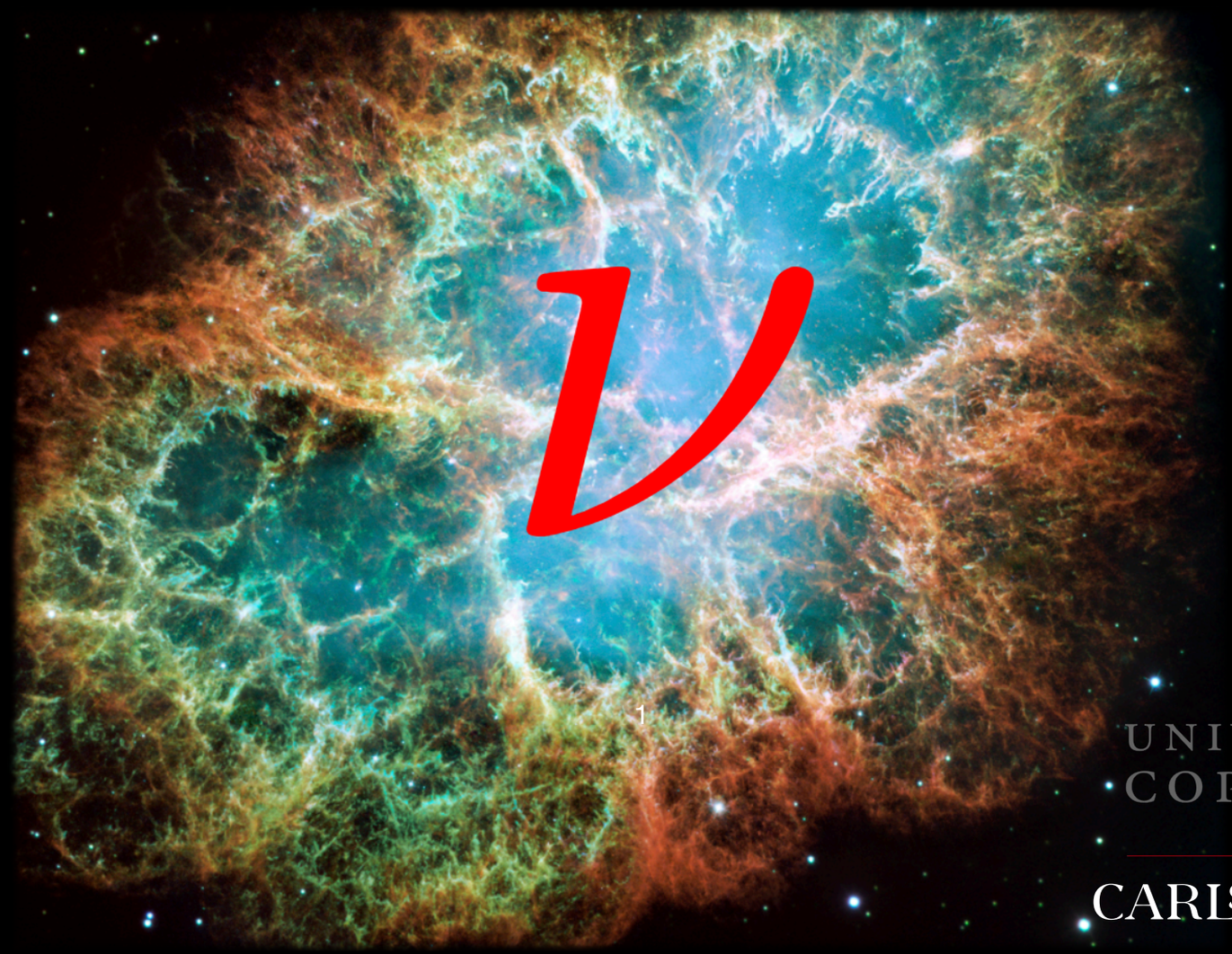
High-energy neutrinos from Interacting Supernovae

