4MOST–Gaia
The Unbiased Quasar Legacy Survey

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Outline

A Purely Astrometric Quasar Survey: based on Gaia proper motions (G < 20.2)
~120.000 quasar candidates, highly complete, no color or redshift bias.

1. **Quasar Feedback and Winds**
   Team leader: Karen Leighly

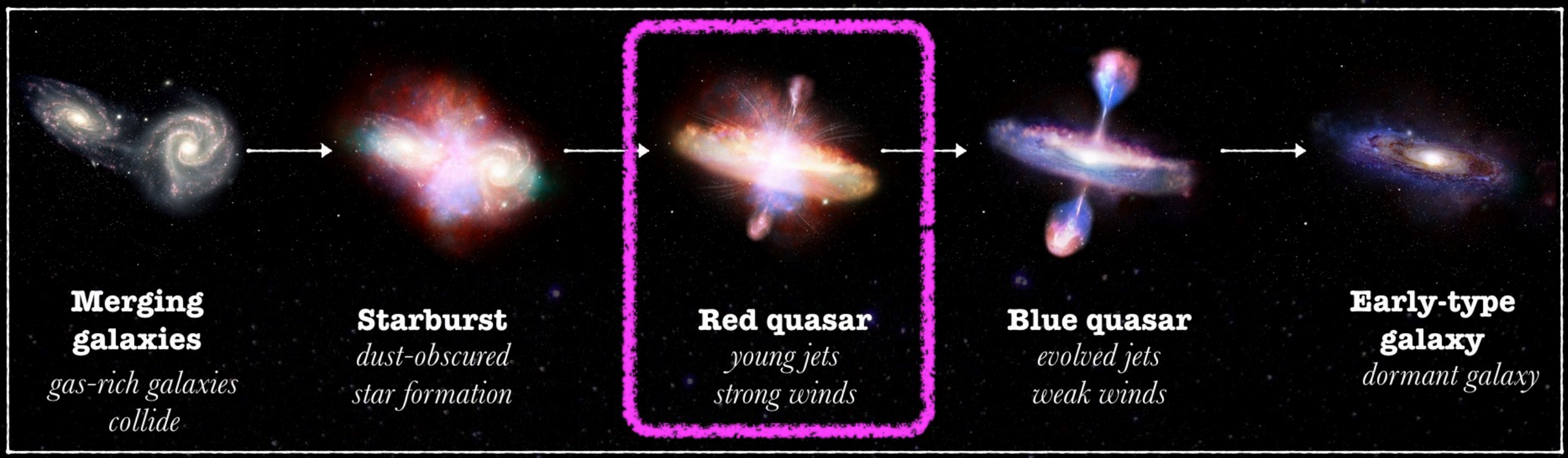
2. **Neutral Gas and Chemical Enrichment over Cosmic Time**
   Team leader: Jens-Kristian Krogager

3. **Survey Details**

Quasar Feedback and Winds

Red Quasars : the missing link in quasar evolutionary studies?

These are typically underrepresented in optical samples



Strong outflows associated to the “red quasar phase”

Original art: Gemini observatory, GMOS-South, NSF.

Broad Absorption Line Quasars

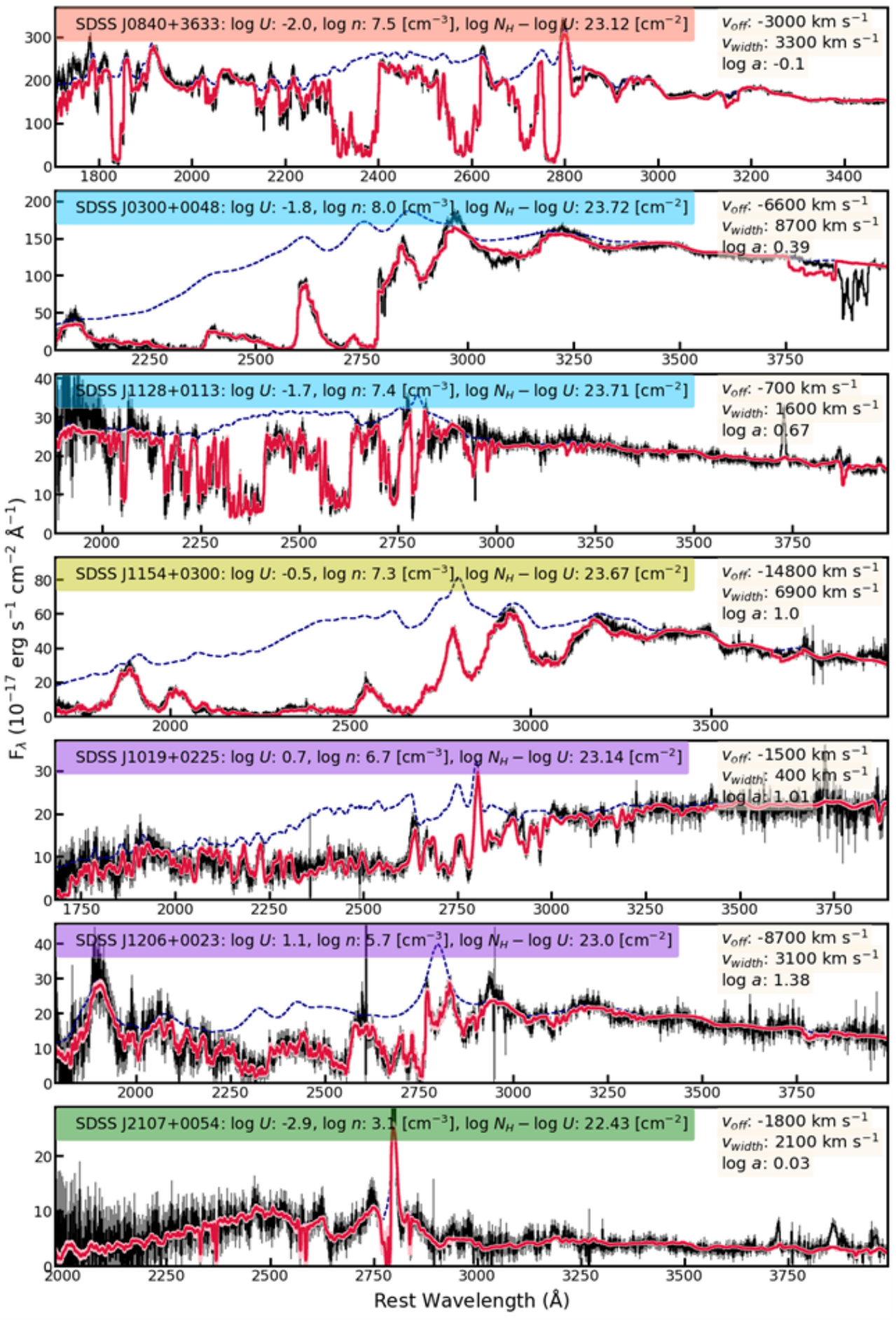
- ~15% of *optically selected* quasars show blue-shifted absorption lines indicating high-velocity winds

- But the potential for quasar feedback largely unconstrained due to spectral complexity.

