

# Rapid follow-up of neutron star mergers and short GRBs

Midwest SN and Transient 2019

**Kerry Paterson**

Postdoc, CIERA, Northwestern

Wen-fai Fong (NU), David Sand, Michael Lundquist (UA),  
Anya Nugent (NU)

Searches  
After Gravitational-  
waves Using Arizona  
Observatories

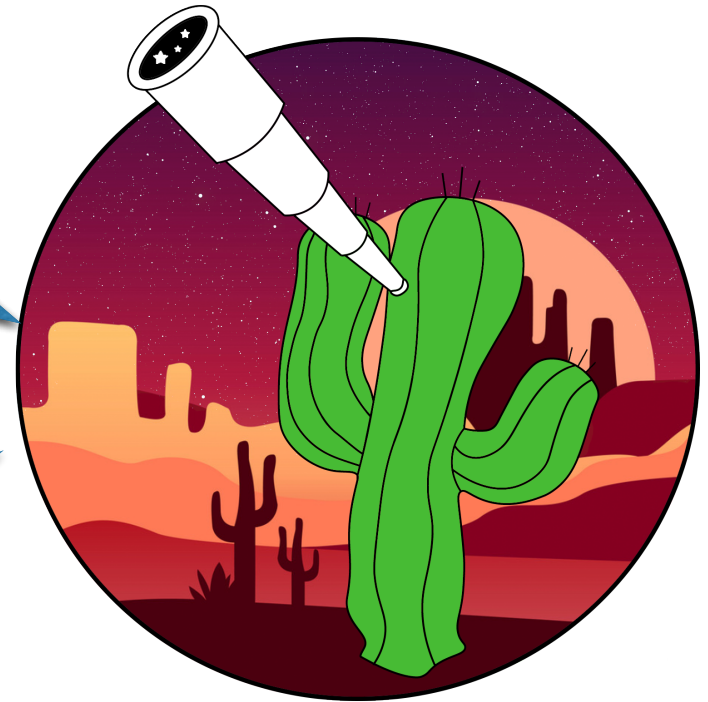


**SAGUARO**



Photo by Peter Gregorie

Searches  
After Gravitational-  
waves Using Arizona  
Observatories



**SAGUARO**

Rapid identification of  
GW counterparts and  
monitoring of kilonovae

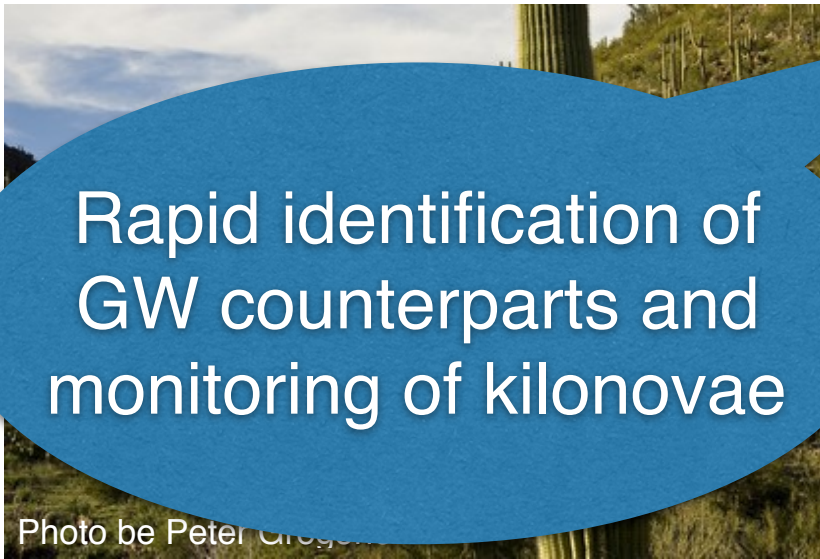
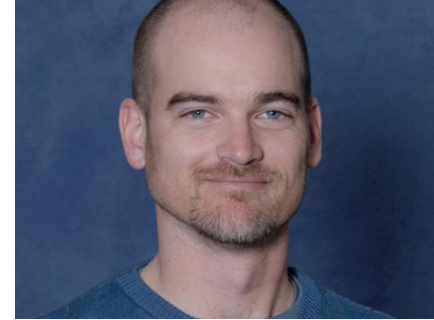


Photo by Peter Crockett



# Catalina Sky Survey

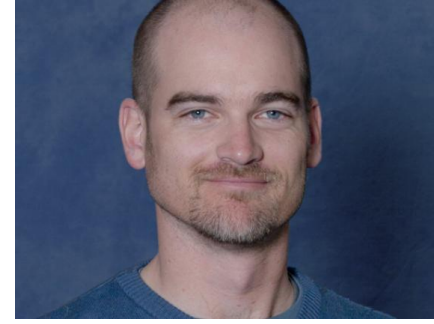


PI: Eric Christensen

- 1.5 m CSS telescope on Mt Lemmon
- FoV of  $5.0 \text{ deg}^2$
- Maps 1000 square degrees every night
- Limiting mag of  $V \sim 21.5 \text{ mag}$  in 30s
- Main aim is moving objects
- 4 visits per field
- Advantage: deep references of all fields

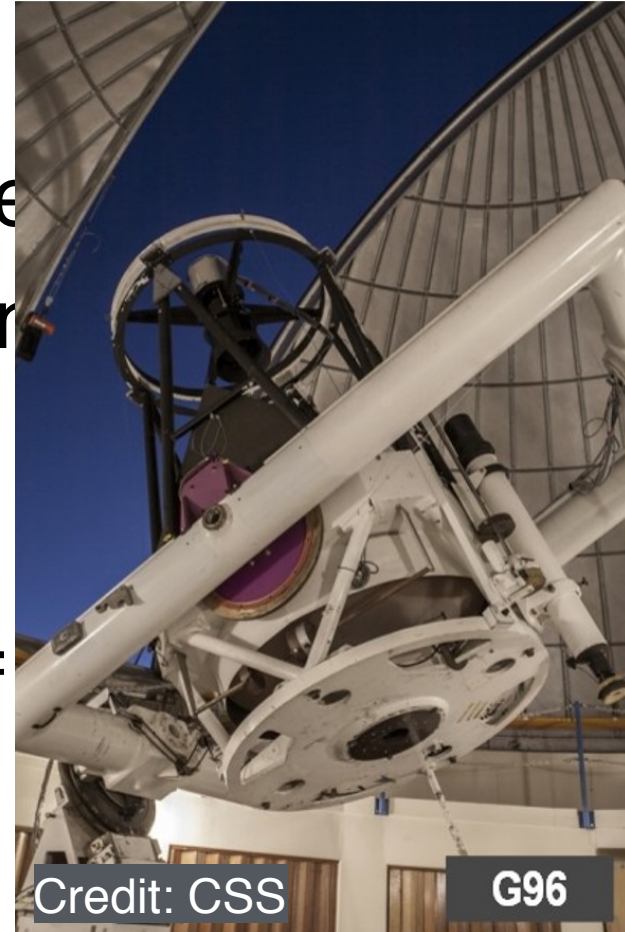


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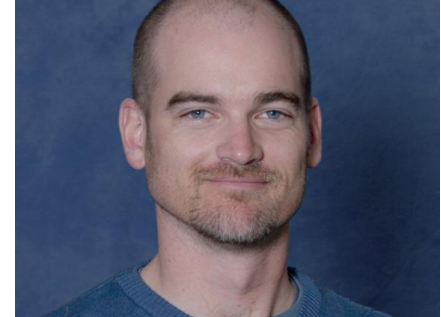


Credit: CSS

G96



# Catalina Sky Survey

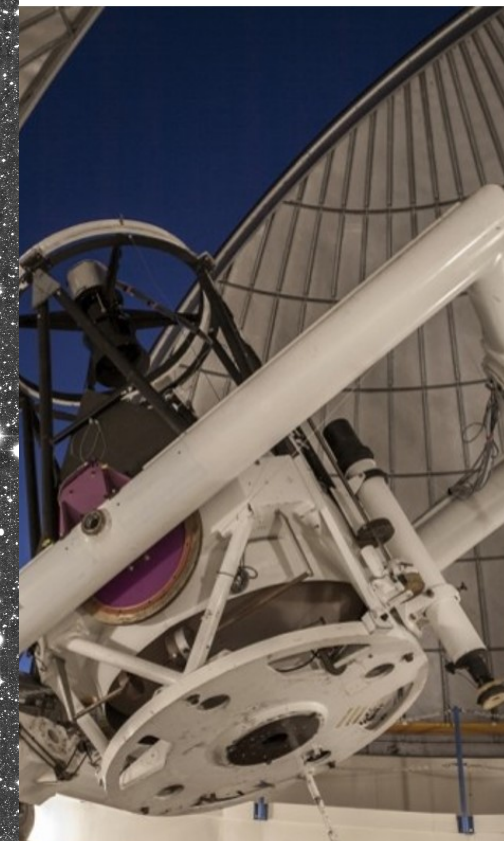


PI: Eric Christensen

- 1.5 m O
- FoV of 5
- Maps 10
- Limiting
- Main air
- 4 visits
- Advanta



on



Northwestern  
University

Credit: CSS

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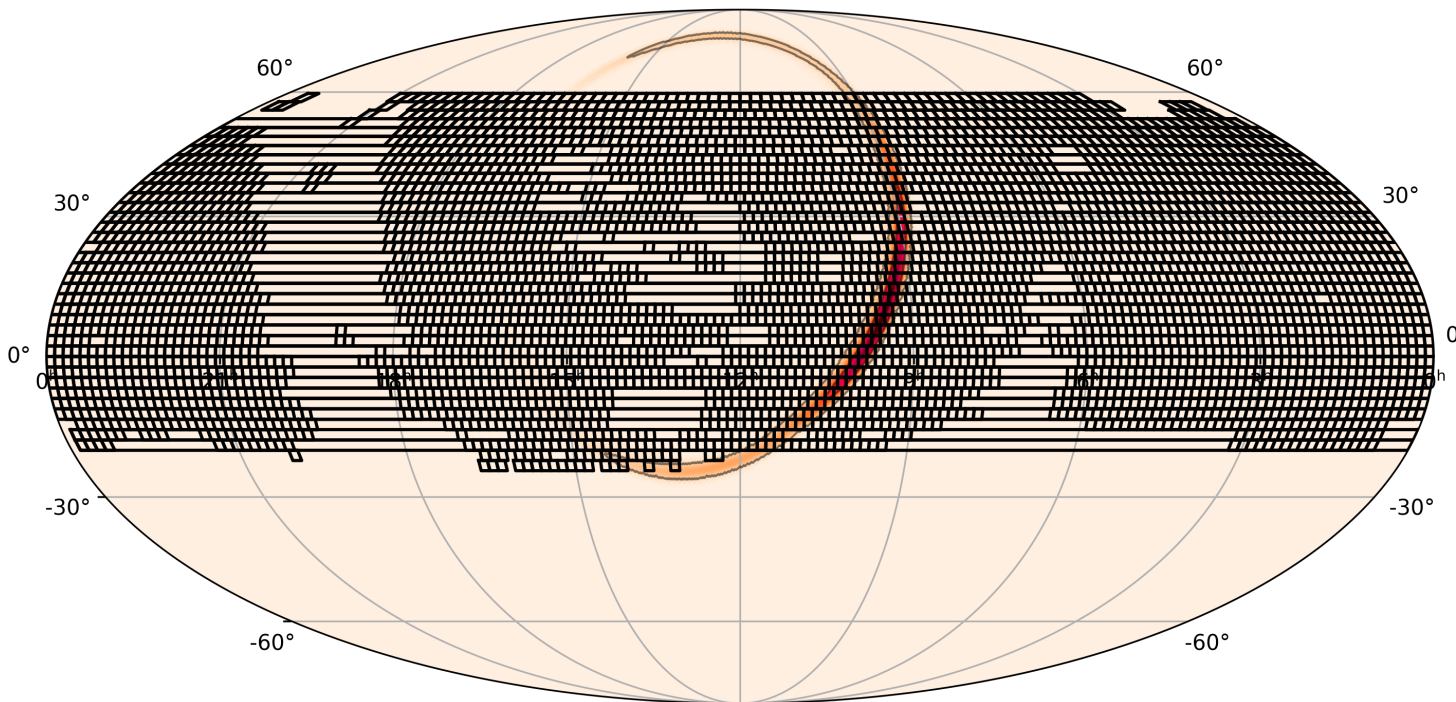


