# Tracing the Milky Way Circum-Galactic Medium with Optical Spectroscopy

Abra Geiger
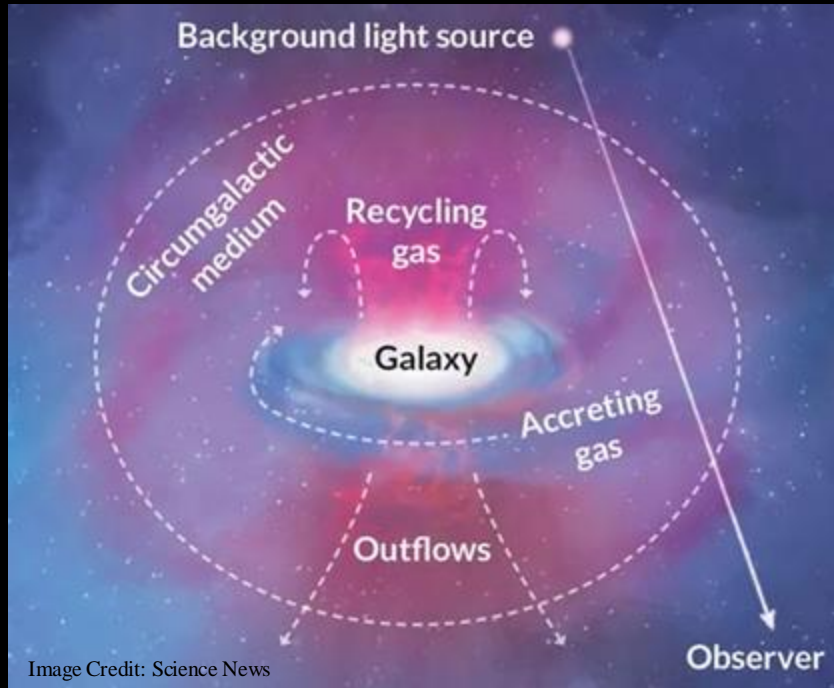*Mentor: Vikram Ravi*

The Circum-Galactic Medium (CGM)