- ***SimBAL*** – Spectral Synthesis for Broad Absorption Line Quasars (Leighly et al. 2018)

  Extract physical parameters from BALQ spectra

Choi et al. 2020b

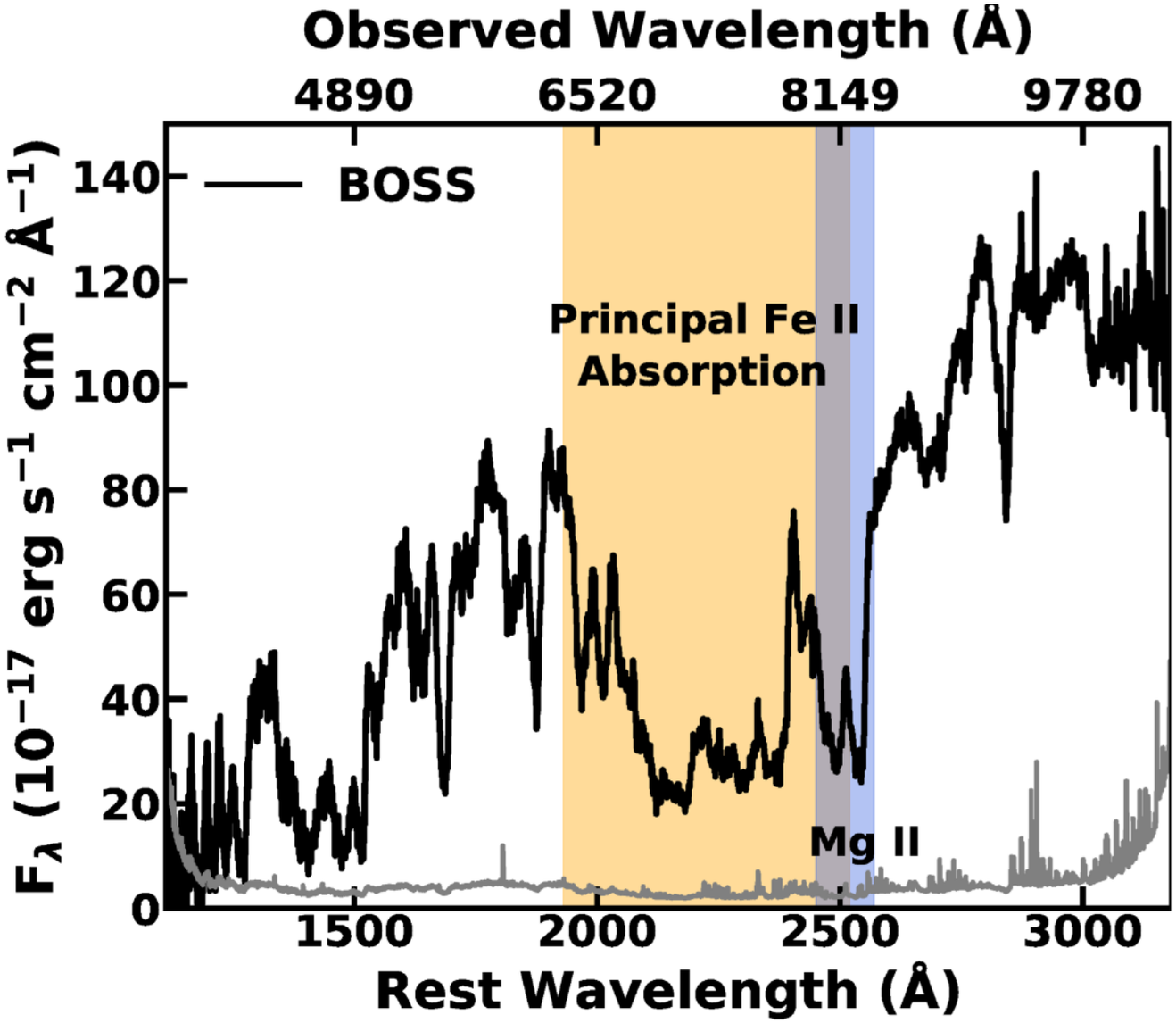


BAL Quasar Selection Bias

- BAL Quasars are known to be redder than ordinary quasars:
  ➠ **not selected** for observation

- Significant absorption can obscure emission lines
  ➠ **not identified** by pipelines

- One example: SDSS 1352+4239 – most energetic outflow known (Choi et al. 2020a)
  Not in the SDSS DR14 quasar catalog!



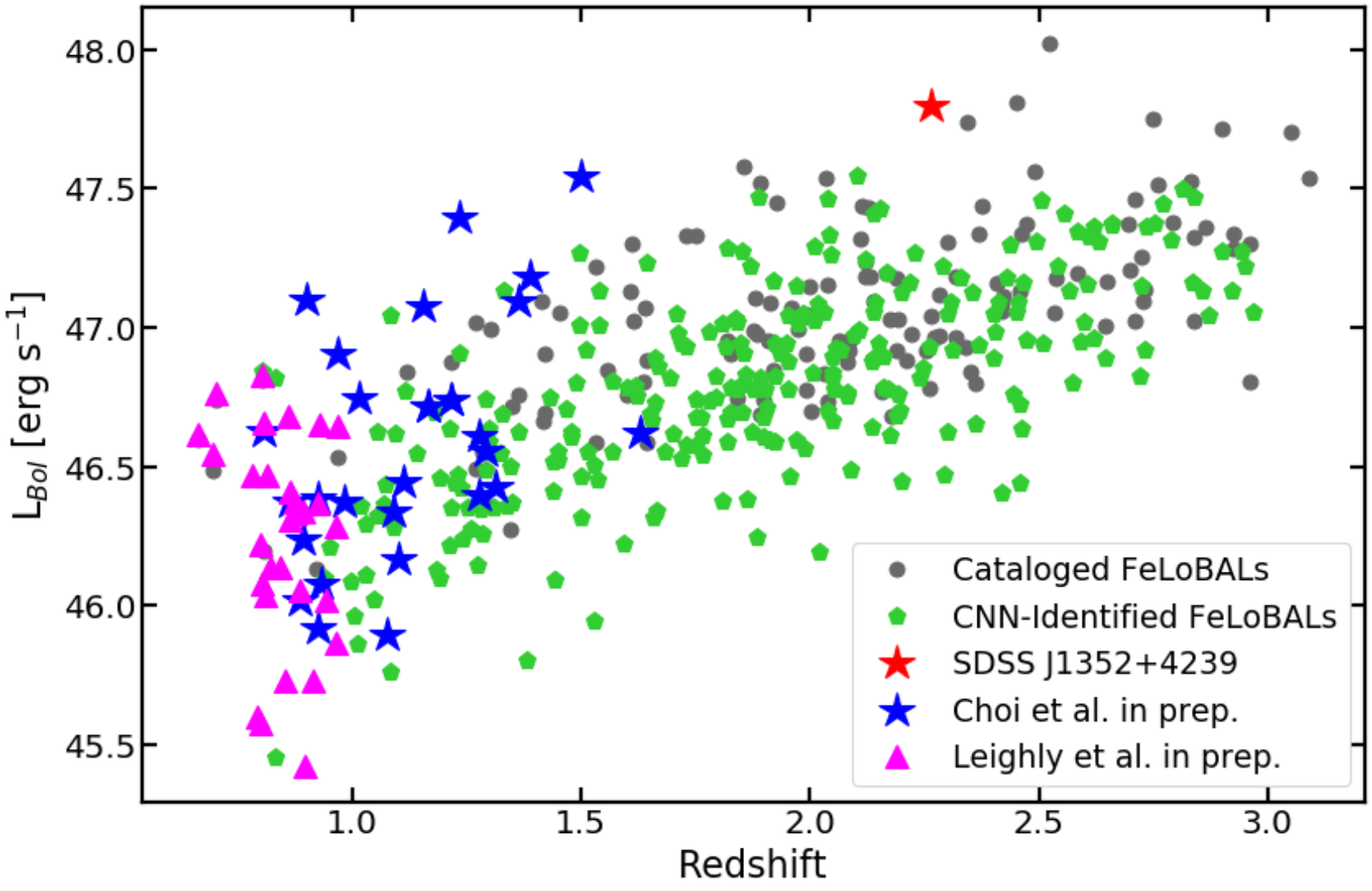
FeLoNET : Quasar Spectral Classification

FeLoNET uses a Convolutional Neural Net to classify quasar spectra.
(Dabbieri et al. 2020)

- Trained using synthetic spectra created by *SimBAL*

- Increased number of known FeLoBALs by a factor of ~3

- Possible contribution to extragalactic pipeline.