# Catalina Sky Survey



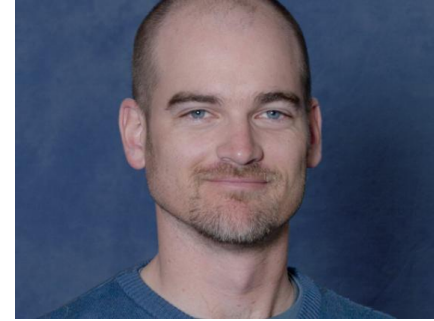
PI: Eric Christensen

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- Fo'
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- Lin
- Ma
- 4 v
- Ad'





# Catalina Sky Survey



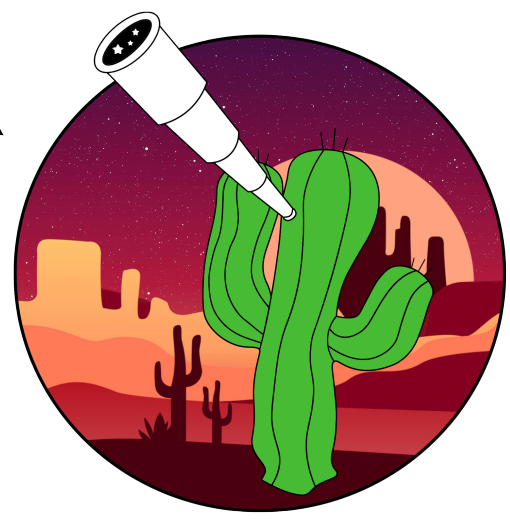
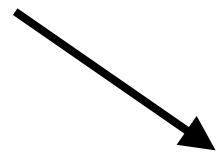
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**LSC** LIGO  
Scientific  
Collaboration

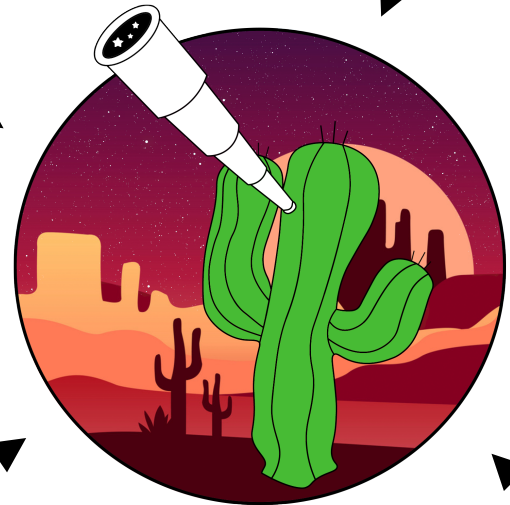
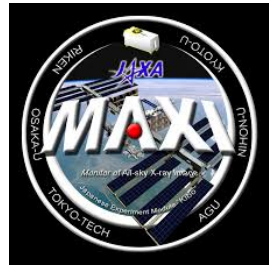
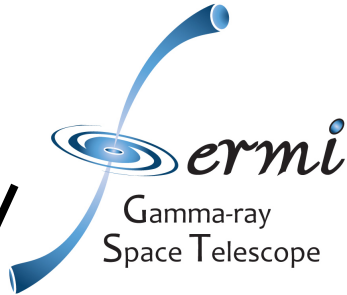
**VIRGO**



**SAGUARO**

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CENTER FOR INTERDISCIPLINARY EXPLORATION  
AND RESEARCH IN ASTROPHYSICS

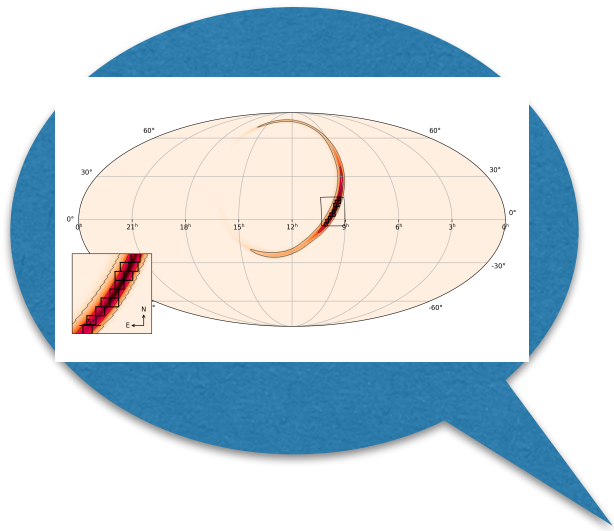


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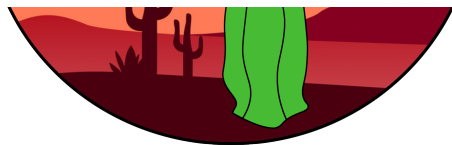
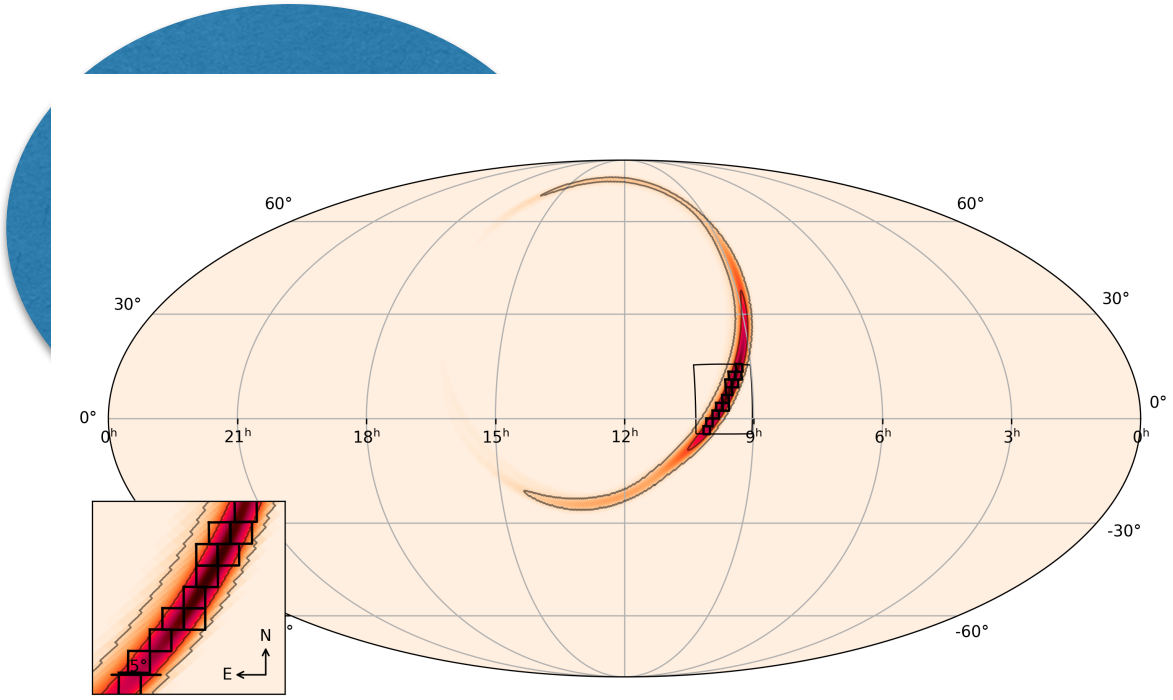
**AGILE**