- Gaseous halos surrounding galaxies

- Galactic disk -> CGM -> intergalactic medium

- Informs theories of galaxy evolution and the fraction of baryonic matter

Image Credit: Tumlinson et al 2017

Studying the CGM
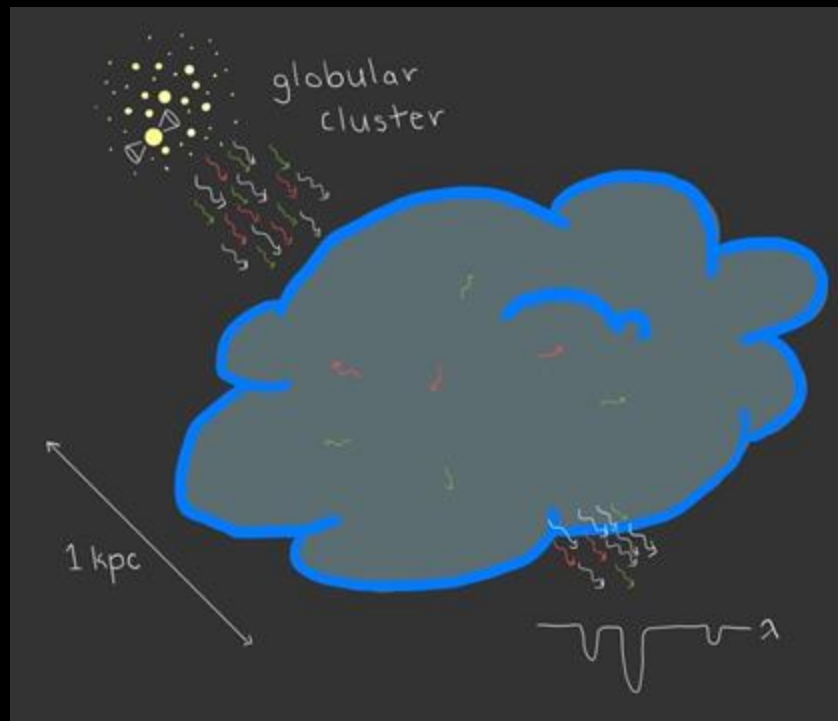

Image Credit: Science News
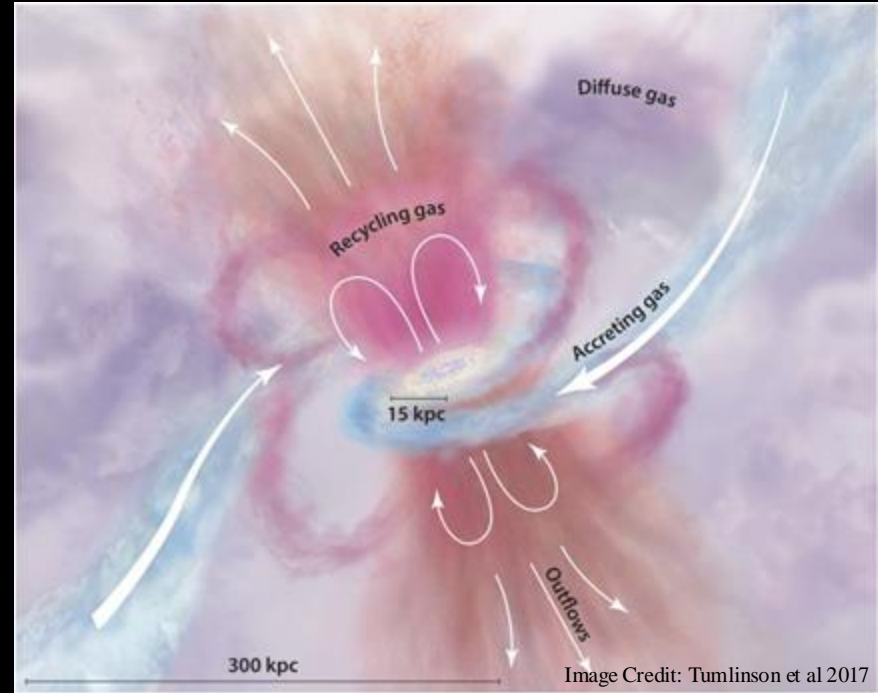
- Absorption against bright background sources, commonly UV

- The Via Project - we focus on the Milky Way CGM in the optical band

- Globular clusters as background sources

$$DM = \int n_e d\ell$$

Our Approach: Cloudy

Spectral Synthesis Code: photoionization

equilibrium in astronomical media

Cloudy Simulation Parameters

Incident Radiation Field: CMB, CRB, galactic, extragalactic, and globular cluster radiation

Cloud Composition: 0.1 H cm^{-3}, $Z = 0.1 * Z_\odot$, half of ISM grains, Jenkins 2009 depletion model, filling factor of 0.3, 10 km/s isotropic turbulence

Cloud Geometry: 1 kpc deep, covering fraction of 1

Cloudy: Our Analysis

- Clouds varying in temperature, density, depth, metallicity, and grain abundance

