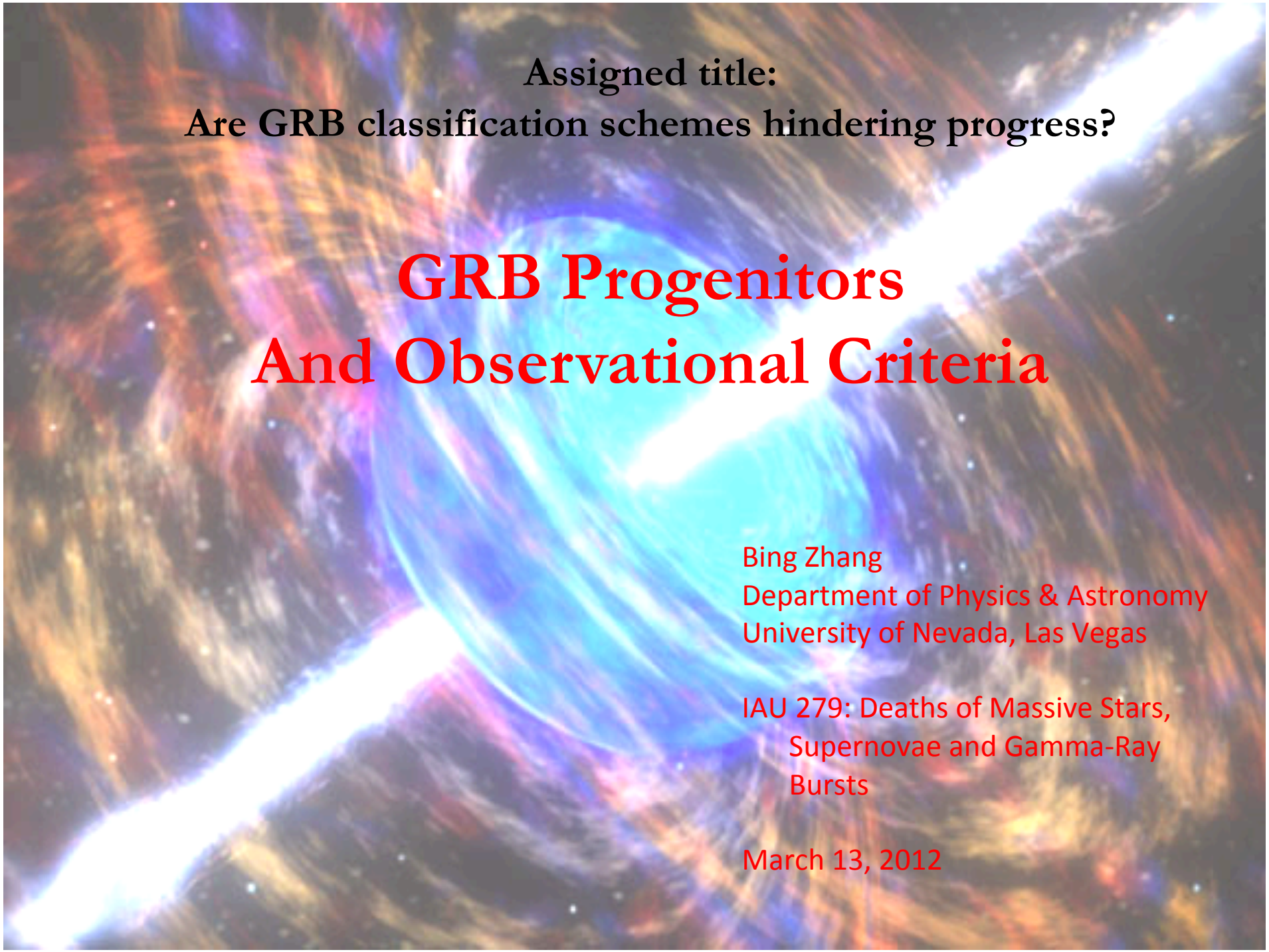


Assigned title:
Are GRB classification schemes hindering progress?

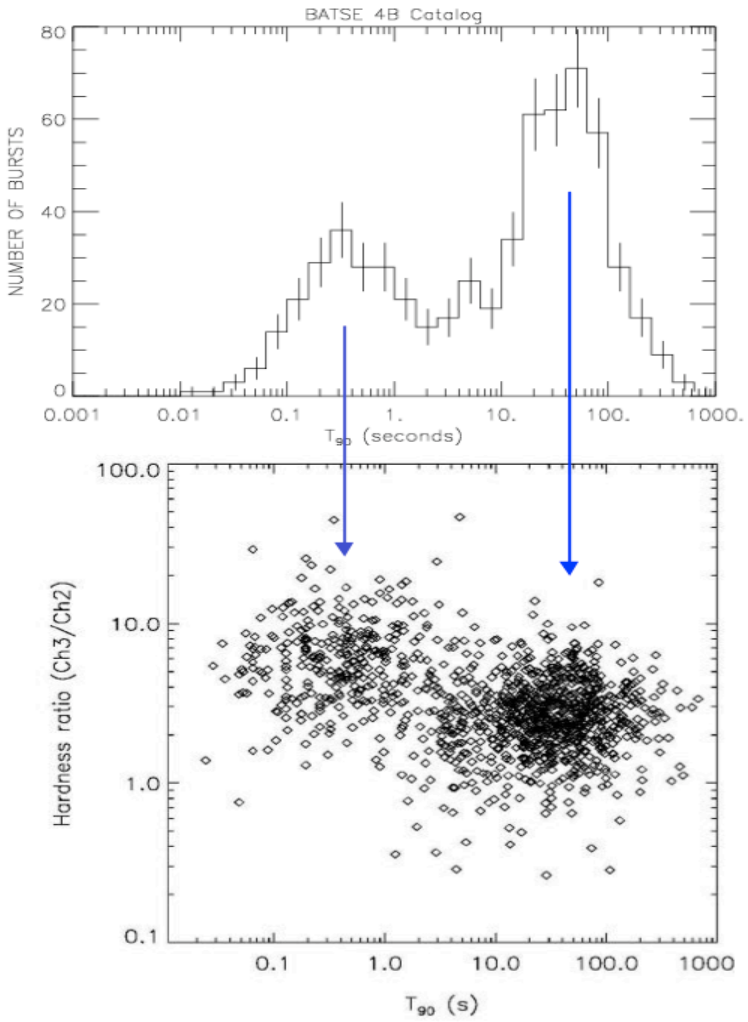
GRB Progenitors And Observational Criteria

Bing Zhang
Department of Physics & Astronomy
University of Nevada, Las Vegas

IAU 279: Deaths of Massive Stars, Supernovae and Gamma-Ray Bursts

March 13, 2012

Two Phenomenological Populations: Long/Soft vs. Short/Hard

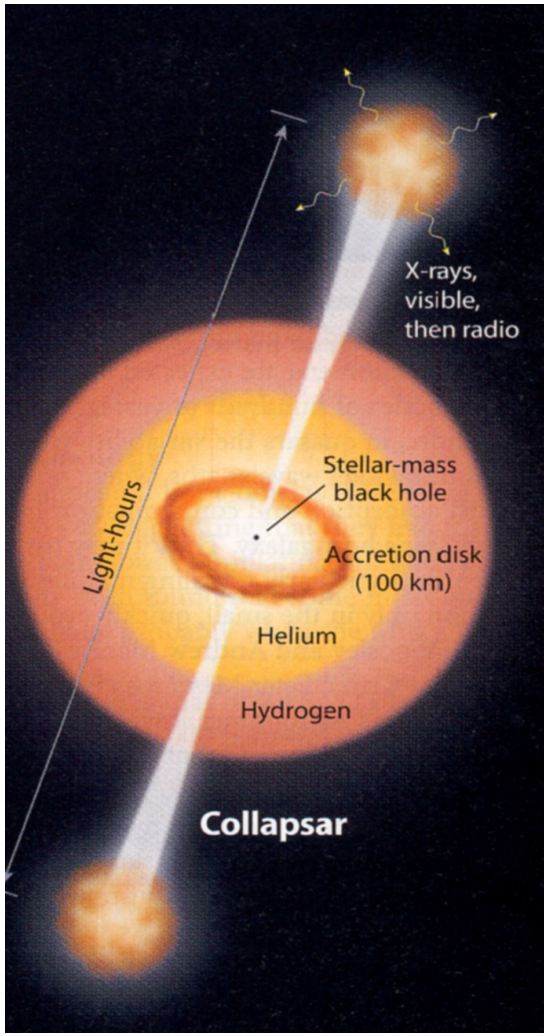


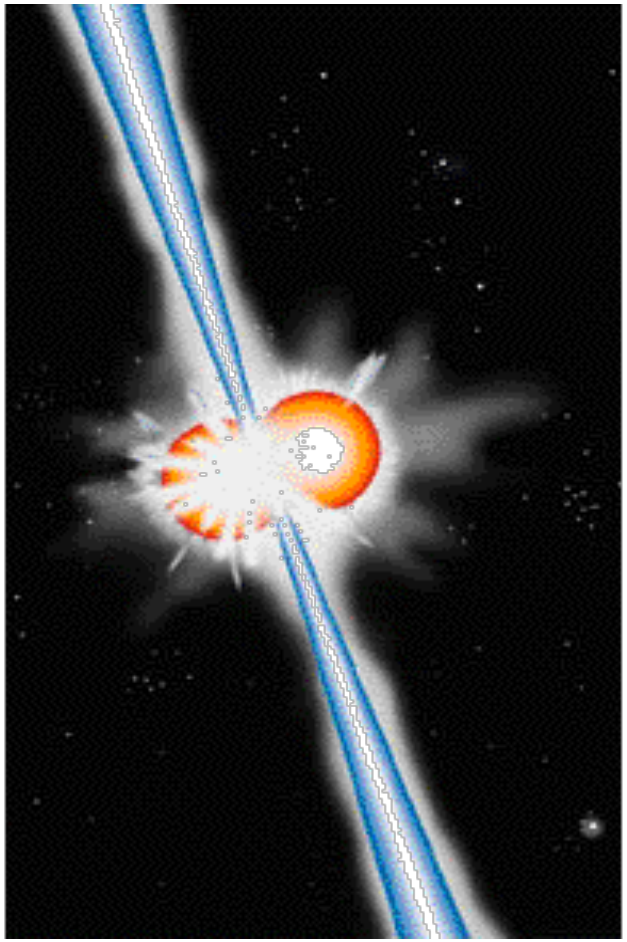
BATSE catalog

Long:
Observed $T_{90} > 2s$ in BATSE band

Short:
Observed $T_{90} < 2s$ in BATES band

Two Types of Progenitors:
Massive stars vs. Compact Stars





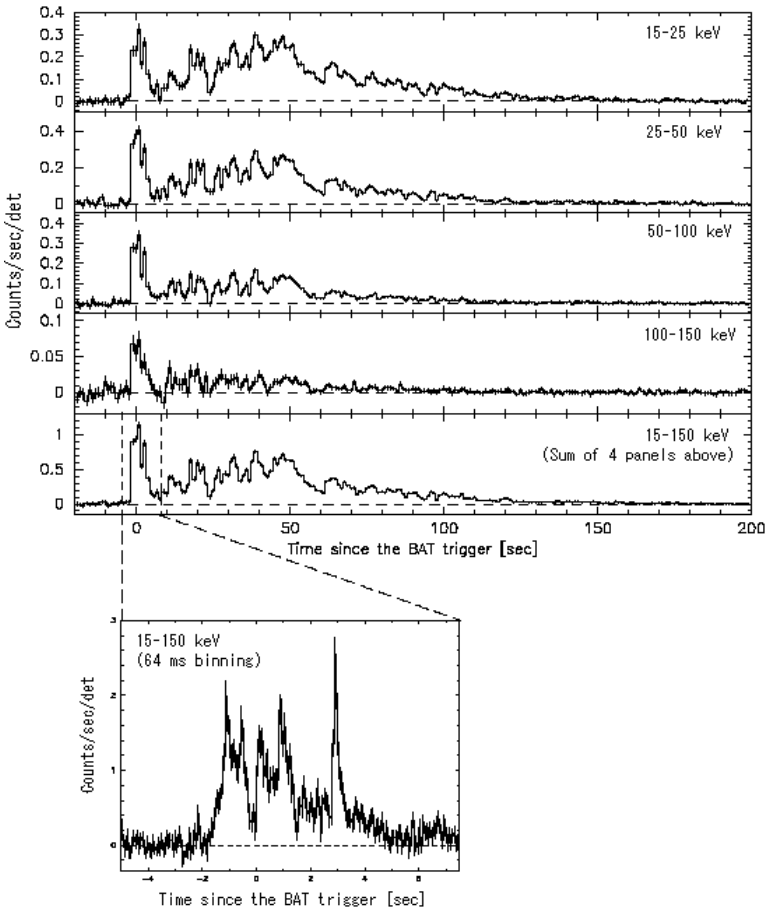
An elegant picture:

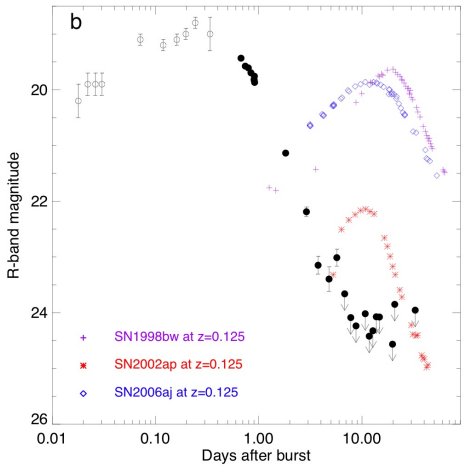
Long GRBs = massive star GRBs (Type II)

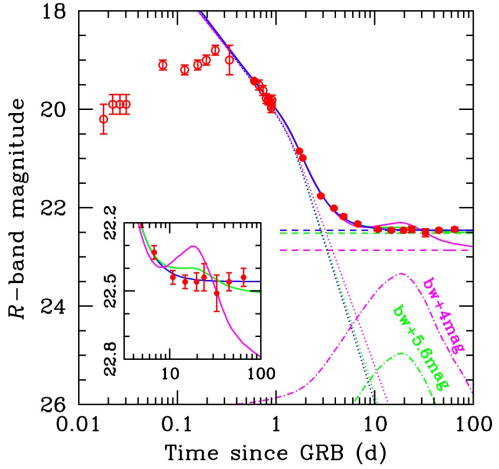
Short GRBs = compact star GRBs (Type I)

But is it that simple?