Northwestern  
University

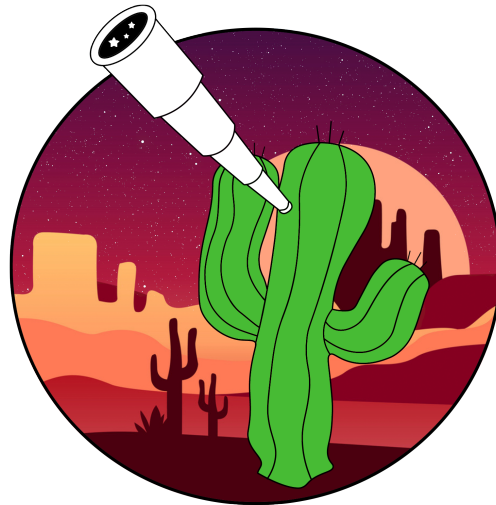
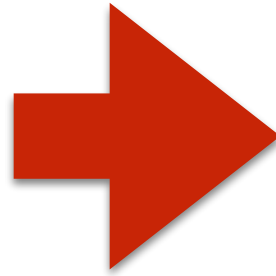
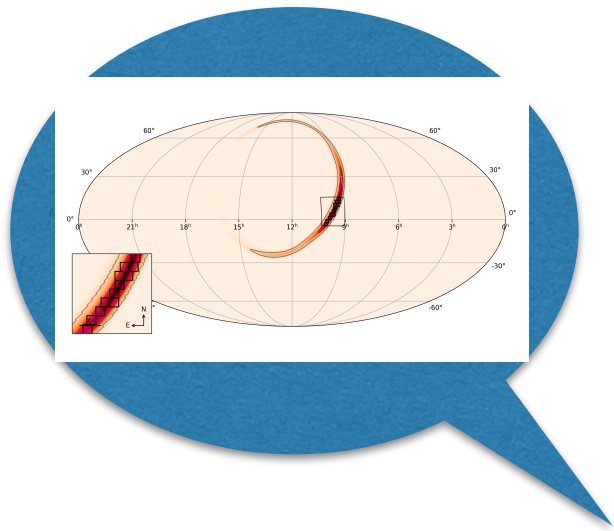
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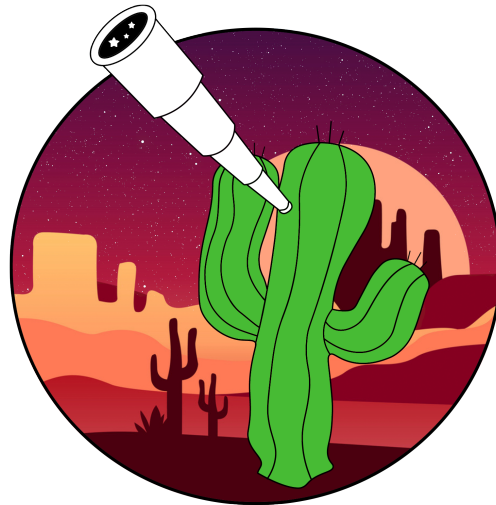
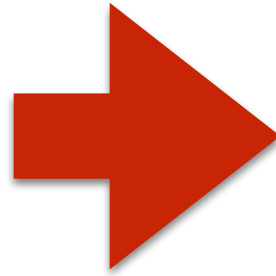
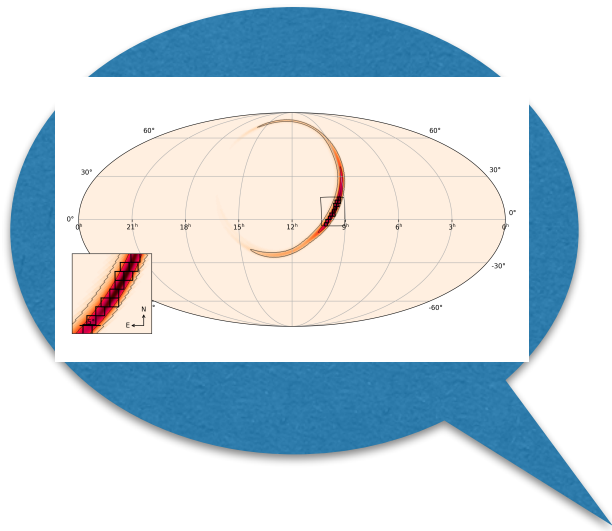
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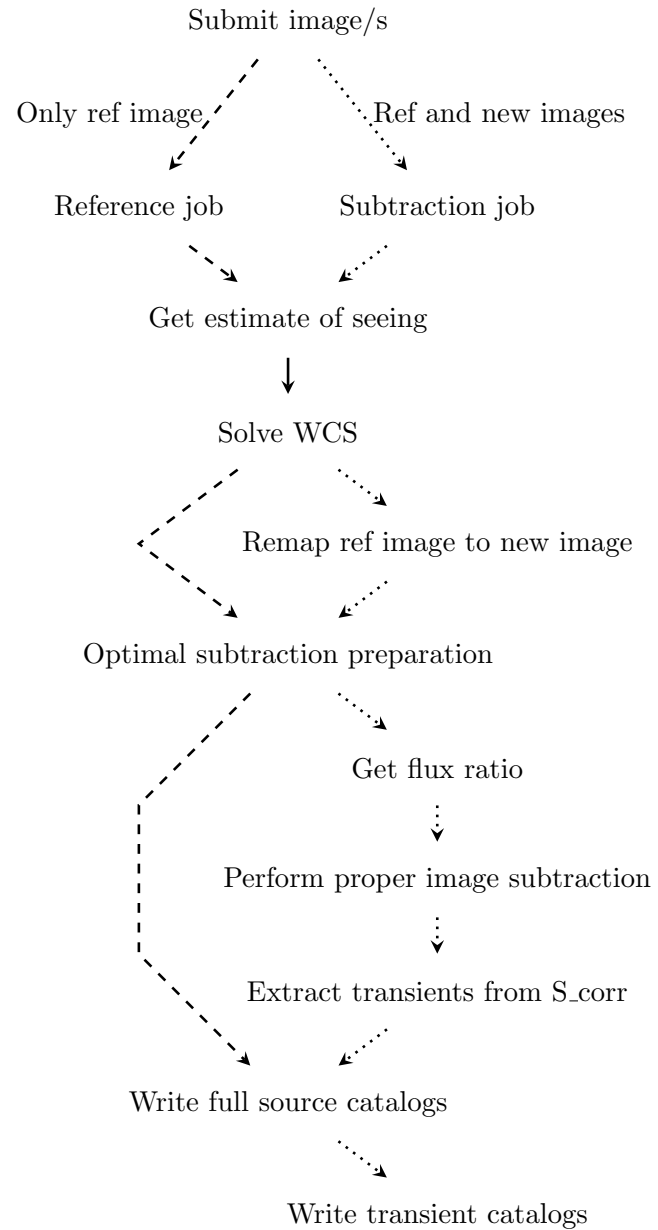
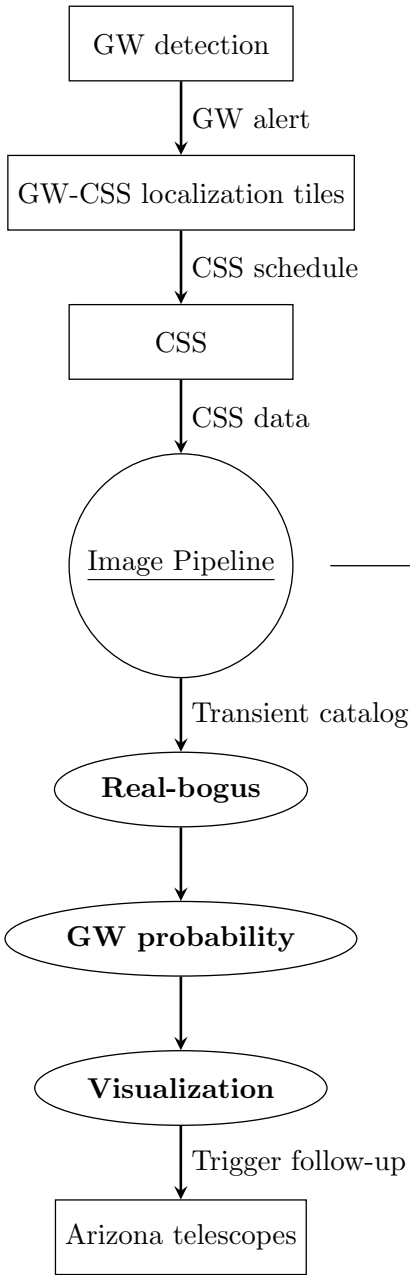
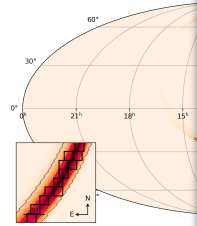
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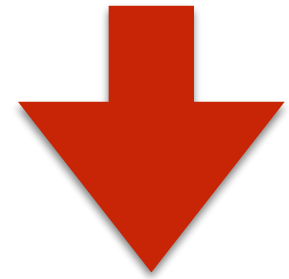
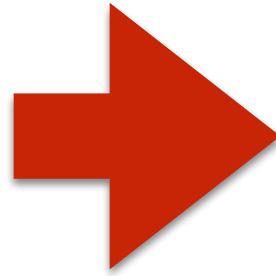
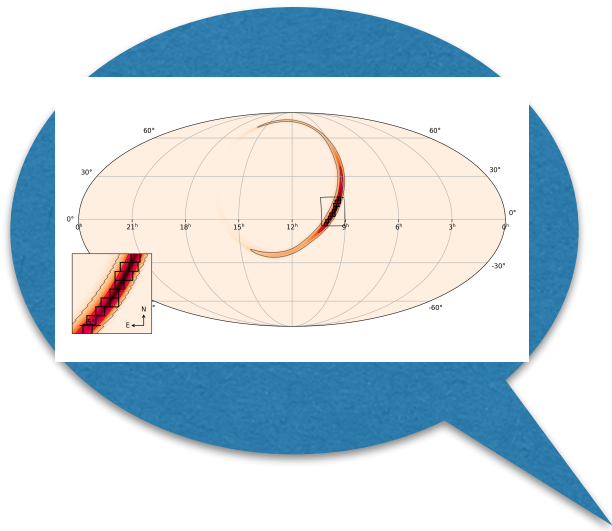


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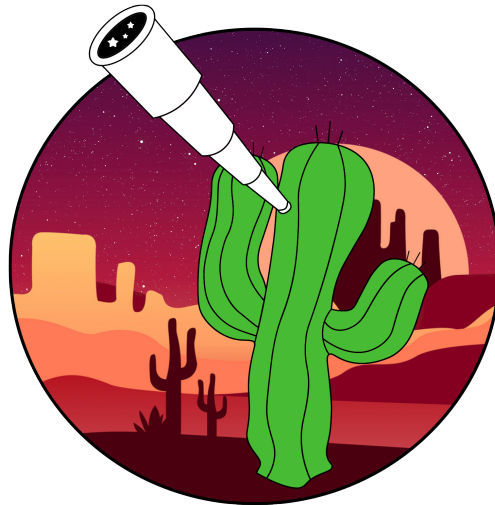
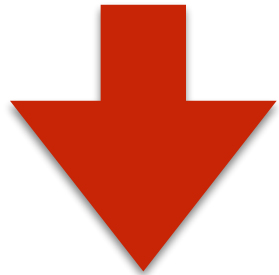
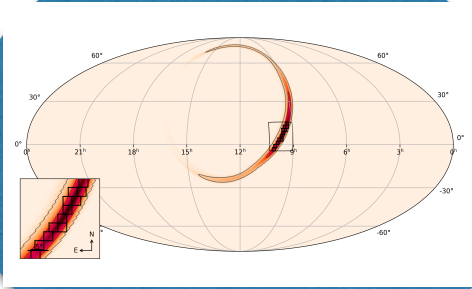
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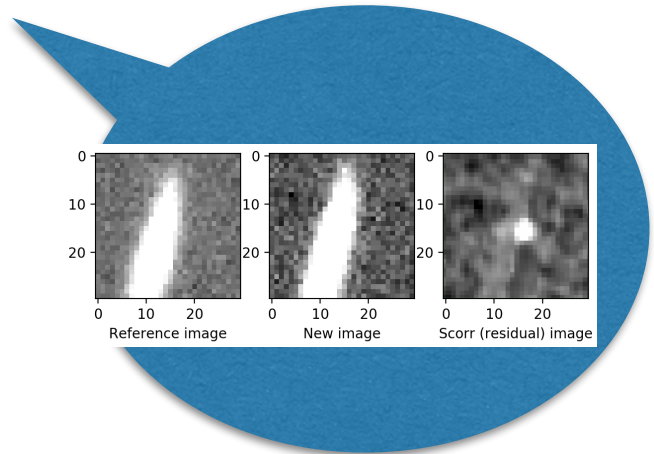


