Non-degenerate Eruptive Variables

TVS subgroup

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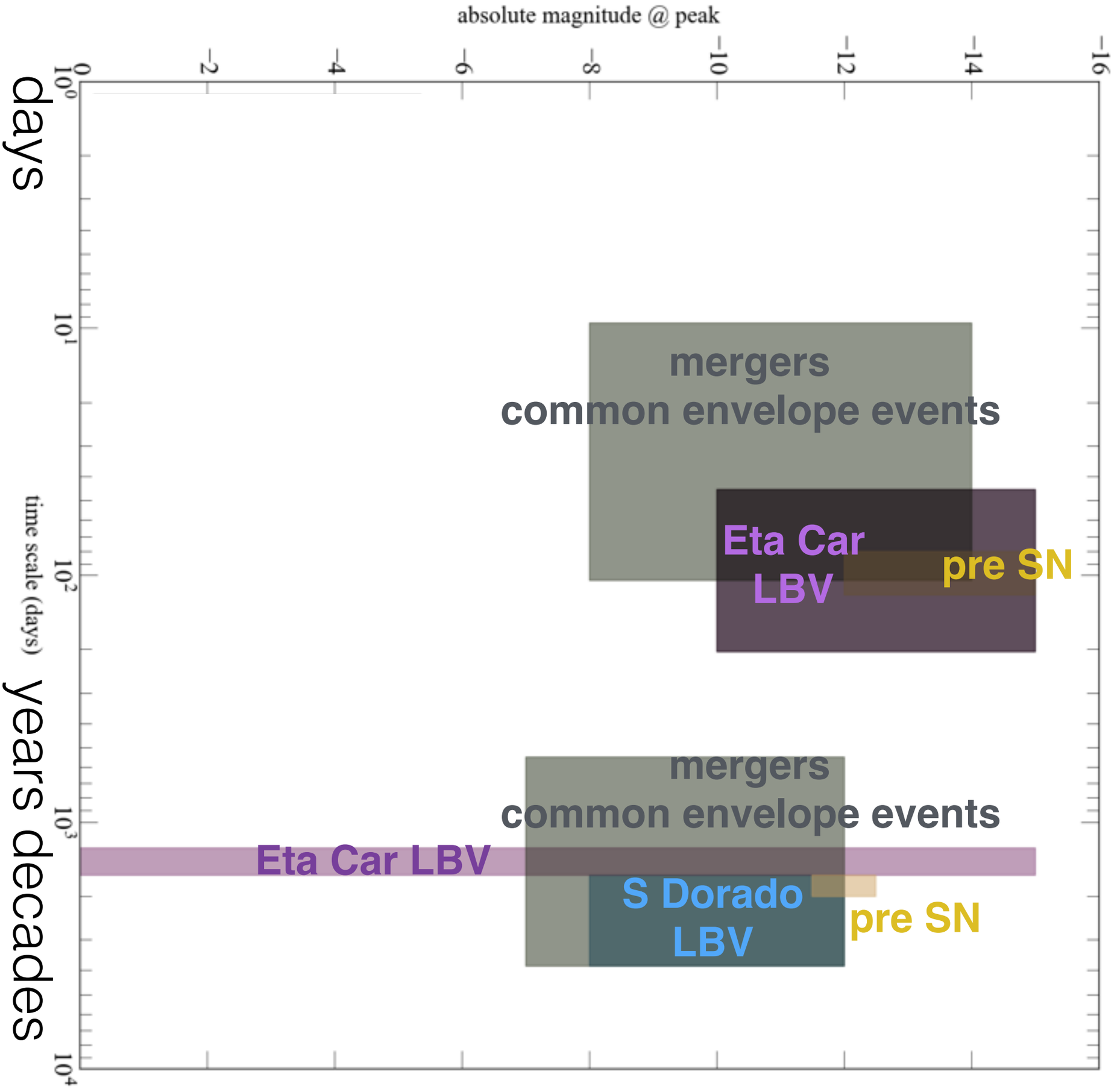
what are they?

