A UVEX view of Stellar Deaths

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As UVEX SN group lead

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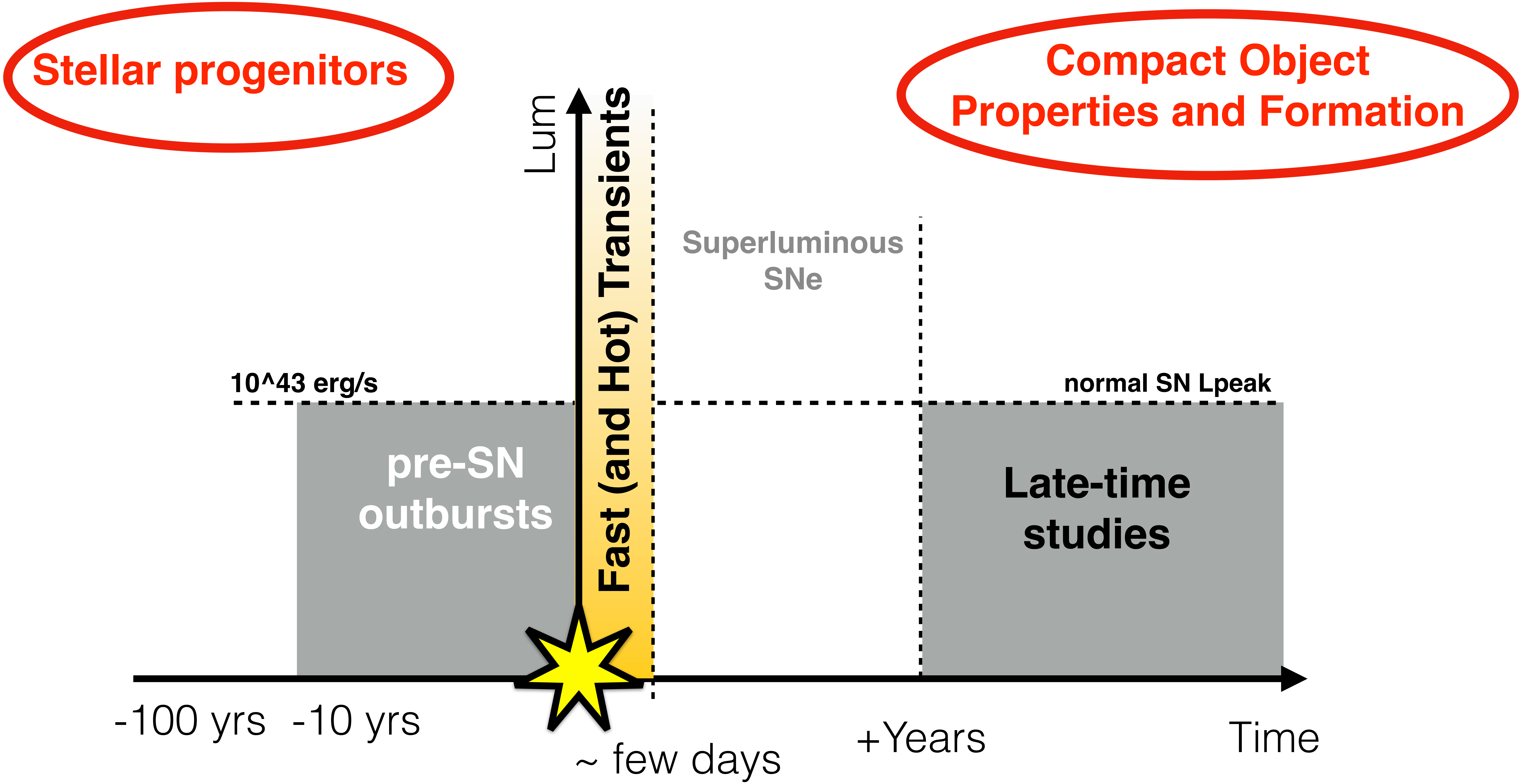
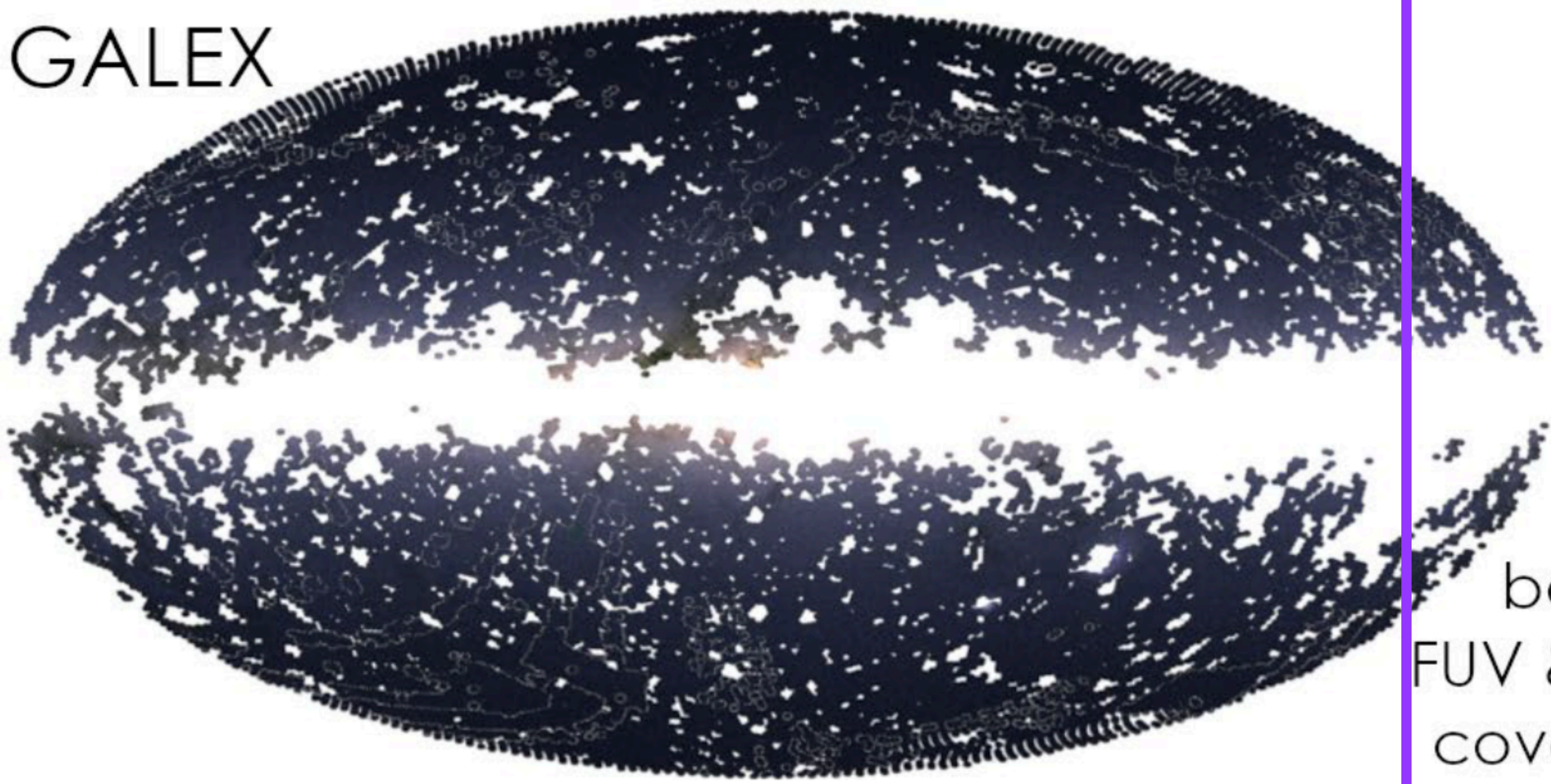
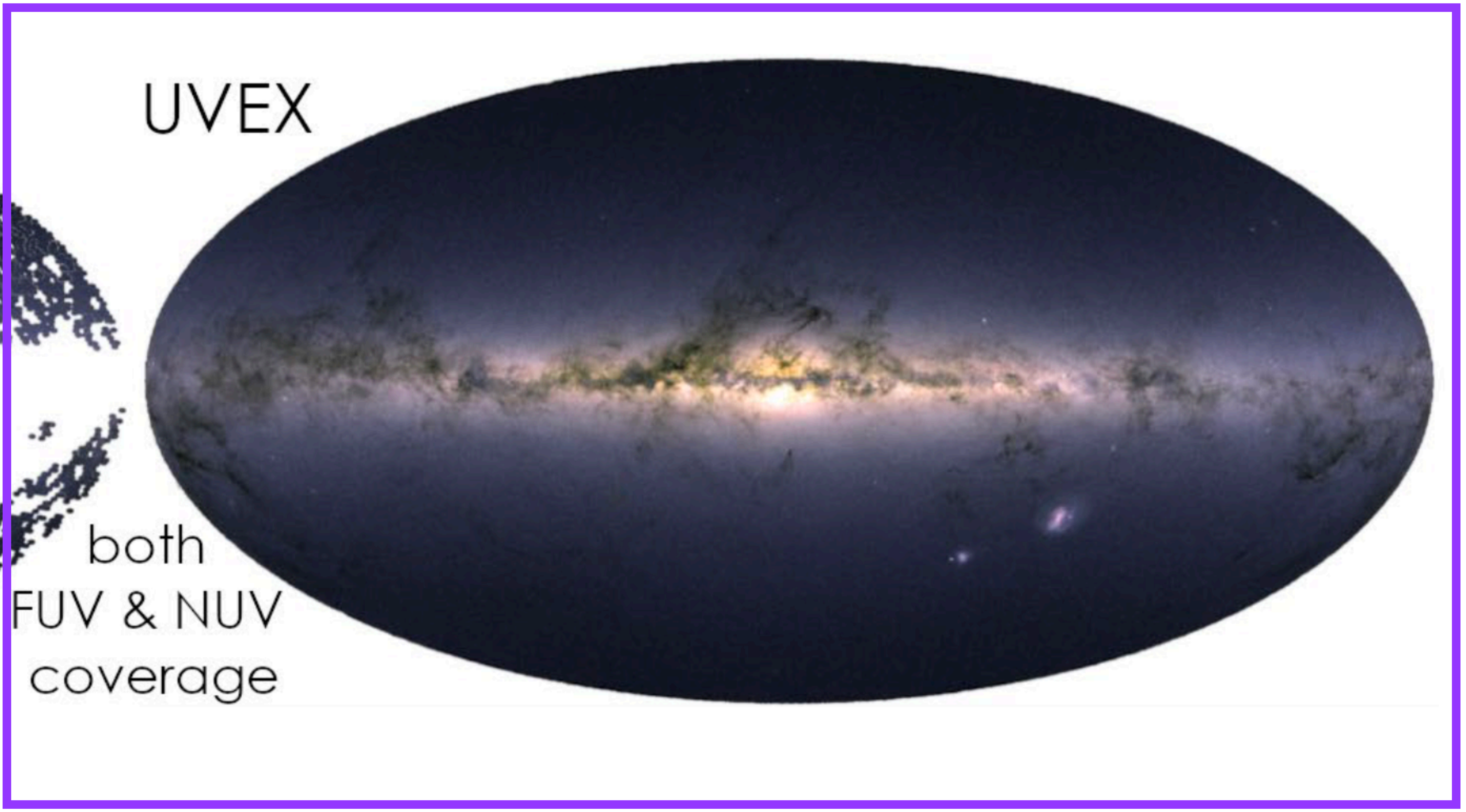
"We always find something, eh Didi, to give us the impression we exist?"