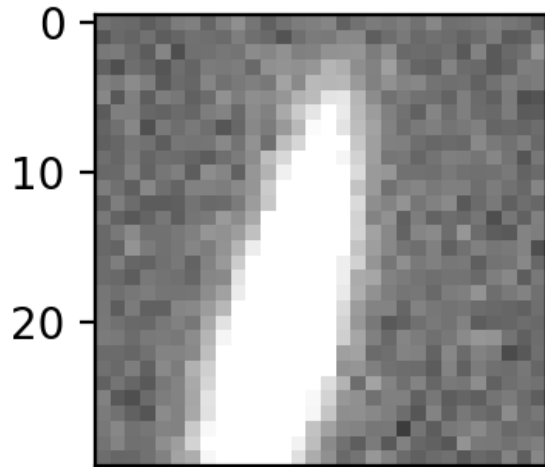
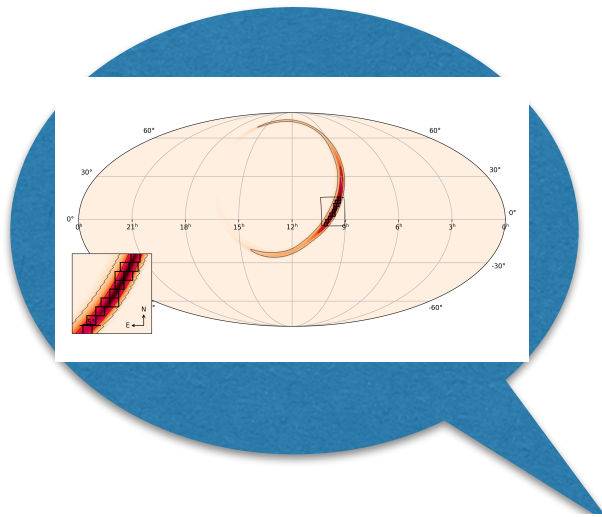
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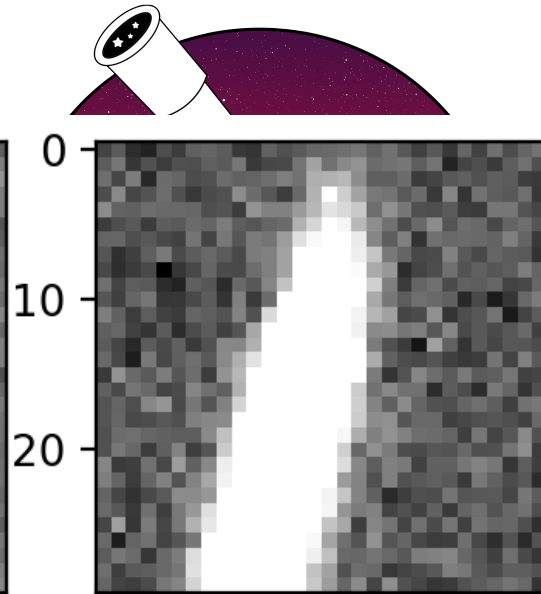


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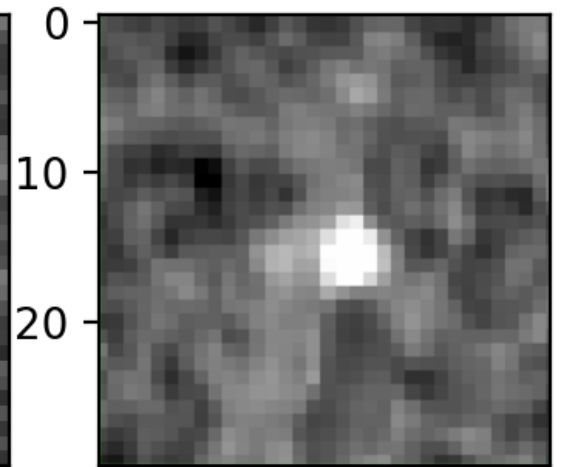




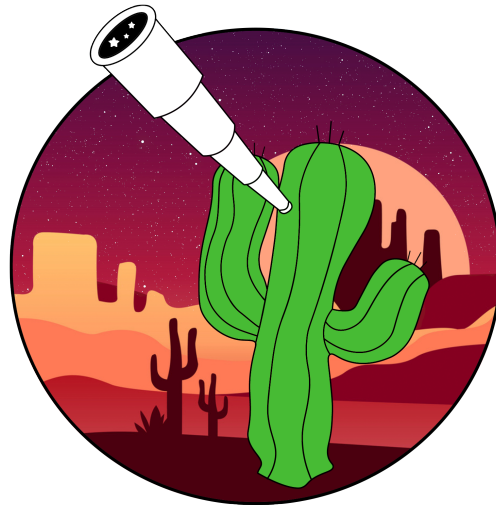
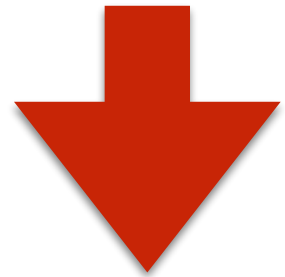
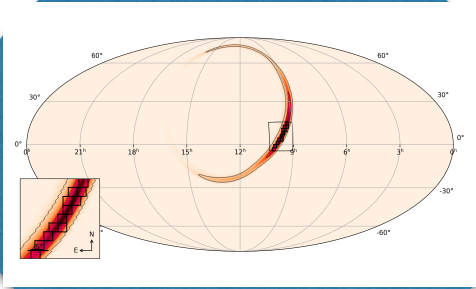
Reference image



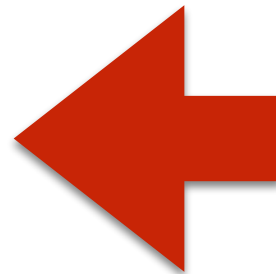
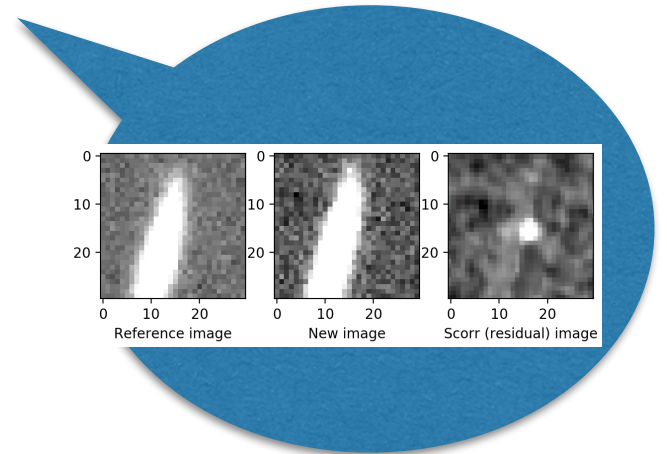
New image

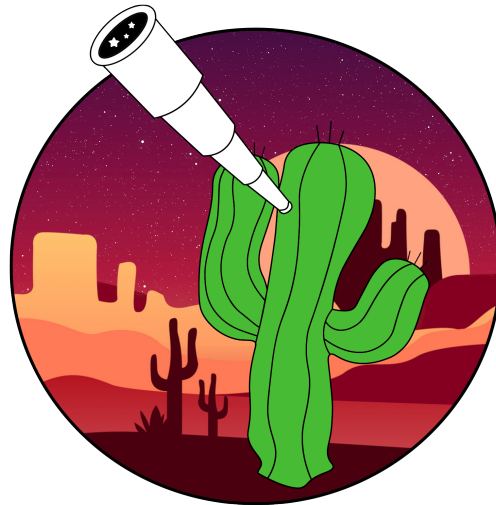
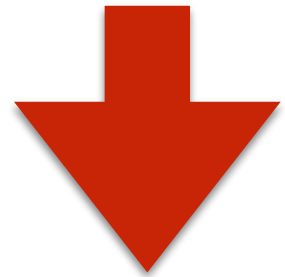
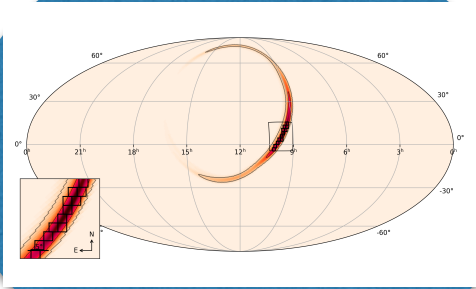


Scorr (residual) image

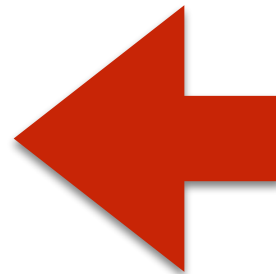
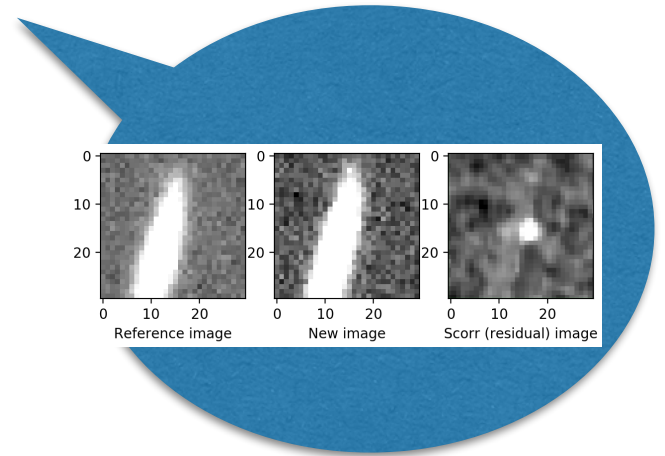


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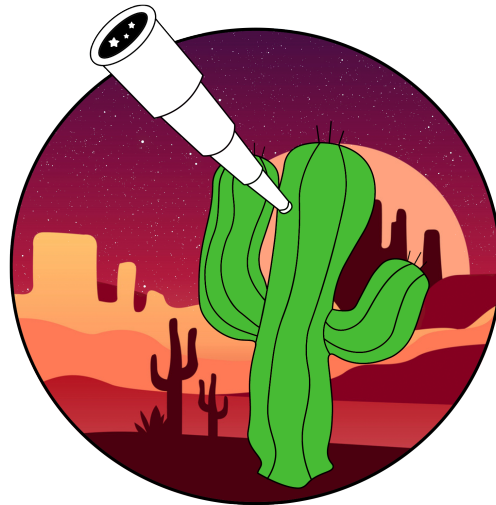
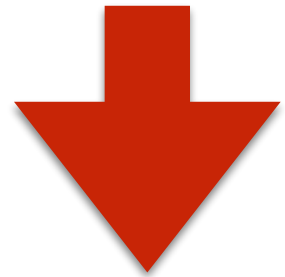
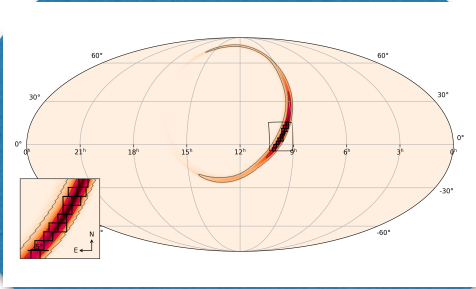