- Equivalent width of the more significant optical band absorption lines

- Dispersion measures (DMs)
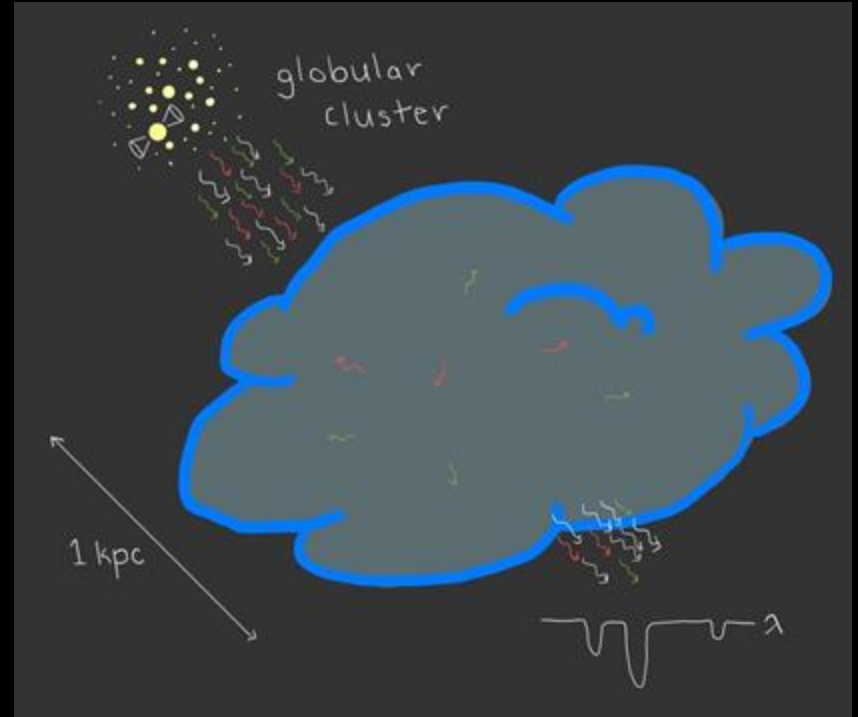
Cloudy Results: Absorption

Lines of importance: resonance lines

- NaI: λ=5890Å (D1) and λ=5896Å (D2)

$$M_{NaI/H} \approx 10^{-44}$$

- CaII: λ=3968Å (H) and λ=3934Å (K)

