Explosive Transients: early moments

Gal-Yam et al. 2014, Nature

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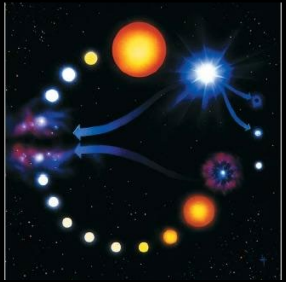
I. Arcavi

Collapsing massive stars are an important source of heavy elements, drive star formation, galaxy evolution

Massive stars are diverse

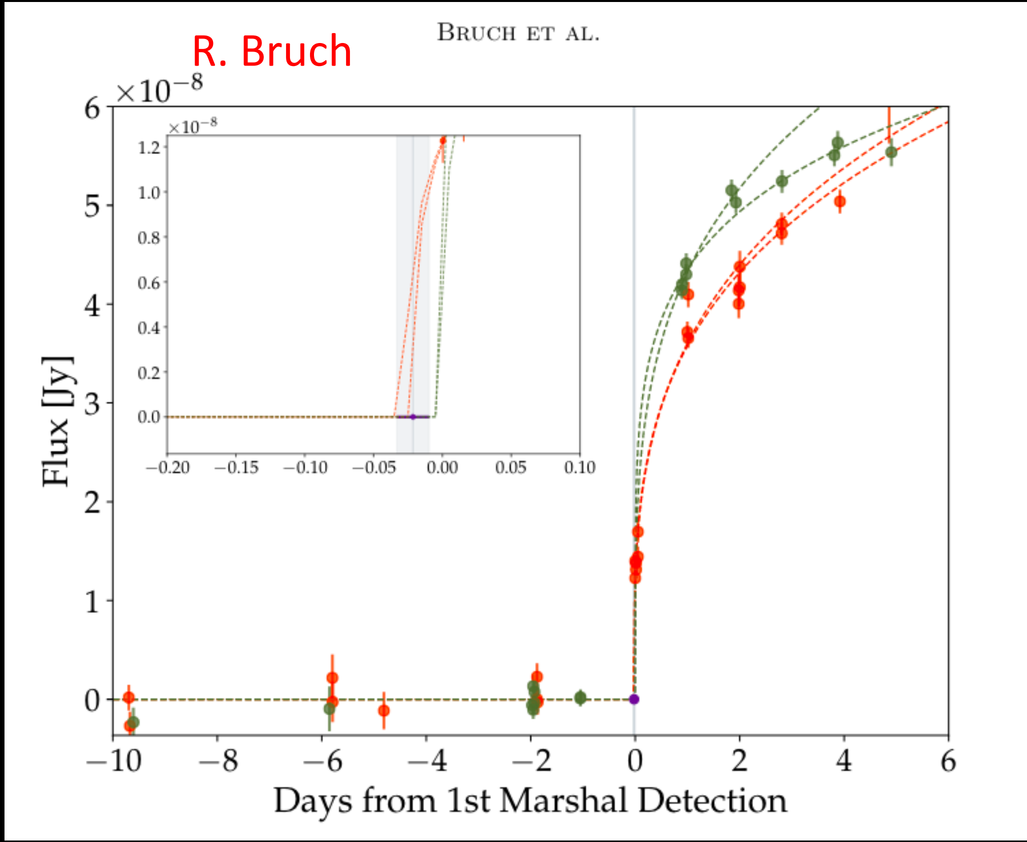
Mass
Metallicity
Rotation
Magnetic field
Binarity
…