MASSIVE STARS	LBVs - normal S Dor eruptions:	
	LBVs - giant eruptions like Eta Car	
	ILOTs	
	mergers and violent common envelope events	
	Chaotic eruptions	
T-Tauri STARS	Fu Ori variables	
	Ex Or variables	
SYMBIOTIC STARS	Symbiotic Stars (M+WD)	

massive stars

peak M	Duration	Cadence
LBVs - normal S Dor eruptions:		
-8 to -12 mag	5-10 yr	repeat irregularly 10-20yr
LBVs - giant eruptions like eta car:		
-10 to -15 mag,	100 days	repeat irregularly on timescales of
up to - 15 mag	10 yr	centuries to millennia (maybe??)
ILOTs (intermediate luminosity optical transients):		
-10 to -15 mag,	100 days	Like 1st LBV peak, no longer time scales
\mergers (?) and violent common envelope events (?):		
-8 to -14 mag,	10-100 days	no recurrence but
-7 to -12	2-10 yr	irregular peak variation, ***very red***
pre-SN eruptions:		
-12 to -15 mag,	100 days	time before SN is 10 days to 10 years
-12	5 yr	can be multiple and repeating, or not

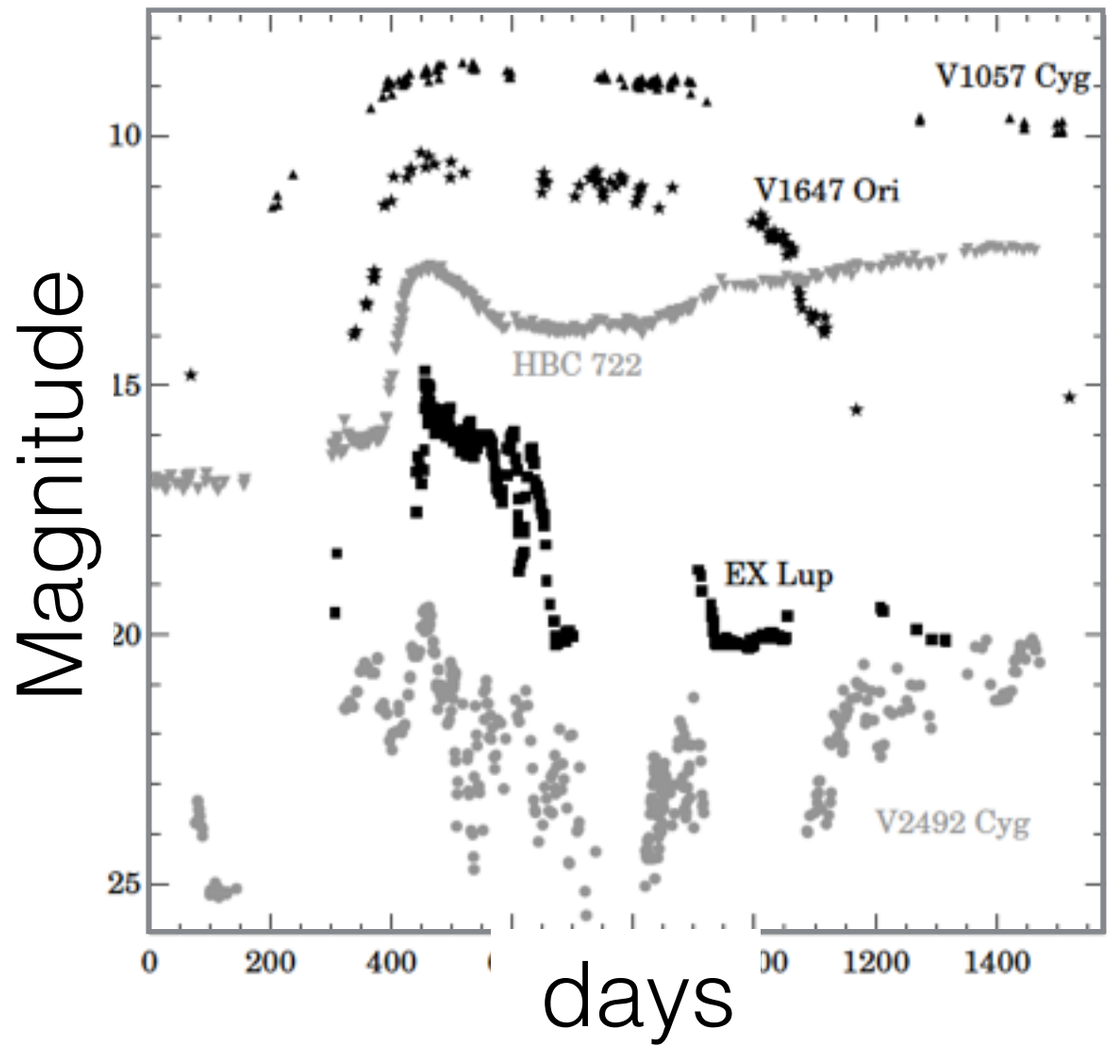
Magnitude


absolute magnitude @ peak
0
−2
−4
−6
−8
−10
−12
−14
−16
days
years decades
time scale (days)
10^0
10^1
10^2
10^3
10^4
mergers
common envelope events
Eta Car
LBV
pre SN
mergers
common envelope events
Eta Car LBV
S Dorado
LBV
pre SN

YSOs

Δ(M)	Rise Duration	Total Duration
	FuOri variables	
>5 mag	months	10 yr
	Ex Or variables	
<2 mag	weeks	months - years

RATE: only a few known



Magnitude

absolute magnitude @ peak

−16
−14
−12
−10
−8
−6
−4
−2
0

mergers
common envelope events

Eta Car
LBV

pre SN

mergers
common envelope events

S Dorado
LBV

pre SN

Eta Car LBV

T-Tauri

10^0 10^1 10^2 10^3 10^4

days

time scale (days)

years decades

Symbiotic Stars

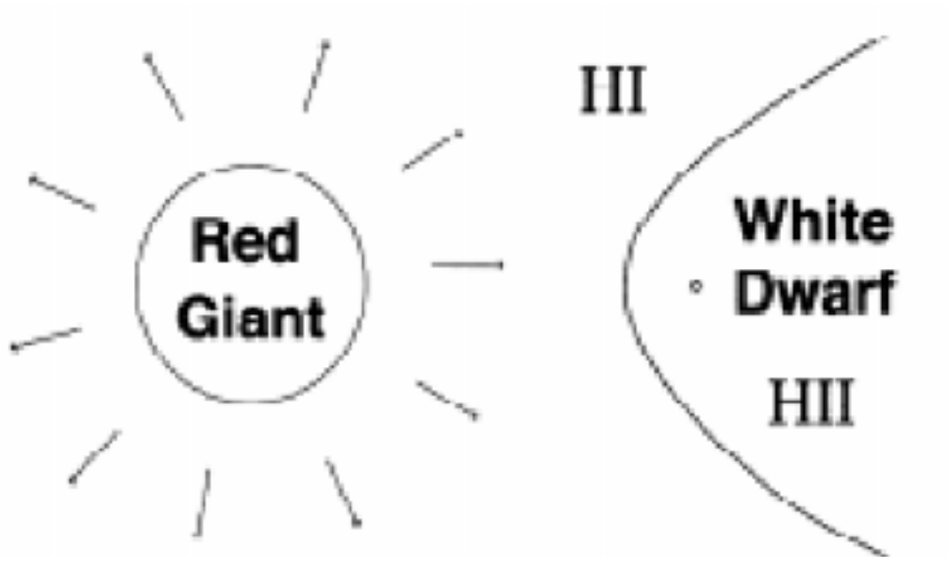
M (G,K) type + WD binary

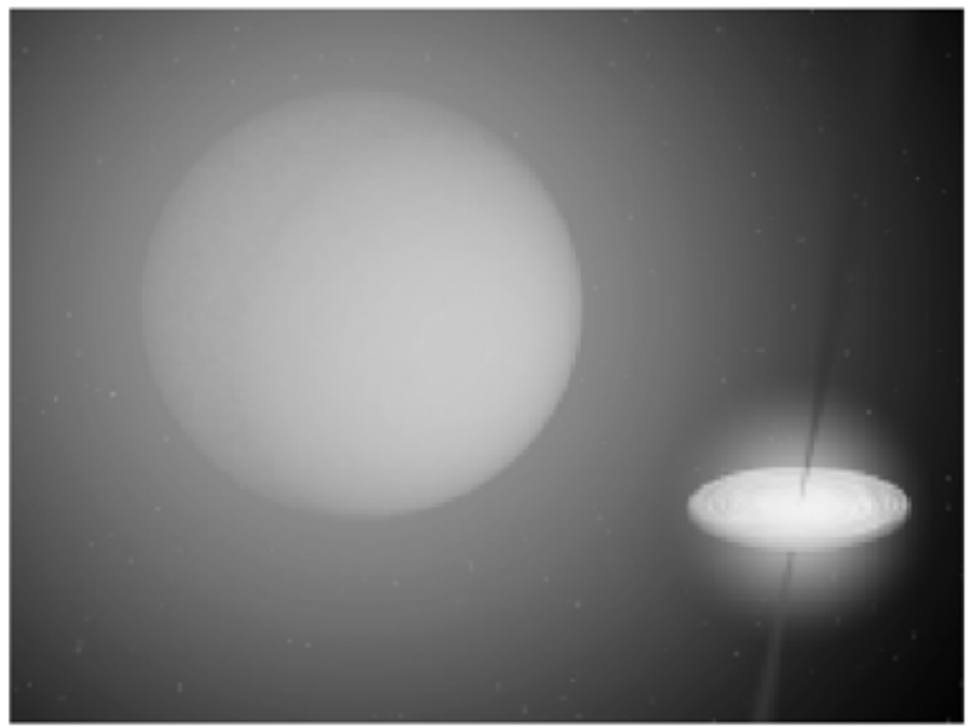
Δ(M)	Total Duration
>6 mag	months
1-5 mag	months

