Tracing the mass-loss history from type II supernova explosions back through the red supergiant phase.

Stefano Valenti

UCDAVIS
UNIVERSITY OF CALIFORNIA

credit: BJ Fulton

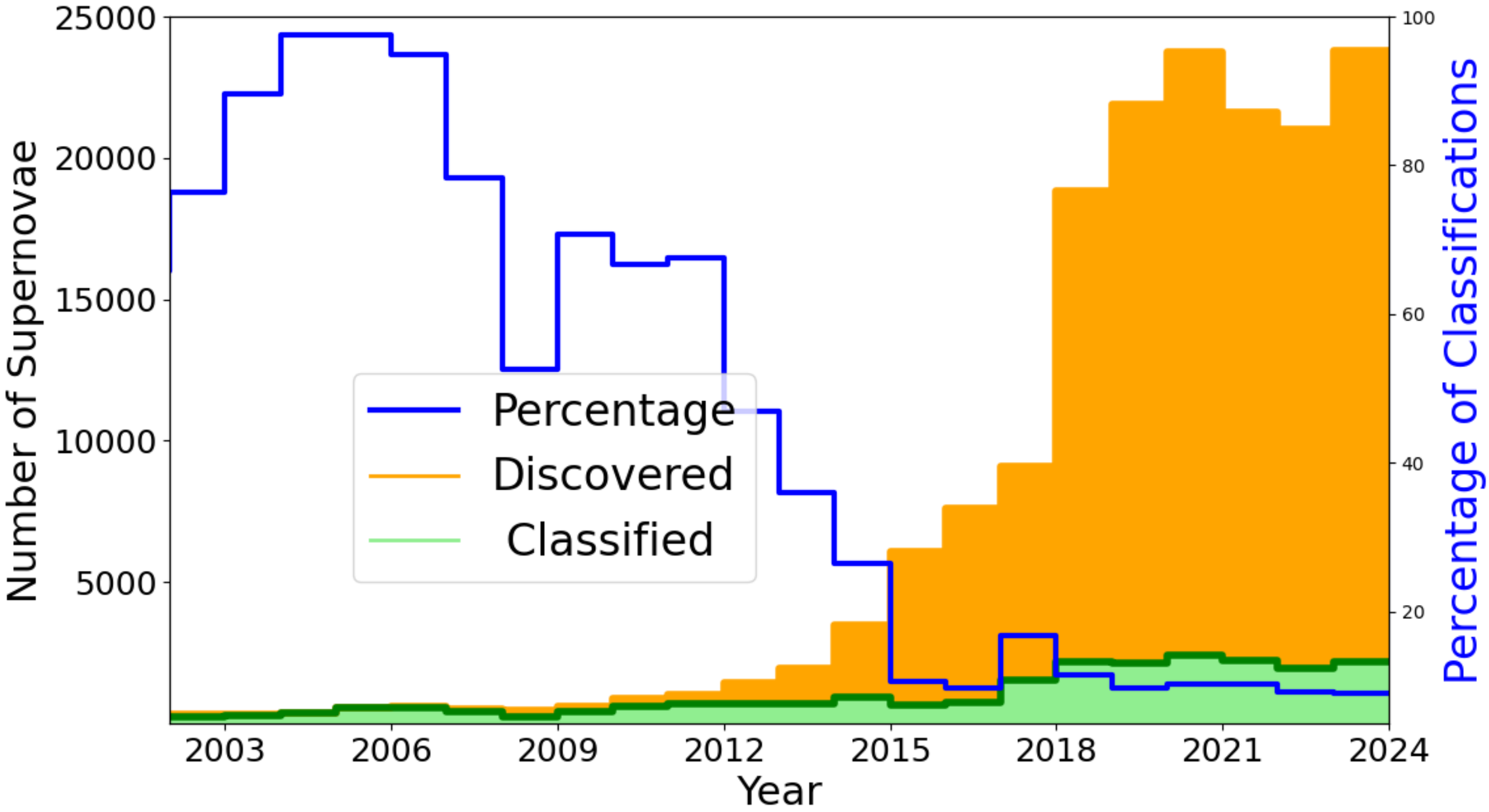
Thank you

Enrico Cappellaro

Padova group meeting 2012

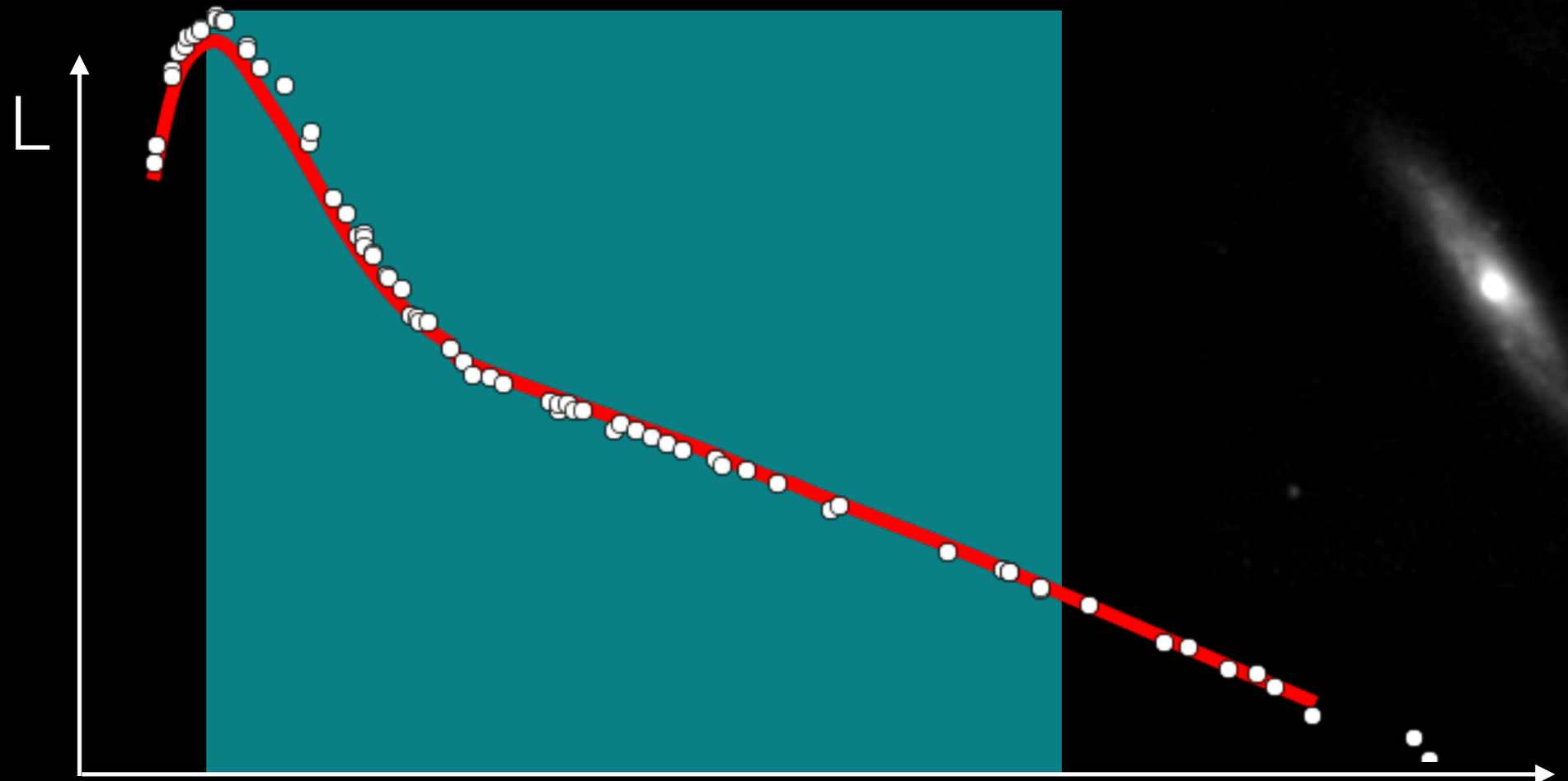
Bachelor's thesis defense 2003

Gold Era to study Transients



Do we still need more SNe?

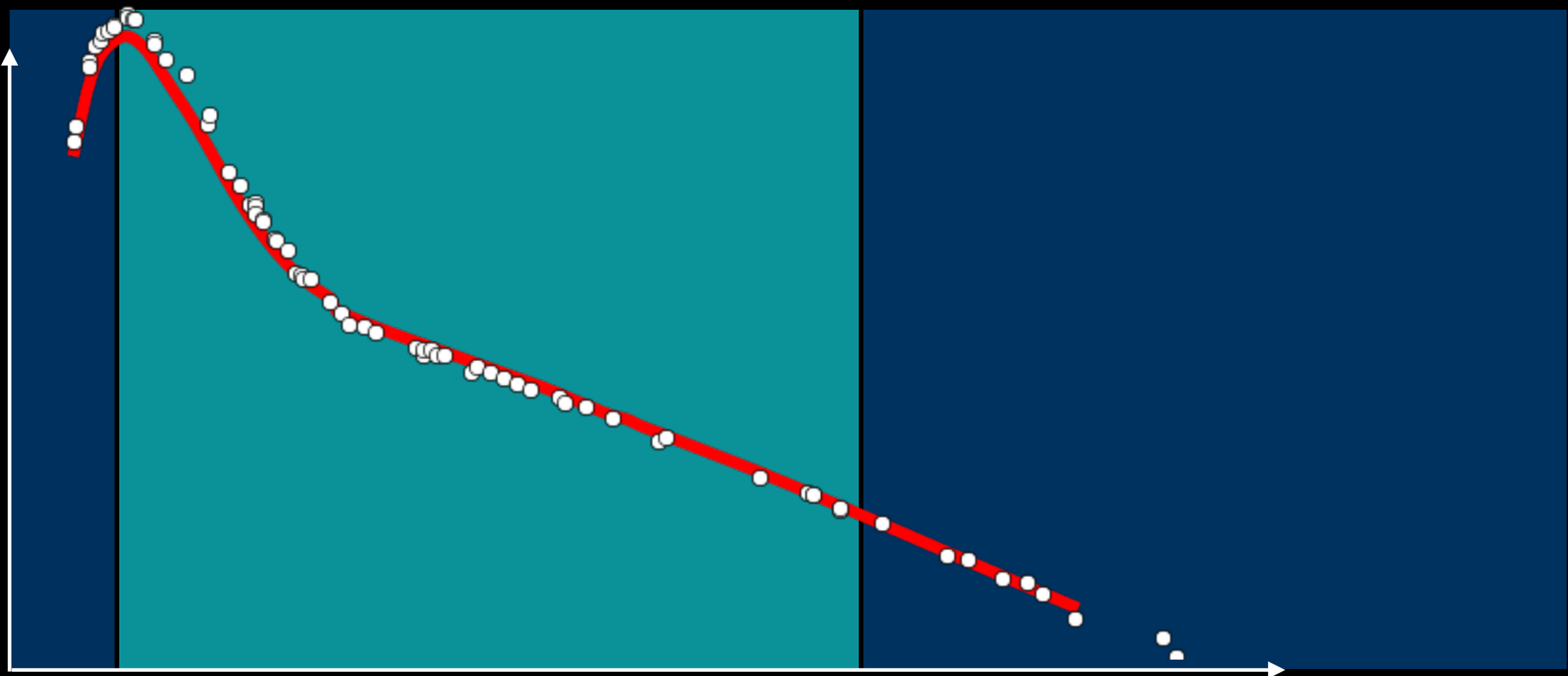
What ANOTHER spectrum two weeks after maximum of a SN is going to teach us? something new?



Explore the unexplored

Infant SN phase

Late time



Distance Less Than 40 Mpc = DLT40

Stefano Valenti
UC Davis

Aravind P. Ravi
UC Davis

Nicolas Retamal
UC Davis

Darshana Mehta
UC Davis

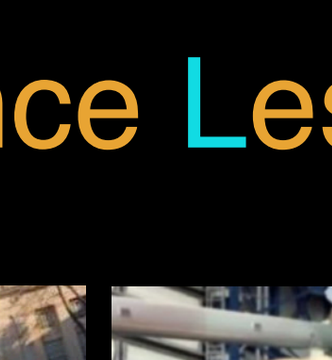
Emily Hoang
UC Davis

Yize Dong
Harward
University

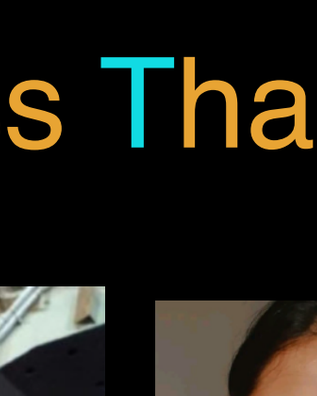
Michael
Lundquist
Keck

David Sand
Univ. of Arizona

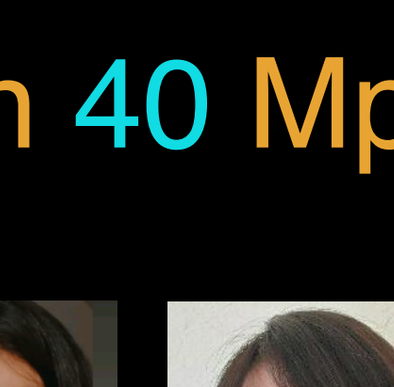
Azalee
Bostroem
University of
Arizona



Jeniveve
Person
Univ. of Arizona

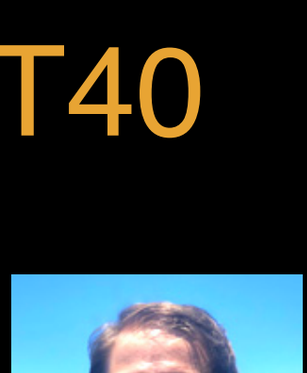


Manisha
Shrestha
Univ. of Arizona



Bhagya
Subrayan
Univ. of Arizona

Lindsey Kwok
Northwestern



Jennifer
Andrews
Gemini

Daryl Janzen
University of
Saskatchewan

Saurabh W Jha
Rutgers
University

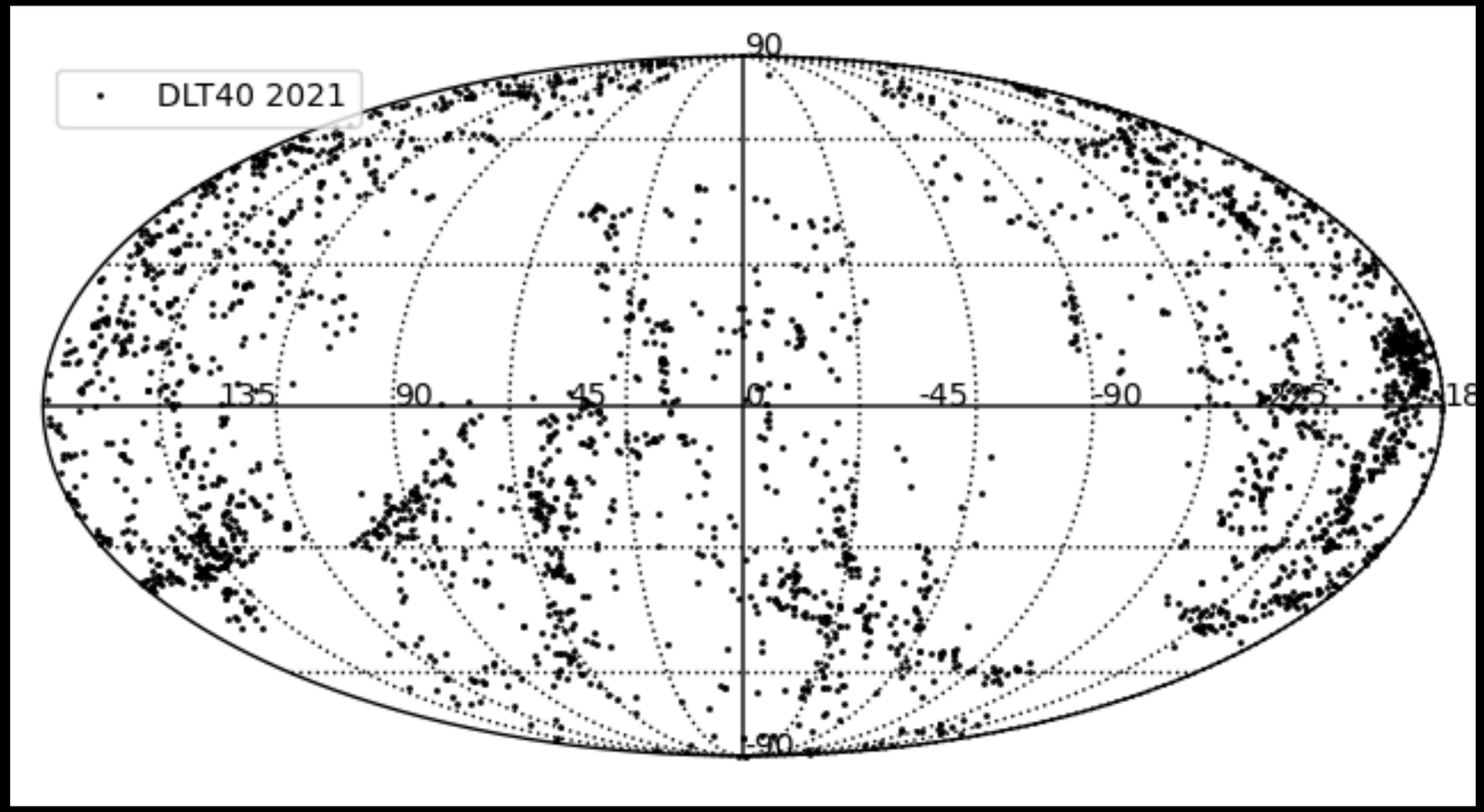
Kaew
Samaporn
Tinyanont
NARIT

Griffin
Hosseinzadeh
UC San Diego

Distance Less Than 40 Mpc = DLT40

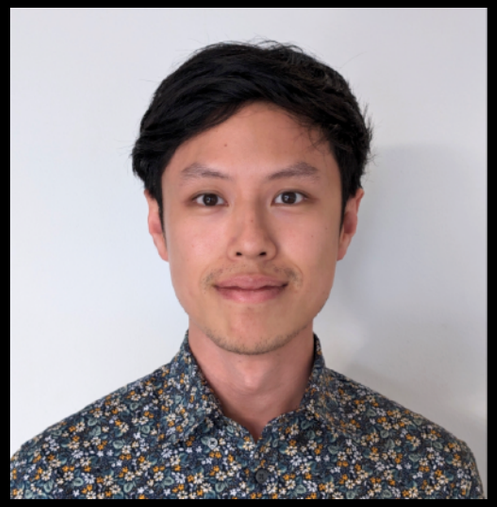
2017	1 Chile	Search for SNe in nearby galaxies with a 24 hours cadence	400-600 galaxies every 24 hours
2019	1 Chile 1 Australia	Search for SNe in nearby galaxies with a 12 hours cadence	400-600 galaxies every 12 hours
2021	1 Chile 1 Australia 1 Canada	Search for SNe in nearby galaxies with a 12 hours cadence 24 hours (dec >20º)	800-1200 galaxies every 12/24 hours