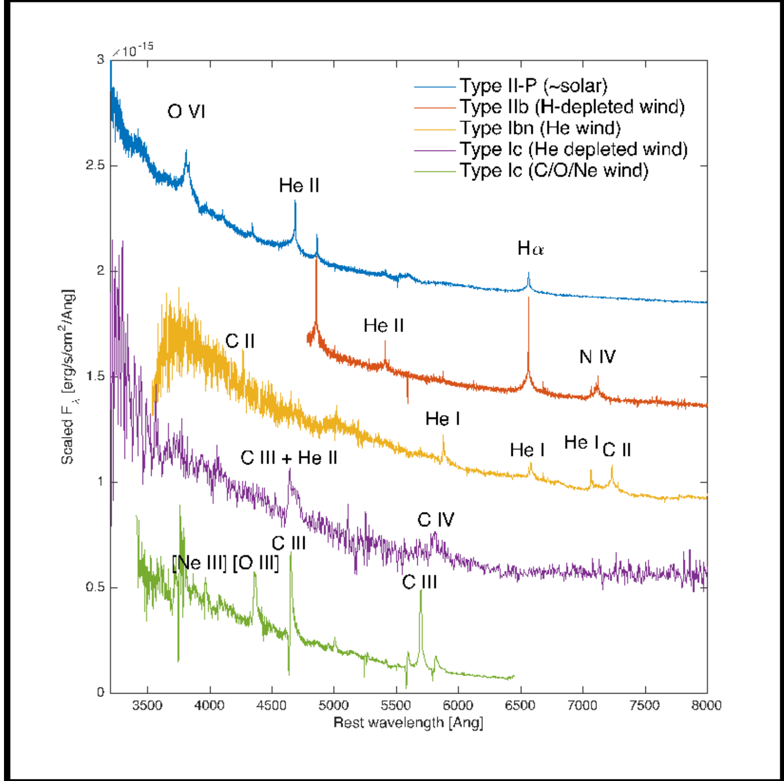


SN-progenitor mapping and explosion mechanism are still open puzzles

First hours and minutes are key

The birth of a supernova

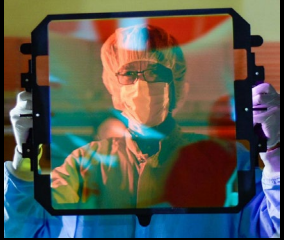




Field of view is key for earliest times

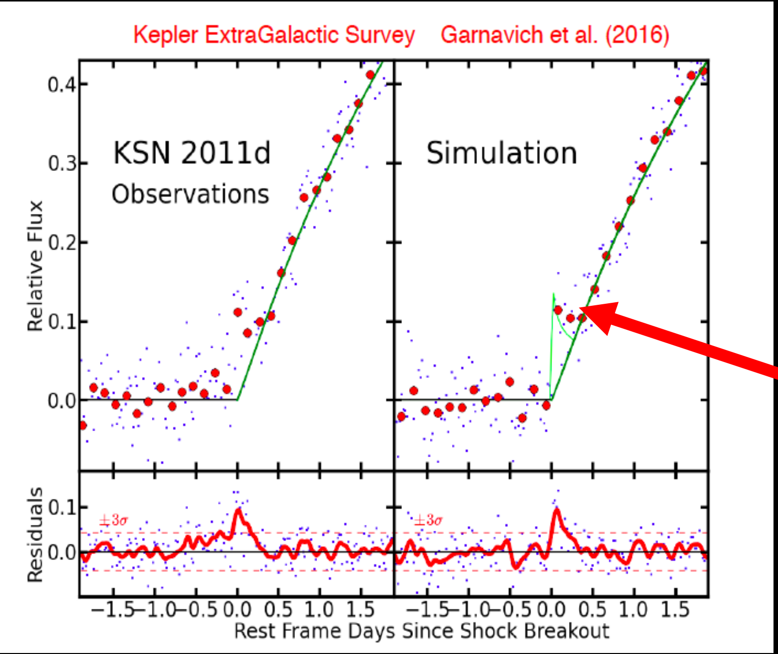
ZTF goes widest though with coarser angular resolution.

ULTRASAT will have 4 times larger FoV



A Supernova's first day: shock breakout

Kepler's view (Garnavich et al. 2016)



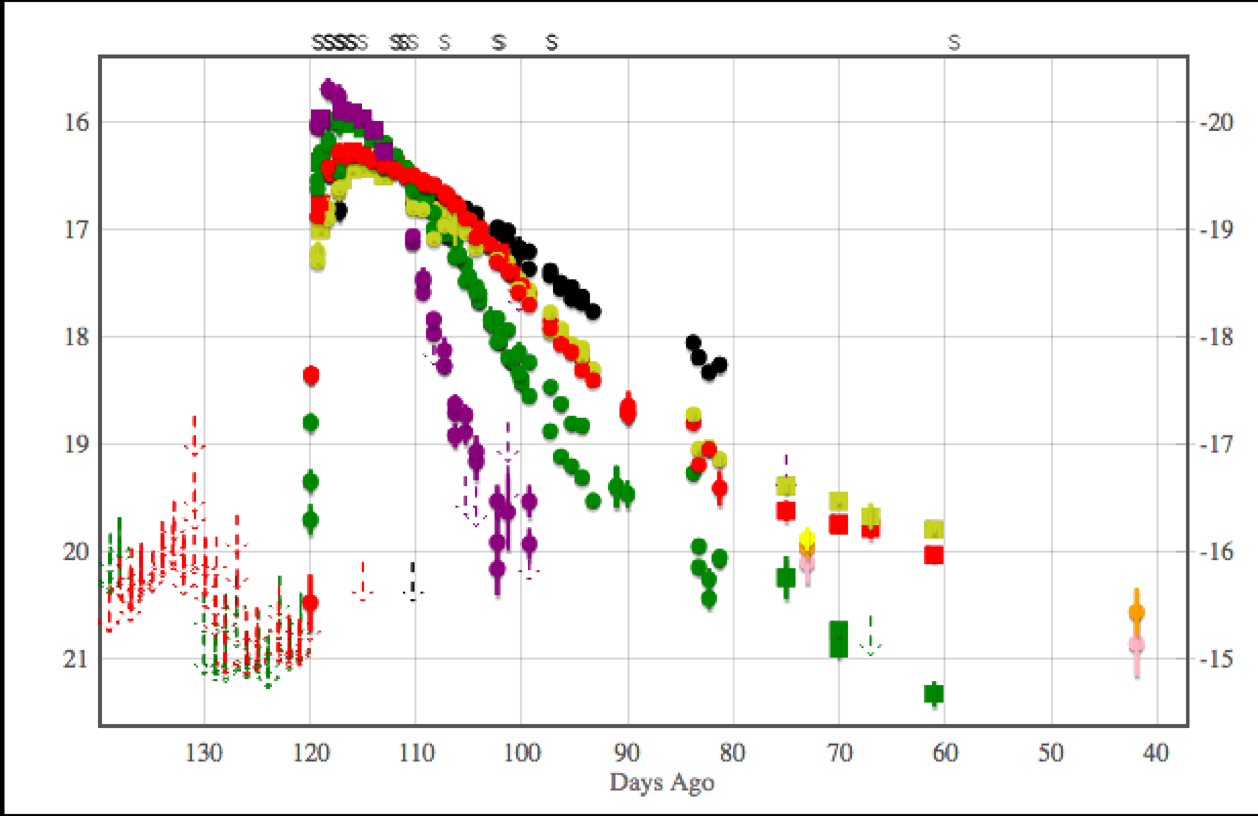
A shock breakout flare from a standard star (but see Goldberg et al. 2022) provides a direct measure of the stellar radius at explosion

