CLU Visual Classification

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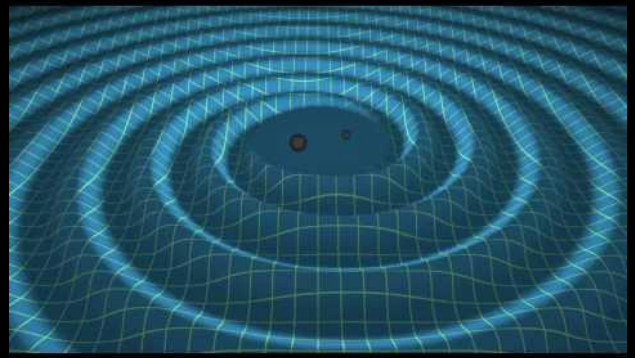
Motivation

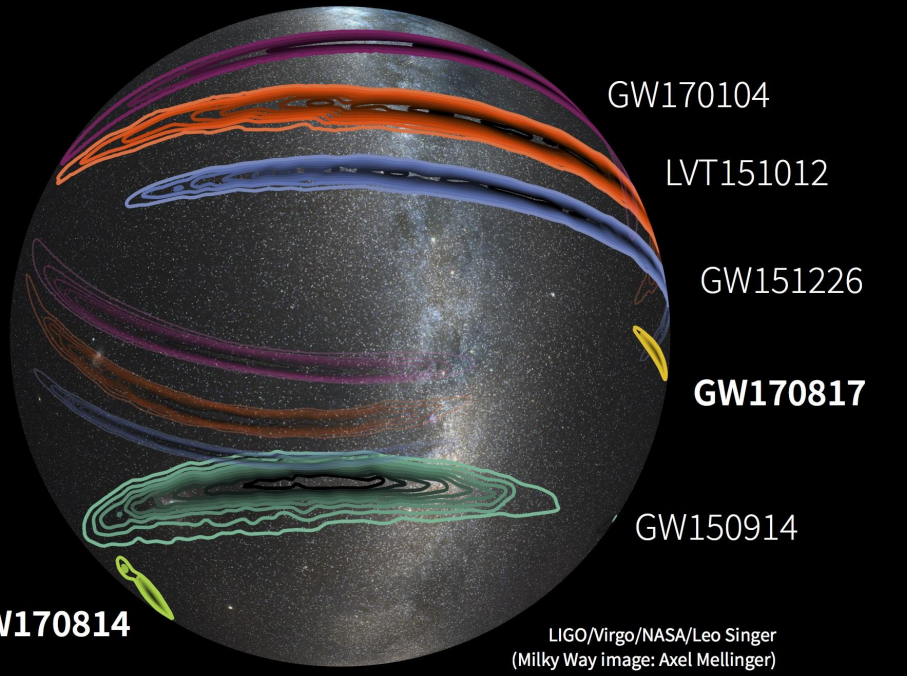


Credit: https://www.ligo.caltech.edu/gallery

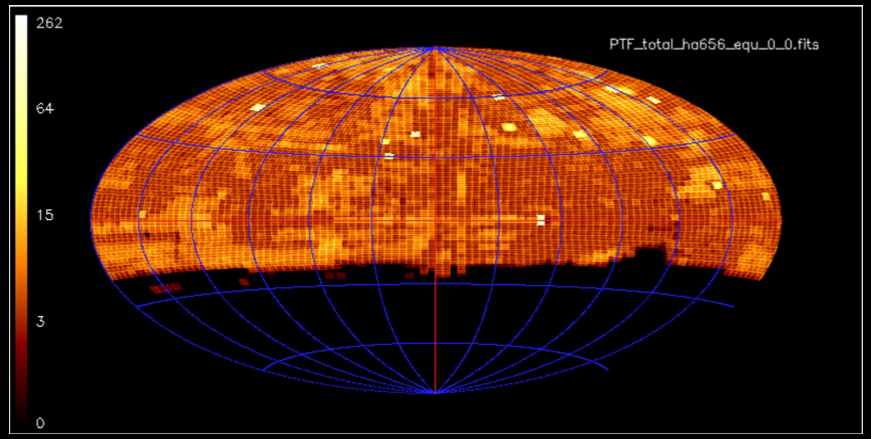
LIGO Gravitational Wave Events

- Gravitational waves enable exciting discoveries
- Hard to pinpoint due to large localizations
- Using galaxies can increase the efficiency of GW searches