Tetyana Pitik

Niels Bohr Institute

based on arXiv: 2306.01833v1

Tetyana Pitik, I. Tamborra, M.Lincetto, A.Franckowiak



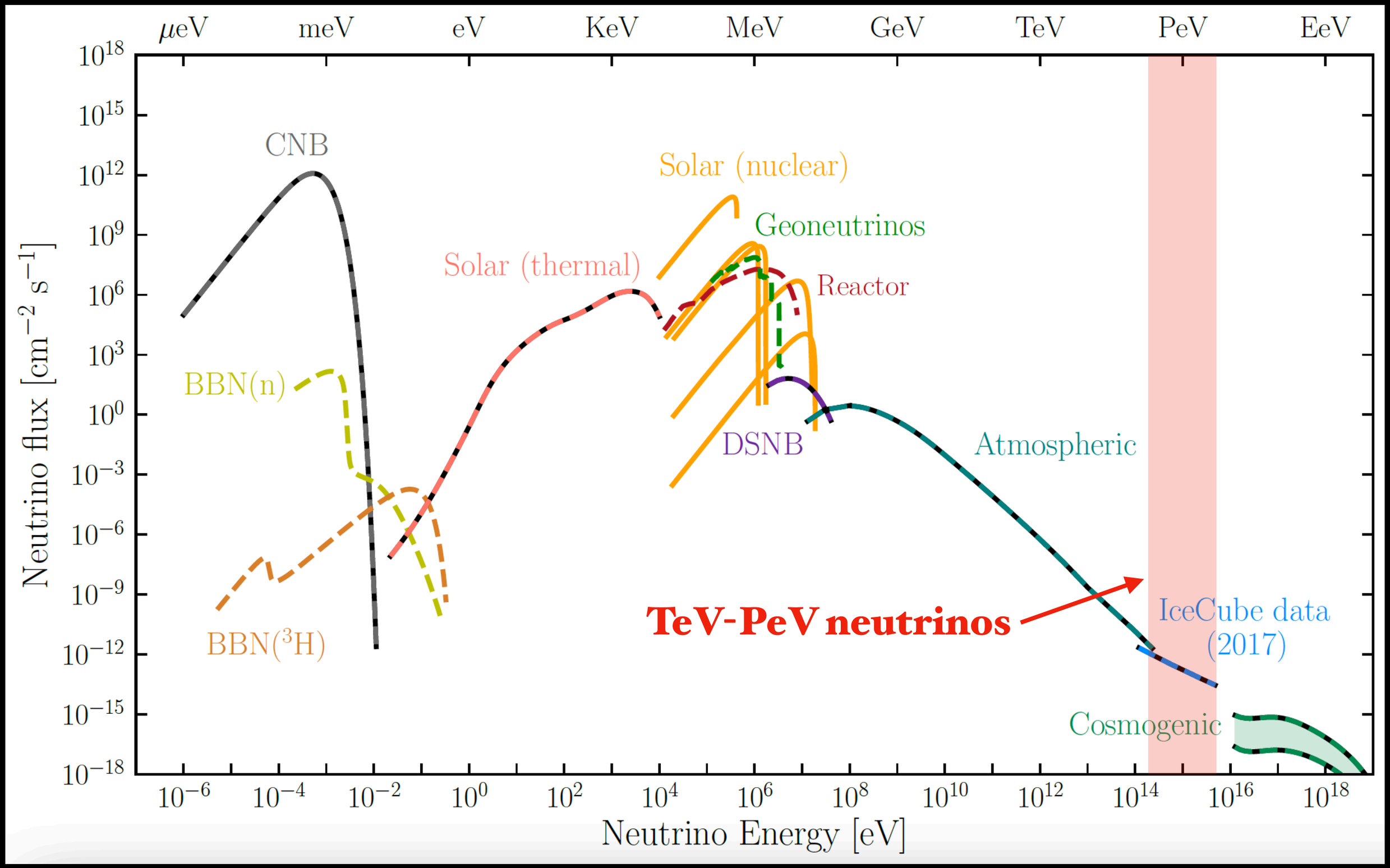
CARGÈSE

June, 2023

UNIVERSITY OF COPENHAGEN

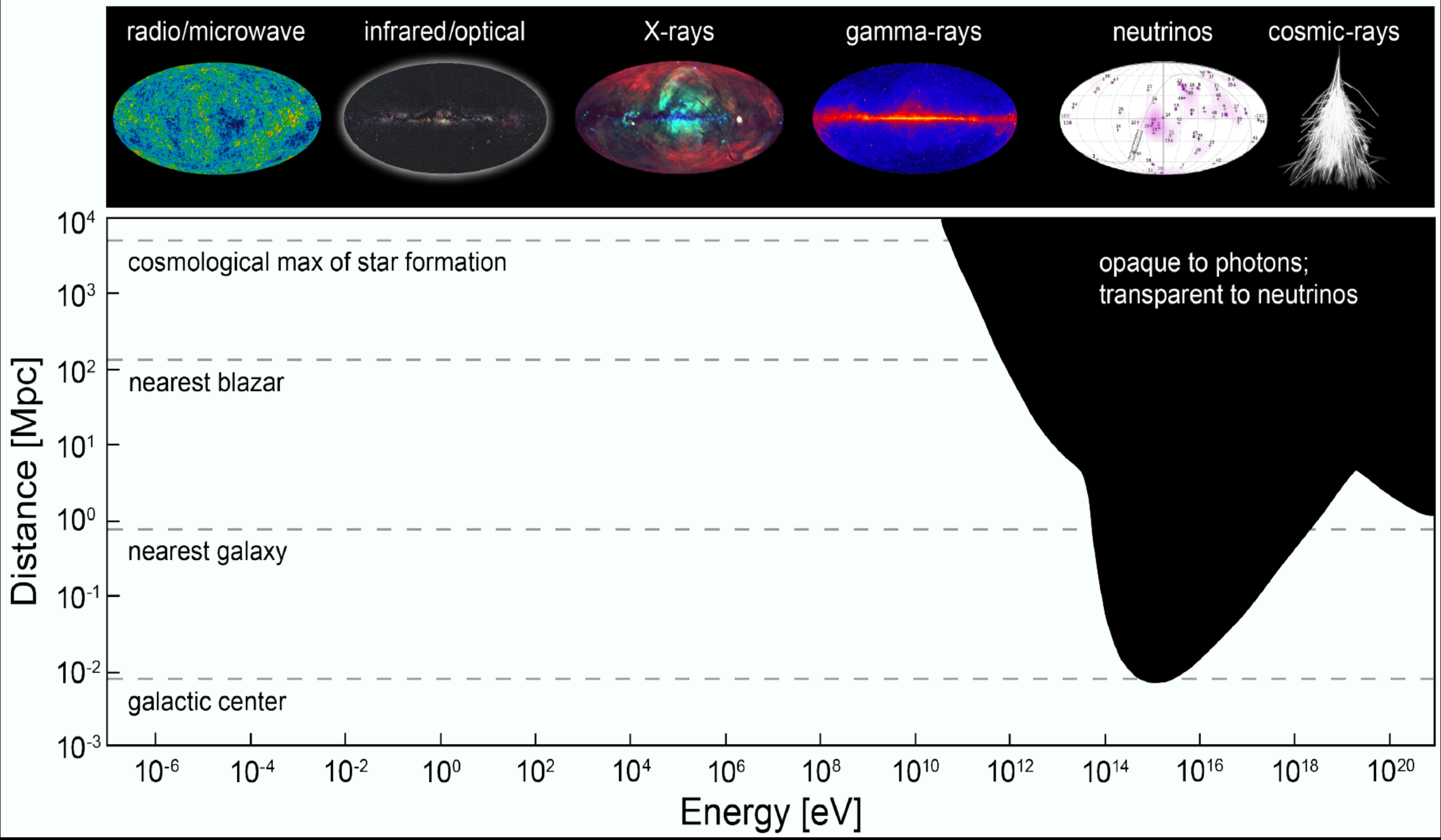
CARLSBERG FOUNDATION

Grand unified neutrino spectrum



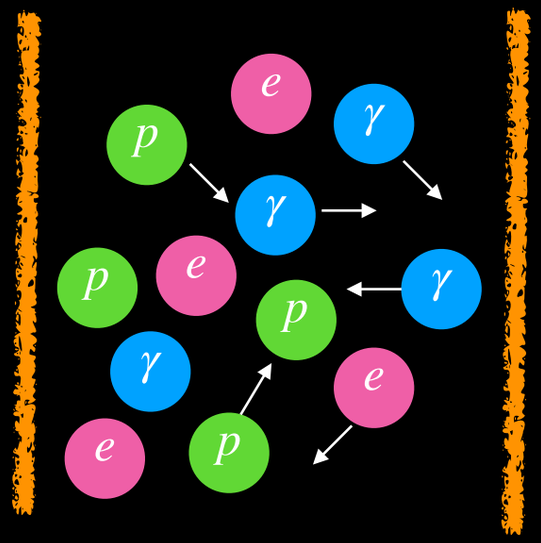
Adapted from E.Vitagliano, I.Tamborra, G.Raffelt Rev.Mod.Phys. 92 (2020)

What makes high-energy neutrinos so exciting?



6 out of 29 decades in energy (from radio waves to UHECRs) can be probed by neutrino astronomy only

How are high-energy neutrinos produced?

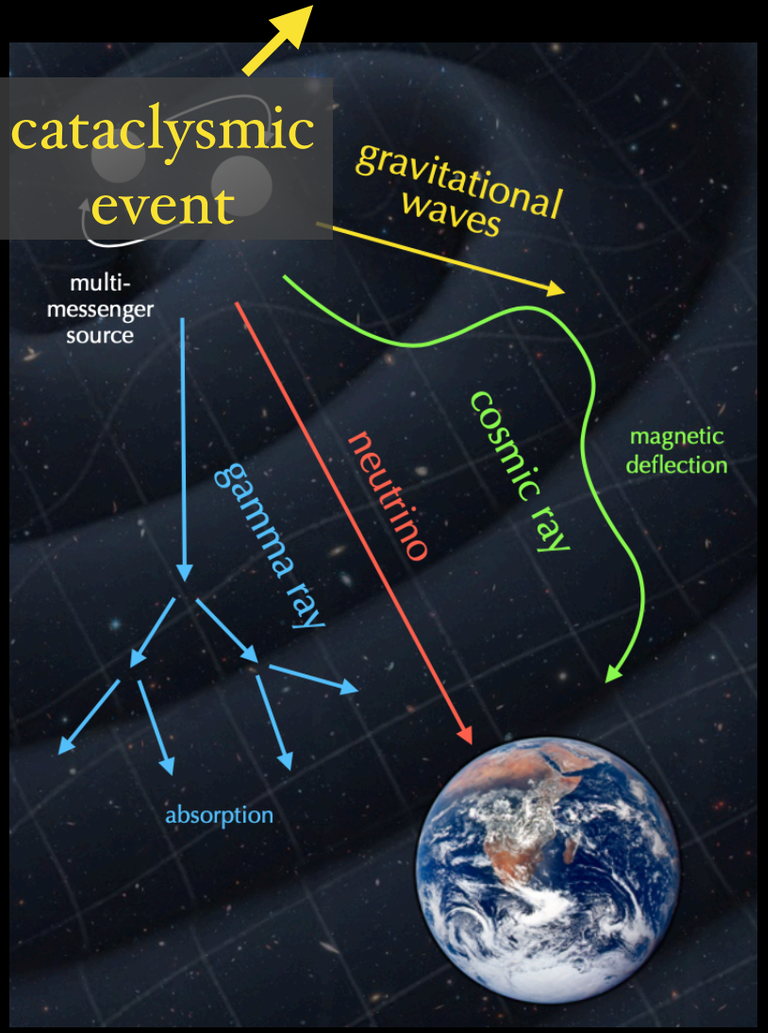


shock acceleration region

photo-hadronic: $p + \gamma$

hadronic: $p + p$

$$\longrightarrow X + \text{many}(\pi^0 + \pi^+ + \pi^-)$$



$$\pi^+ \longrightarrow \mu^+ + \nu_\mu \longrightarrow e^+ + \nu_e + \bar{\nu}_\mu + \nu_\mu$$