RATE: 330 known, 1/2outbursting
associated wit jets

1) reveal systems in outburst;
2) enable TOO observations (X-ray to radio)
3) determine the fraction of symbiotic stars that have outbursts;
4) determine basic outburst statistics
5) generally characterize symbiotic-star long-term optical variability

Sokoloski 03





Magnitude

absolute magnitude @ peak

−16
−14
−12
−10
−8
−6
−4
−2
0

mergers
common envelope events

Eta Car
LBV

pre SN

mergers
common envelope events

S Dorado
LBV

pre SN

SS

Eta Car LBV

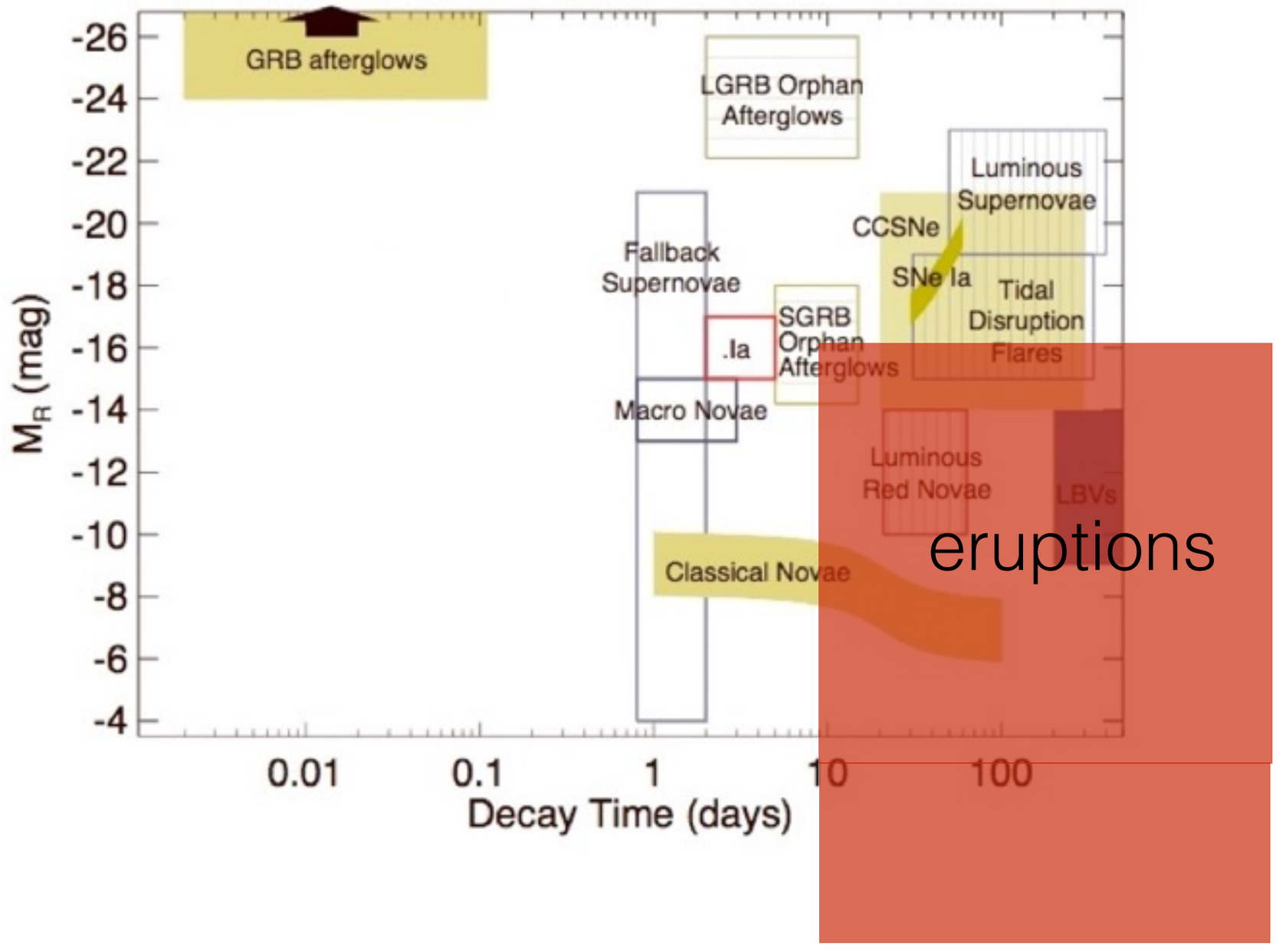
T-Tauri

10^0 10^1 10^2 10^3 10^4

days

time scale (days)

years decades


GRB afterglows
LGRB Orphan Afterglows
Luminous Supernovae
CCSNe
Fallback Supernovae
SNe Ia
Tidal Disruption Flares
SGRB Orphan Afterglows
.Ia
Macro Novae
Luminous Red Novae
LBVs
Classical Novae
eruptions
-26
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
M_R (mag)
0.01
0.1
1
10
100
Decay Time (days)

foundamental questions

- Understanding late stages of Massive star evolution
- Connection between eruptions and CCSN explosions
- Do all T Tauri stars undergo FU Ori and Exor outburst during their formation?
- Understanding Accretion: duty cycles of outbursts of different accretion rates
- Fraction of final stellar mass accreted during T-Tauri eruptive events

also though more specultive:

- Detections of Chaotic Eruptions (Arnett+Meakin 11)
- Discovery of Extrasolar KBs after ILOTs (Bear+Soker 16)

timeline to answer with LSST

- **Connection to SN explosions:**
  detection of pre-SN eruptions
  so far a few in PS1, PanSTARRs
  wait for SN then look for precursor on time
  scales days-decades before SN. Also SS for Ia

SHOULD BE DOABLE WITH ~1YEAR OF DATA