Quasar Feedback and Winds

An highly complete and unbiased view of quasar evolution and outflows

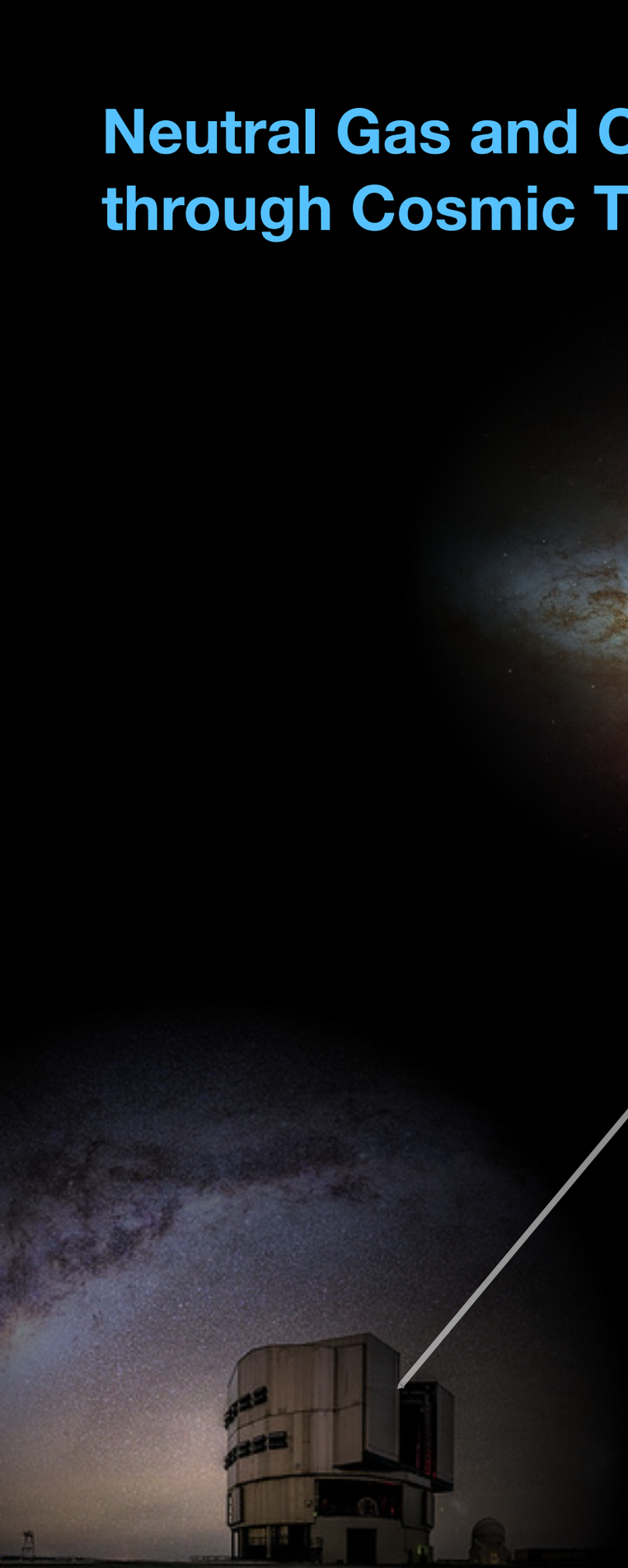
Select using ***only*** *Gaia* proper motions down to G < 20.2

Low resolution spectra to extract physical properties:

- Black hole masses and accretion rates

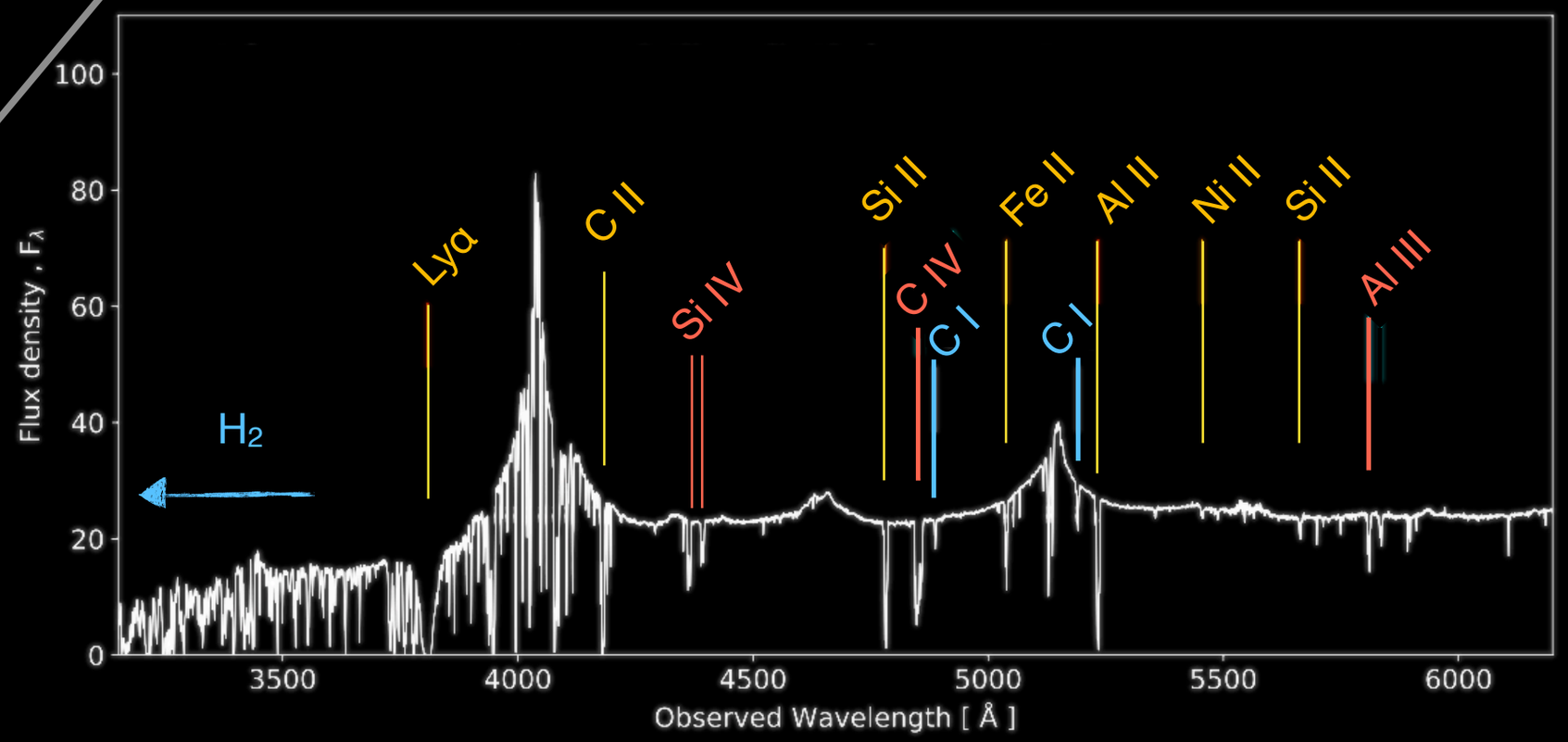
- BAL outflows: density, ionization parameter, distance to central engine, mass outflow rate