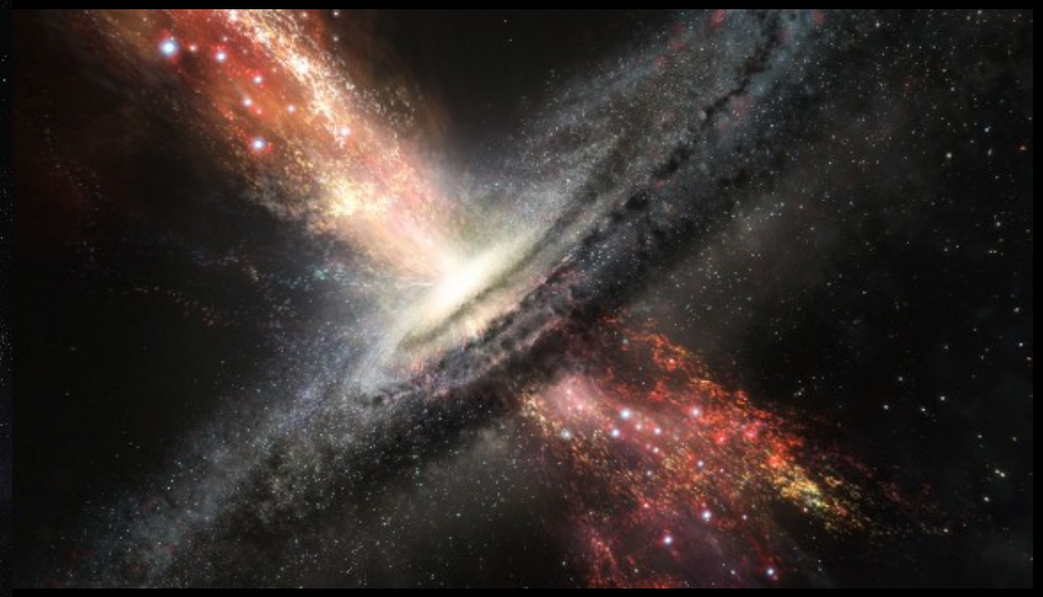
$$\pi^- \longrightarrow \mu^- + \bar{\nu}_\mu \longrightarrow e^- + \bar{\nu}_e + \nu_\mu + \bar{\nu}_\mu$$