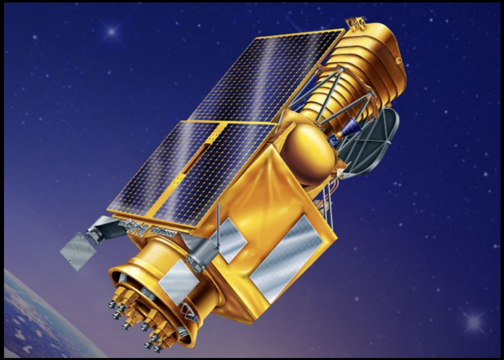
Such a plateau can be sampled >60 times by ULTRASAT

Kepler result is not as significant as initially reported, See Rubin & Gal-Yam 2017

Multi-visit strategies are required for intra-night discoveries

A. Ho



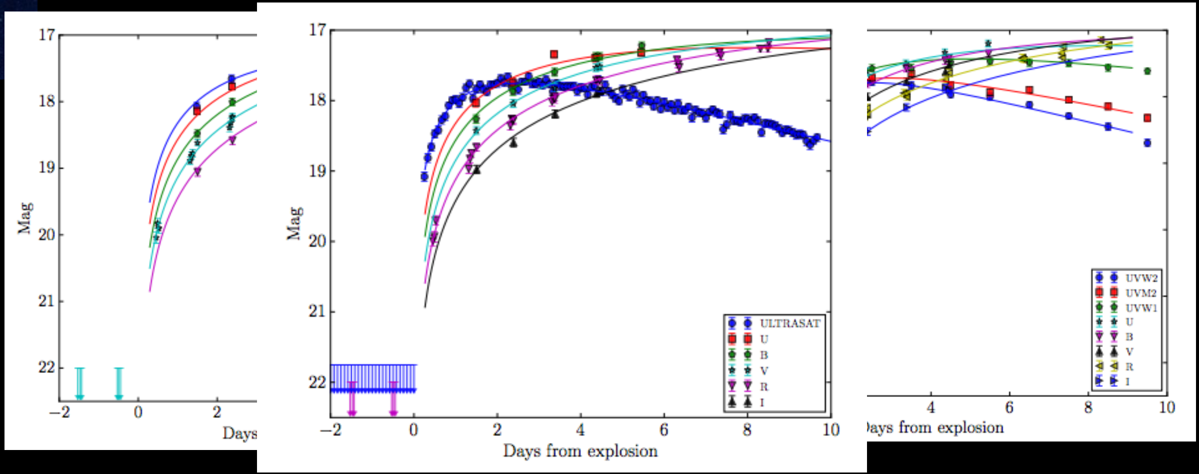


Early UV data can directly constrain progenitor and explosion properties

	Progenitor	$R_s/R_\odot$	$v_{s8.5}$	$M/M_\odot$	A_V
True value	RSG	500	1.00	10	0.10
BVRI	RSG	355—1342	0.80—1.18	5—20	0.00—0.36
UBVRI	RSG	300—835	0.83—1.17	5—20	0.00—0.23
UBVRI + UVOT	RSG	391—694	0.88—1.11	5—20	0.04—0.21
UBVRI + ULTRASAT	RSG	420—577	0.89—1.11	5—20	0.05—0.14

ULTRASAT
שער לחלל

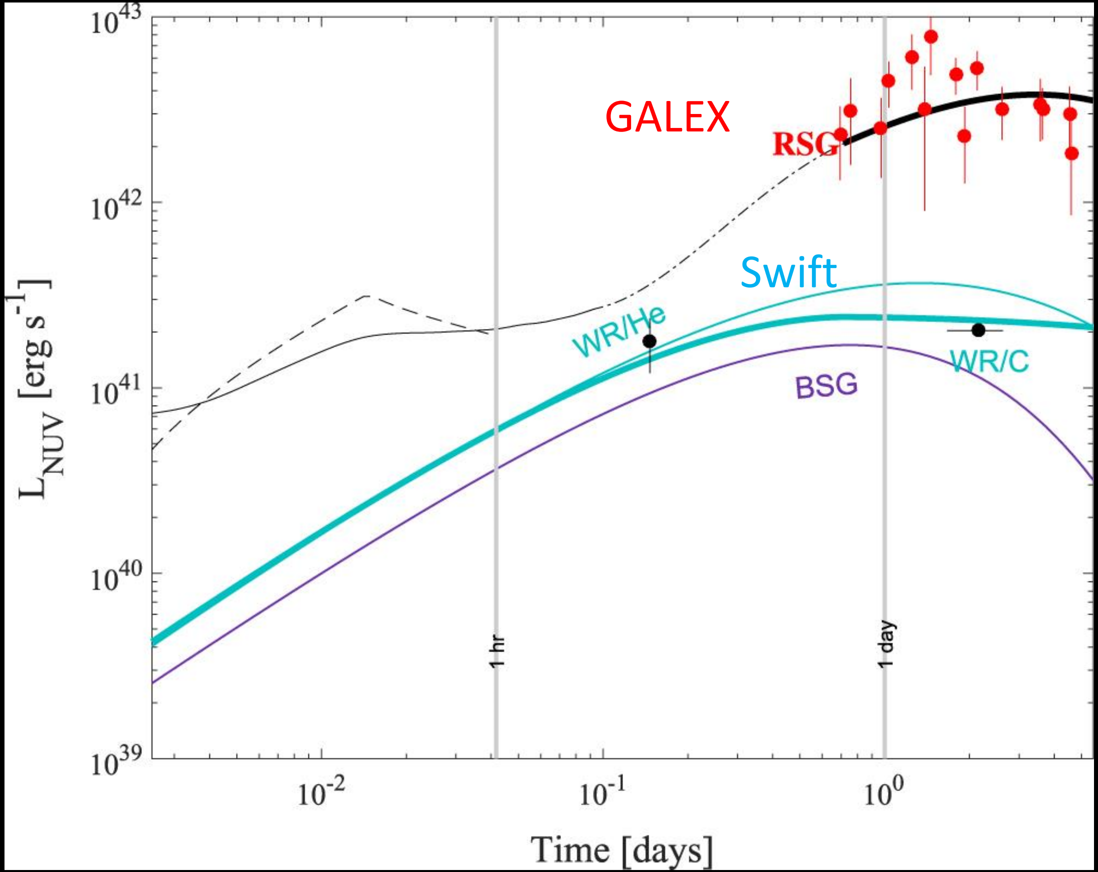
Optical alone does not robustly constrain R*, but does provide a measure of E/M, which is **0.85 10^{51}** per 10 Msolar ejecta (Rubin et al. 2016).



