

高エネルギー宇宙ニュートリノ 超新星起源説の観測的検証方法

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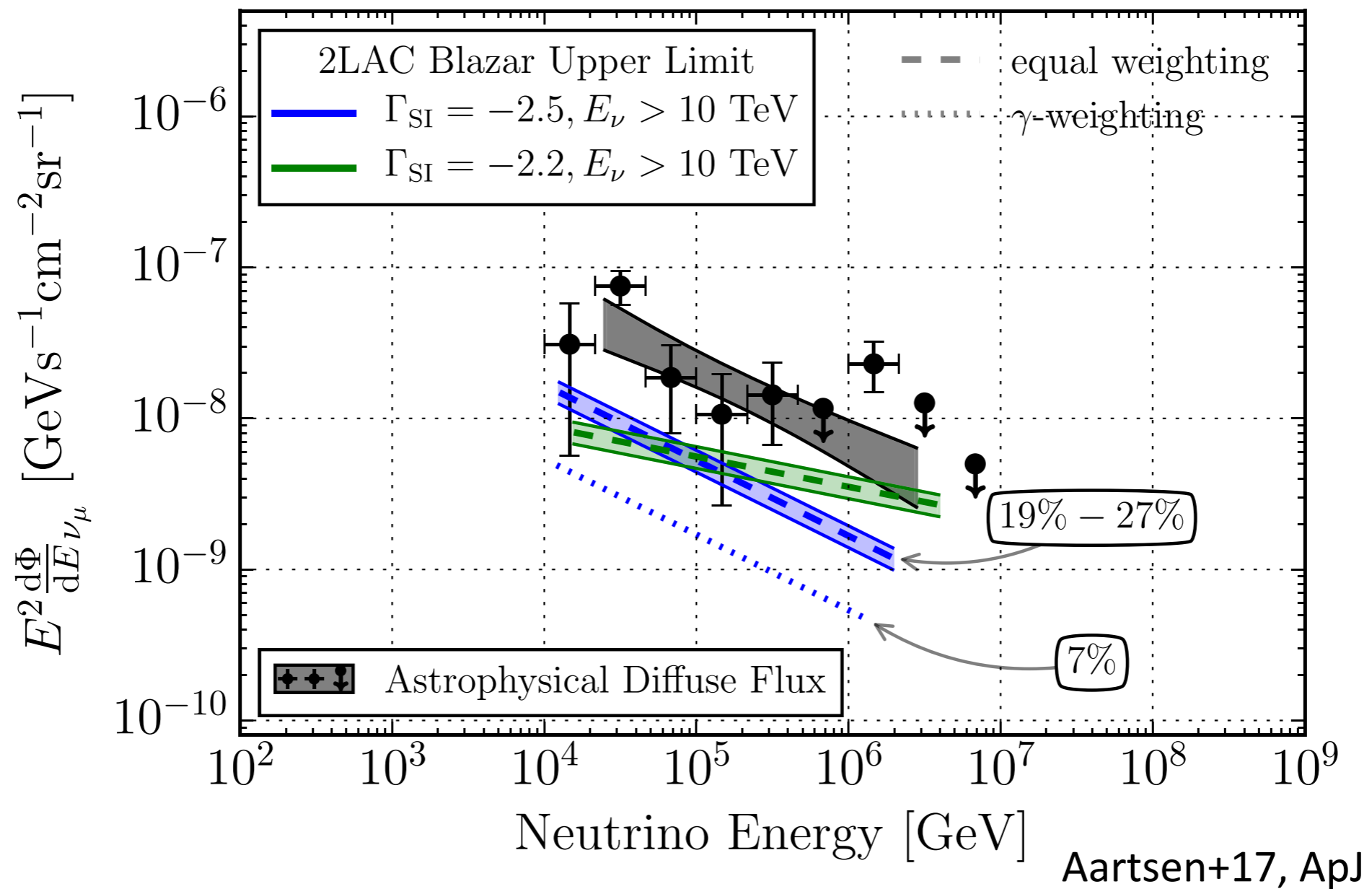
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富永望 山口正輝 (甲南大) 守屋堯 (国立天文台)

他 HSC Transient WG

Why supernovae (SNe)?