Neutral Gas and Chemical Enrichment through Cosmic Time

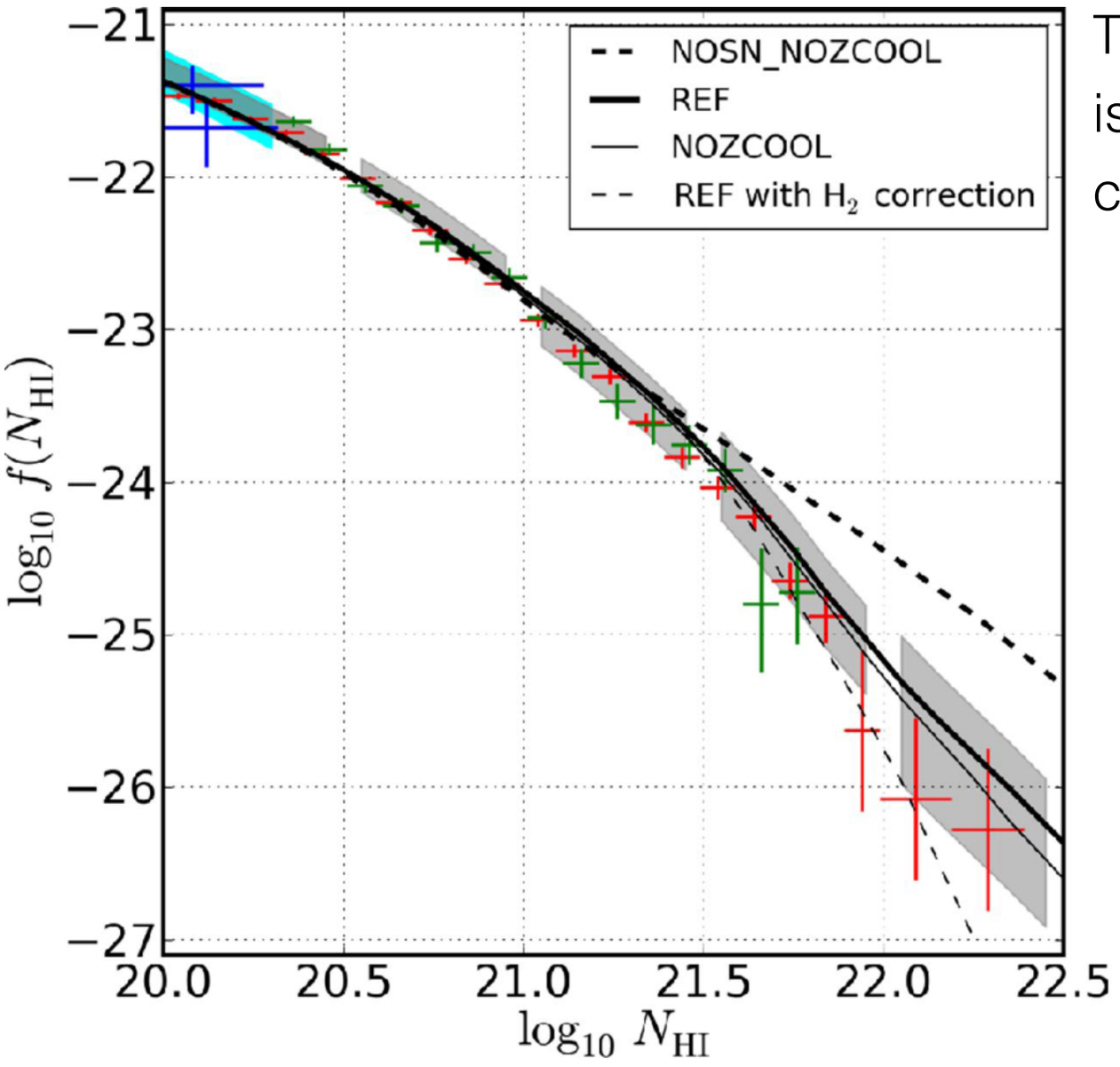


Absorption spectroscopy is **a great probe** of gas **at high redshift**

One sightline simultaneously probes ionised and warm, neutral gas, and in some cases even cold and molecular gas.



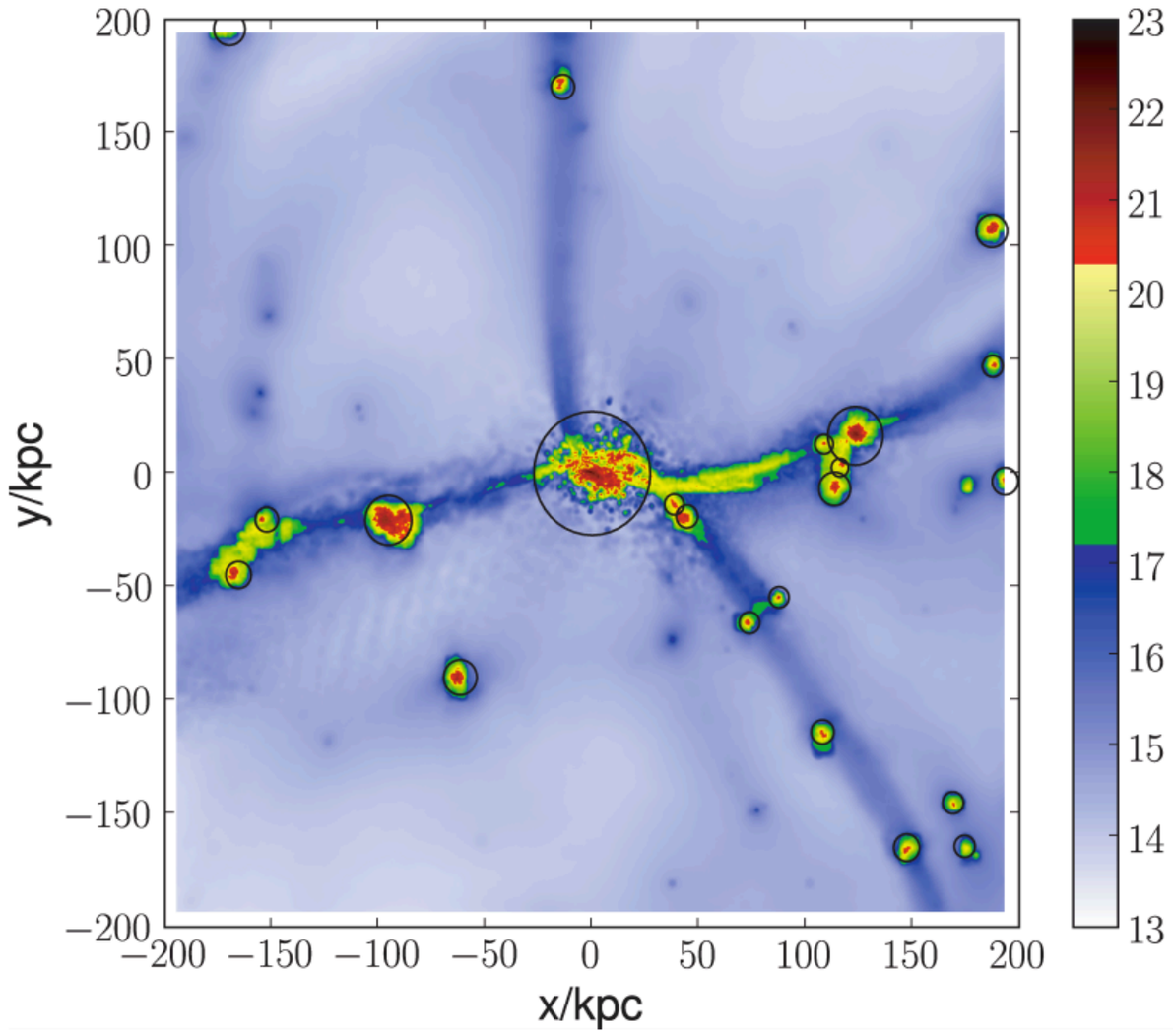
Predictions from simulations



Altay et al. 2013

The high-column density end of the distribution is sensitive to star formation feedback and conversion of neutral gas into molecules

(e.g., Altay et al. 2013, Rahmati et al. 2013, Bird 2014, Hassan et al. 2020)