$$M_{CaII/H} \approx 10^{-41}$$

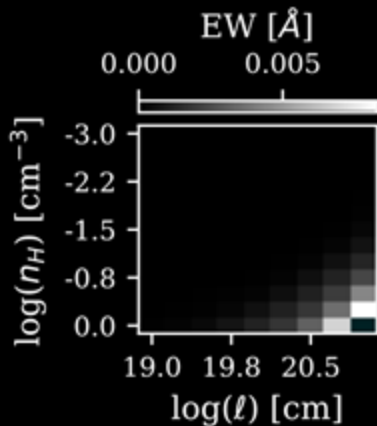- MgII: λ=2803Å and λ=2796Å

$$M_{MgII/H} \approx 10^{-38}$$

CaII

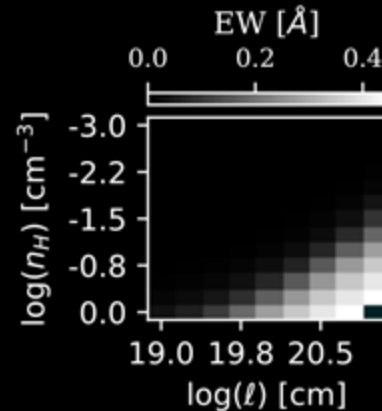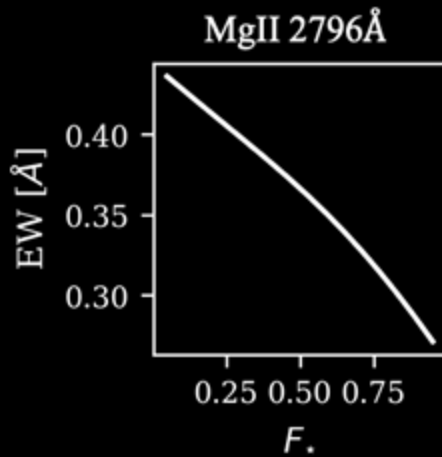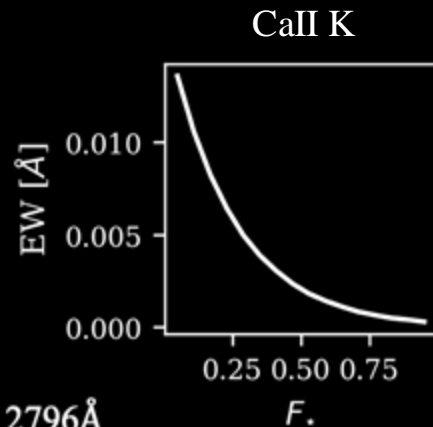# NaI
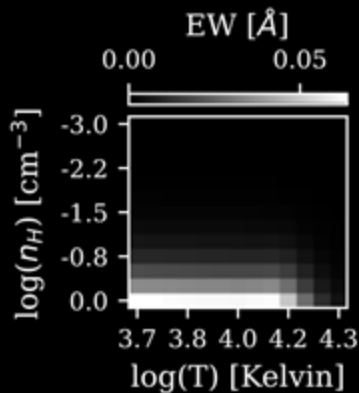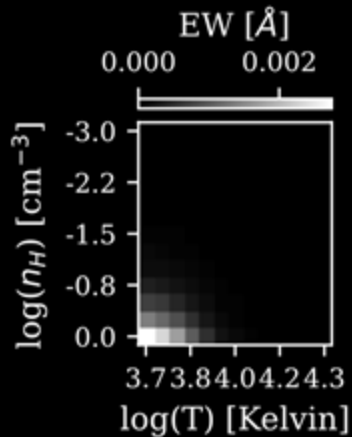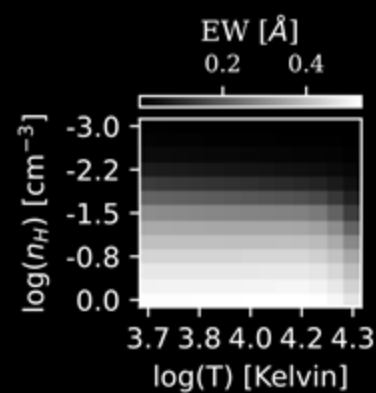
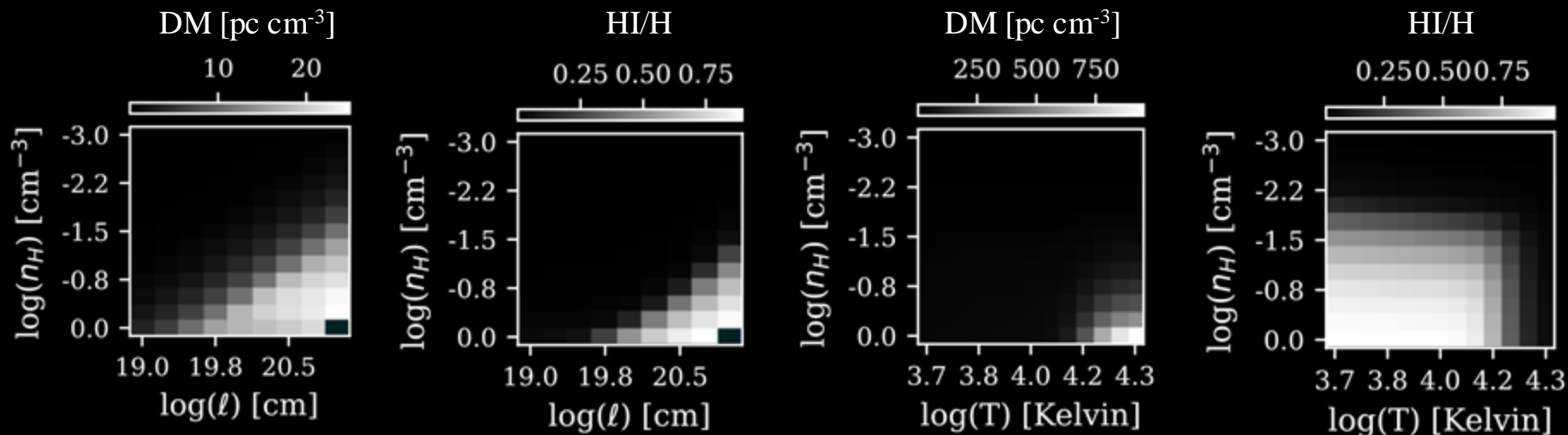Essentially no absorption