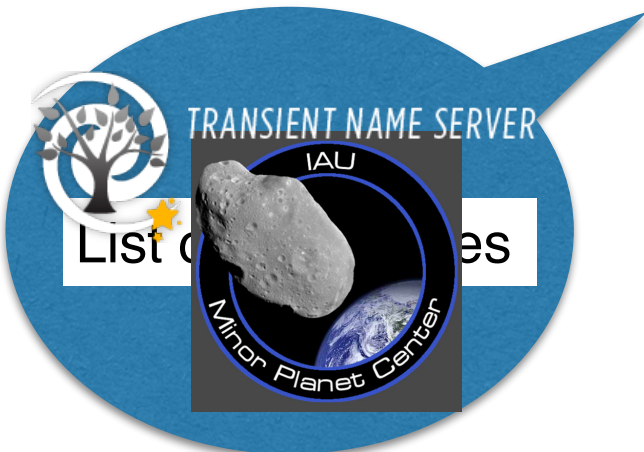
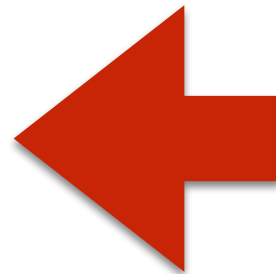
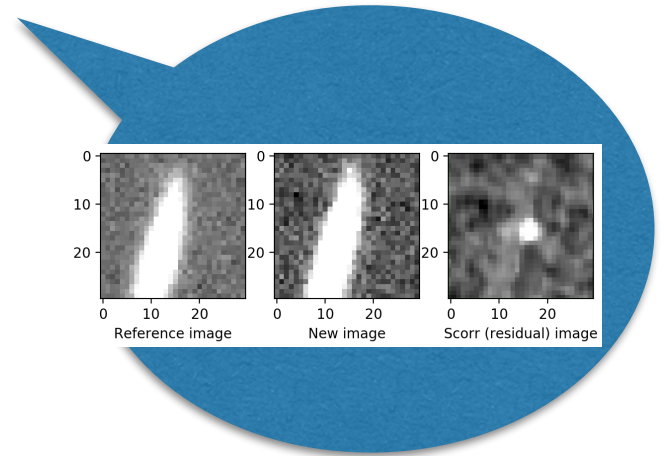
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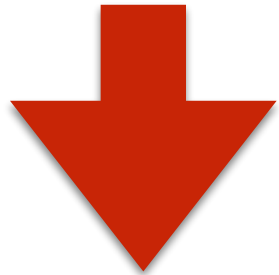
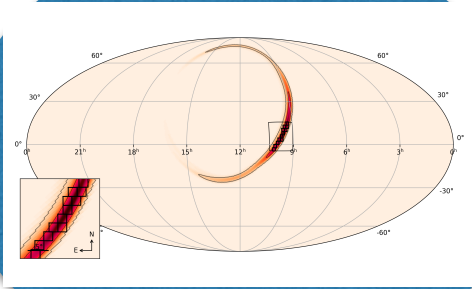


List of candidates

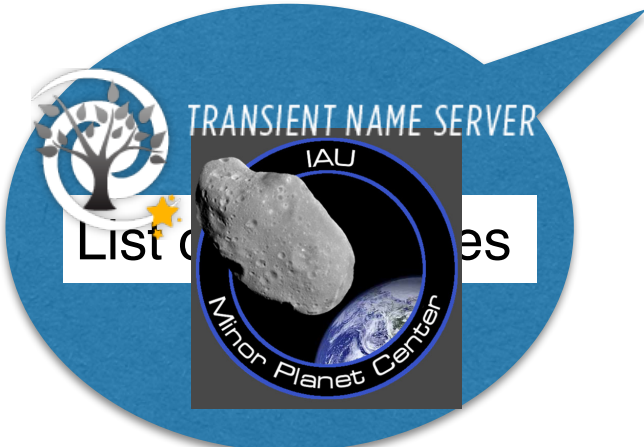
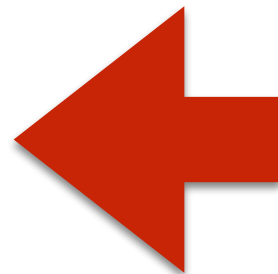
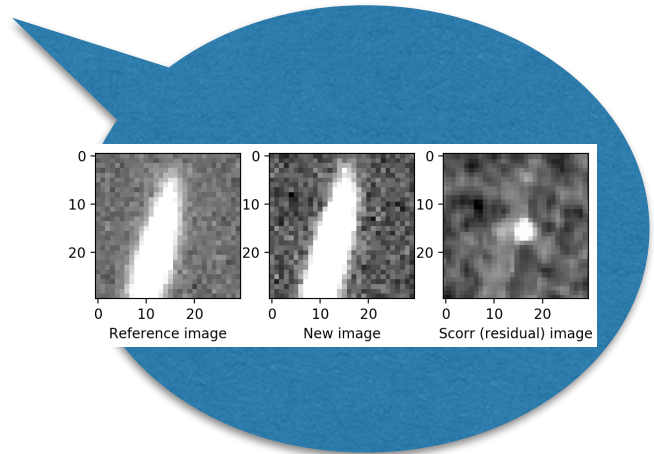


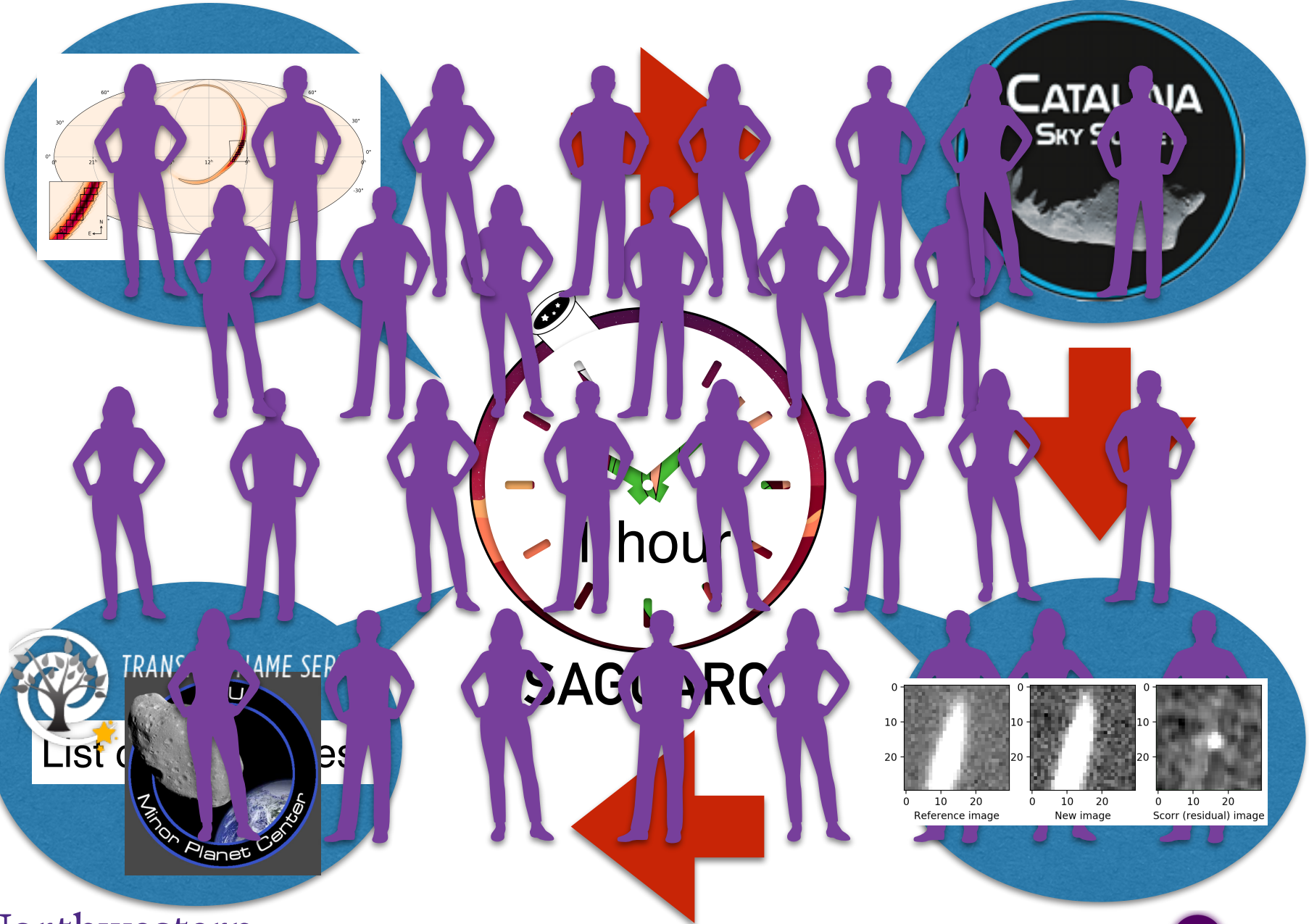
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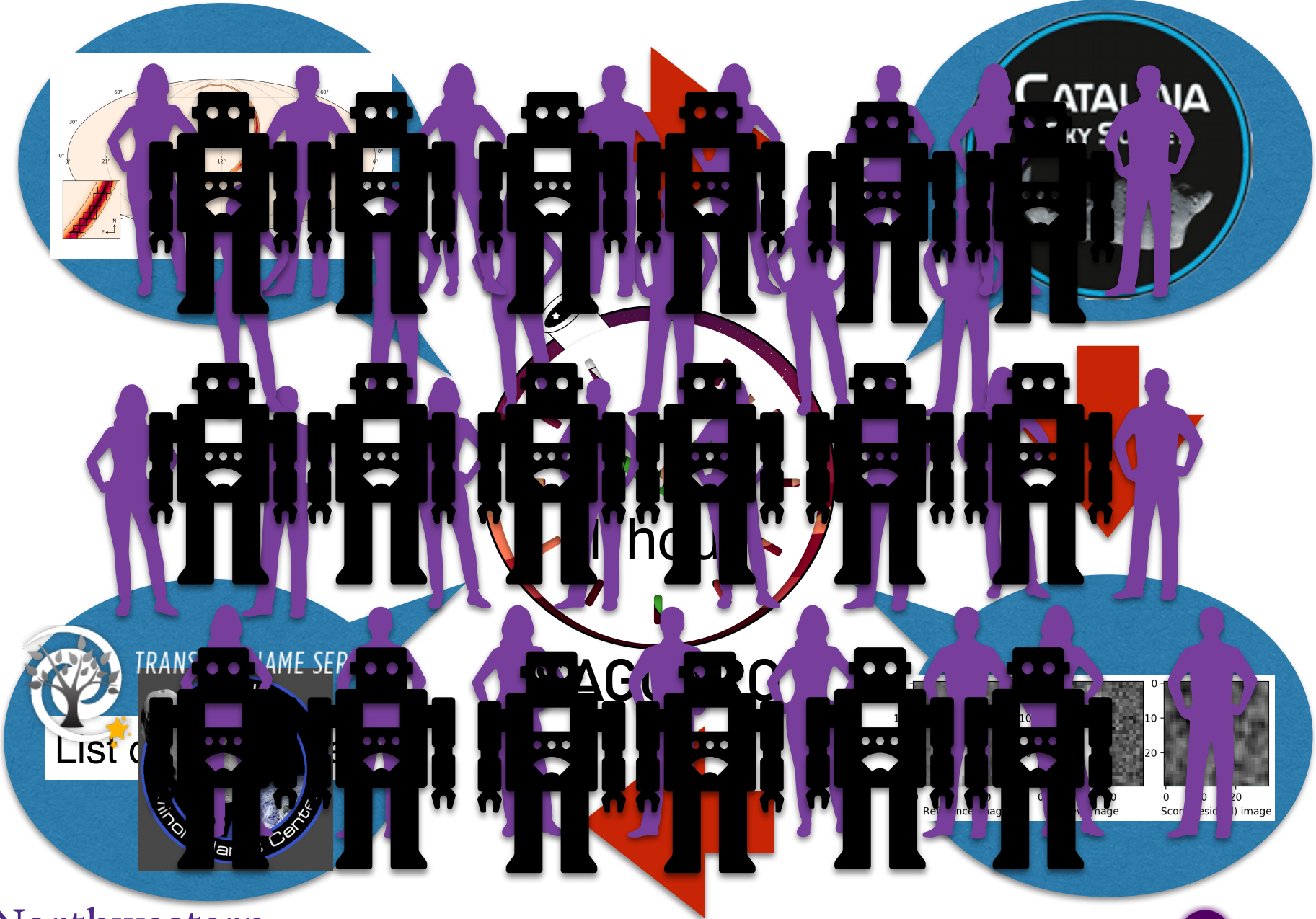