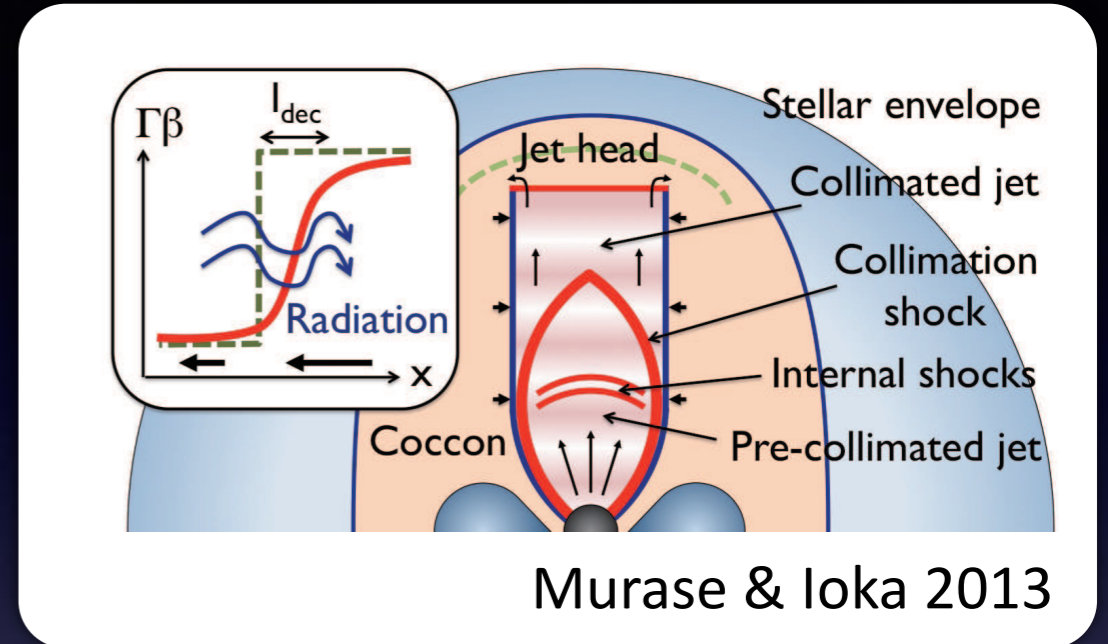
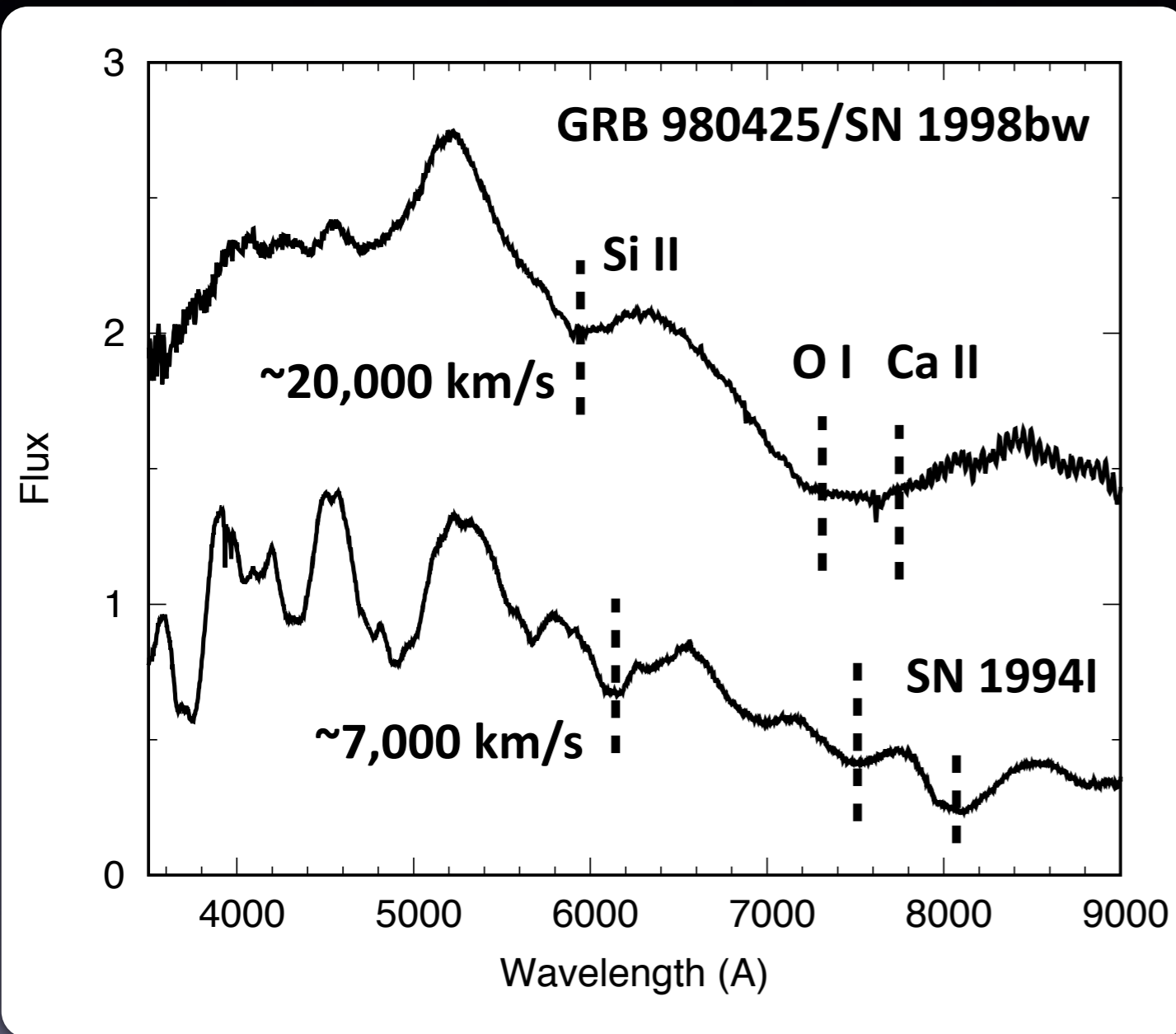
Blazars' contribution to the diffuse neutrino flux (Talks by Ishihara-san and Hayashida-san)