A. Rubin

N. Ganot

Early UV data can directly constrain progenitor and explosion properties: previous work



N. Ganot
I. Irani
M. Soumagnac
J. Morag

Early UV data can directly constrain progenitor and explosion properties: Swift + ground

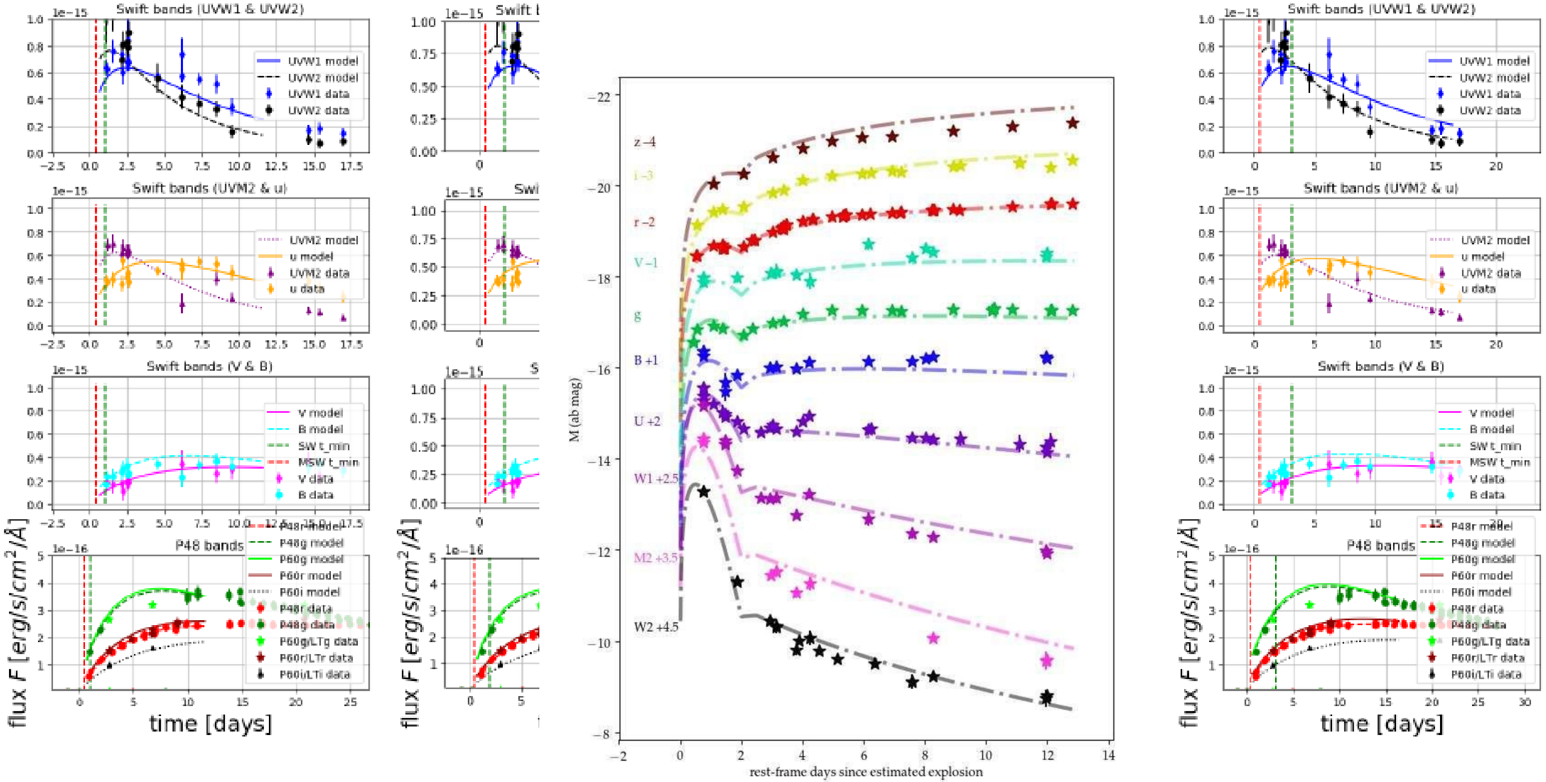
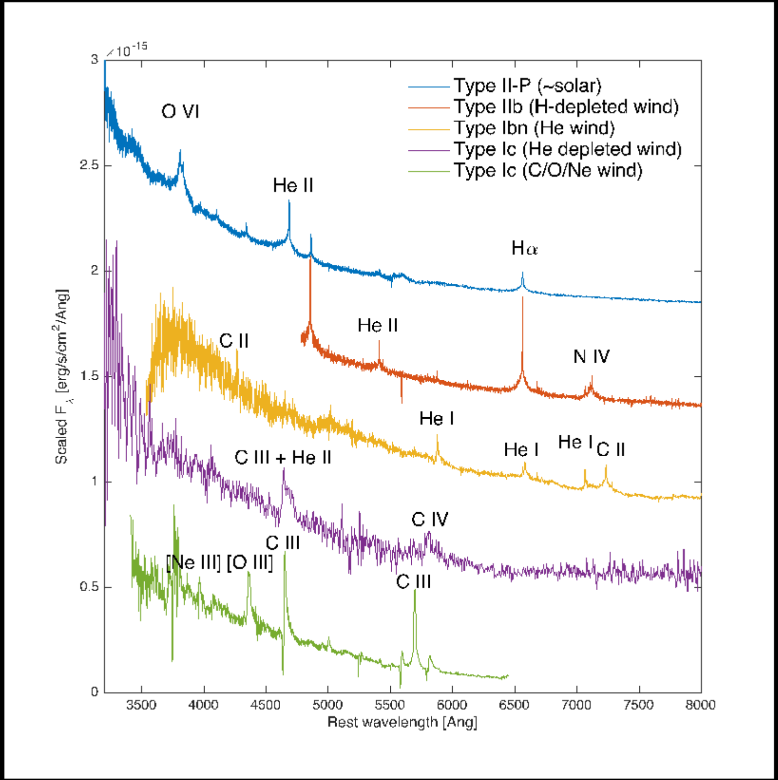


