Upcoming T CrB outburst: Probing Particle Acceleration in Recurrent Nova

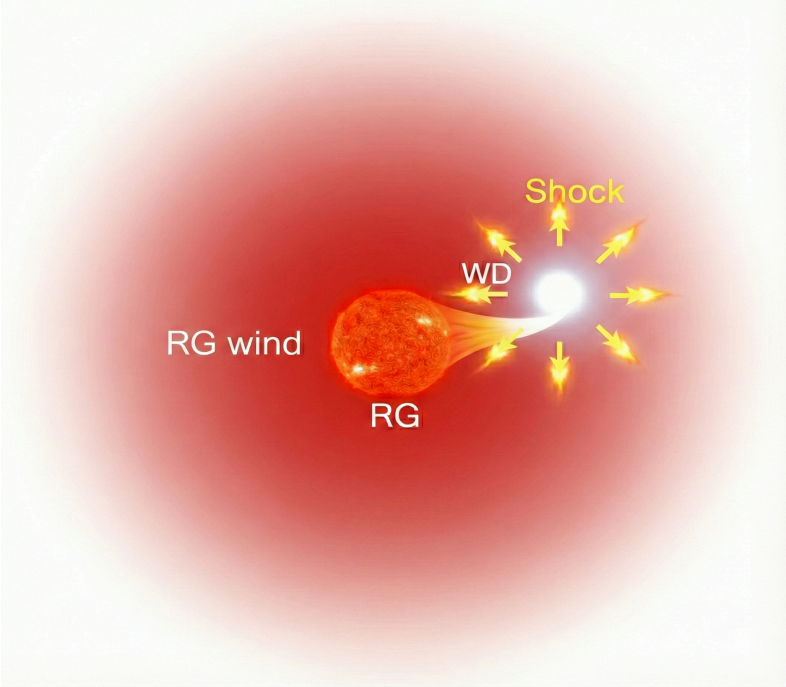


Sovan Chakraborty

PANE-26, Bodoland University

Kokrajhar, 18th November, 2026.

- **Recurrent nova**
- **T Coronae Borealis**
- **Neutrino emission models**



P. Sarmah, S. Chakraborty and X. Wang, Astrophys. J. Lett. (2026)

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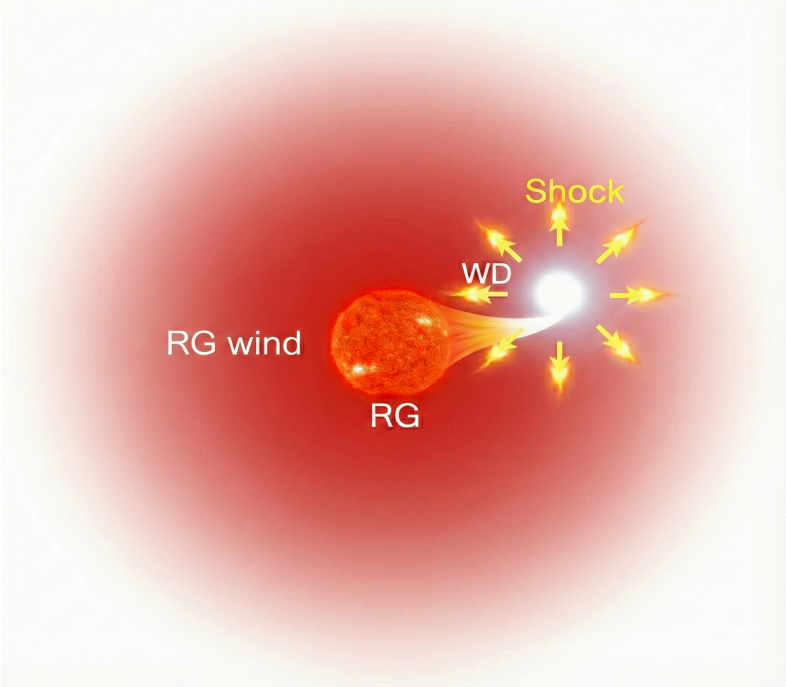

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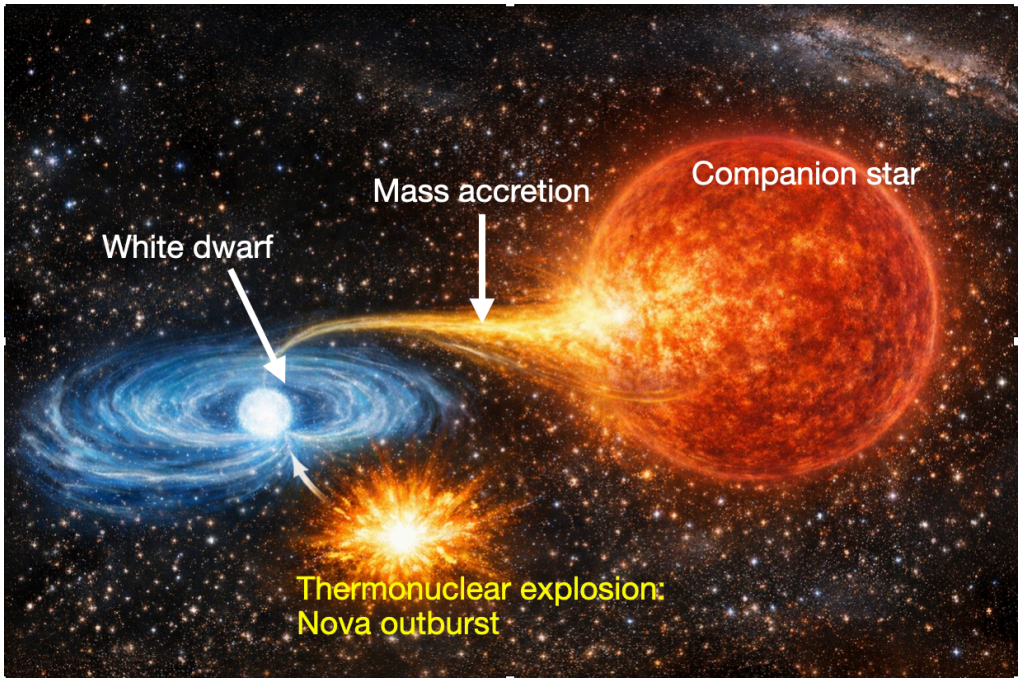
Recurrent Novae

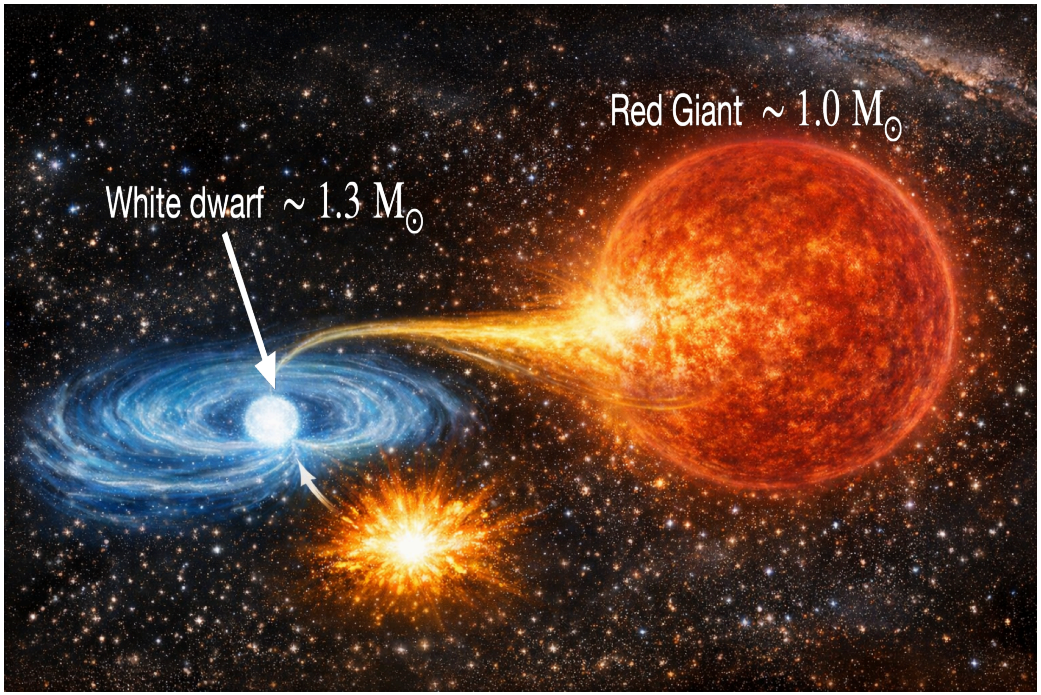
Recurrent novae:
Massive WD + Red giant (RG).
Thermonuclear burning.

Outburst cycle: 10-100 years.



Example: RS Ophiuchi, U Scorpii, V407 Cygni
& T Coronae Borealis,

Recurrent Novae: RS Ophiuchi 2021



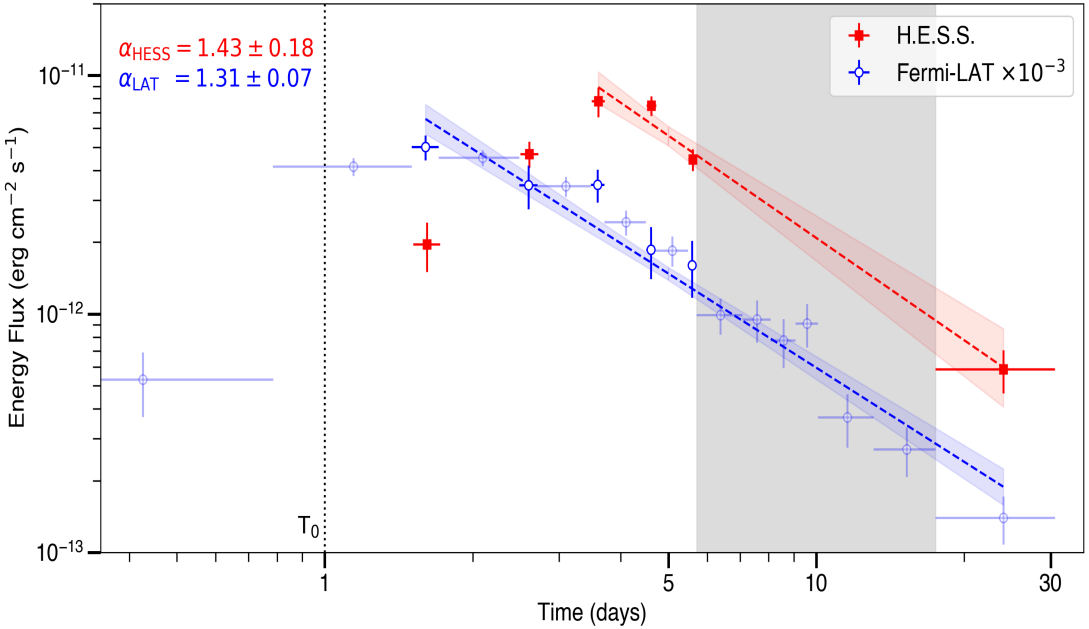
- A recurrent nova at 2.45 kpc.
- Binary separation: 2.5×10^8 Km
- Orbital period: 1.24 years.