~ 15-20 nearby SNe per year within 24h from last non-detection

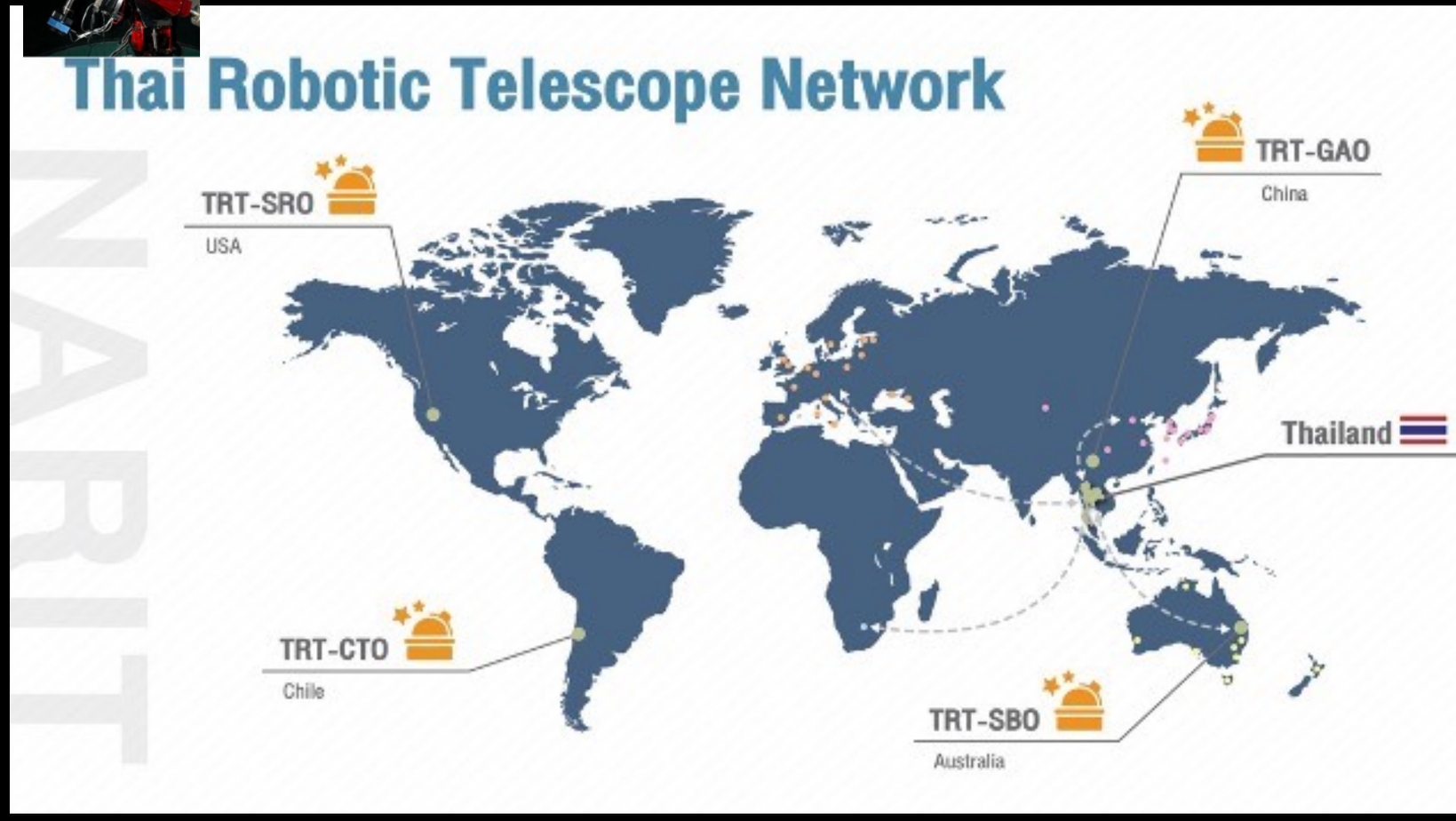


DLT40 SN Search

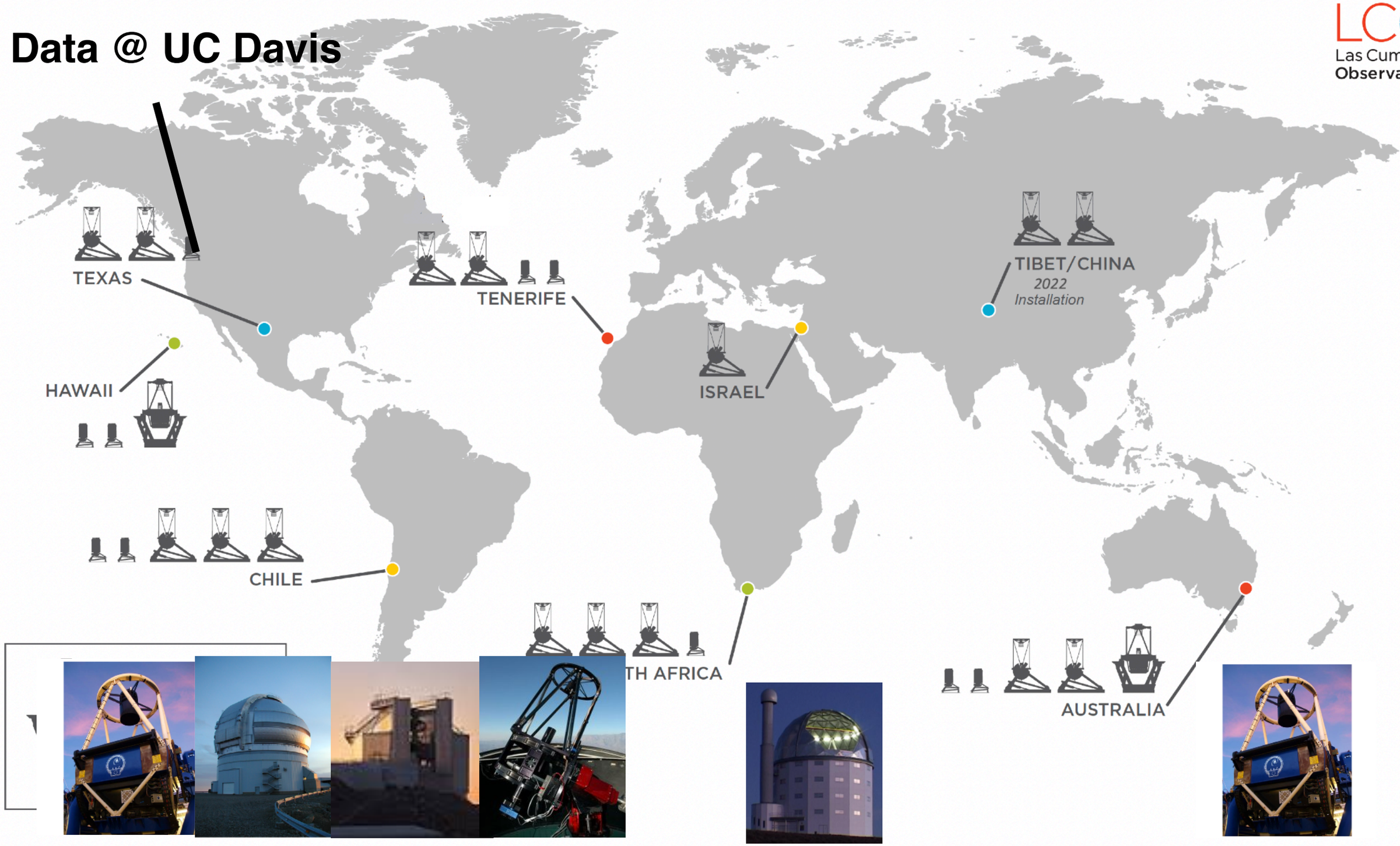
SKYNET ROBOTIC TELESCOPE NETWORK



Kaew Samaporn Tinyanont



DLT40 follow-up



DLT40 timeline

- No human in the loop
- Human in the loop

DLT40 BOT APP 4:11 PM
TNS transient in DLT40 - 25.290 Mpc - 0.88 arcmin
TNS object: 2025fvw DLT40 galaxy: NGC5957 1871
jd dateobs mag magerr limmag filter telescope
2460761.2986 2025-03-26 17.4 None None Clear- XLT

I will add this object to the idcandidate table
new candidate: 9656861
I am also triggering an image to confirm if the object is real
HST VISIBILTY:
visible with HST Now!!
2025-01-04-2025-04-26
2025-05-06-2025-06-04
2025-07-09-2025-07-15
2026-01-04-2026-03-29

DLT40 BOT APP 9:45 PM
45791089.diff.fits Prompt2
@here Trigger Multiband photometry and Clear for object 108359 in galaxy 1412

DLT40 BOT APP 5:48 PM
45619115.diff.fits Prompt5
@channel TRIGGERING SPECTRUM for object 9586853 in galaxy 27435

triggerid= 2176690

TNS object in nearby galaxy

~1h

Skynet observations

~12-24h

DLT40 SN search

~5 min

~10 min

~ 6 hours

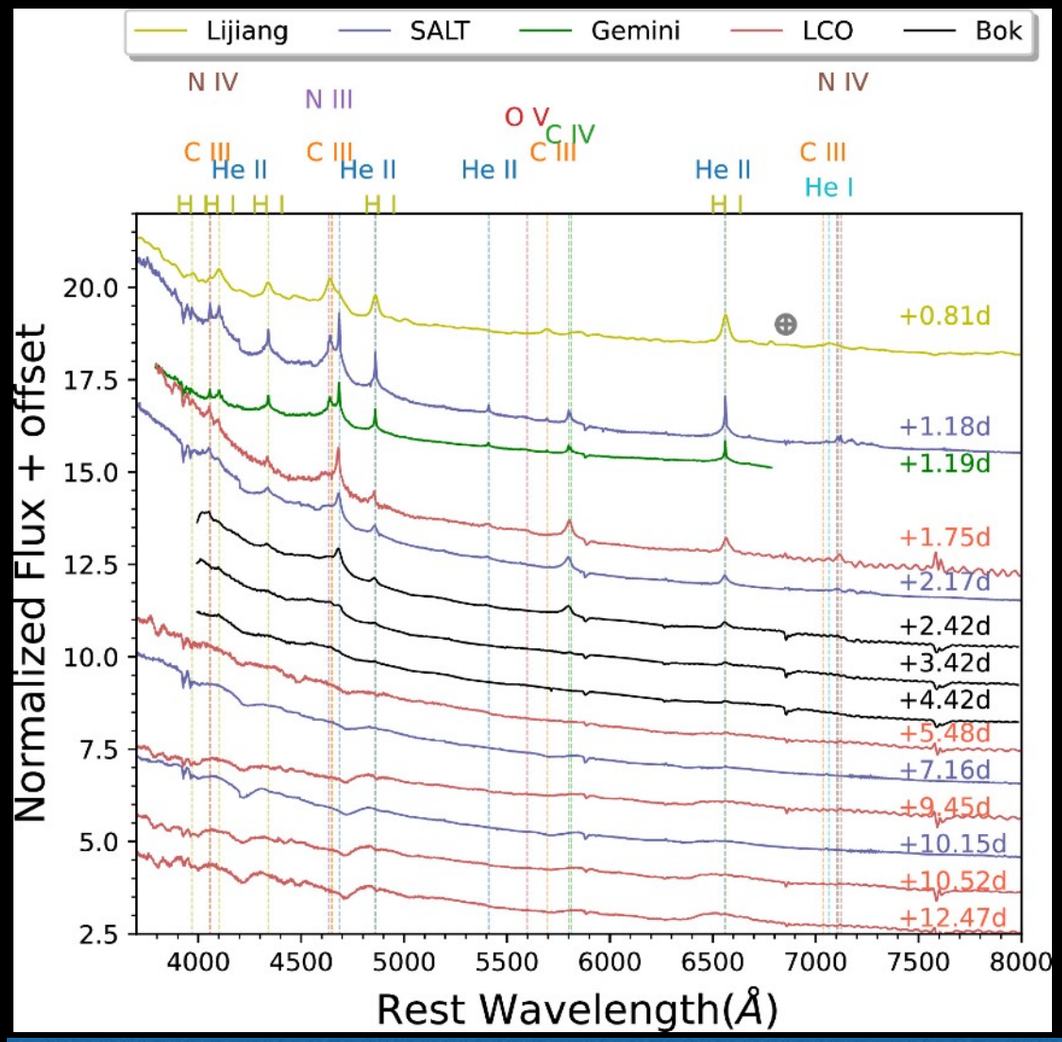
Automatic confirmation image for high ML score

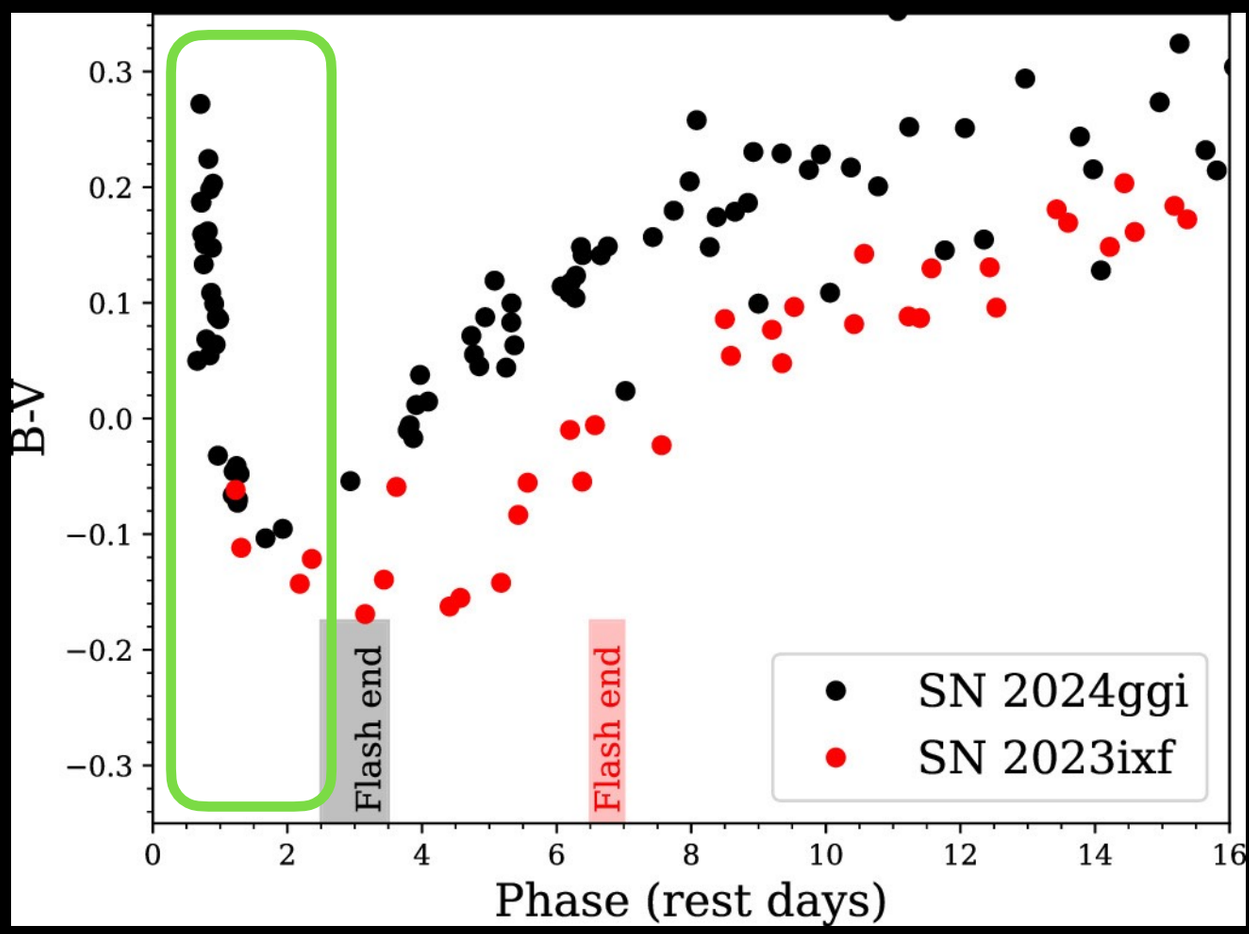
If the object is real, trigger multi bands photometry

Trigger a FLOYDS spectrum

Gemini, swift SALT, Keck, SOAR, Lick

Distance Less Than 40 Mpc = DLT40



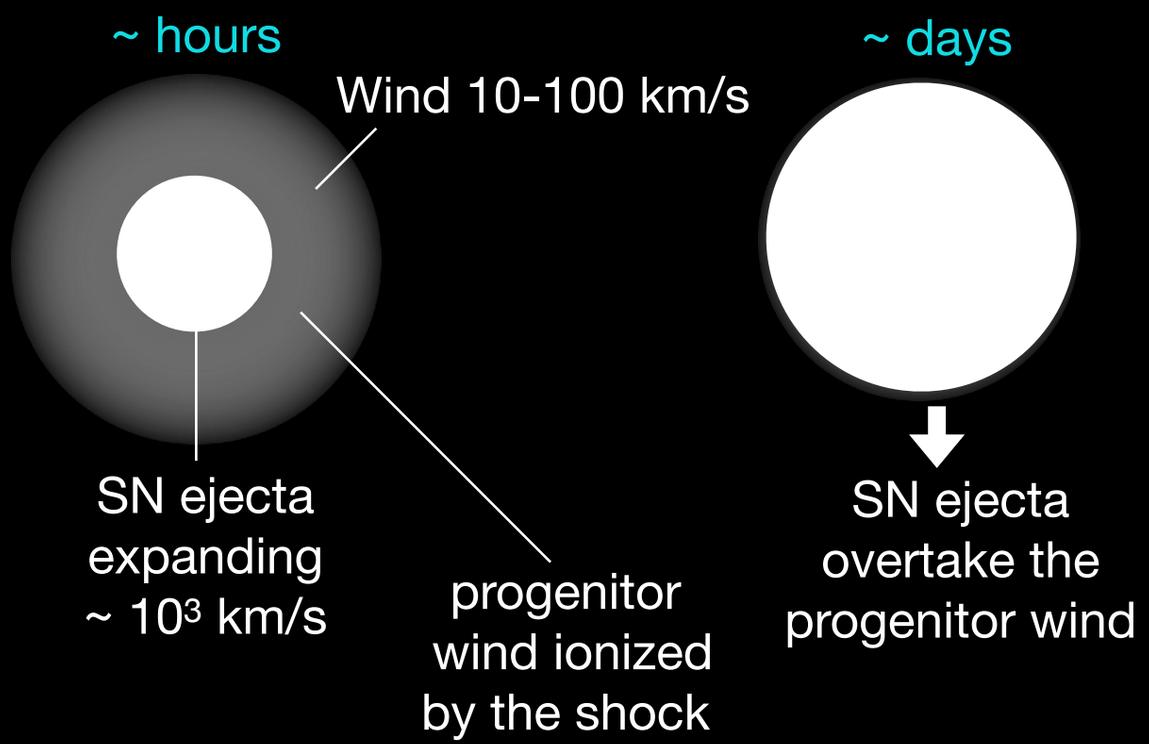


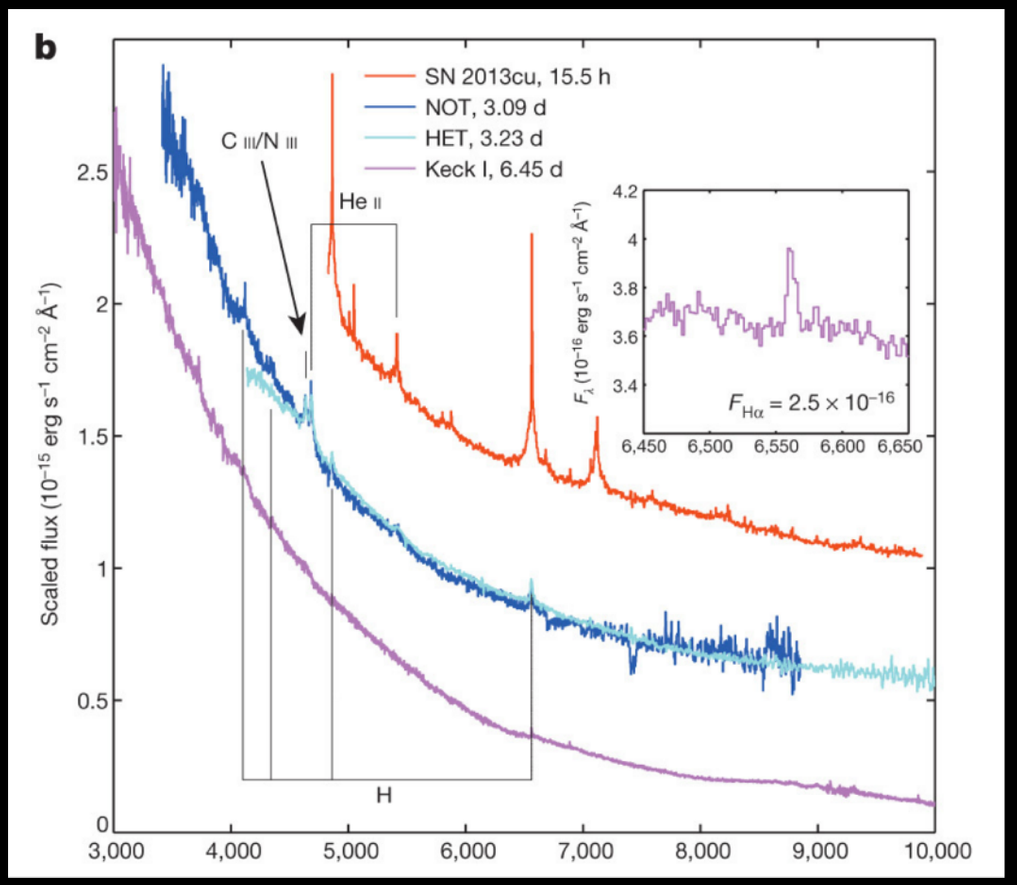
Constrain the mass loss from the early spectroscopy M_{CSM} ~10^{-3}-10^{-2} $M_\odot$ /yr

Shrestha+ 2024

Robotic small telescope are the only way to provide high cadence observations of nearby transient!

