

Galaxy Evolution at the Keck Diffraction Limit

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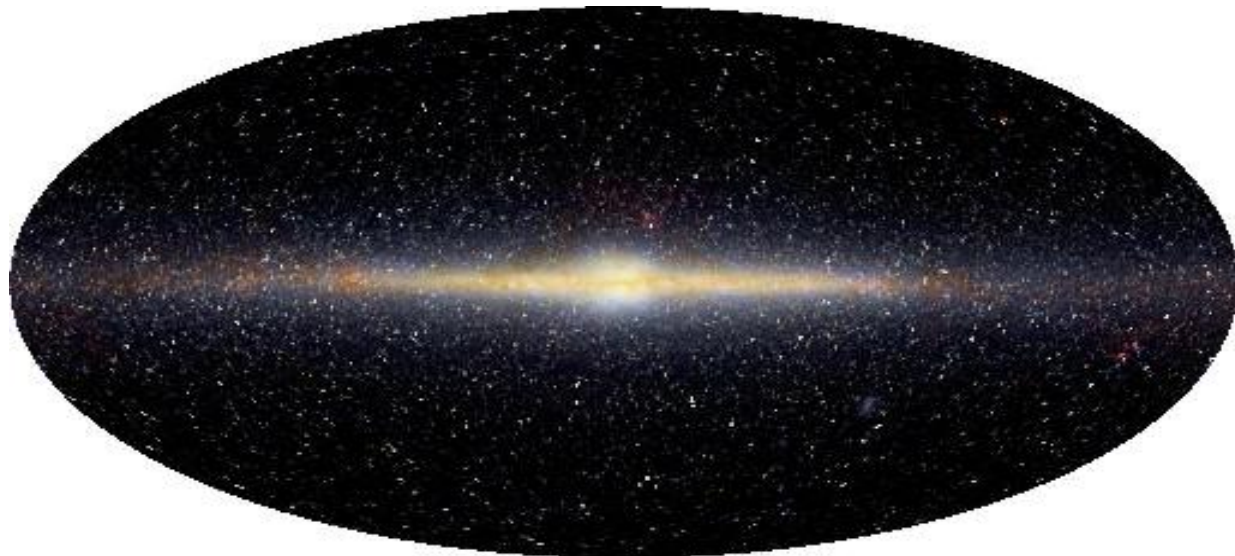


Overview

- **Goals of Project**
- **Datasets** (COMBO – 17 and CATS)
- **Process**
- **Results**
- **Conclusion**

Goals of Project

- Study the structure and morphology of galaxies like our own Milky Way and also to understand star formation
- Creation and Evolution of Galaxies
- Analyze data collected on galaxies at various wavelengths using different filters
- Study galaxies at High Resolution



COMBO-17

(Classifying Objects by Medium Band Observations)

- Made a catalog of 63,501 Objects found in the Chandra Deep Field South at a 35' x 35' field of view and made it public. Included information at **optical wavelengths** such as:

- Redshift

- Magnitudes use the U,B,V,R,I filters (brightness)

- Distances

- Position in the sky (Right ascension, RA and Declination, DEC)

(Survey completed by Max-Planck-Institute for Astronomy, Germany)



CATS

(Center for Adaptive Optics Treasury Survey)

- **Infrared wavelengths** observed by Keck AO and NIRC-2 to achieve high resolution
- Adaptive Optics to observe galaxies uses natural guide stars (NGS)
- Corrects atmospheric turbulence in order to resolve galaxies
- List 20 NGS targeted

(Survey conducted by CFAO, UCSC, UCLA)



Specific Goals of the Project



- Combine high resolution infrared images from the CATS with the optical COMBO-17 dataset
- Produce a catalog of the 20 NGS from CATS that contains the COMBO-17 information of the surrounding galaxies

Why?



- COMBO-17 information allows us to have general knowledge of the age, distance, total luminosity, and types of stars of the galaxy
- CATS information allows us to study the substructure of the galaxies because of AO

Process

- Wrote a python program to search the database to list all objects from the COMBO-17 within $\pm 35''$ area within each of the 20 NGS's from the CATS ($1^\circ = 3600$ arc seconds("))



- Created a catalog of the output in an excel workbook with all the information from the COMBO-17 survey on each galaxy within that area of each NGS

Process

IDL programs used to ...