Most recent outbursts: 2021

- Recurrence period: 15-20 years.
- Past outbursts: 2006, 1985, 1967, 1958, 1933.

Recurrent Novae: RS Ophiuchi 2021

First nova detected in TeV gamma-rays.



RS Ophiuchi 2021 outburst: TeV Gamma-rays

Detected by High Energy Stereoscopic System (HESS) in Namibia.

HESS collaboration 2022, Science, Vol 376, Issue 6588

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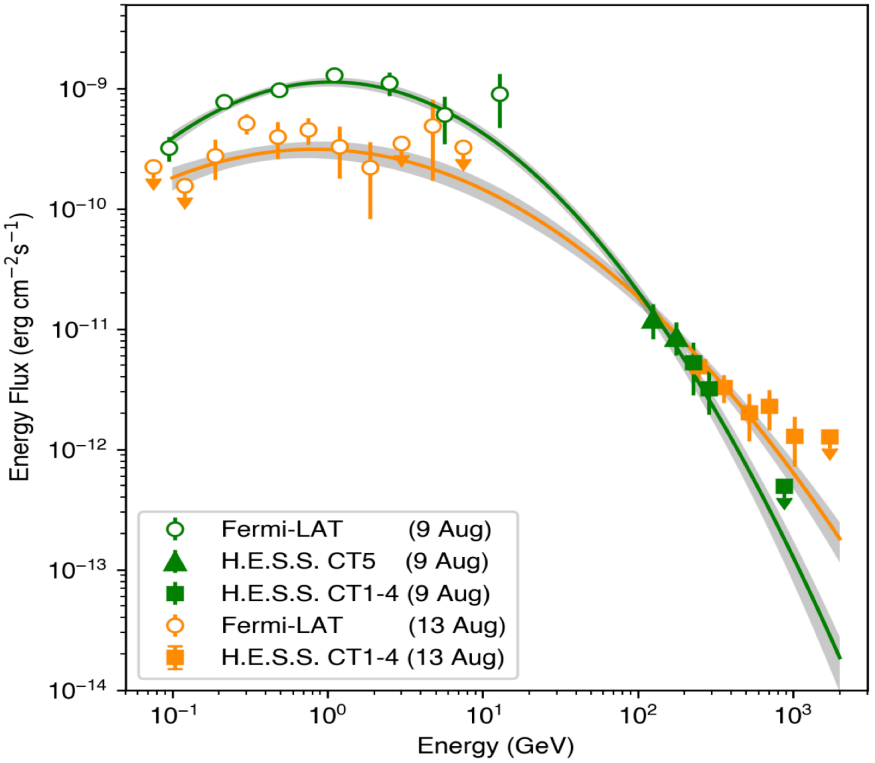

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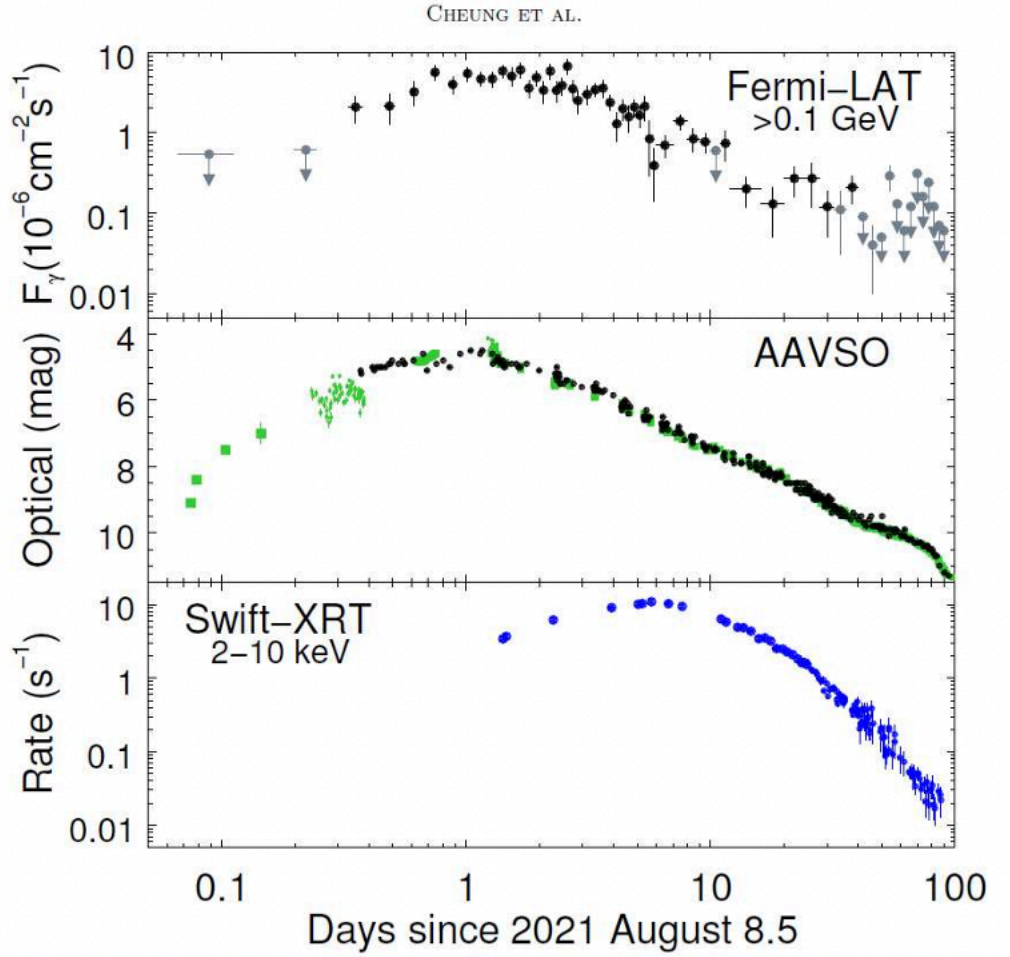

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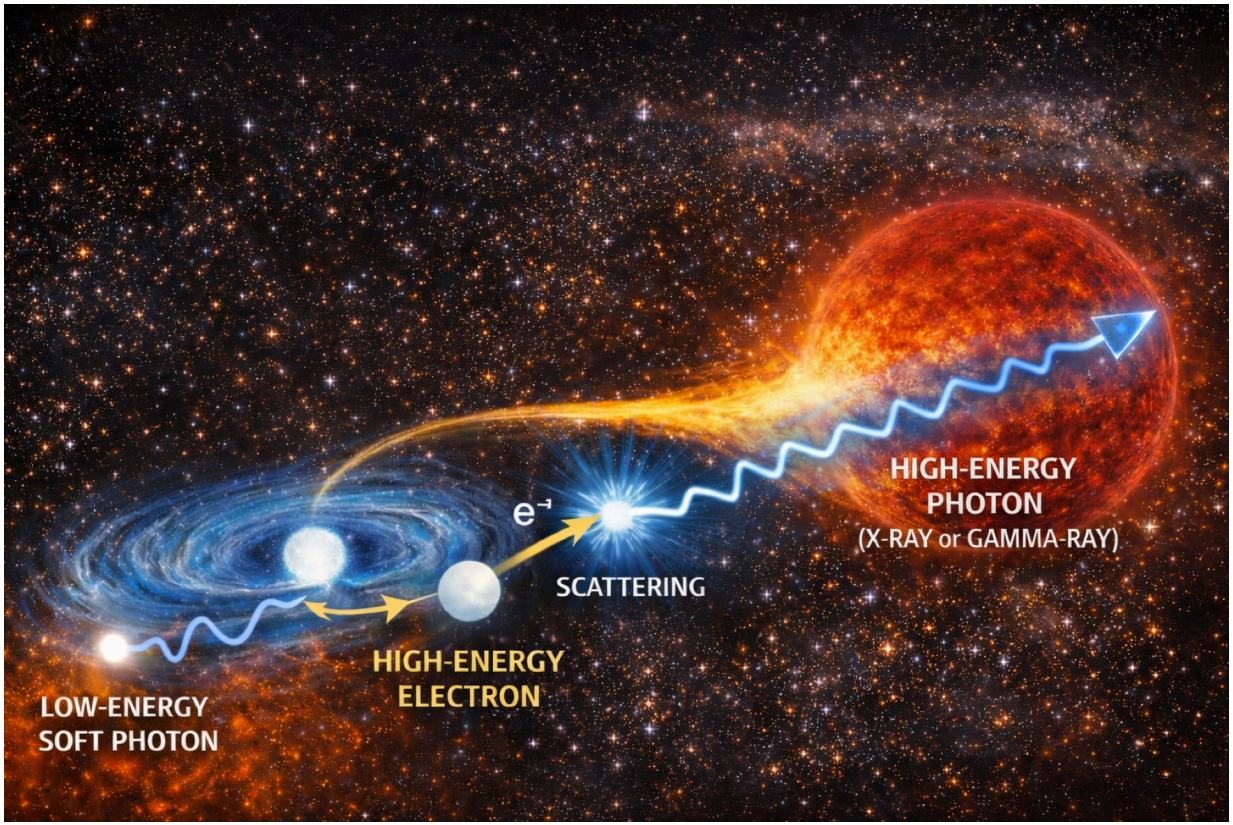
Recurrent Novae: RS Ophiuchi 2021

How are these gamma-rays created?

Leptonic: Inverse Compton scattering

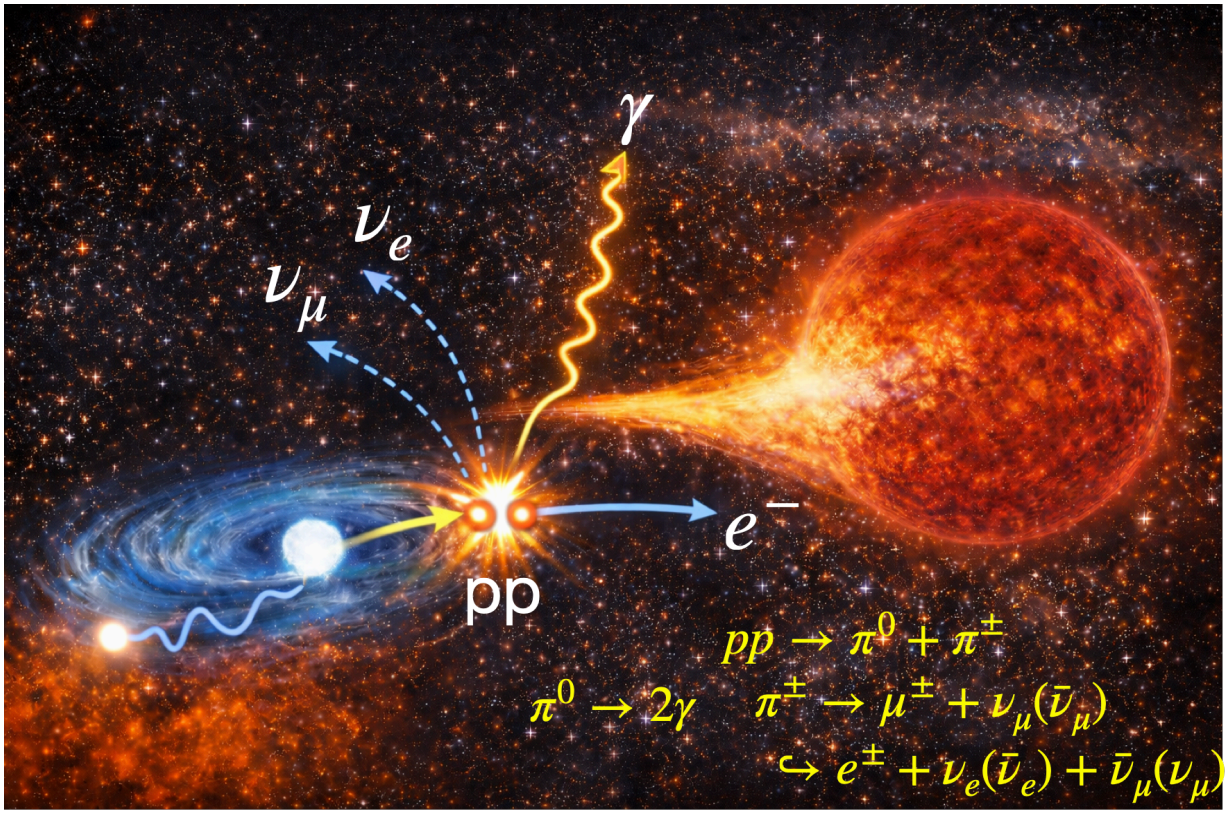


OR

Recurrent Novae: RS Ophiuchi 2021

How are these gamma-rays created?