GW event localizations

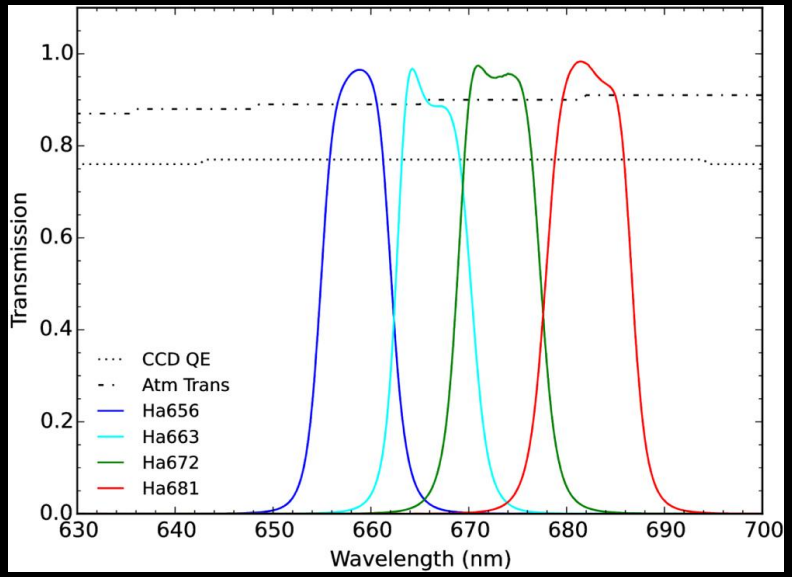


Motivation



The Census of the Local Universe (CLU)

- CLU is a survey designed to find 10s of thousands of galaxies in the local universe
  - 170,000 total candidates
  - star and junk contamination

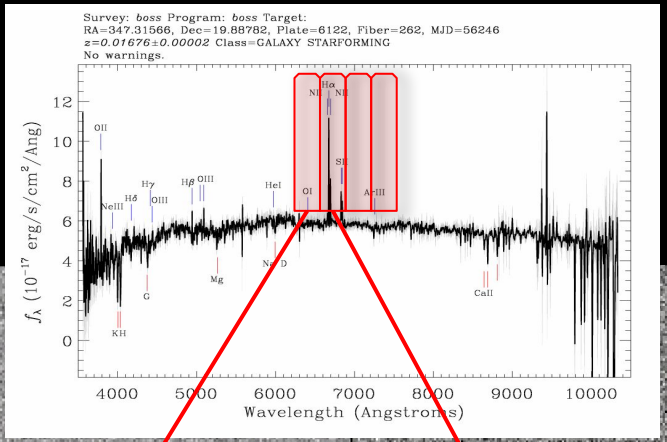


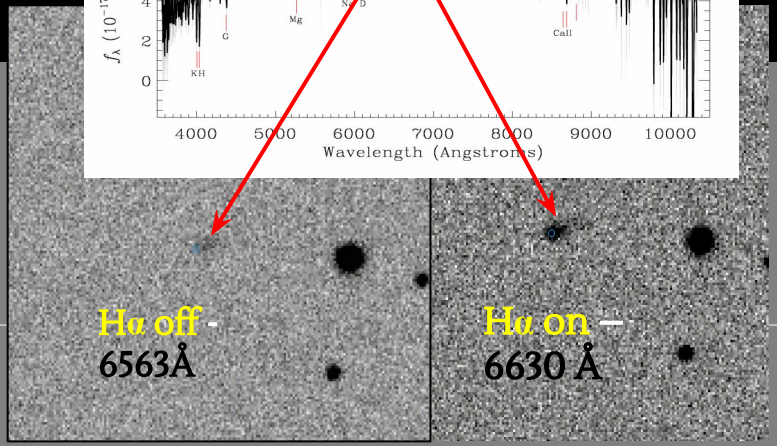
Narrow-band Hα Filter Properties

Filter Name	Filter λ (Å)	Filter Δλ (Å)	Redshift Range (#)
Hα1	6584.2	76.1	$-0.0026 < z < 0.0090$
Hα2	6663.7	77.9	$0.0094 < z < 0.0213$
Hα3	6730.9	90.1	$0.0187 < z < 0.0324$
Hα4	6822.1	92.1	$0.0325 < z < 0.0471$

Cook et al. (2019)

Method





Search By Params:

5.0	<= Csig <=	1000.0	
0	<= VisClas <=	5	
0.0	< RA <	10.0	
0.0	< Dec <	10.0	
2	<= N detections <=	100	
HaOff MagErr <=	0.5		