NEARLY ANY PROPOSED CADENCE WOULD DO SINCE ERUPTIONS LAST ~DAYS AT LEAST

timeline to answer with LSST

- **Understanding late stages of Massive star evolution:** color is a strong discriminant for ejection mechanism (winds vs hydrostatic events…)
  sampling at the cadence of ~week is generally sufficient as the duration is long
  inference is limited by the slow evolution of the transients

~1 YEAR should collect+characterize ~100 eruptions

(based on the expected SN detections compared to current surveys, without accounting for a presumibly different luminosity function though. anyone did anything better yet??)

timeline to answer with LSST

- **Evolutionary sequence:**

  looking at association of star types O, LBV, WR in (relatively) high resolution images

  SHOULD BE DOABLE WITH THE FIRST STATIC SKY RELEASE (6 month, independent of cadence)

timeline to answer with LSST

- T - Tauri questions:

  FU Ori and EXor extremely rare: (~dozens sources known in the entire sky - Audard+ 2014). LSST will allow probing

  1) systems deeply embedded in their molecular clouds and envelopes and
  2) regions far beyond nearby molecular clouds.

Nearly any proposed cadence will do.
Longer wavelengths are preferred.
RARITY IS THE BOTTLE NECK BUT RESULTS NEW DISCOVERIES SHOULD HAPPEN QUICKLY AND RESULTS START WITH THE FIRST ~6 MONTH DATA

other questions and goals??

WHAT HAVE I MISSED??

observing requirements

regular sampling, colors.

the time scales are long and the differences are in the recurrence rate, color, lightcurve shape (rise time) but the relevant time scales are always >days: each event can be well characterize by sampling every few days in a few bands.

observationally these events don't have strict requirements: most proposed cadences should work.