Hadronic: proton-proton (pp) collisions.



Hadronic Process:

1) Creates HE Neutrinos,
2) IceCube is sensitive to these HE Neutrinos

Recurrent Novae: RS Ophiuchi 2021

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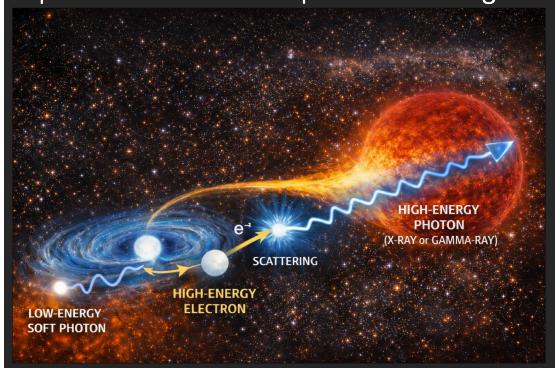

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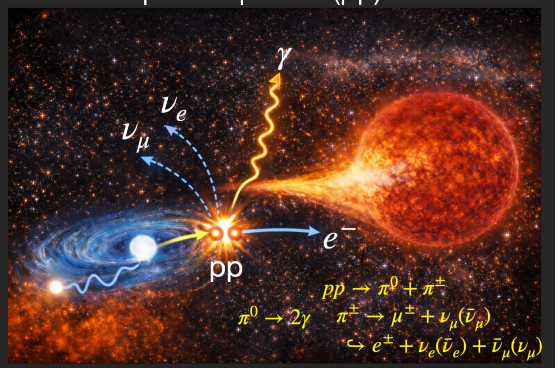


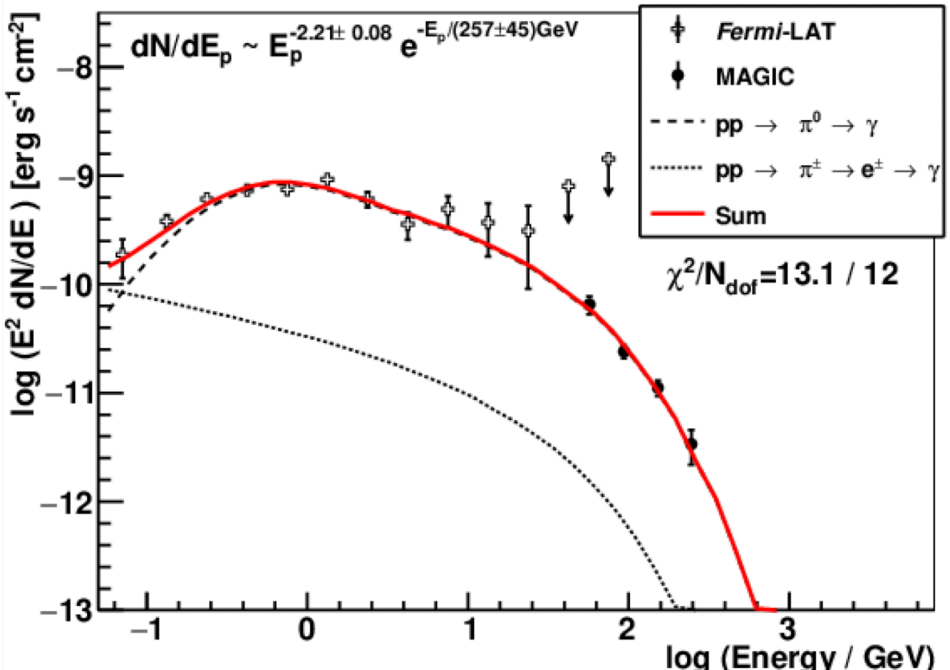
- No neutrinos were detected from RS Oph!
- The flux was below IceCube's sensitivity!

Acciari et. al. 2022

TeV Gamma Ray Detected by Major Atmospheric Gamma Imaging Cherenkov telescope (MAGIC)

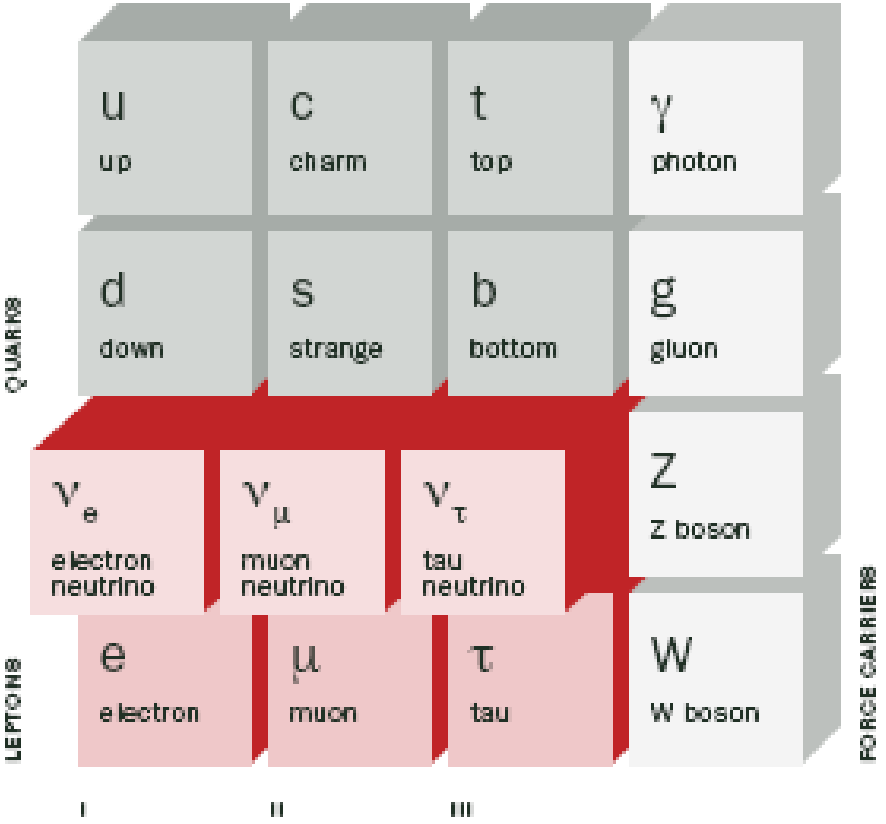
Fits very well with hadronic Gamma Processes

What about the HE Neutrinos?



HE Neutrinos in Astrophysics

- **Spin ½**
- **Chargeless:** No bending in magnetic fields → Points back to the source
- **Weakly interacting:** Minimal scattering → Arrive from regions opaque to light
- **Almost massless**



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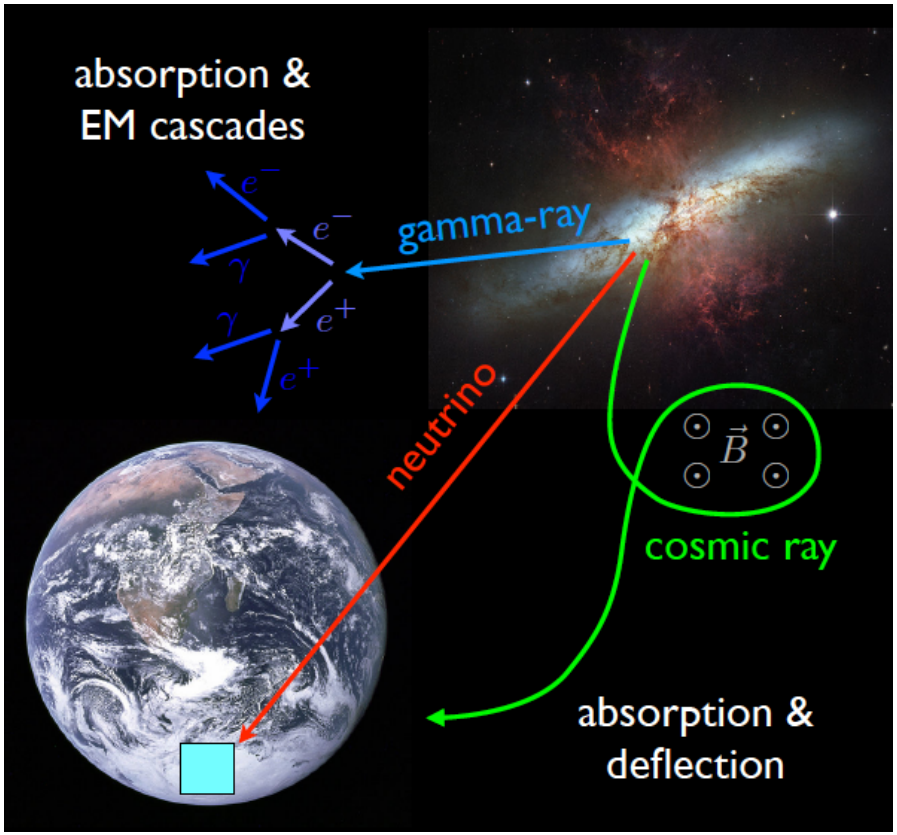
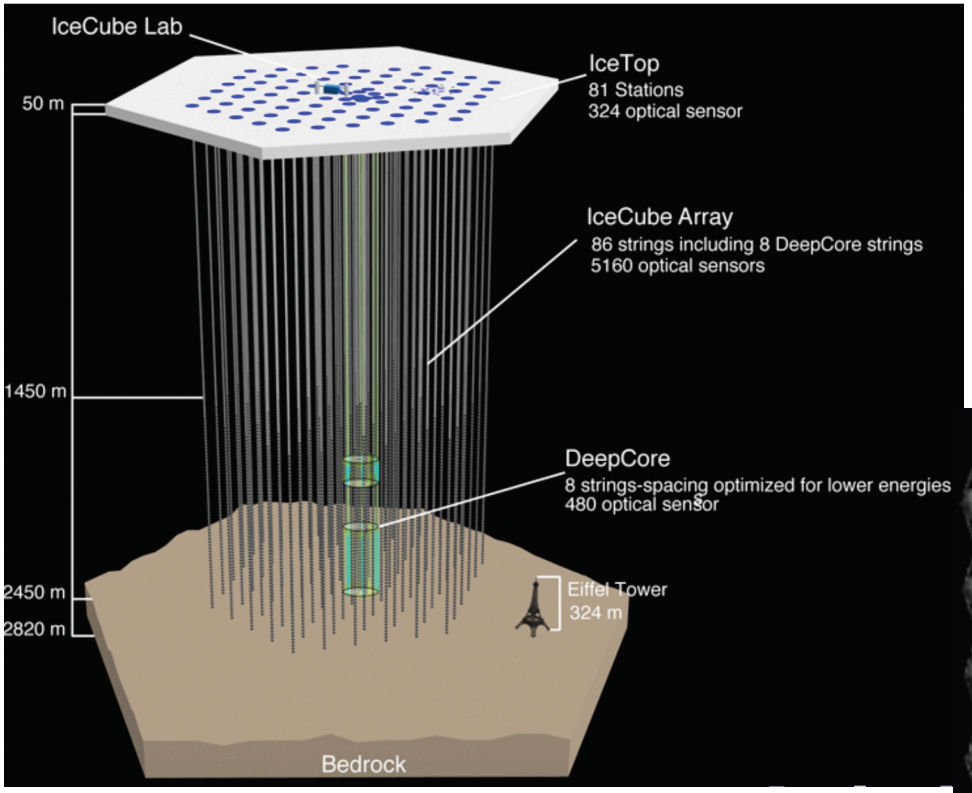