Discovery Frontiers:







Each point on the sky will be visited a minimum of 10 times during the prime mission with cadences ranging from 12 hrs to 6 months. **Actually strategy to do so is TBD. Please share your thoughts!!**

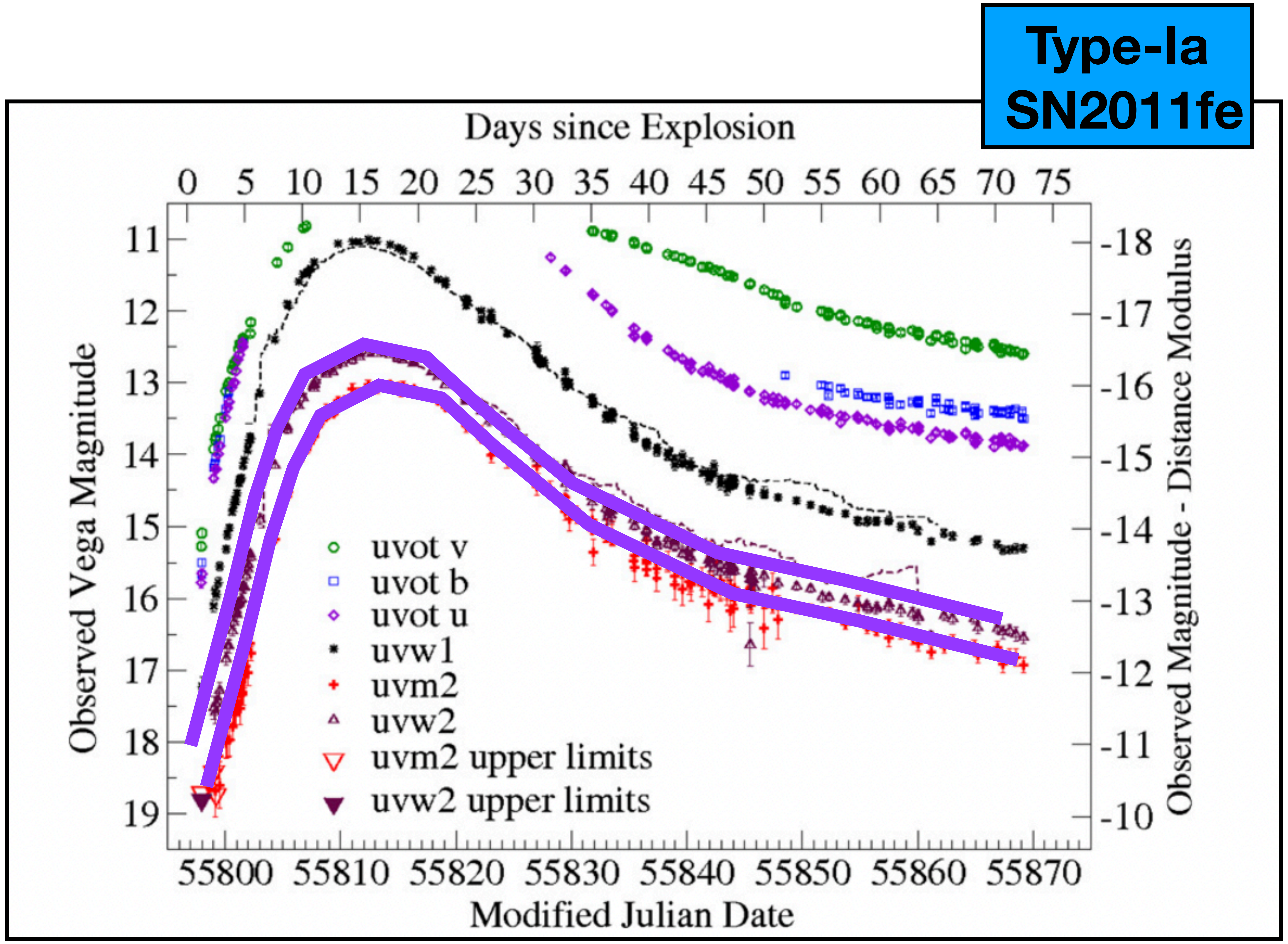
+ The LMC/SMC survey will have weekly cadence
+ Deep extragalactic fields required for instrument calibrations.

UVEX as a discovery machine + ToO!!

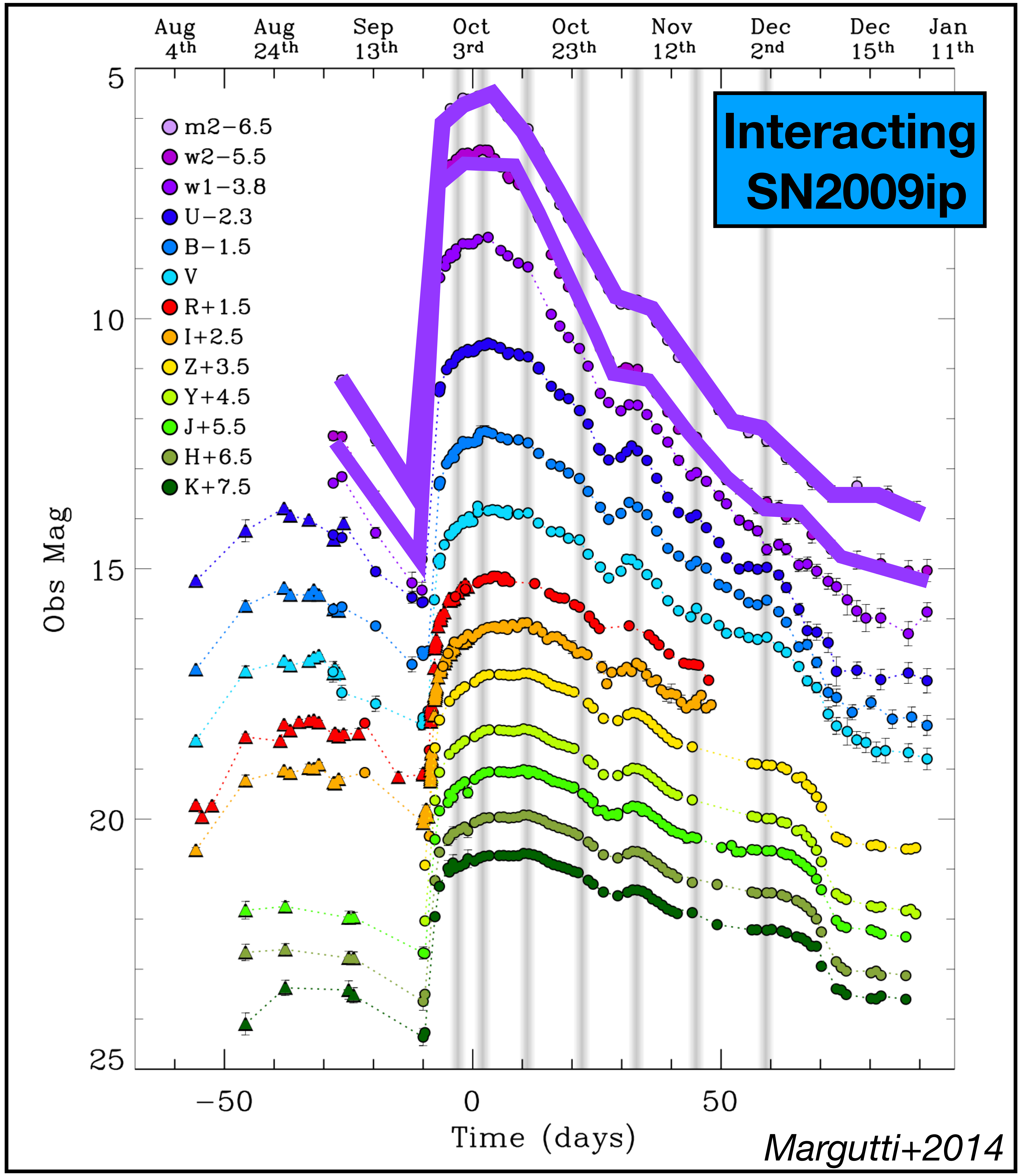
(Photometry AND spectroscopy!!)

Stay tuned for next session!

Swift/UVOT has transformed the field of UV photometry of “normal” Stellar Explosions



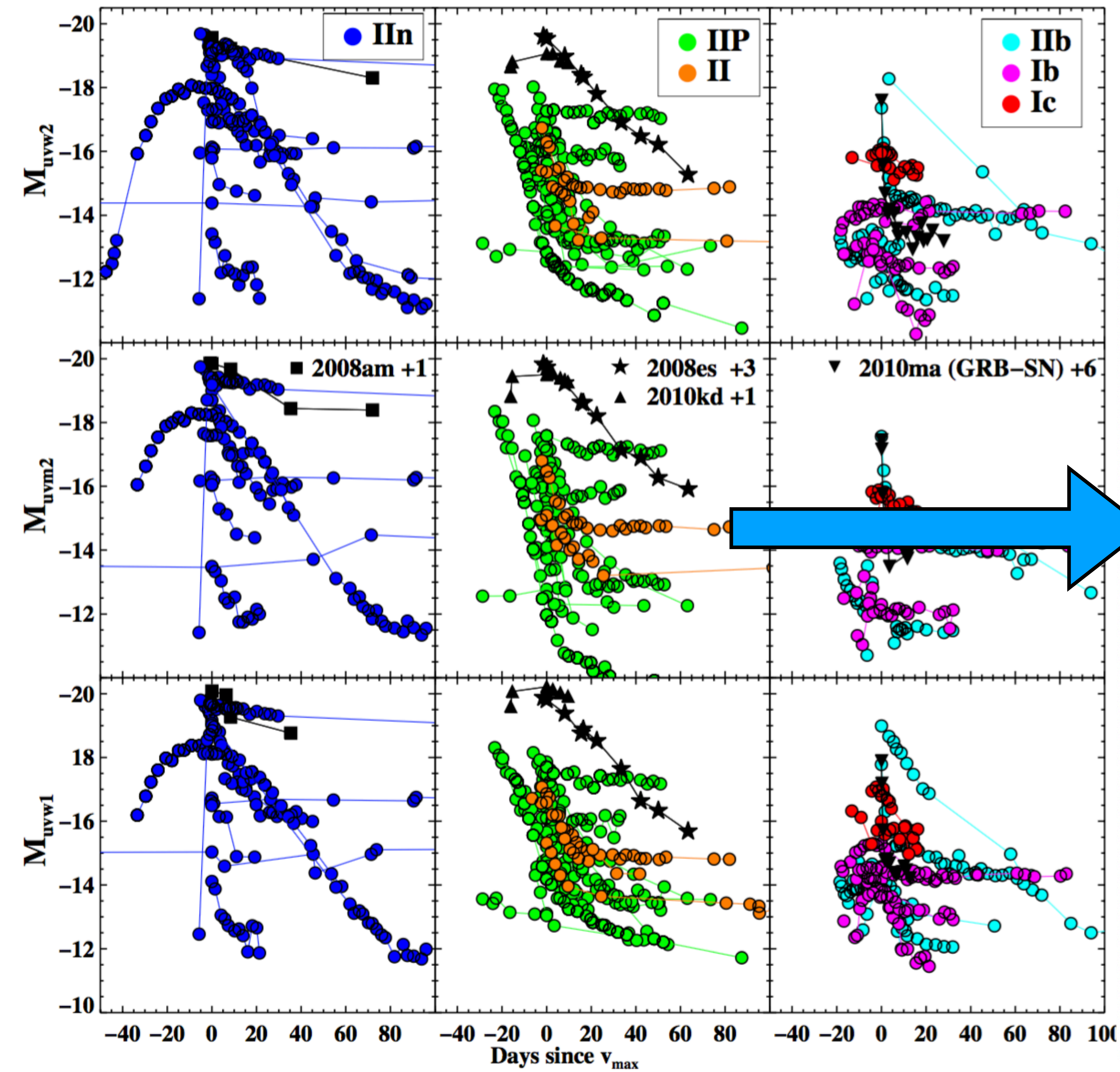
Brown+2012



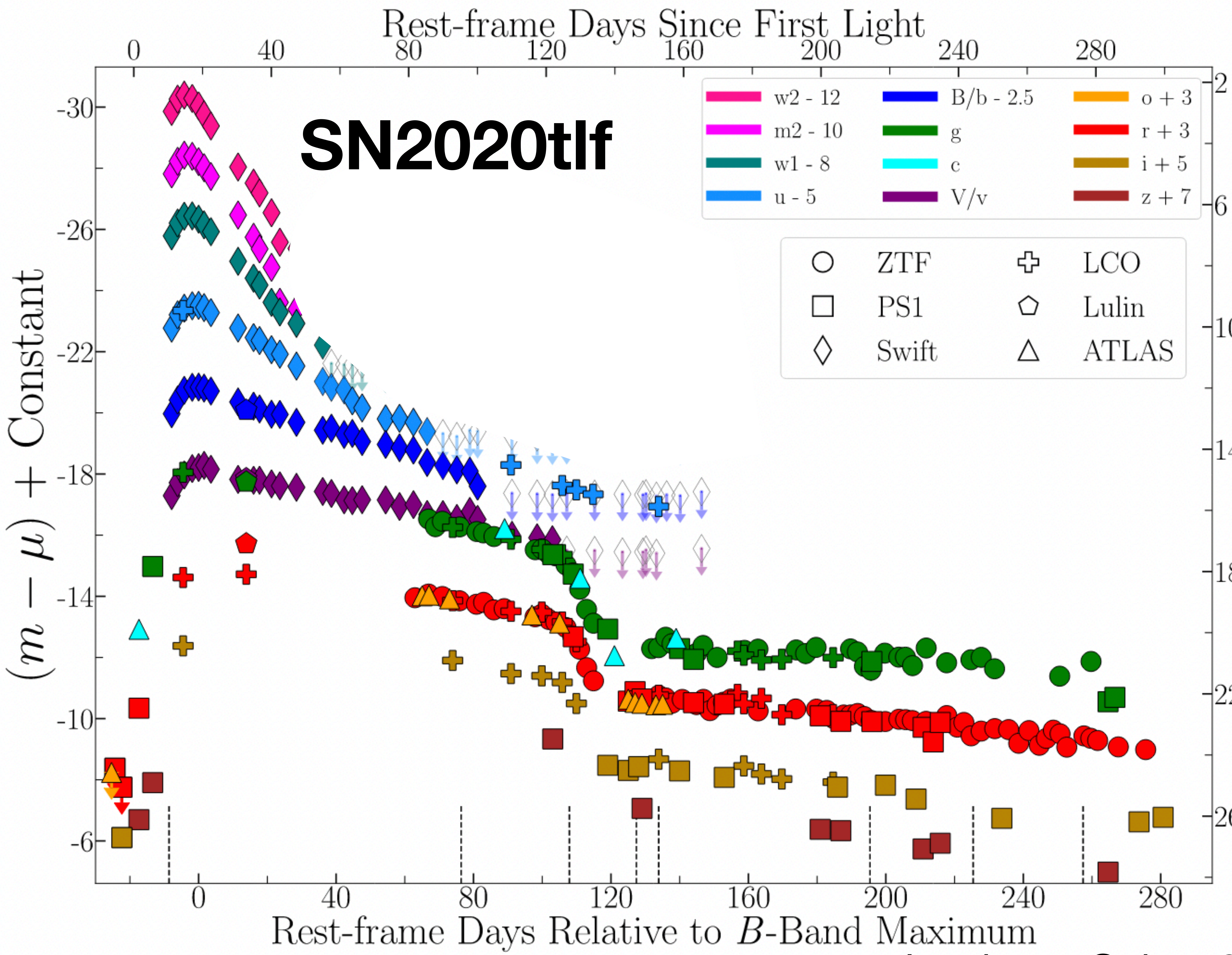
Margutti+2014

Swift/UVOT has transformed the field of UV photometry of “normal” Stellar Explosions