Constrast (0-1; default=0.05) 0.05 (higher = brighter)

FOV (arcsec) 50.0

Update Search

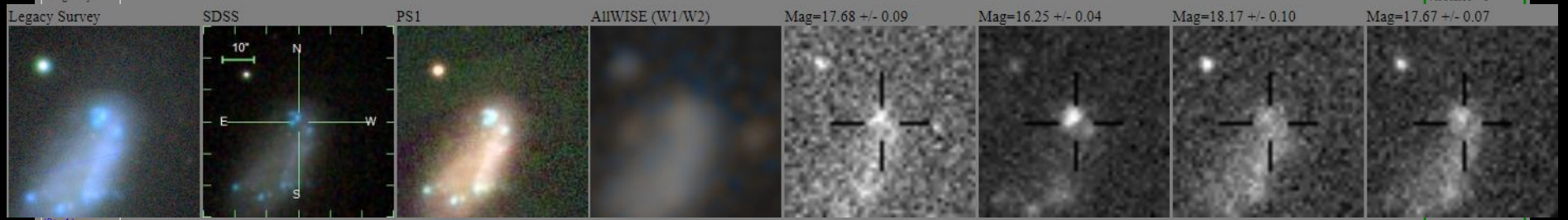
N objects found=298

Final Stack Mags:

Ha1 mag	Ha2 mag	Ha3 mag	Ha4 mag	Max(Csig)	Cand Filter
18.21+/-0.11	**18.02**+/-0.09	**15.15**+/-0.01	**18.17**+/-0.13	**100.82**	**13**