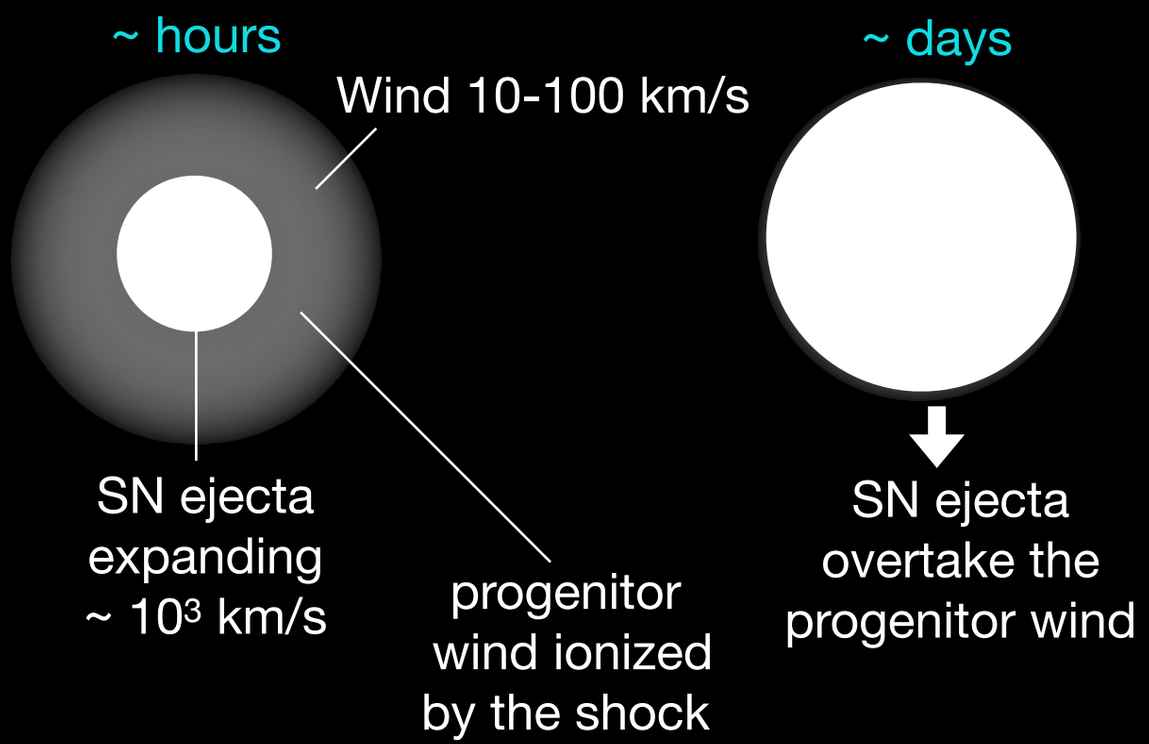
Measure mass loss after SN exploded

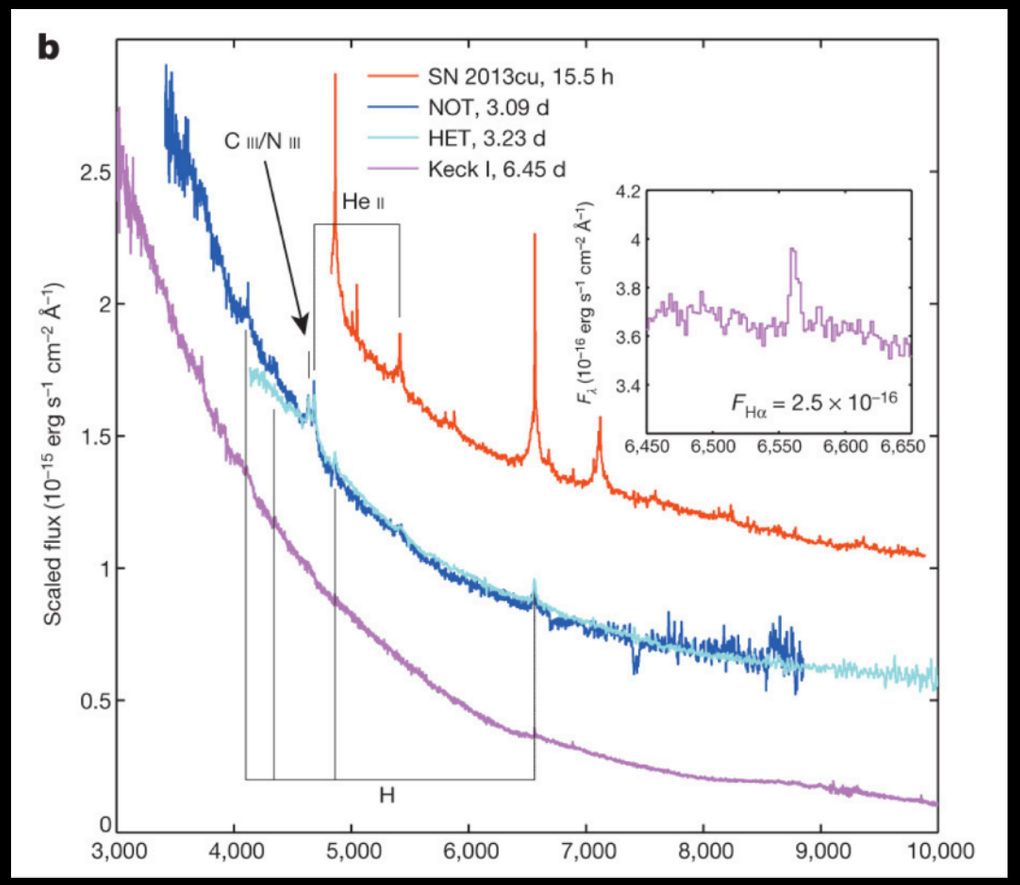




Gal-Yam+ 2014

Measure mass loss after SN exploded





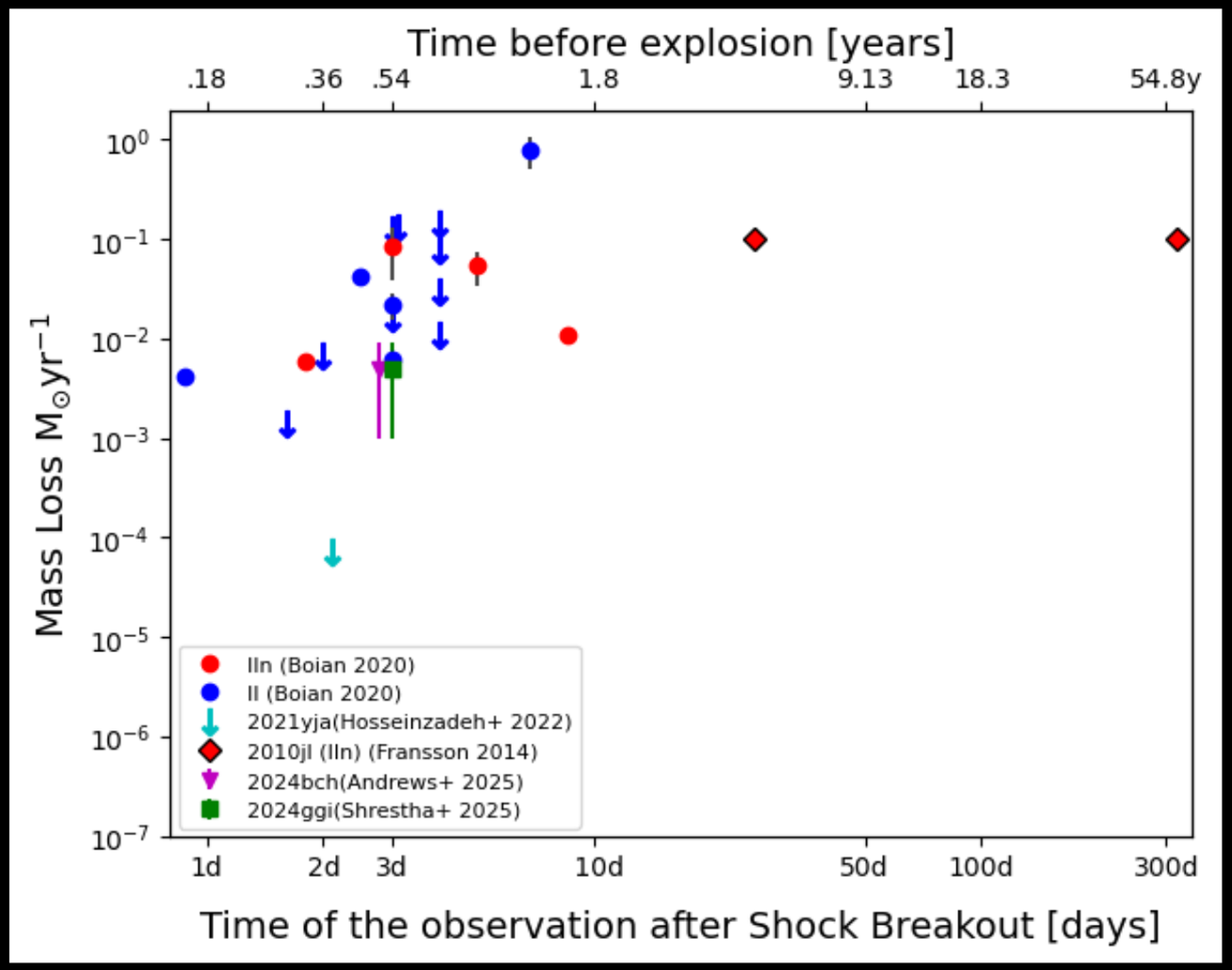
Gal-Yam+ 2014

Gal-Yam+ 2014, Groh 2014, Shivvers+ 2015, Terreran+ 2015, Khazov+ 2016, Dessart+ 2017, Yaron+ 2017, Leonard+ 2000, Hosseinzadeh + 2022, Terreran+ 2022, Bostroem+ 2023, Pearson+ 2023, Jacobson-Galán+ 2023, Dessart+ 2023 ,Shrestha+ 2024, Andrews+2024,, Hiramatsu+ 2024, Meza-Retamal+ 2024, Jacobson-Galán+ 2024, Andrews+2025 ….

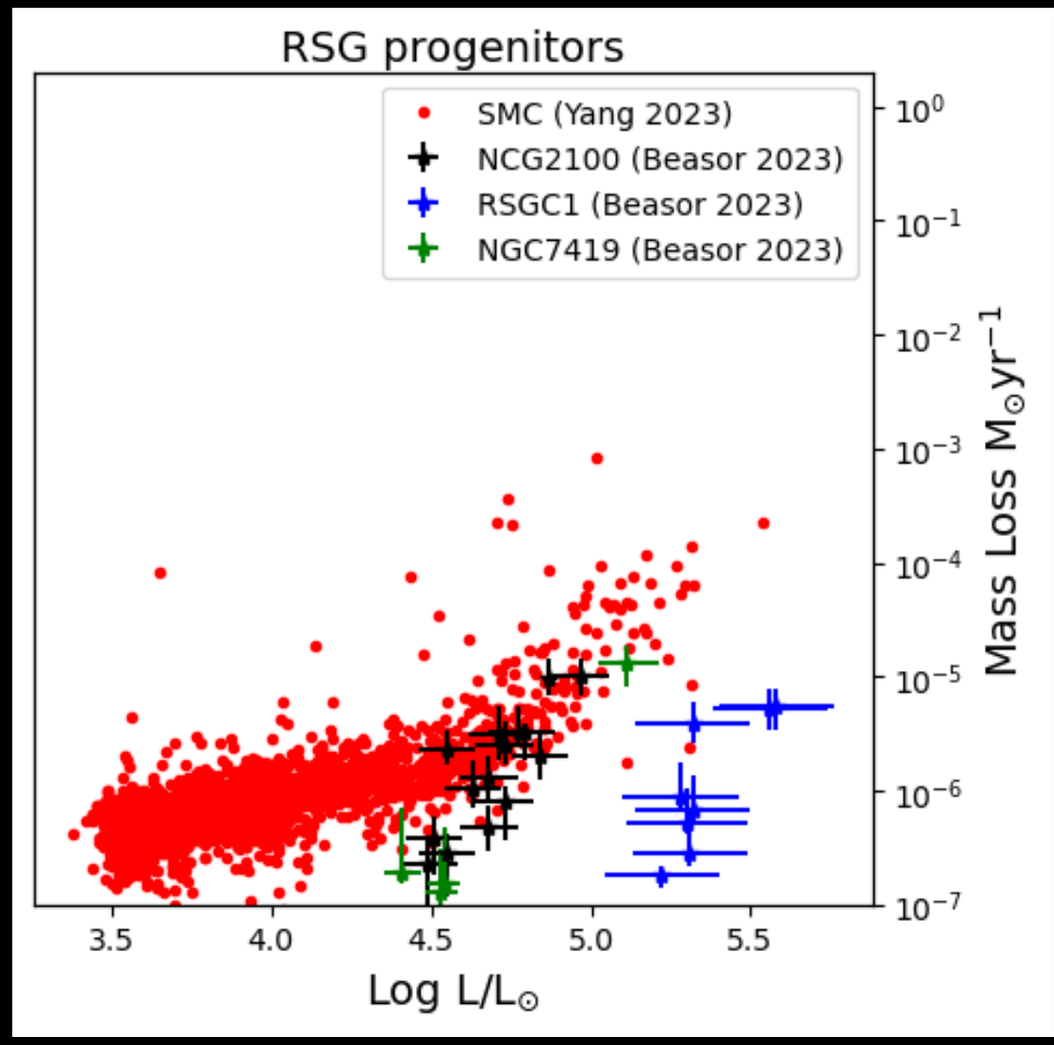
Enhanced mass loss before exploding

$$\dot{M}_{CSM} \sim 10^{-3} - 10^{-1} M_{\odot}/yr$$

What is making mass loss to increase in RSG?



?



Enhanced mass loss before exploding

$\dot{M}_{CSM} \sim 10^{-3} - 10^{-1} M_\odot/yr$

?

Mass loss in RSG

$\dot{M}_{CSM} \sim 10^{-7} - 10^{-5} M_\odot/yr$

Tracing the mass-loss history from type II supernova explosions back through the red supergiant phase.

UV

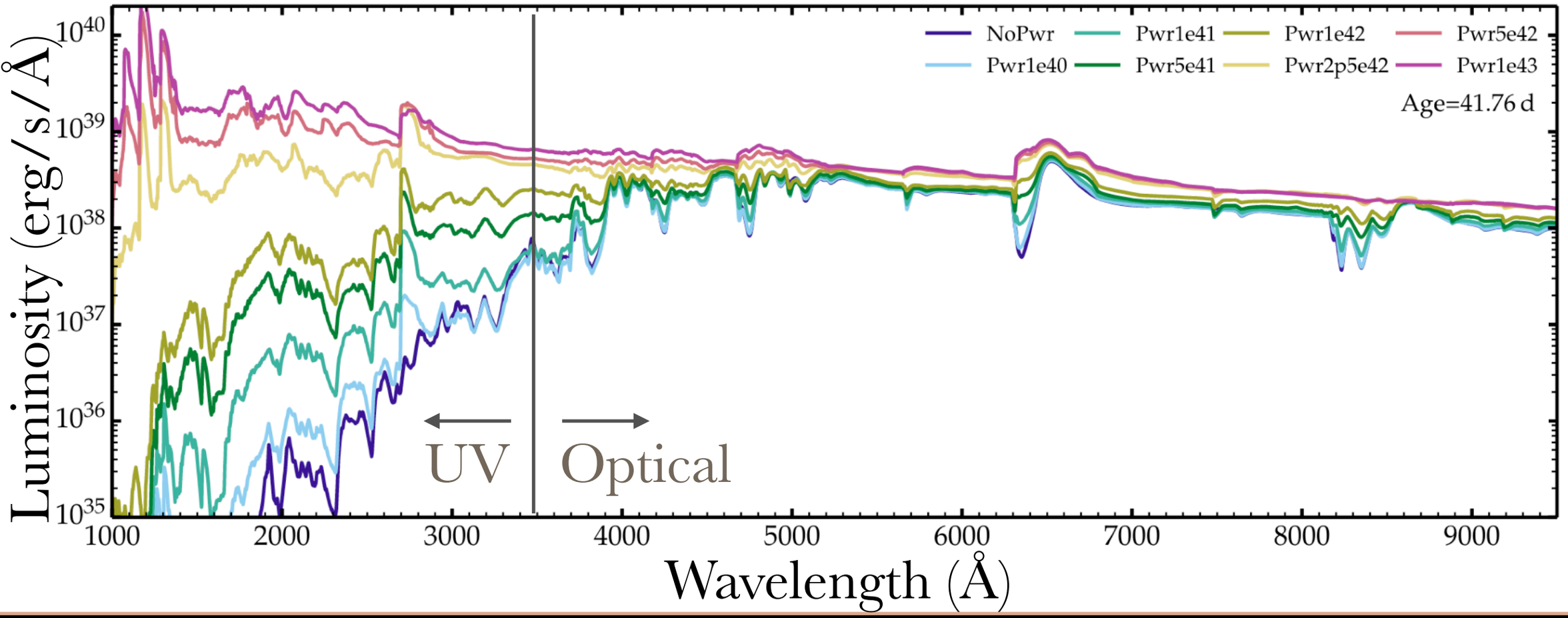
X-ray

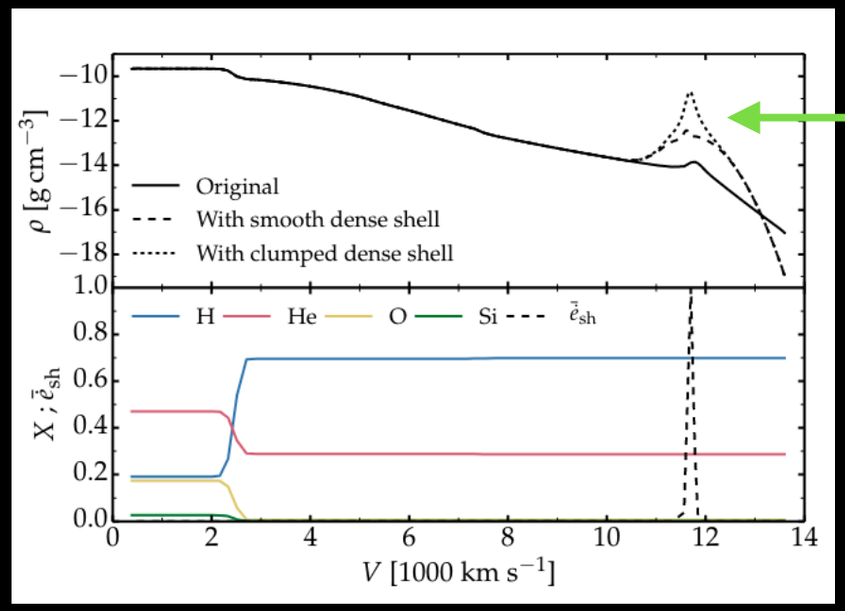
Light curve modeling

Radio

UV as a Probe of Mass Loss

CSM + SN shock power

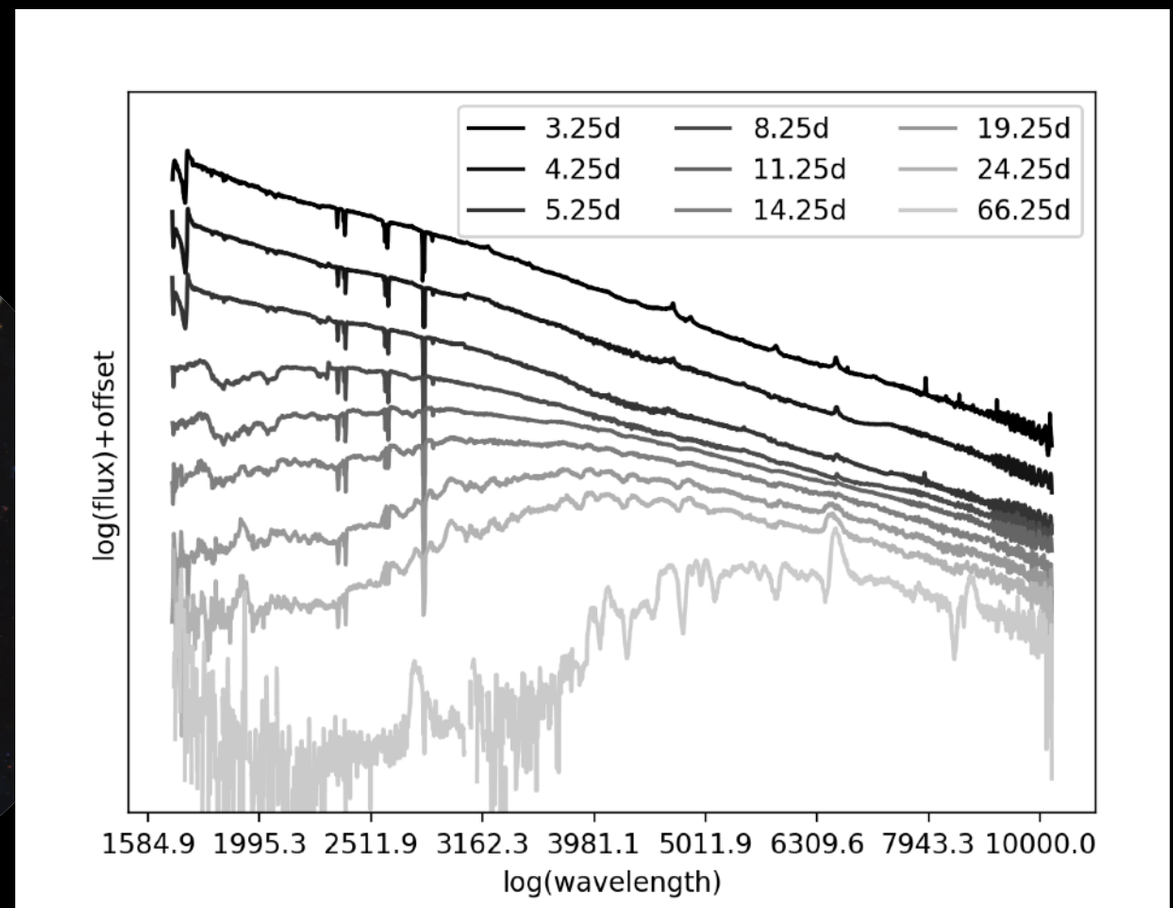




- Artificial introduce a dense shell
- Deposit a “shock power” in the dense shell