MgII 2796Å

Dust Depletion

- For these lines, depletion of gas-phase metals onto dust grains important

- Jenkins 2009 model, F_*

- Cloudy built in ISM abundances

- Jenkins 2009 aligns better

CaII K

MgII 2796Å

NaI D1
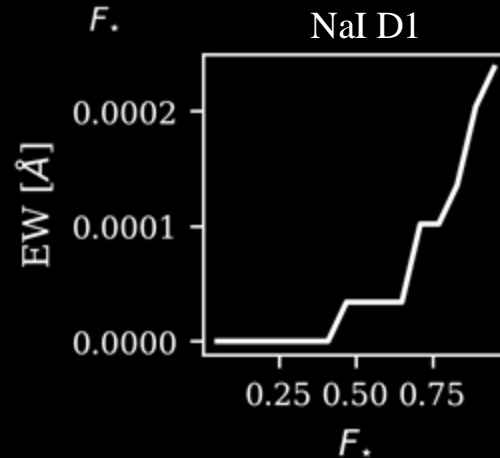
Dispersion Measure [pc cm⁻³]

Cloudy Results: Emission

- Dominance of hydrogen, as expected

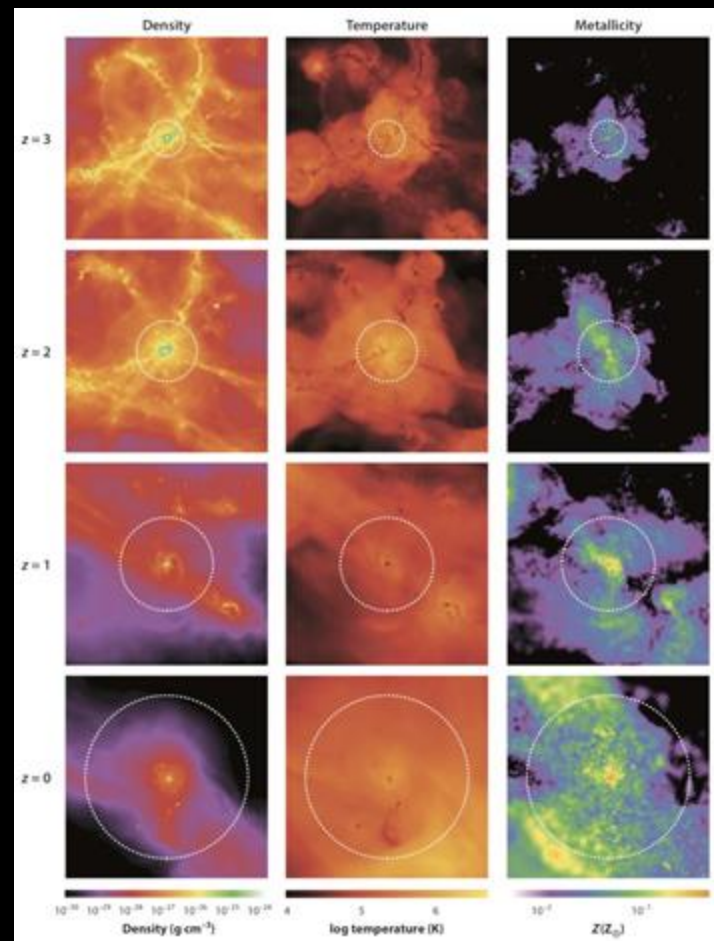- Diffuse emission is observationally challenging
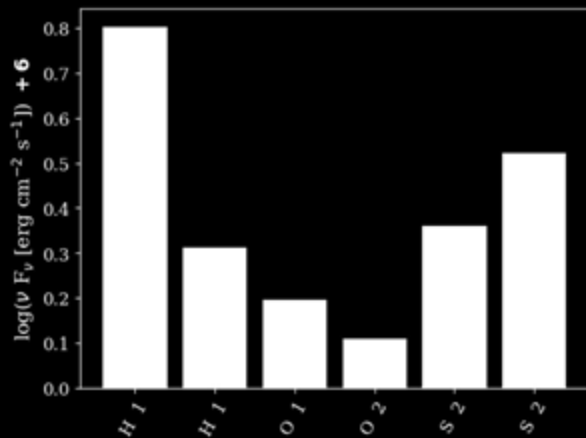
- Exciting prospects