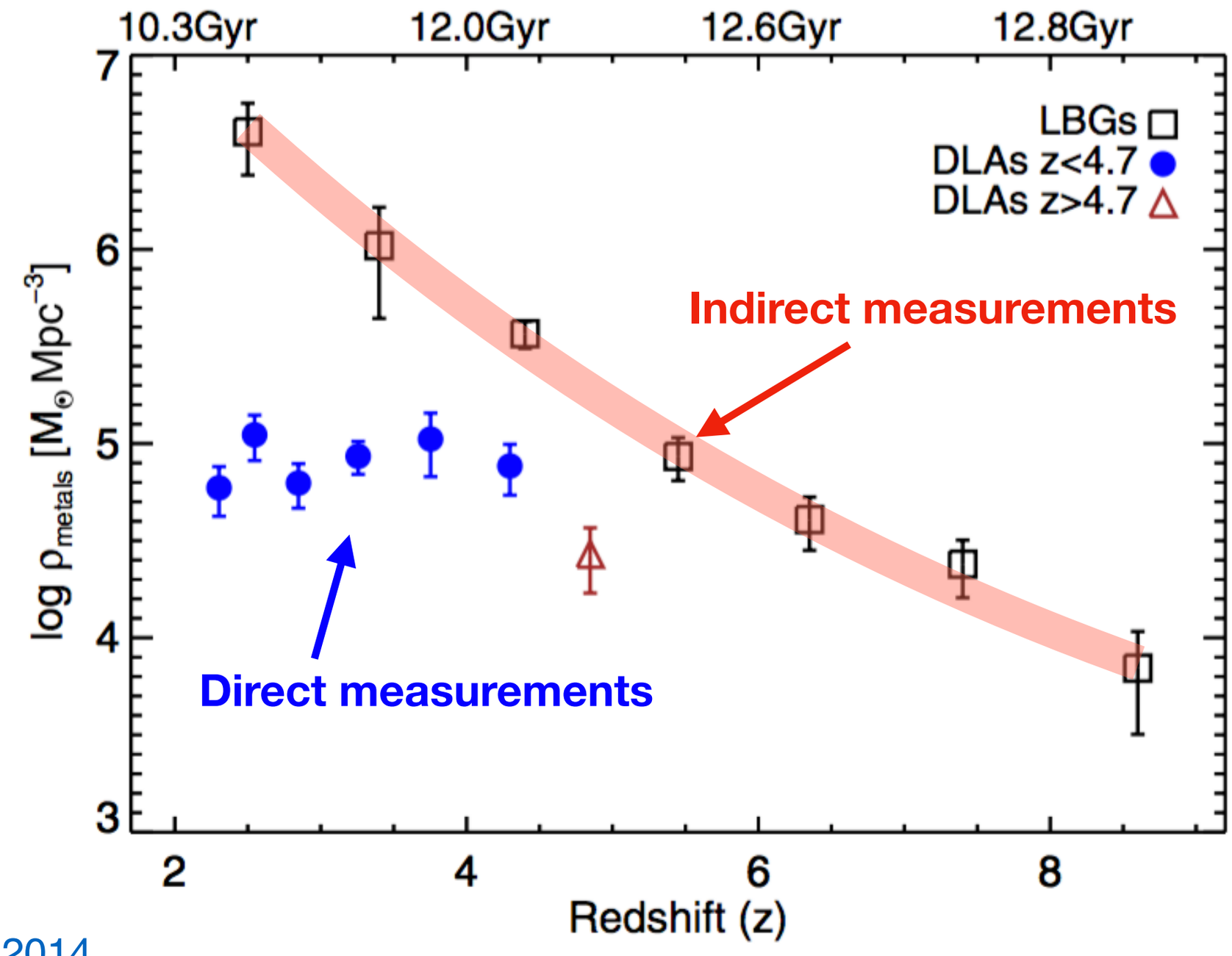


Pontzen et al. 2008

Simulations are still not able to match the redshift evolution!

Metallicity Evolution in DLAs

The chemical evolution is important for models of galaxy evolution, supernova rates, chemical yields and cosmic star formation