$$\pi^0 \longrightarrow \gamma + \gamma$$

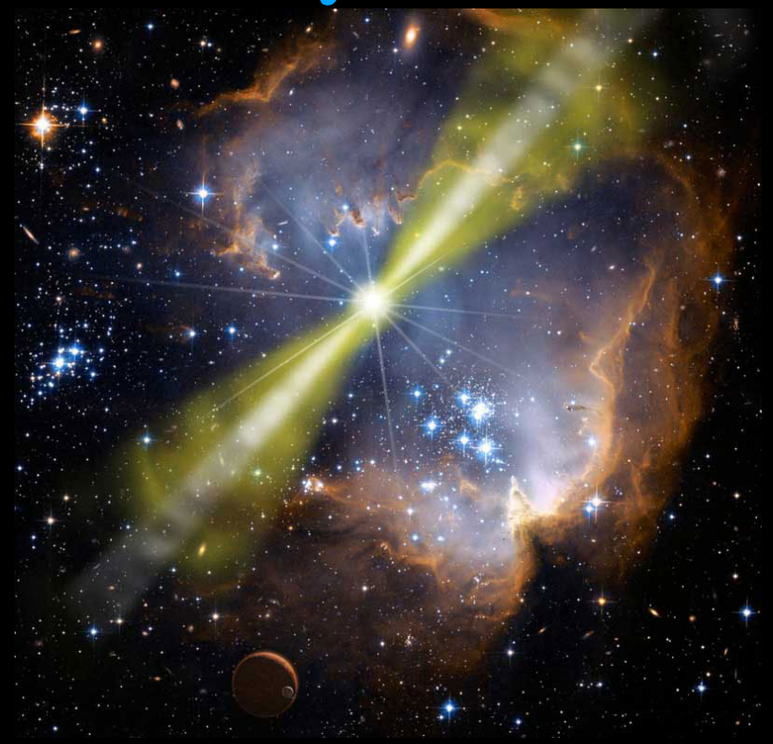
Many candidate sources

Starburst galaxies

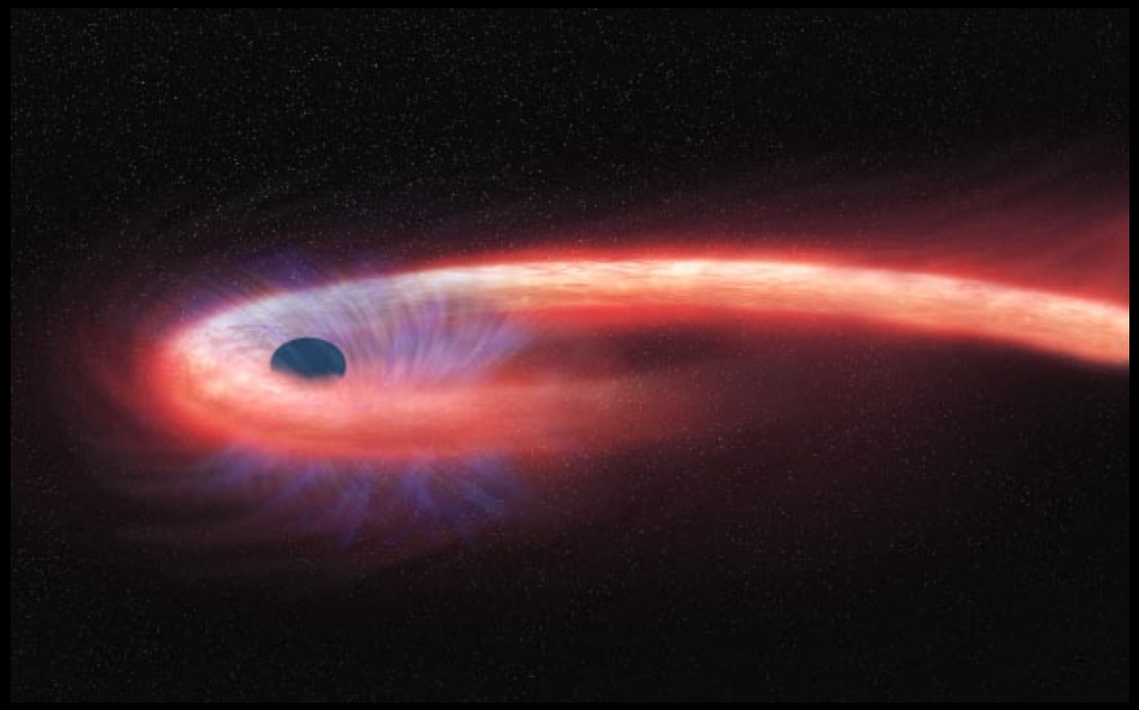
Active Galactic Nuclei



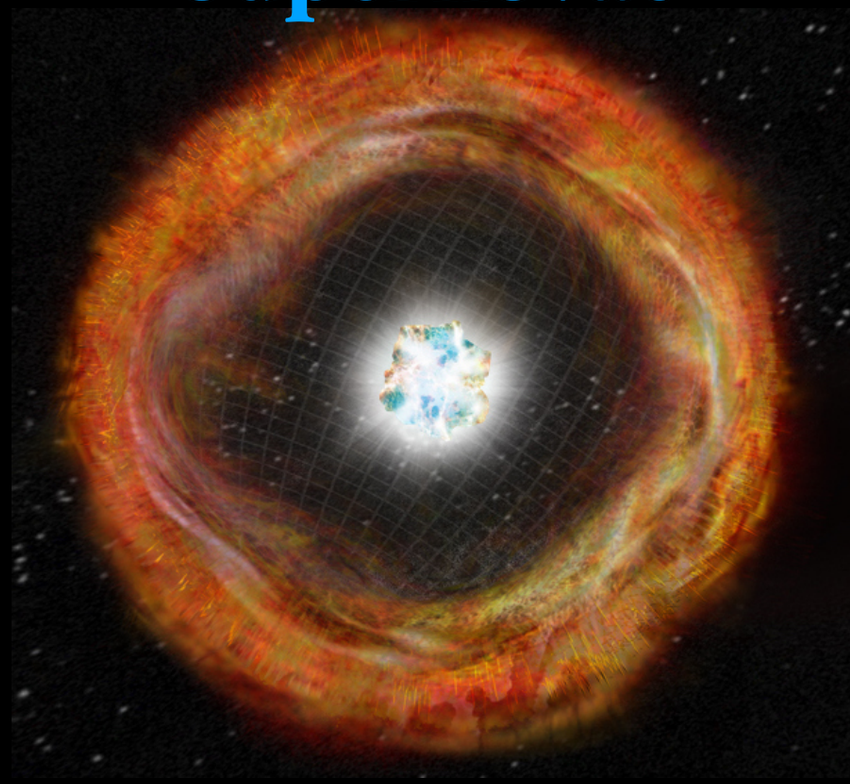
γ-ray bursts



Tidal Disruption Events



Supernovae

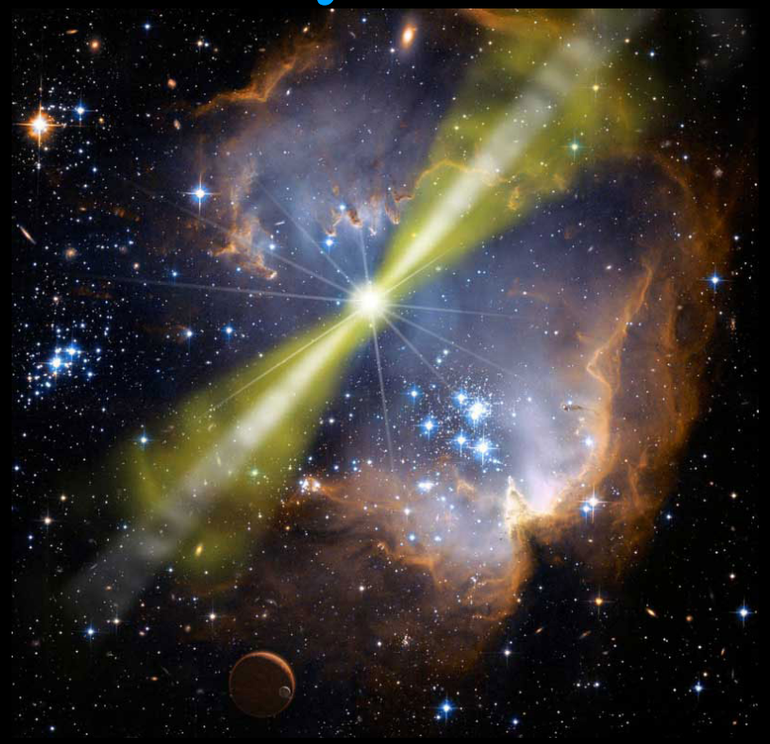