- graph color vs. color diagrams and color vs. red shift diagrams using the magnitudes from the different filters used by the COMBO-17 survey (color i.e. B-R)
- create a 70" x 70" fits image containing each NGS and its surrounding galaxies
- create 5" x 5" fits image of each galaxy

RESULTS: Excel Catalog

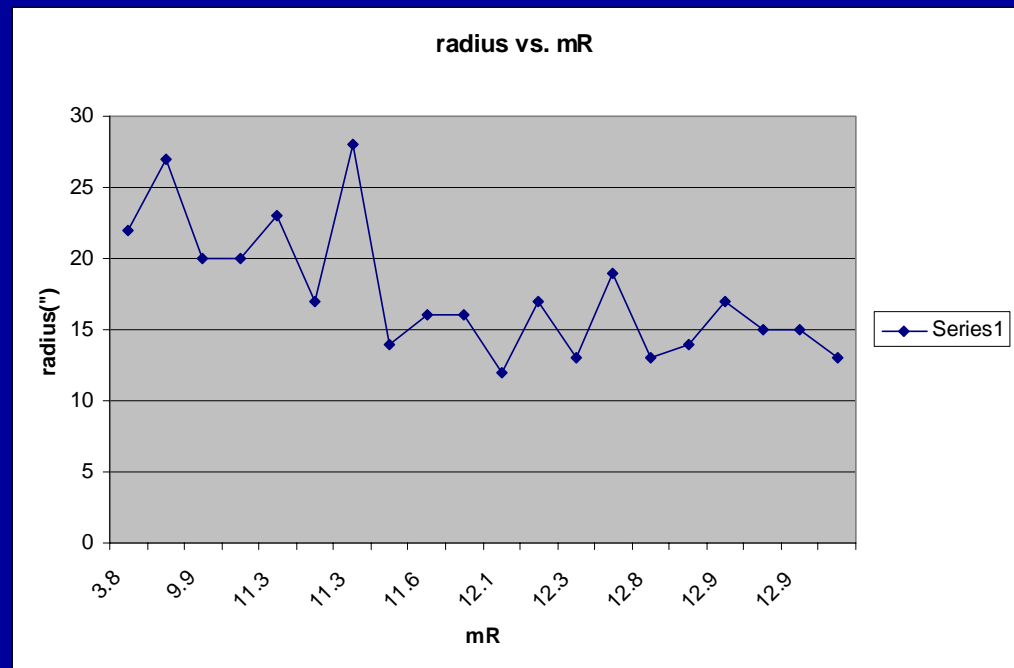
Seq	RAh	RAm	RAs	Ded	DEm	DEs	x	y	Rmag	e_Rmag	Ap_Rmag	ApD_Rmag	mu_max	MajAxis	MinAxis	PA	phot_flag	var_flag
47	3	32	47.017	-28	3	53.49	2751.99	4.31	26.31	0.21	25.816	0.49	25.225				19	0
95	3	32	51.393	-28	3	52.41	2508.58	9.16	25.204	0.283	26.356	-1.157	25.314				17	0
110	3	32	50.62	-28	3	53.43	2551.56	4.85	24.172	0.135	26.094	-1.927	24.971				19	0
121	3	32	47.281	-28	3	53.85	2737.3	2.84	22.009	0.019	22.302	-0.297	22.633				26	0
154	3	32	48.214	-28	3	53.57	2685.41	4.07	23.39	0.058	24.796	-1.41	24.109				27	0
195	3	32	50.666	-28	3	51.09	2548.99	14.65	24.369	0.165	26.546	-2.181	25.257				3	0
213	3	32	48.206	-28	3	48.64	2685.86	24.79	26.195	0.257	27.165	-0.973	25.363	0.71	0.71	3.438	513	0
217	3	32	50.941	-28	3	53.13	2533.72	6.13	22.946	0.086	25.919	-2.977	25.098				27	0
247	3	32	49.543	-28	3	47.6	2611.5	29.24	26.308	0.286			25.439			5.48	1	0
265	3	32	49.474	-28	3	49.32	2615.3	22.02	24.127	0.157			25.433	0.71	0.71	6.248	515	0
299	3	32	50.957	-28	3	46.14	2532.81	35.48	25.603	0.251	25.369	0.23	25.224	1.82	1.17	3.578	3	0
316	3	32	51.384	-28	3	46.51	2509.09	33.93	25.458	0.211			25.212	1.43	1.02	4.73	0	0
320	3	32	48.73	-28	3	52.59	2656.89	8.24	21.894	0.03	24.421	-2.531	23.868				27	0
342	3	32	48.439	-28	3	47.46	2672.88	29.75	23.206	0.031	23.411	-0.209	23.43	1.29	1.03	6.074	3	0
356	3	32	48.378	-28	3	45.37	2676.31	38.53	24.924	0.145	24.871	0.049	24.563	0.95	0.87	5.131	2	0
376	3	32	50.343	-28	3	52.25	2566.96	9.77	23.101	0.071	25.701	-2.604	24.967				19	0
416	3	32	47.913	-28	3	45.04	2702.15	39.86	23.281	0.043	23.428	-0.152	23.67	1.44	1.04	5.48	0	0
417	3	32	50.868	-28	3	44.87	2537.78	40.78	24.156	0.138	24.752	-0.6	25.016	1.33	1.16	5.306	2	0
418	3	32	47.474	-28	3	44.27	2726.57	43.07	25.252	0.214	25.649	-0.402	25.226	1.48	1	5.742	0	0
450	3	32	48.701	-28	3	45.93	2658.33	36.19	22.662	0.025	22.887	-0.229	23.03	1.18	1.09	4.939	2	0
467	3	32	49.864	-28	3	52.27	2593.63	9.64	21.675	0.029	24.675	-3.004	23.757				19	0
659	3	32	49.209	-28	3	44.67	2630.05	41.52	21.184	0.008	21.6	-0.421	21.71	1.18	1.14	4.677	3	0
1104	3	32	49.198	-28	3	50.28	2630.65	17.95	20.899	0.01	23.48	-2.585	23.536				27	0