Difficulties also in spectral slope
(see talks by Murase-san)

Supernova with choked jet? (low-luminosity GRB?)

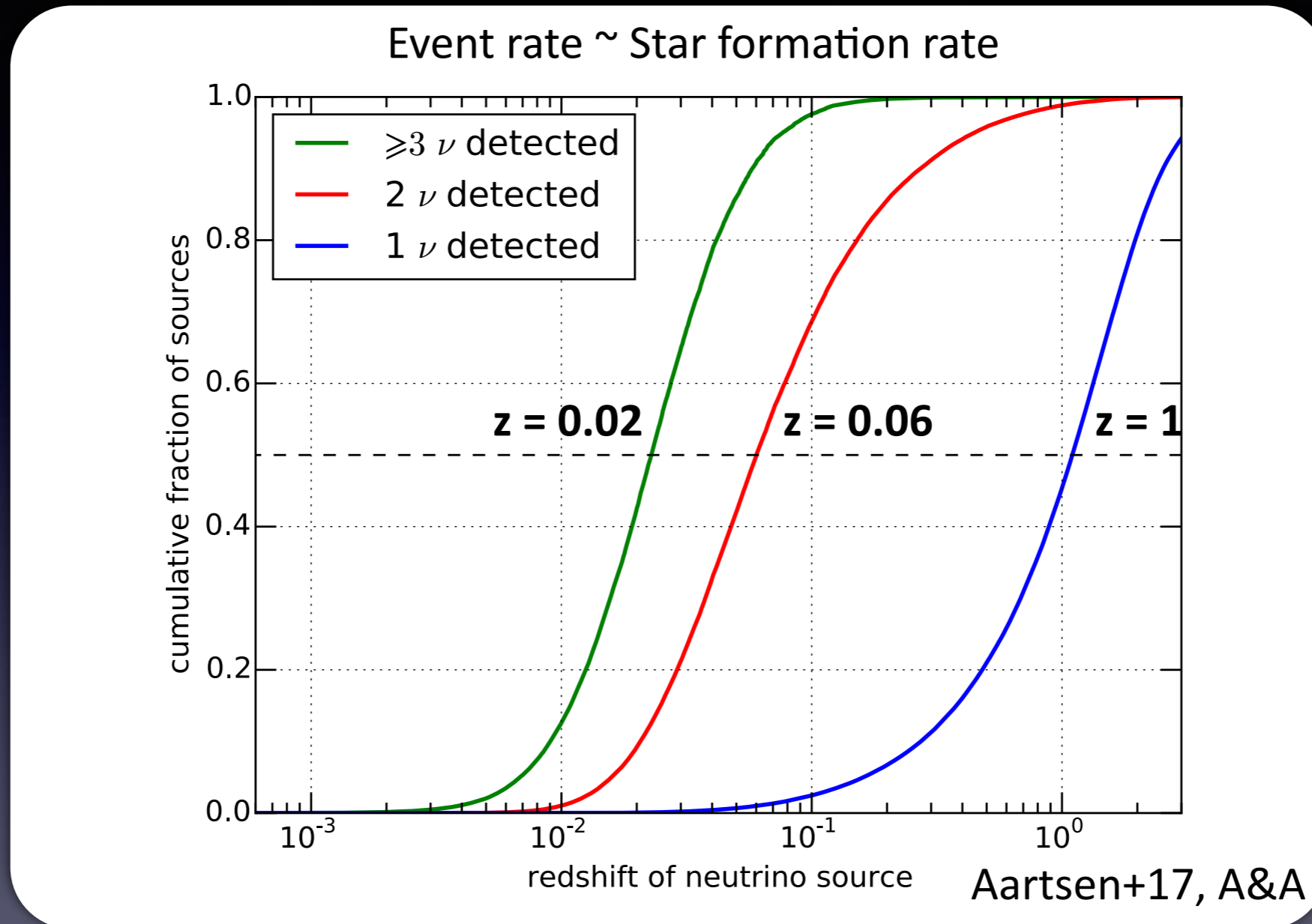
Sakamoto-san's talk



Observed as "broad-line" SNe
(~1 % of core-collapse SNe)

c.f. Long GRBs (~0.1 % of core-collapse SNe)