Many candidate sources

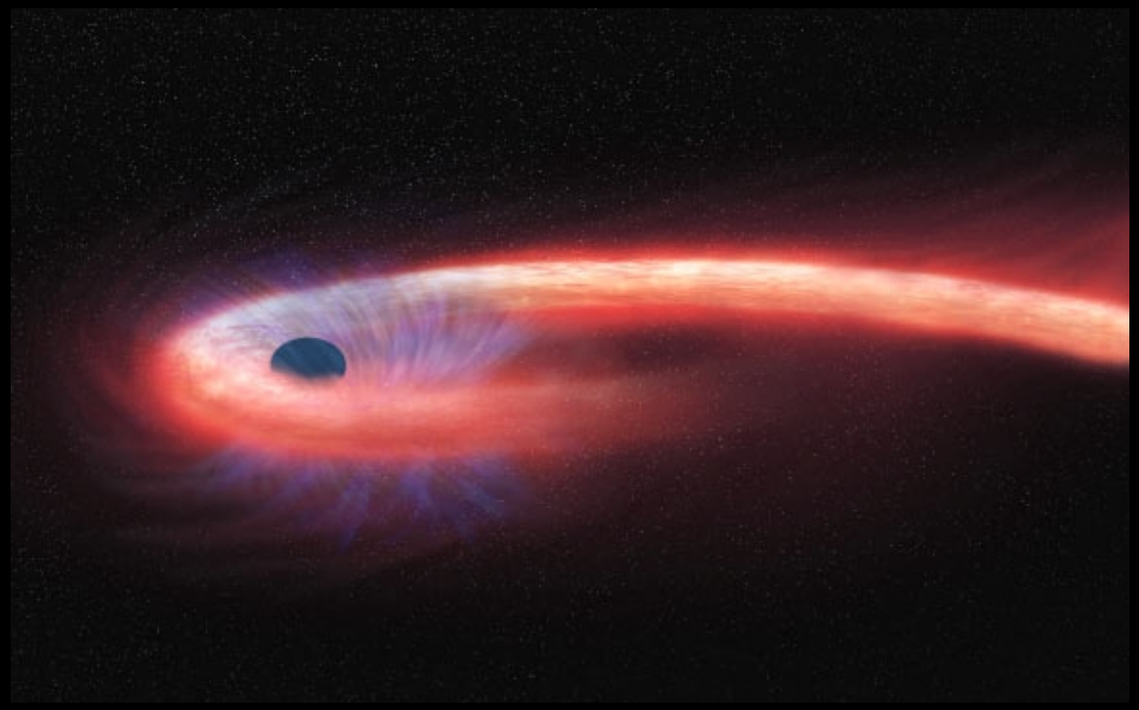
Starburst galaxies

Active Galactic Nuclei

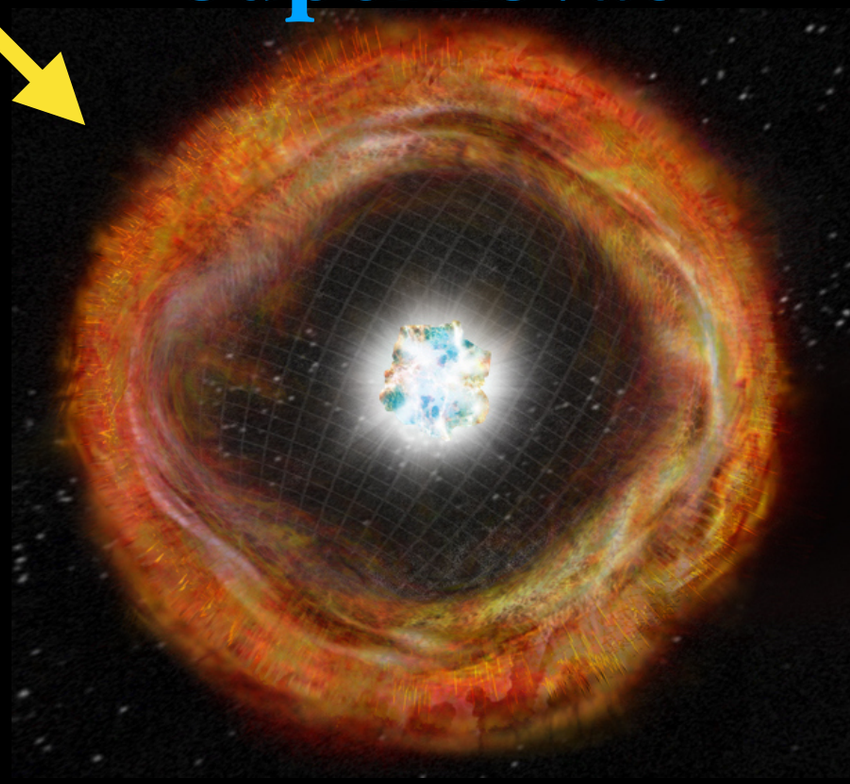
γ-ray bursts



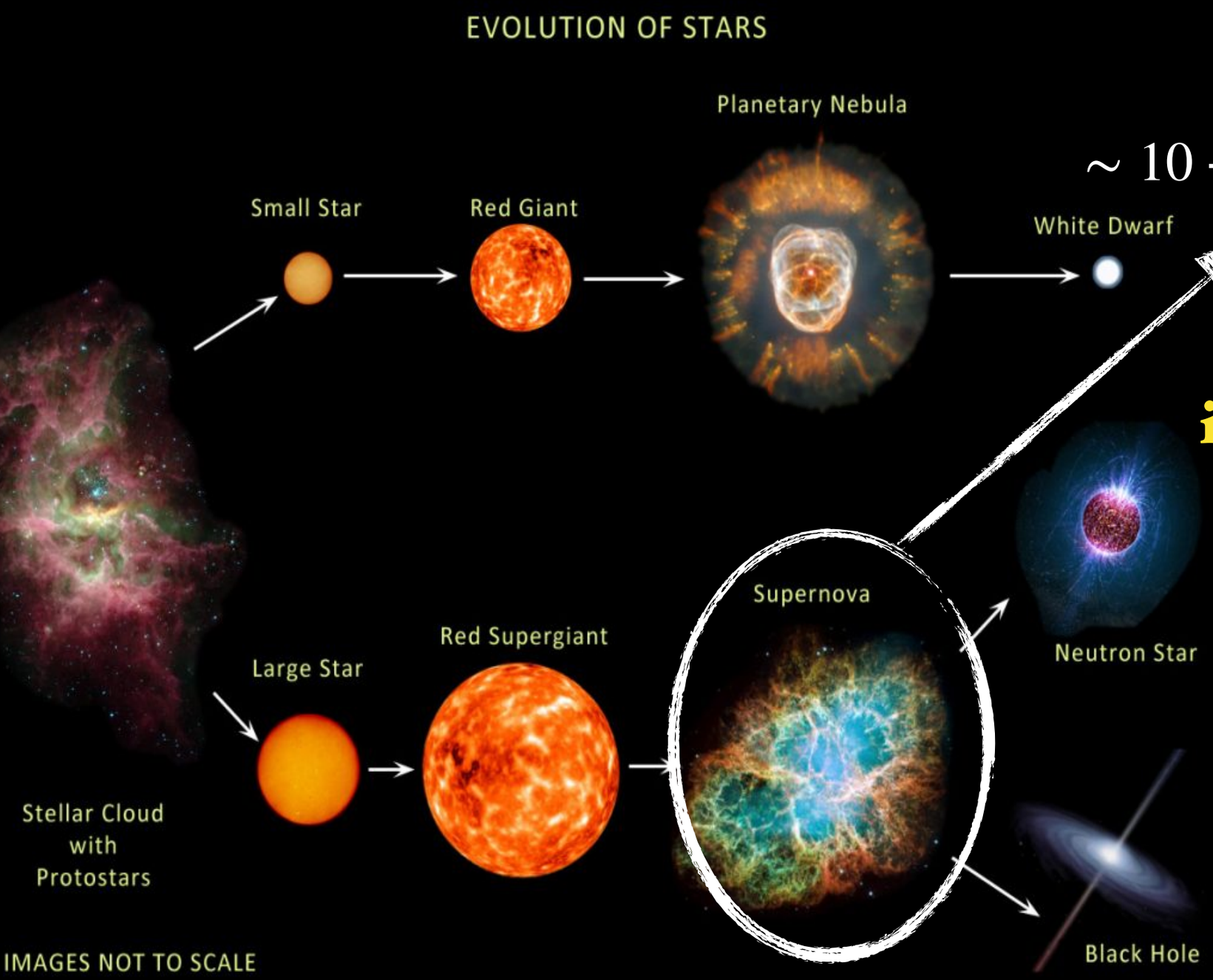
Tidal Disruption Events



Supernovae

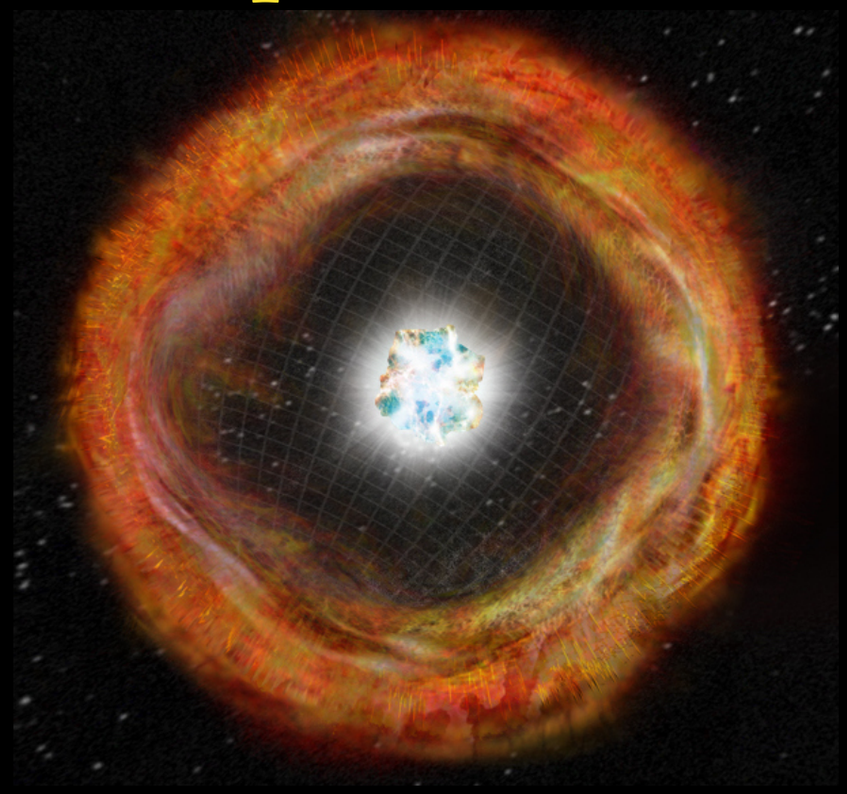


What is an interacting supernova?