Example of output in excel of the COMBO-17 information on objects found around NGS 7 from the CATS list

1518 galaxies found to be studied in all

Radius vs. Brightness

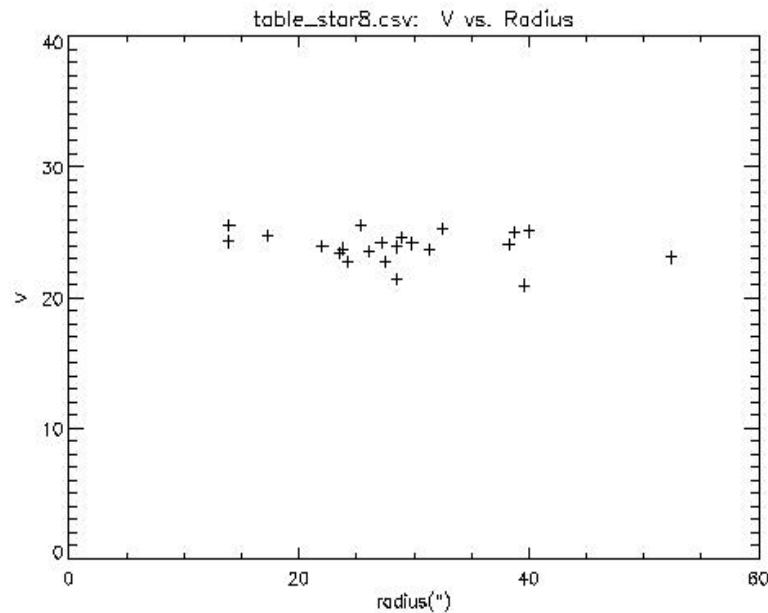
- According to the graph, roughly, the brighter the star, the farther you must go before observing a galaxy
- Radius is the distance to the first galaxy detected from the NGS



brighter

The lower the magnitude the brighter the object

RESULTS



One example of ...