Dessart+ 2022

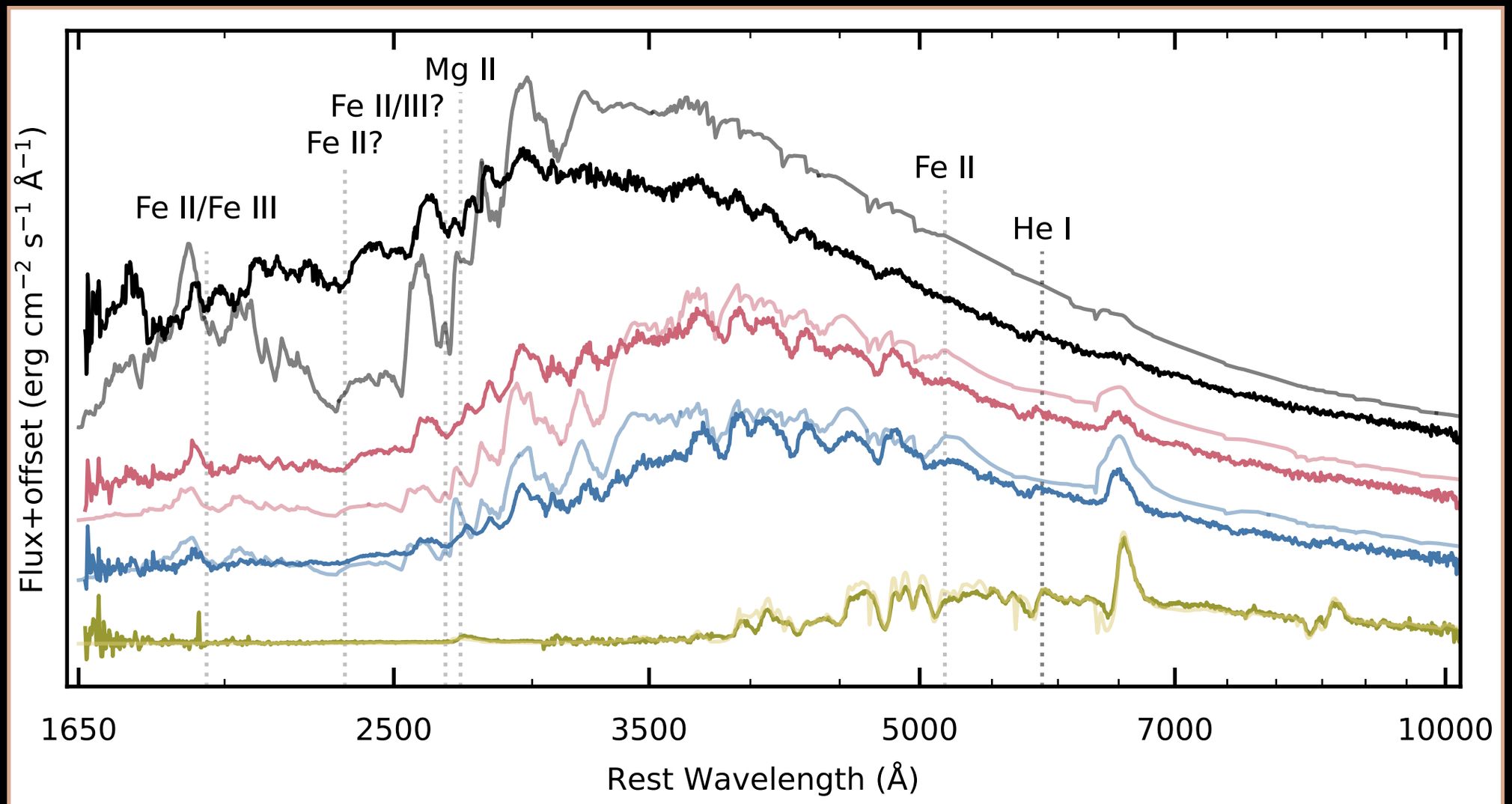
SN 2023ixf in M101



Bostroem et al 2024

GO-17205 (PI Zimmerman)
DD- 17313 (PI Bostroem)
GO-17497 (PI Valenti)
DD-17610 (PI Valenti)
GO-17772 (PI Bostroem)

Modeling CSM Interaction Power



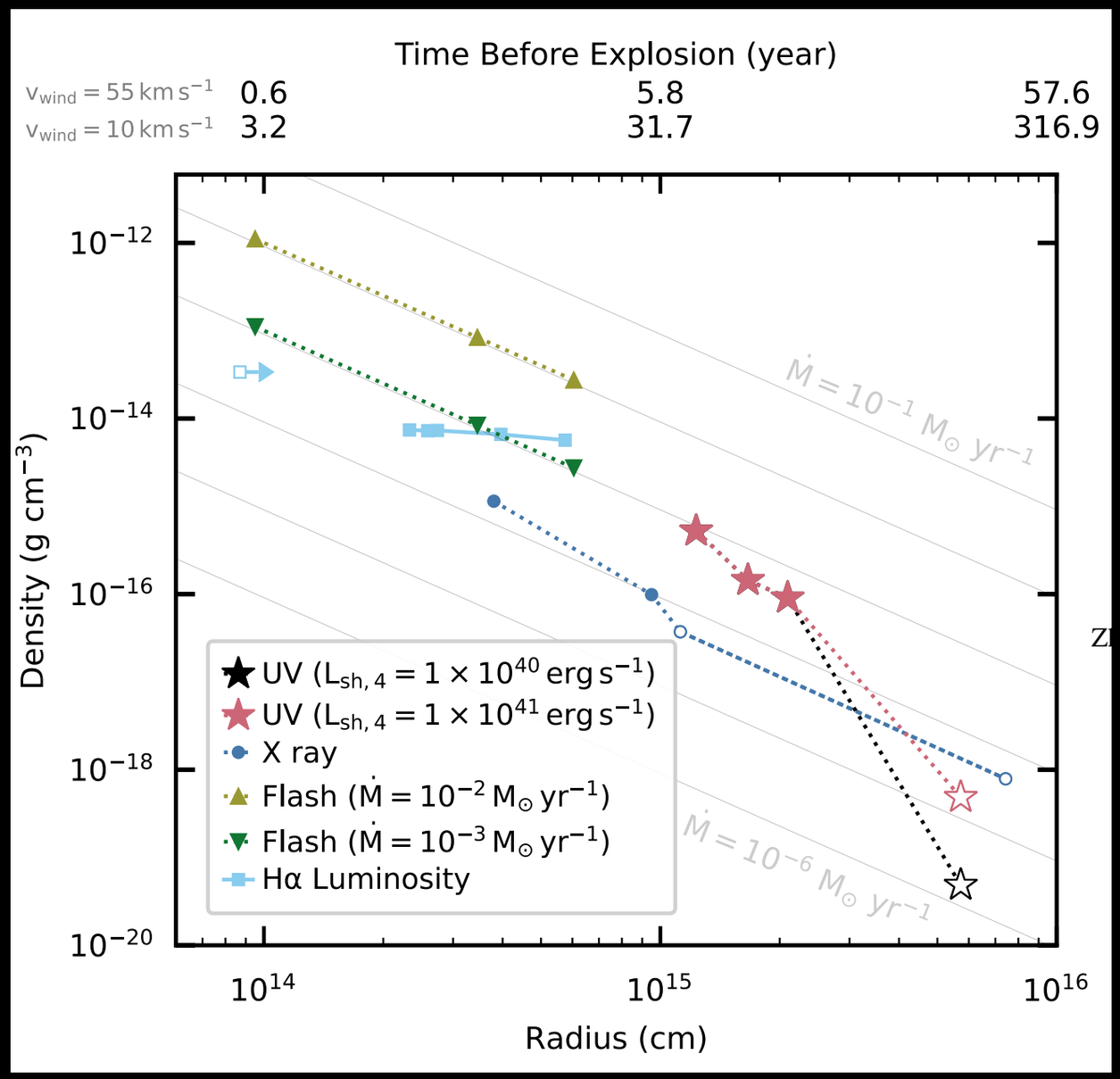
Phase	CSM Shock Power	$\dot{M}_{CSM}$
14d	5x10^{42} erg/s	$8.7x10^{-4}M_{\odot}yr^{-1}$
19d	2.5x10^{42} erg/s	$4.4x10^{-4}M_{\odot}yr^{-1}$
25d	2.5x10^{42} erg/s	$4.4x10^{-4}M_{\odot}yr^{-1}$
66d	1x10^{40} erg/s	$1.7x10^{-6}M_{\odot}yr^{-1}$

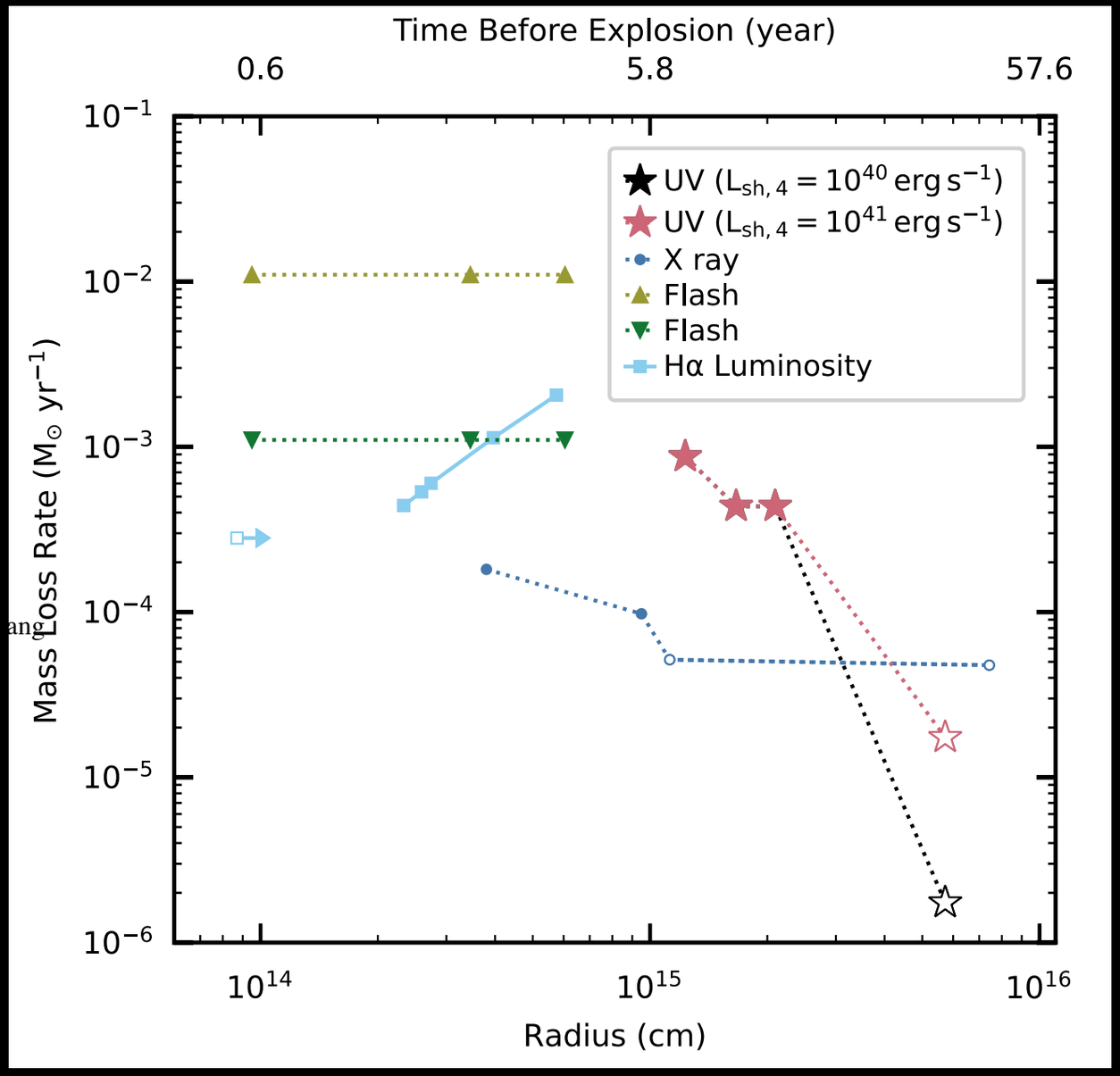
CMFGEN models from Dessart+ 2022

Mass loss increased a few years before the explosion

Bostroem+ 2024

Tracing the Full Mass-loss History



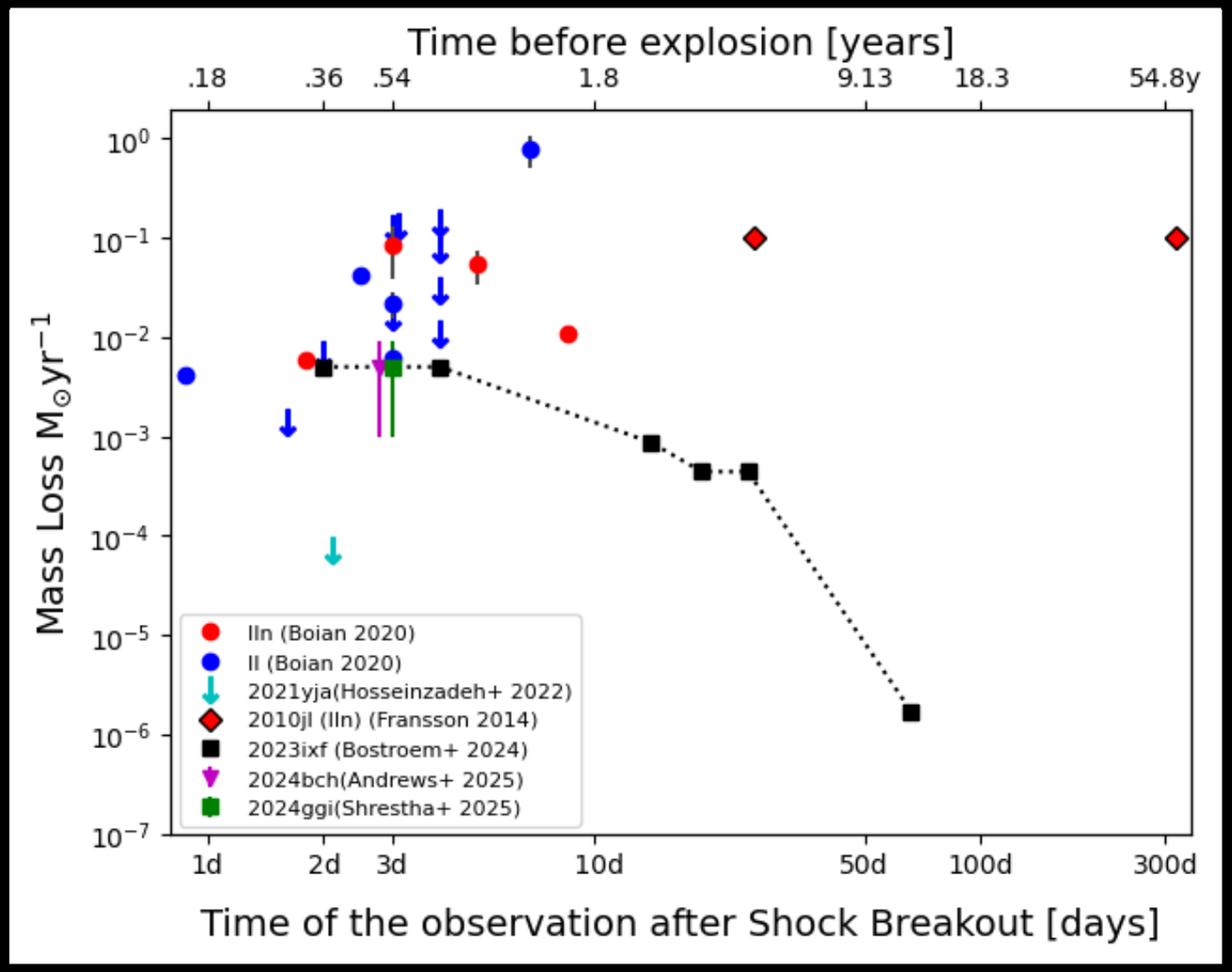


Zhang+2023, Jacobson-Galán+ 2023, Grefenstette+2023, Chandra+ 2024

Mass loss increased a few years before the explosion

Bostroem+ 2024

We will trace even further mass-loss history for SN 2023ixf



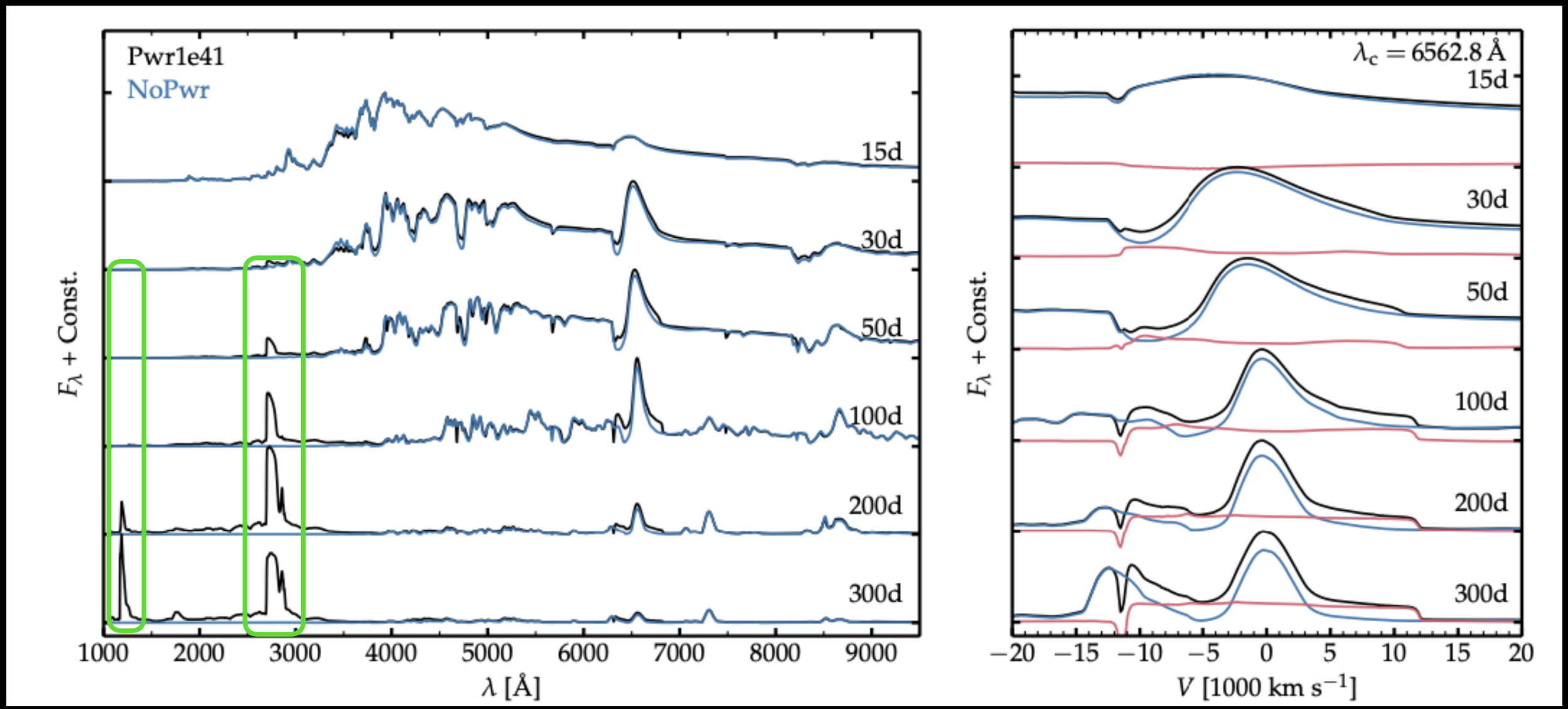
Additional UV spectra have been acquired and will be used to trace mass-loss up to ~600-700 days.