PHYSICAL JOURNAL, 787:157 (20pp), 2014 June 1 PRITCHARD ET AL.



Type-IIP SNe

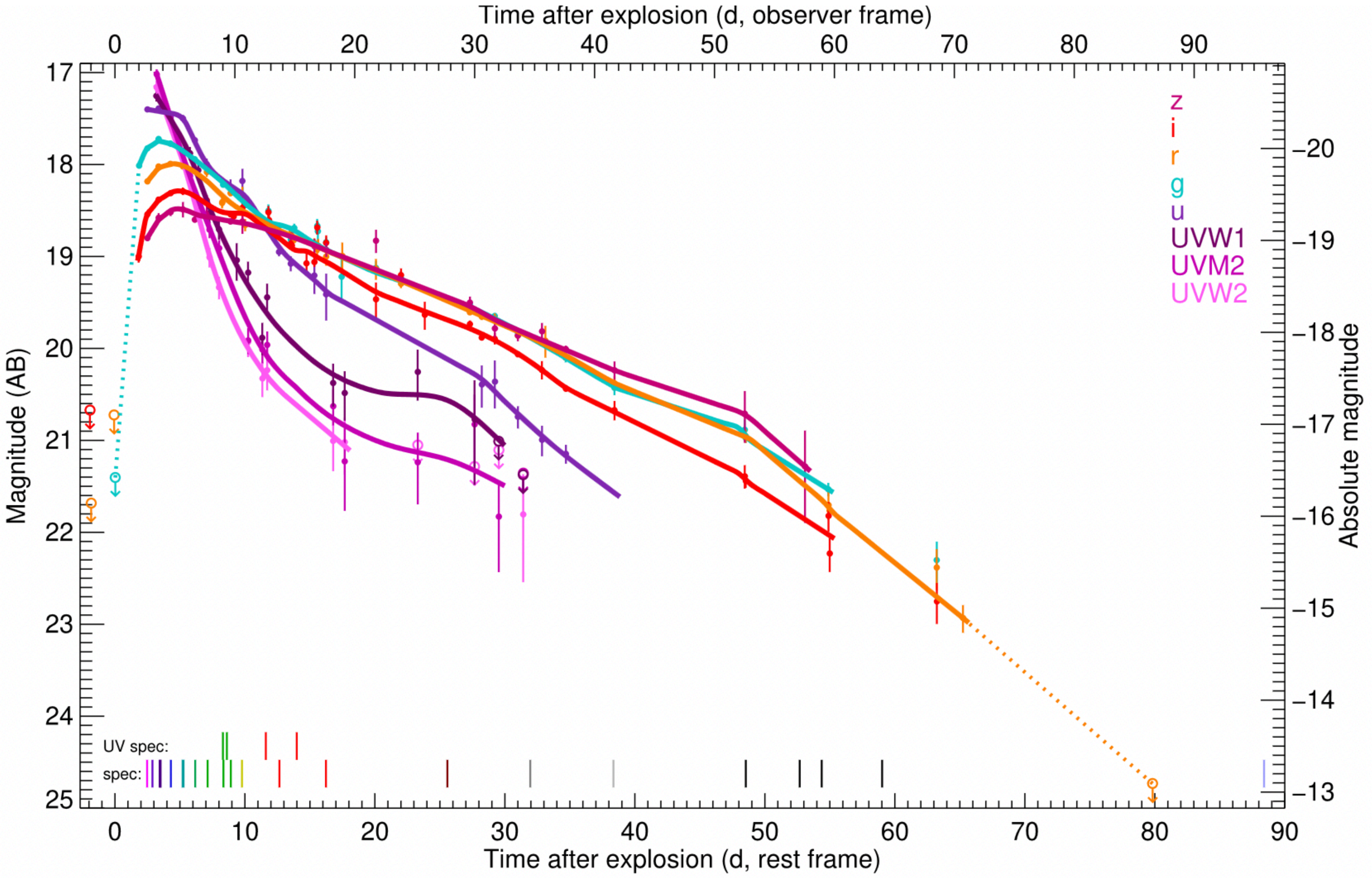


Jacobson-Galan+2022

Swift/UVOT has transformed the field of UV photometry of “normal” Stellar Explosions

Type-Icn SN2021csp

We have a handful of Icn SNe known to date!!



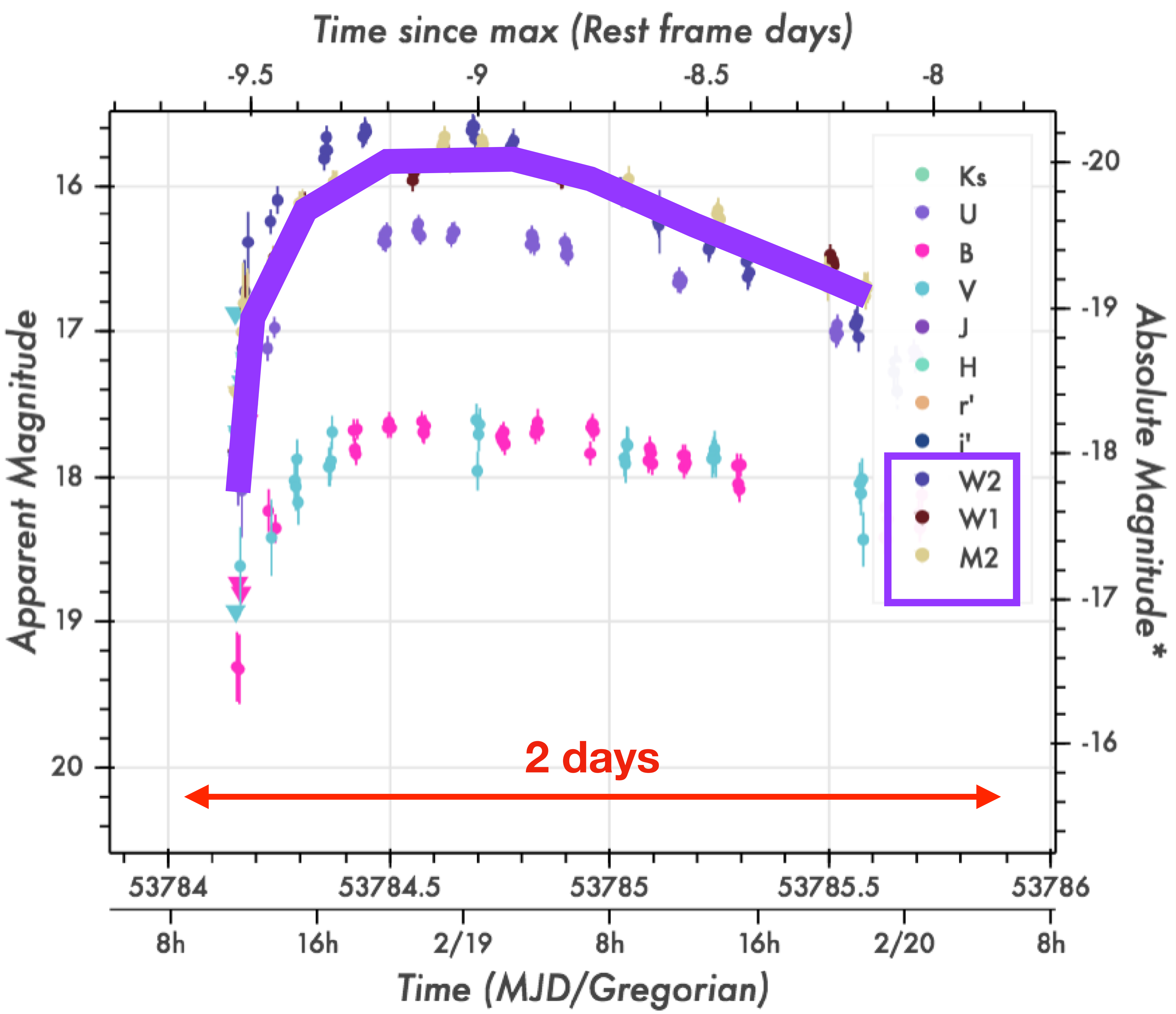
Perley+2022

Relativistic Explosions

The most extreme stellar deaths

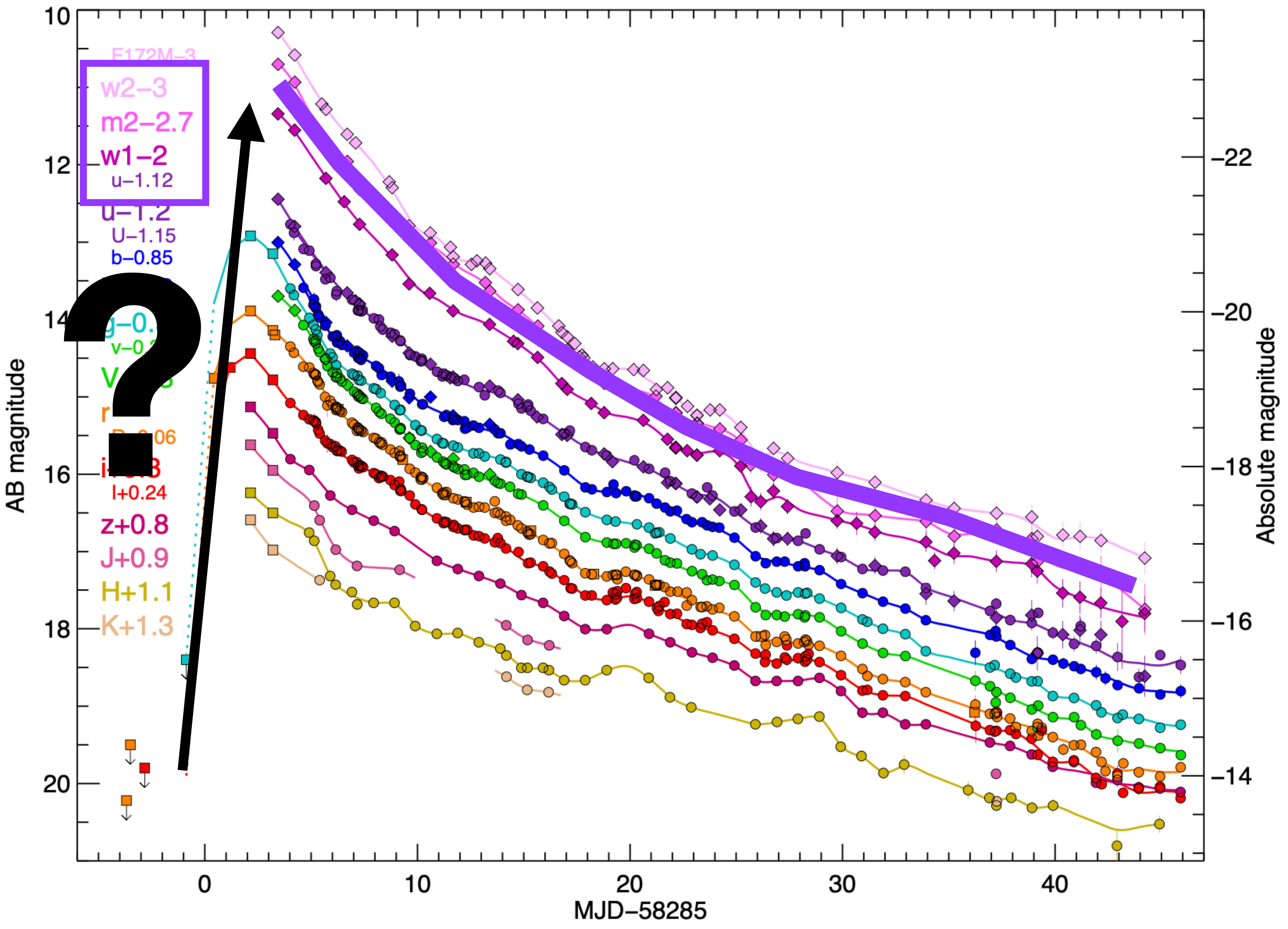
UV luminous + rapid rise time! → Rare!