Rafelski et al. 2014

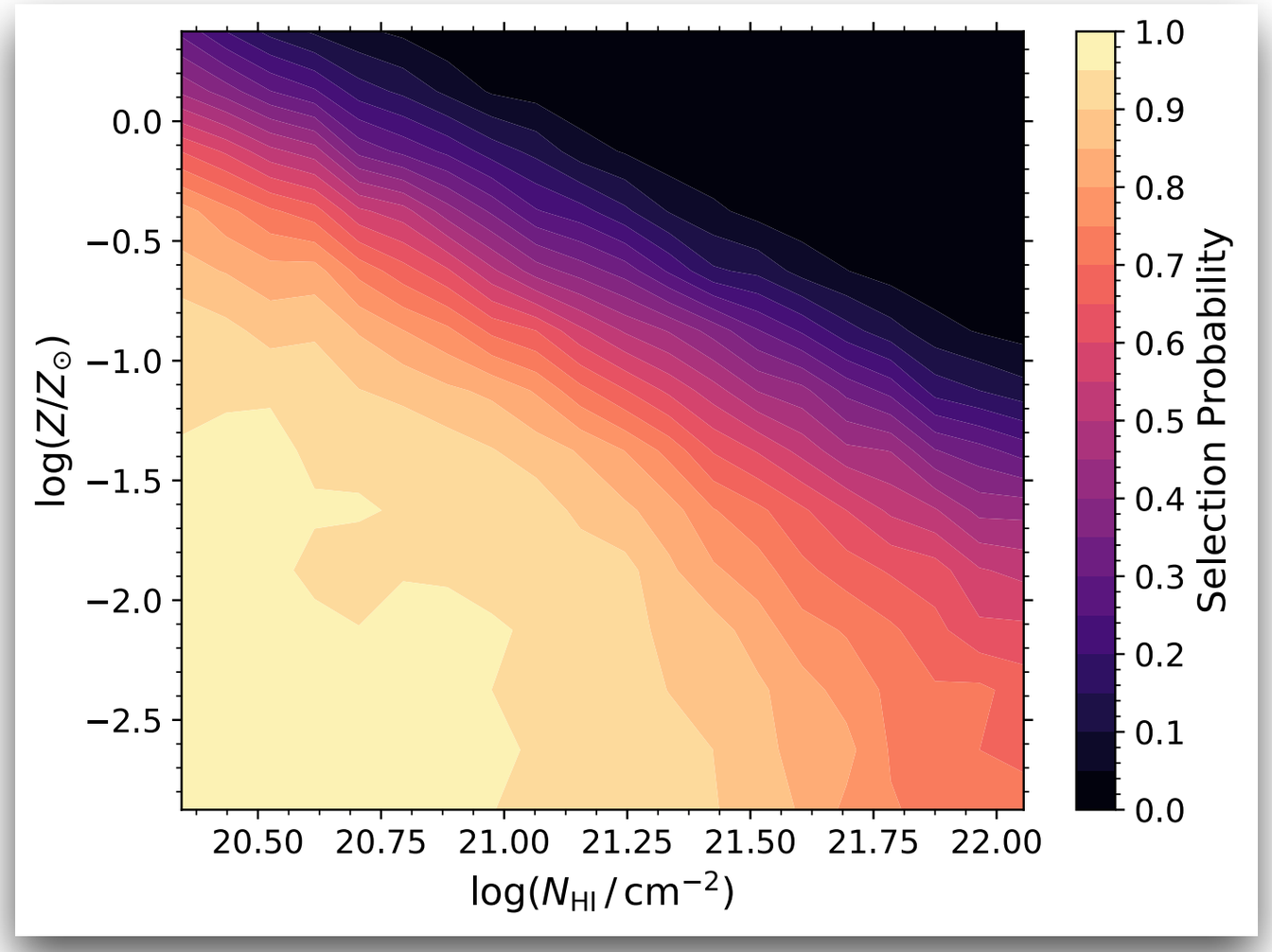
Dust bias in Optical Qusar Samples

Problem: Quasars are mostly selected by optical color criteria

⇒ Dust in foreground abs. system changes the colors

⇒ High-z quasars look like stars in optical colors

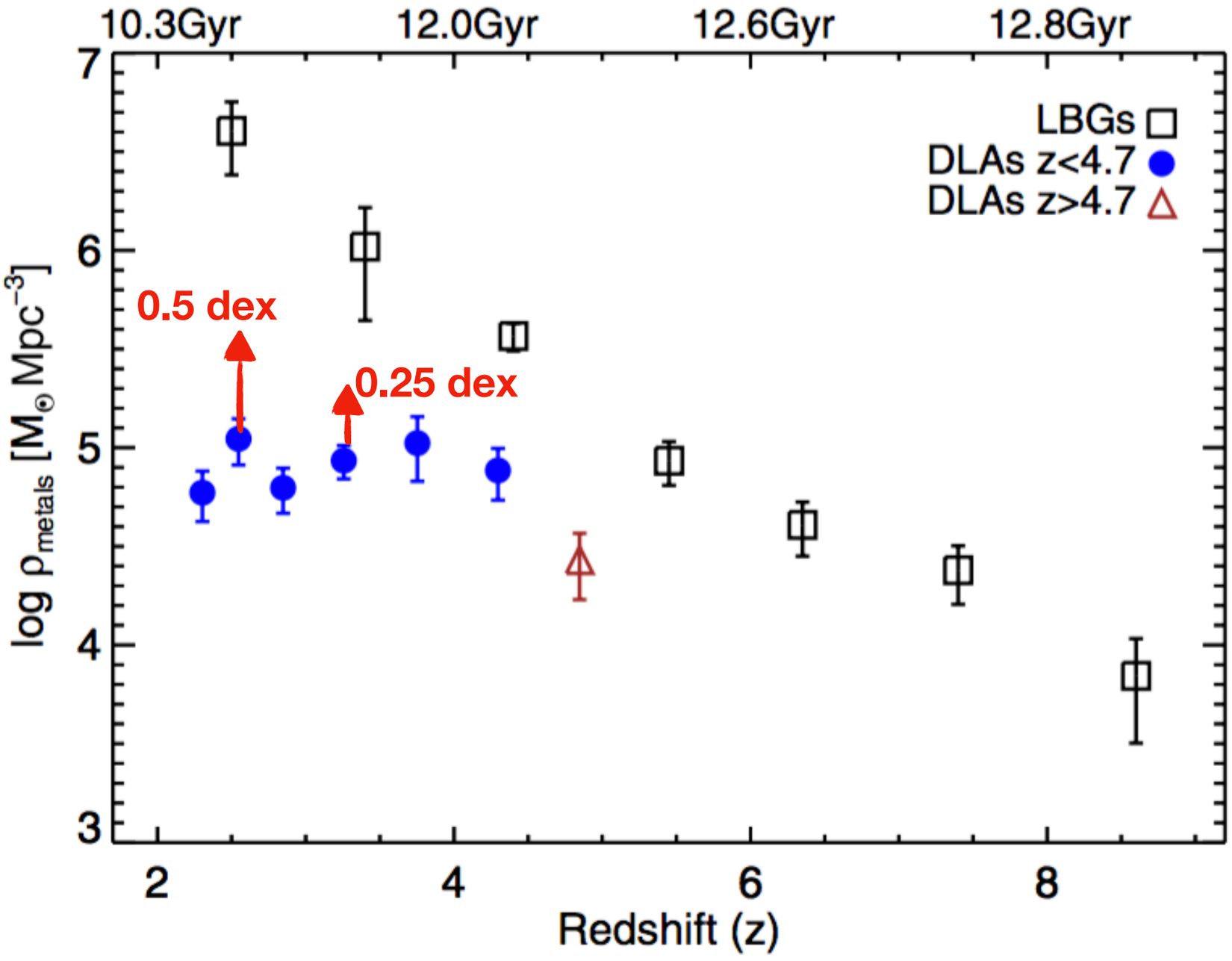
Selection effects create a **bias against absorption sightlines** which **depends on redshift** !



Krogager et al. 2019

Dust Bias on Metallicity

Calculated bias correction for SDSS DR7 (Krogager et al. 2019)



Challenges for Absorption Spectroscopy

Spectral Resolution : at least R ~ 6000 is needed to measure metal abundances

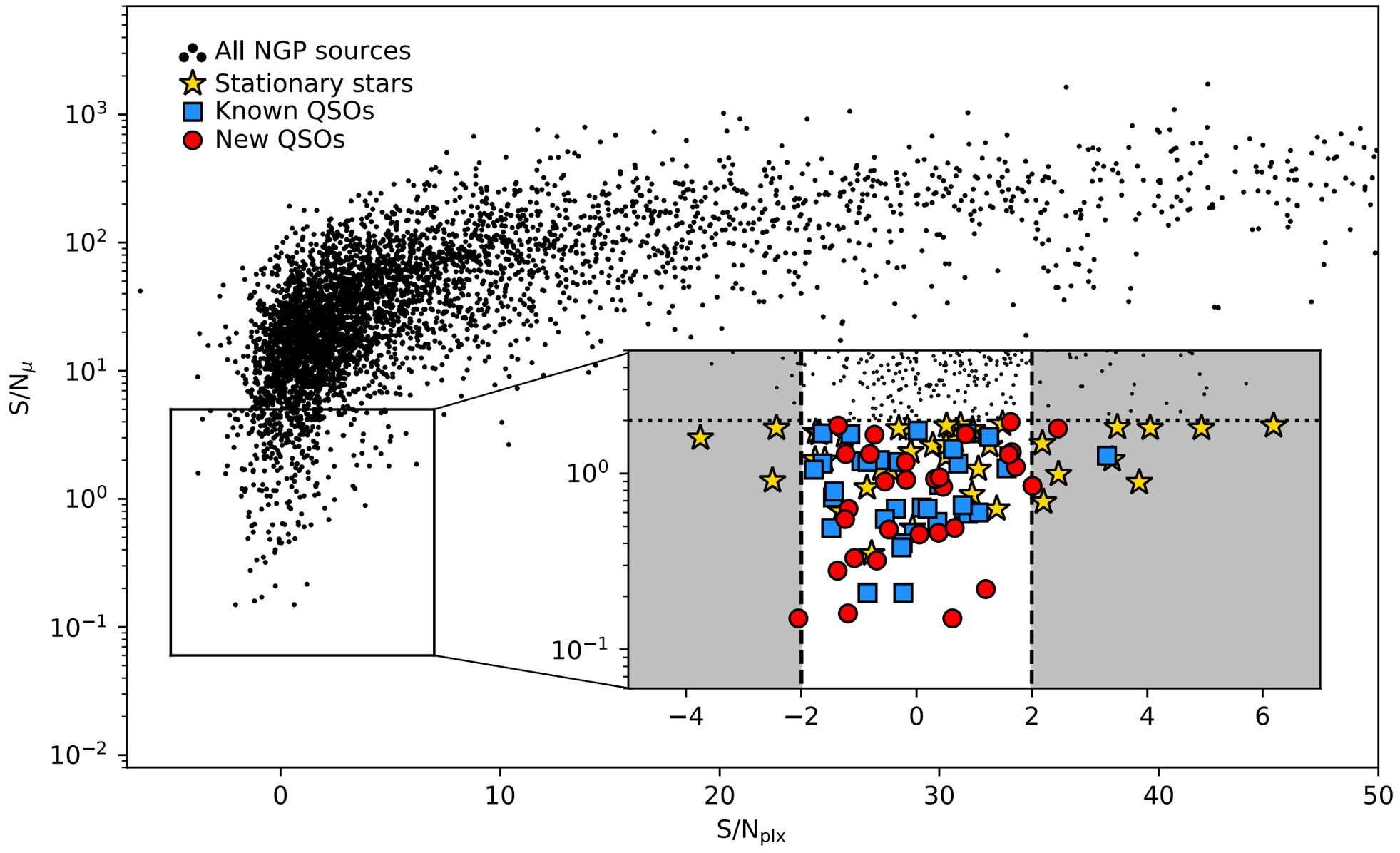
With 4MOST we can do this directly ⇒ no need for expensive follow-up

Cross-validation with higher resolution data using UVES archival data
and 4MOST HR spectra (PI: Céline Péroux).

We’re planning simulations of systematics in spectral fitting using synthetic data:
VoigtFit (Krogager 2018).

Survey Details: Target Selection

Purely selected based on astrometry: zero proper motion (at 2σ; 95% completeness)
Possibly with a cut on parallax (currently being investigated).



Heintz et al., in prep.