Challenges in identifying SNe as neutrino sources



	Redshift	Distance	SN brightness
Singlet	$z \sim 1$	7 Gpc	26 mag
Doublet	$z \sim 0.06$	280 Mpc	19 mag
Triplet	$z \sim 0.02$	90 Mpc	17 mag

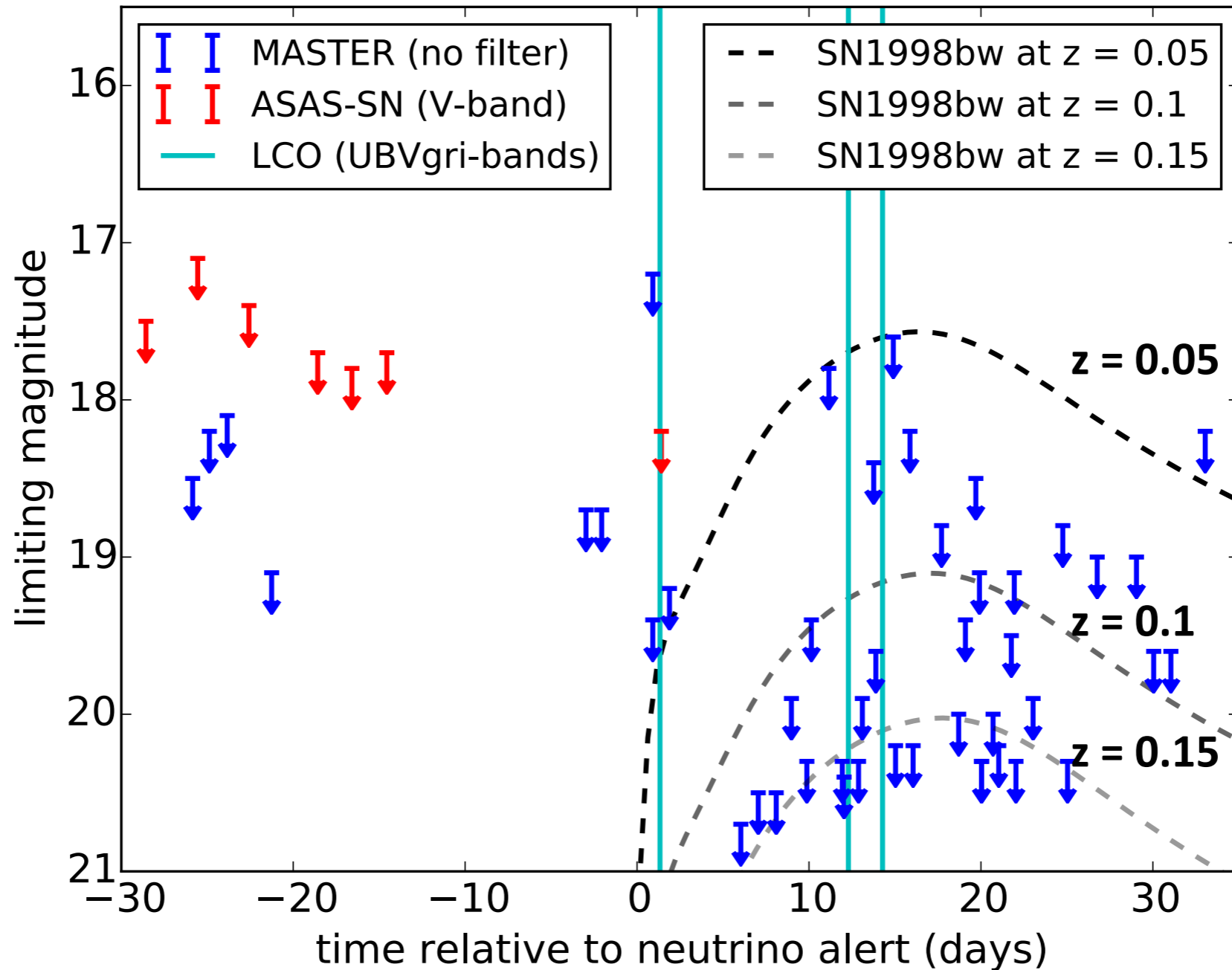
8m telescope!!