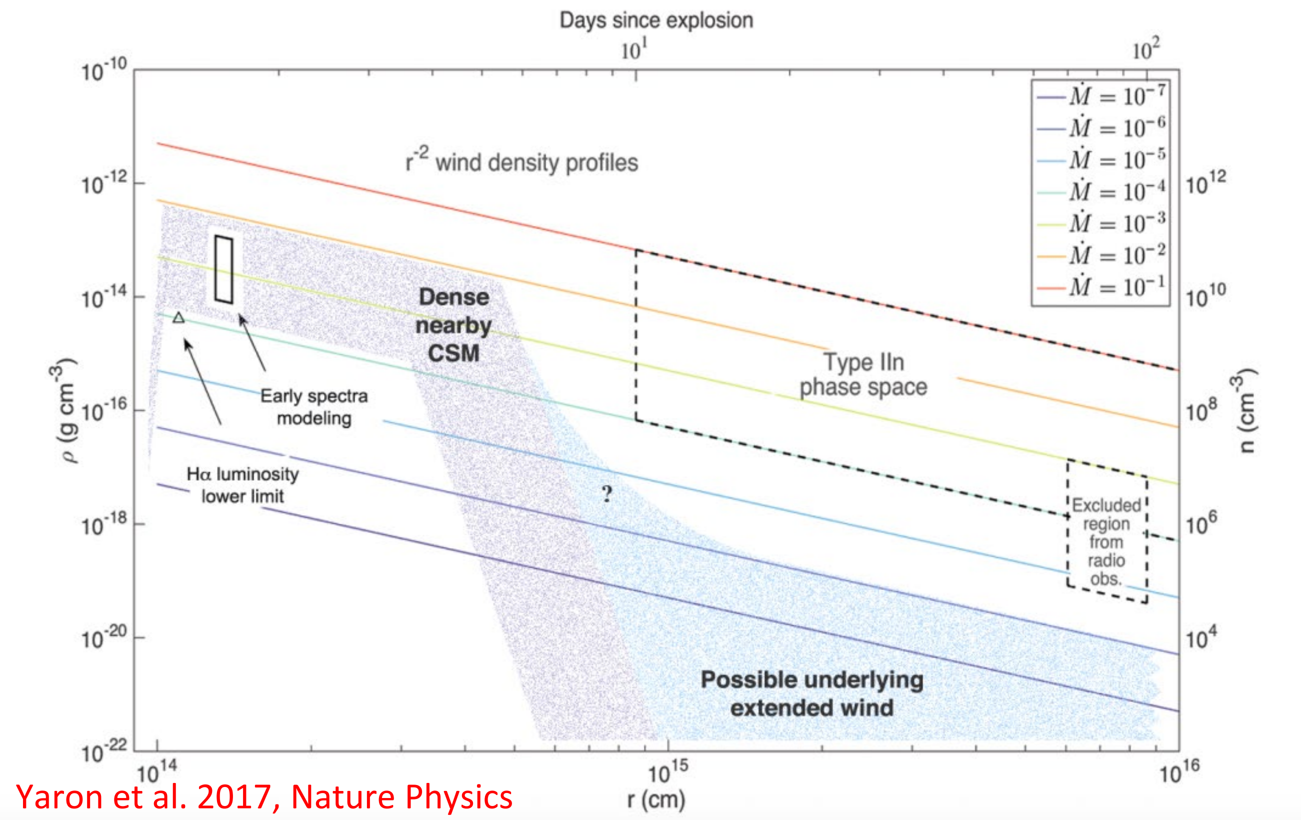
Figure 1: From l ... 3,4.70)

Flash spectroscopy: map exploding star composition

Rapid spectroscopy is key!