Odd ball: GRB 060614
A nearby long GRB without SN







Gehrels et al. 2006
Fynbo et al. 2006
Della Valle et al. 2006
Gal-Yam et al. 2006

Zhang et al. 2007

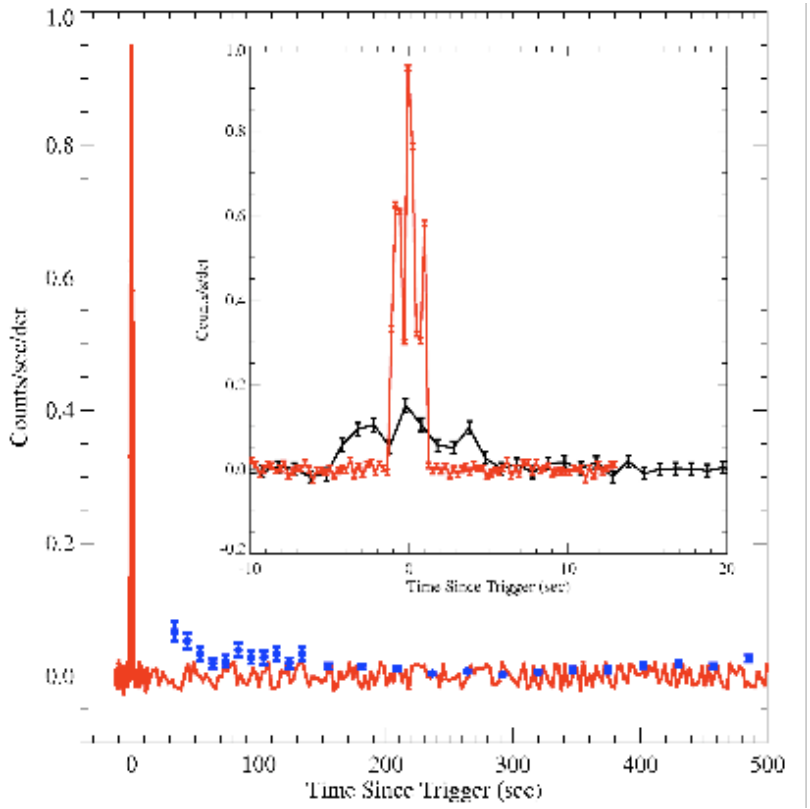
Some long GRBs may be from compact star (Type I) GRBs

Three highest-z GRBs:

GRBs 080913 @ z=6.7, 090423 @ z=8.2, 090429B @ z=9.4

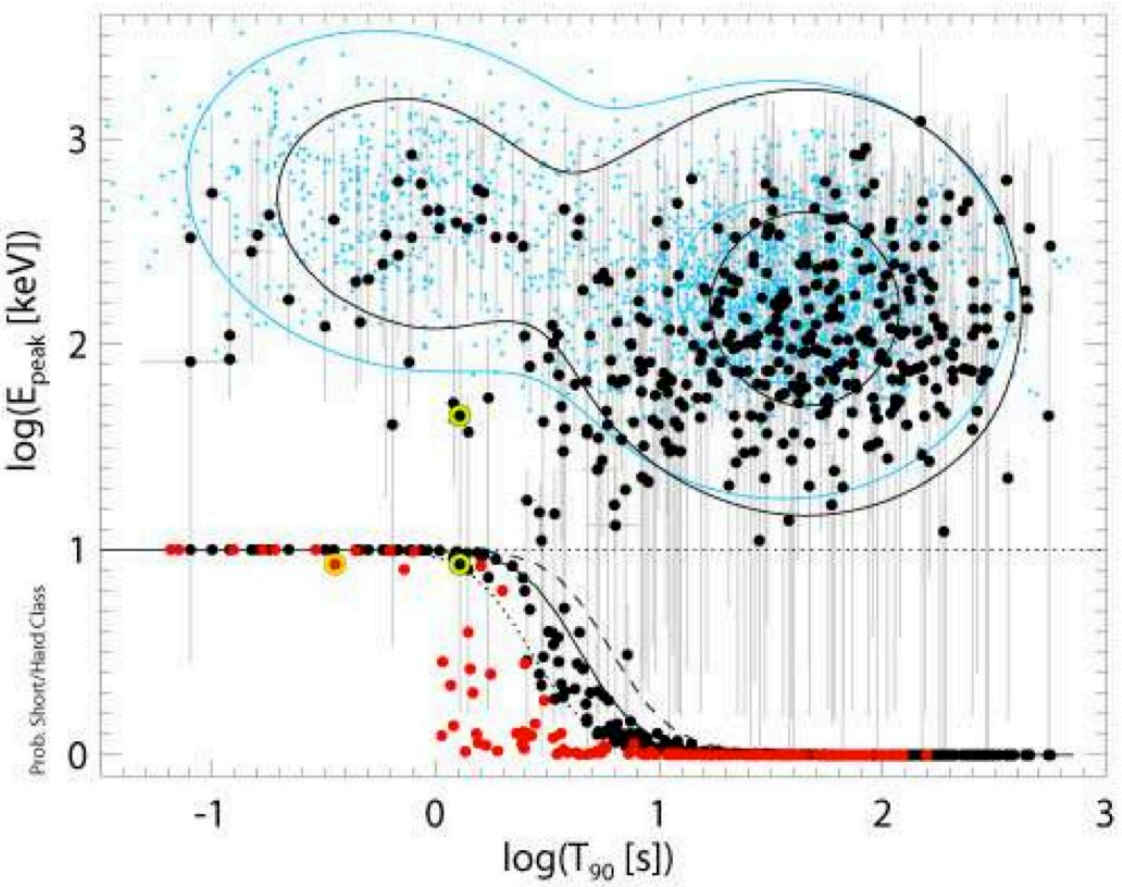
are rest-frame “short” GRBs but are massive star GRBs

Greiner et al. 2009
Tanvir et al. 2009
Salvaterra et al. 2009
Cucchiara et al. 2011



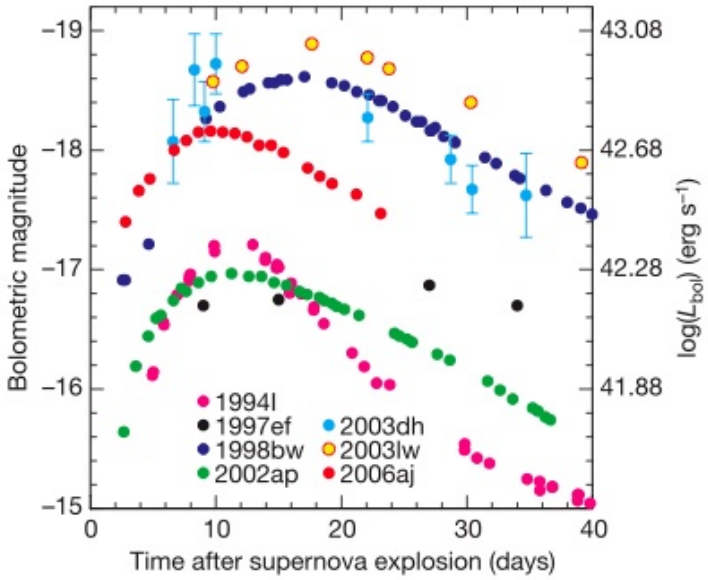
Zhang et al. 2009

Odd ball: GRB 090426
A short GRB likely of a massive star origin



Levesque et al. 2010
Antonelli et al. 2009
Thone et al. 2011
Xin et al. 2011

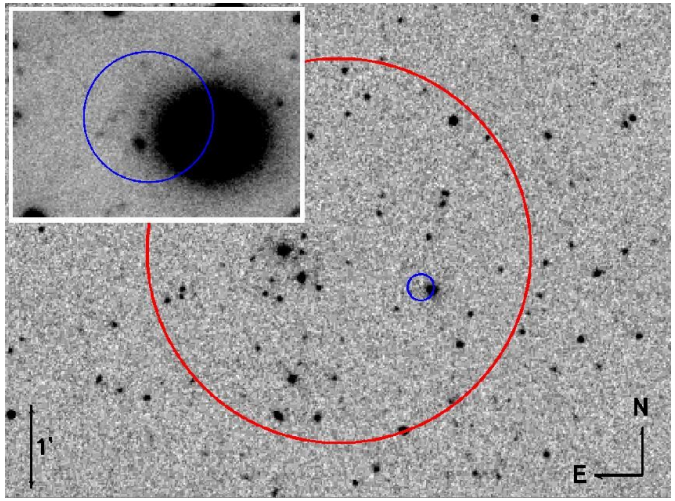
Why long GRBs = massive star GRBs?

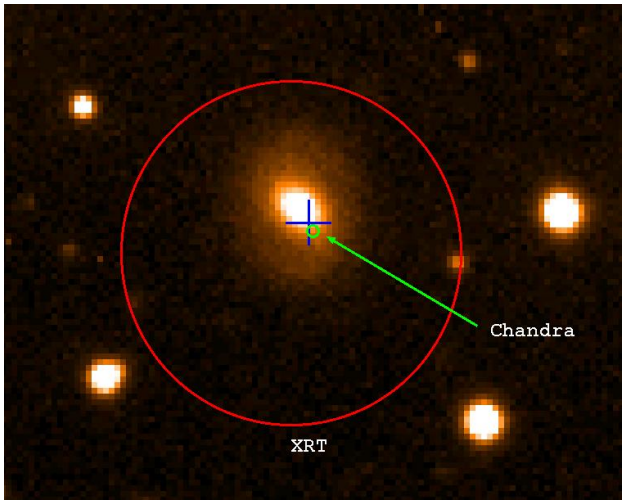


Pian et al. (2006)

- A handful case of secure GRB/SN associations (optical spectroscopic features of SNe emerging in otherwise fading GRB optical afterglows)
- Many more cases of SN red bumps in lightcurves
- Long GRB host galaxies are star-forming galaxies. Most are irregular galaxies (only three are spiral galaxies)
- Bursts located in active star forming regions inside the star forming galaxies.
- Free-fall time of a star is "long"

Why short GRBs= compact star GRBs?

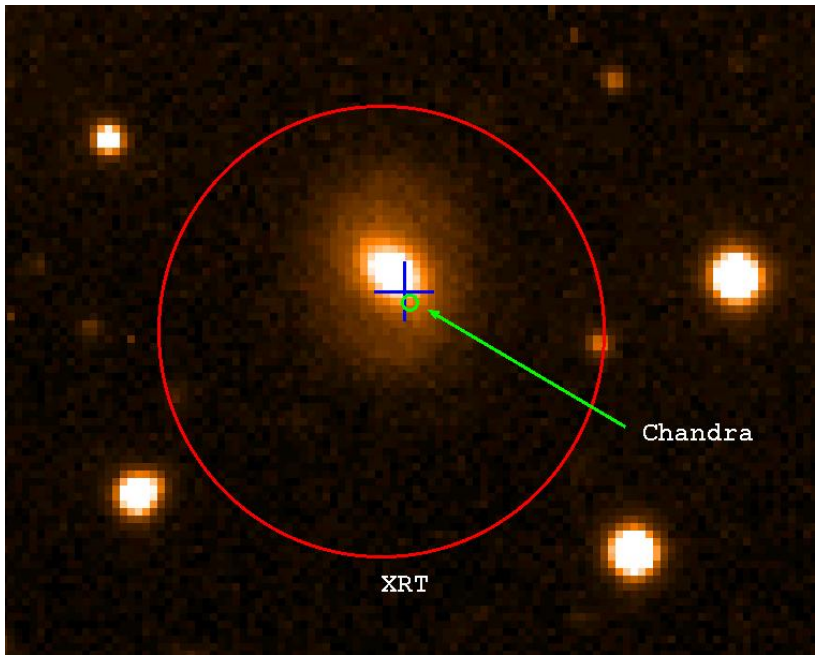


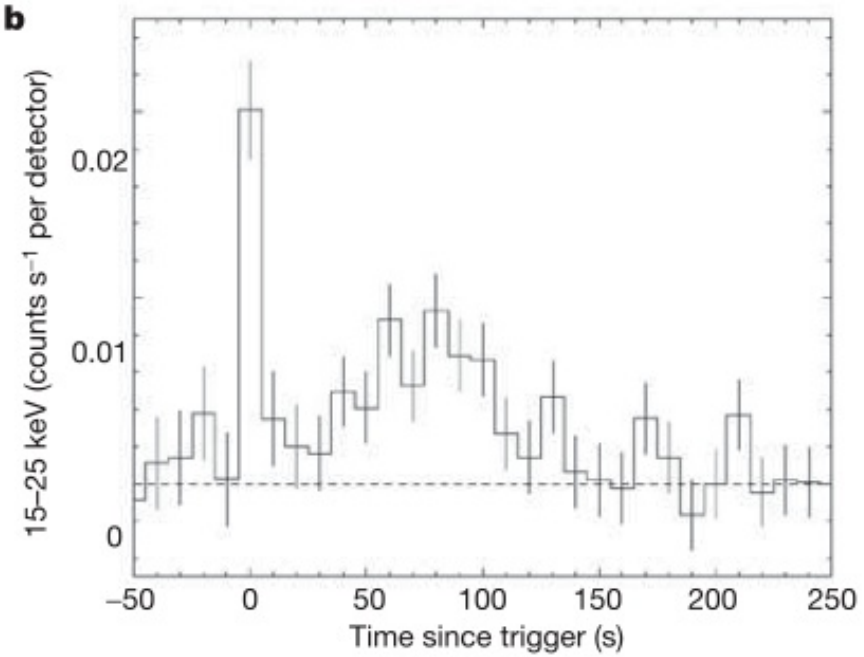


- Nearly 20 with afterglow detections. No SN signature.
- In different types of host galaxies, including elliptical and other early-type galaxies, and star-forming galaxies (2/3 and 3(4)/many more)
- Typically at outskirts of the host galaxies
- In regions of low star formation in star-forming galaxies
- Free fall time of a compact star is "short"

Gehrels, Fox, Berger, Barthelmy, Hjorth …

The smoking-gun compact star GRB: GRB 050724 is not short!





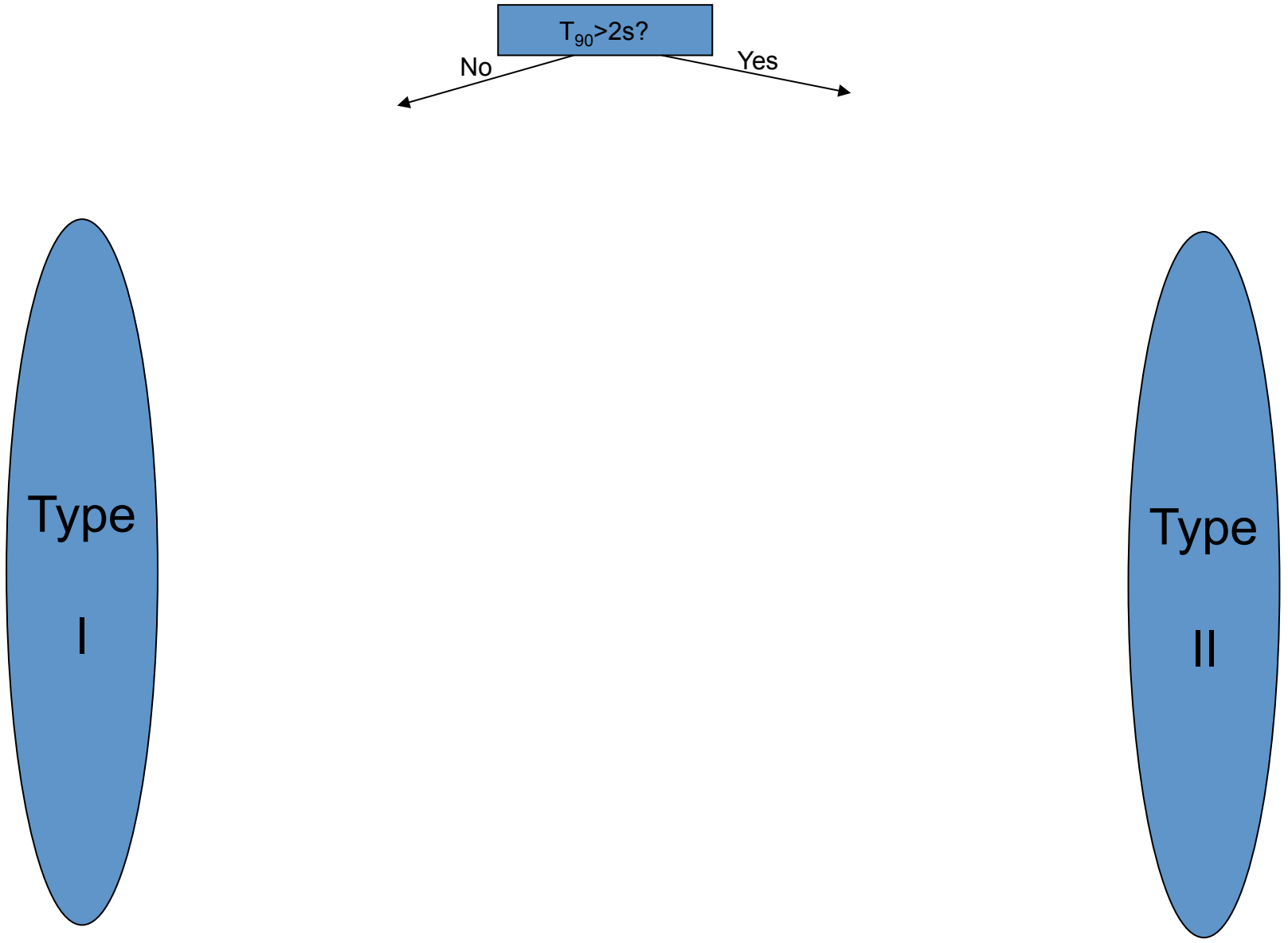
Barthelmy et al. (2005)