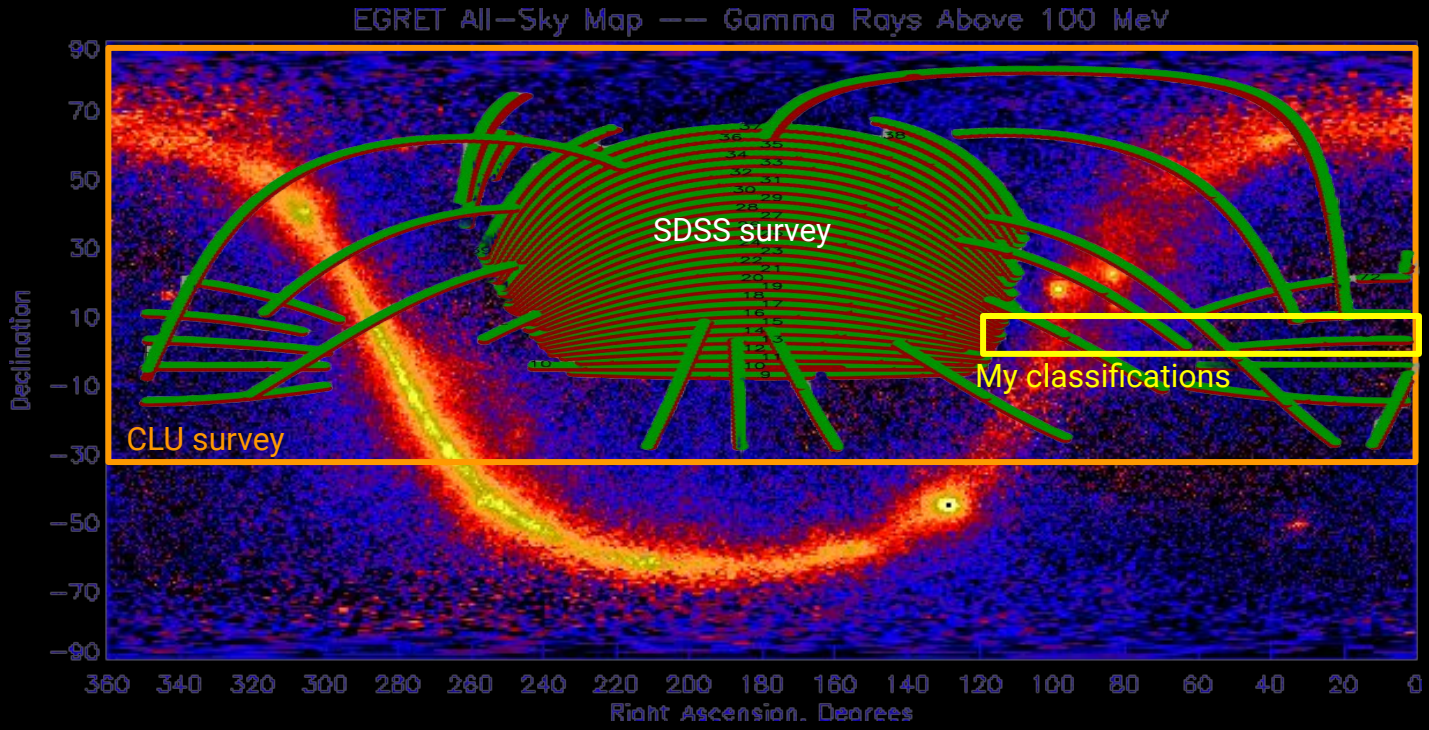
Galactic Lat = -59.551
star/galaxy =

VisClass = 3
VisClass1 = 3



(Stack)

Method



https://user-web.icecube.wisc.edu/~jkelley/galactic/unblinding.html

- SDSS took spectra of millions of objects, but in a limited area
- A small area was chosen due to time constraints
- Statistics can be extrapolated to the whole survey for an estimation of new galaxies

Classification Results

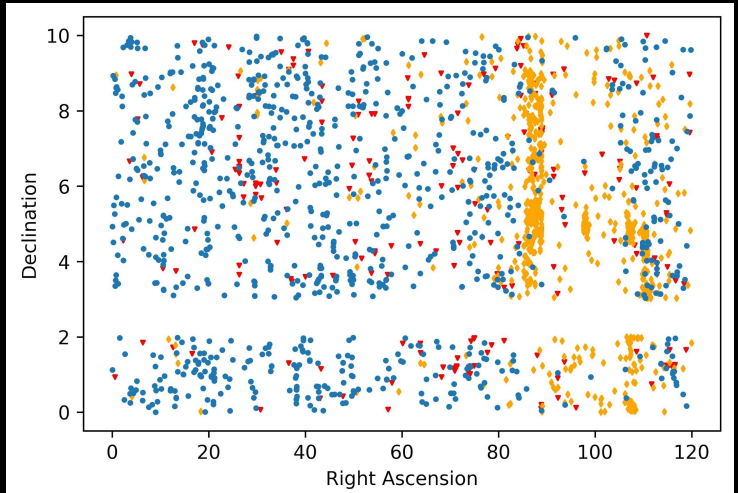
Distribution of candidates across the sky

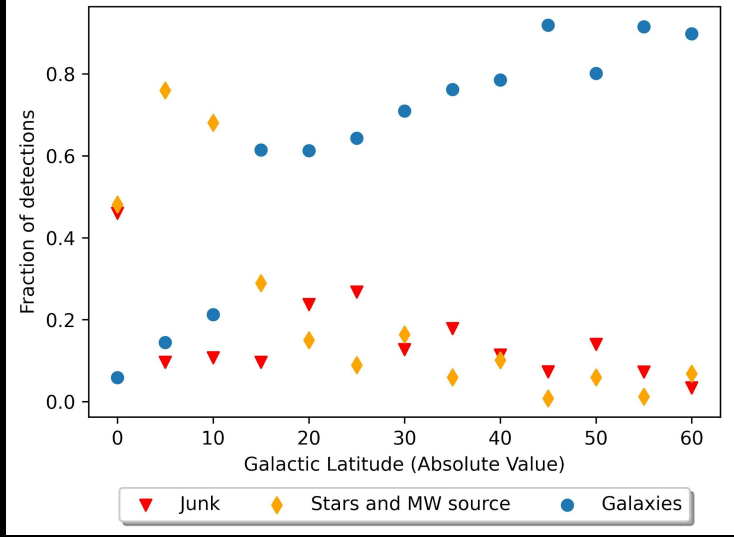
- star classifications are clumped in an area