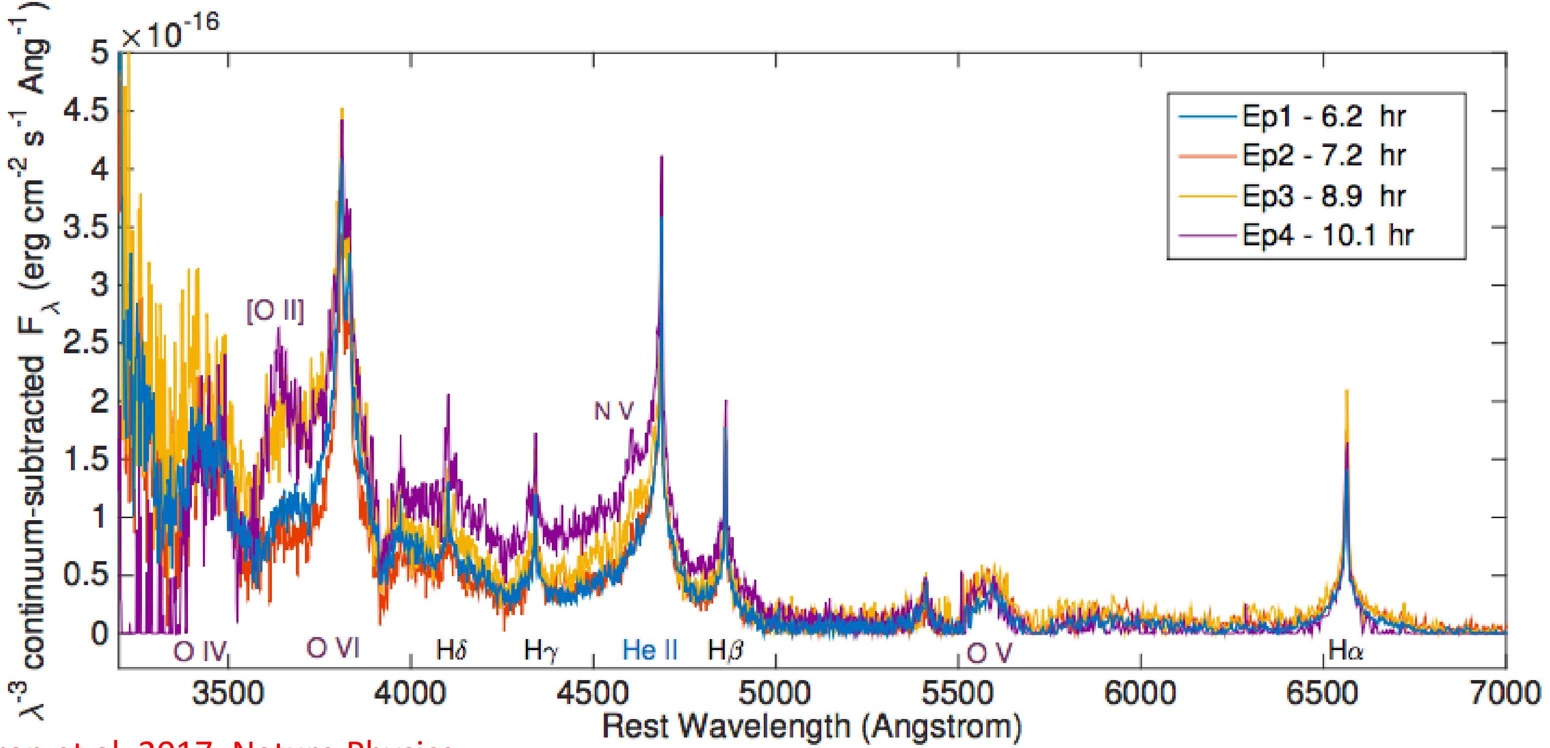
Confined CSM



Yaron et al. 2017, Nature Physics

A shell of dense CSM around the progenitor suggests a pre-explosion instability; need to change explosion model initial conditions?

A natural thermometer



Yaron et al. 2017, Nature Physics

A unique probe of shock cooling physics

Measuring the fraction of Unstable SN progenitors

IAU name	Internal ZTF name	Type	Redshift z	Explosion JD Date [d]	Error [d]	First detection [d] [a]	Last non detection [d]	First spectrum [d]	Telescope/ instrument	Flash
2018grf	18abwlsoi	SN II[b]	0.050	2458377.6103	0.0139	0.0227	-0.8725	0.1407	P60/SEDM	✓
2018fzn	18abojpnr	SN IIb[c]	0.037	2458351.7068	0.0103	0.0102	-0.0103	0.1902	P60/SEDM	✗
2018dfi	18abffyqp	SN IIb[d]	0.031	2458307.2540	0.4320	0.4320	-0.4320	0.6180	P200/DBSP	✓
2018cxn	18abckutn	SN IIP[e]	0.040	2458289.8074	0.4189	0.0576	-0.0494	0.9406	P200/DBSP	✗
2018dfc	18abeajml	SN II[f]	0.037	2458303.7777	0.0118	0.0213	-0.9806	1.0153	P60/SEDM	✓
2018fif	18abokyfk	SN II[g]	0.017	2458350.9535	0.3743	-0.0635	-1.0525	1.0525	P200/DBSP	✓
2018gts	18abvvmdf	SN II[h]	0.030	2458375.1028	0.5551	-0.4688	-1.3648	1.5162	P60/SEDM	✓
2018cyg	18abdbysy	SN IIP[i]	0.011	2458294.7273	0.2034	0.0297	0.0147	1.6727	WHT/ACAM	?
2018cug	18abcptmt	SN II[j]	0.050	2458290.9160	0.0250	-0.0066	-0.0670	1.7960	P60/SEDM	✓
2018egh	18abgqvwv	SN IIP[k]	0.038	2458312.7454	0.4351	0.9846	0.0931	1.8236	WHT/ISIS	?