Bostroem+ (in prep)

GO-17205 (PI Zimmerman)
DD- 17313 (PI Bostroem)
GO-17497 (PI Valenti)
DD-17610 (PI Valenti)
GO-17772 (PI Bostroem)

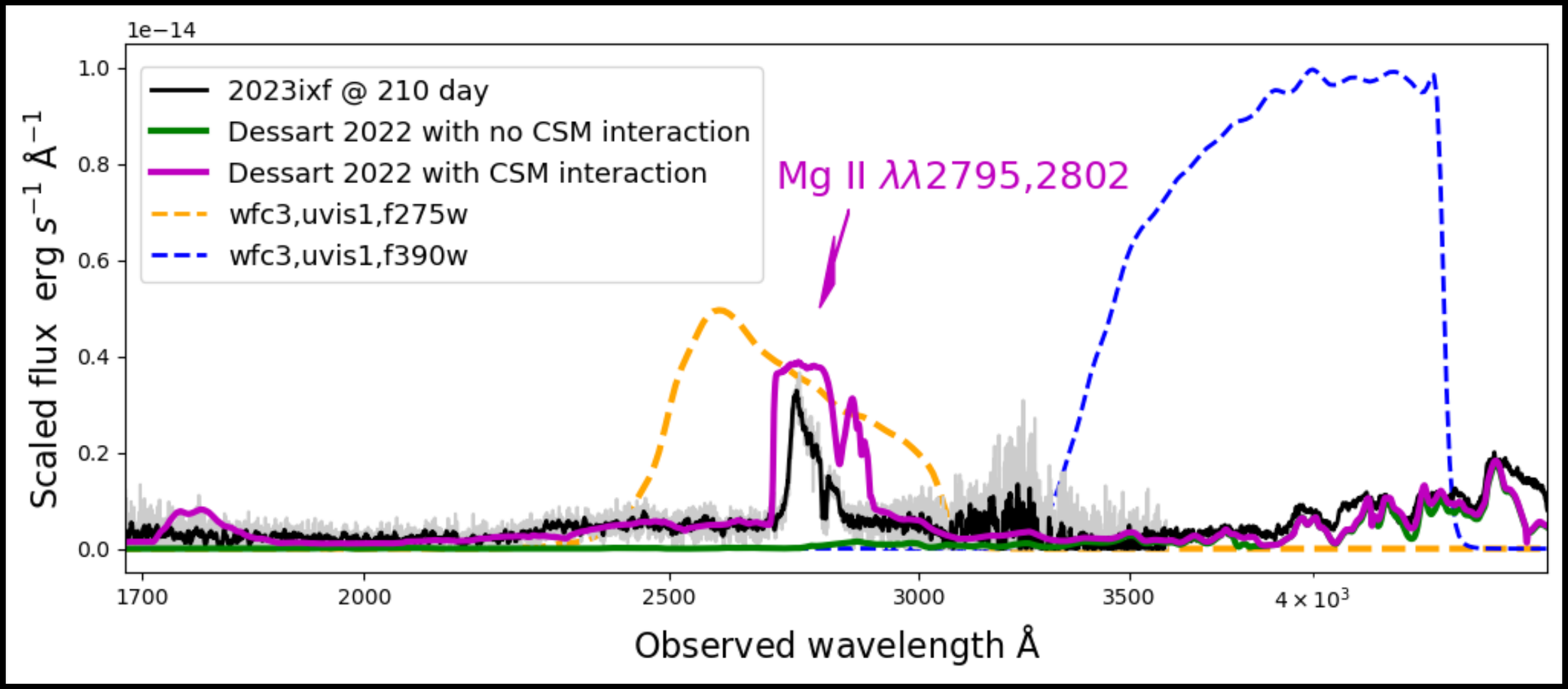
Can we use UV to trace mass-loss back in time for a larger sample?

Can we use UV to trace mass-loss back in time for a larger sample?



Dessart+ 2022

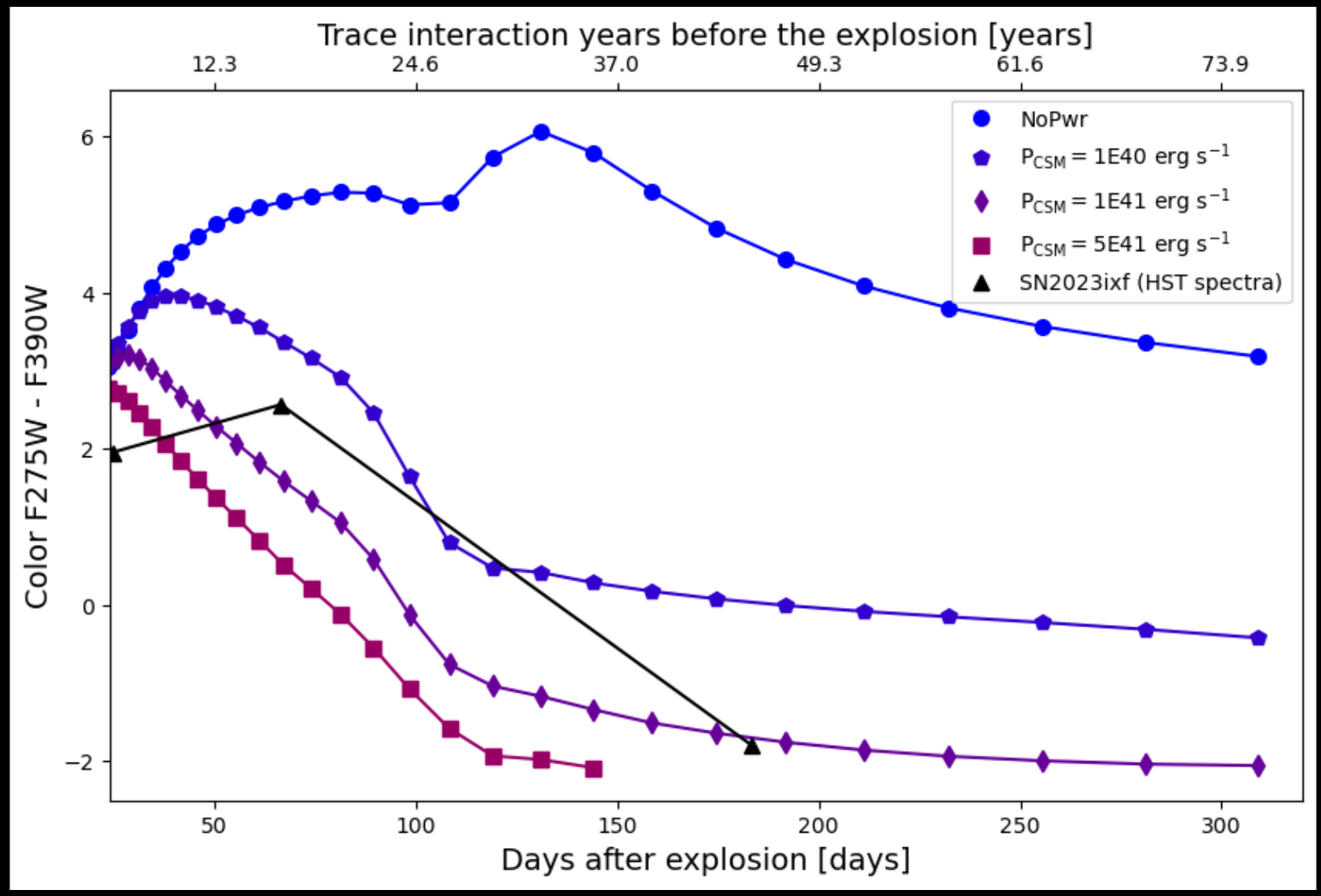
Can we use UV to trace mass-loss back in time for a larger sample?



You can use UV photometry with two filters to trace the mass loss of a larger sample of SNe (10 SNe during current HST cycle).

GO-17796 (PI Valenti)

Can we use UV to trace mass-loss back in time for a larger sample?



Mass loss

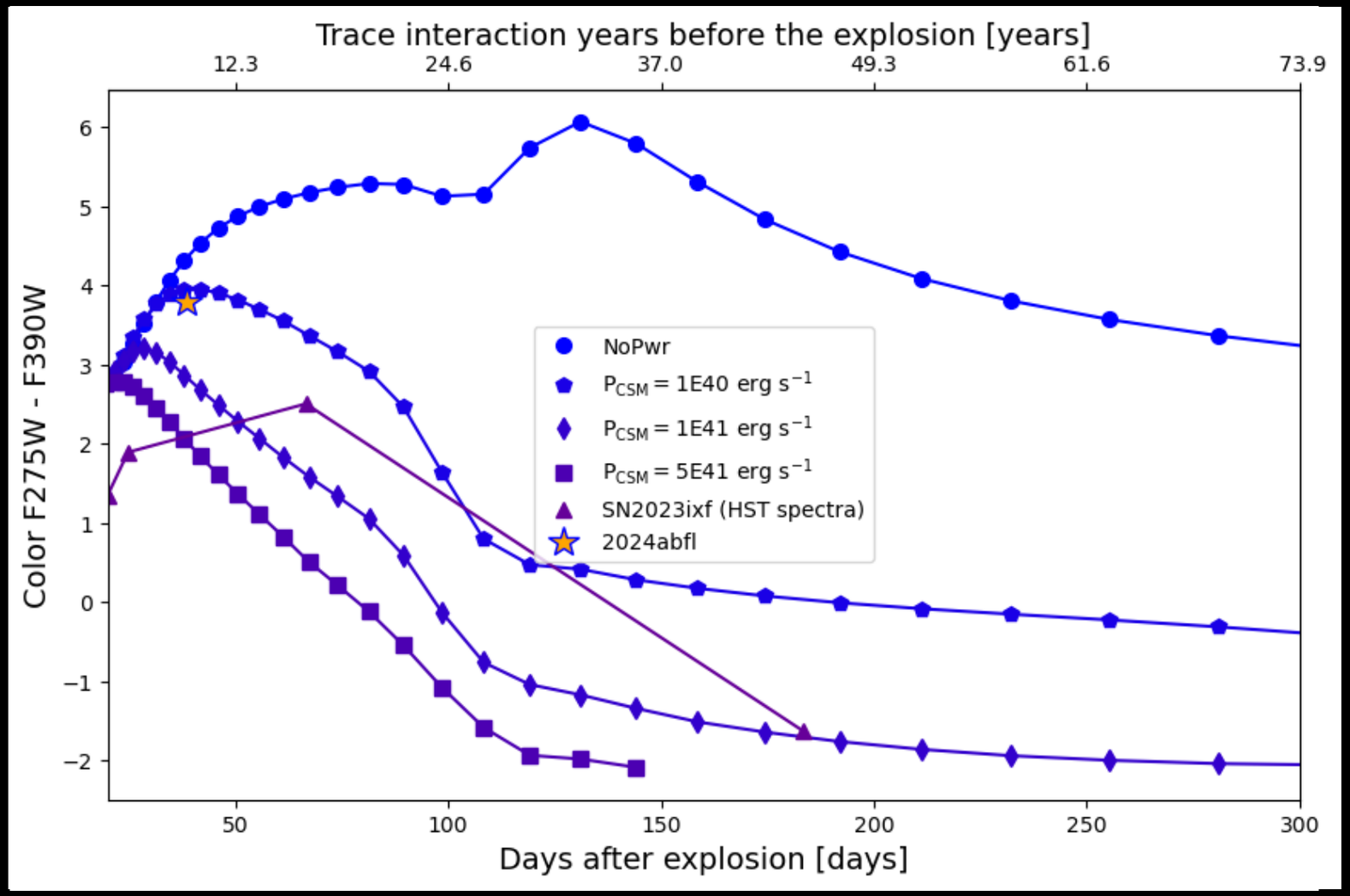
You can use UV photometry with two filters to trace the mass loss of a larger sample of SNe (10 SNe during current HST cycle).

GO-17796 (PI Valenti)

Thanks

extra slides

Can we use UV to trace mass-loss back in time for a larger sample?



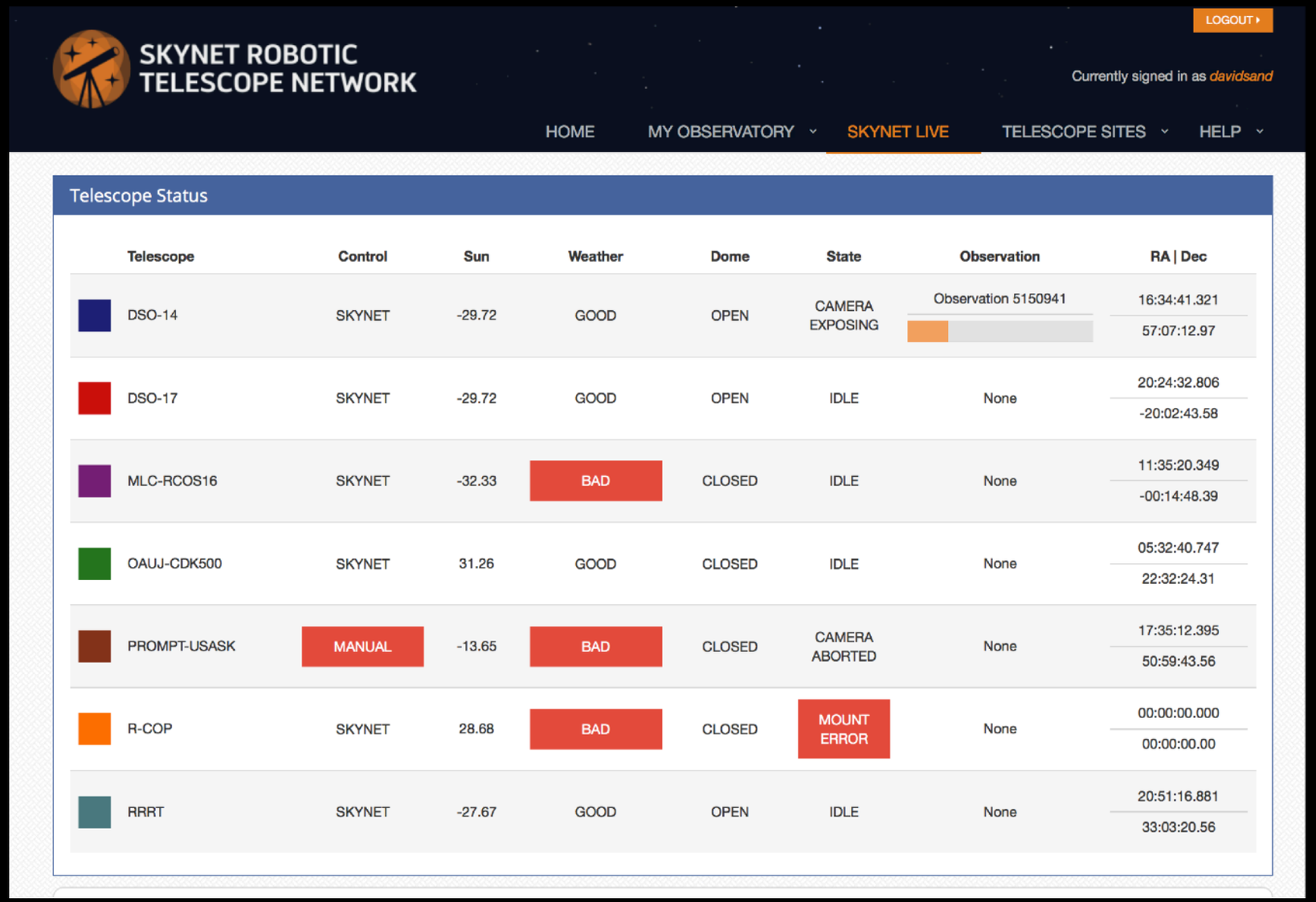
Mass loss

You can use UV photometry with two filters to trace the mass loss of a larger sample of SNe (10 SNe during current HST cycle).

GO-17796 (PI Valenti)

DLT40 timeline

Skynet observations



Telescope	Control	Sun	Weather	Dome	State	Observation	RA | Dec
DSO-14	SKYNET	-29.72	GOOD	OPEN	CAMERA EXPOSING	Observation 5150941	16:34:41.321 57:07:12.97
DSO-17	SKYNET	-29.72	GOOD	OPEN	IDLE	None	20:24:32.806 -20:02:43.58
MLC-RCOS16	SKYNET	-32.33	BAD	CLOSED	IDLE	None	11:35:20.349 -00:14:48.39
OAUJ-CDK500	SKYNET	31.26	GOOD	CLOSED	IDLE	None	05:32:40.747 22:32:24.31
PROMPT-USASK	MANUAL	-13.65	BAD	CLOSED	CAMERA ABORTED	None	17:35:12.395 50:59:43.56
R-COP	SKYNET	28.68	BAD	CLOSED	MOUNT ERROR	None	00:00:00.000 00:00:00.00
RRRT	SKYNET	-27.67	GOOD	OPEN	IDLE	None	20:51:16.881 33:03:20.56

DLT40 timeline

- flat field, astrometry
- cosmic rejection
- zeropoint
- difference image
- candidate detection
- Machine learning score

download @ UC Davis
processed < 5 minutes

Skynet
observations

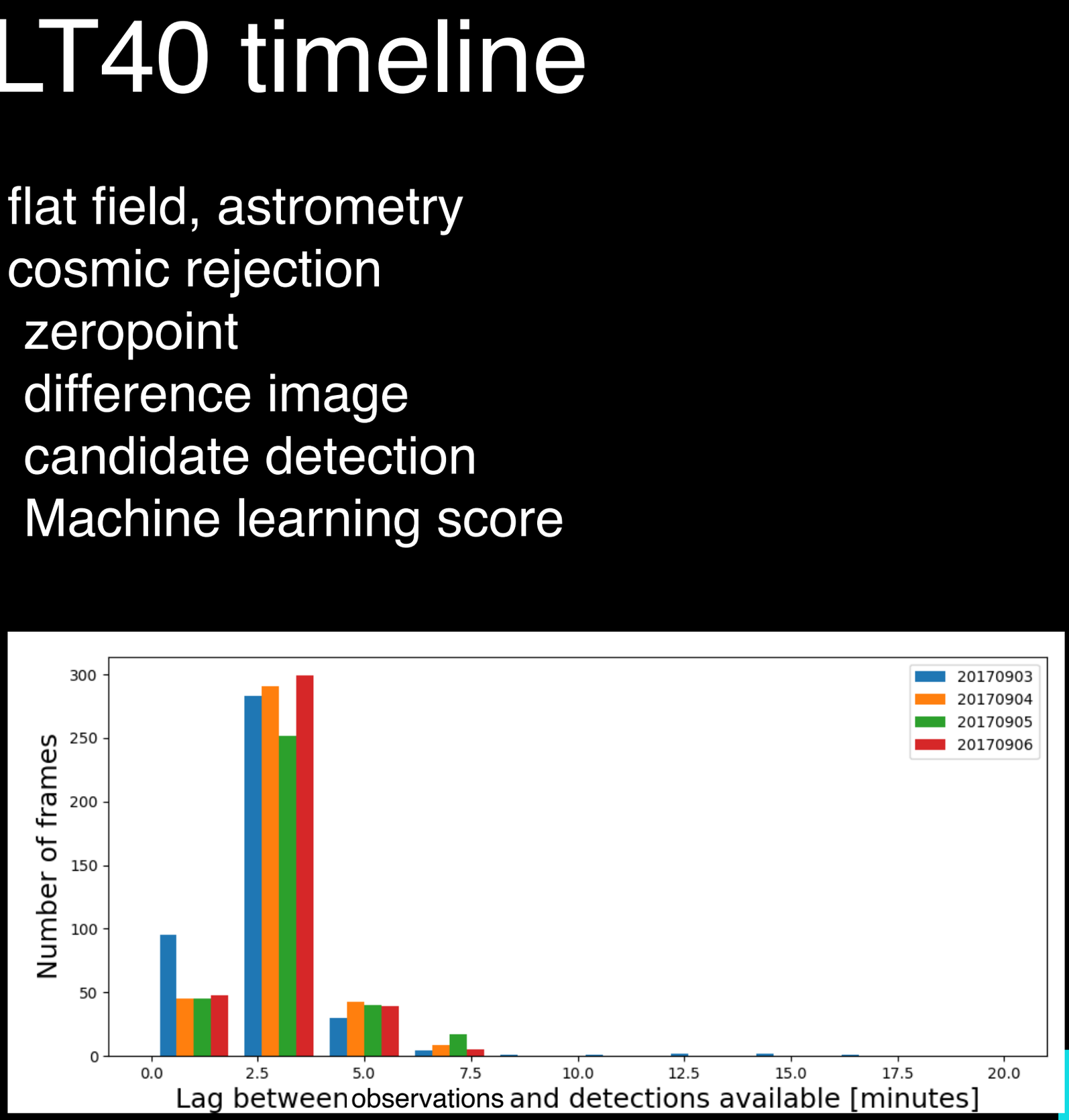
DLT40 timeline

- flat field, astrometry
- cosmic rejection
- zeropoint
- difference image
- candidate detection
- Machine learning score