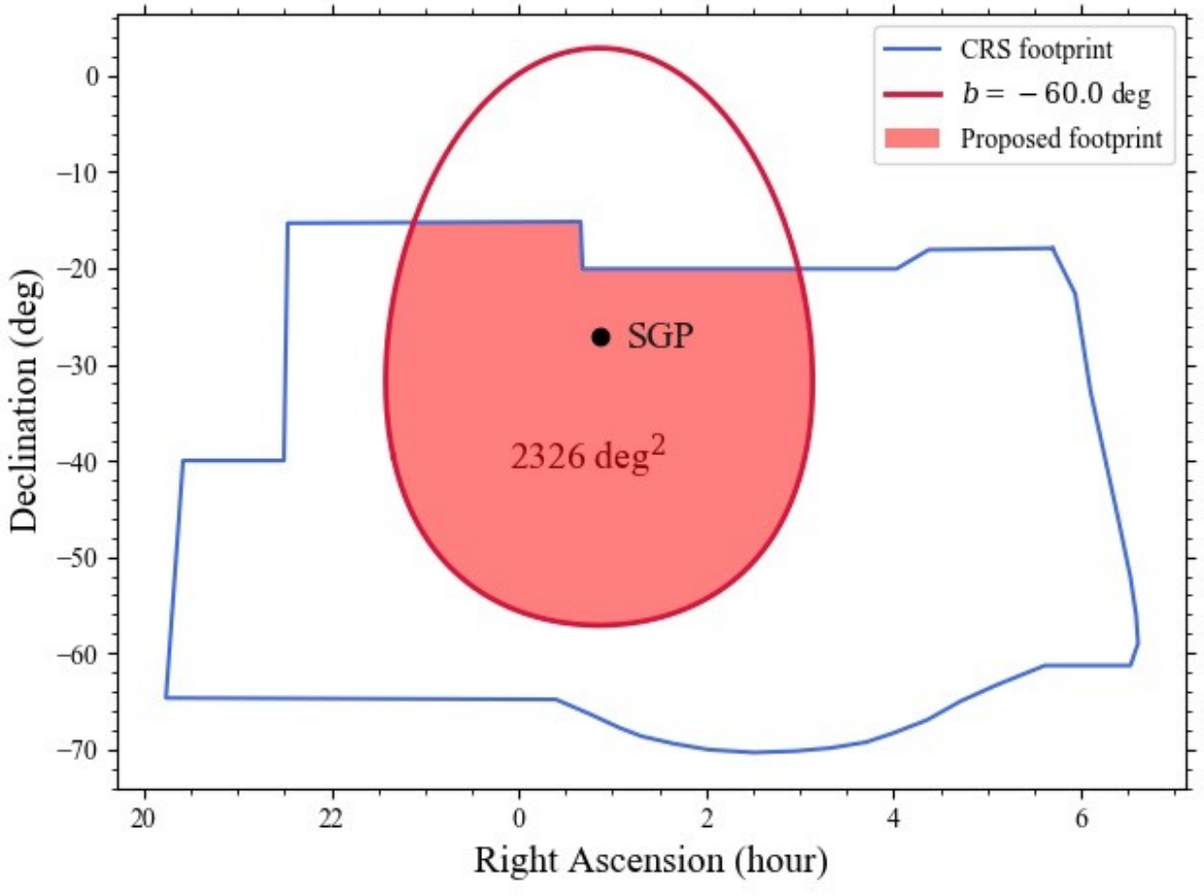
Survey Details

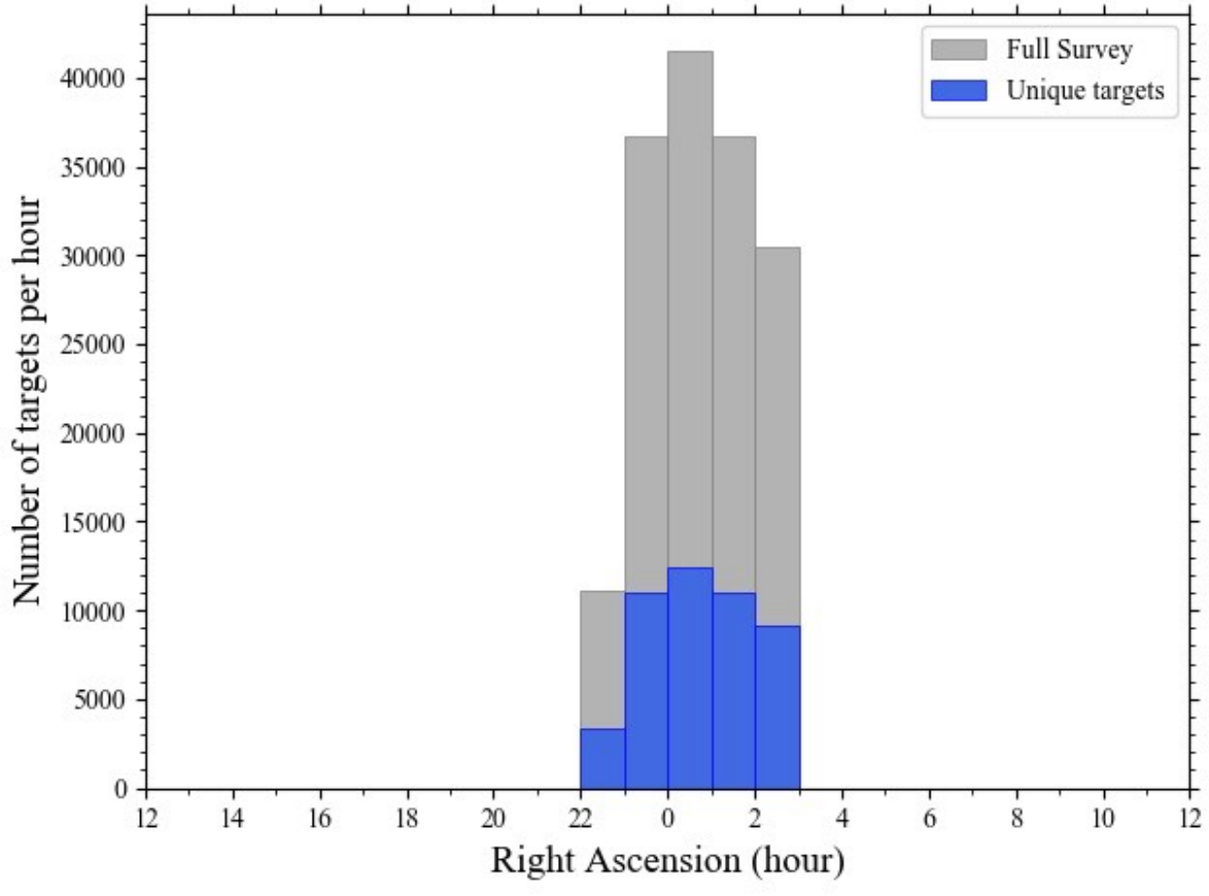
Centred on South Galactic Pole: minimizes stellar contamination

A large fraction will be stars: ~45% averaged over the survey area (Heintz et al. 2015)

- Potential overlap with the S1 survey (Halo stars).
- Complementary to S6 (AGN) and S8 (CRS)