Rachel Bruch Ph.D project, SNe II selected to have:

- Tight constraints on explosion time
- Early spectrum
- A confirmation spectrum

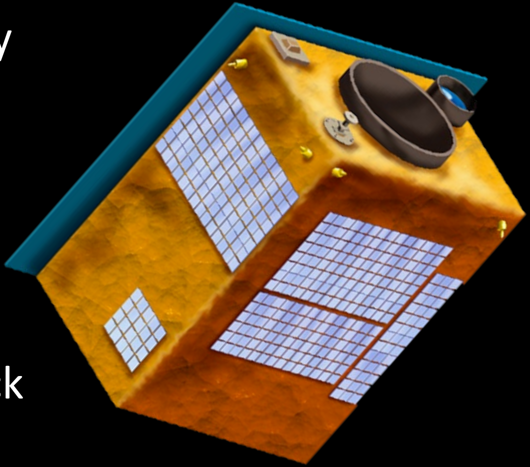
>50% of exploding massive stars are embedded in dense material

… and the distribution of material is often not spherical (M. Soumagnac)

Understanding the origin of the elements with ULTRASAT

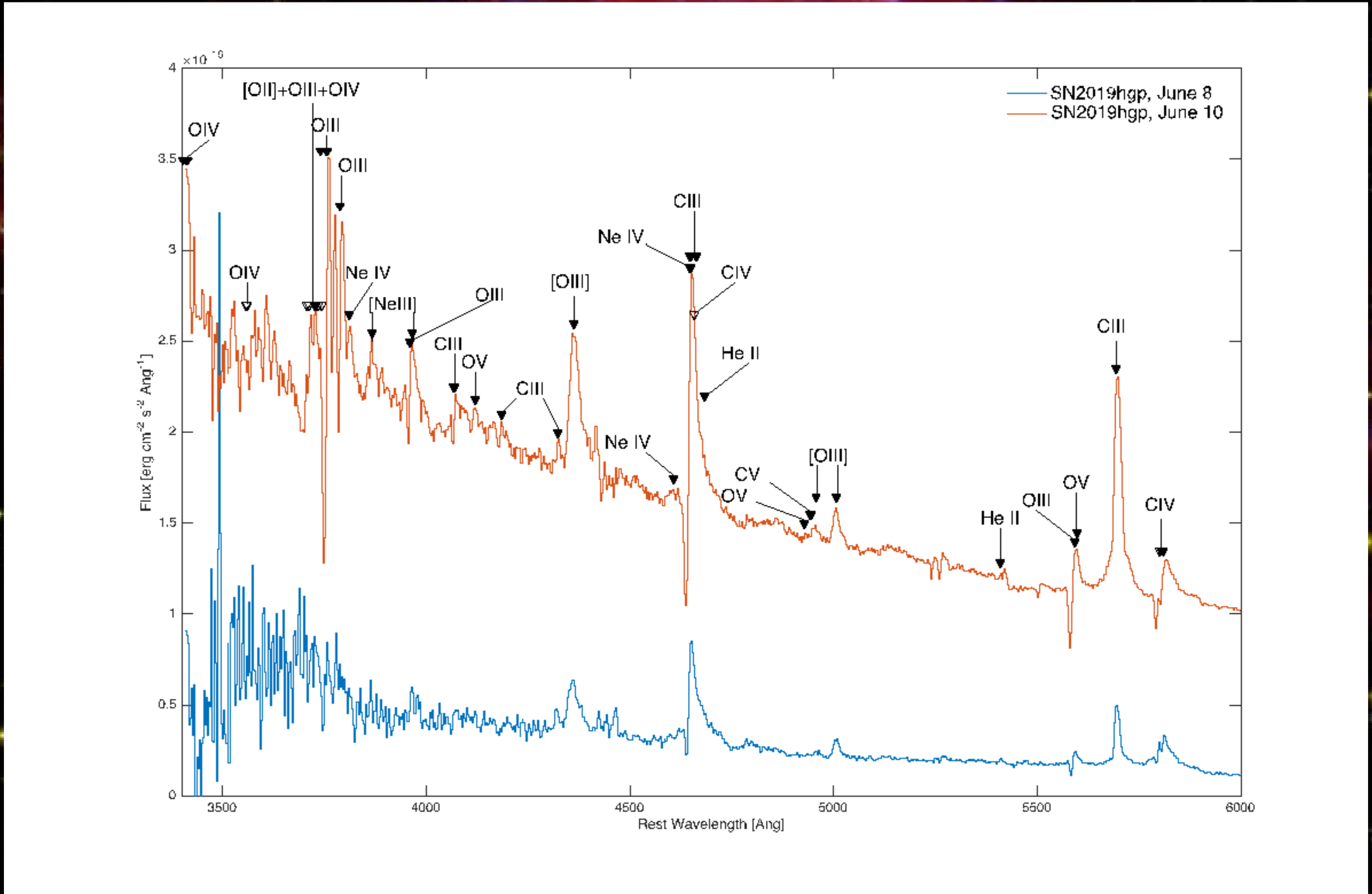
ULTRASAT will:

- Survey 200 degree^2 every 300s
- Find >100 SNe/y in the FoV
- Resolve shock breakout flares
- Robust measures of shock cooling (progenitor radii) for a large sample



PI: Waxman

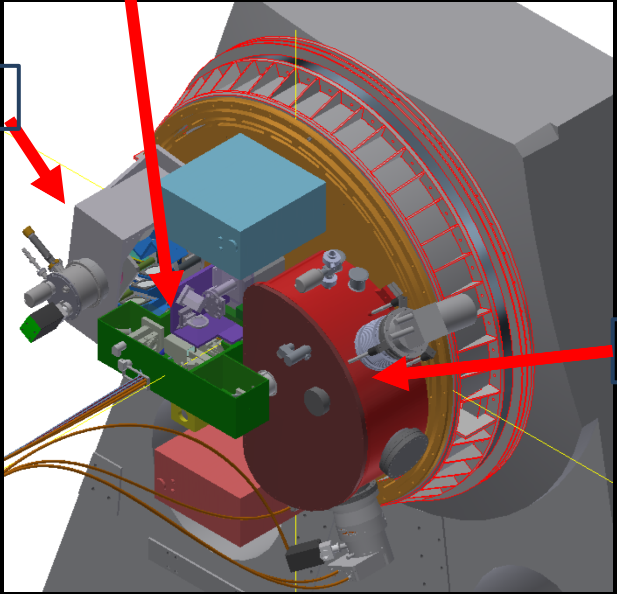
How do we see the elements?