SN2006aj/GRB060218 (Low-Lum)



The Open Supernova Catalog (OSC) *Pian+2006, Campana+ 2006*

Luminous FBOT AT2018cow

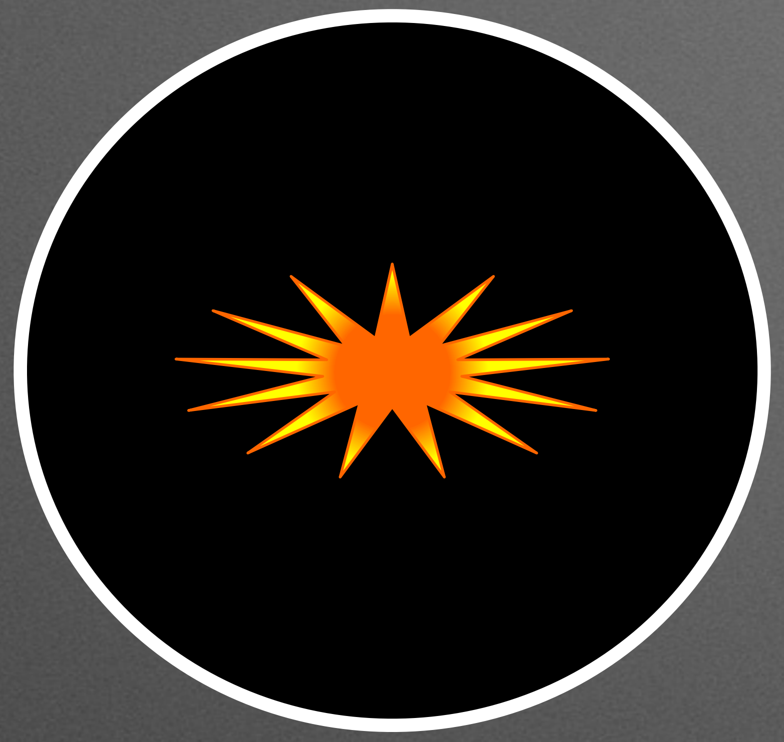


Perley+2018, Prentice+2018, Margutti+2019

What makes an explosion UV luminous on short time scales?

"It sort of makes you stop and think, doesn't it."

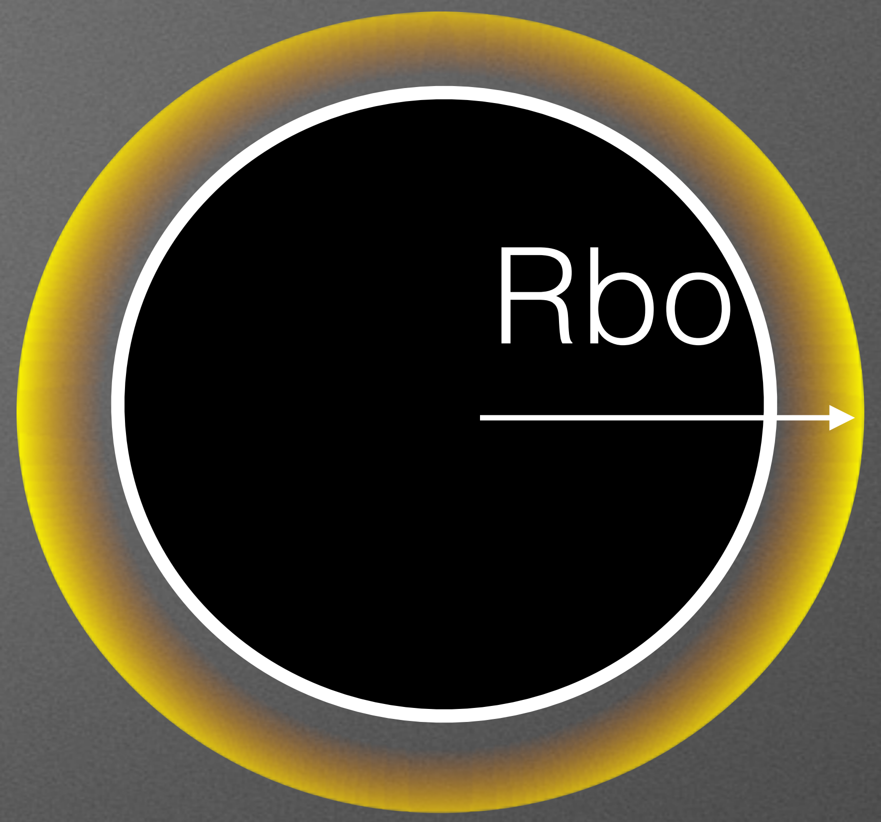
Fast Time Scales + UV lum



Central Source of Energy

$$t_{\rm pk} \approx \left(\frac{M_{\rm ej}\kappa}{4\pi v_{\rm ej} c}\right)^{1/2} \approx 2.7\,{\rm d}\left(\frac{M_{\rm ej}}{0.3M_\odot}\right)^{1/2}\left(\frac{v_{\rm ej}}{0.1c}\right)^{-1/2}$$

Small Mej ⟶ Ruled out 56Ni

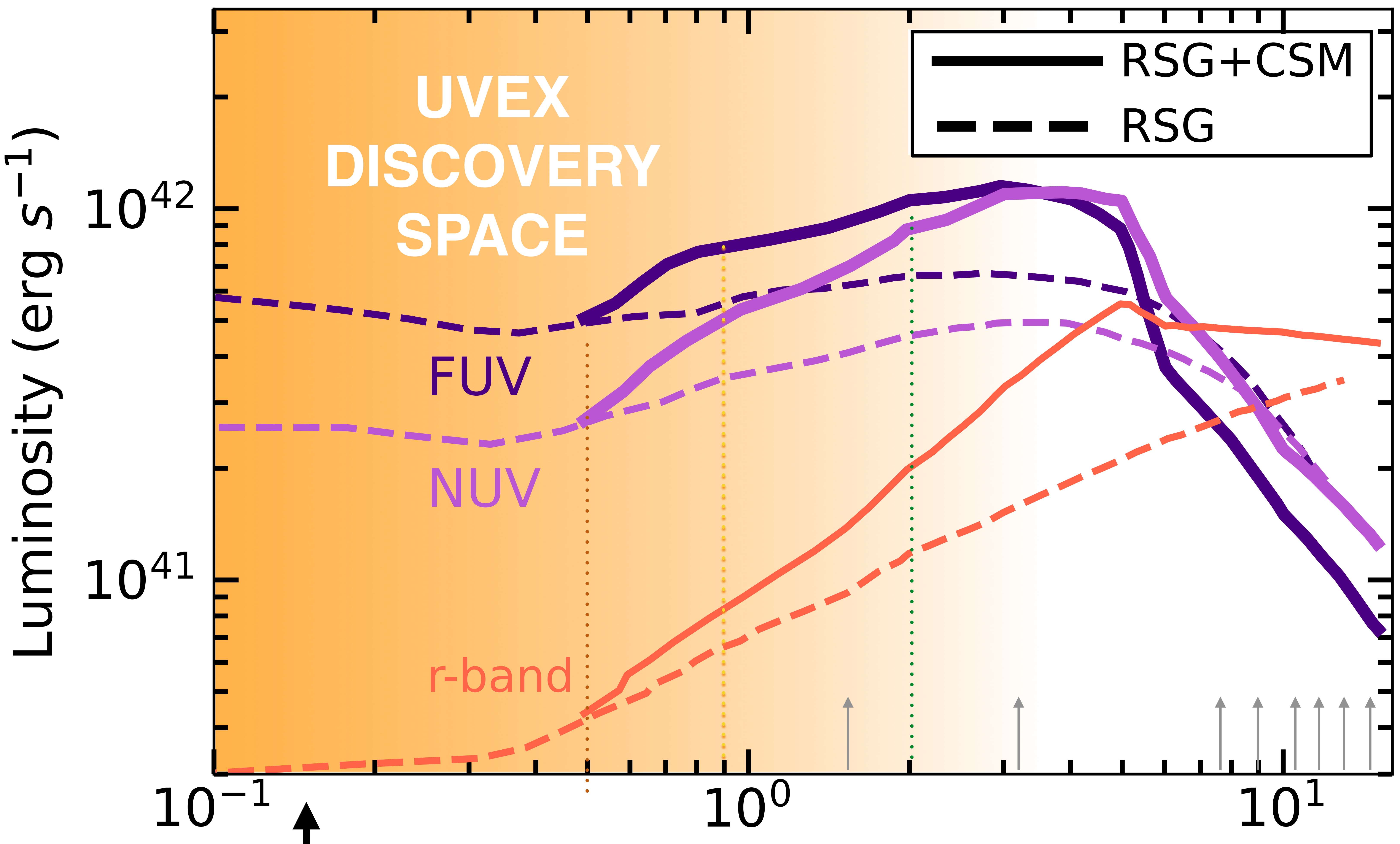


Shock interaction

Break out Radius (Rbo)

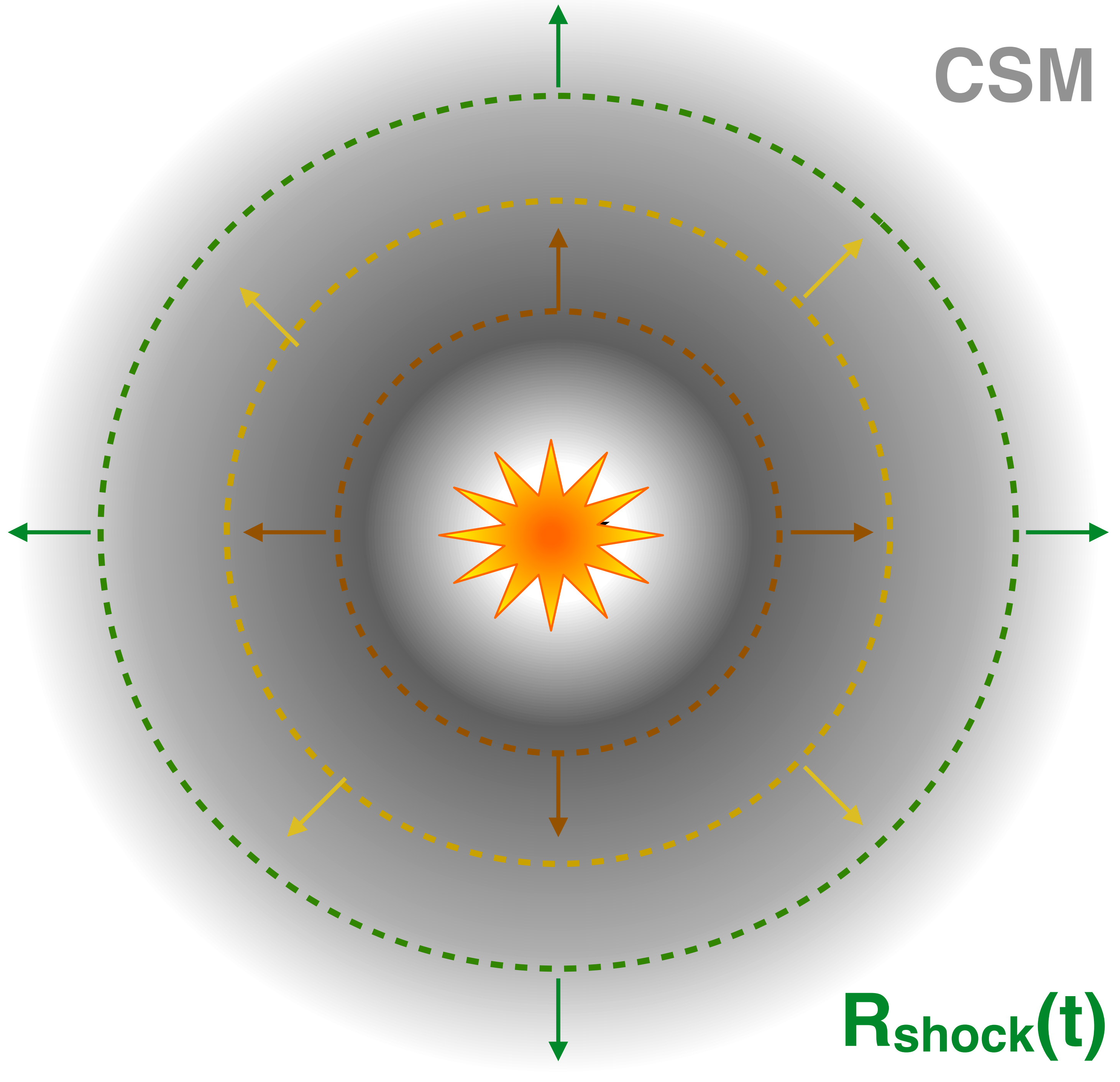
- Cooling with time
- No fast variability time scales
- No relativistic ejecta