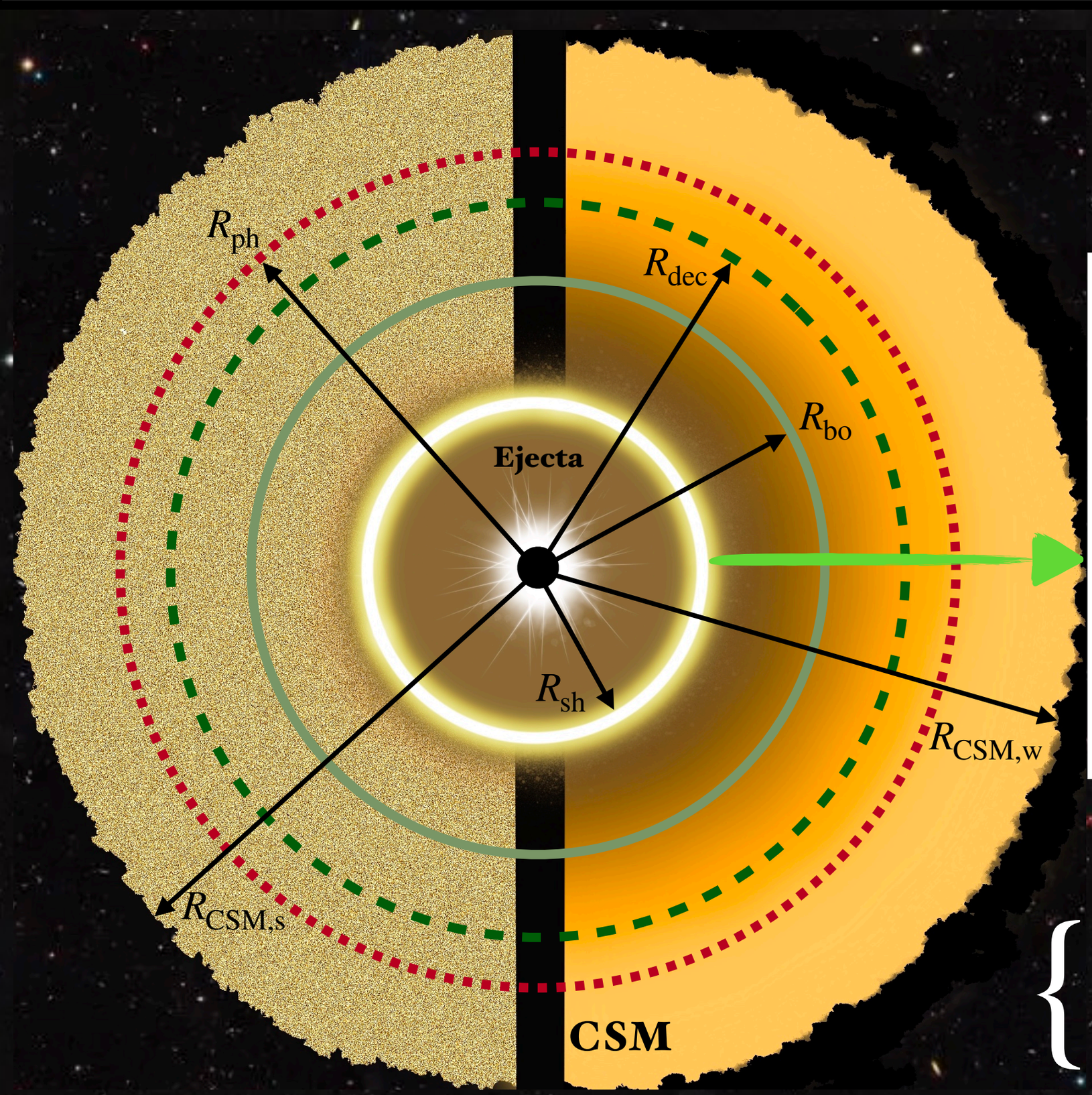


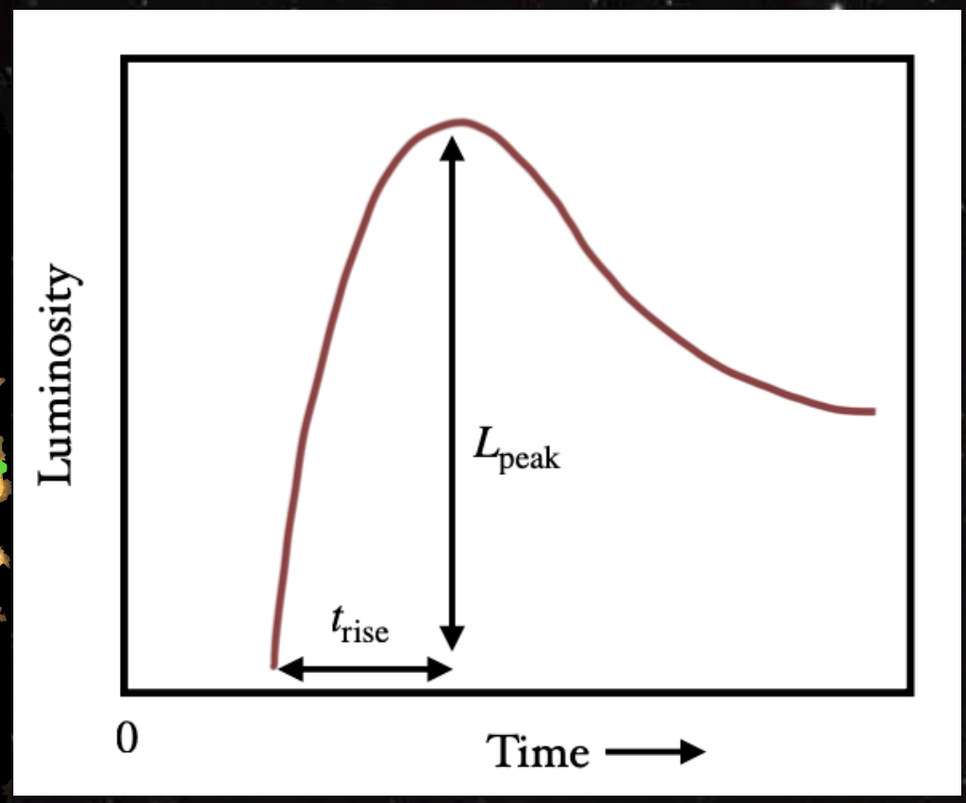
~ 10 – 100 **times brighter than typical SNe**

interaction-powered supernova



Searching for high-energy neutrinos from interacting-powered supernovae





connection?

$$\left\{ \begin{matrix} L_{\rm peak} \\ t_{\rm rise} \end{matrix} \right. \longleftrightarrow \left\{ \begin{matrix} E_{\nu,\rm max} \\ E_{\nu,\rm tot} \end{matrix} \right.$$

Neutrino production

$\forall\, E_k, M_{ej}, M_{CSM}, R_{CSM}$

1 **we solve the evolution equation for relativistic protons:**

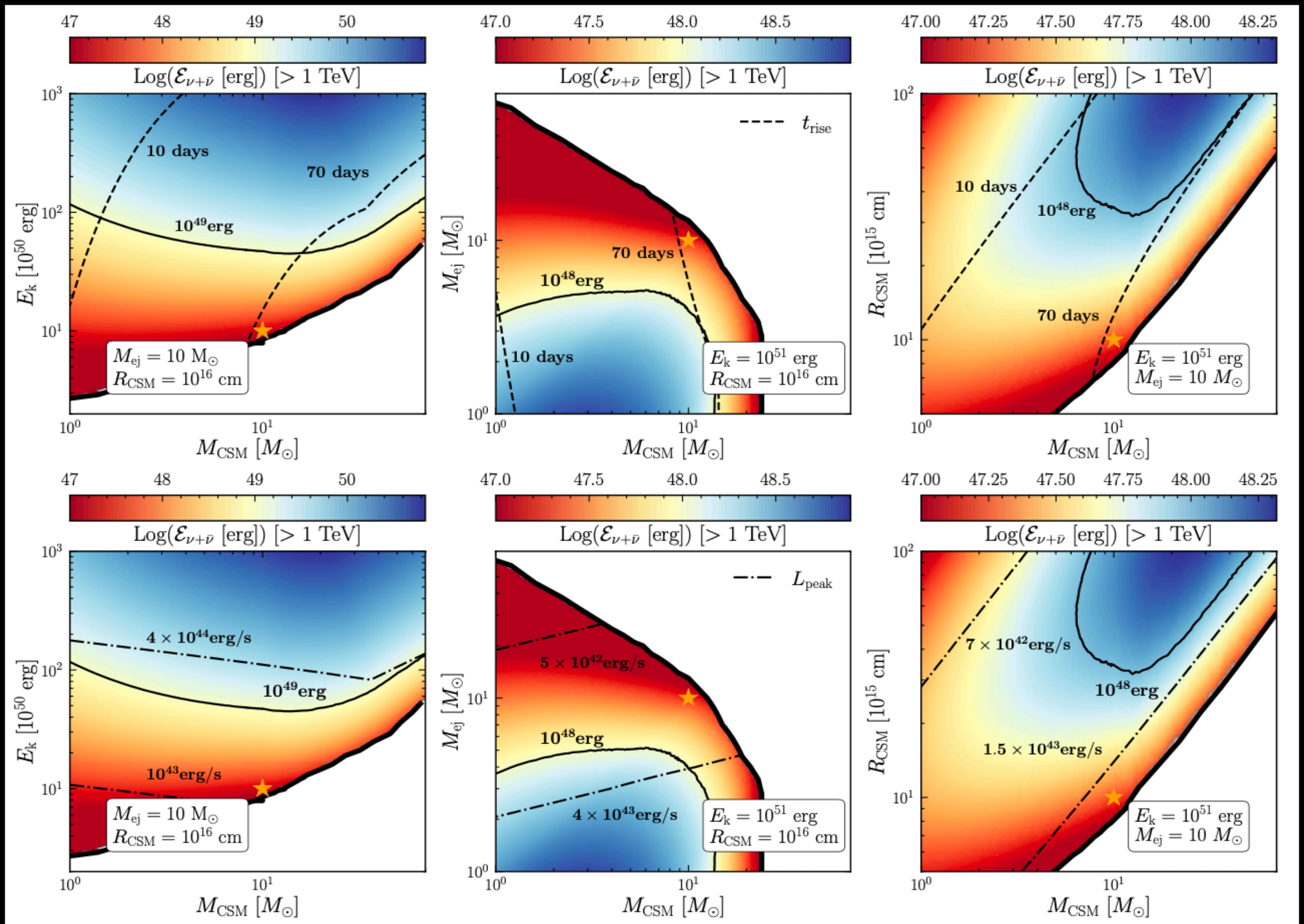
$$\frac{\partial N_p(\gamma, R)}{\partial R} - \frac{\partial}{\partial \gamma}\left[\frac{\gamma}{R} N_p(\gamma, R)\right] + \frac{N_p(\gamma, R)}{v_{sh} t_{pp}(R)} = Q_p(\gamma, R)$$