- Color vs. Redshift
- Color vs. Color
- Magnitude vs. Radius

Smaller the magnitude the brighter the object

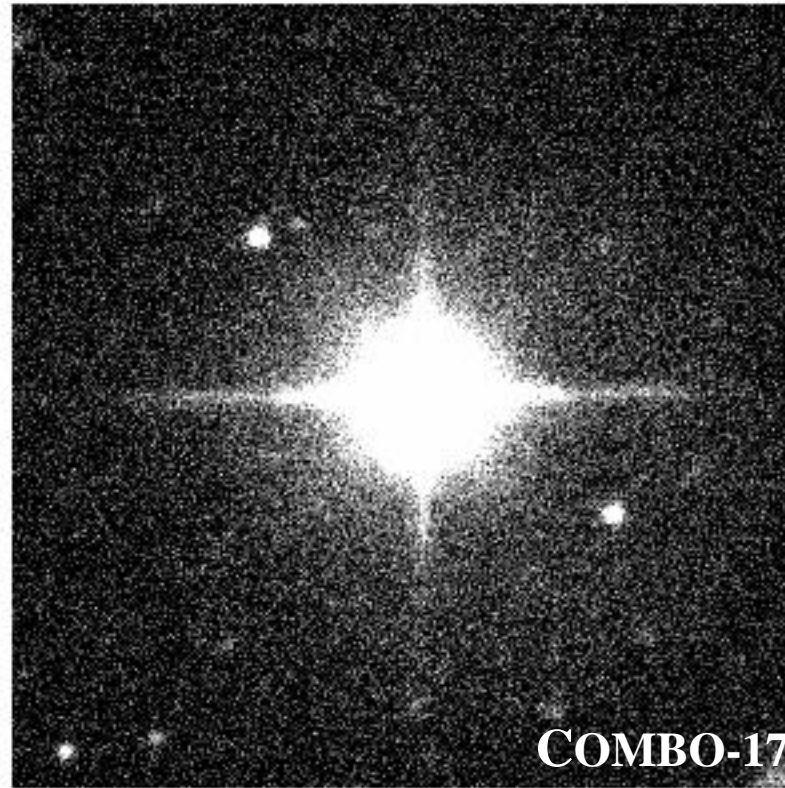
$B - R < 0 \rightarrow$ more blue

$B - R = 0 \rightarrow$ no color

$B - R > 0 \rightarrow$ more red

RESULTS

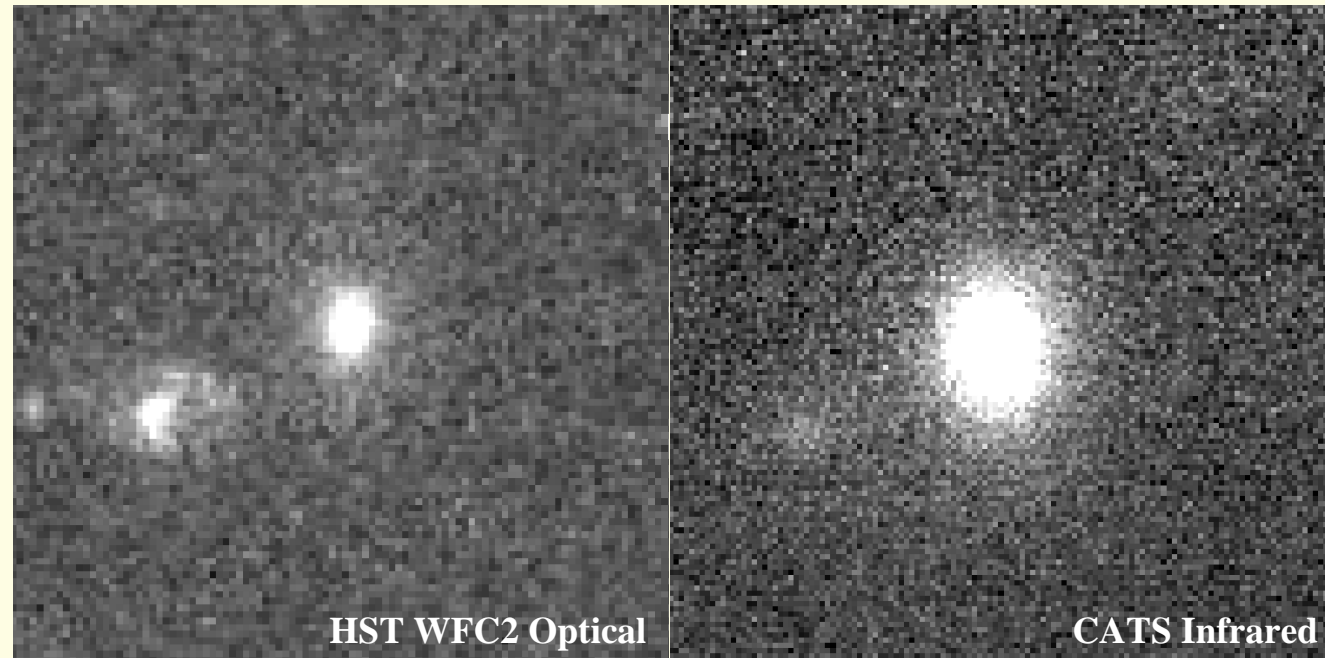
- 70" x 70" image of a star as seen through the U-band filter



- From the optical view you see galaxies with little to no detail

RESULTS: 5'' x 5'' prints of galaxy

Two galaxies
possibly
merging ...



Combining information ...

- COMBO – 17 yields a $z = 0.858$ \Rightarrow The light travel time is 7.1 Gyr
It is now 13.7 Gyr since the Big Bang
 \therefore The age at $z = 0.858$ is 6.6 Gyr
- Merge quickly with its neighboring galaxy which is within 30,000 light years
- We are observing it at a time when our Galaxy is 1/3 as old

Conclusion

- **Successful completion of catalog with information on all galaxies within a 70'' x 70'' area of the CATS list of 20 NGS's to help match field of views between the optical and infrared observations**
- **Images of each NGS and its field of view as well as images of each galaxy around it to aid astronomers observations**
- **Ability to combine the COMBO-17 optical information from the catalog with the infrared images captured to study the different galaxies similar to our own as a function of time and eventually be able to create a history of galaxy evolution**

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