1m telescope

Strategy for multiplet event is straightforward

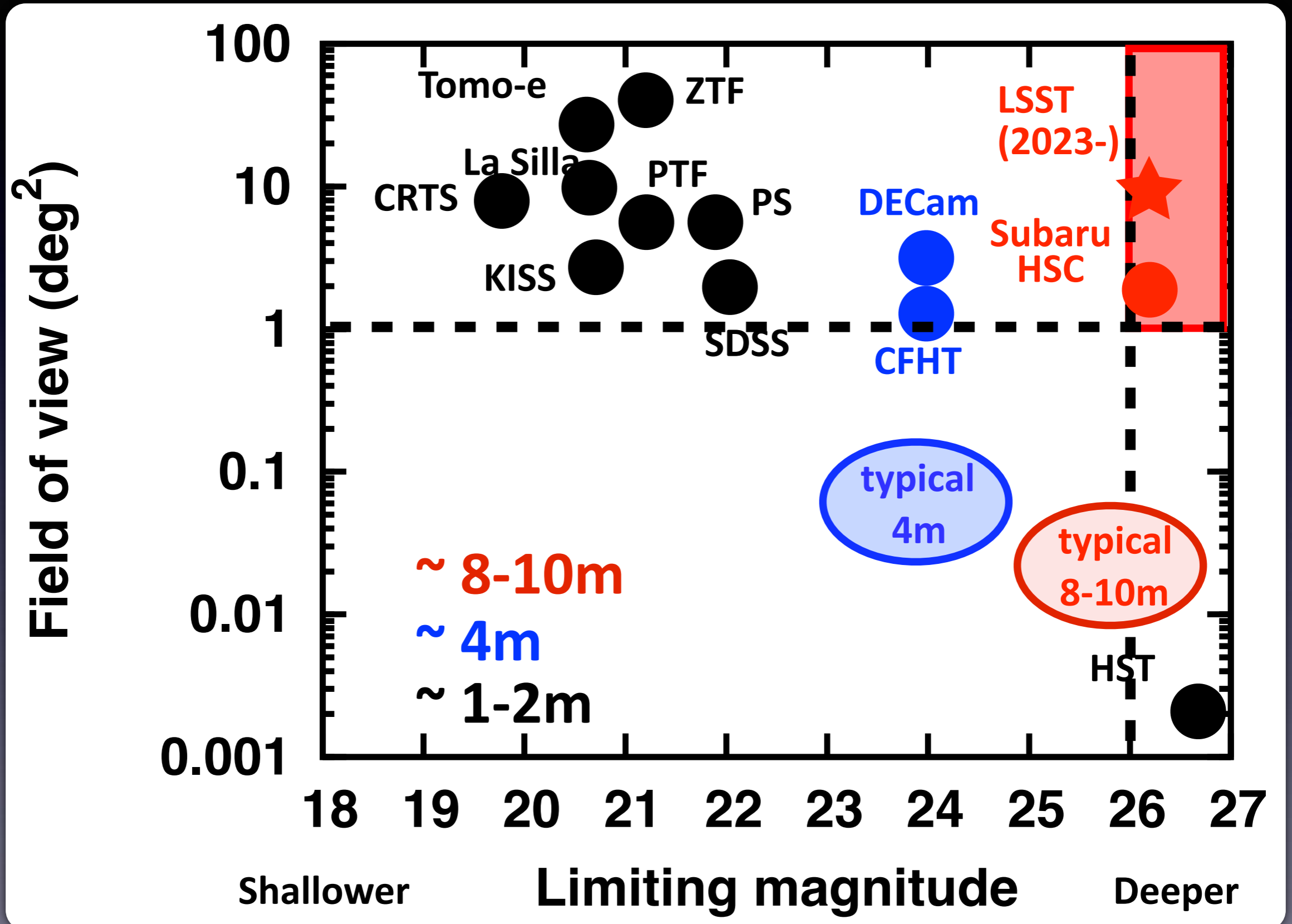
IceCube-160217 (**triplet**, $z \sim < 0.05$)