$$p + p \longrightarrow \text{many}(\pi^0 + \pi^+ + \pi^-) \longrightarrow \text{many}(\nu_e + \bar{\nu}_e + \nu_\mu + \bar{\nu}_\mu)$$

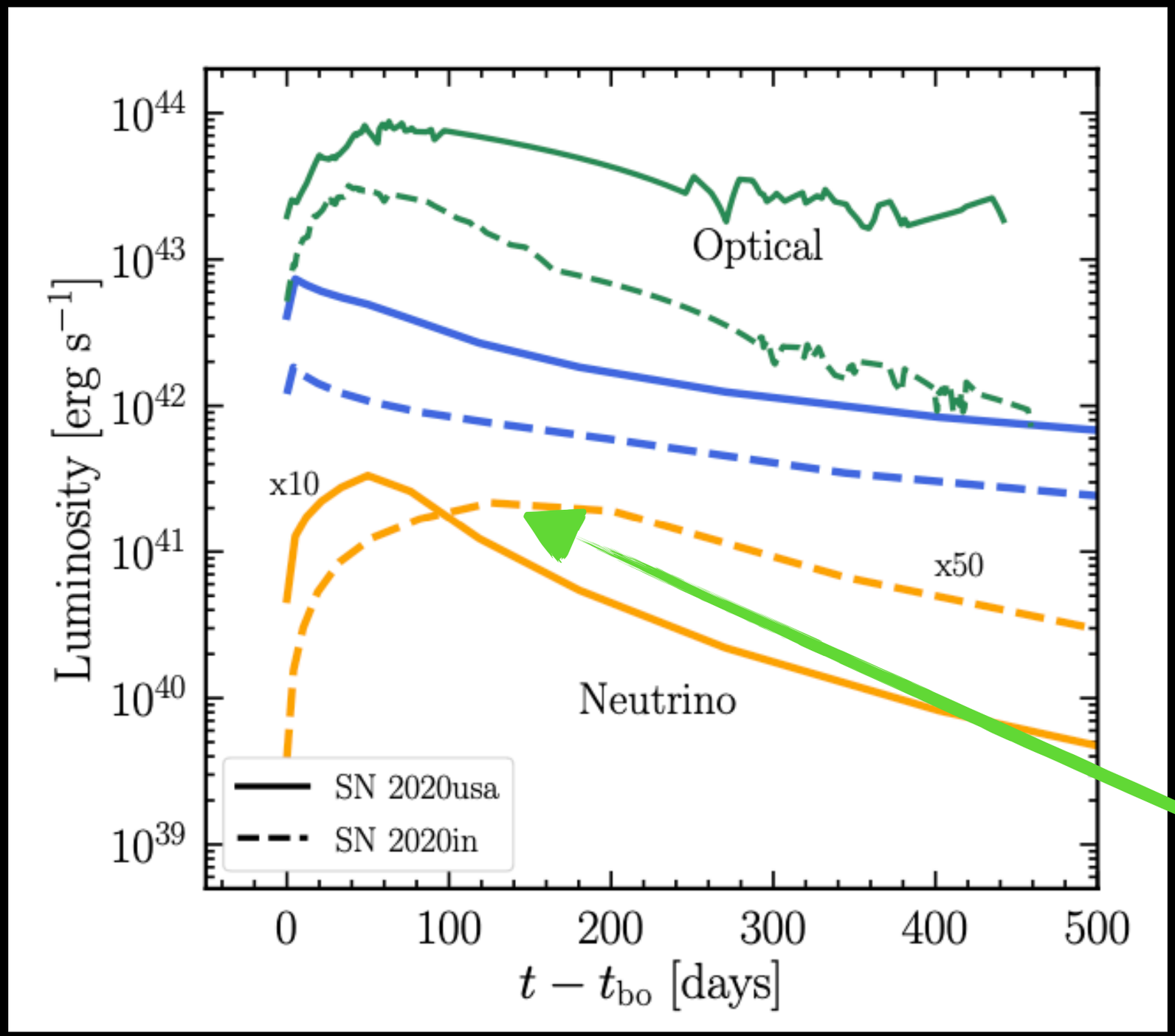
and compute the total energy that goes into neutrinos with $E_\nu \geq 1\,\text{TeV}$

2 **we estimate** t_{rise} **and** L_{peak}

Searching for high-energy neutrinos from interacting-powered supernovae



Application to two of the brightest SLSNe detected by the Zwicky Transient Facility