download @ UC Davis
processed < 5 minutes

Skynet
observations

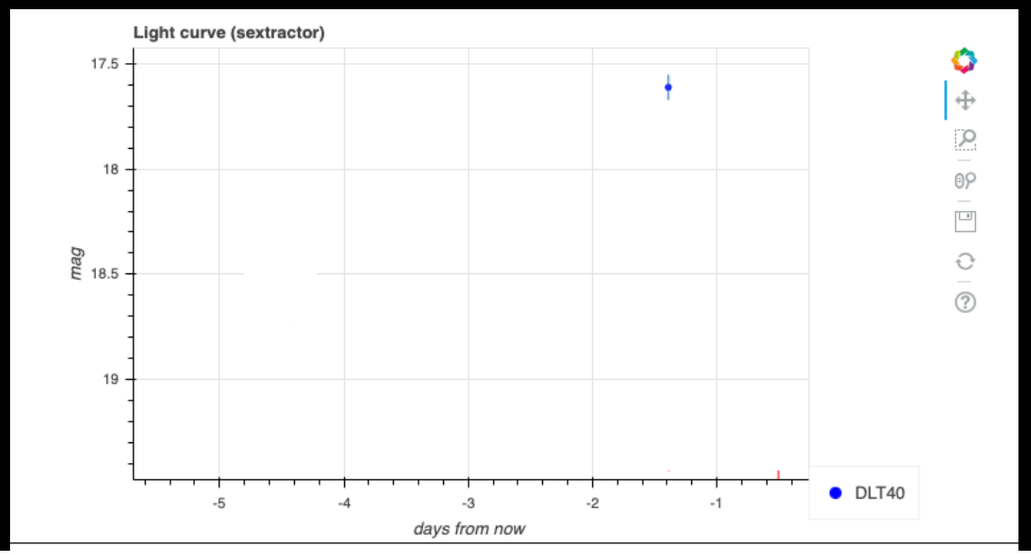
5 min



DLT40 timeline

download @ UC Davis
processed < 5 minutes

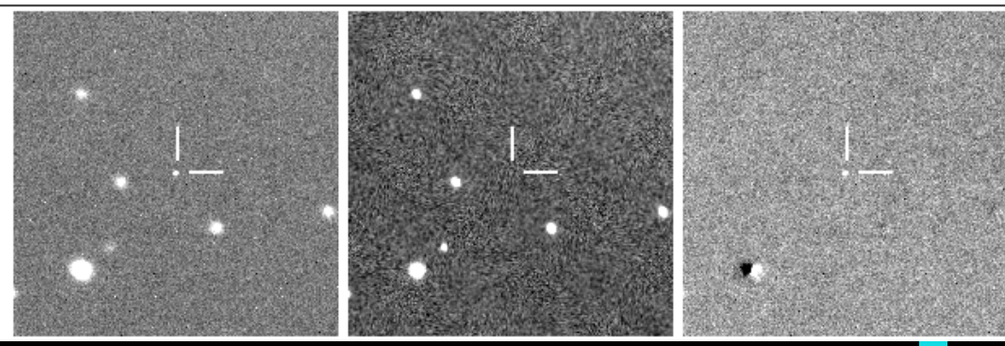
Skynet
observations



Telescope	Filter	ML Score	Score	Date	Classification	target	Reference	Difference
PROMPT-MO-1	Open	0.66	24.48070	20240502	eyeball			

eyeball

change status



5 min

DLT40 timeline

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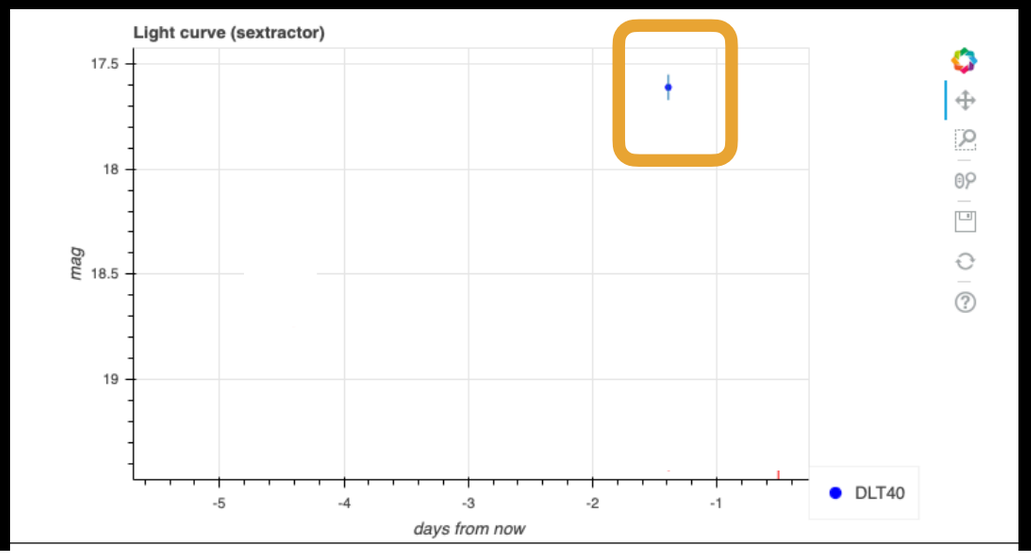
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score



Telescope	Filter	ML Score	Score	Date	Classification	target	Reference	Difference
PROMPT-MO-1	Open	0.66	24.48070	20240502	eyeball			

eyeball

change status

~15 min

DLT40 timeline

Probably a cosmic ray, do not trigger more

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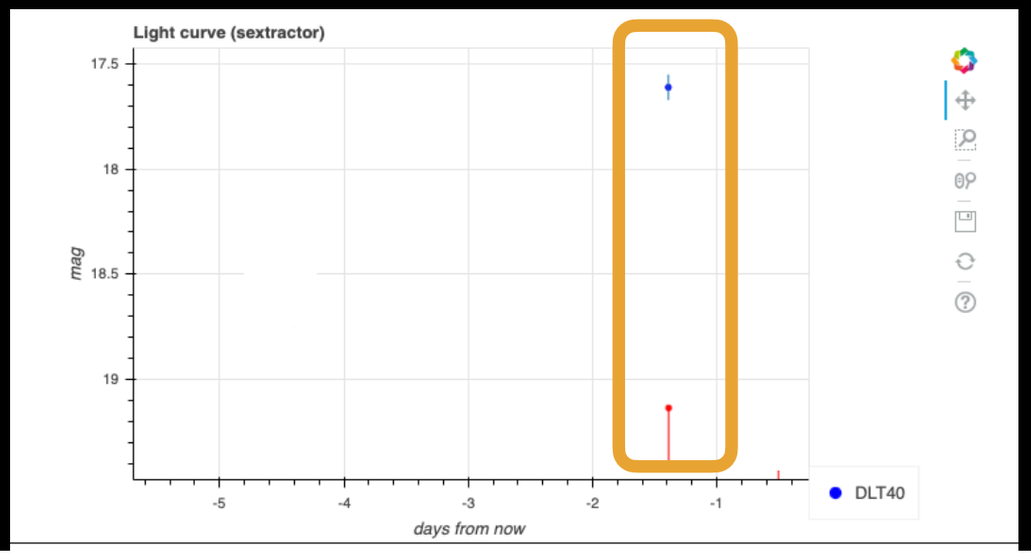
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score



Telescope	Filter	ML Score	Score	Date	Classification	target	Reference	Difference
PROMPT-MO-1	Open	0.66	24.48070	20240502	eyeball			

eyeball

change status

~15 min

DLT40 timeline

Robotic follow-up (activated in January 2024)
DLT40 discover and TNS transients within 40 Mpc

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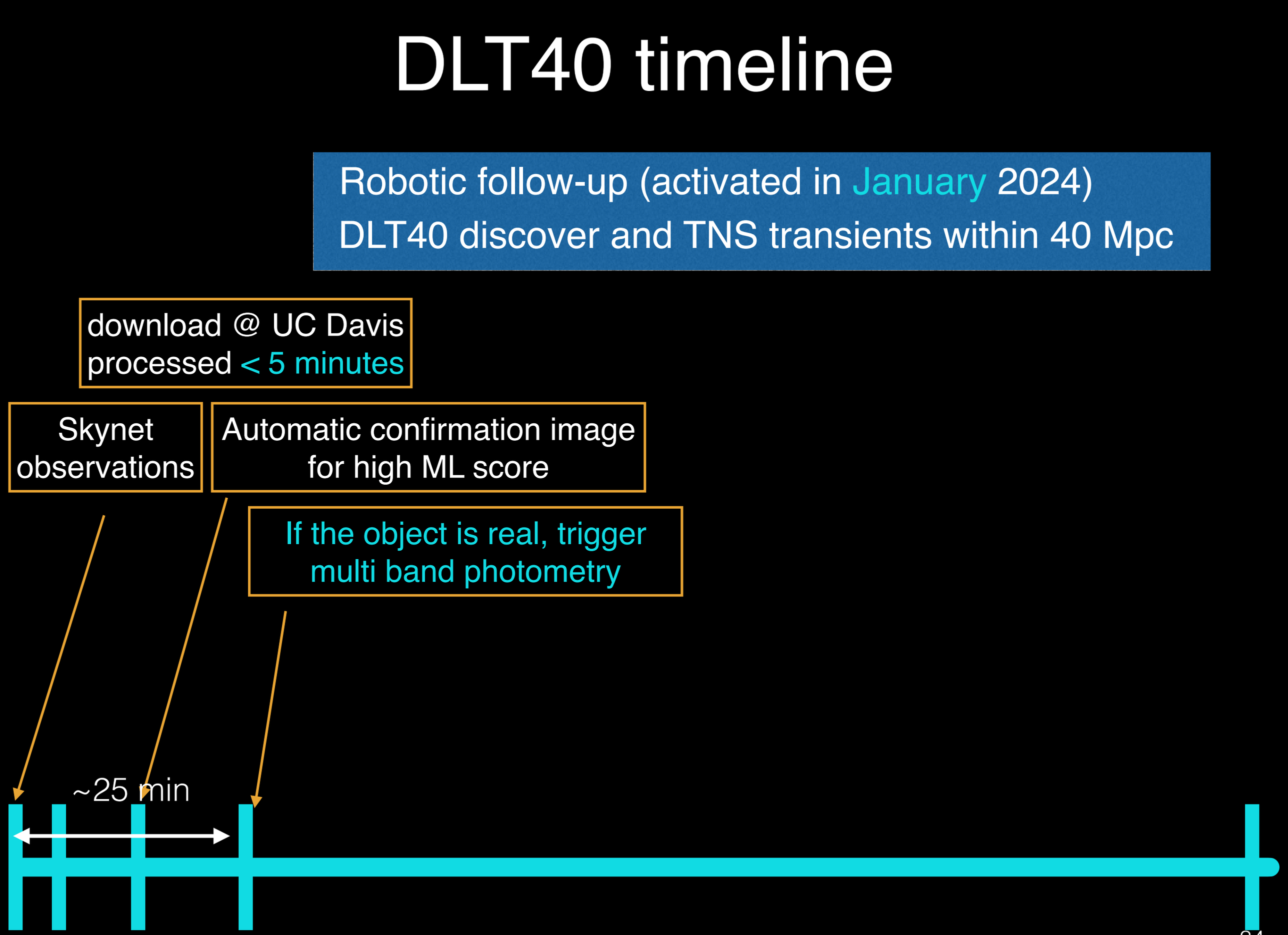
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score

If the object is real, trigger multi band photometry



DLT40 timeline

Robotic follow-up (activated in April 2024)
DLT40 discover and TNS transients within 40 Mpc

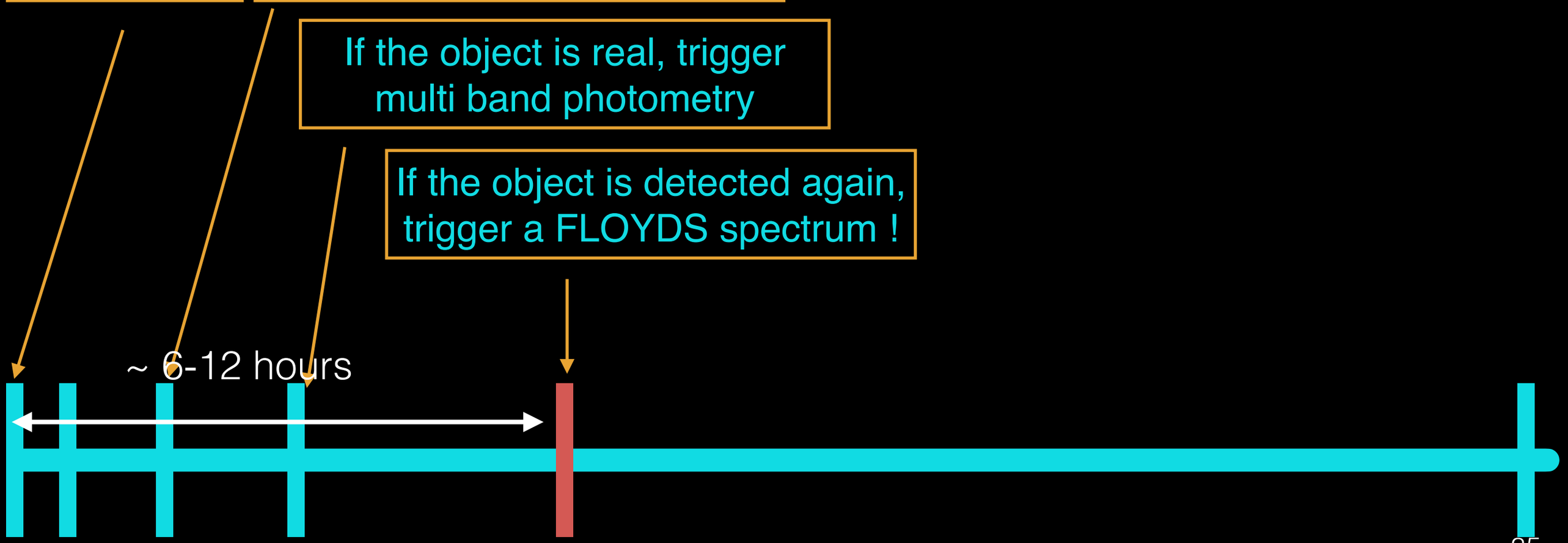
download @ UC Davis
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score

If the object is real, trigger multi band photometry

If the object is detected again, trigger a FLOYDS spectrum !



DLT40 timeline

Robotic follow-up (activated in April 2024)
DLT40 discover and TNS transients within 40 Mpc

or

Manual follow-up activated by a DLT40 member from the webpage

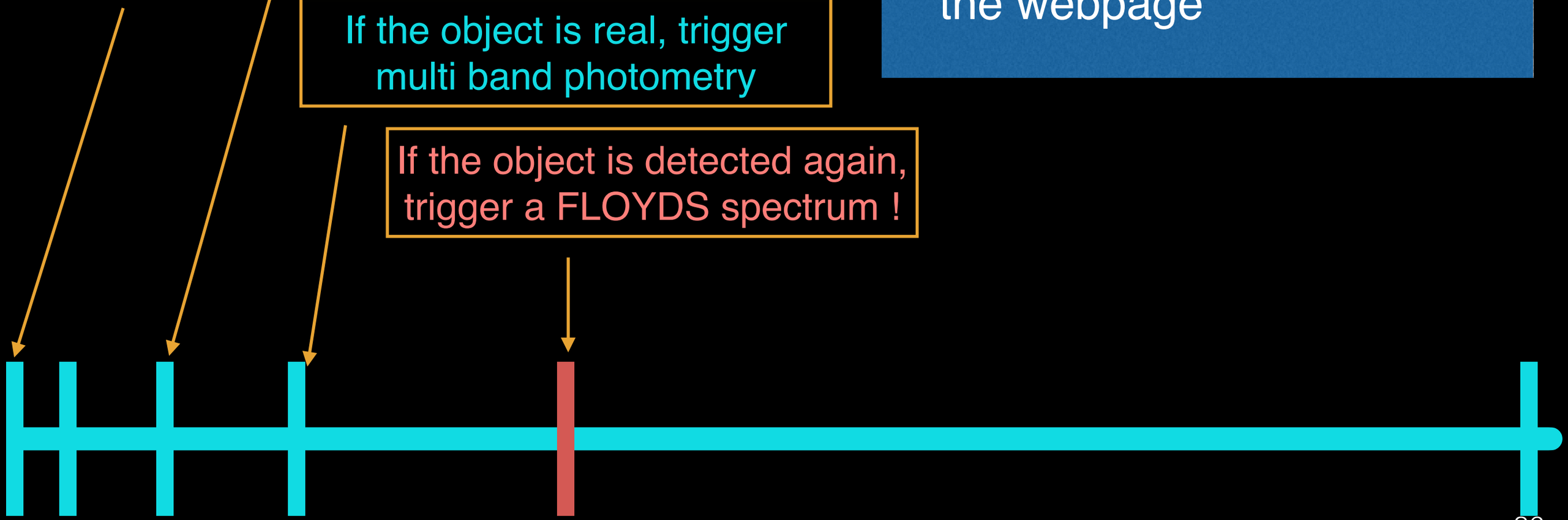
download @ UC Davis
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score

If the object is real, trigger multi band photometry

If the object is detected again, trigger a FLOYDS spectrum !



DLT40 timeline

Robotic follow-up (activated in April 2024)
DLT40 discover and TNS transients within 40 Mpc

or

Manual follow-up activated by a DLT40 member from the webpage

download @ UC Davis
processed < 5 minutes

Skynet observations

Automatic confirmation image for high ML score

If the object is real, trigger multi band photometry

TNS Name	SNEX	DLT40 Name	Targetid (idcandidates)	Field	Classification	Targetid (idsource)
	NED		9110547	995	None	5316120
RA	DEC	RA (ecliptic)	DEC (ecliptic)	RA (galactic)	DEC (galactic)	Following
168.33568	-26.71102	180.85775	-28.96264	277.23781	31.22053	No

change classification	add DLT name	Submit TNS	Submit GCN	run limits	run atlas	run ztf check ztf	fast trigger Prompt5	fast trigger PROMPT-MO-1	fast trigger PROMPT-USASK	fast trigger Prompt2	submit to MMT (beta)
eyeball		20		20	60414-60434	60414-60434	45 Open 1 no delay	45 Open 1 no delay	45 Clear 1 no delay	45 Open 1 no delay	Longslit 45

DLT40 timeline

Robotic follow-up (activated in April 2024)
DLT40 discover and TNS transients within 40 Mpc

or

Make the discovery public on TNS or GCN

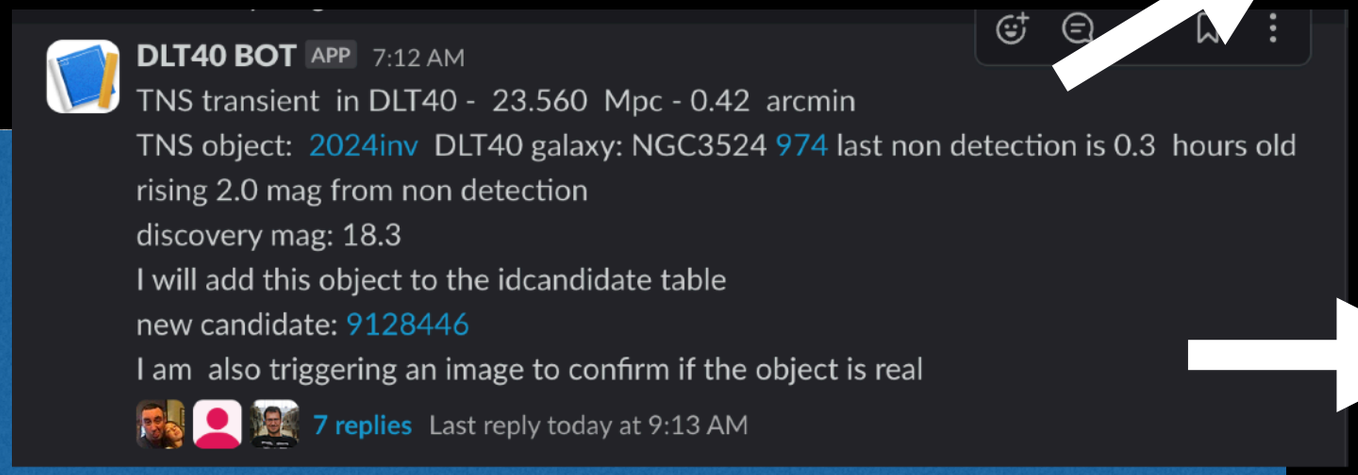
Manual follow-up activated by a DLT40 member from the webpage

TNS Name	SNEX	DLT40 Name	Targetid (idcandidates)	Field	Classification	Targetid (idsource)
	NED		9110547	995	None	5316120
RA	DEC	RA (ecliptic)	DEC (ecliptic)	RA (galactic)	DEC (galactic)	Following
168.33568	-26.71102	180.85775	-28.96264	277.23781	31.22053	No

change classification	add DLT name	Submit TNS	Submit GCN	run limits	run atlas	run ztf check ztf	fast trigger Prompt5	fast trigger PROMPT-MO-1	fast trigger PROMPT-USASK	fast trigger Prompt2	submit to MMT (beta)
eyeball		20		20	60414-60434	60414-60434	45 Open 1 no delay	45 Open 1 no delay	45 Clear 1 no delay	45 Open 1 no delay	Longslit 45

Robotic follow-up on TNS discovery

Robotic follow-up (activated in April 2024)
DLT40 discover and TNS transients within 40 Mpc



or

Manual follow-up activated by a DLT40 member from the webpage

TNS Name	SNEX	DLT40 Name	Targetid (idcandidates)	Field	Classification	Targetid (idsource)
	NED		9110547	995	None	5316120
RA	DEC	RA (ecliptic)	DEC (ecliptic)	RA (galactic)	DEC (galactic)	Following
168.33568	-26.71102	180.85775	-28.96264	277.23781	31.22053	No

