# An Extreme Population of Heavily Buried AGN

DARTMOUTH

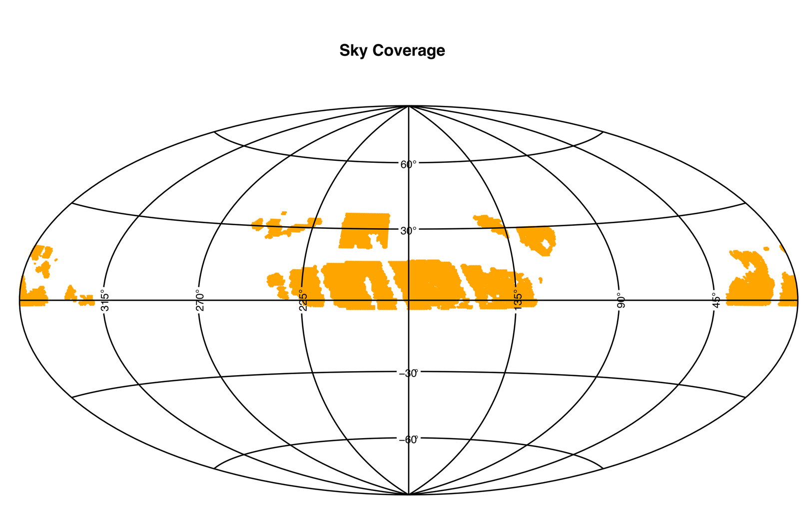
**Christopher M. Carroll**, Ryan C. Hickox
Dartmouth College

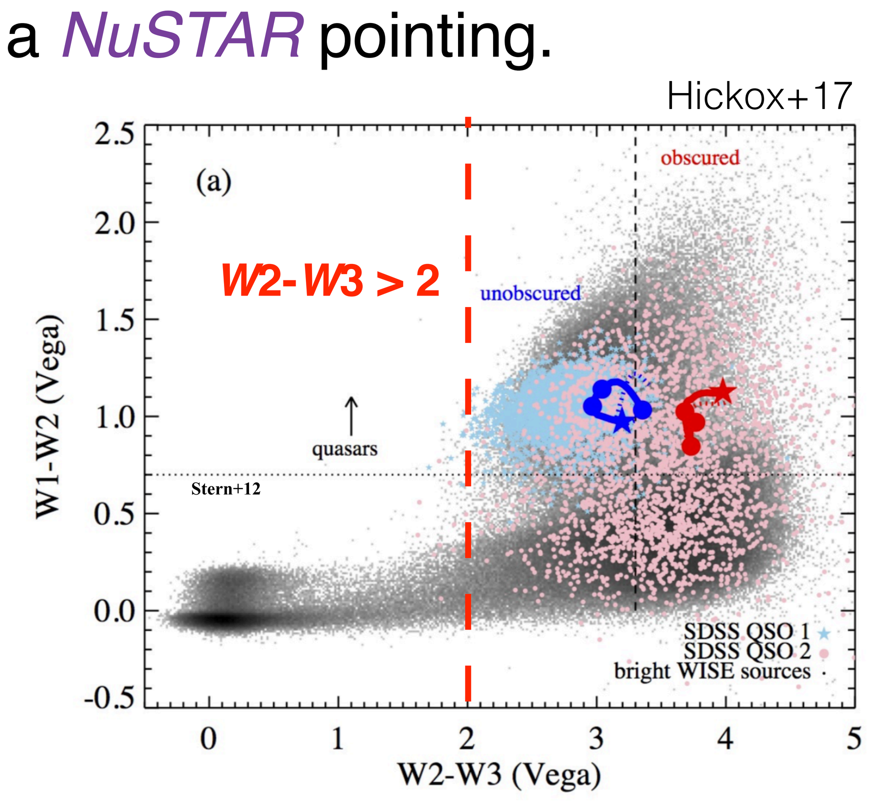
## Objective

Obscured quasars represent a large fraction of the total number of powerful active galactic nuclei (AGN). Understanding the complete quasar population requires a full accounting of these sources, which is difficult in the presence of complex selection effects. Additionally, dust extinction in obscured quasars allow us to observe their host galaxies and make connections between AGN emission and physical properties of their hosts. Using optical to mid-IR broadband photometry we model the spectral energy distributions (SEDs) for these systems with no prerequisite AGN selection and uncover dozens of powerful obscured quasars which lack hard X-ray counterparts in *NuSTAR* survey and serendipitous fields. At the *NuSTAR* flux limits, a lack of detection indicates extremely heavy obscuration with hydrogen column densities beyond $10^{25}$ cm$^{-2}$. This points to a population of very deeply buried AGN.