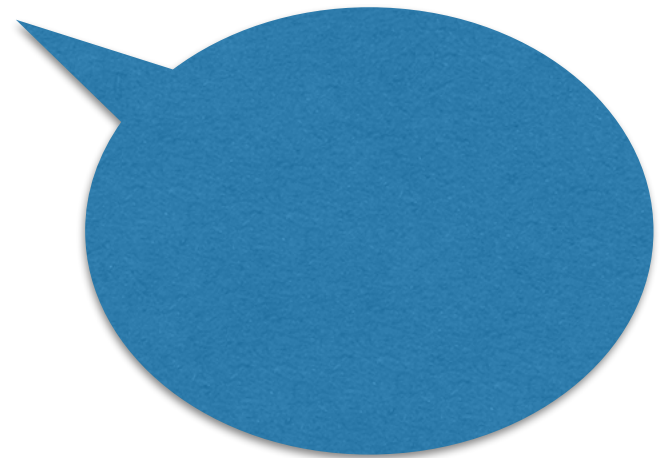
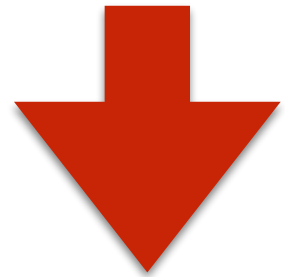
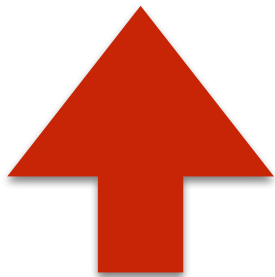
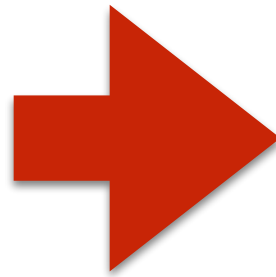
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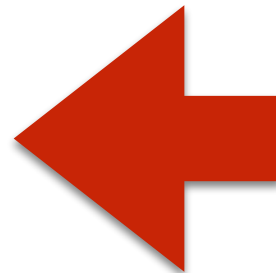








**SAGUARO**



Credit: Keck

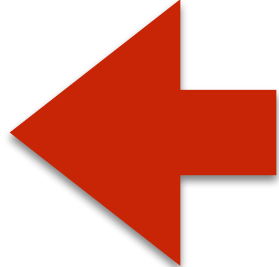
Northwestern  
University



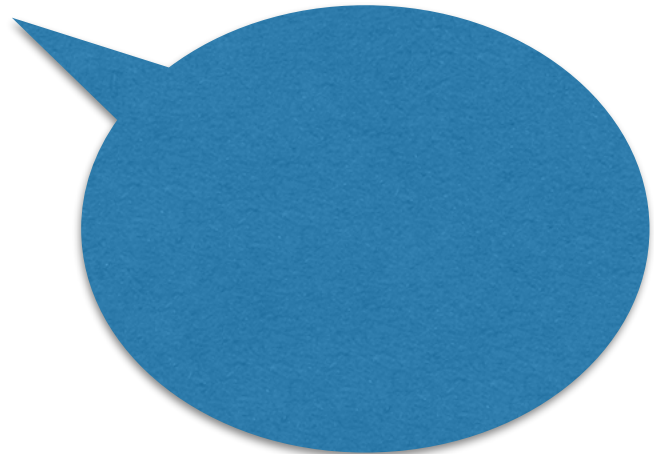
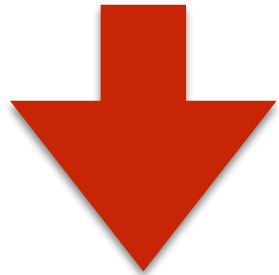
Credit: Bok



GUARO



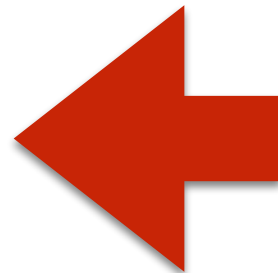
Credit: Keck





Credit: LBT

# SAGUARO



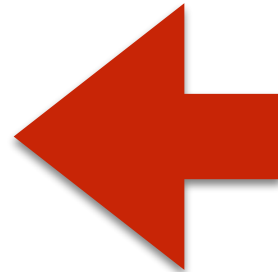
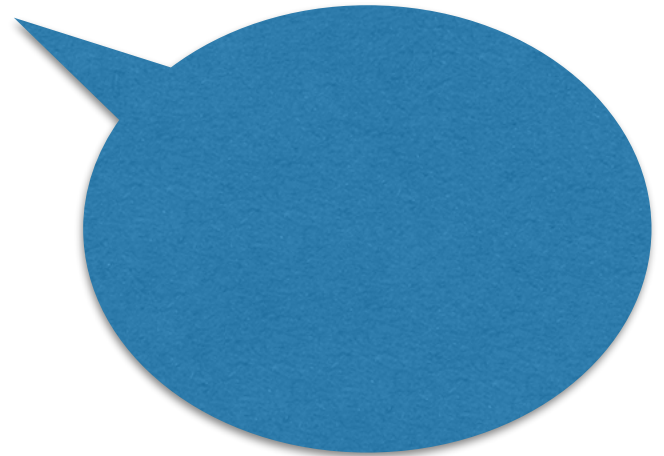
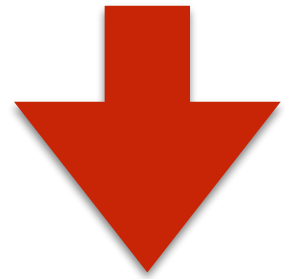
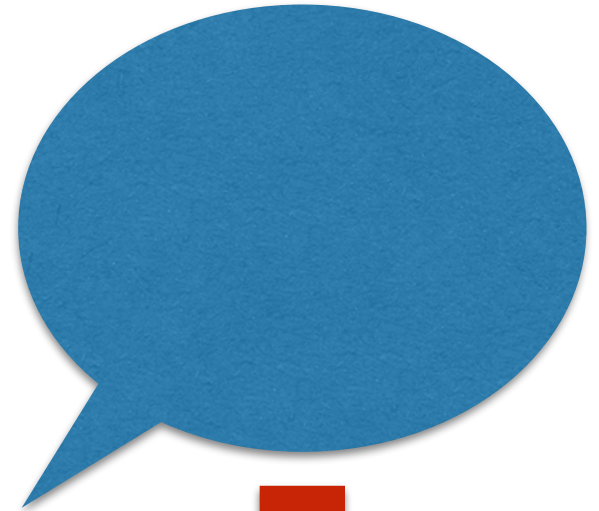
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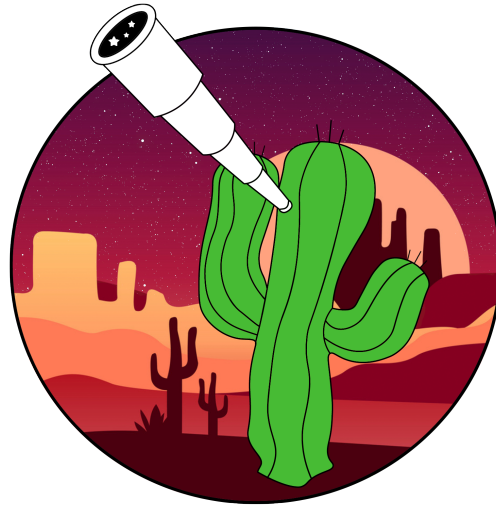
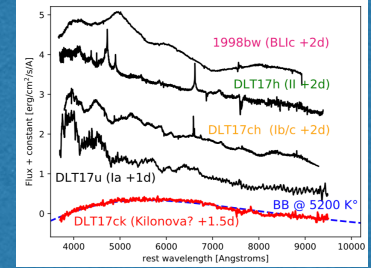
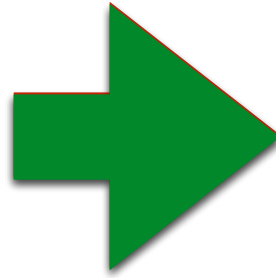
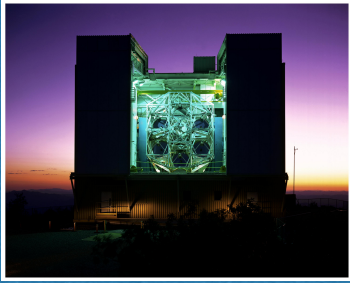
Northwestern  
University



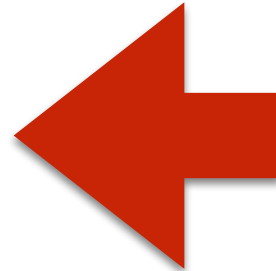
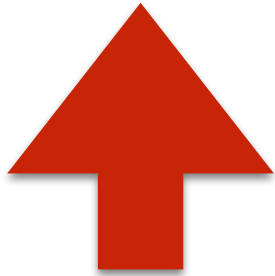
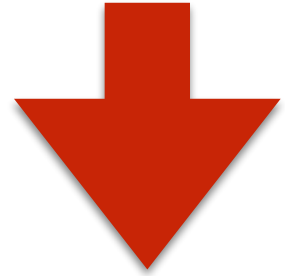
Credit: MMT