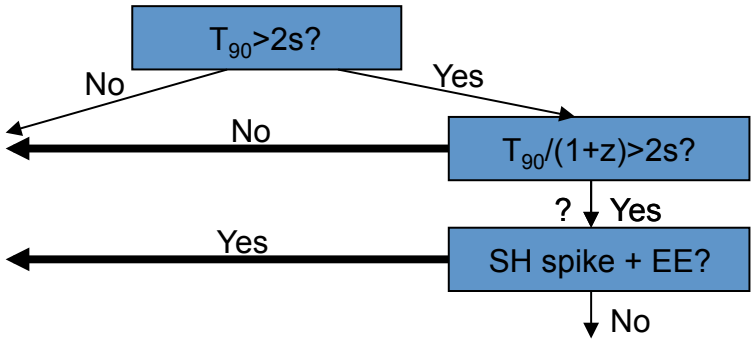
How to tell the physical category from the observations?

Multiple observational criteria needed!

TABLE 2
OBSERVATIONAL CRITERIA FOR PHYSICALLY CLASSIFYING GRBS.

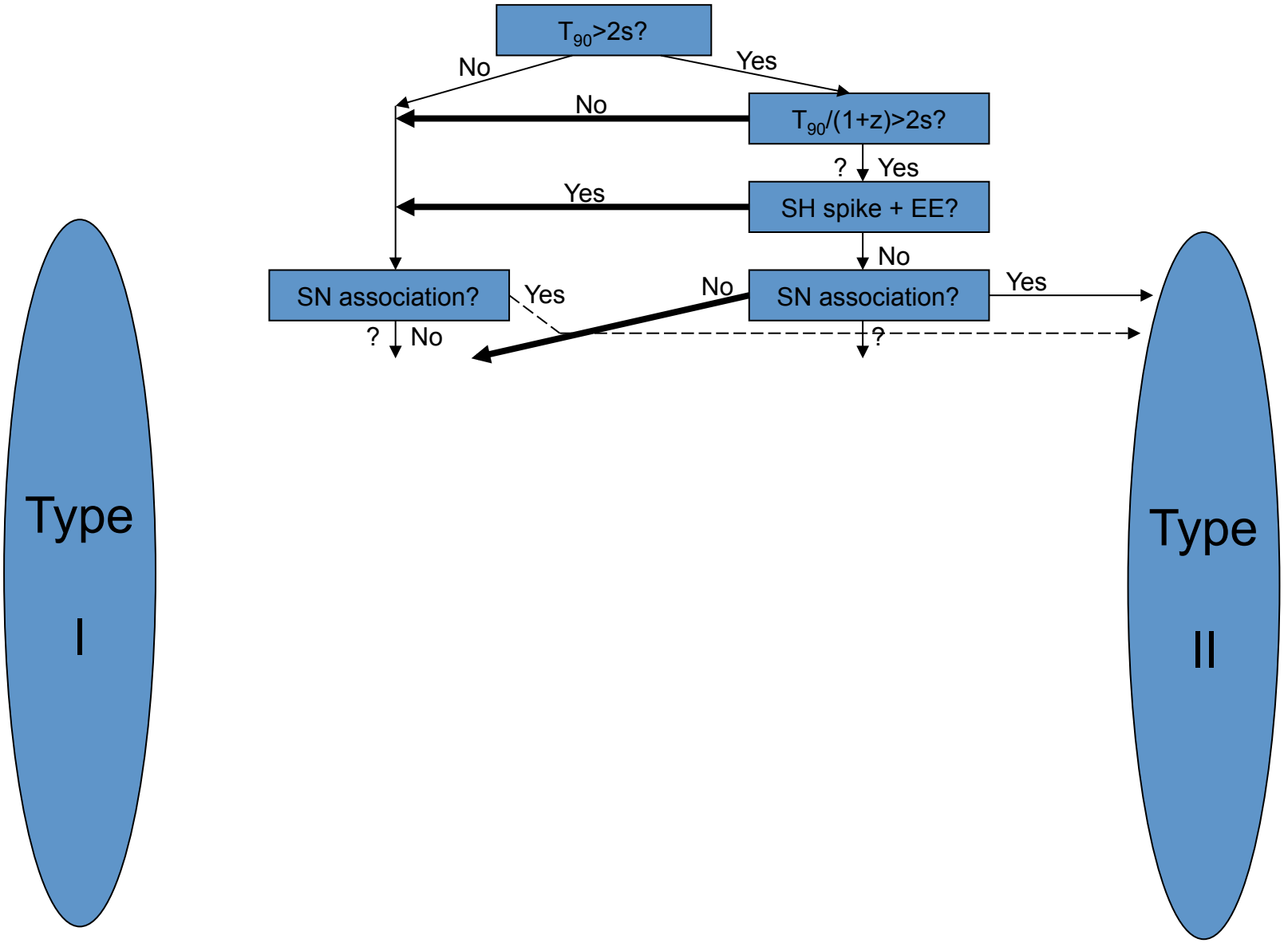
Criterion	Type I	Type II	Issues
Duration	Usually short, but can have extended emission.	Long without short/hard spike, can be shorter than 1s in rest frame.	No clear separation line.
Spectrum	Usually hard (soft tail)	Usually soft	Large dispersion
Spectral Lag	Usually short	Usually long, can be short.	Related to variability time scale
$E_{\gamma,iso}$	Low (on average)	High (on average)	Wide dstribution in both
$E_p - E_{\gamma,iso}$	Usually off the track.	Usually on the track.	Some Type II off the track.
$L^p_{\gamma,iso}$–lag	Usually off the track.	Usually on the track.	Some Type II off the track.
SN association	No.	**Yes.**	Some Type II may have no association.
Medium type	Low-n ISM.	**Wind** or High-n ISM.	Large scatter of n distribution.
$E_{K,iso}$	Low (on average)	High (on average)	Large dispersion
Jet angle	Wide (on average)	Narrow (on average)	Difficult to identify jet breaks
E_γ and E_K	Low (on average)	High (on average)	Type I BZ model $\sim$ Type II.
Host galaxy type	**Elliptical, early** and late	Late	Deep spectroscopy needed.
SSFR	**Low** or high	High (exception GRB 070125)	
Offset	Outskirt or outside	Well inside	How to claim association if outside?
z-distribution	Low average z	High average z	
L-function	?	Broken power law, 2-component	