Fraction of classifications with galactic latitude

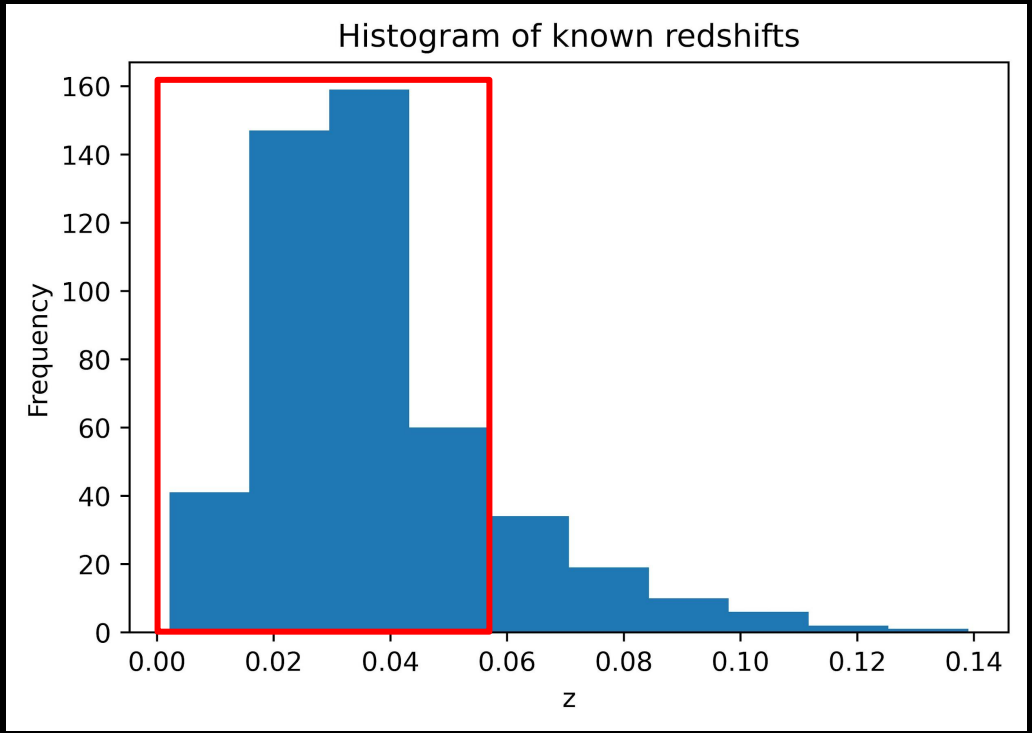
- classifications depend on proximity to the Galactic Plane

Object	% of candidates	# of classifications
Galaxies/PofG	49.6%	994
Stars/MWsrc	39.7%	796
Junk	10.7%	214