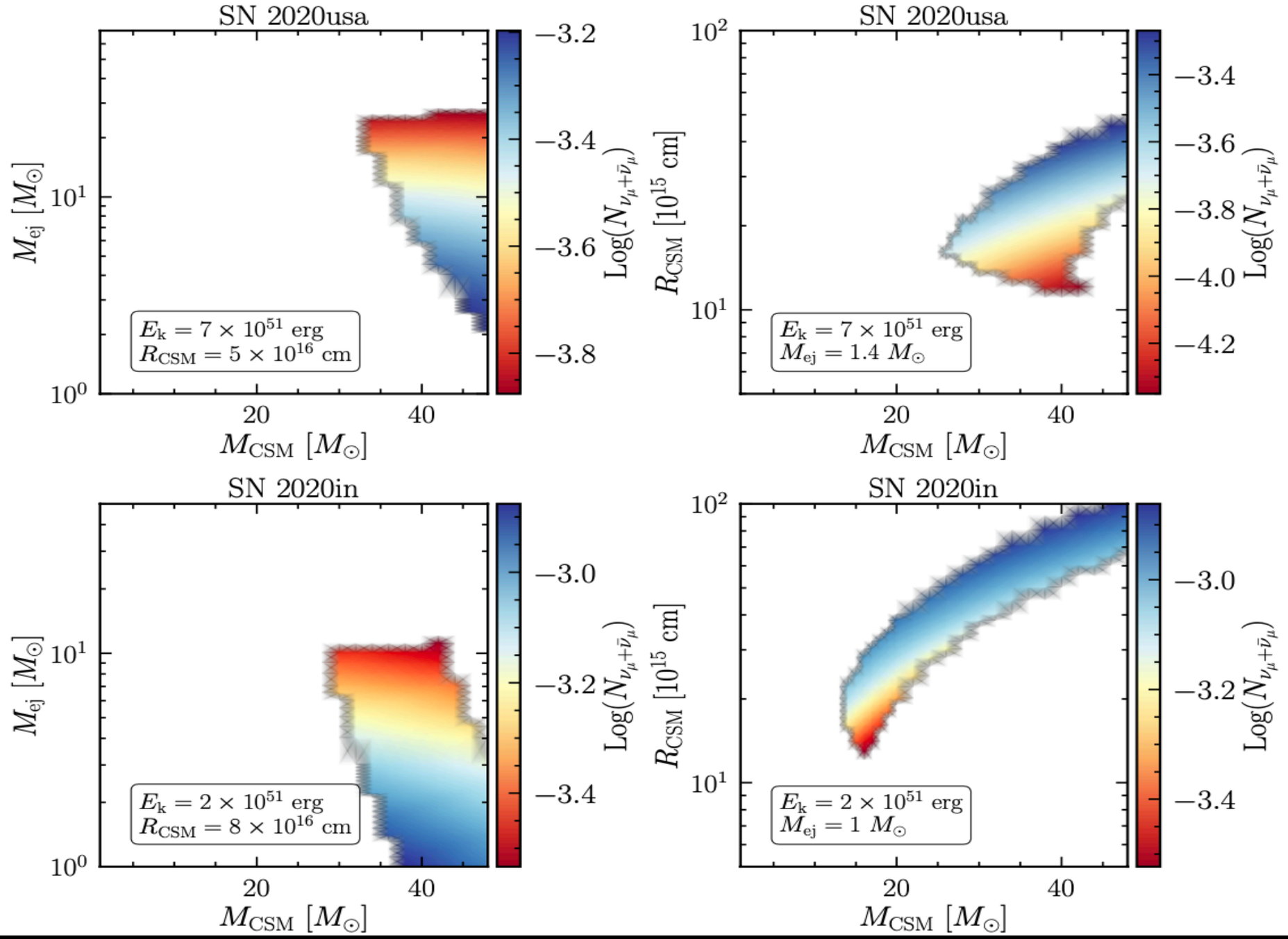
100 GeV – 100 TeV

100 TeV – 1 PeV

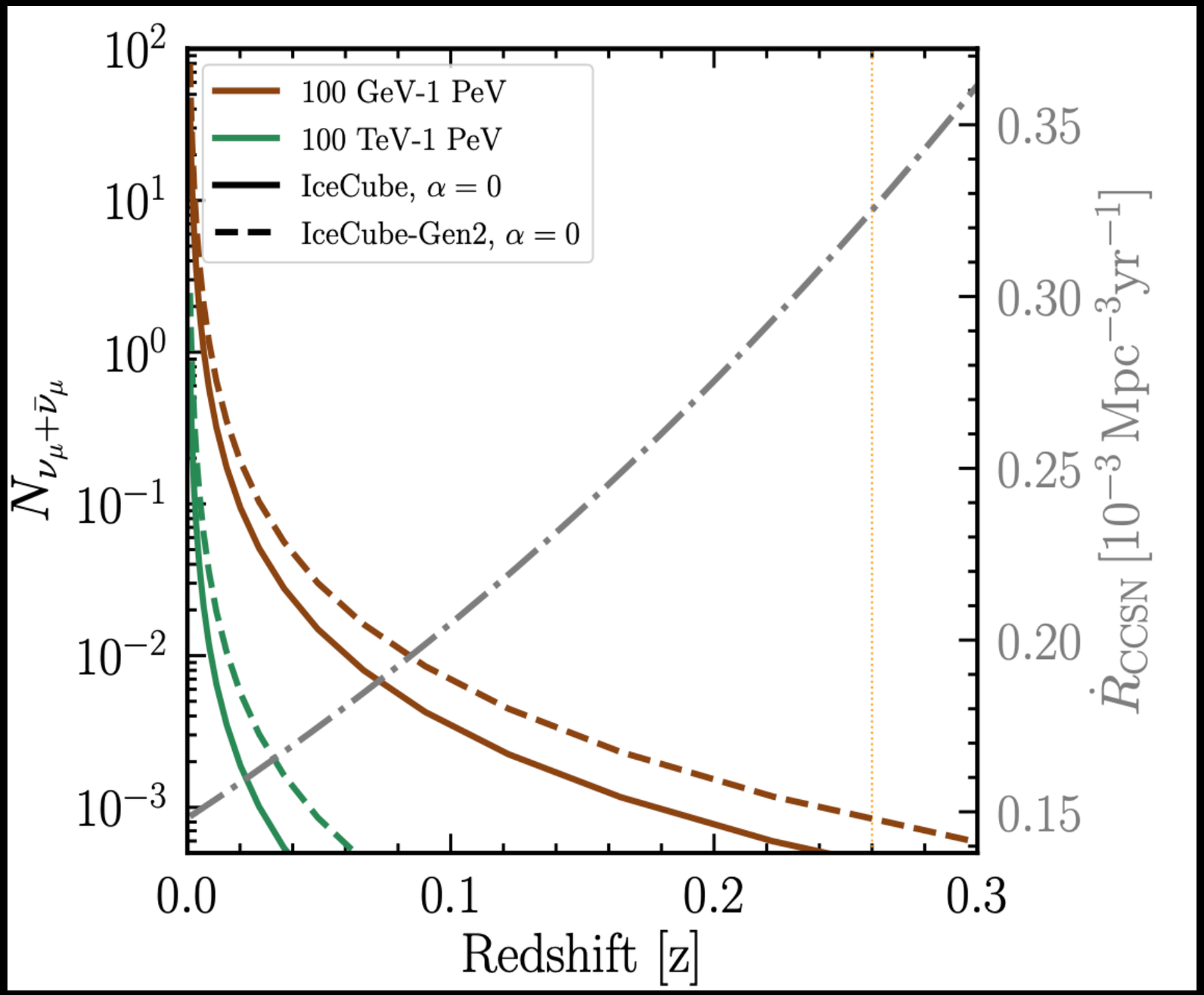
high-energy neutrino curve can have late peak with respect to $L_{\rm peak}$

Application to two of the brightest SLSNe detected by Zwicky Transient Facility

	Redshift	$t_{\rm rise,obs}$ [days]	$L_{\rm peak,obs}$ [erg s^{-1}]	$E_{\rm rad,obs}$ [erg]	$t_{\rm dur,obs}$ [days]	Declination [deg]
SN 2020usa	0.26	65	8×10^{43}	1.3×10^{51}	350	−2.3
SN 2020in	0.11	42	3×10^{43}	3.3×10^{50}	413	20.2



Expected number of neutrinos as a function of z



$N_{\nu_\mu+\bar{\nu}_\mu} \gtrsim 10$ for $d_{\rm L} \lesssim 10$ Mpc ($z \lesssim 0.002$)

Take home message

High-energy neutrinos from interacting SNe

➡ **Are efficiently produced in SNe events with:**

$L_{\rm peak} \gtrsim (10^{43} - 10^{44}) {\rm erg\ s^{-1}}$
$t_{\rm tise} \gtrsim (10 - 50)$ days → **necessary but not sufficient** → **Multiwavelenght observations are crucial**

➡ **The peak of the neutrino curve does not coincide with the optical peak. The time window in which to search should be optimized to guarantee a good signal discrimination with respect to the background.**

➡ **Point sources can be observable with high significance only for $d_{\rm L} \lesssim 10$ Mpc**

➡ **A detection would help unveil the mechanism powering SNe IIn , and constrain the SNe parameters (e.g. SLSN candidate AT2019fdr)**

Thank you !!!