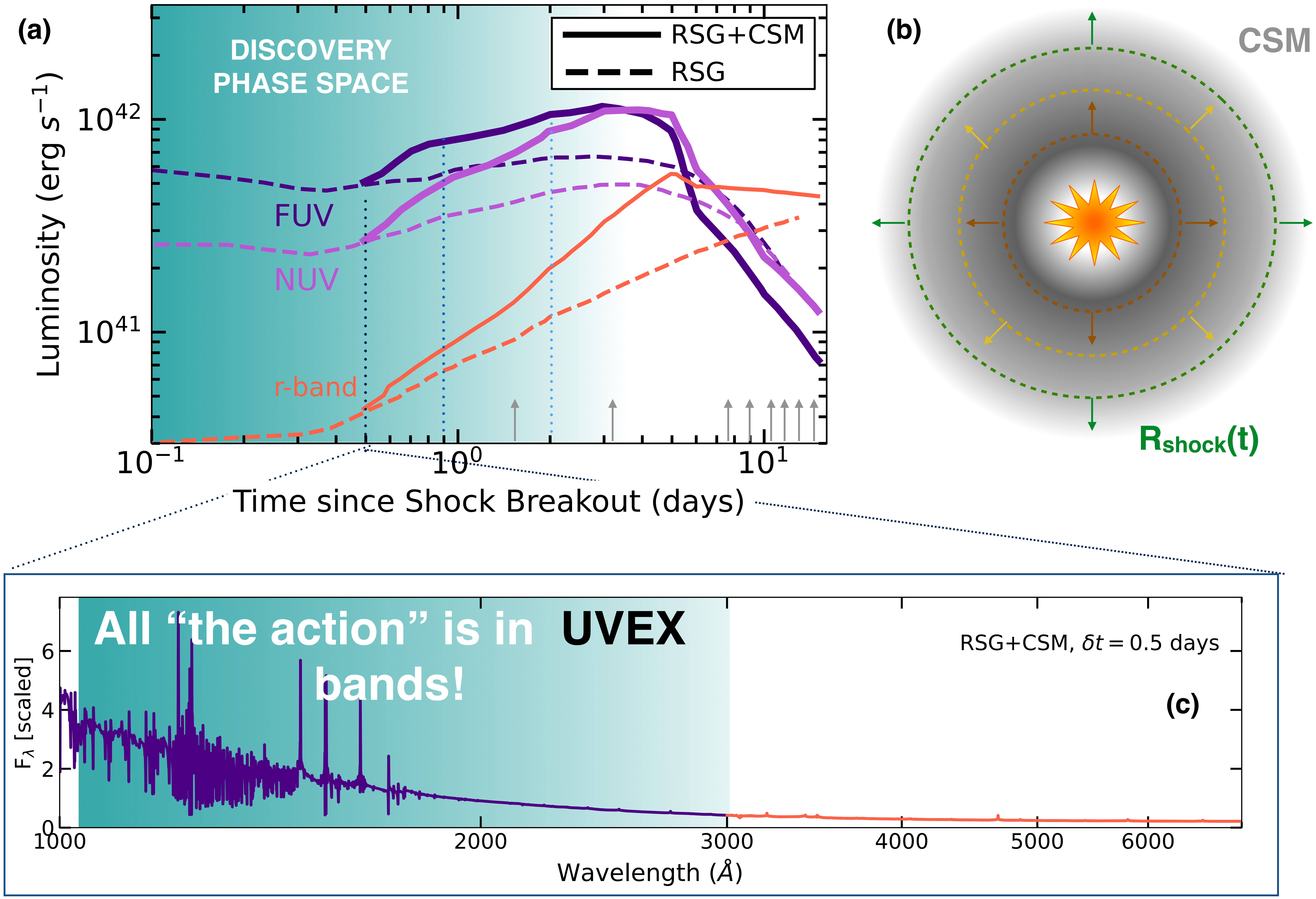
Explosion of a Red Super Giant with and without dense circumstellar medium (CSM)



LOG scale x-axis!!!!

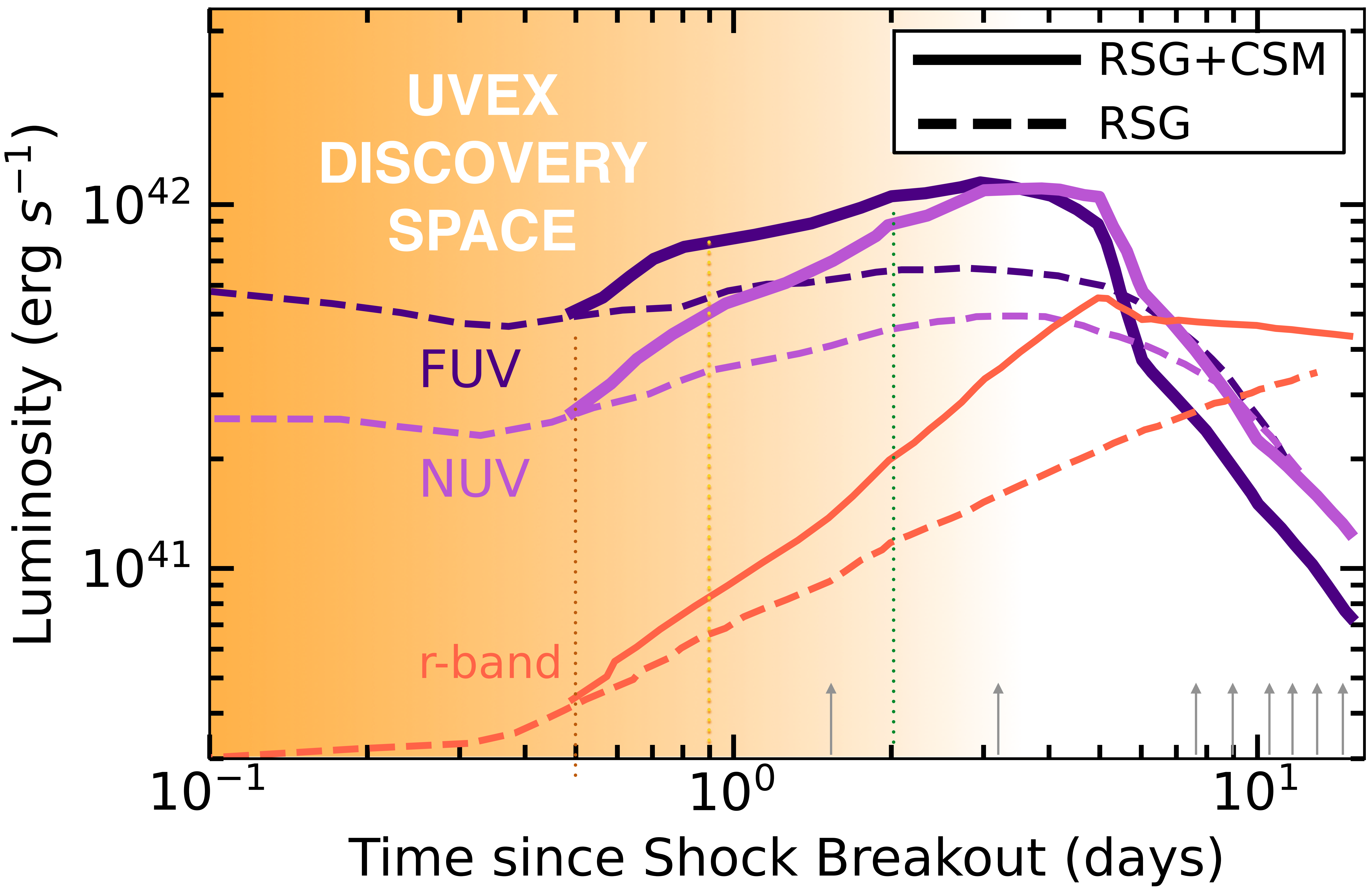
Models by Luc Dessart

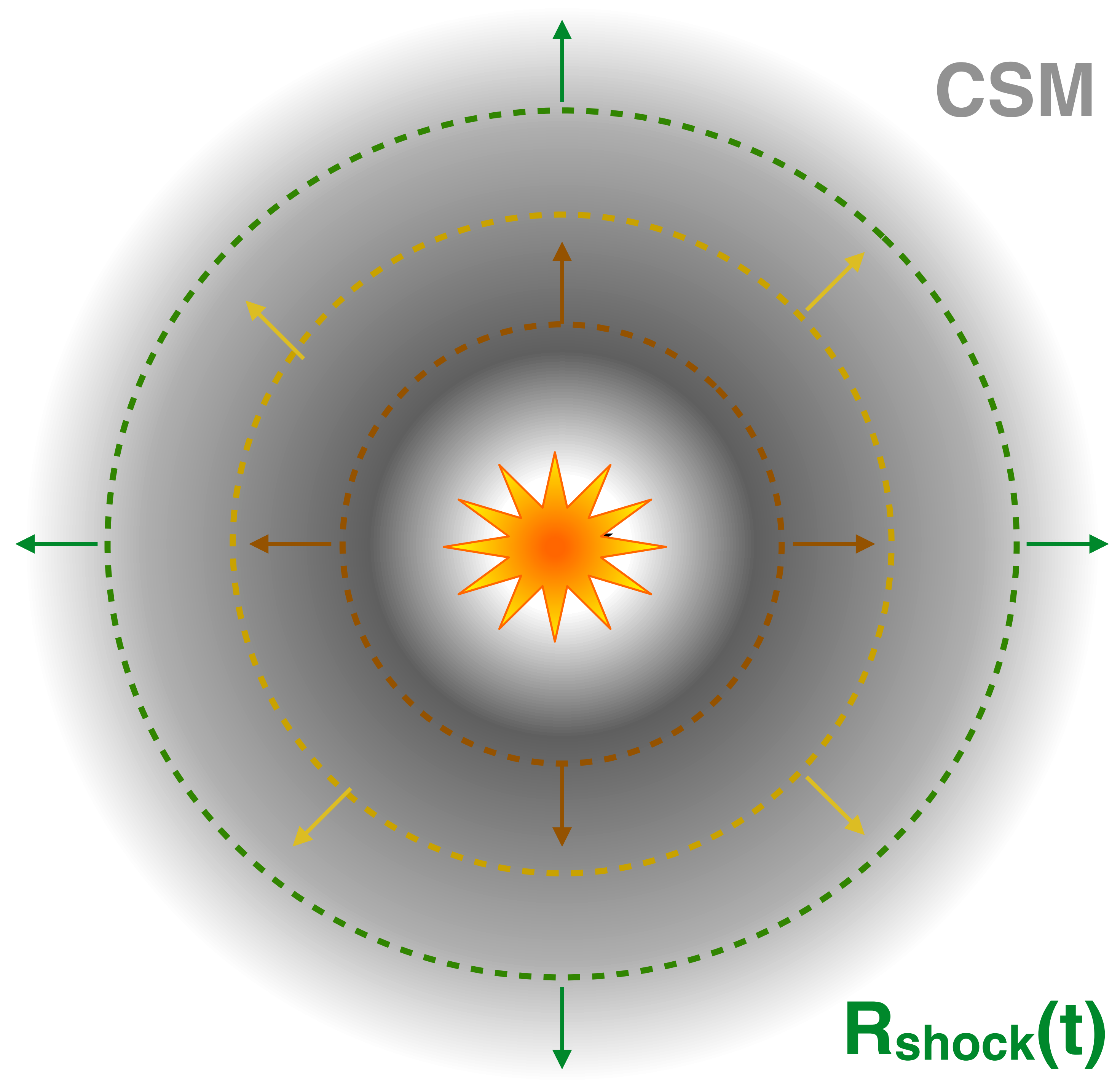




(a)
DISCOVERY PHASE SPACE
RSG+CSM
RSG
FUV
NUV
r-band
Luminosity (erg s^{-1})
10^{42}
10^{41}
10^{-1}
10^{0}
10^{1}
Time since Shock Breakout (days)
(b)
CSM
$R_{shock}(t)$
All "the action" is in UVEX bands!
RSG+CSM, $\delta t = 0.5$ days
(c)
F_λ [scaled]
0
2
4
6
1000
2000
3000
4000
5000
6000
Wavelength (Å)