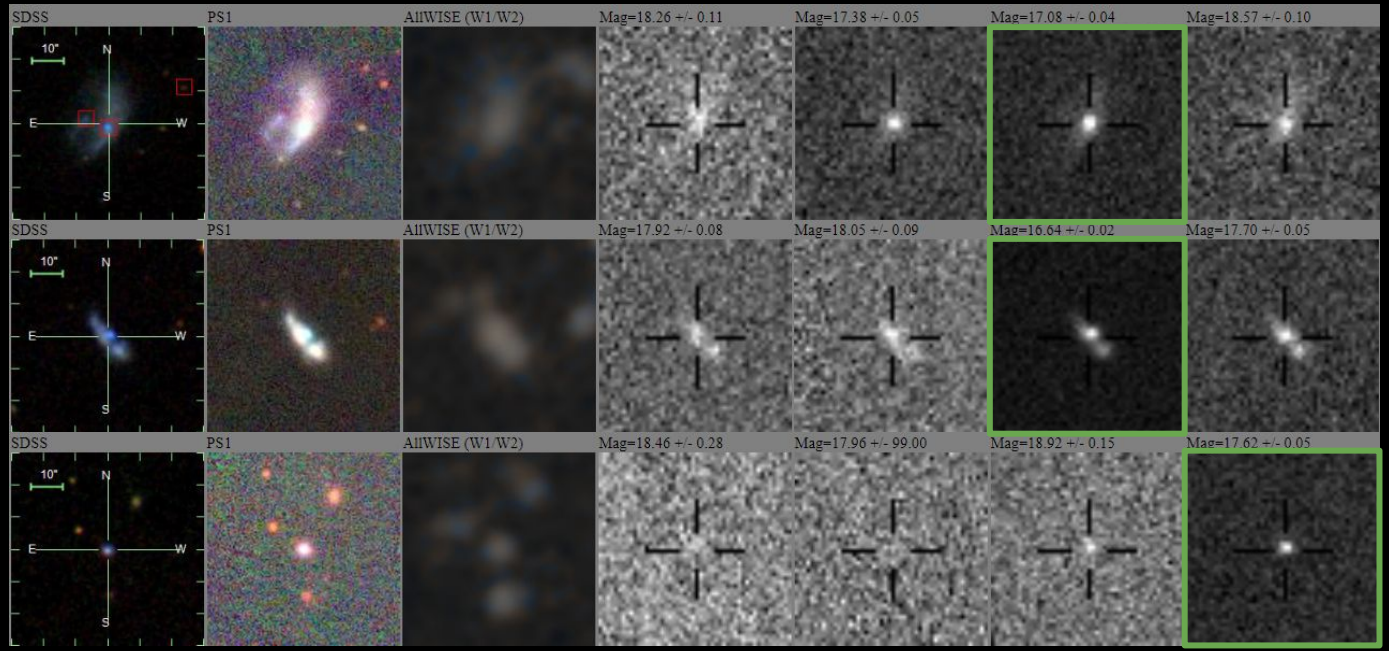


Galaxy candidates



- Galaxy candidates crossmatched to known galaxies (NED)
  - New: 511 (51.4%)
- Expected new galaxies in the survey outside of the SDSS coverage
  - 130,000 / 2 ≈ 65,000
- Tail to the right comes from fainter objects whose fluxes/colors are more uncertain
  - Additional contamination: 94 (4.7%)

Extreme candidate examples



LEDA 3524 (known)

- Seyfert 1 galaxy with known redshift and spectra

Blue Compact Dwarf (new!)

- High star formation rate per area
- Similar to high-redshift galaxies

Conclusion

- The CLU survey can help us more precisely pinpoint the location of GW events detected by LIGO by discovering new galaxies
- Human visual classification is needed to weed out contaminants and junk
- Star and MW contamination becomes a significant issue as we get closer to the Galactic Plane, so less galaxies are able to be detected
- Around 50% of galaxy candidates were new discoveries, which extrapolates to ~65,000 estimated total new galaxies for the entire CLU coverage (excluding SDSS area)
- Studying newly discovered rare/extreme objects can tell us more about the evolution and behavior of galaxies

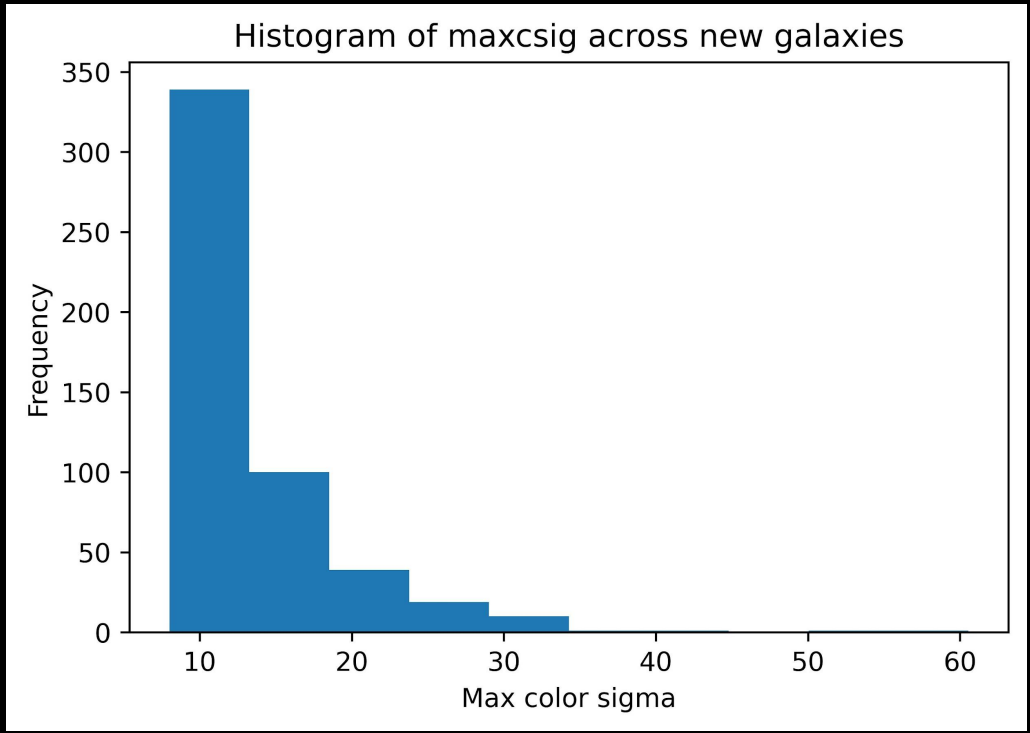
Acknowledgements

Dr. David Cook

Caltech SRC team

Additional slides

Color sigma of candidates



- Color sigma = significance of color
  - difference in brightness between filters