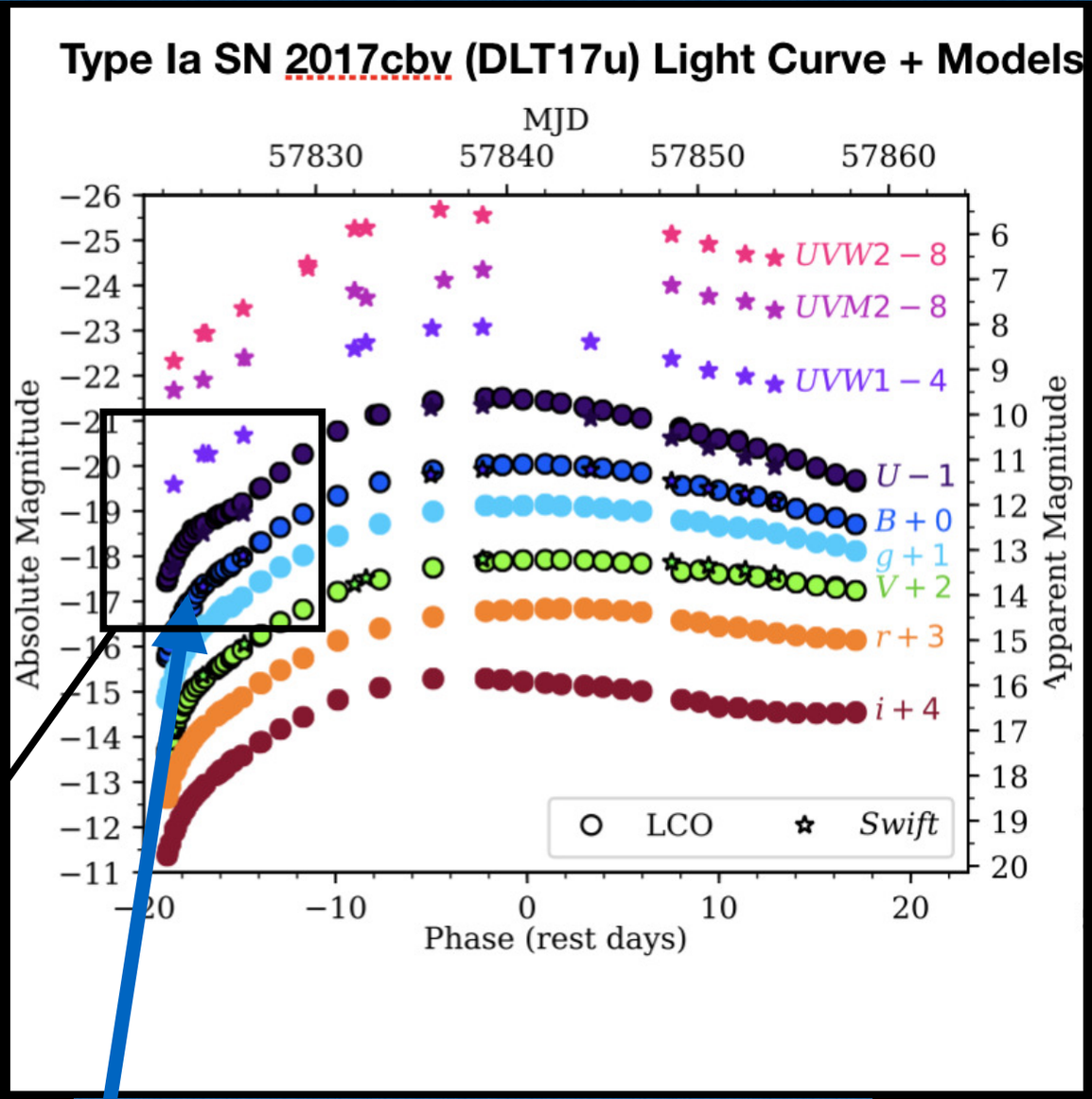
change classification	add DLT name	Submit TNS	Submit GCN	run limits	run atlas	run ztf check ztf	fast trigger Prompt5	fast trigger PROMPT-MO-1	fast trigger PROMPT-USASK	fast trigger Prompt2	submit to MMT (beta)
eyeball		20		20	60414-60434	60414-60434	45 Open 1 no delay	45 Open 1 no delay	45 Clear 1 no delay	45 Open 1 no delay	Longslit 45

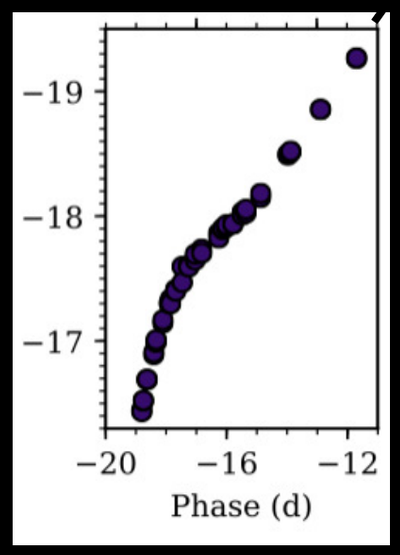
DLT40: result I

A supernova slamming in the companion star ~ 20 times the radius of the Sun

UV

Optical





A Blue Bump !!

Hosseinzadeh+ ApJ 2017

Griffin Hosseinzadeh
UCSB/LCO

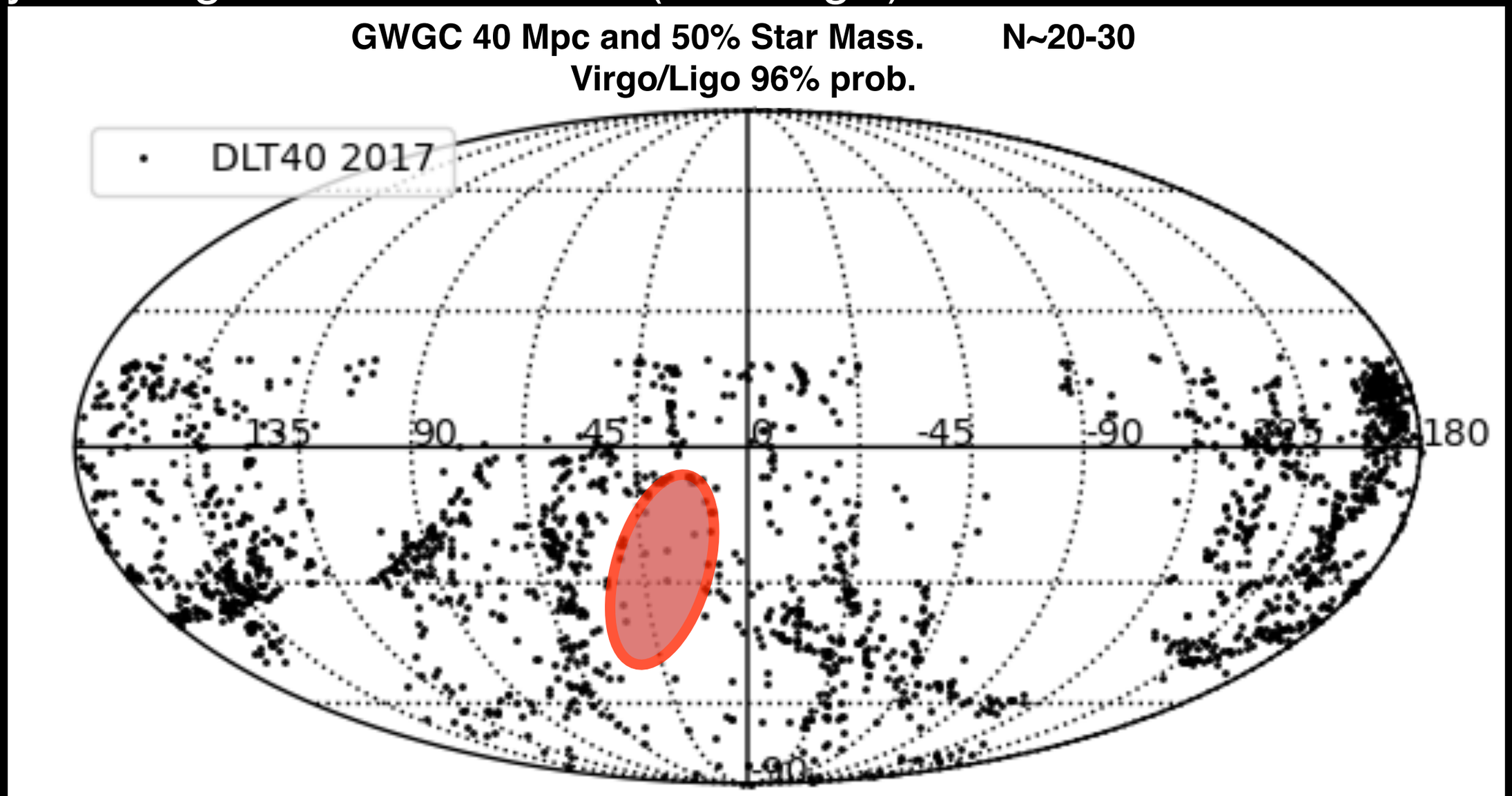
Search for EM counterpart of GW with DLT40

O2

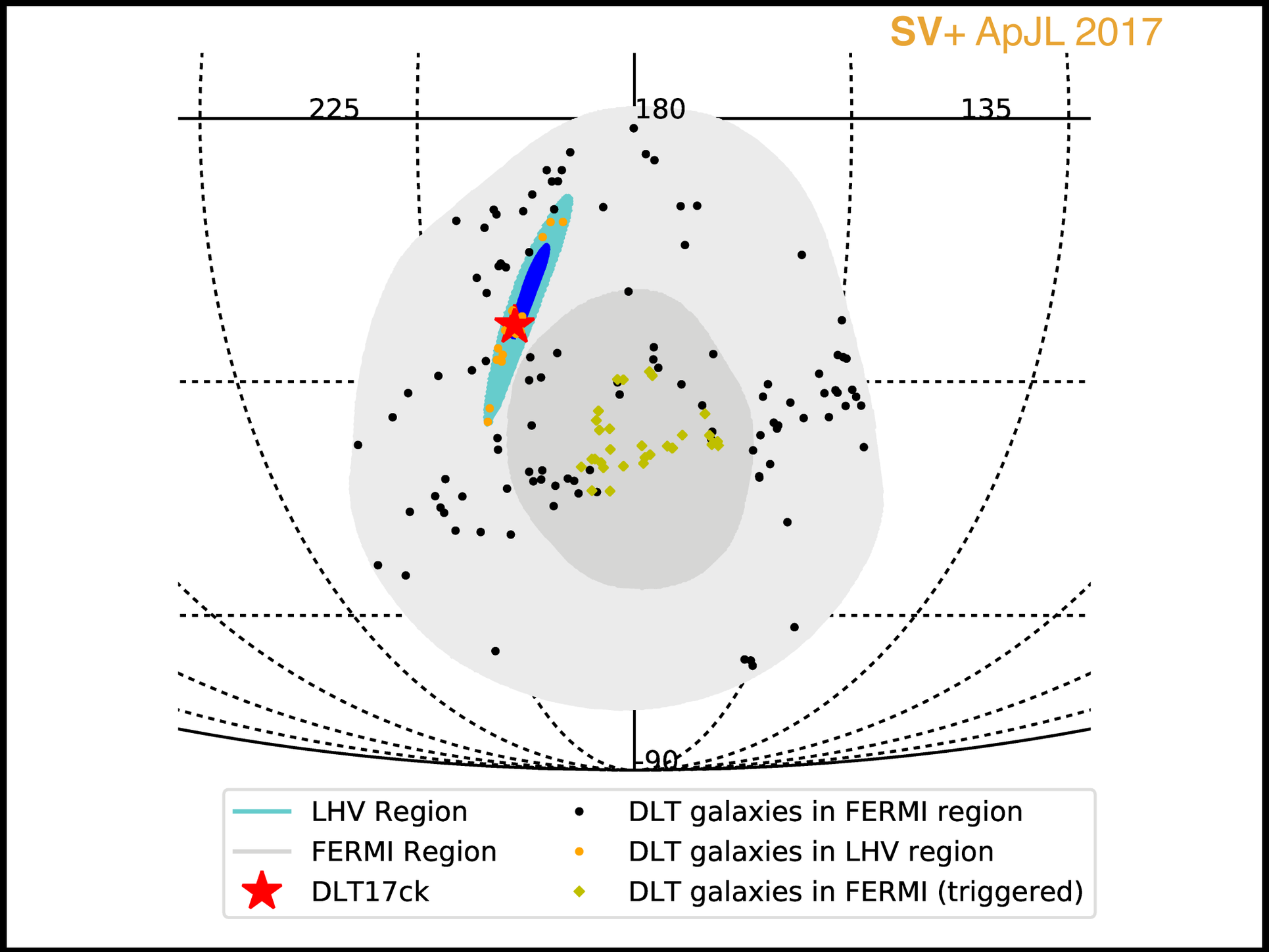
Select all galaxies within 40 Mpc

Select only galaxies with 50% of the mass

Only 20-30 galaxies to monitor (500 deg^2)

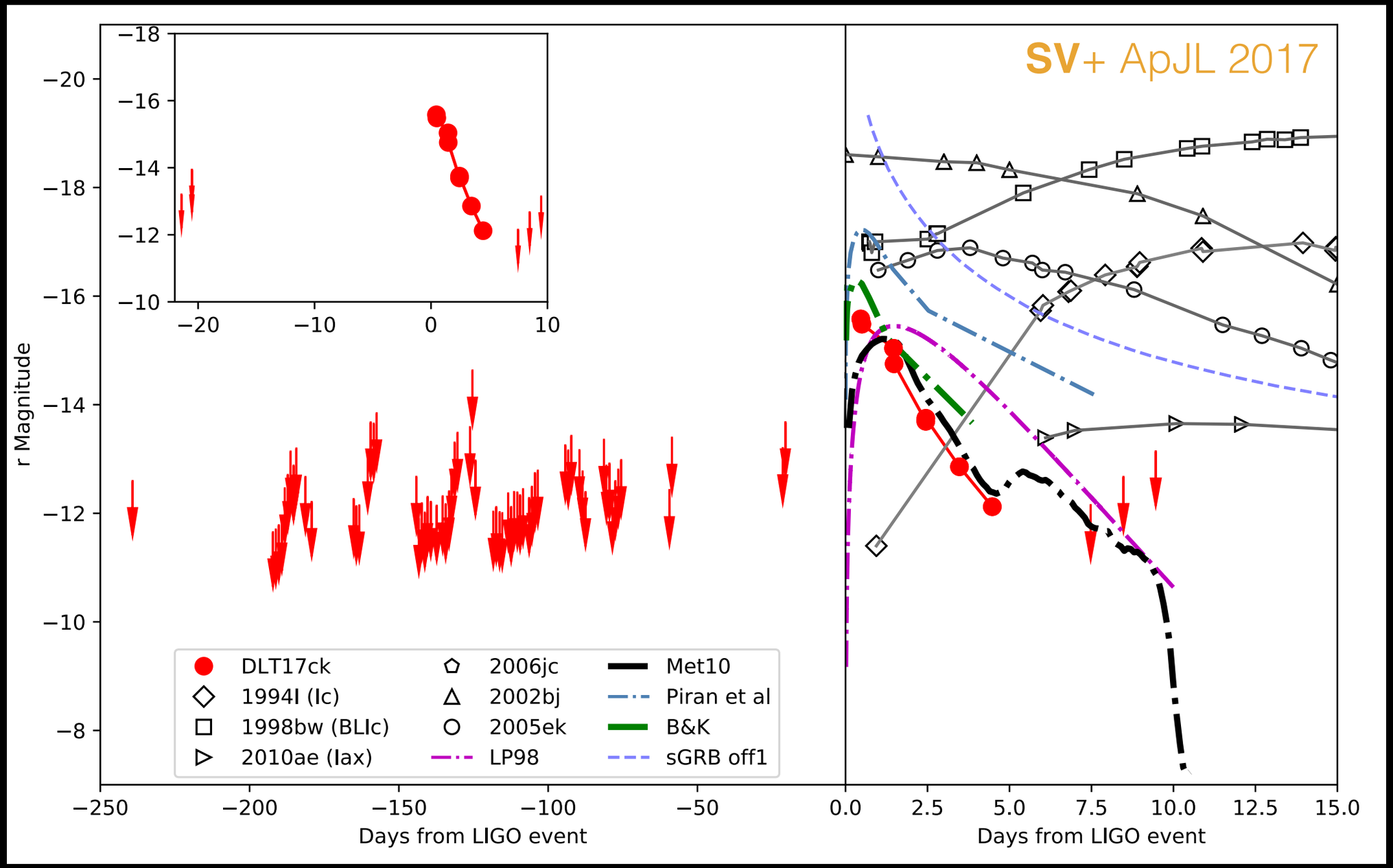


DLT40 Kilonova discovery



20 galaxies in the aLIGO/aVirgo region
30 galaxies in the FERMI region

NGC4993 obs. by DLT40



8 months observations of NGC4993

The luminosity of DLT17ck decrease 1.1mag per day

Search for EM counterpart of GW with DLT60

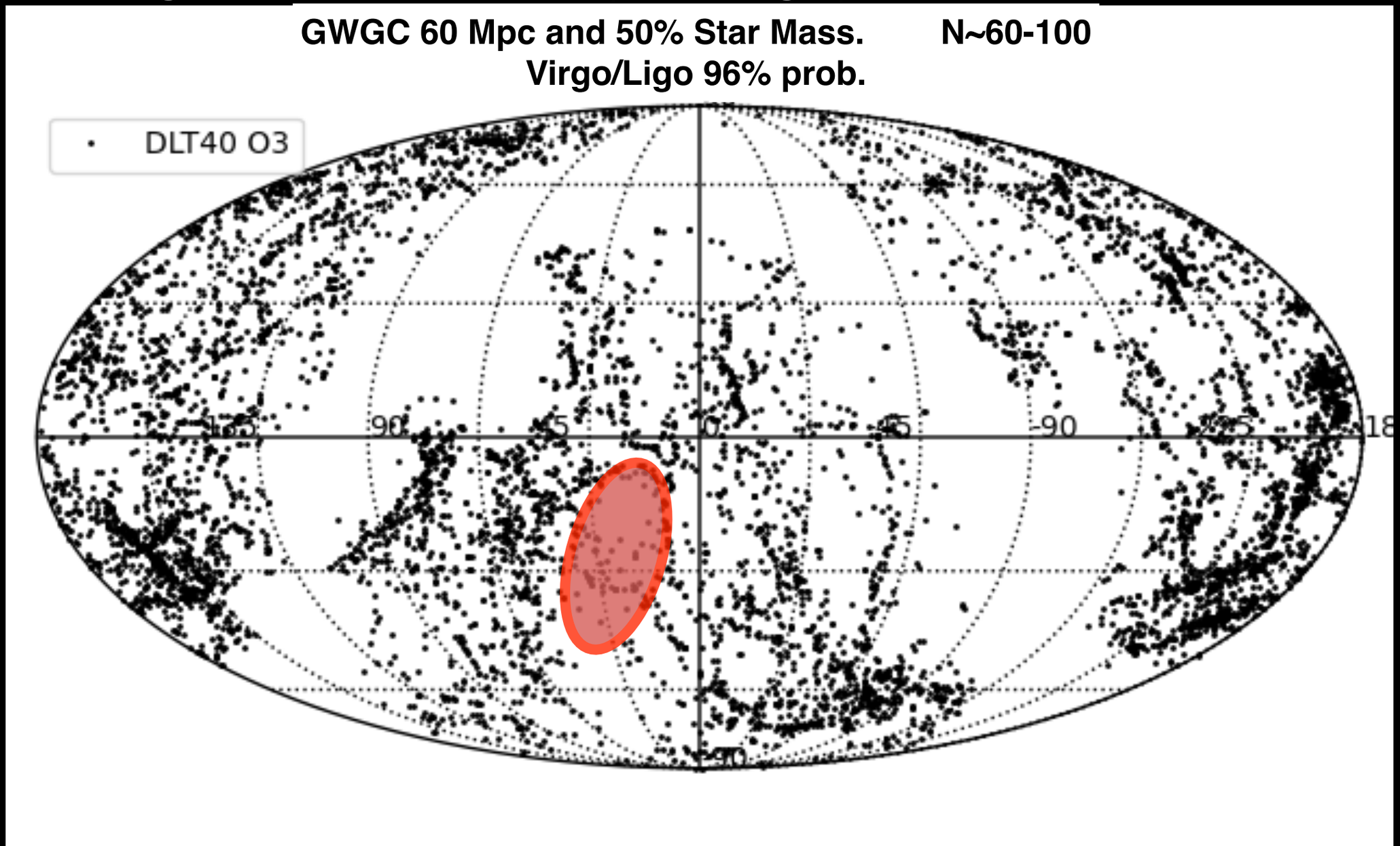
O2

O3

Select all galaxies within 60 Mpc

Select only galaxies with 50% of the mass

Only 20-30 galaxies to monitor (500 deg^2)