Excellent Astronomical Messenger!!

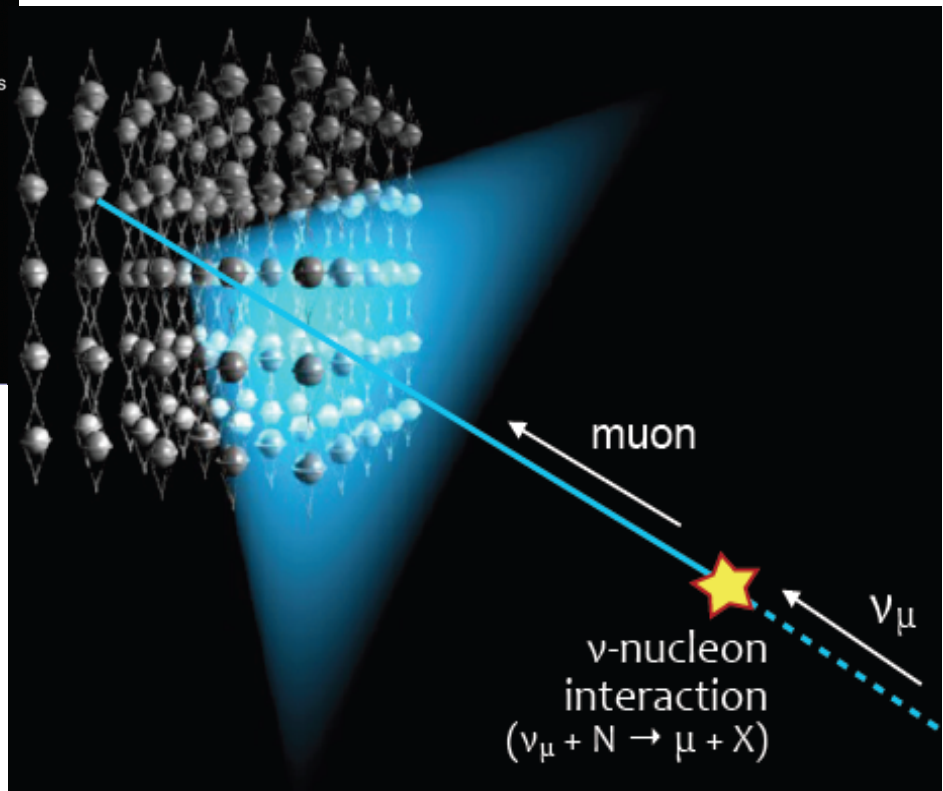
Neutrino Telescopes: IceCube

Ultra high energy Neutrino Detector: IceCube



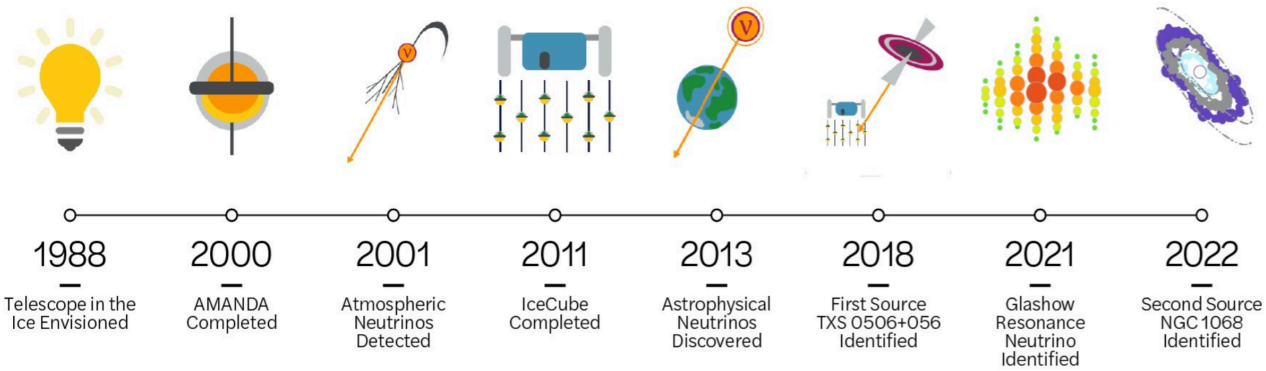
$$(\nu_\mu + N \rightarrow \mu + X)$$

Charged lepton Cherenkov light illuminates the photomultipliers



IceCube & Neutrino Timeline

A History of Neutrino Astronomy in Antarctica



1988 — Telescope in the Ice Envisioned

2000 — AMANDA Completed

2001 — Atmospheric Neutrinos Detected

2011 — IceCube Completed

2013 — Astrophysical Neutrinos Discovered

2018 — First Source TXS 0506+056 Identified

2021 — Glashow Resonance Neutrino Identified

2022 — Second Source NGC 1068 Identified

2026

Francis Halzen

Conceived and designed the IceCube Neutrino Observatory at the South Pole, and discovered high-energy cosmic neutrinos from deep space.



Francis Halzen won this year's Nobel Prize in physics for his vision and leadership in establishing the IceCube Neutrino Observatory in Antarctica, which discovered high-energy neutrinos from beyond the solar system.

Recurrent Novae: RS Ophiuchi 2021

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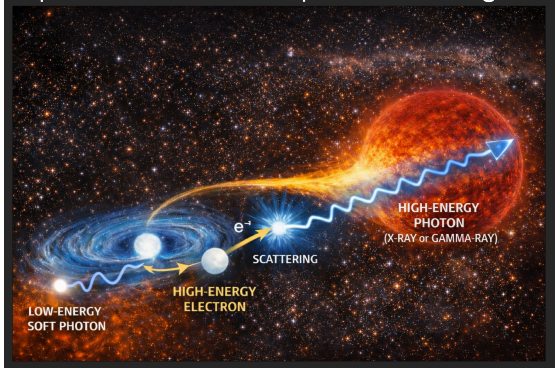

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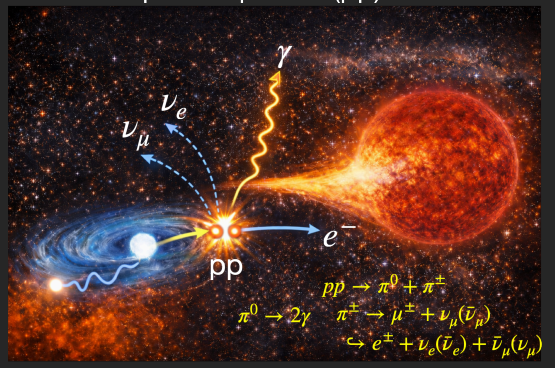


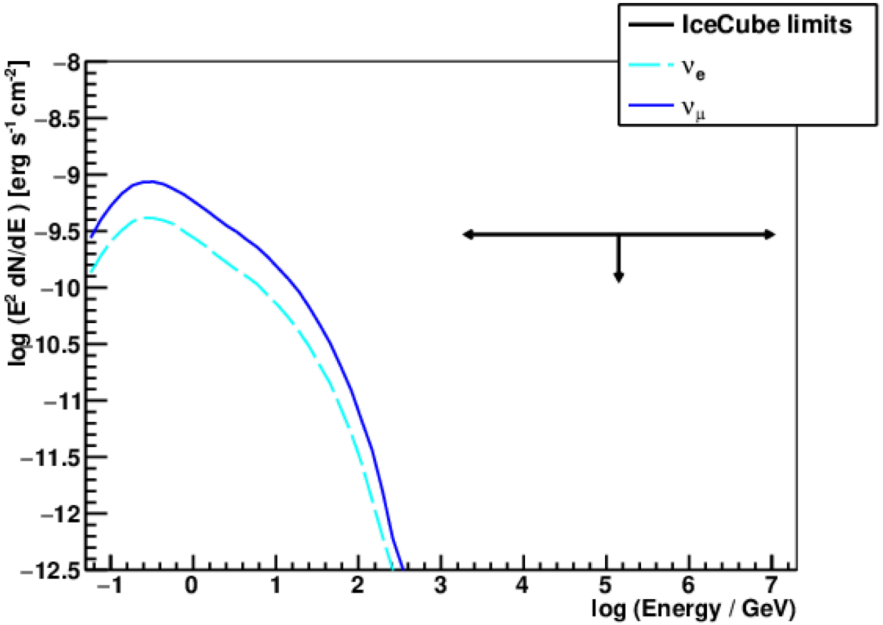
- No neutrinos were detected from RS Oph!
- The flux was below IceCube's sensitivity!

Acciari et. al. 2022

What about the HE Neutrinos?

No neutrinos detected from RS Oph 2021

What about future such Novae?