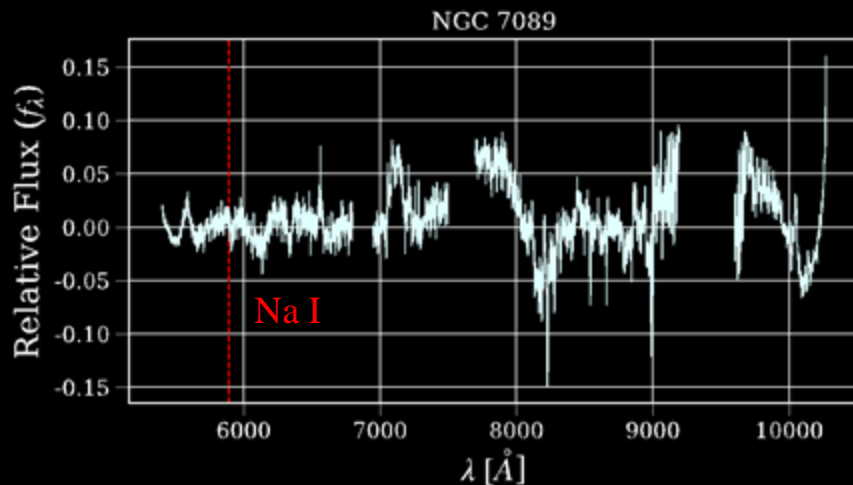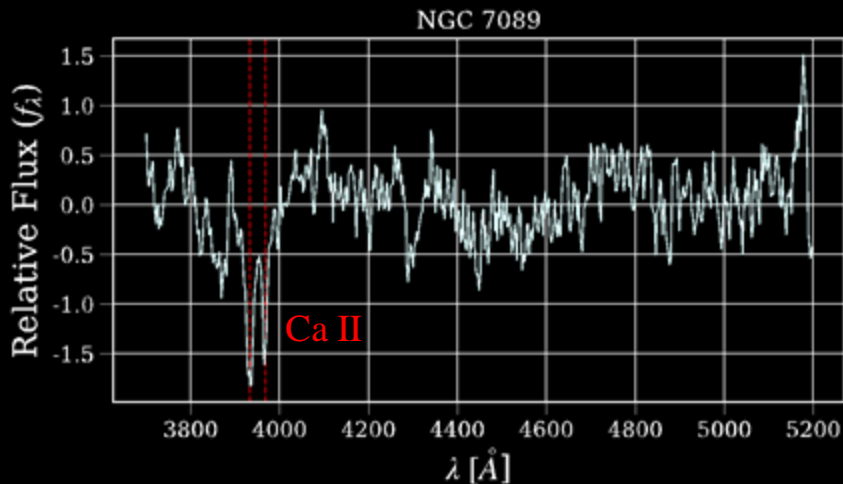

Image Credit: Tumlinson et al 2017

Observations

Keck

- Leavens 3: 62 kpc, no pulsars

- NGC 7089: 11.5 kpc away, 2 pulsars

- M53: 17.9 kpc away, 4 pulsars

Palomar

- NGC 7006: 39 kpc, no pulsars

- Palomar 14: 74 kpc, no pulsars

Conclusions and Future Work

- Simulated DMs > Observed DMs: these clouds are more neutral than modeled

- Dust plays an important role for the elements of concern

- Write up results, forecasting for projects like Via

- Survey of archival SDSS halo star spectra

Thank You!

Questions?

CGM	Studying the CGM	Cloudy	Our Cloudy Analysis

	Observations	Conclusions	