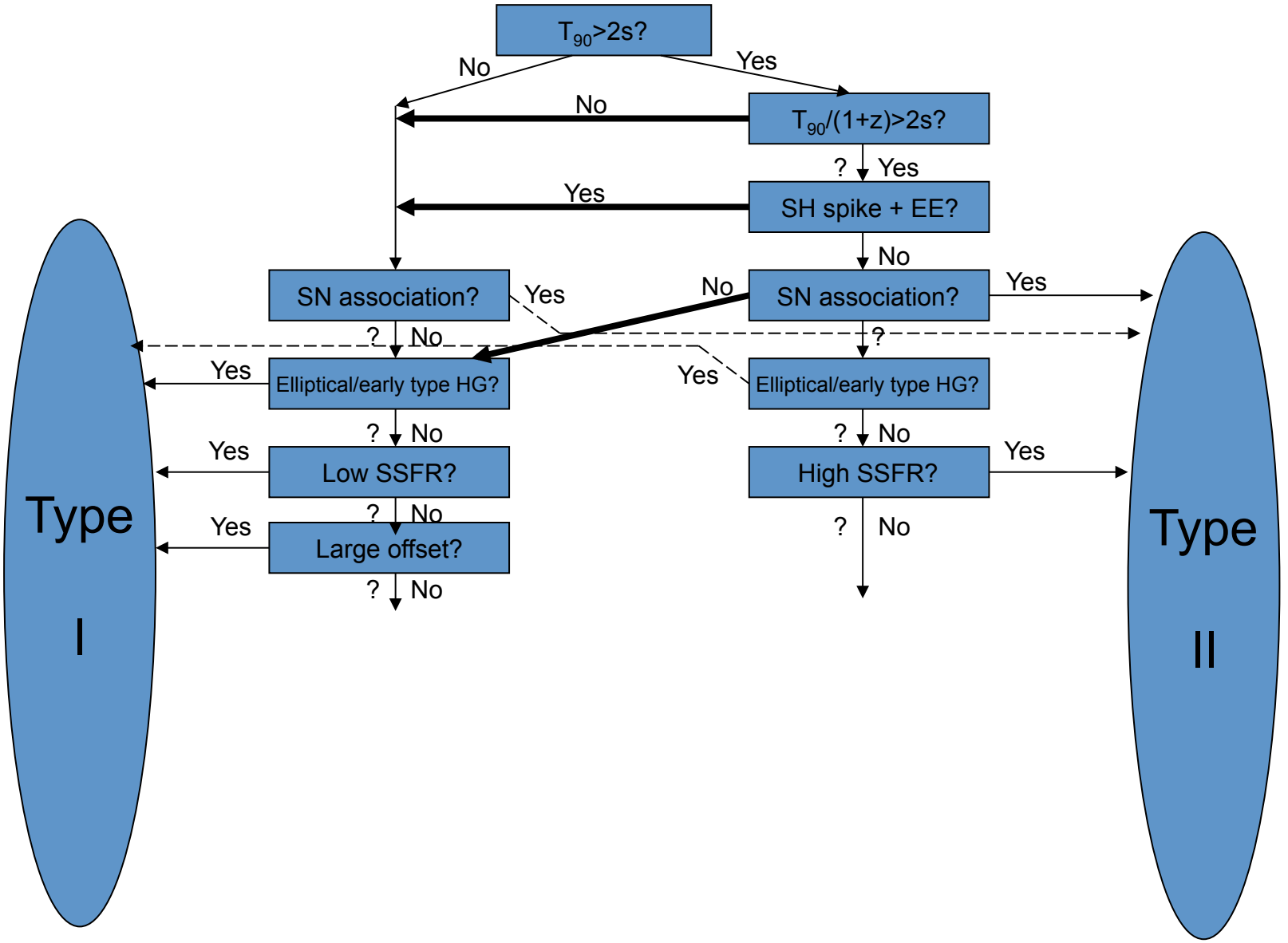

T_{90}>2s?
No
Yes
Type
I
Type
II

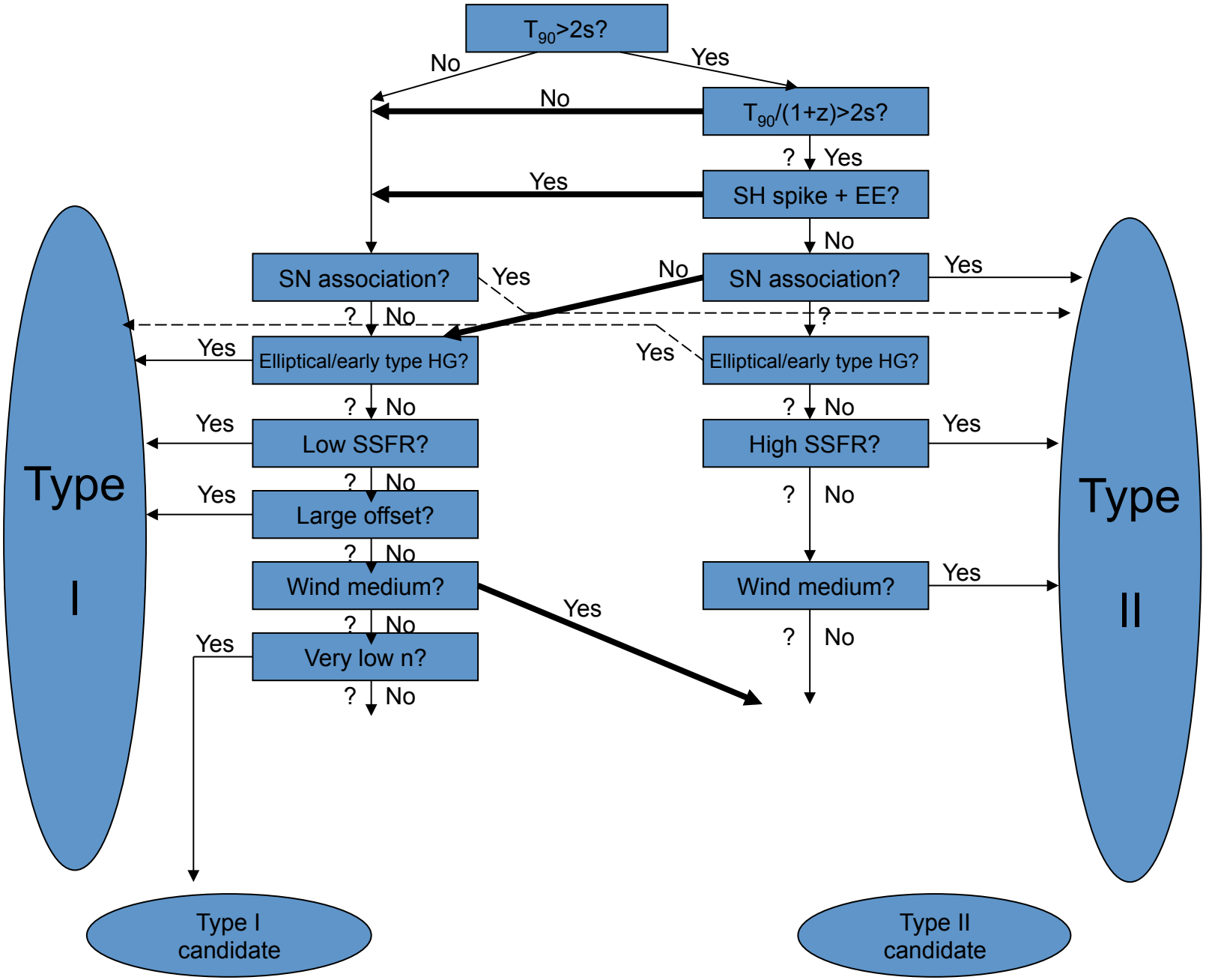


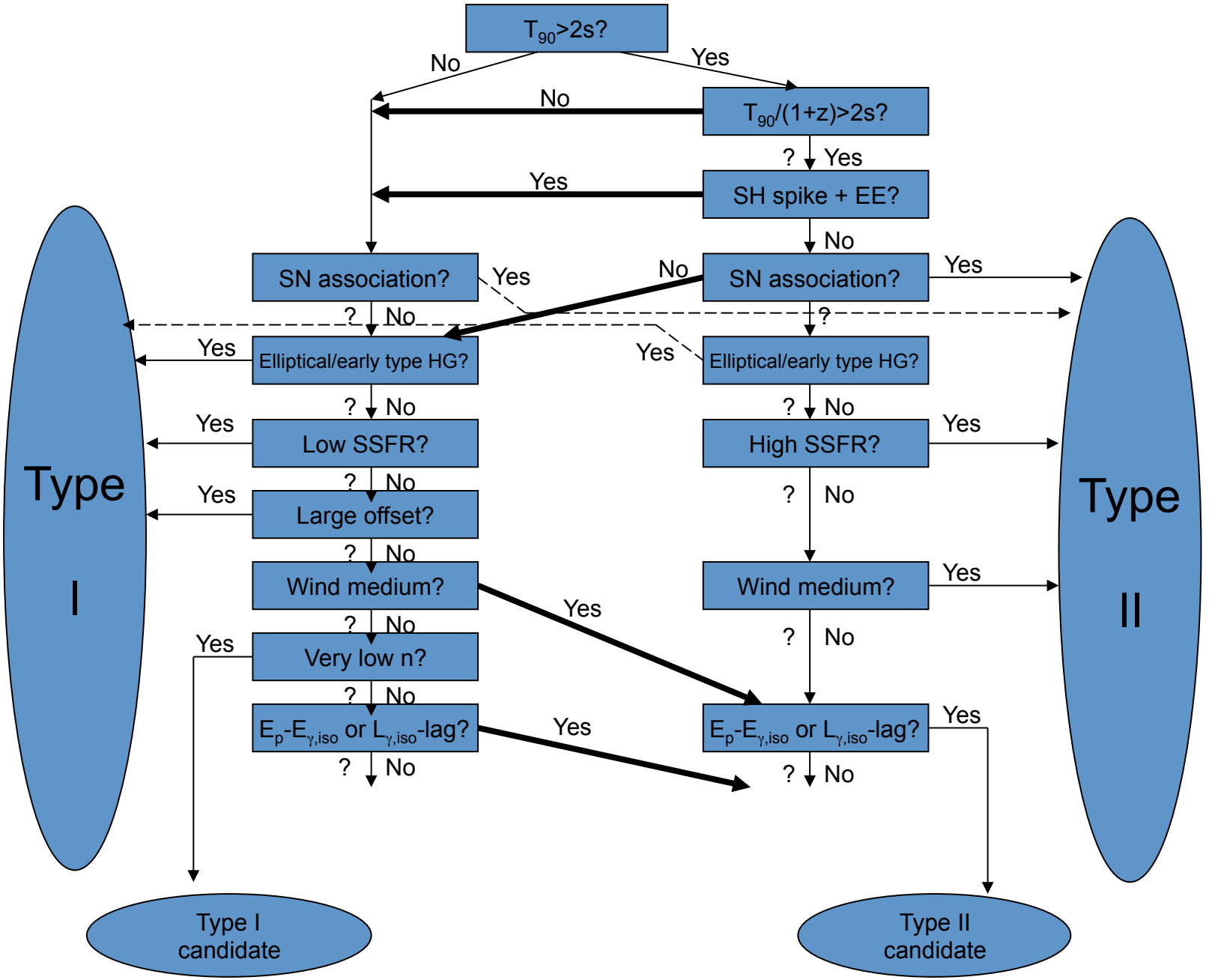
Type I

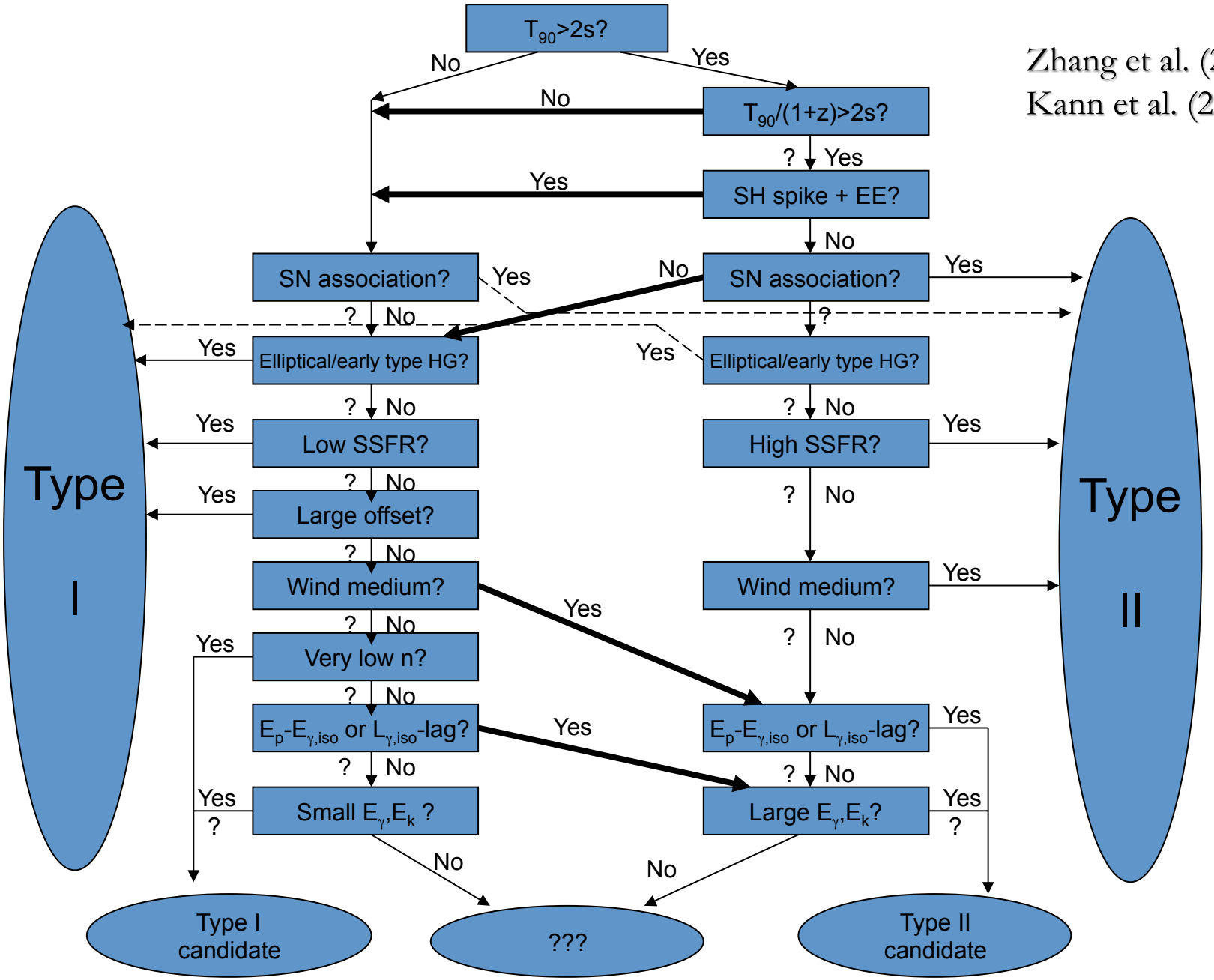
Type II


T_{90}>2s?
No
Yes
No
T_{90}/(1+z)>2s?
? Yes
Yes
SH spike + EE?
No
SN association?
Yes
No
SN association?
Yes
? No
?
Type I
Type II


T90>2s?
No
Yes
No
T90/(1+z)>2s?
? Yes
Yes
SH spike + EE?
No
SN association?
Yes
No
SN association?
Yes
? No
?
Yes
Elliptical/early type HG?
Yes
Elliptical/early type HG?
? No
? No
Yes
Low SSFR?
High SSFR?
Yes
? No
? No
Yes
Large offset?
? No
Type I
Type II

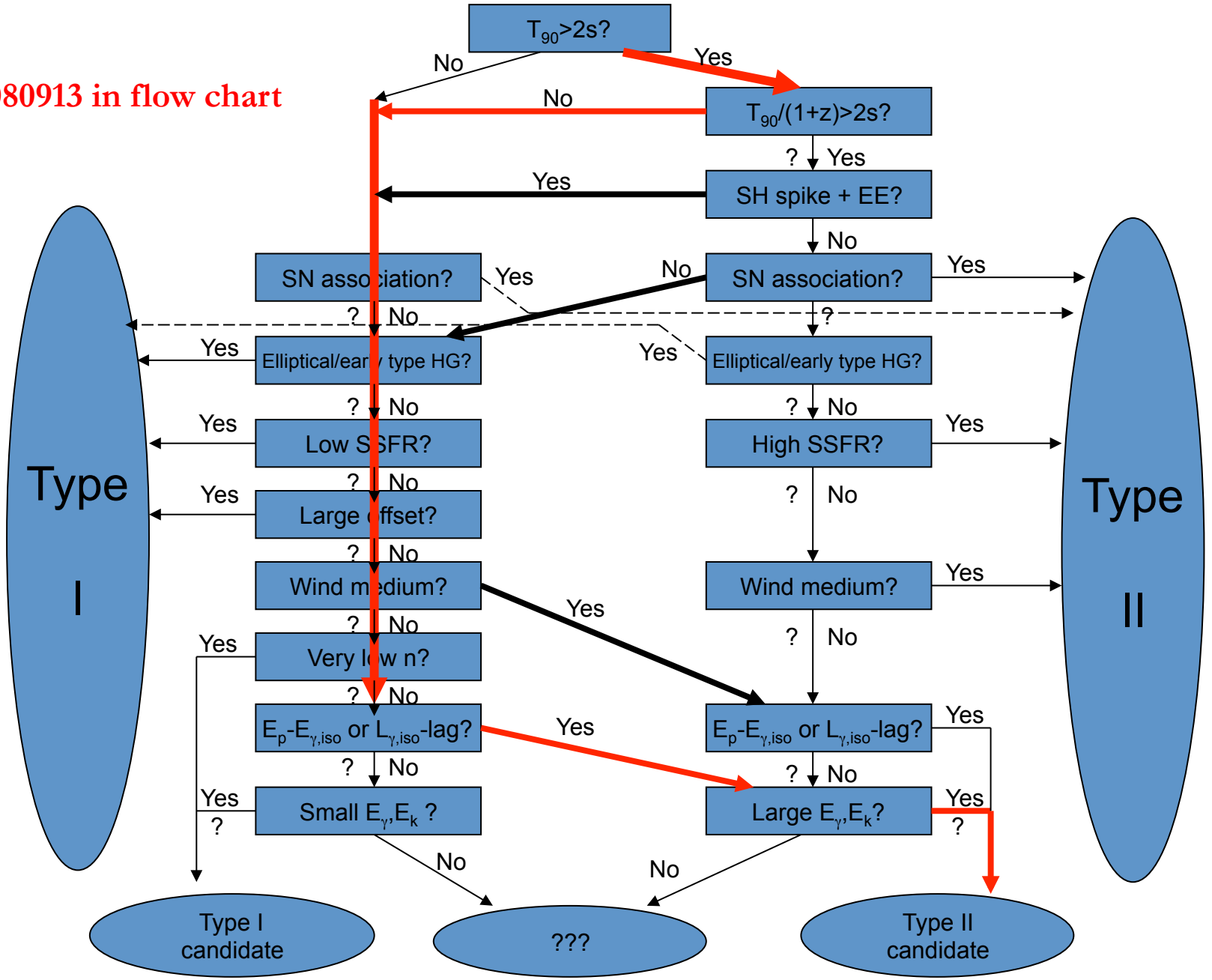

T90>2s?
No
Yes
No
T90/(1+z)>2s?
? Yes
Yes
SH spike + EE?
No
SN association?
Yes
No
SN association?
Yes
? No
?
Yes
Elliptical/early type HG?
Yes
Elliptical/early type HG?
? No
? No
Yes
Low SSFR?
High SSFR?
Yes
? No
Yes
Large offset?
? No
Wind medium?
Yes
? No
Wind medium?
Yes
Yes
Very low n?
? No
? No
Type I
Type II
Type I candidate
Type II candidate


T_{90}>2s?
No
Yes
No
T_{90}/(1+z)>2s?
? Yes
Yes
SH spike + EE?
No
SN association?
Yes
No
SN association?
Yes
? No
?
Yes
Elliptical/early type HG?
Yes
Elliptical/early type HG?
? No
? No
Yes
Low SSFR?
High SSFR?
Yes
? No
Yes
Large offset?
? No
Wind medium?
Yes
? No
Wind medium?
Yes
Yes
? No
Yes
Very low n?
? No
E_p-$E_{\gamma,iso}$ or $L_{\gamma,iso}$-lag?
Yes
E_p-$E_{\gamma,iso}$ or $L_{\gamma,iso}$-lag?
Yes
? No
? No
Type I
Type II
Type I candidate
Type II candidate

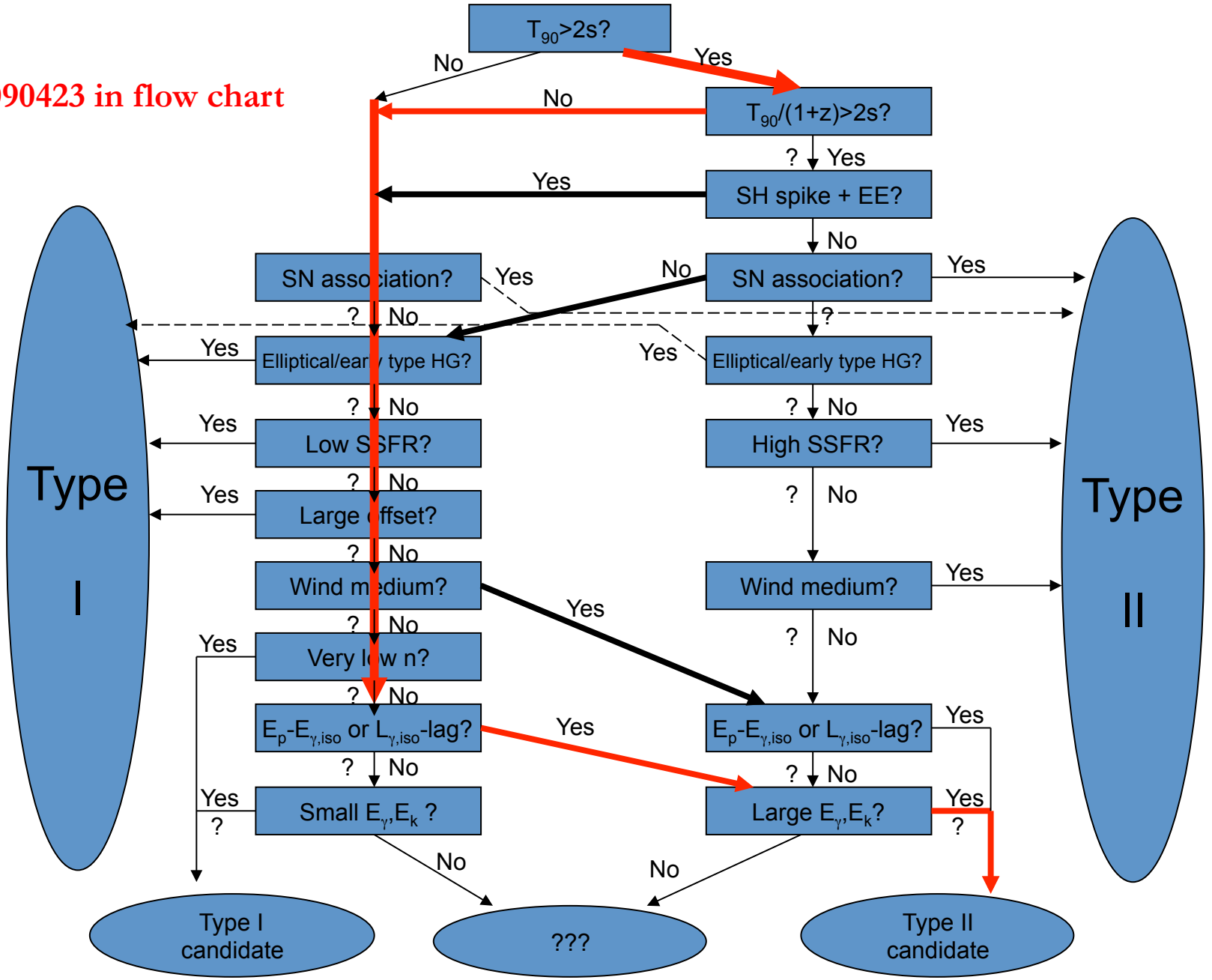


Zhang et al. (2009)
Kann et al. (2011)