*32% probability of a chance alignment of background



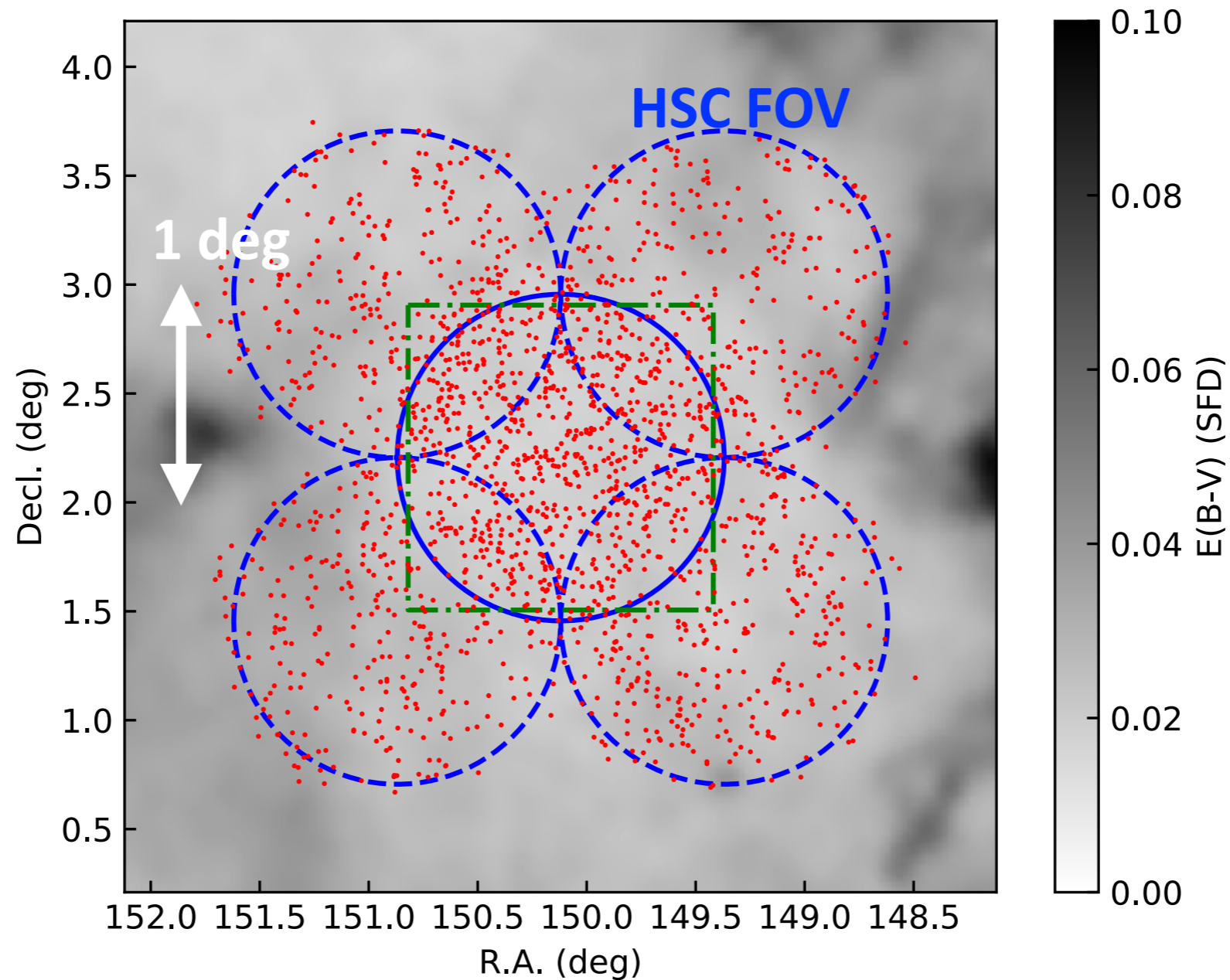
Aartsen+17, A&A

Strategy for singlet event



Subaru HSC transient surveys (~ 26 mag sensitivity)

~ 1800 SNe in 0.5 yr (~ 6 deg 2)



Yasuda, MT, Tominaga+18, submitted

~ 50 SNe / deg 2 / 1 visit
(c.f. $\sim 500,000$ objects / deg 2)

How many supernovae in 1 visit (26 mag)?

$$N \sim RV \Delta t f_{\Omega} \sim 10 \left(\frac{R}{10^5 \text{ Gpc}^{-3} \text{ yr}^{-1}} \right) \left(\frac{V}{100 \text{ Gpc}^3} \right) \left(\frac{\Delta t}{20 \text{ days}} \right) \left(\frac{\Omega}{1 \text{ deg}^2} \right)$$

Type	M _{abs} (mag)	z _{max}	Δt (days)	Local rate (Gpc ⁻³ yr ⁻¹)	N (deg ⁻²)	N (deg ⁻²)
Ia	-19	1.3	20	0.3 x 10 ⁵	10 - 30	0.01
II (H-rich)	-17	0.7	50	0.7 x 10 ⁵	10 - 30	0.05
IIn (CSM)	-18	1.0	50	0.1 x 10 ⁵	4 - 12	0.007
Ibc (H-free)	-17	0.7	20	0.2 x 10 ⁵	1 - 3	0.006
Broad line (hypernova)	-18	1.0	20	0.01 x 10 ⁵	0.2 - 0.6	0.0003

z < 0.1

For IceCube-170922A
0.15 deg² (50 %) and 0.97 deg² (90%)