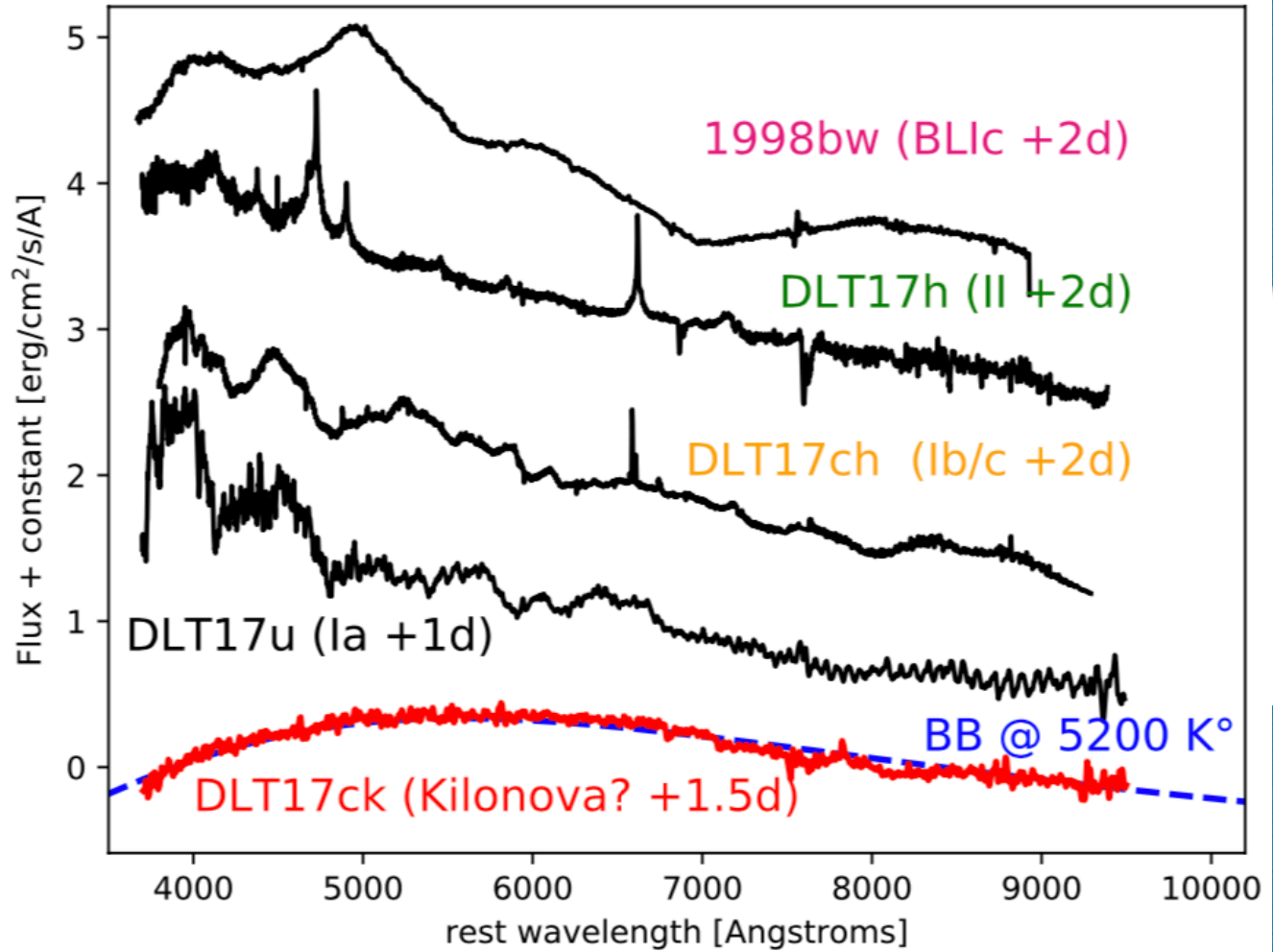
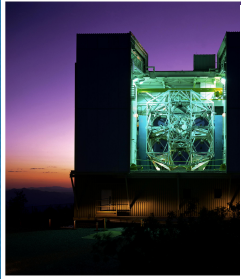
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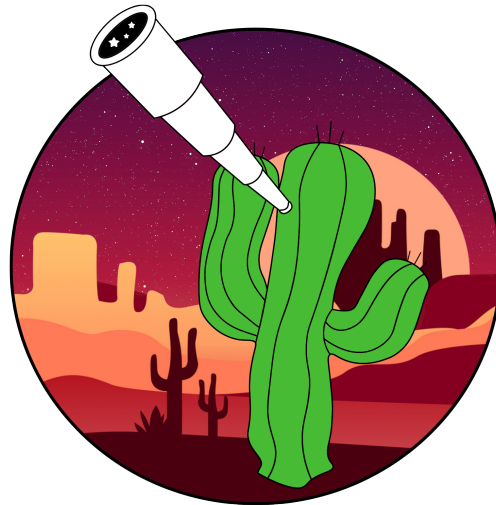
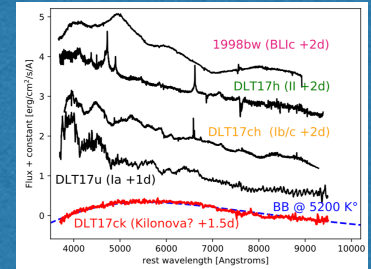
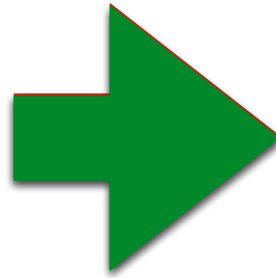
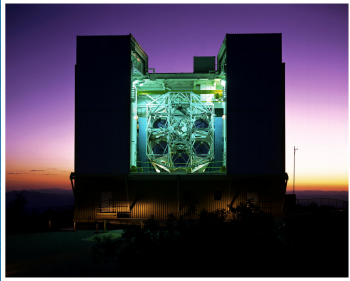




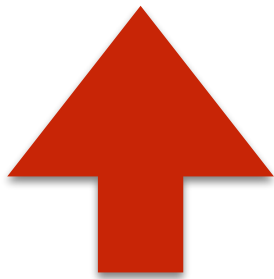
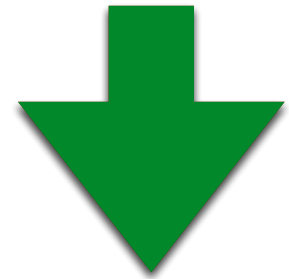
**SAGUARO**

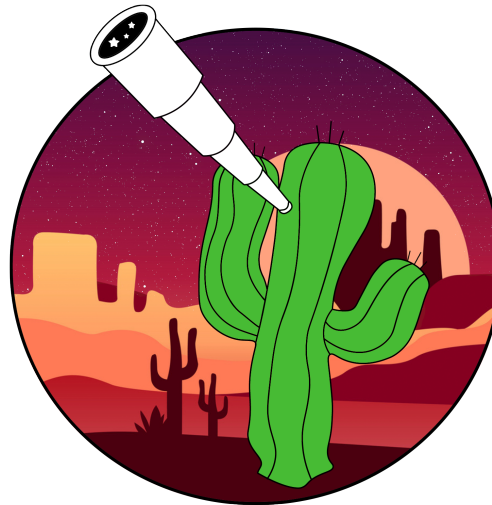
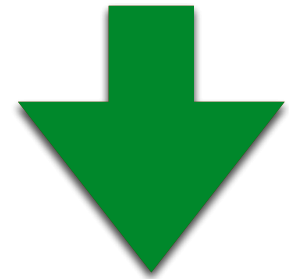
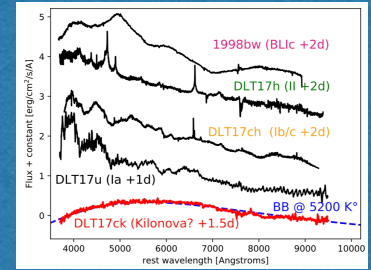
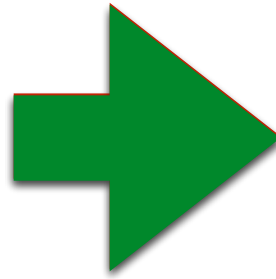
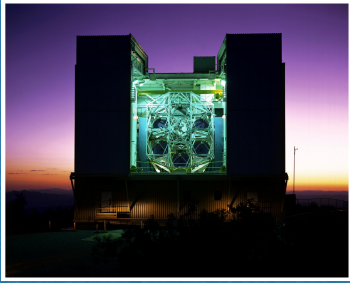




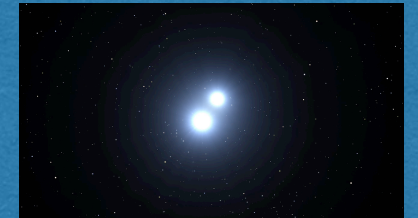


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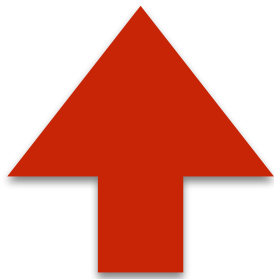
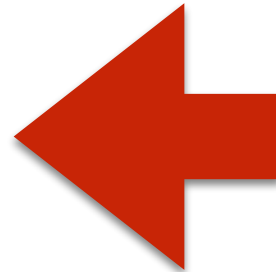




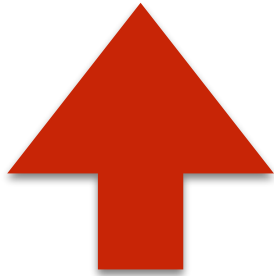
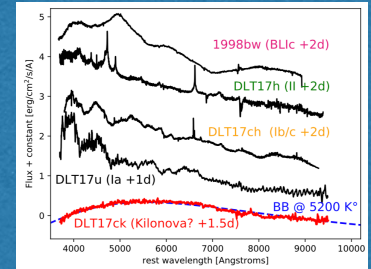
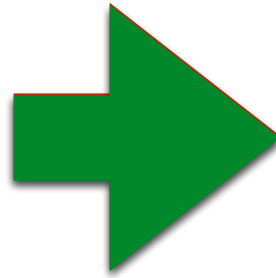
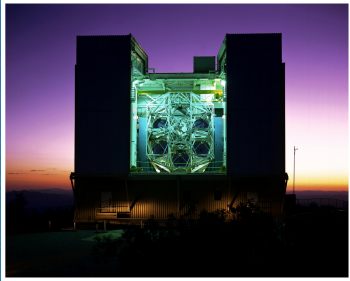
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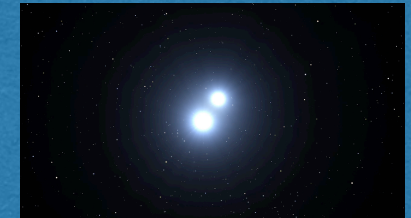
Credit: ESO