Search for EM counterpart of GW with DLT100

O2

O3

O4

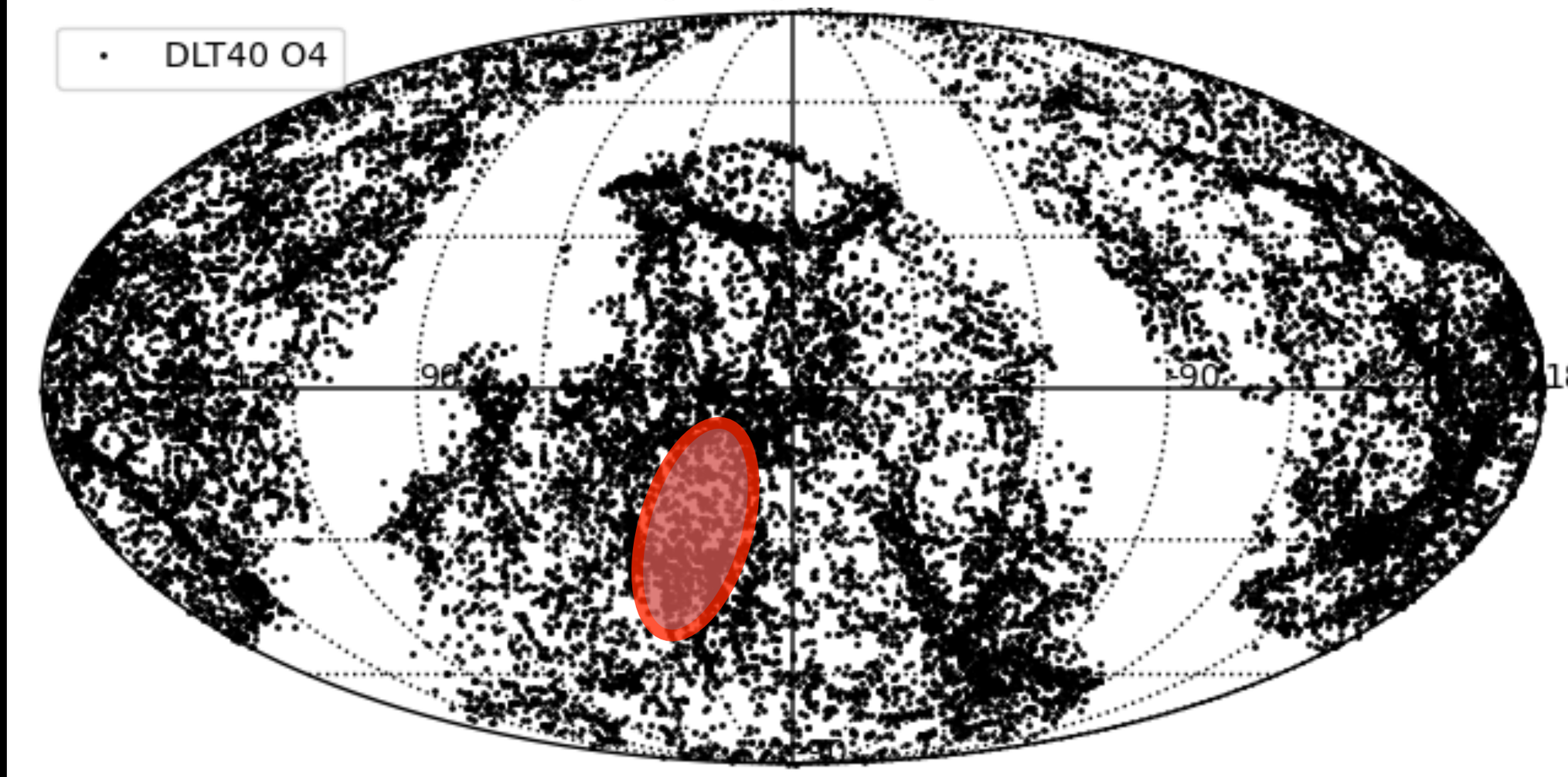
Select all galaxies within **100** Mpc

Select only galaxies with 50% of the mass

Only 20-30 galaxies to monitor (500 deg^2)

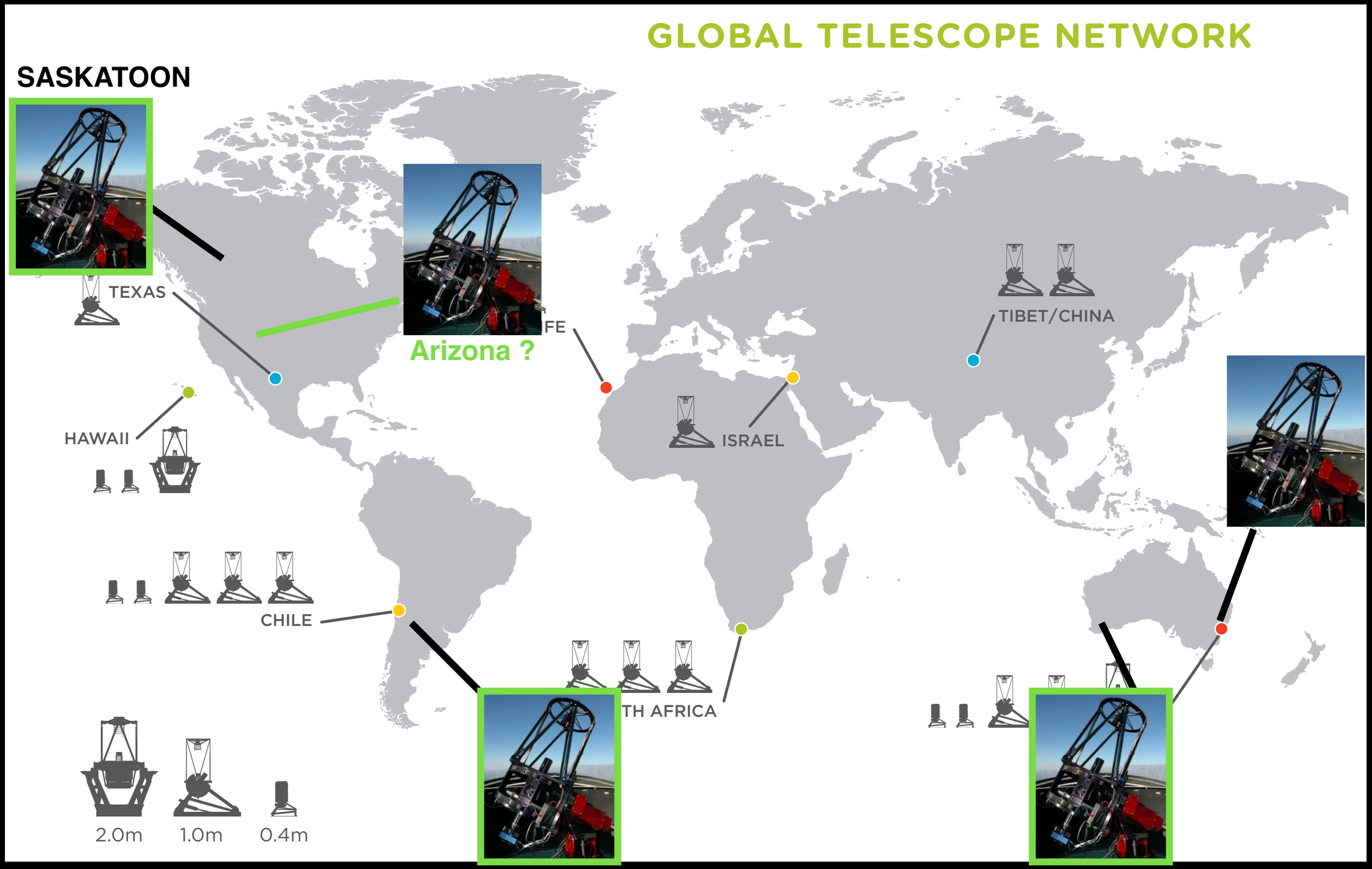
GWGC 100 Mpc and 50% Star Mass. N~100-200

Virgo/Ligo/Kagra 96% prob.



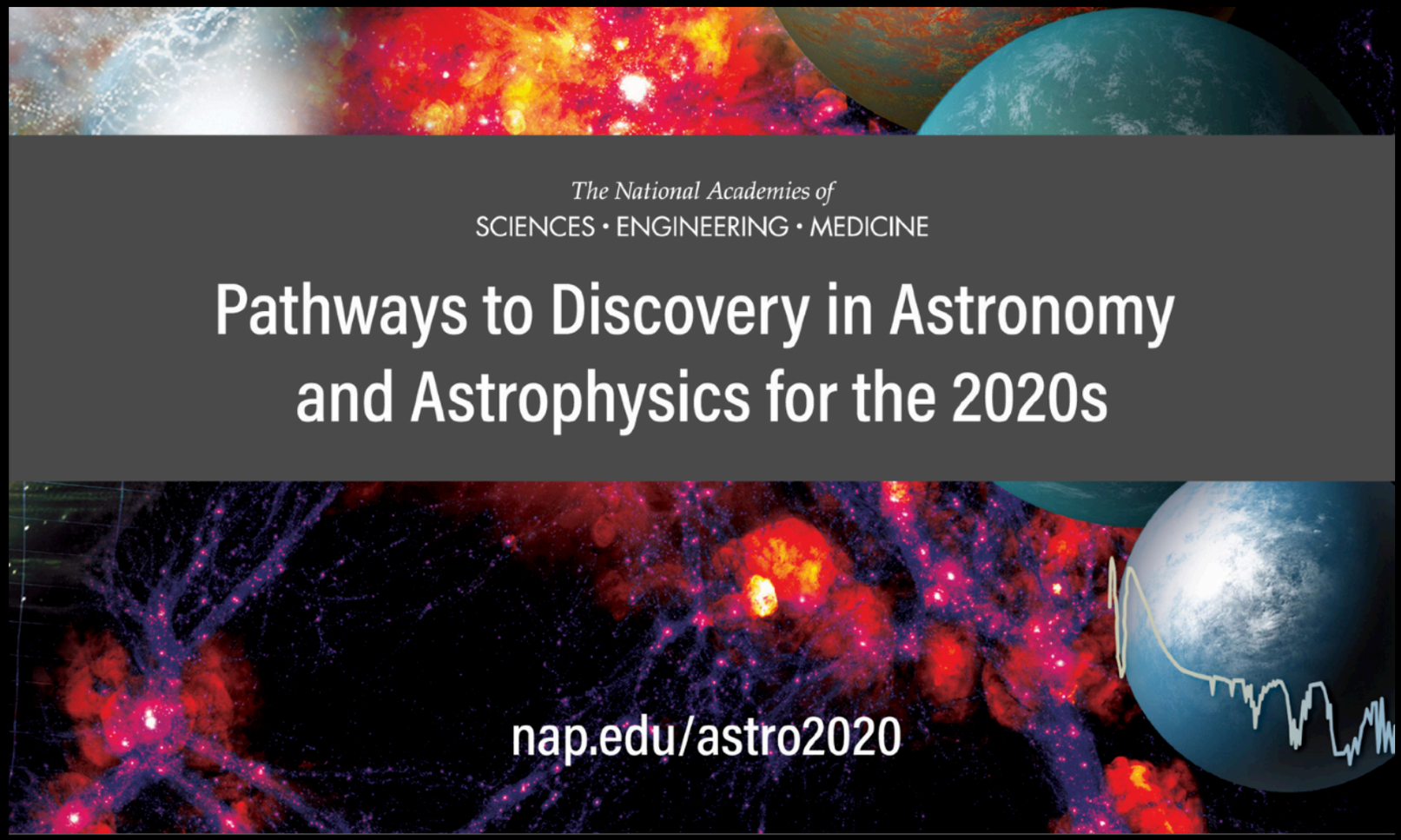
25,500 galaxies

DLT40:3 sites, 4 telescopes(100Mpc)



What's next?

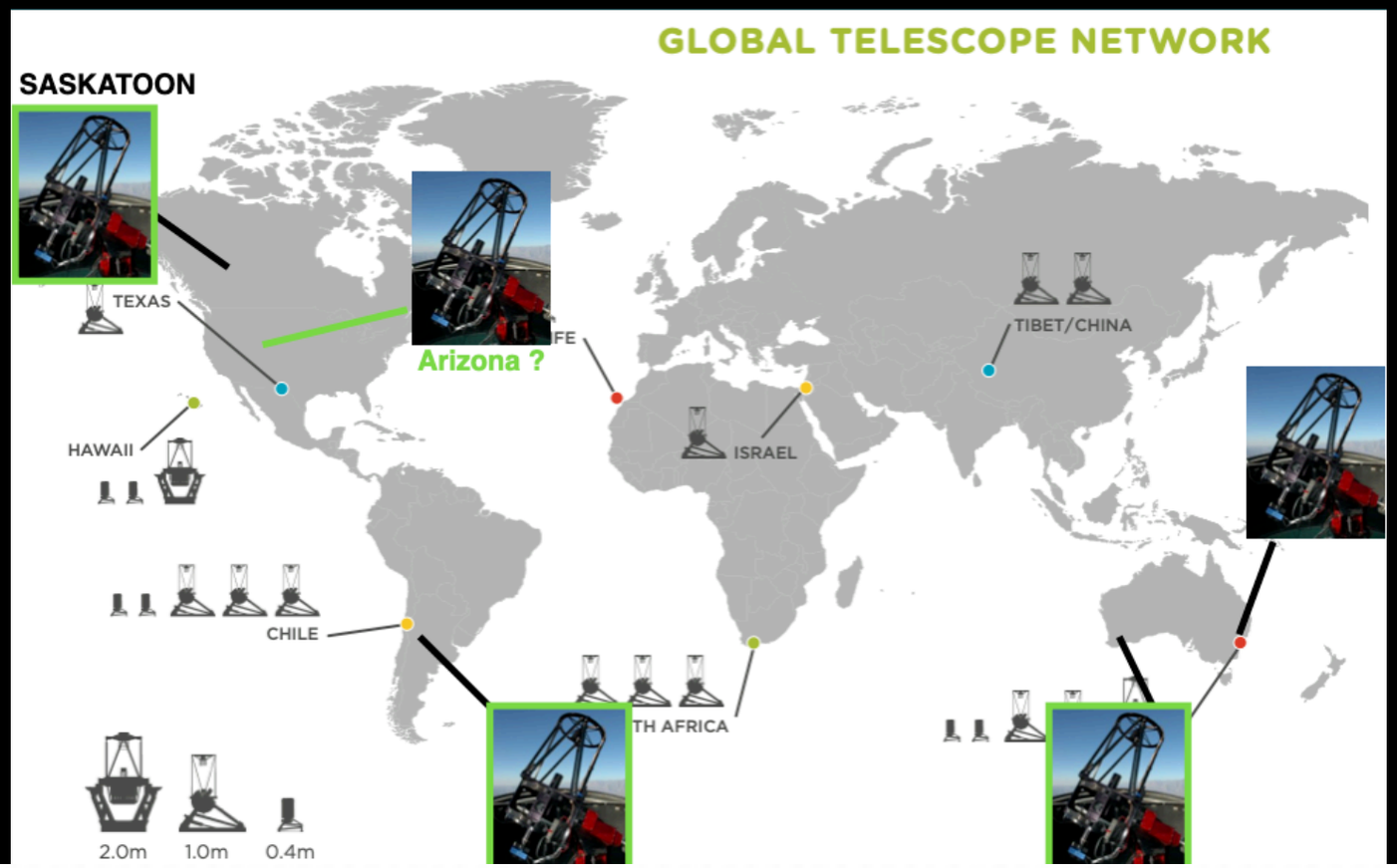
Is DLT40 still useful for transient astronomy?

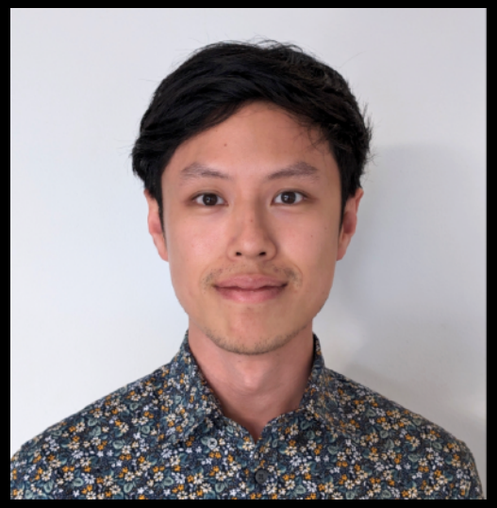


- A suite of small- and medium-scale ground- and space-based observational facilities across the electromagnetic spectrum to discover and characterize the brightness and spectra of transient sources as they appear and fade away.

DLT40 on steroids?

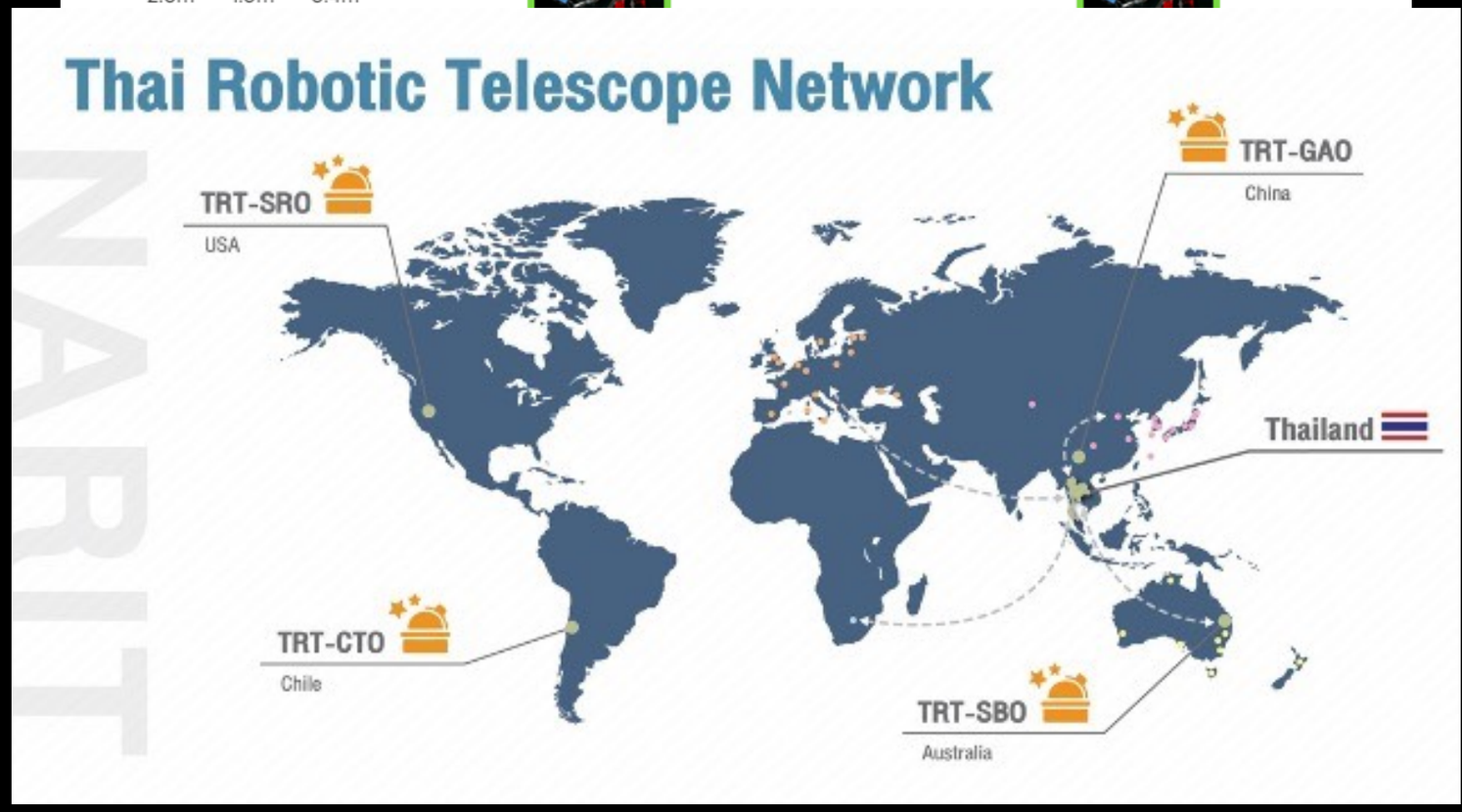
Adding a new network of telescopes to monitor nearby transients and follow-up new transients





Kaew Samaporn Tinyanont

National Astronomical Research Institute of Thailand



DLT40

Search for SNe in nearby galaxies with a 12 hours cadence

Supernova Feature	Time Scale	Brightness	Probe of?
Core Collapse SNe			
Shock Breakout Cooling/ Flash Spectroscopy	$\lesssim$3 days (best case)	$-17<M_V<-15$	Progenitor Radius & Energy/Ejecta Mass CSM Comp/Extent
Pre-Explosion Outburst	Days to weeks	$-15<M_V<-14$	Ejected mass & Explosion Mechanism
SN Ia			
Light Curve Shocking	<5 days (Red Giant)	$-17<M_V<-16$	Nondegenerate
	$\lesssim$1 day (MS)	$-16<M_V<-15$	Companion Test
Early light curve shape	<3 days	$M_V<-14$	Nickel Dist. Progenitor Radius
Carbon	Early as possible	NA	Double Degenerate Test
Faint/Fast Transients (not exhaustive)			
SN .Ia	$\sim$1 wk	$M_V\sim-16$ at max	WD-WD Physics
Ca-Gap Transients	$\sim$10 days	$-15\lesssim M_V\lesssim-16$	Unknown Stellar Death
Kilonova	$\sim$1 day	$M_I\sim-15$?	GW Physics
Off-Axis/Dirty GRBs	$\sim$2 days	Varies	Relativistic Explosion Physics