↑ ↑
Local rate x 3

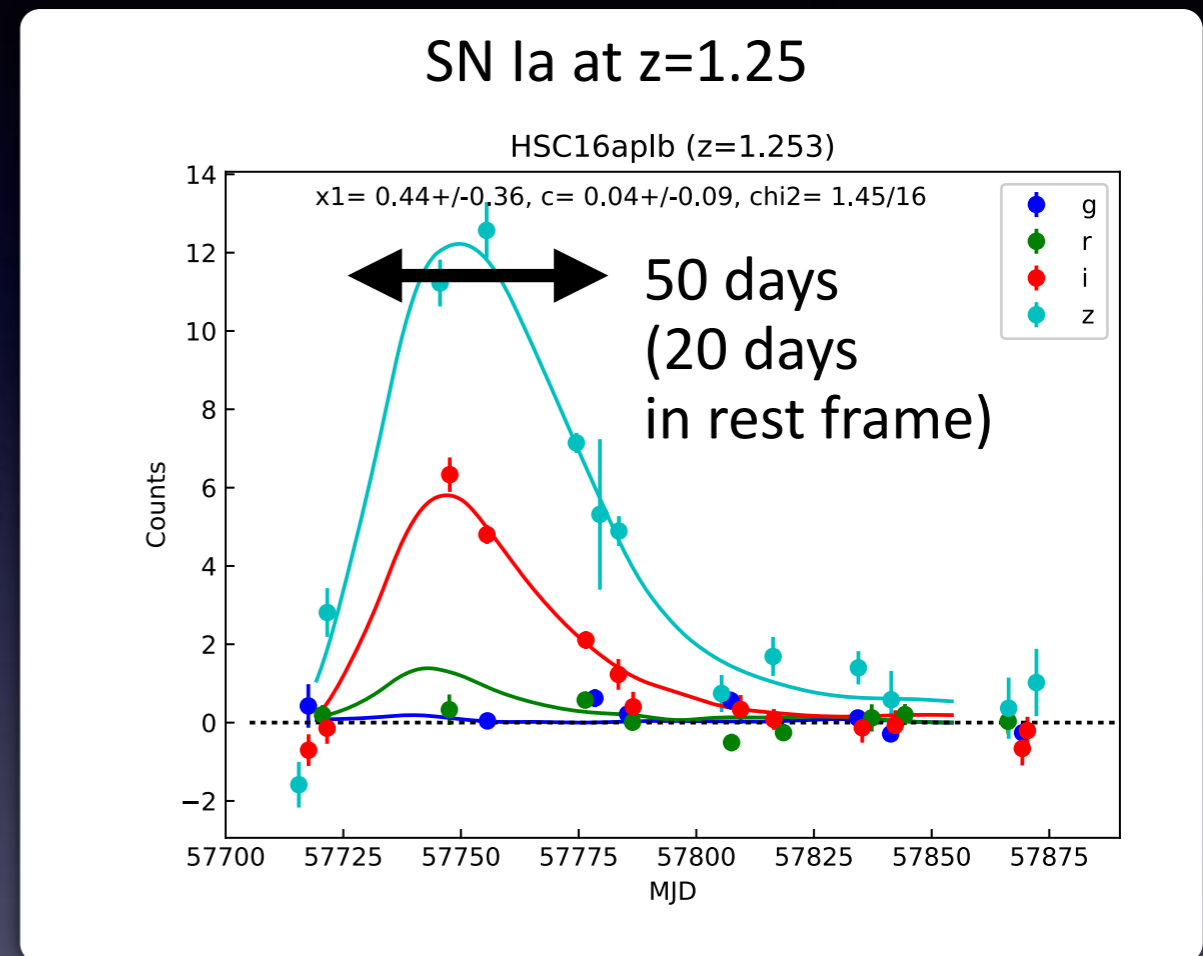
How to identify broad-line SNe at $z \sim 1$? (among >10 of Type Ia/II SNe)

(1) Photometric classification

- **Need good time sampling**
cadence of 2-3 days
continuous monitoring for ~ 50 days
- **Need color information**
 ≥ 3 filters
(no redshift information in advance)

(2) Spectroscopic confirmation

- **Need realtime spectroscopy**
Multi-object spectroscopy? (Subaru/PFS)
30m-class telescope (late 2020?)