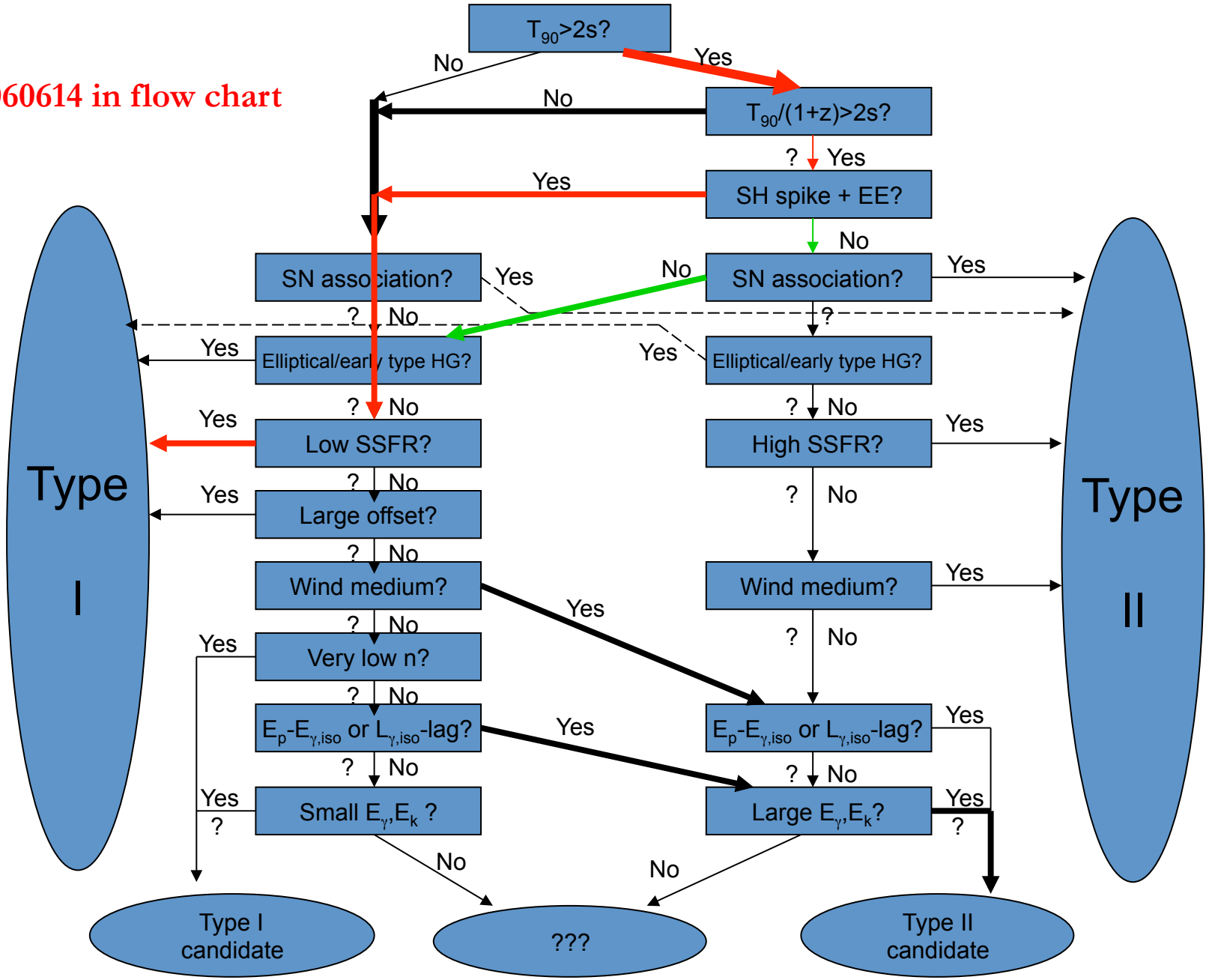
080913 in flow chart



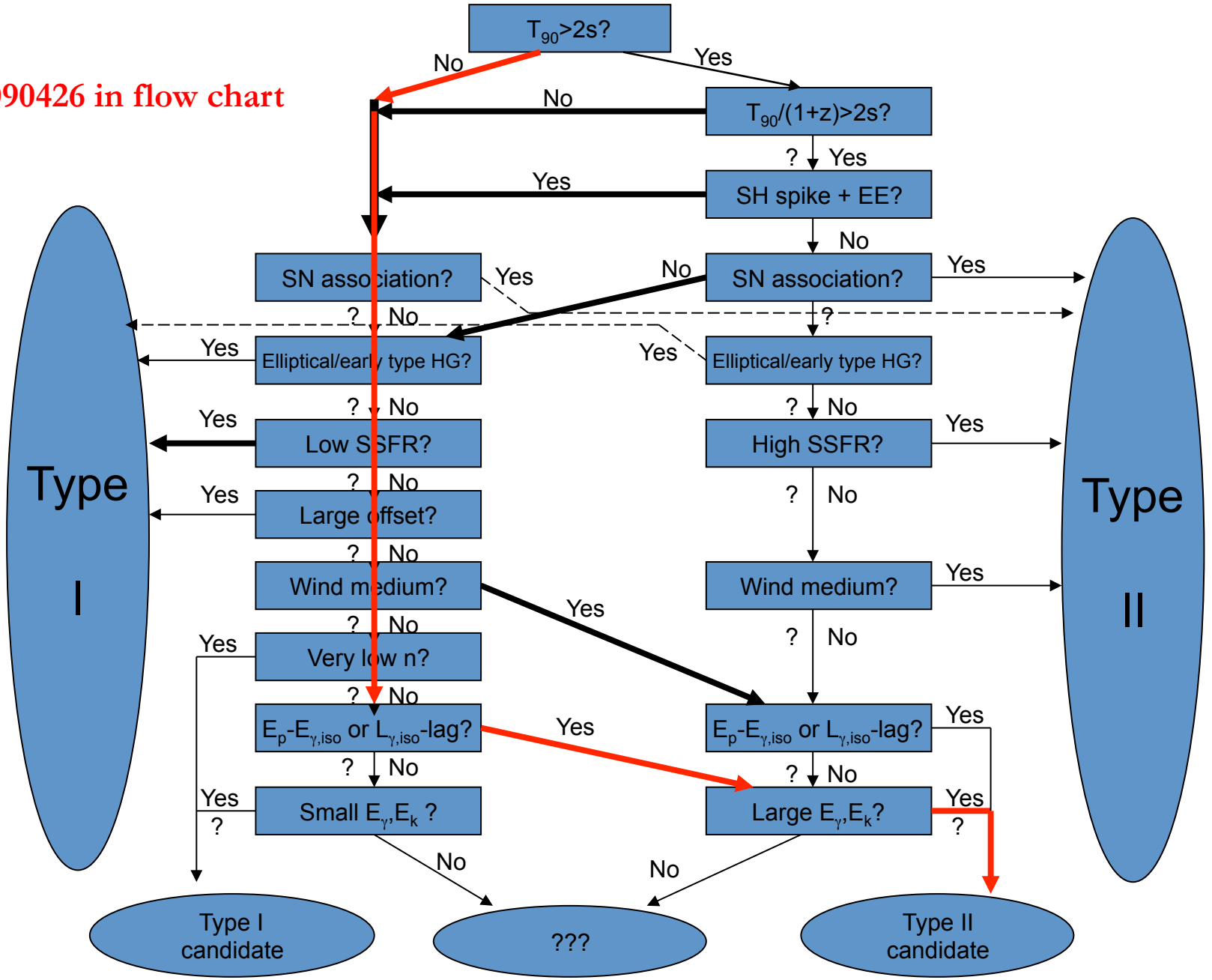
090423 in flow chart



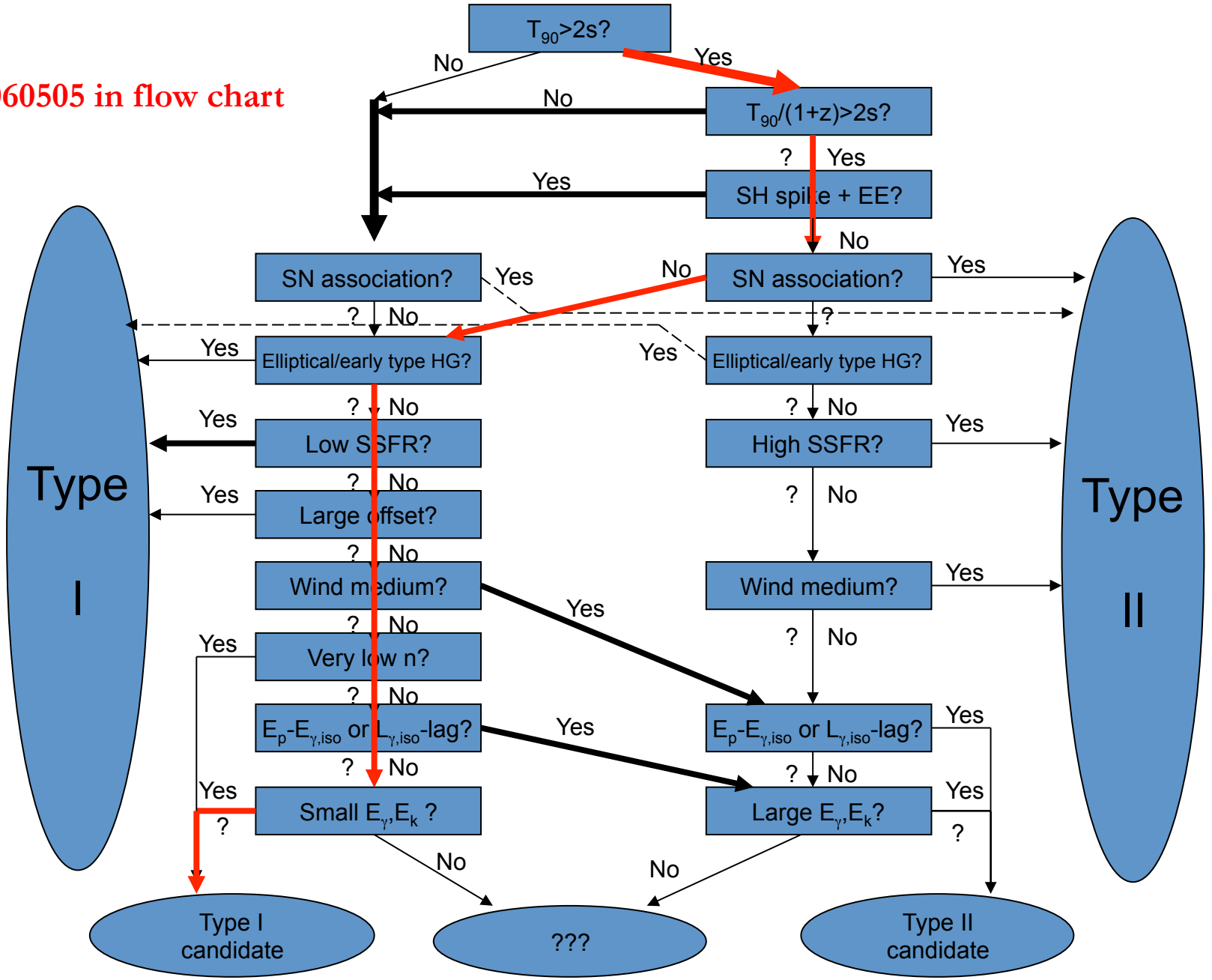
060614 in flow chart



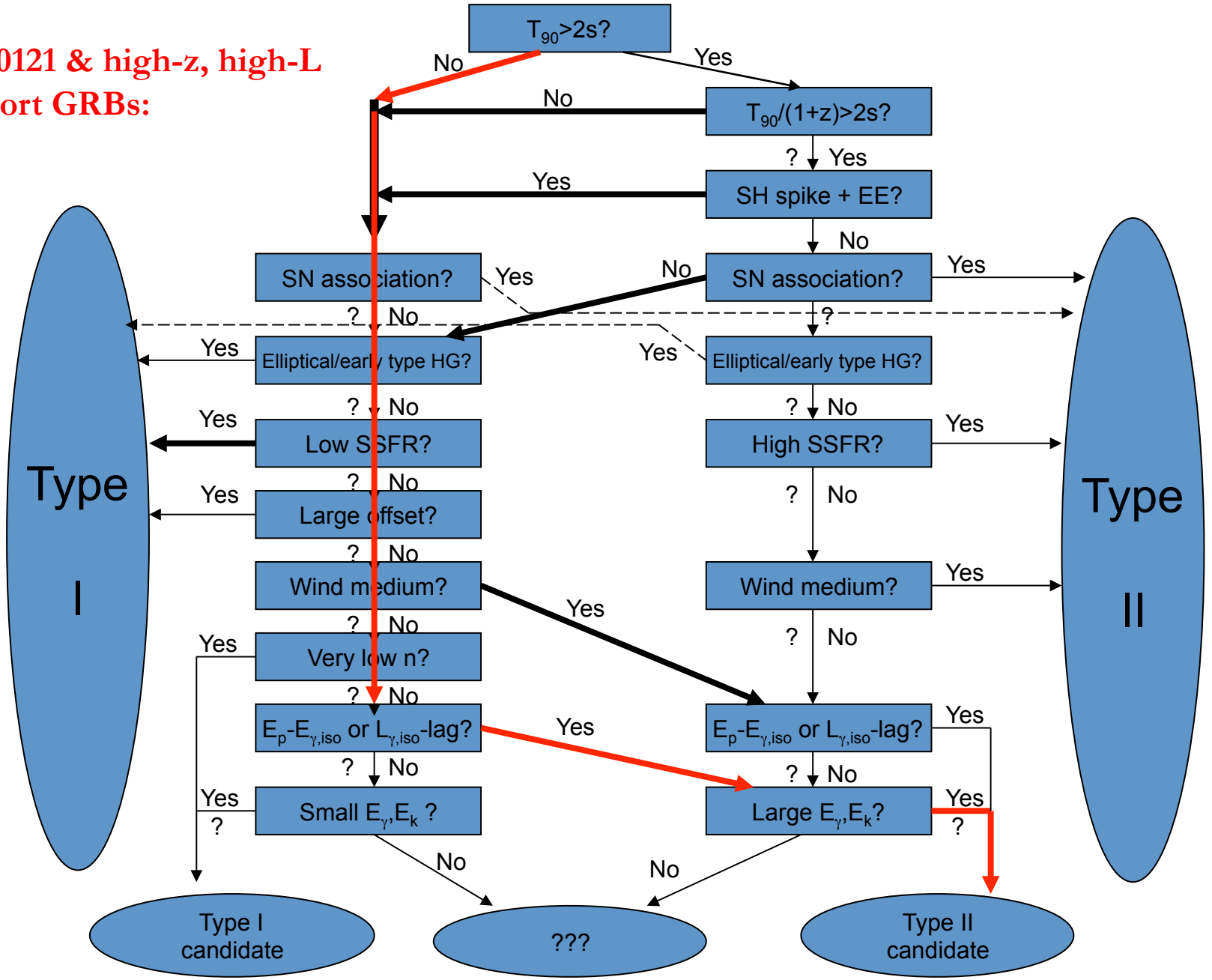
090426 in flow chart



060505 in flow chart



060121 & high-z, high-L Short GRBs:



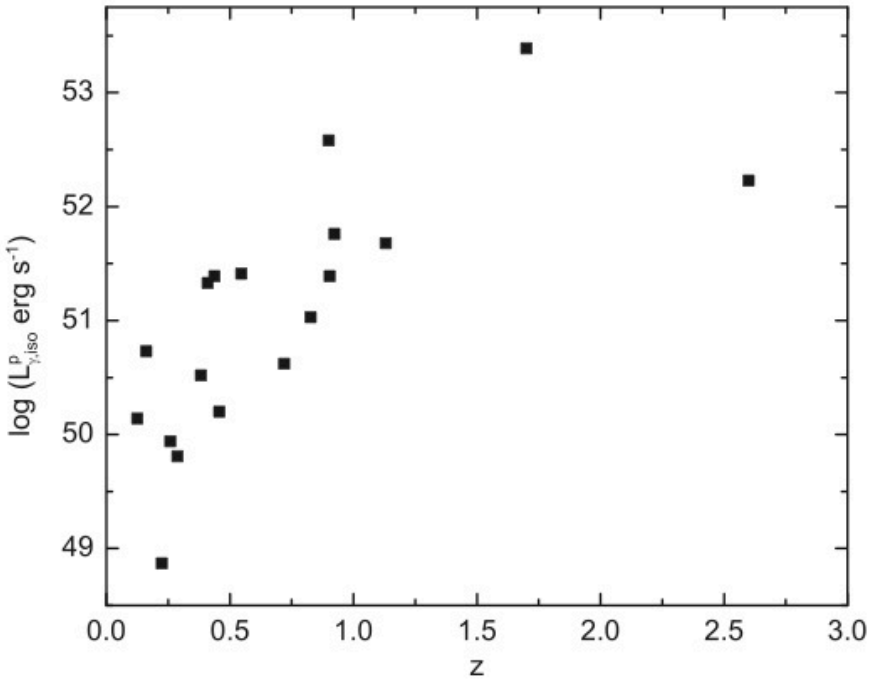
Caution:

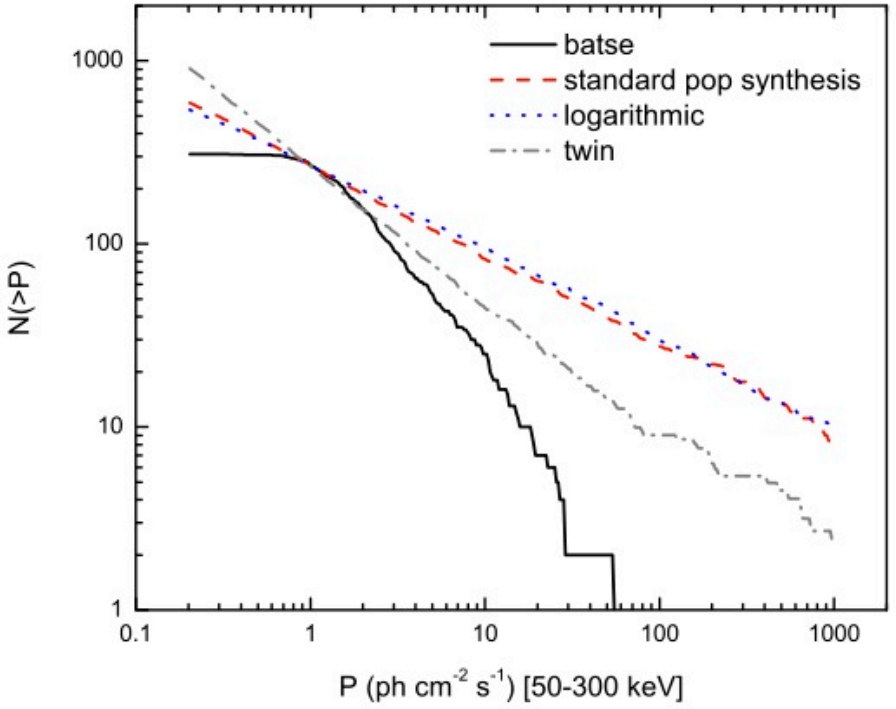
Our current knowledge about compact star (Type I) GRBs is mostly based on nearby short (not always short) GRBs.

The possibility that high luminosity, high redshift short GRBs could be of massive star (Type II) GRBs is not ruled out.

The compact star merger model cannot simultaneously reproduce Swift and BATSE short GRB sample!

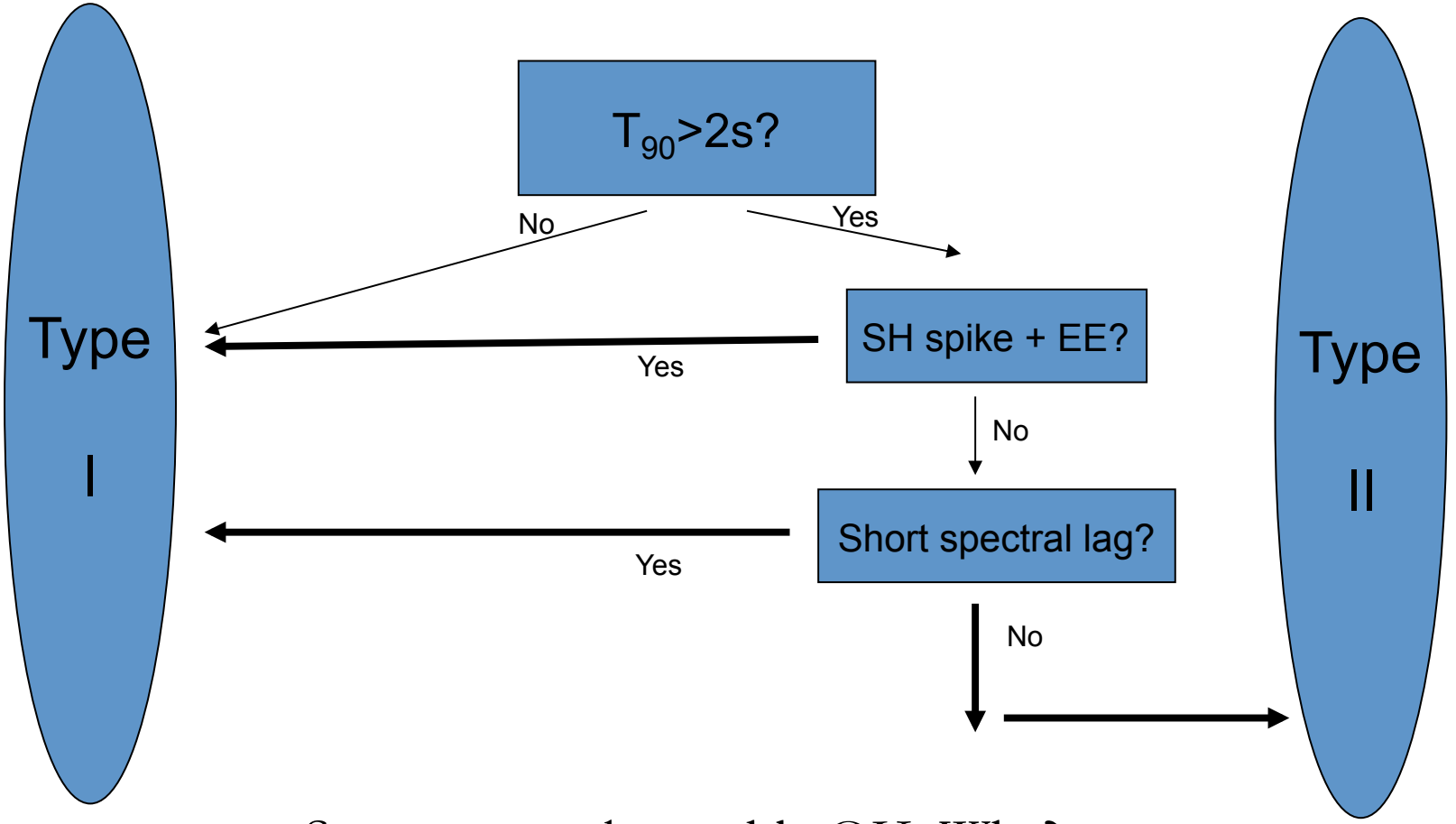
Virgili et al. (2011)





Practical criteria

e.g. by Swift team



Seems to work roughly OK. Why?

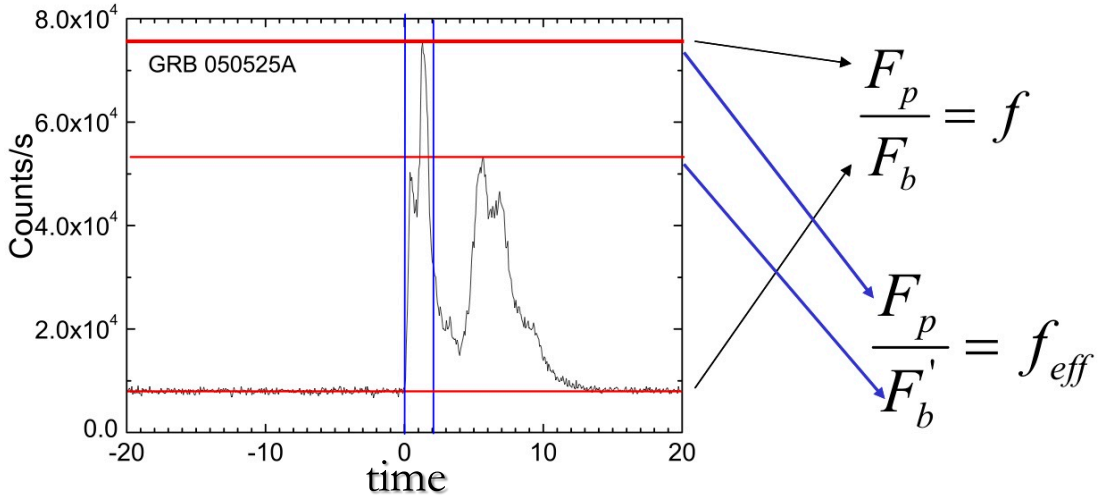
Duration & hardness. Enough?

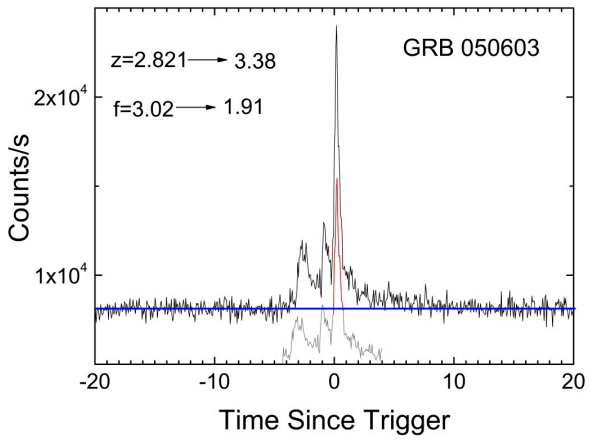
Add one more dimension: amplitude!