SOXS

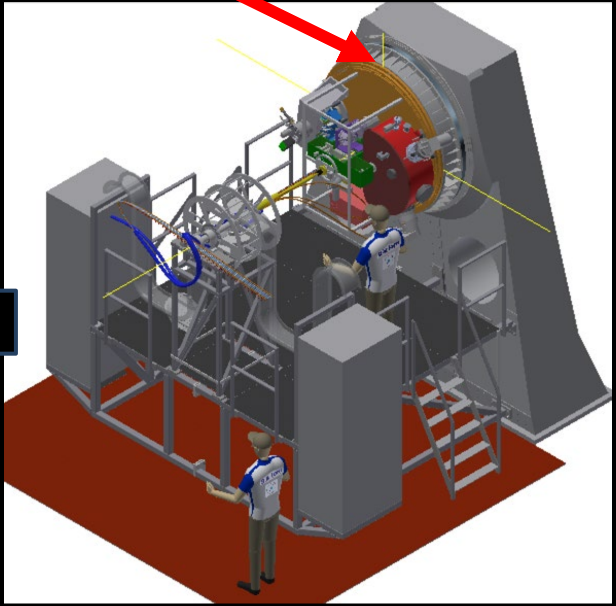
Common Path

VIS



NIR

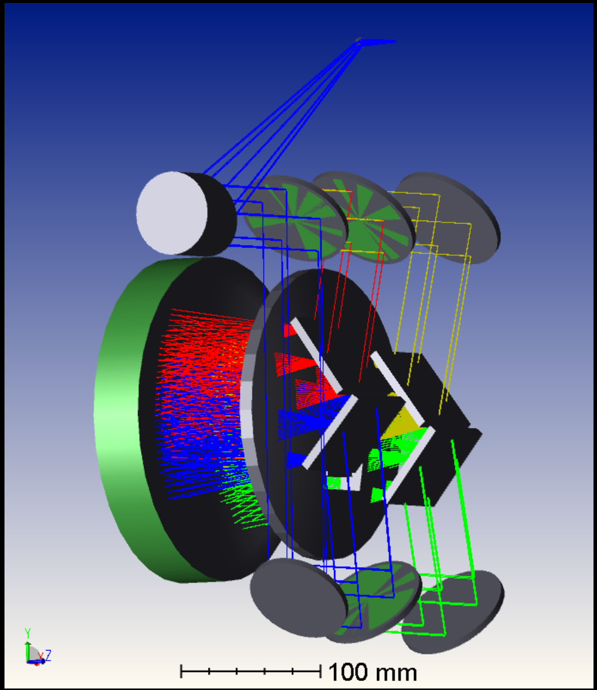
NTT nasmyth flange



INAF-led consortium: PI S. Campana; WIS-led visible arm (Ben-Ami, Rubin) - delivered

Design overview

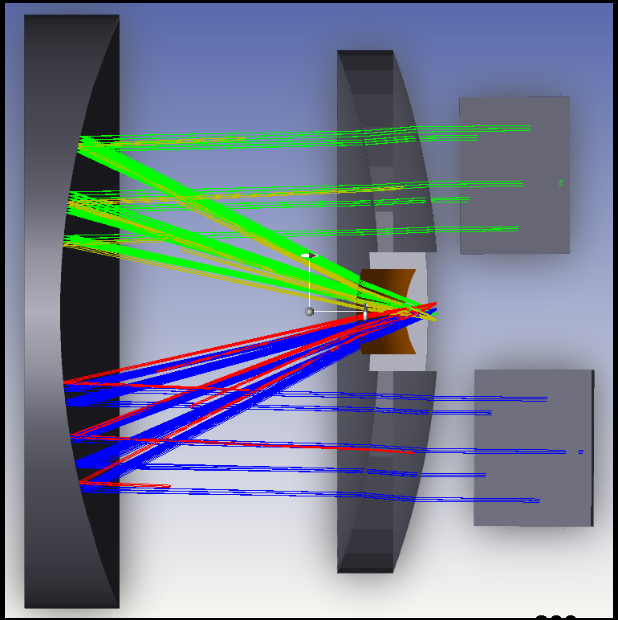
- A visible spectrograph
- Waveband: 350-850nm.
- Band is divided to four quasi-orders to optimize gratings performance.
- Ion-etched gratings from iof-Fraunhofer (>80% efficiency) used at order m=1

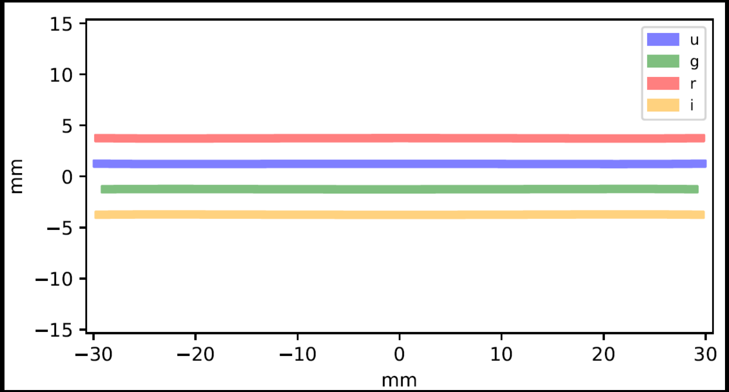


	u-band	*g*-band	*r*-band	*i*-band
Passband [nm]	350 - 439.5	427 - 545	522 - 680	656 - 850

Single Camera for four bands

- The four bands feed a single catadioptric camera composed of three (!) aspheric surfaces
- Use highly transmissive glasses: fused silica and CaF2
- Images onto single detector
- Inspired by the camera for VLT/MOONS





Thanks