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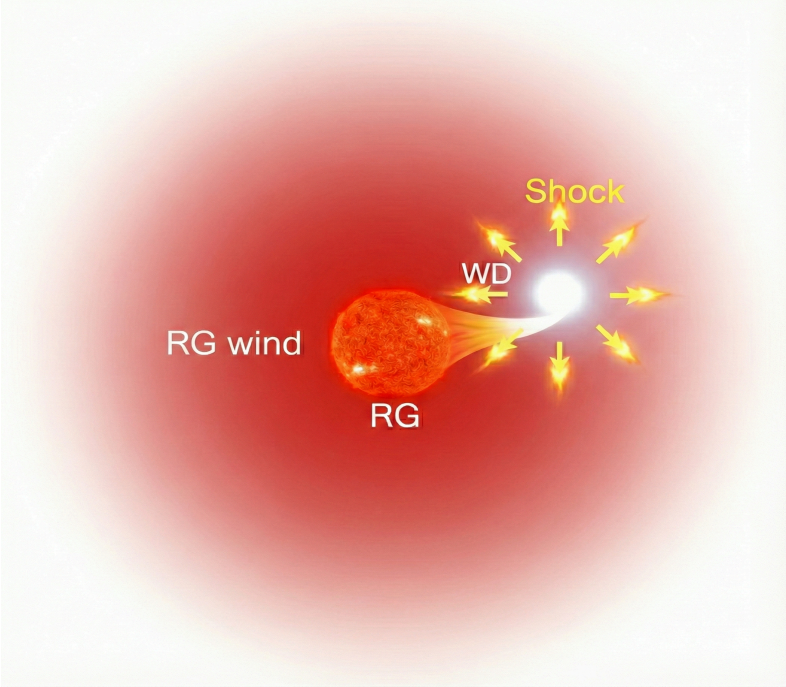


P. Sarmah, S. Chakraborty and X. Wang, Astrophys. J. Lett. (2026)

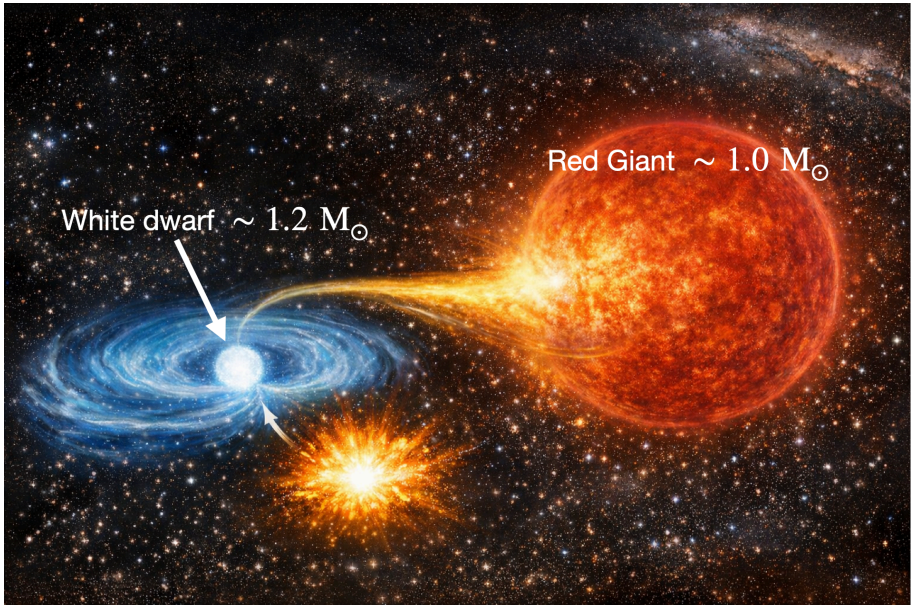
Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)

- Distance ~ 900 pc (3200 lys).
- Binary separation: 2.5×10^8 Km
- Orbital period: 0.62 years.

- Recurrence period: 80 years.
  Past outbursts: 1866 and 1946.

Did it emit High energy neutrinos and Gamma-rays in 1866 and 1946?

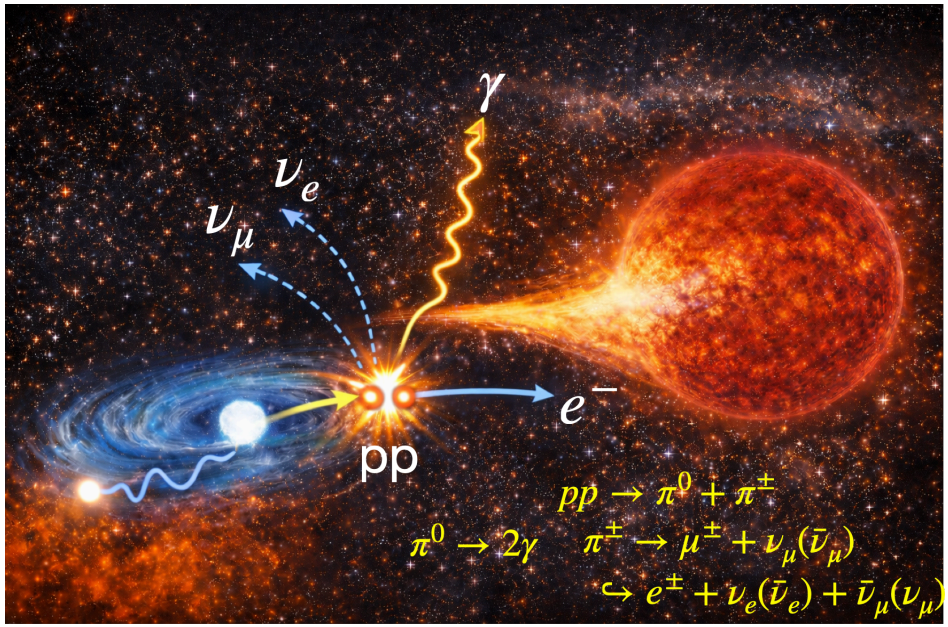


T CrB (0.9 kpc) closer than RS (2.45 kpc) Ophiuchi.
T CrB 1946 was **10 times** optically brighter than RS Ophiuchi 2021.

Will we observe T CrB in neutrinos at IceCube?

HE Neutrinos: T CrB 202X

Hadronic: proton-proton (pp) collisions: Accelerated Protons Collide



How are these protons accelerated?

- External shock (ES): Protons are accelerated by nova shock.

Or/And

- Magnetic reconnection (MR): Protons are accelerated by strong magnetic field .

Recurrent Novae: T CrB 202X

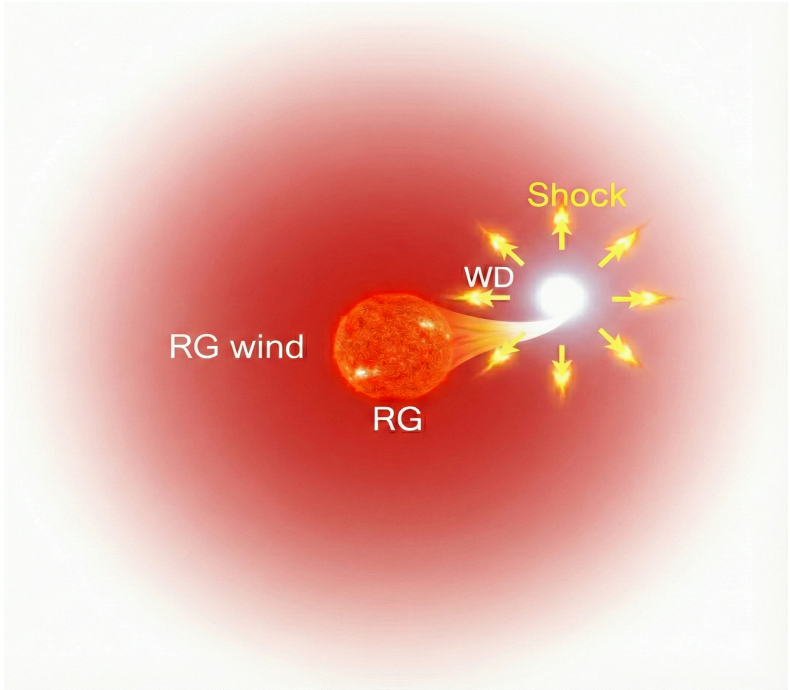
How are these protons accelerated?

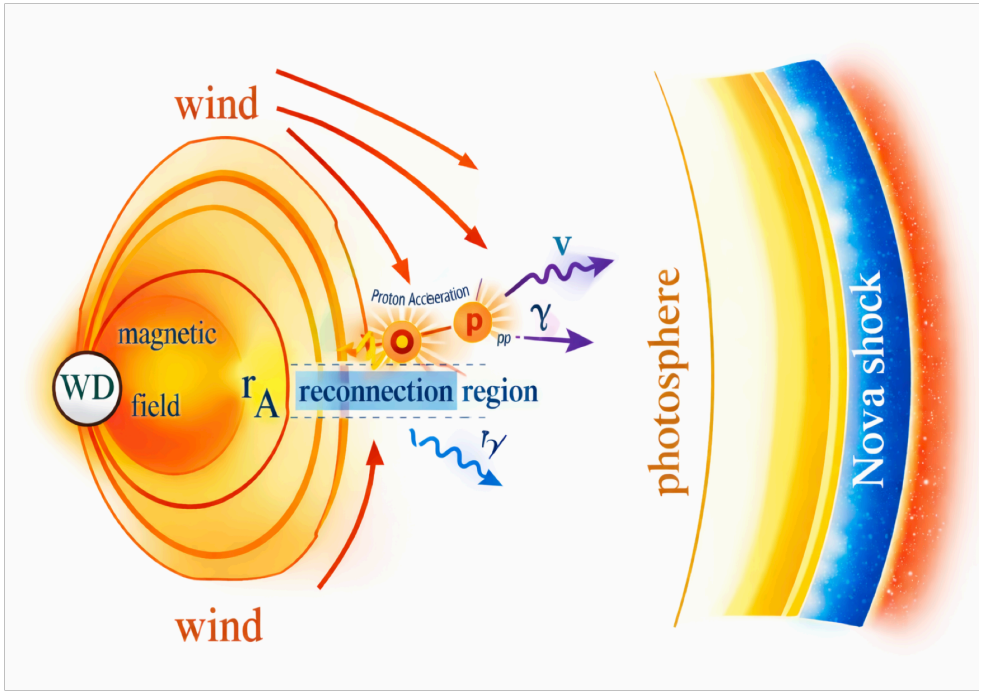
External shock (ES) :

- Protons accelerated by nova shock.
- Far from WD ~ 10^8 km.
- Both neutrinos and gamma-rays escape.

Magnetic reconnection (MR) :

- Protons accelerated by strong mag field.
- Close to WD ~ 10^4 km.
- Only neutrinos escape.