Target distribution is even on sky: ~50 deg^{-2}

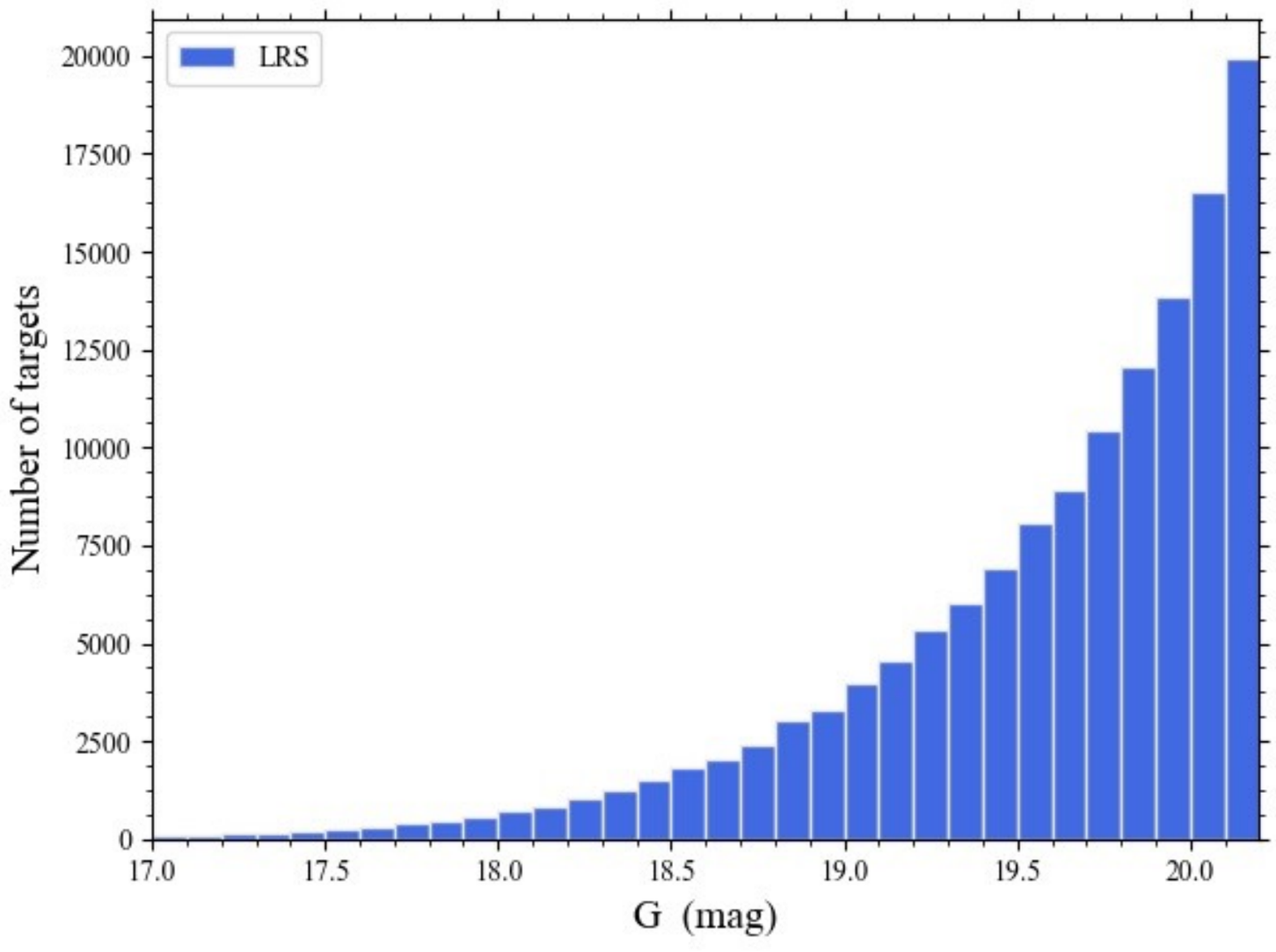




Survey Details: Signal-to-Noise

- for DLA identification : ~5 $Å^{-1}$ (unabsorbed continuum @ 480 nm)
- for BAL identification : ~10 $Å^{-1}$ (unabsorbed continuum @ 600 nm)
- for metal abundances : ~10 $Å^{-1}$ (unabsorbed continuum @ 650 nm, R ~ 6000)

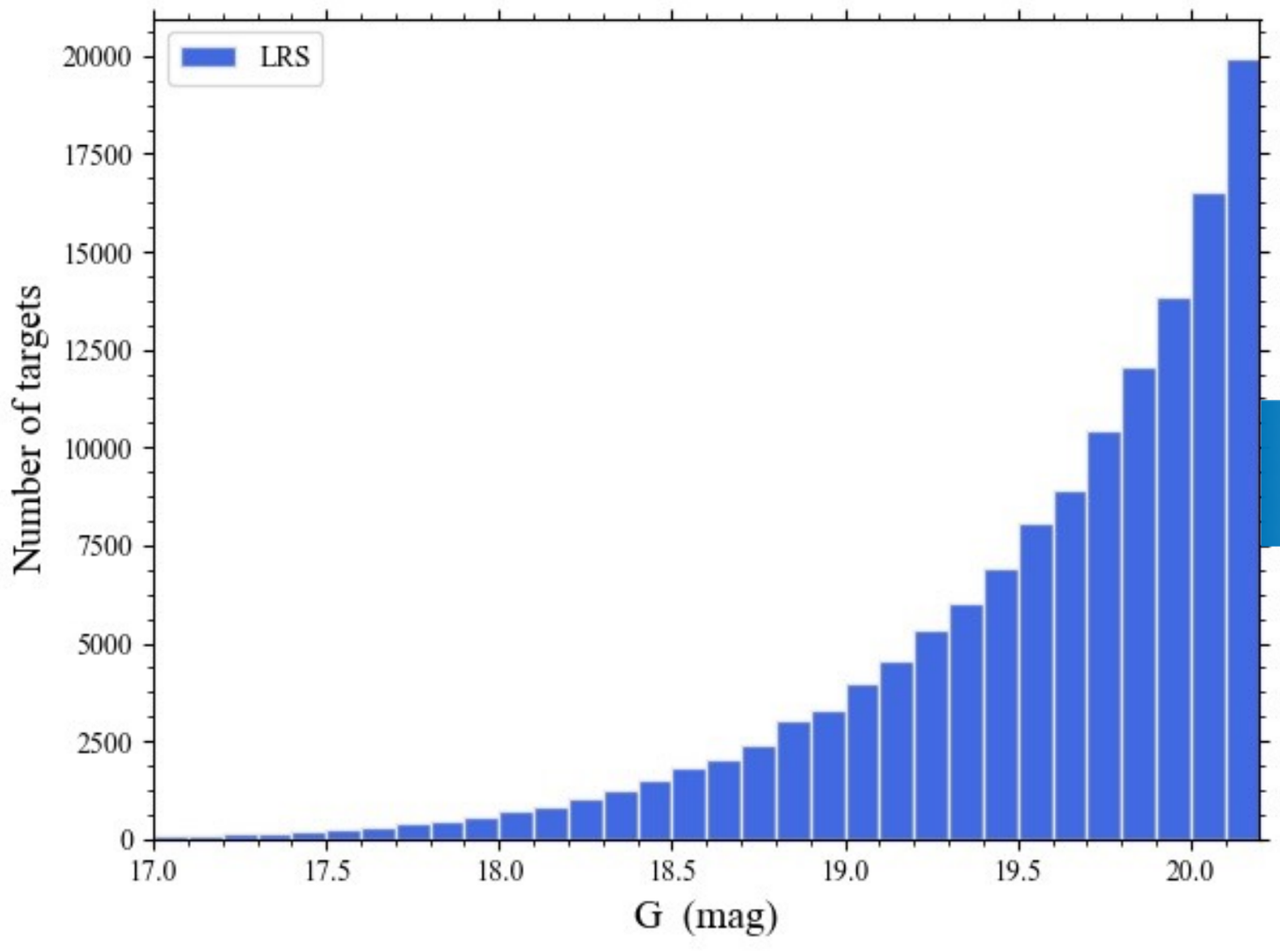
Exp. time of ~1 hr is sufficient



Potential for Supplementary Targets

Selecting stationary sources down to the limit of Gaia: G < 21

- These are available over the entire sky
- Provide a balance in terms of stellar and extragalactic science.



Lower completeness but still unbiased

Not suitable for absorption analysis

but we can identify rare objects

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The Unbiased Quasar Legacy Survey

A Purely Astrometric Quasar Survey: based only on Gaia proper motions (G < 20.2)

~120.000 quasar candidates, highly complete, no color or redshift bias.

Low Resolution observations of ~1hr per target.

1. **Study details of quasar evolution and BAL quasars**
   ~65.000 quasars of which ~20.000 BAL quasars
   - Physical properties of quasar outflows using SimBAL: density, ionisation parameter…
   - Spectral classification using FeLoNET
   - Black hole mass estimates, line-widths, fluxes

2. **Neutral Gas and Chemical Enrichment over Cosmic Time**
   ~2000 DLAs at z > 2, comparable to SDSS analysis (Noterdaeme et al. 2012)
   - Measurement of equivalent widths, N_{HI} column, metallicity
   - Identification of absorption lines

Unbiased training set for future classification algorithms!

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