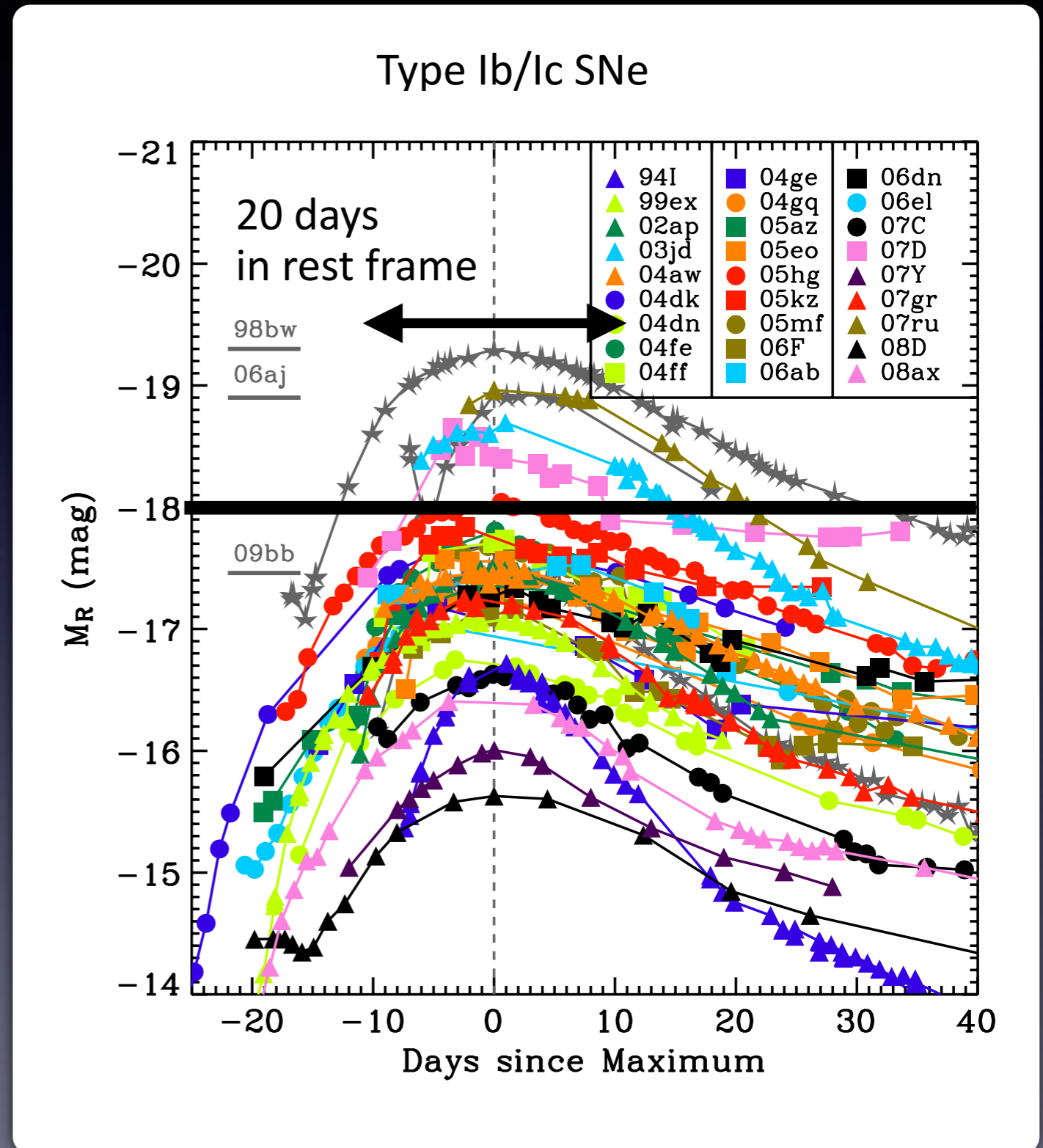
Yasuda, MT, Tominaga+18

How to estimate the explosion date?

Observations are sensitive to SNe around the peak
=> measure maximum date
=> assume “rise time”
(13 +/- 2 days for GRB-SN, Cano+16)

~5 days uncertainty should remain for objects at $z \sim 1$

Number of unrelated broad-line SNe in a window of $\Delta t \sim 5$ day
 $\sim 0.05-0.15 / \text{deg}^2$



Summary: how to identify SNe as neutrino sources

- **Multiplet events ($z < 0.1$)**
 - Follow-up with 1-2m telescopes => spectroscopy
 - Low contamination
- **Singlet events ($z \sim 1$)**
 - Follow-up with Subaru/HSC and LSST
 - High contamination
 - Dense, multi-color imaging
 - => photometric classification and estimate of explosion date
 - => Spectroscopy
 - ~ 0.2 broad-line SNe / deg² for a time window of $\Delta t \sim 5$ days
- **IceCube-Gen2**
 - Better sensitivity => more multiplet
 - Better localization => lower contamination