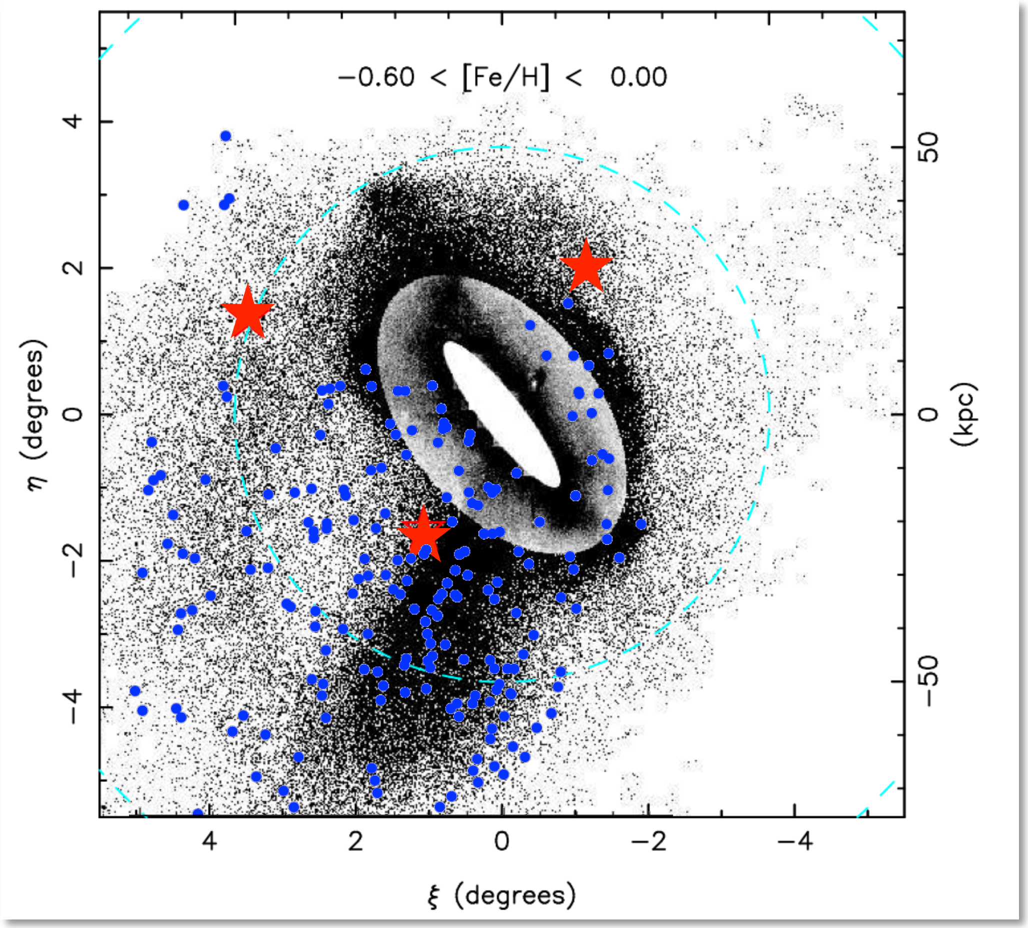
→ The "halo" component (-240 km/s) is highly ionized (log U = -2.6).

→ The metallicities of all 3 absorbers are ~Solar (-0.13±0.3), in contrast to the Stream's stellar [Fe/H] (CaT) of -0.7 dex (Ibata et al. 2015).

→ Typical cloud masses are $\sim 10^3\ M_\odot$; log $N_H \sim 10^{-16}\ cm^{-2}$.

Outlook

Ideally, probe the Stream gas right on the Stream, sampling its whole extent.



Map of metal-rich stars (Ibata et al. in prep.)

COS QSOs

526 LAMOST QSOs

(Huo et al. 2013)

z = 0.1 – 3.2

g = 17 – 21 mag

Summary

- Gas absorption in QSO spectra is a powerful tool to study galaxy halos.
- We detect metal-rich gas associated with the M31 halo, possibly even the Stream, placing constraints on the progenitors properties.
- Comparison with Stream velocities (simulations and stellar) and metallicities leaves room for association with the halo and/or Stream.