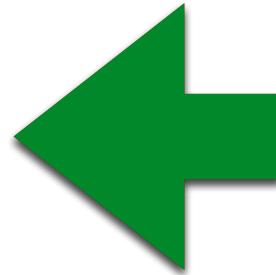


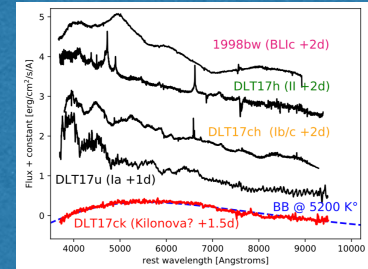
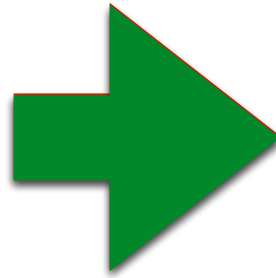
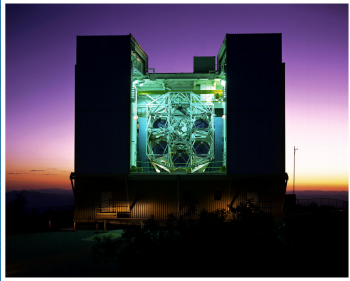


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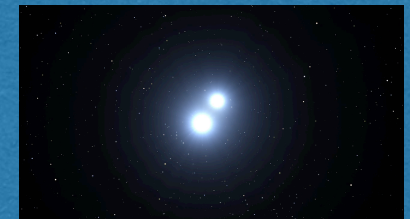
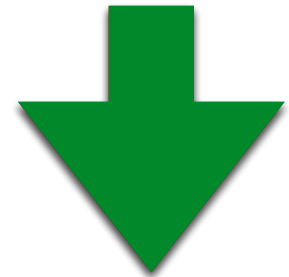


Credit: ESO





Credit: Keck



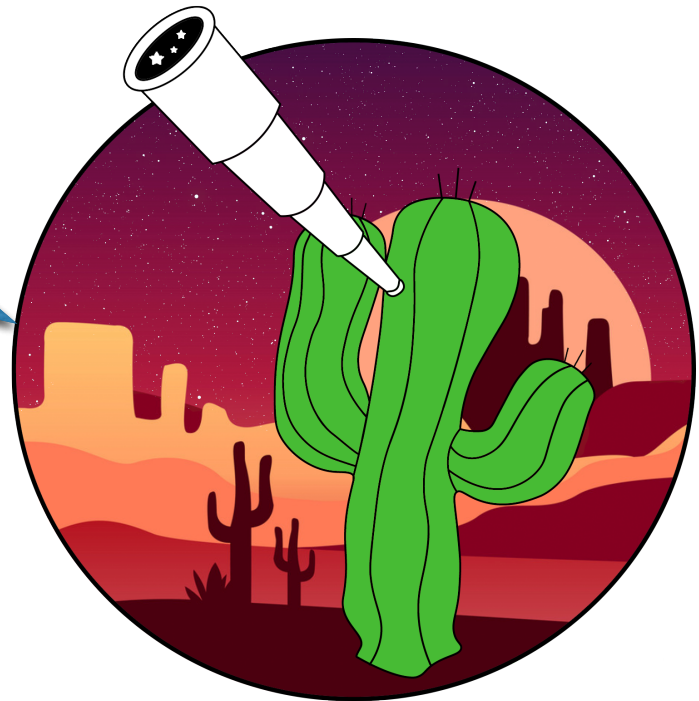
Credit: ESO

What does this mean  
for the community?



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Sharing is caring!



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Coming  
soon to a website  
near you!



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# SAGUARO

- Home
- GCN Events
- GW Events
- All Candidates
- CSS Visits
- More Information

## Events Filter

Select date:

Select Observatory:

Observation Type:

**Submit**

**Reset**

Preliminary

Observatory	GW Event Name	Obs Type	Alert Type	BNS Prob	BNS Prob	BNS Prob	Noise Prob	False Alarm Rate	Sites	Data Analysis Group	Distance	Retracted ('Yes/NULL')
"LIGO Virgo"	"MS190210q"	test	Preliminary	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1
"LIGO Virgo"	"MS190210q"	test	Preliminary	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	1
"LIGO Virgo"	"MS190210p"	test	Preliminary	0.821351538361	0.0	0.0	0.178648461639	9.11069936486e-14	H1,L1	CBC	141.145197388	0
"LIGO Virgo"	"MS190210p"	test	Preliminary	0.821351538361	0.0	0.0	0.178648461639	9.11069936486e-14	H1,L1	CBC	141.145197388	0

# SAGUARO


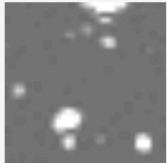



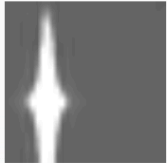
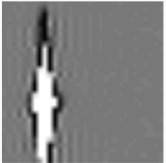
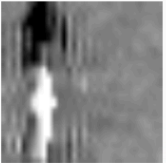




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## Candidate Search

Select date: Select type: Select field: Signal to noise cutoff: 

12113 results returned.

Preliminary

ID	Date	Field	RA	DEC	Classification	Target	Reference	Difference	Score
3079746	2019-02-09	N14050	111.288124	13.897239	Moving Object				
3079744	2019-02-09	N14050	111.51742	13.897786	Moving Object				
3079885	2019-02-09	N14050	112.4956	13.960909	Moving Object				

# Case study: GRB181123B

- Paterson, Fong, Nugent (in prep.)
- Short GRB on 23 Nov 2018
- Rapid follow up on Keck and Gemini
- No afterglow to deep limits



# Case study: GRB181123B

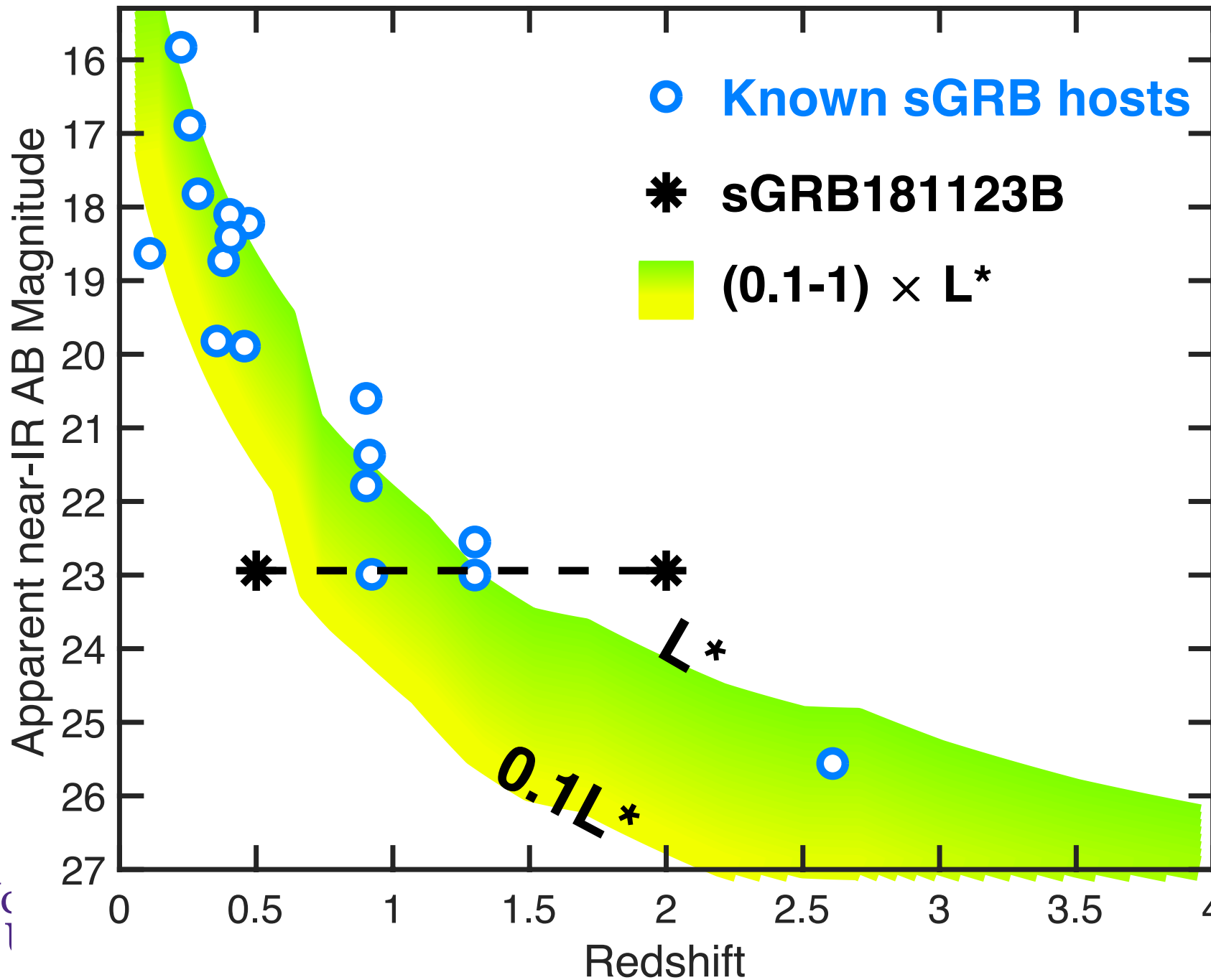
- Paterson, Fong, Nugent (in prep.)
- Short GRB on 23 Nov 2018



Epoch 1

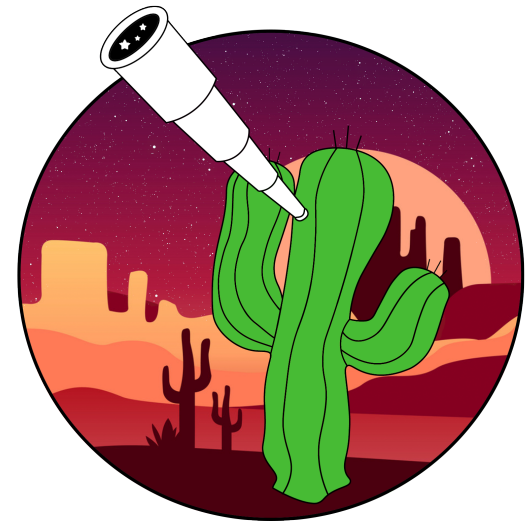
Epoch 2

Subtraction



# Conclusions

- SAGUARO aims to identify GW candidates within 1 hour of detection
- Classification of candidates
- Public
- Access to large facilities allow follow up of faint transients



**SAGUARO**