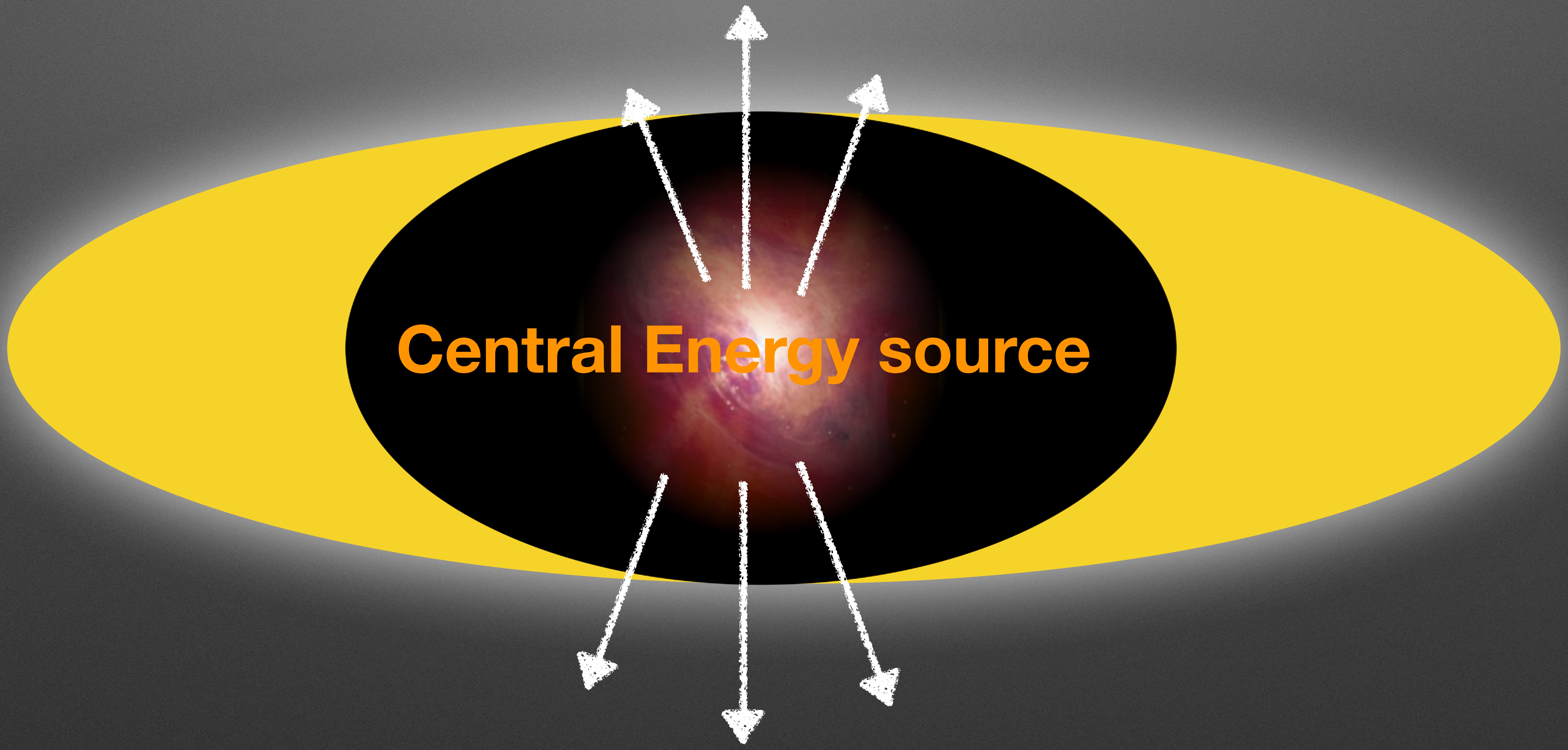
Explosion of a Red Super Giant
with and without dense circumstellar medium (CSM)





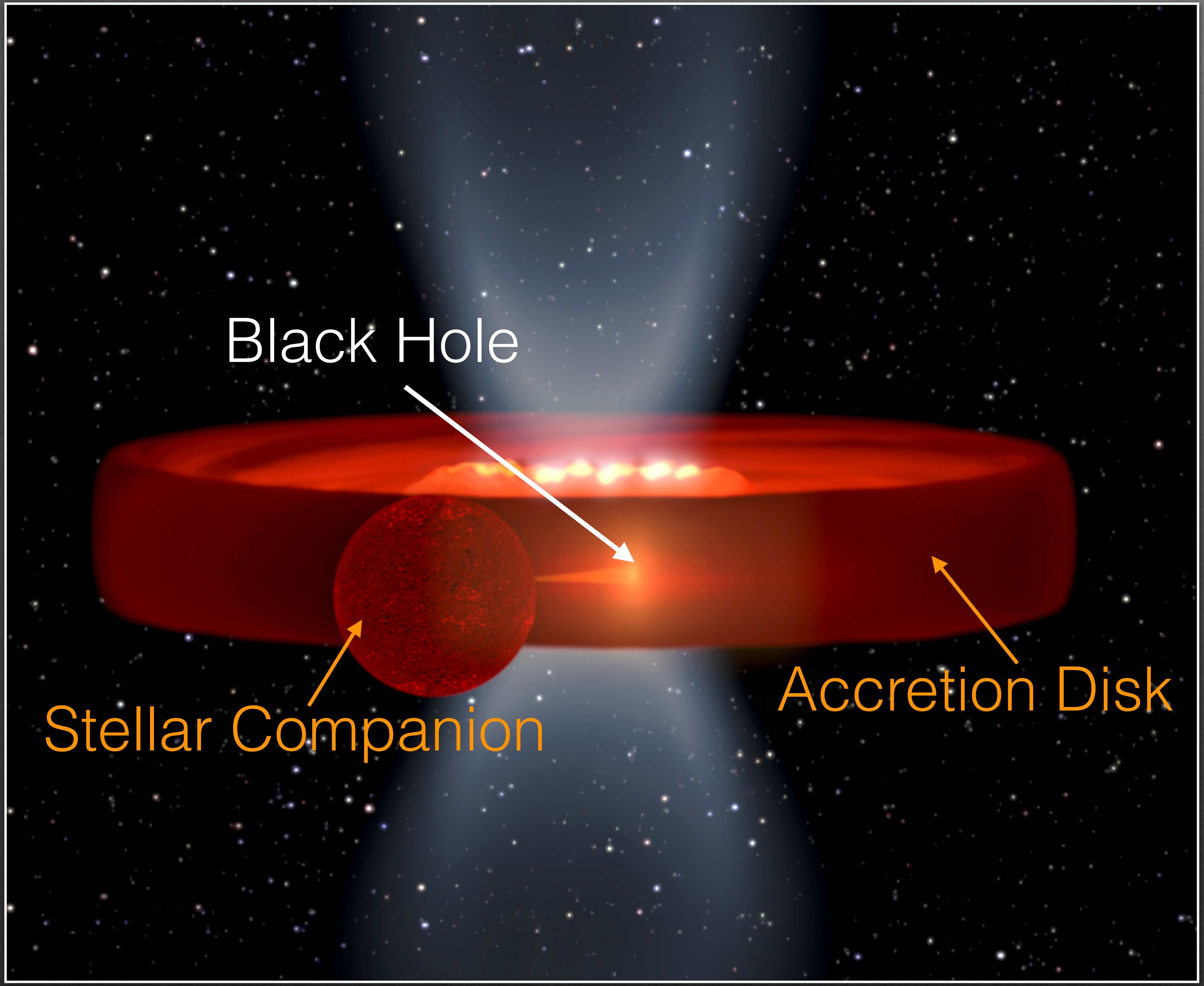
Models by Luc Dessart

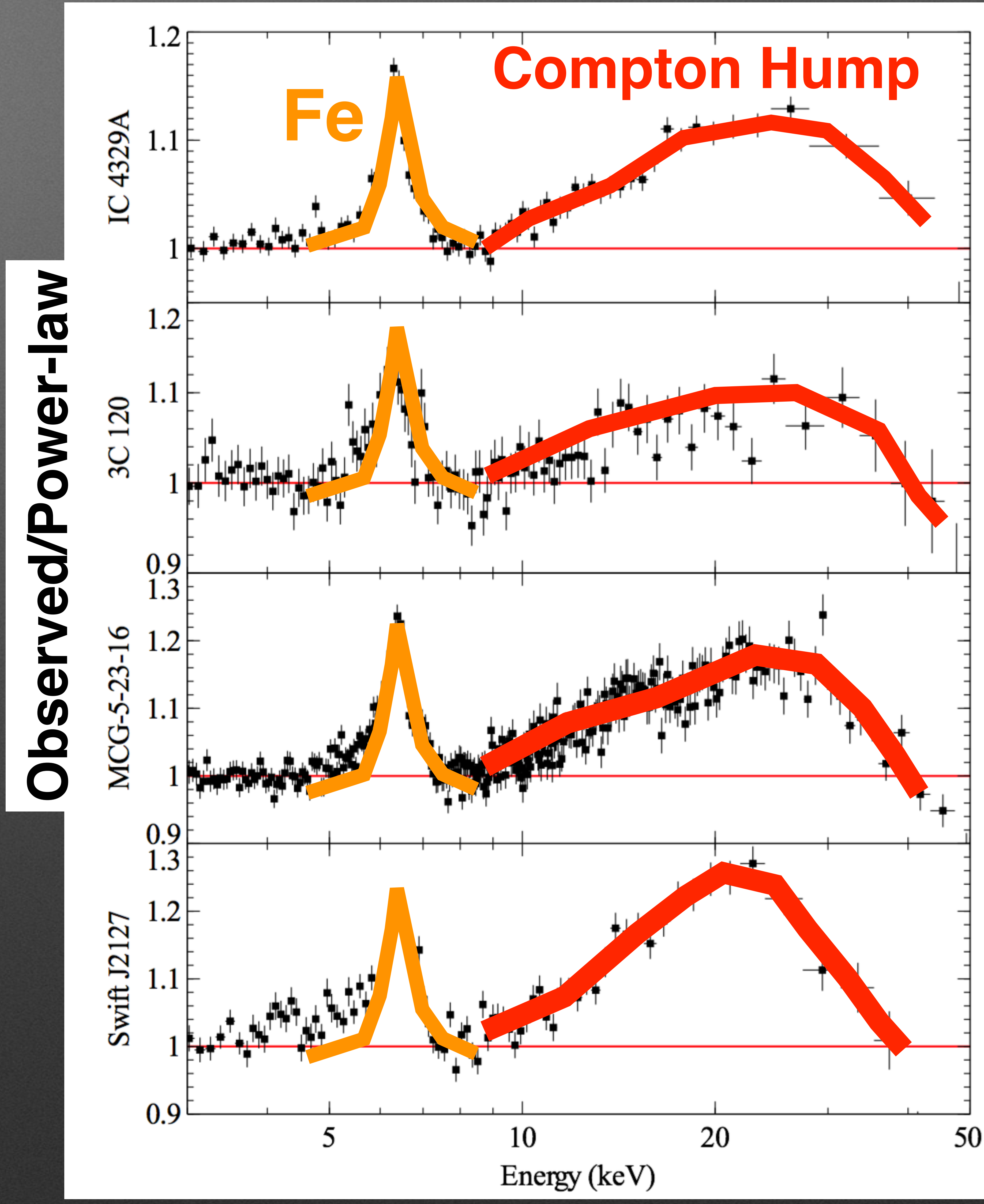
Explosions with Small +Asymmetric ejecta Mass become transparent earlier:



we can see the “inside” right at the time of the explosion

Compton Hump Spectra are Common around accreting Black Holes





Fabian+15

AT2018cow in the X-rays

RM+18

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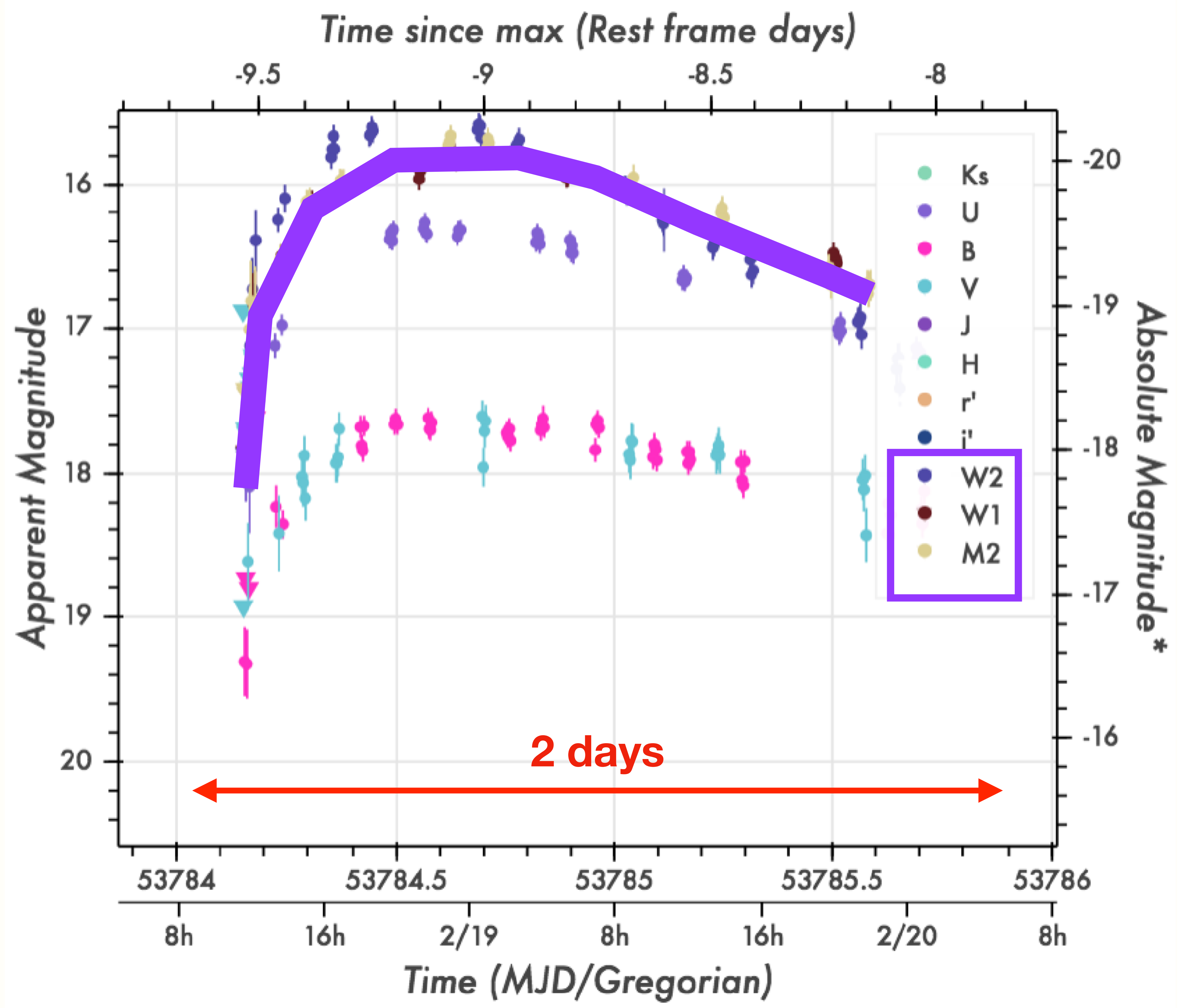
UV luminous! | Rare!

Low-Lum SN2006aj/GRB060218



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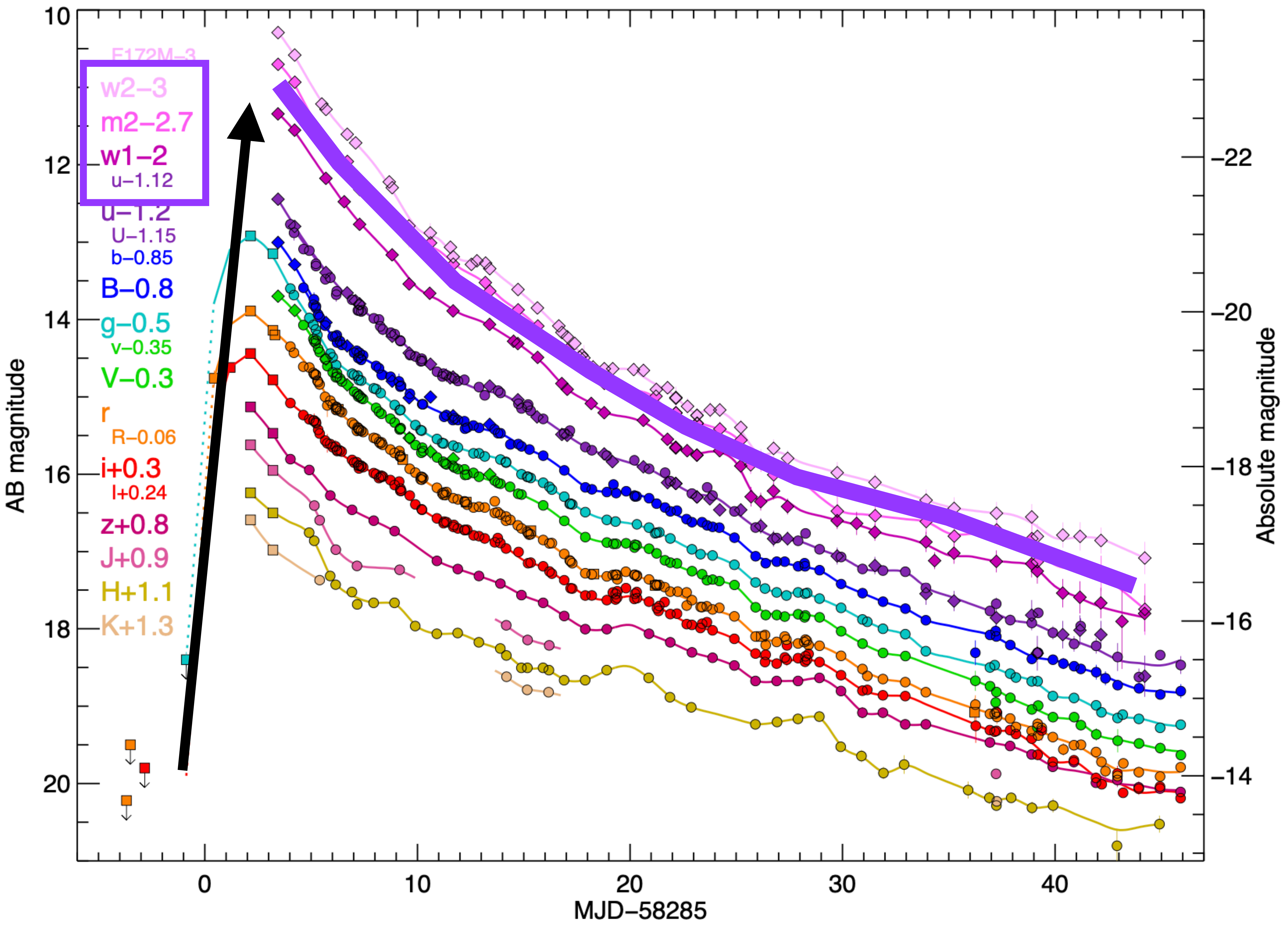


Perley+2018, Prentice+2018, Margutti+2019

How rare is rare?

Luminous FBOTs

Coppejans+2020

Table 2

Volumetric Rate Estimates for the Entire Population of FBOTs (Upper Part) and for the Most Luminous FBOTs (Lower Part)

References	Abs Mag Range at Peak (mag)	Timescale (days)[a]	z	FBOT Rate (Gpc^{-3} yr^{-1})	versus CCSNe[b]	versus SLSNe[c]	versus sub-E GRBs[d]
Drout et al. (2014)	$-20 < M_g < -16.5$	<12	<0.65	4800–8000	7%–11%	2400%–4000%	2100%–3500%
Pursiainen et al. (2018)	$-15.8 < M_g < -22.2$	<10	$0.05 \leqslant z \leqslant 1.56$	$\gtrsim$1000	$\gtrsim$1.4%	$\gtrsim$500%	$\gtrsim$430%
Tampo et al. (2020)	$-17 < M_i < -20$	$\lesssim$15	$0.3 \leqslant z \leqslant 1.5$	~4000	~6%	~2000%	~1700%
Ho et al. (2020)	$M_g < -20$	<5	$\lesssim$0.1	<560	<0.8%	<280%	<240%
This work (PS1-MDS)	$M_g < -19$	<12	<0.65	700–1400	1%–2%	350%–700%	300%–600%
This work (PTF)	$M_R = -20 \pm 0.3$	$\lesssim$3	$\lesssim$0.1	<300	<0.4%	<150%	<130%

Notes.

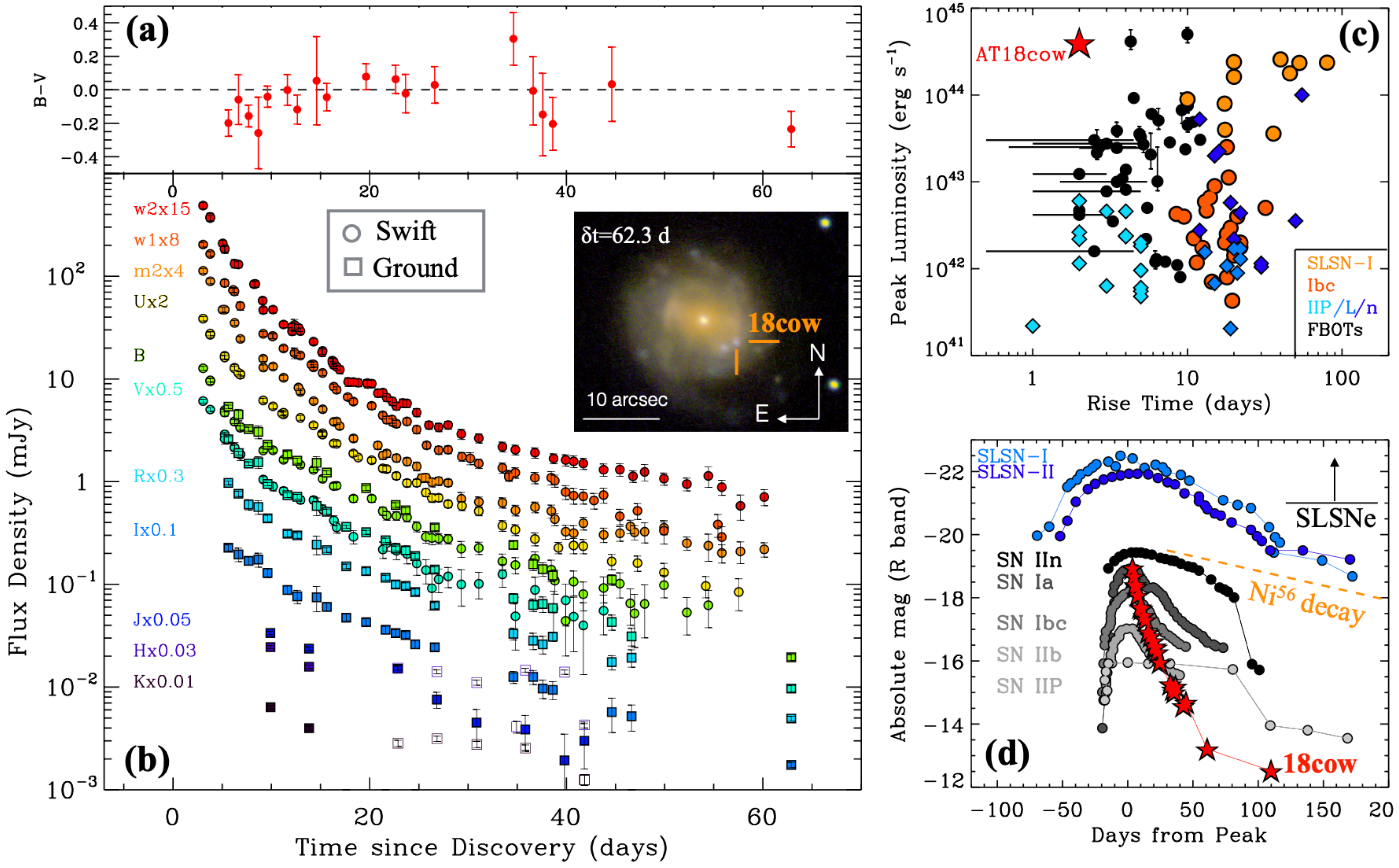
[a] Rest frame.

[b] Local universe core-collapse SN rate from Li et al. (2011a) $\mathfrak{R} \sim 70500$ Gpc^{-3} yr^{-1}.

[c] SLSN rate at $z \sim 0.2$ from Quimby et al. (2013), including type I and type II events $\mathfrak{R} \sim 200$ Gpc^{-3} yr^{-1}.

[d] Rate of sub-energetic long GRBs before beaming correction from Soderberg et al. (2006b) $\mathfrak{R} \sim 230$ Gpc^{-3} yr^{-1}.

We have a handful of FBOTs that we were able to identify in real time and for which we could do follow up in real time!!!