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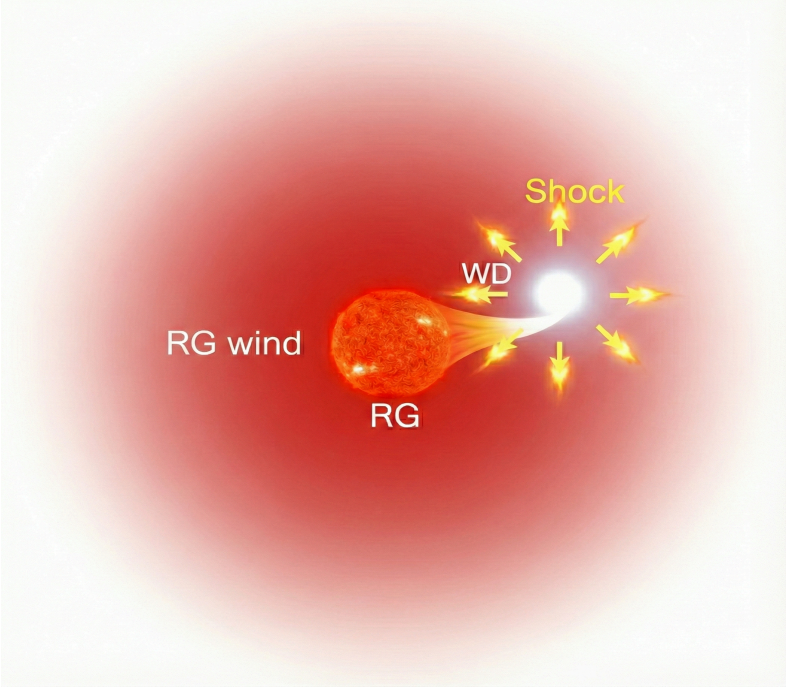
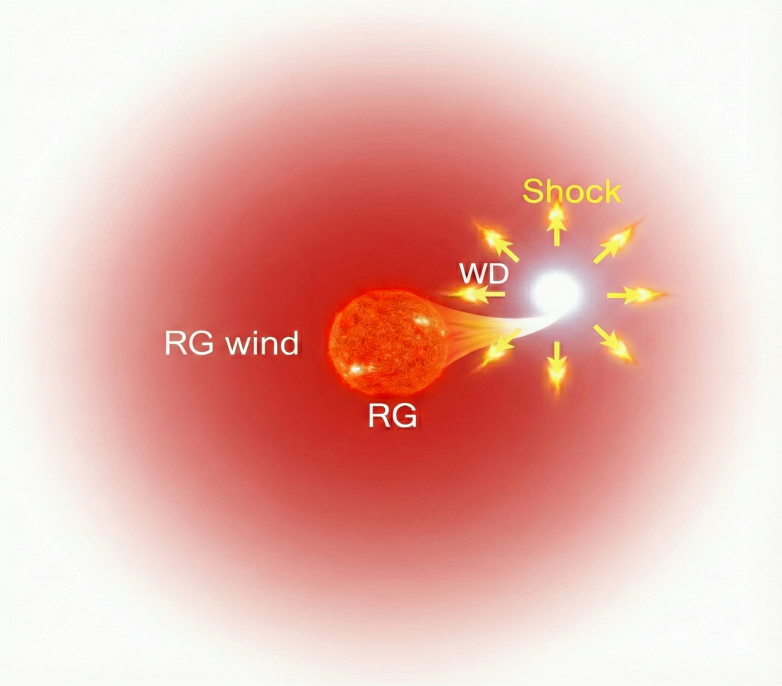


P. Sarmah, S. Chakraborty and X. Wang, Astrophys. J. Lett. (2026)

Recurrent Novae: T CrB 202X

External shock (ES) :



Shockwaves from Nova ejecta

+

RG Wind collision.

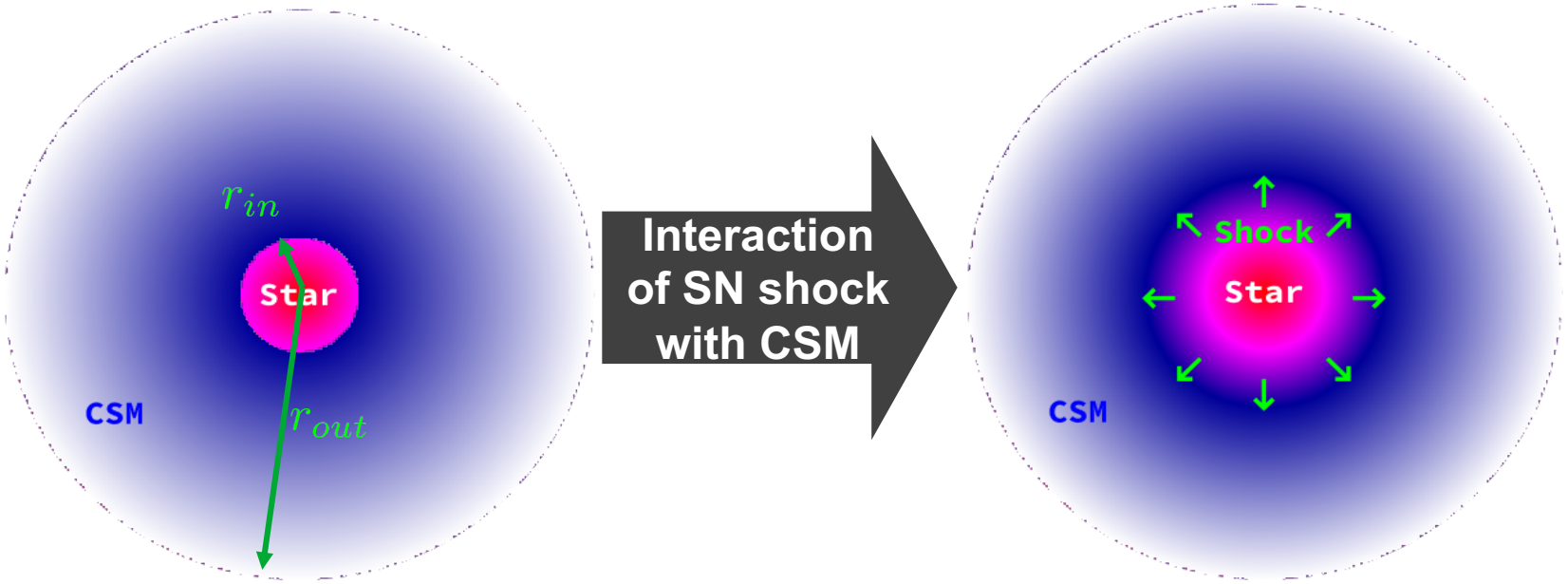
Similar to circumstellar interaction in young supernovae
(P Sarmah et. Al. JCAP 2022, MNRAS 2023, PRD 2023, JCAP 2024).

Accelerate protons to few 10s of TeV.

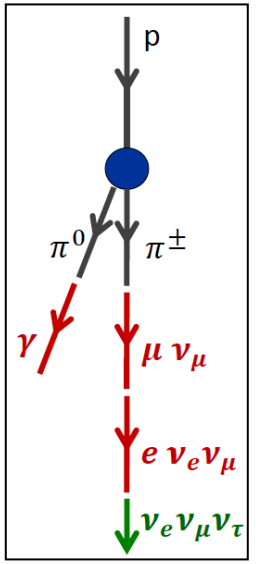
Leads to proton-proton (pp) collision in the RG wind.

Acciari et al. 2022, De Sarkar et al. 2023

Young SNe and Dense Circumstellar Material



- Heavy mass loss (up to 10 $M_\odot$/yr) prior to explosion creates a Dense Circumstellar Medium (CSM), mostly protons.
- Shock-CSM interaction: Accelerates protons to up to 10-100 PeV, initiating hadronic channels for neutrinos and gamma ray's



Fluxes at source:

$$\phi^S_{\nu/\gamma}(E_{\nu/\gamma}, r) \propto n_{CSM}(r) N_p(E_p, r) F_{\nu/\gamma}(E_p, E_{\nu/\gamma})$$

Fluxes at detector:

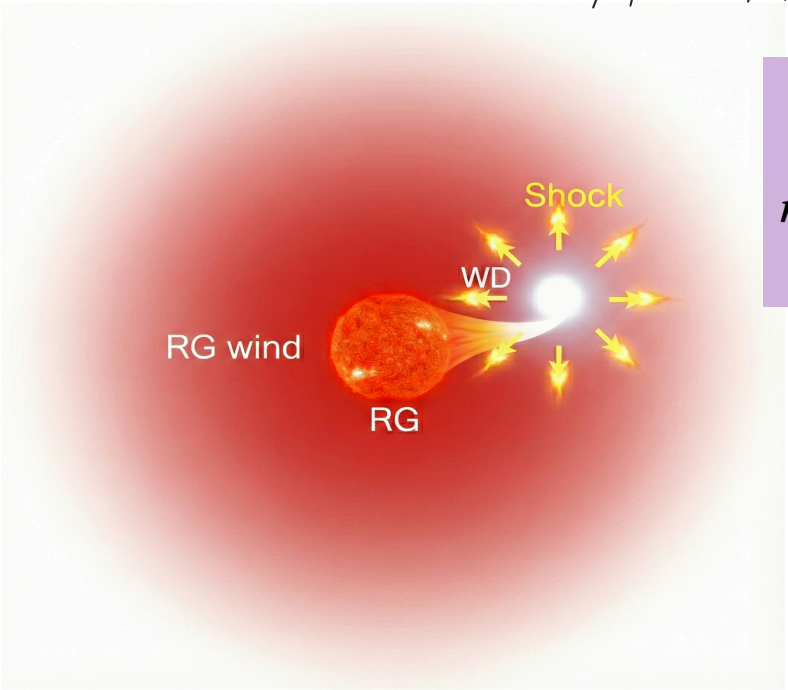
$$\phi^S_{\nu/\gamma}(E_{\nu/\gamma}, r) \propto n_{CSM}(r) N_p(E_p, r) F_{\nu/\gamma}(E_p, E_{\nu/\gamma}) f_a(E_\gamma)$$

(P. Sarmah, S.C, I Tamborra, K. Auchettl, JCAP 2022, PRD 2023)

Recurrent Novae: T CrB 202X

External shock (ES) :

$$\phi^{S}_{\nu/\gamma}(E_{\nu/\gamma}, r) \propto n_{RG}(r) N_p(E_p, r) F_{\nu/\gamma}(E_p, E_{\nu/\gamma}$$



Target protons:

$$n_{\rm RG} \sim 10^{10} \left(\frac{10^{13}\ {\rm cm}}{r} \right)^2$$

Accelerated protons:

$$N_p(E_{\rm p}) \propto E_{\rm p}^{-\alpha_{\rm p}} \exp\left(-\frac{E_{\rm p}}{E_{\rm p,max}} \right)$$

Neutrino/gamma-ray spectra:

$\sigma_{\rm pp} F_{\nu/\gamma}(E_{\rm p}, E_{\nu/\gamma})$

Kelner et al. 2006

Acciari et al. 2022, De Sarkar et al. 2023

Recurrent Novae: T CrB 202X

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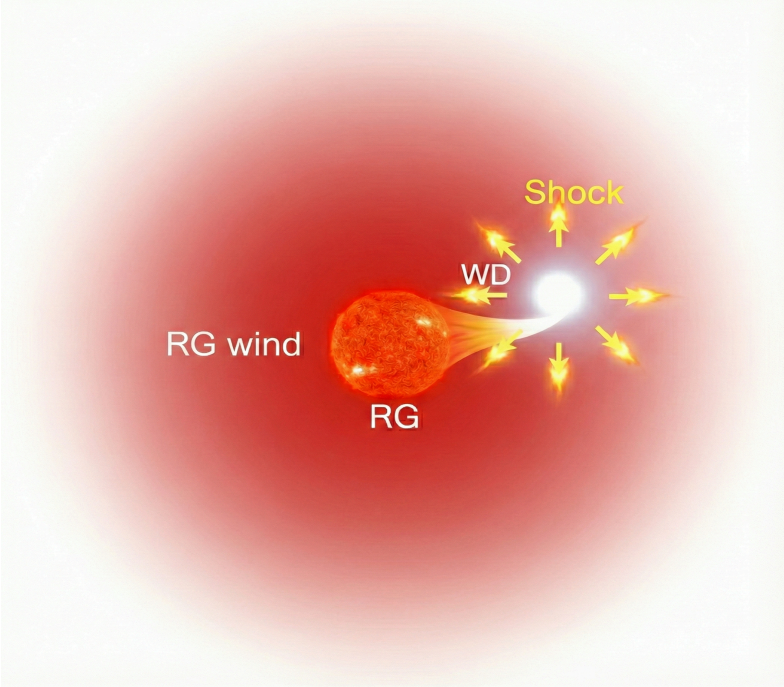
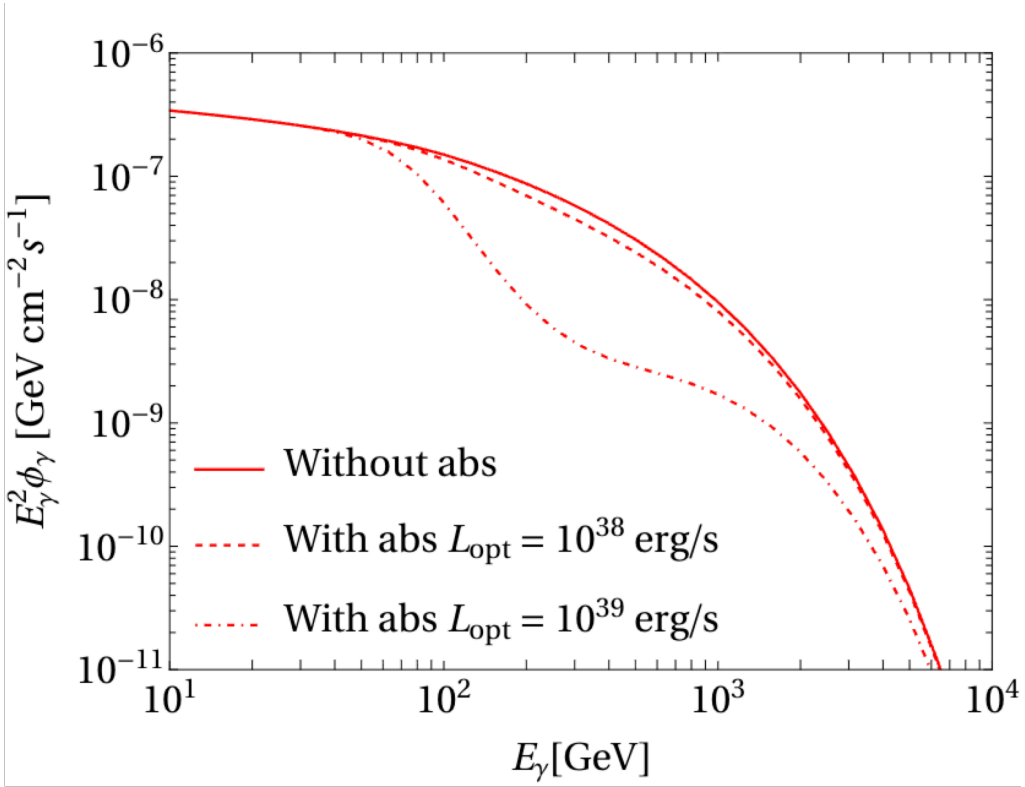


Absorption due to: $\gamma + \gamma_{\rm opt} \rightarrow e^- + e^+$

$e^{-\tau_{\rm opt}}$, $\tau_{\rm opt} \propto L_{\rm opt} \times T_{\rm opt}$



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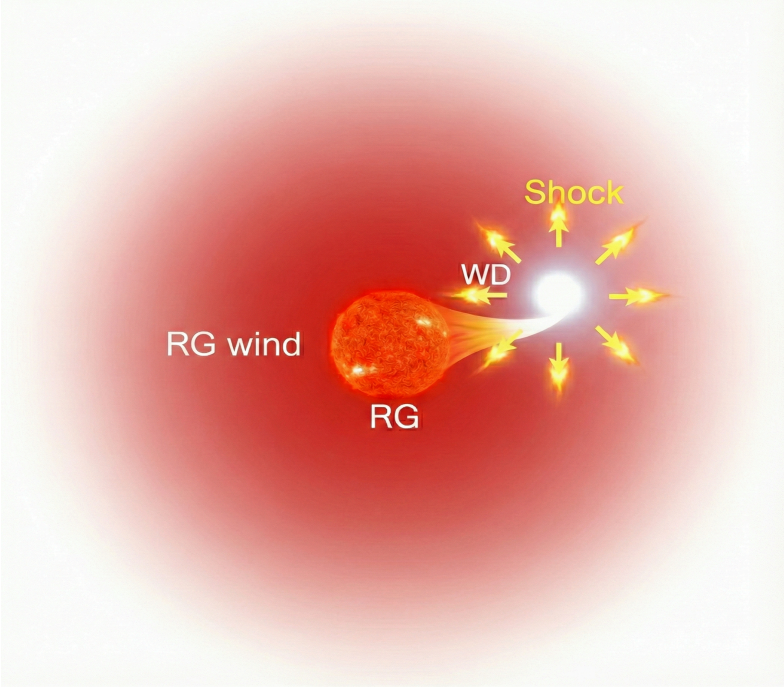
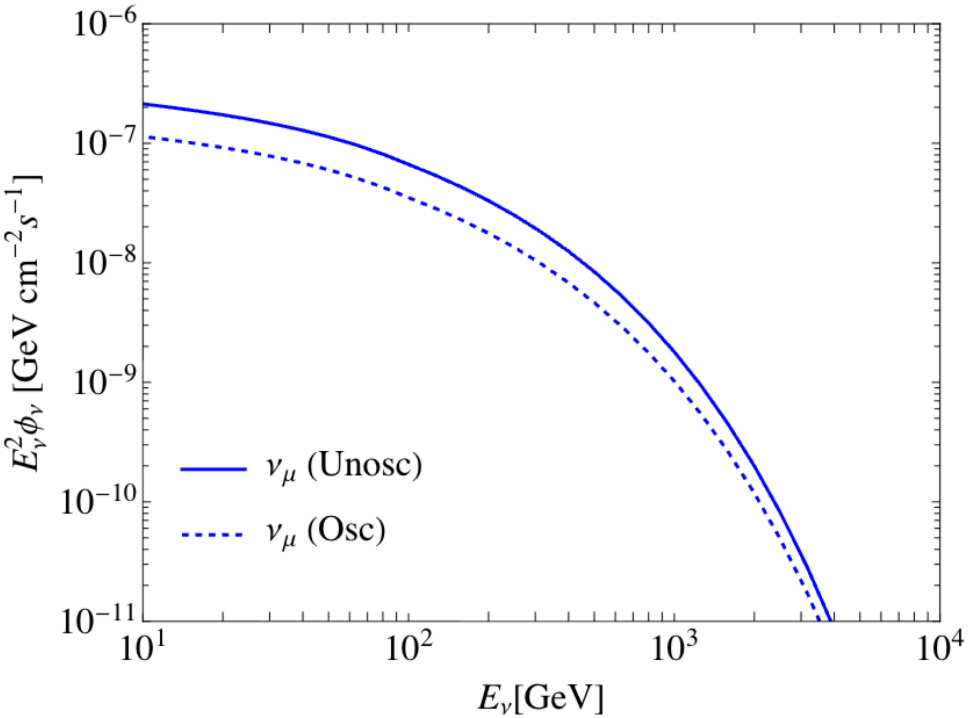


MSW suppressed by large Earth matter potential for E > 50 GeV (Razzaque et al 2010, 1008.5193).



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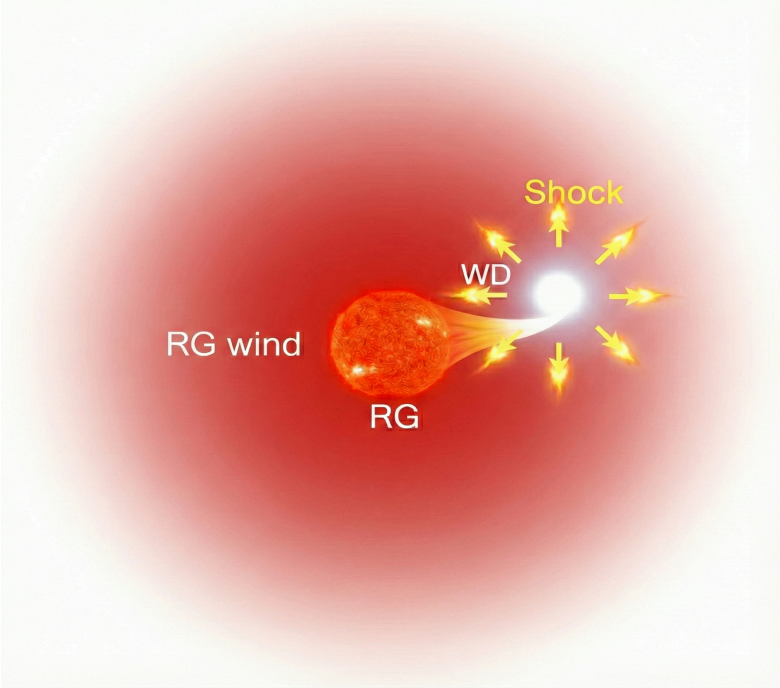
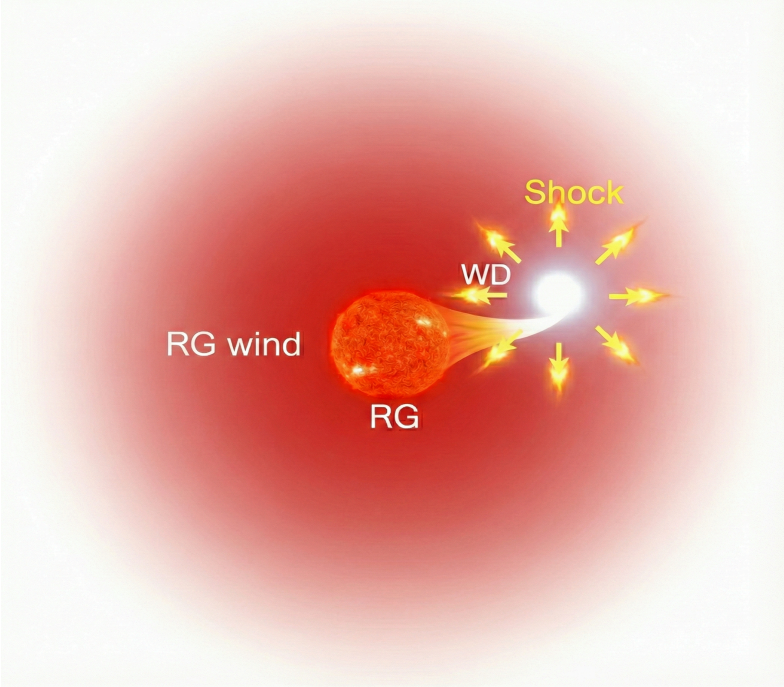