## Quasar Sample

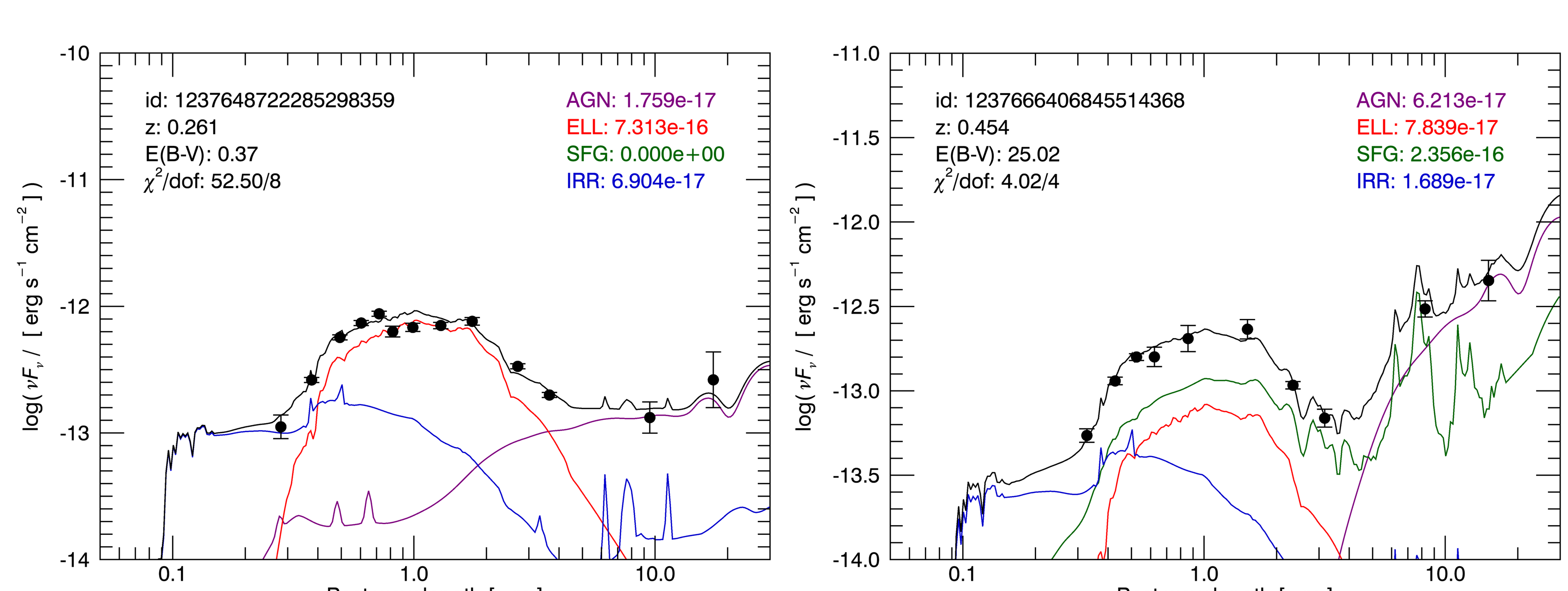
Combining data from SDSS, UKIDSS, and *WISE* (XDQSOz, DiPompeo et al. 2015; unWISE, Lang et al. 2016), our sample consists of ~8 million galaxies with redshift measurements. To address selection effects we make no prior selection to target AGN. Of our sample, 58 are detected by *NuSTAR* in the COSMOS field and Serendipitous Survey, while an additional ~4000 are undetected but within a *NuSTAR* pointing.