Define: $f \equiv \frac{F_p}{F_b}$

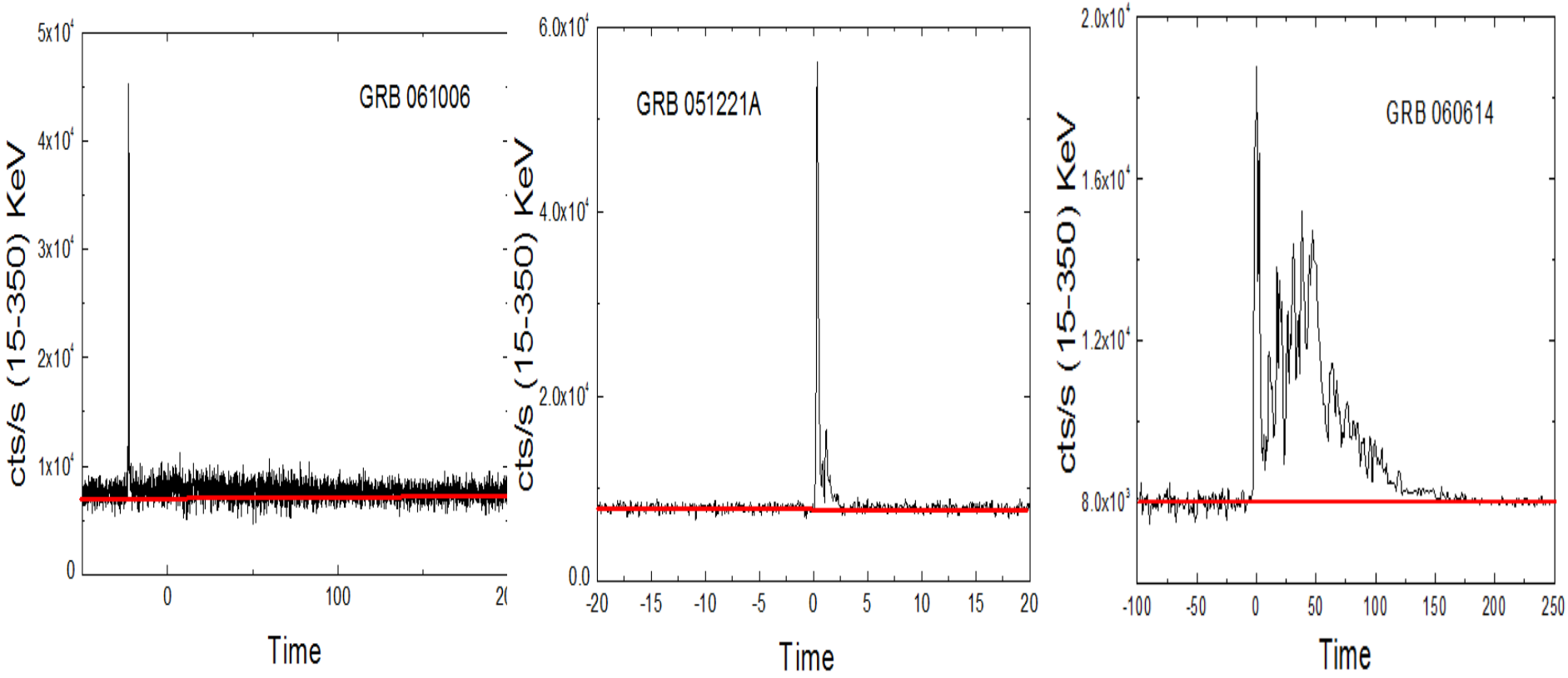
$f_{eff} \equiv \frac{F_p}{F_b'}$

$f_{eff,z} \equiv \frac{F_{p,z}}{F_{b,z}'}$



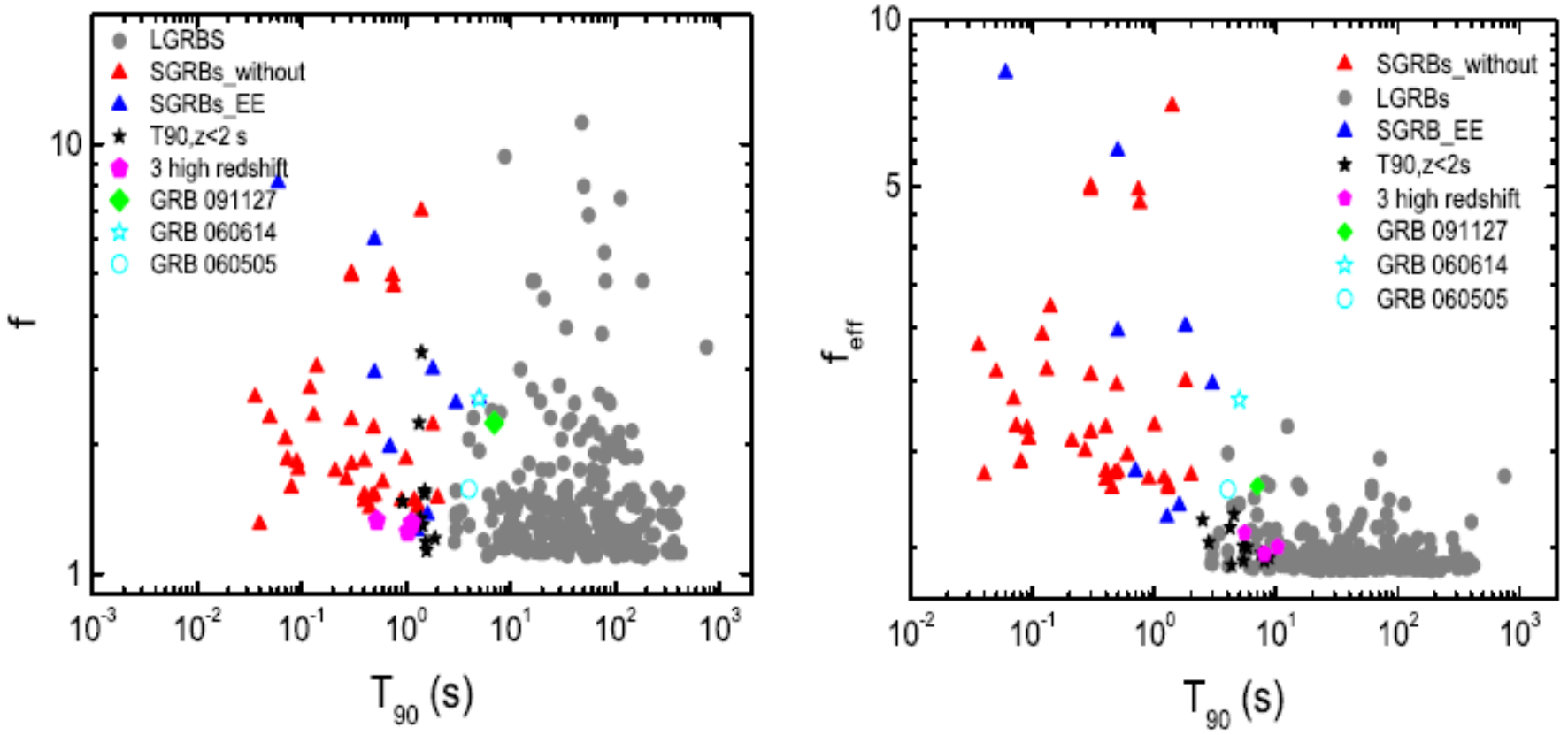


Short GRBs have high f >> f_{eff}



f vs. f_{eff} :

Most short GRBs are not "tip of iceberg" of long GRBs

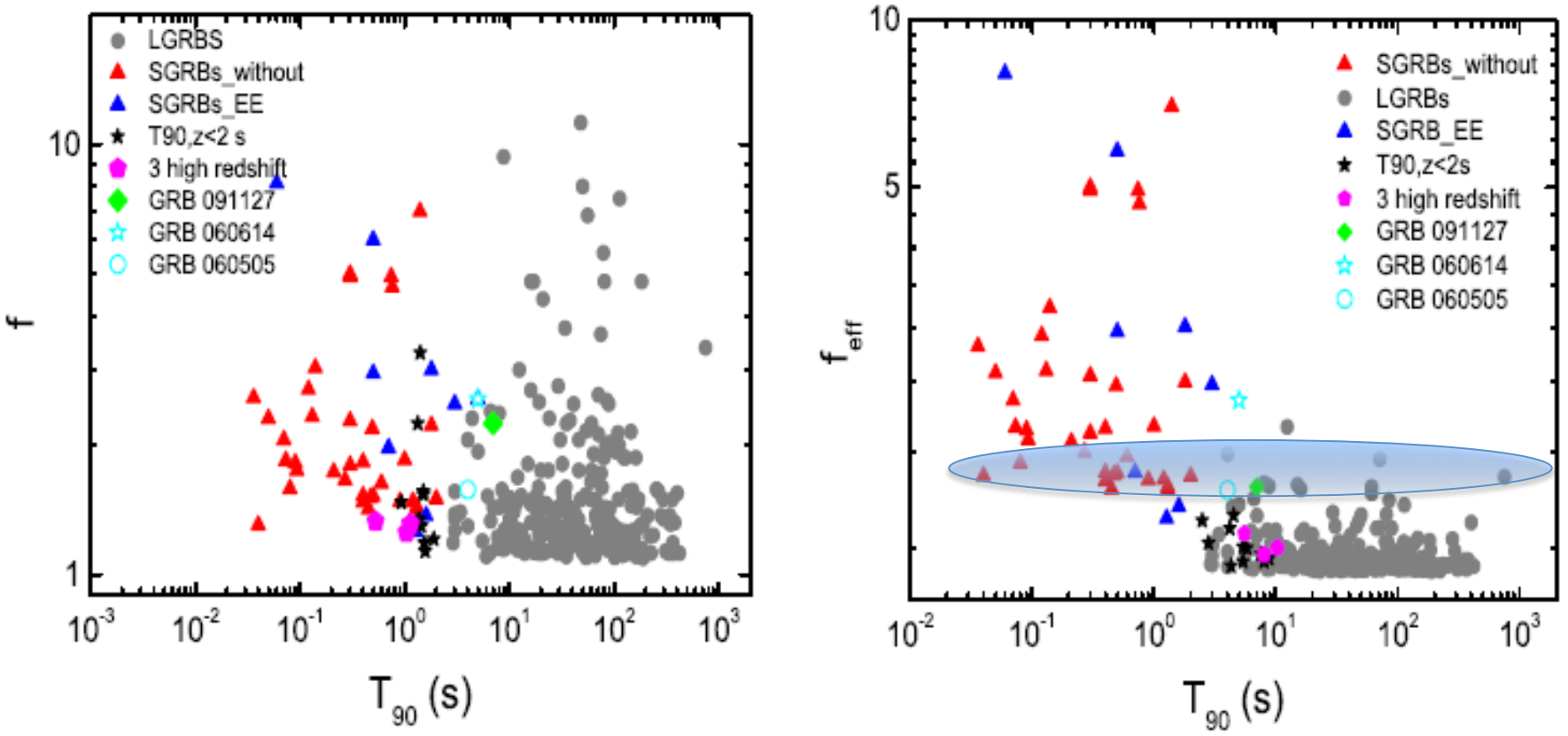


Hou-Jun Lü et al. 2012, in preparation

f vs. f_{eff} :

Most short GRBs are not "tip of iceberg" of long GRBs

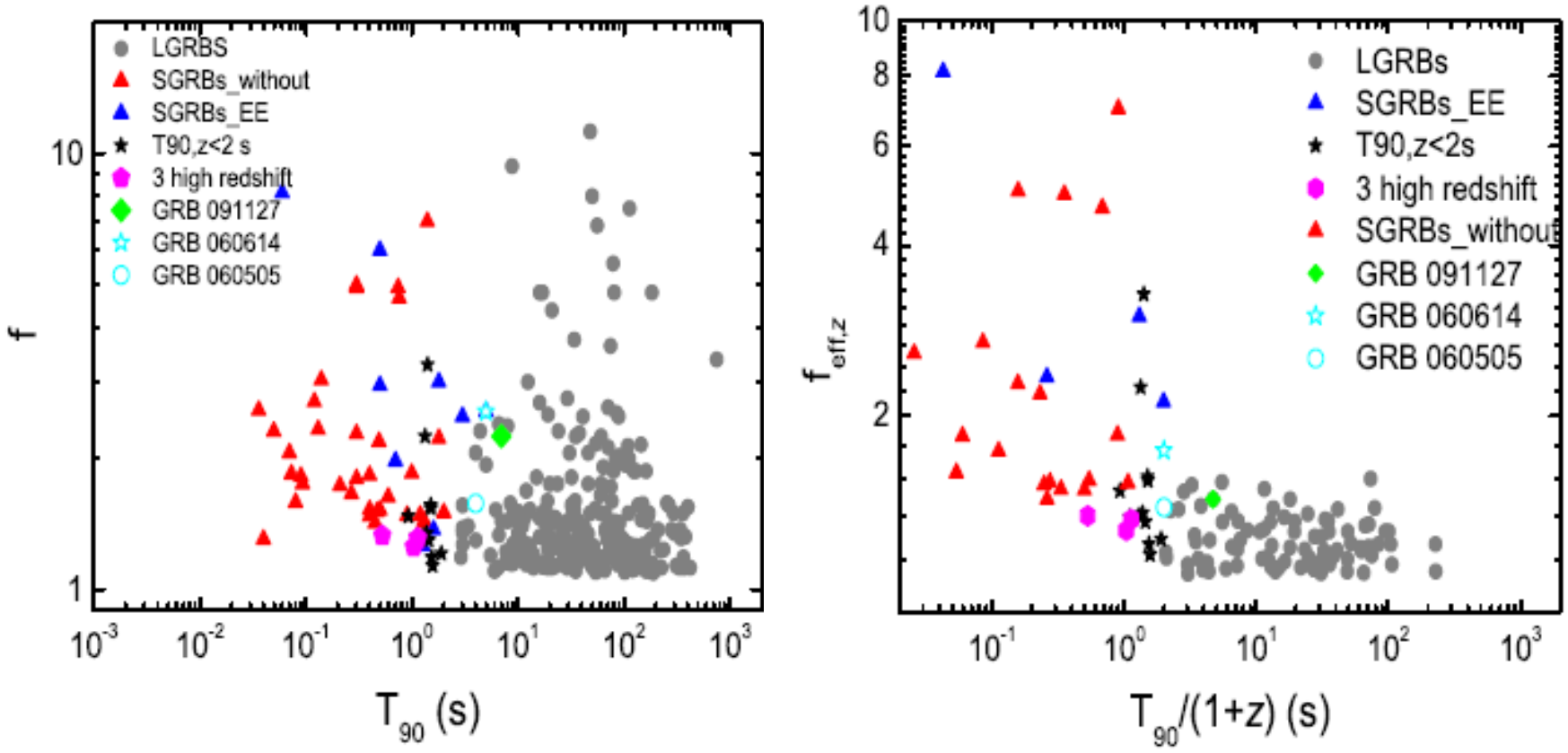
But still some parameter space for confusion. Be cautious!



Hou-Jun Lü et al. 2012, in preparation

f vs. $f_{eff,z}$:

Most rest-frame short GRBs could be "tip of iceberg"!

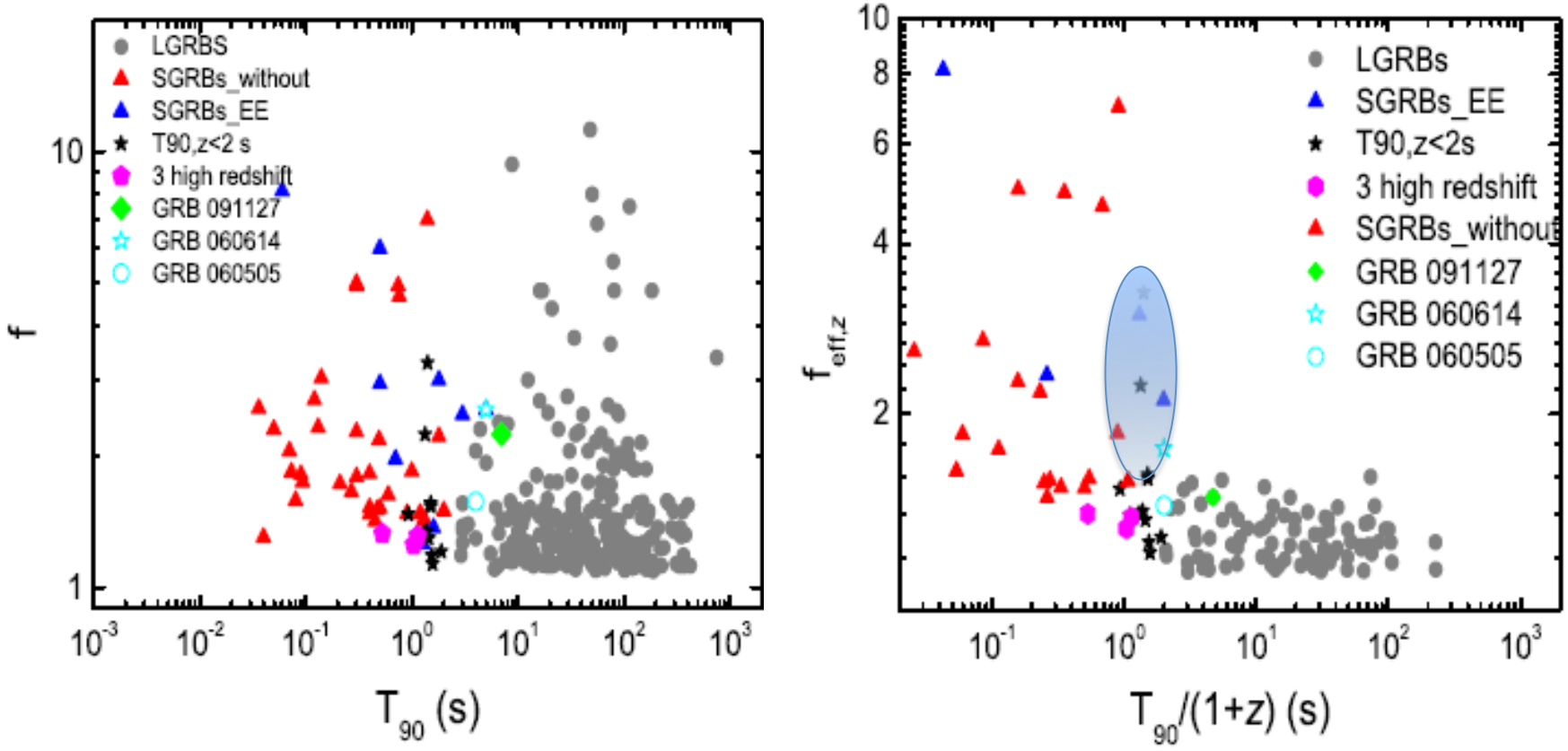


Hou-Jun Lü et al. 2012, in preparation

f vs. $f_{eff,z}$:

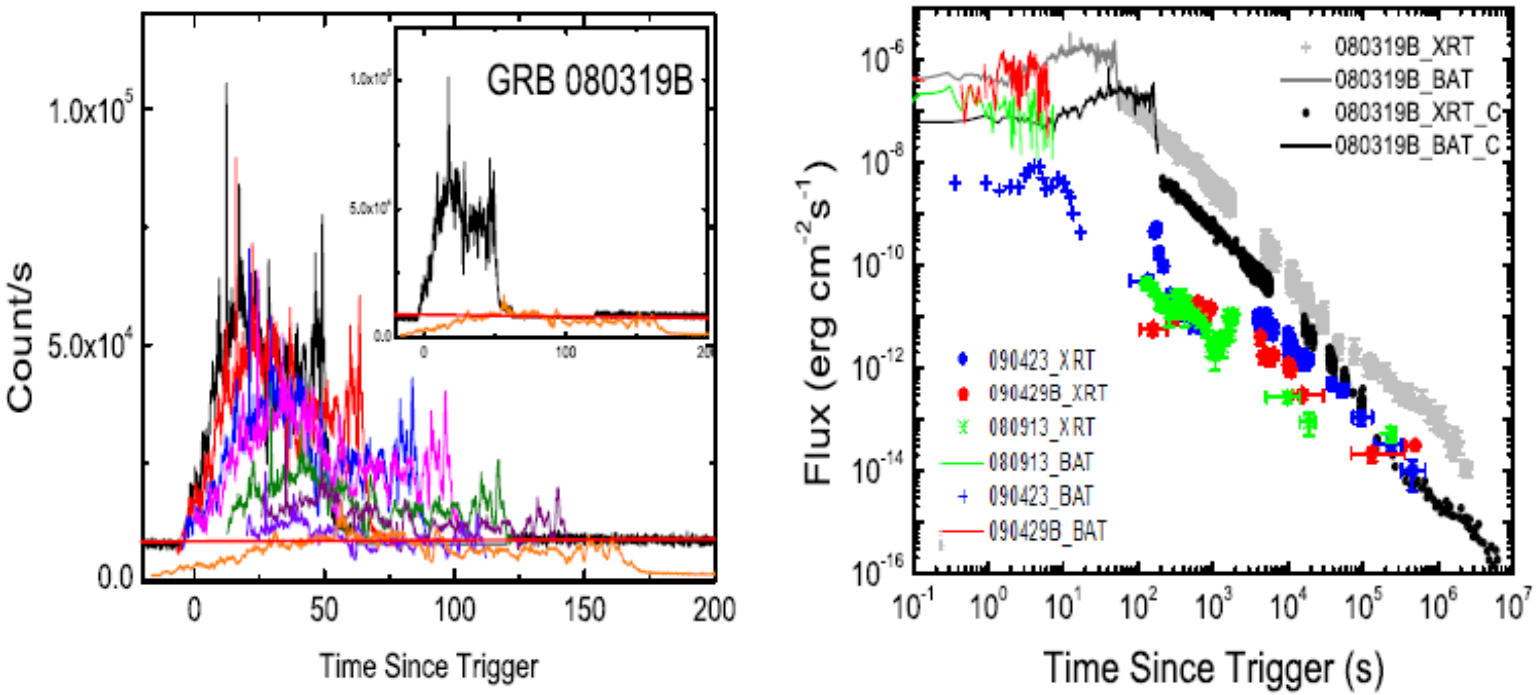
Most rest-frame short GRBs could be "tip of iceberg"!

But some could be confused with real short ones.



Hou-Jun Lü et al. 2012, in preparation

Three high-z rest-frame short GRBs (080913, 090423, 090429B) could be "tip of iceberg"

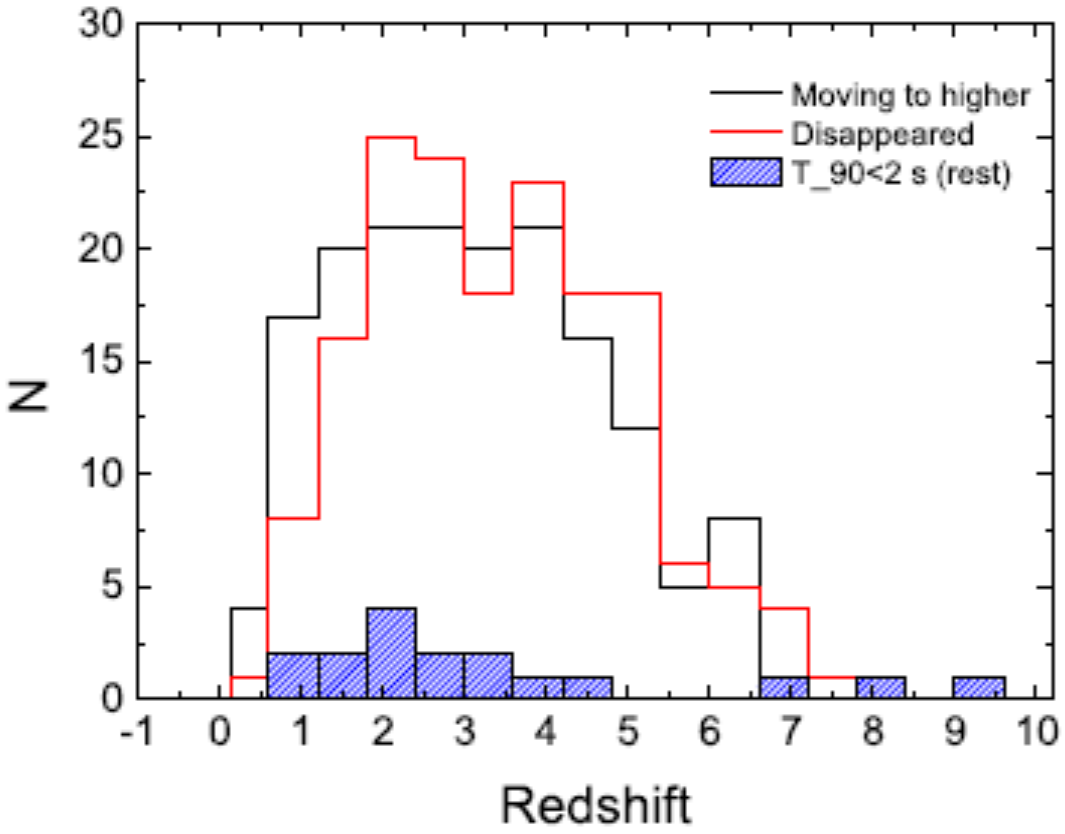


Moving GRB 080319B to high-z

Hou-Jun Lü et al. 2012, in preparation

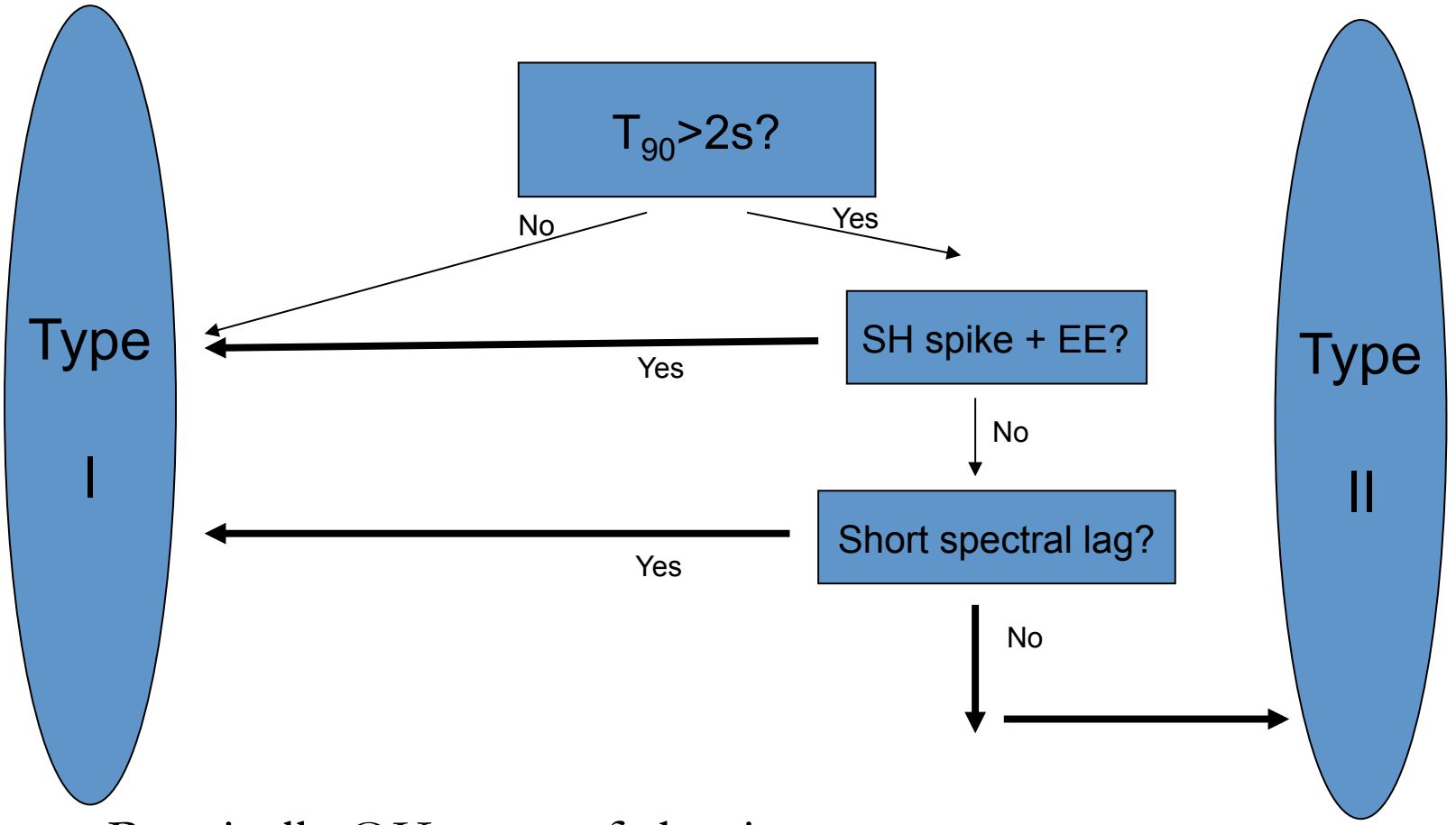
Three high-z rest-frame short GRBs (080913, 090423, 090429B) could be "tip of iceberg"

But …



Hou-Jun Lü et al. 2012, in preparation

Practical criteria

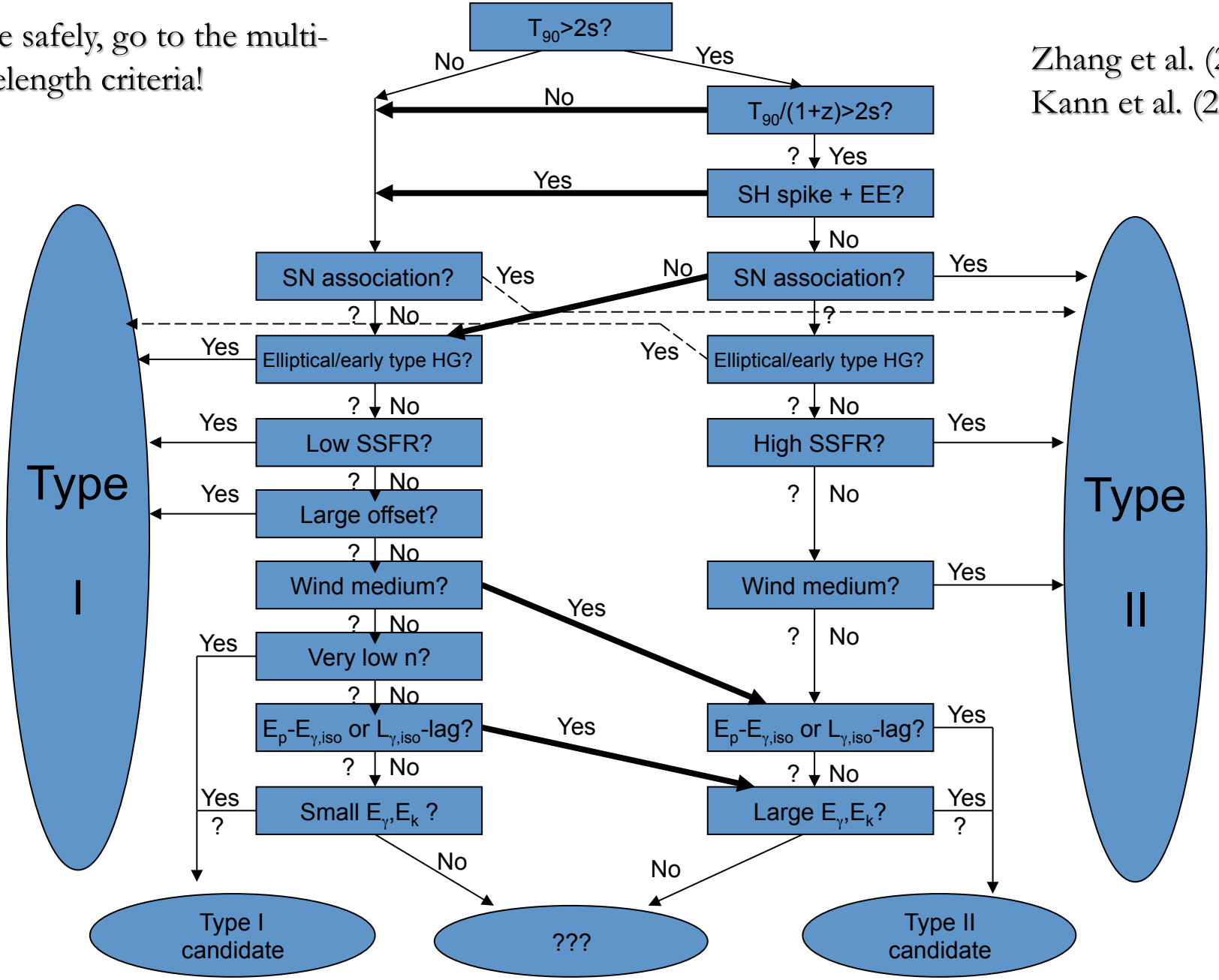


Practically OK most of the time

One has to be cautious, especially for low "f" short GRBs!

More safely, go to the multi-wavelength criteria!

Zhang et al. (2009)
Kann et al. (2011)



Conclusions

- The two physically distinct types of GRBs (massive star vs. compact star) generally coincide with two phenomenologically typed (long vs. short), but not exactly. Long Type I and short Type II GRBs have been discovered.
- The compact star merger model cannot simultaneously account for both the Swift and the BATSE short GRB samples. It may be too soon to draw the conclusion that "all short GRBs are of a compact star merger origin".
- Multi-criteria are needed to diagnose the physical nature of GRBs. A practical approach works roughly, but one should be cautious about the approach.
- Most short GRBs are not "tip of iceberg" of long GRBs; high-z rest-frame short GRBs may be "tip of iceberg" of long GRBs. But some confusions may occur, especially for low "f" GRBs.