(a)
B−V
0.4
0.2
0.0
−0.2
−0.4
0
20
40
60
(b)
w2x15
w1x8
m2x4
Ux2
B
Vx0.5
Rx0.3
Ix0.1
Jx0.05
Hx0.03
Kx0.01
Swift
Ground
δt=62.3 d
18cow
N
E
10 arcsec
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
Flux Density (mJy)
Time since Discovery (days)
(c)
AT18cow
Peak Luminosity (erg s^{-1})
10^{45}
10^{44}
10^{43}
10^{42}
10^{41}
1
10
100
Rise Time (days)
SLSN−I
Ibc
IIP/L/n
FBOTs
(d)
SLSN−I
SLSN−II
SLSNe
SN IIn
SN Ia
SN Ibc
SN IIb
SN IIP
Ni^{56} decay
18cow
Absolute mag (R band)
−22
−20
−18
−16
−14
−12
−100
−50
0
50
100
150
20
Days from Peak

UVEX +

5-day survey
20,000 deg2 minus 20% (avoid high-extinction)
15hr cadence
Mag lim 25 (phot)
Mag lim 20 (spec)
~0.5 mag extinction
Require discovery 1 mag above effective threshold
Require explosion in the first 3 days

photo-z

Transient ID

+

Class	Horizon phot (spec)	Vol. Rate ($\mathrm{yr}^{-1}\,\mathrm{Gpc}^{-3}$)	# Disc. (phot)	# Disc. (spec)
Cows	8.5 Gpc (2 Gpc)	0.7–70	6–600	0.08–8
LLGRB	8.5 Gpc (2 Gpc)	7–70	60–600	0.8–8
Icn	8.5 Gpc (2 Gpc)	0.7–70	6–600	0.08–8
Ibn	4.2 Gpc (680 Mpc)	7	7	0.03

Read: Luminous FBOTs

This is 0.001%-0.1% the CCSN rate

Simulations by Anna Ho

The KNOWLEDGE GAP

The

KNOWLE DGE

GA P

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UDI
ES

BONUS SLIDES

Ordinary SNe, UVEX simulations by Yuhan Yao:

Class	Horizon phot (spec) D_L (Mpc)	Vol. Rate ($\mathrm{yr^{-1}\,Gpc^{-3}}$)	# Discovered (phot)* (yr^{-1})	# Discovered (spec)** (yr^{-1})
IIP	2000 (200)	33981^{+5097}_{-5097}	$2.1^{+0.5}_{-0.5} \times 10^4$	$5.4^{+1.2}_{-1.2}$
IIL	2000 (200)	4417^{+663}_{-663}	$2.7^{+0.4}_{-0.4} \times 10^3$	$0.7^{+0.1}_{-0.1}$
IIn	2000 (200)	6204^{+930}_{-930}	$6.4^{+1.0}_{-1.0} \times 10^3$	$< 1^{+0.15}_{-0.15}$
IIb	2000 (200)	7473^{+1120}_{-1120}	$< 4.6^{+0.7}_{-0.7} \times 10^3$	$< 1.2^{+0.2}_{-0.2}$
Ib/Ic	462 (< 50)	18330^{+4400}_{-4200}	$3.6^{+0.9}_{-0.9} \times 10^2$	$0.05^{+0.01}_{-0.01}$
Ia	316 (< 30)	30100^{+3800}_{-3700}	$1.8^{+0.25}_{-0.25} \times 10^2$	$0.02^{+0.002}_{-0.002}$

Table 2: Summary of yields for normal stellar explosions. For details about assumptions that leads to these numbers see below. Volumetric rates of SNe from [10] Li et al., 2011 (LOSS sample); for ratios of types of CCSNe, [11] Smith et al., 2011.

* I assumed that the IIP, IIb, Ibc, Ia SNe are above the threshold for photometric detection for ~1 week; IIn for 10 days;

** Rate of SNe discovered within 2 days of explosion, above our spectroscopic threshold and for which we have pre-explosion imaging within 48hrs before the first detection.

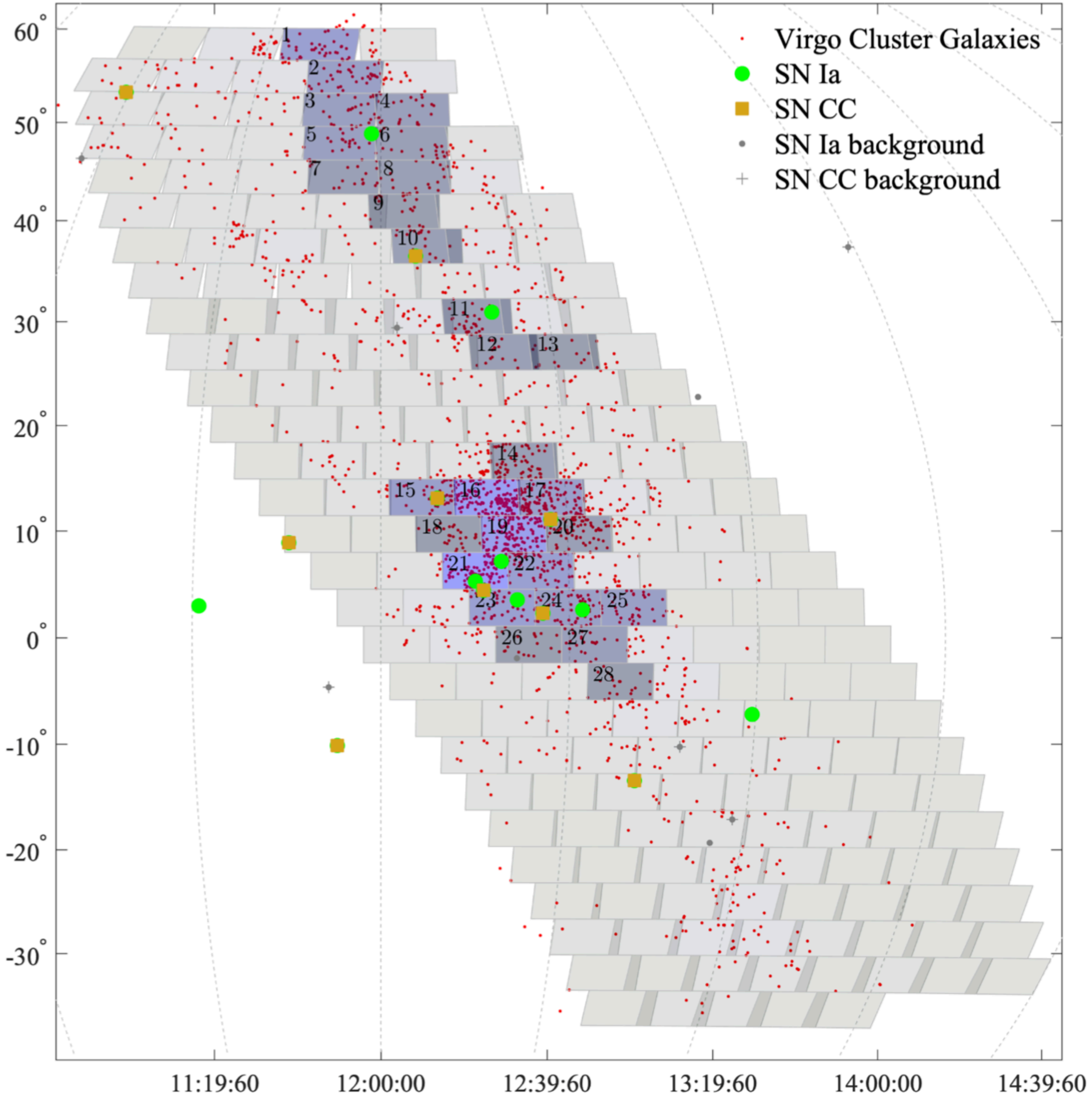
Assumptions:

- Intrinsic volumetric rates from the papers referenced in the table.
- Reduction of 20% of the sky available due to regions of high extinction.
- Reduction of 0.5 mag in depth for both spectra and photometry to account for MW and intrinsic extinction (same as Anna above).
- Sky coverage: I used the results from the simulations from Yuhan: On average we cover 468 deg^2 during one day, and 812 deg^2 during 2 days. If we do not count the quick tiling dwells (so we have 730-80=650 days), then the answer is 427 deg^2 per day and 715 deg^2 per 2 days. On average, 48.8% of the sky has an observation $\leq$ 24 hrs before, and 48.8% of the sky has an observation $\leq$ 48 hrs before.
- For all SNe, I assumed we want to sample at least 1 mag below the peak UV brightness

A dedicated Virgo cluster survey (d~16.5 Mpc)

Simulations by Christoffer Fremling

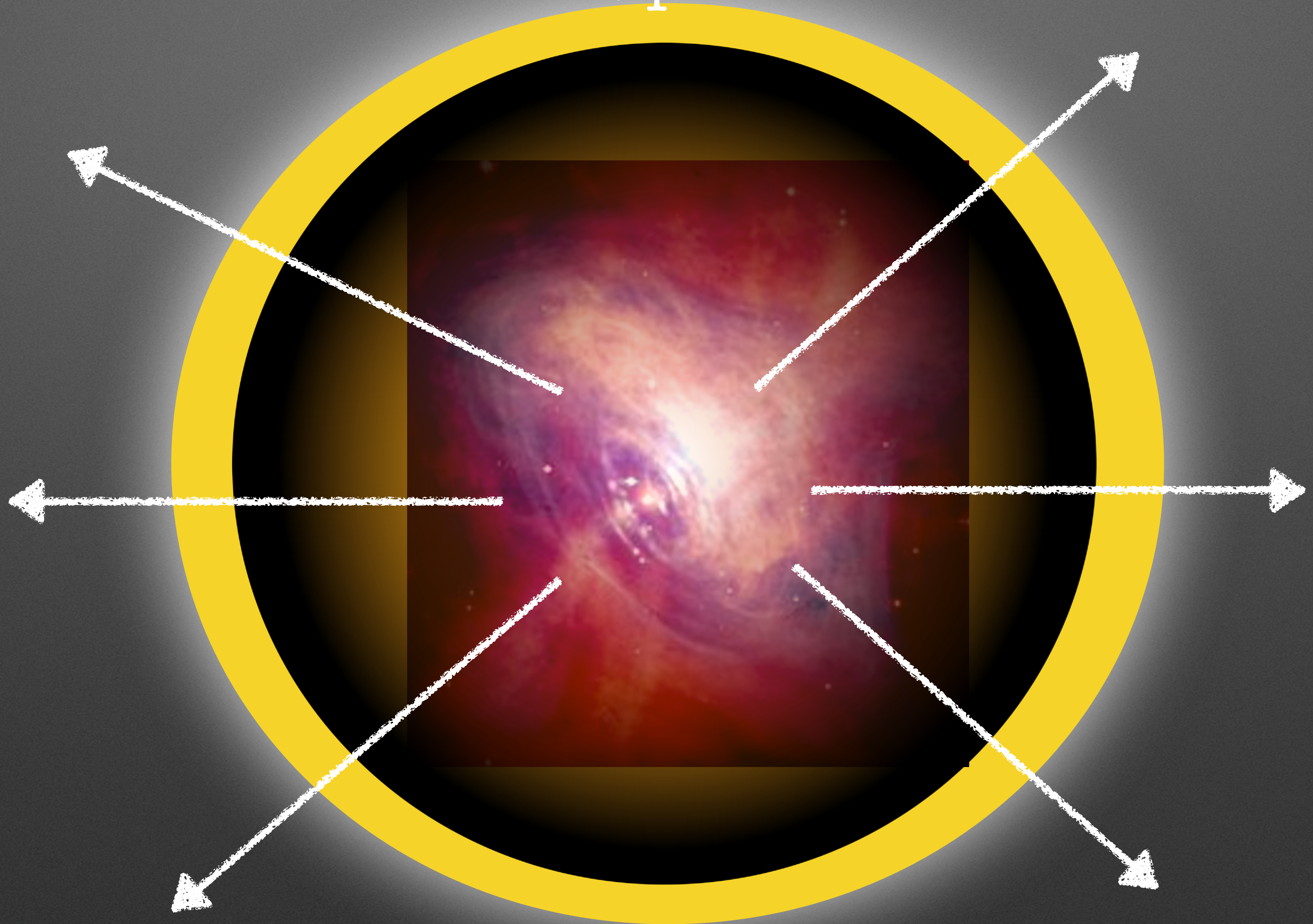
(Not part of the 2-yr plan)



12hr-cadence survey, 200s exposure, for half a year
Expected yield of at least ~4 SNe (of which ~2 Ia)
All above threshold for spectroscopy
With a 12hr pre-explosion non-detection

Total time for photometry: 1 Msec for core Virgo (2 Msec for extended Virgo)

Explosions with Small ejecta Mass become transparent earlier:



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