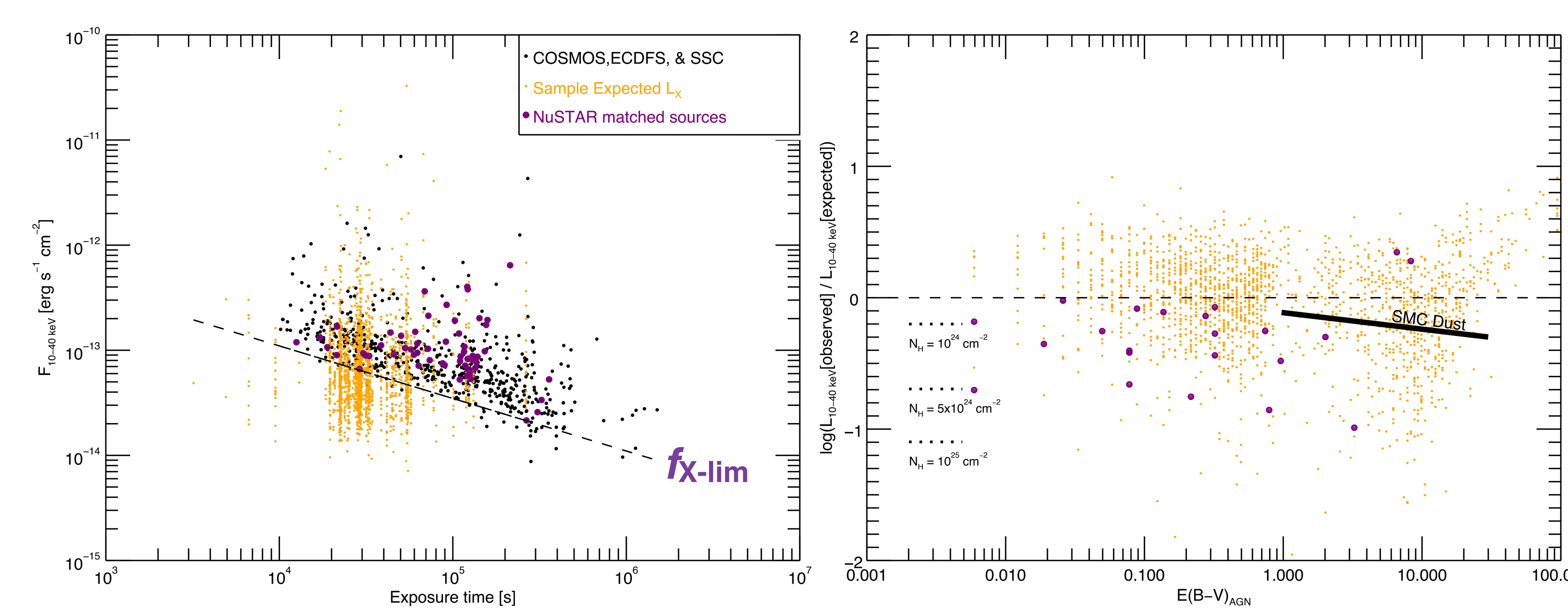

## SED Modelling

We model our SEDs with a combination of galaxy+AGN templates from Assef et al. (2010) and Kirkpatrick et al. (2015). We simulate nuclear obscuration with an SMC-like extinction curve for λ < 3300 Å (Gordon & Clayton 1998), and a Galactic extinction curve at longer wavelengths (Cardelli et al. 1989). We calculate 6-micron AGN luminosities and find ~3 million candidate AGN with $L_{6\mu m} \geq 10^{43}$ erg s$^{-1}$.



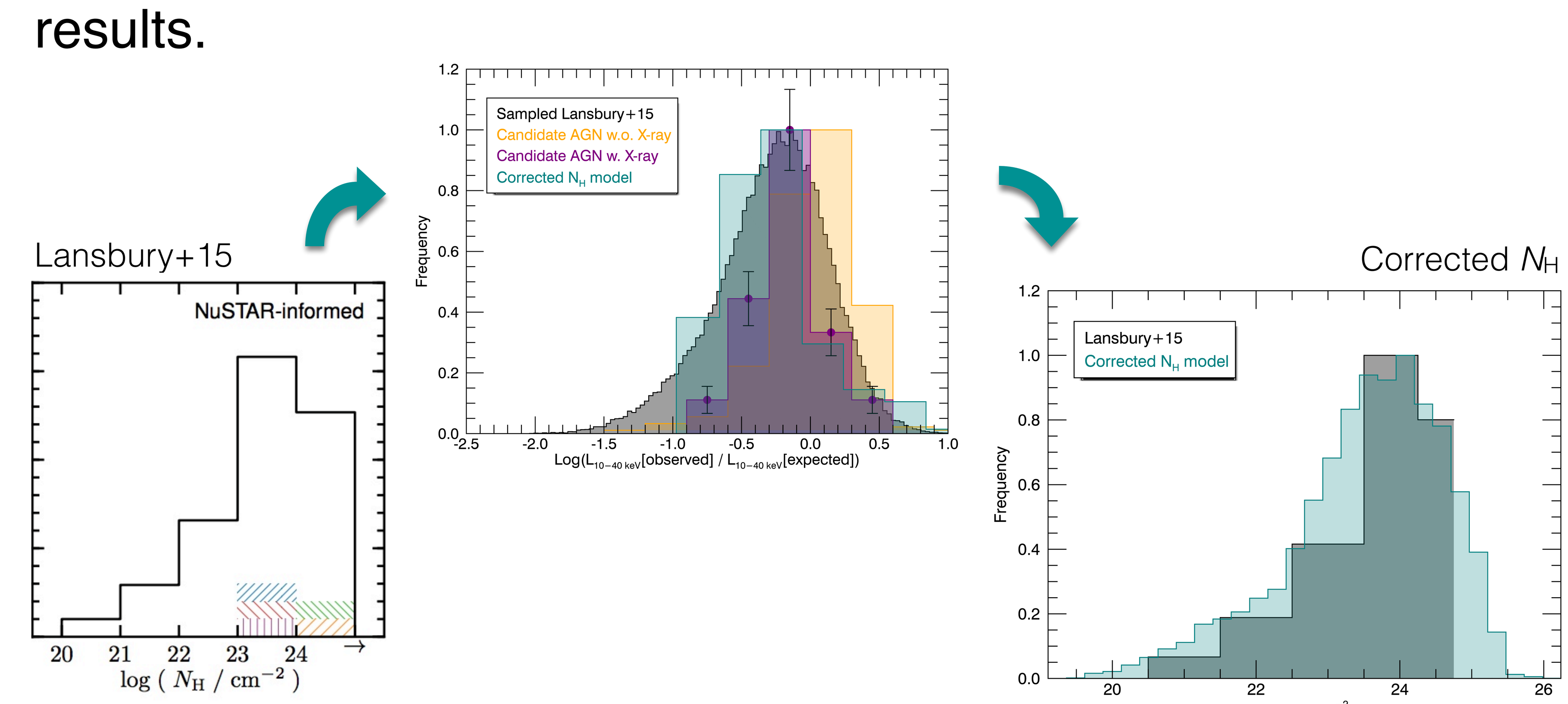

## X-ray Flux Limit and Luminosities

Using the $L_X - L_{MIR}$ relation of Chen et al. (2017), we determine the X-ray flux detection threshold ($f_{X\text{-lim}}$) of *NuSTAR* and apply this upper limit to our undetected sources. We use the ratio of observed/expected $L_X$ as a proxy for obscuration and estimate the distribution of $N_H$ for our candidate AGN.




## Forward Modeling the $N_H$ Distribution

We sample the observed $N_H$ distribution from Lansbury et al. (2017) and model an additional gaussian component representative of highly obscured sources ($N_H \geq 10^{24}$ cm$^{-2}$), which we convert to match to our observed/expected $L_X$ ratio. We find that a significant population of heavily obscured sources with $N_H \approx 10^{24}$-$10^{25}$ cm$^{-2}$ must exist to reproduce our results.




## Conclusion

We model the SEDs of candidate AGN within the SDSS+UKIDSS+*WISE* footprint and obtain estimates of IR and X-ray luminosities. We compute the expected $L_X$ from Chen et al. (2017) and use the ratio of observed to expected $L_X$ as a proxy for nuclear obscuration. We forward model the $L_X$ ratio and determine that a significant population of X-ray undetected, heavily obscured AGN must exist with $N_H > 10^{24}$ cm$^{-2}$ to account for the observed AGN luminosities.

### References

Assef et al. 2010, ApJ, 713, 970
Cardelli et al. 1989, ApJ, 345, 245
Chen et al. 2017, ApJ, 837, 145
DiPompeo, et al., 2015, MNRAS, 452, 3124
Gordon & Clayton 1998, ApJ, 500, 816
Hickox et al. 2017, ApJ, 849, 53
Kirkpatrick et al. 2015, ApJ, 814, 9
Lang et al. 2016, AJ, 151, 36
Lansbury et al. 2015, ApJ, 809, 115
Stern et al. 2012, ApJ, 753, 30

### Acknowledgements

This material is based upon work supported in part by the National Science Foundation under Grant Nos. 1211096 and 1515986, and the NASA ADAP under Grant No. NNX12AE38G. This work made use of data from the Southern African Large Telescope (SALT). Special thanks to the AAS for support through the International Travel Grant 2018-1.