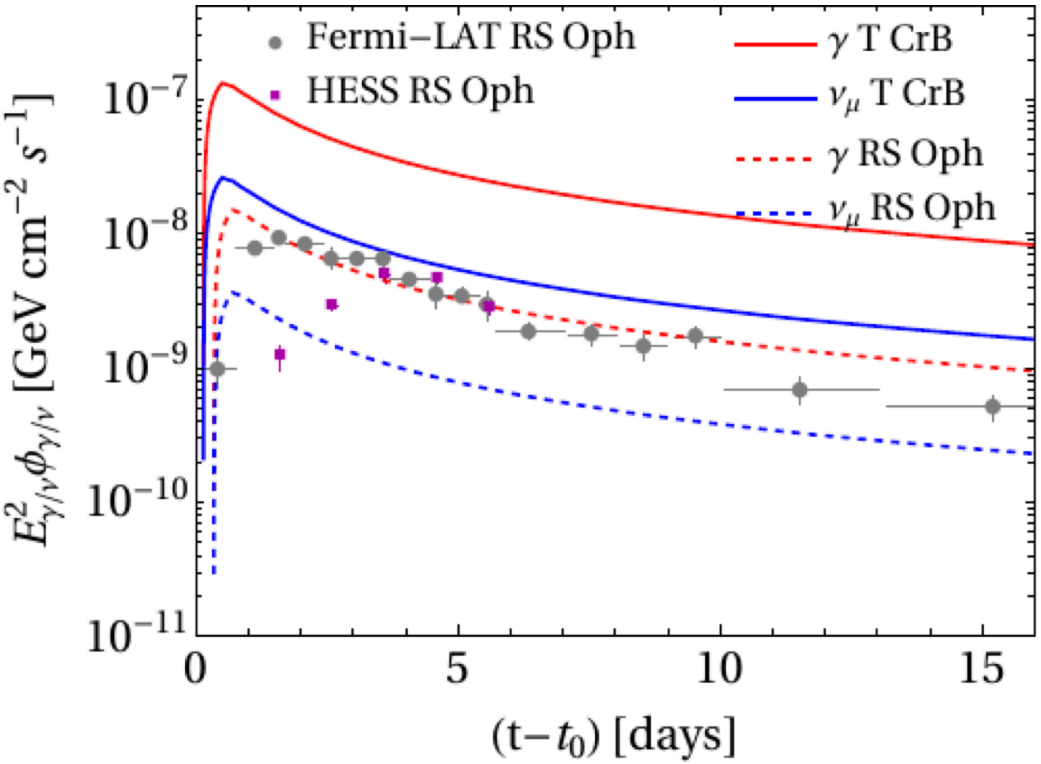
Parameter	Benchmark	Range
$\dot{M}_{\rm RG}$ $(\mathrm{M_\odot\,yr^{-1}})$	5×10^{-7}	$(2\text{–}10) \times 10^{-7}$
$v_{\rm RG}$ $(\mathrm{km\,s^{-1}})$	10^*	10–30
$v_{\rm sh,i}$ $(\mathrm{km\,s^{-1}})$	4500	3000–6000
$\alpha_{\rm p}$	2.2	2.0–2.4
$T_{\rm RG}$ (K)	1500	700–5000
$\epsilon_{\rm p}$	10^{-1}	$(1\text{–}20) \times 10^{-2}$
$L_{\rm opt}$ $(\mathrm{erg\,s^{-1}})$	10^{38}	10^{37}–10^{39}
$T_{\rm opt}$ (K)	8500	7000–10000

Benchmark is based on RS Oph.
Variation based on RS Oph and other novae.

Recurrent Novae: T CrB 202X

External shock (ES) :





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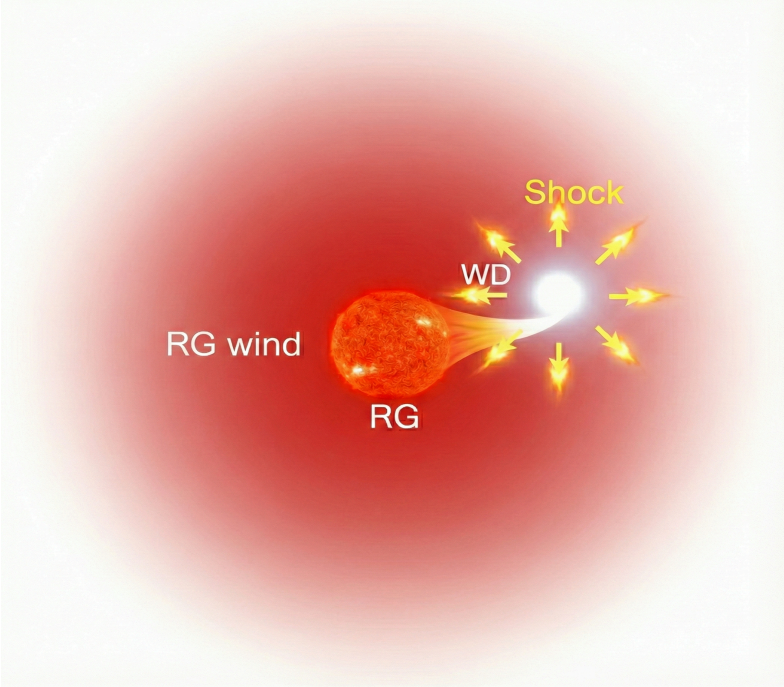

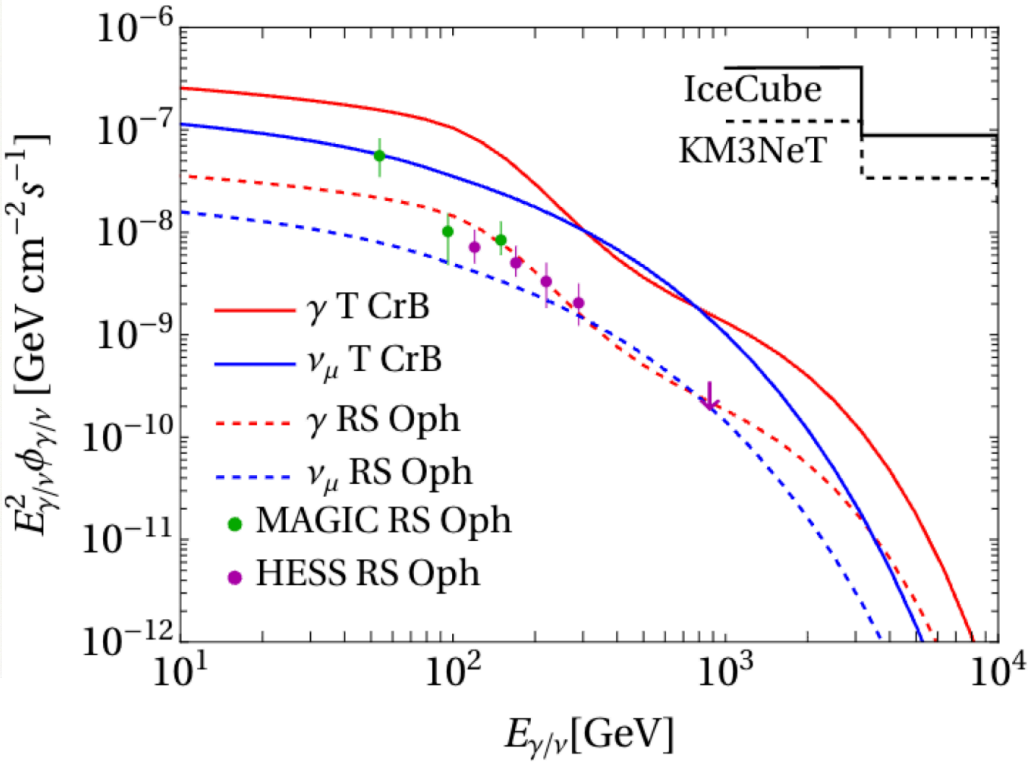

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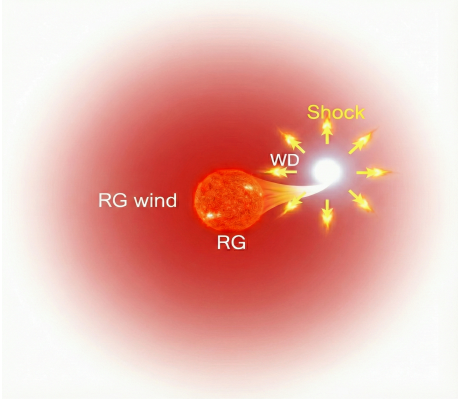

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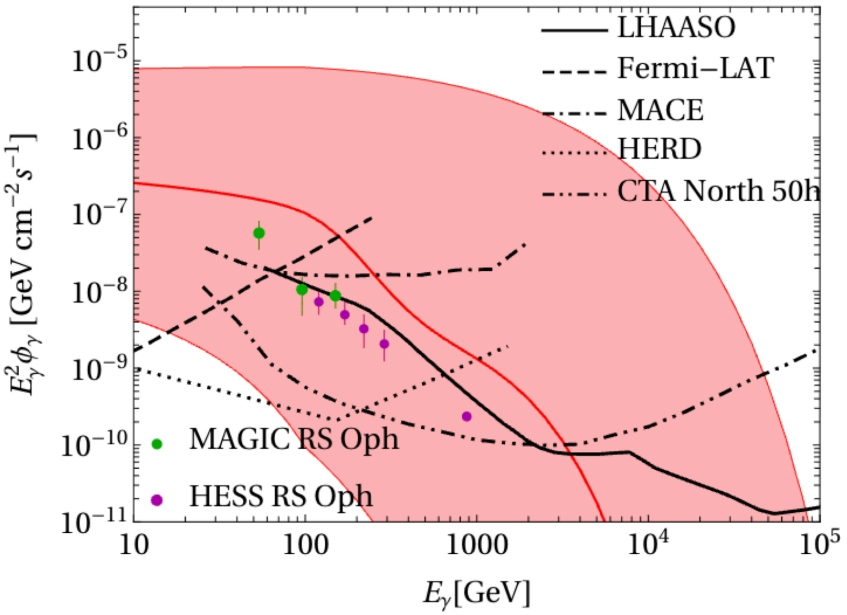
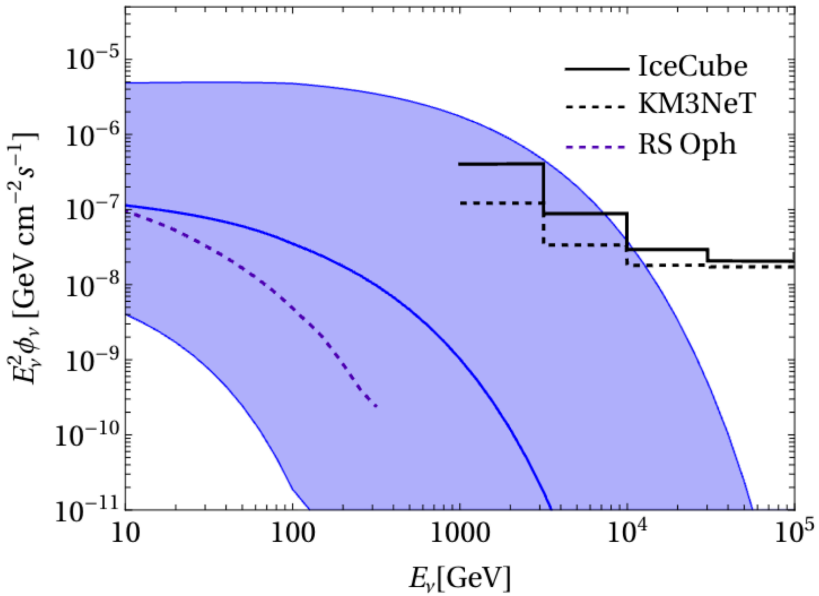
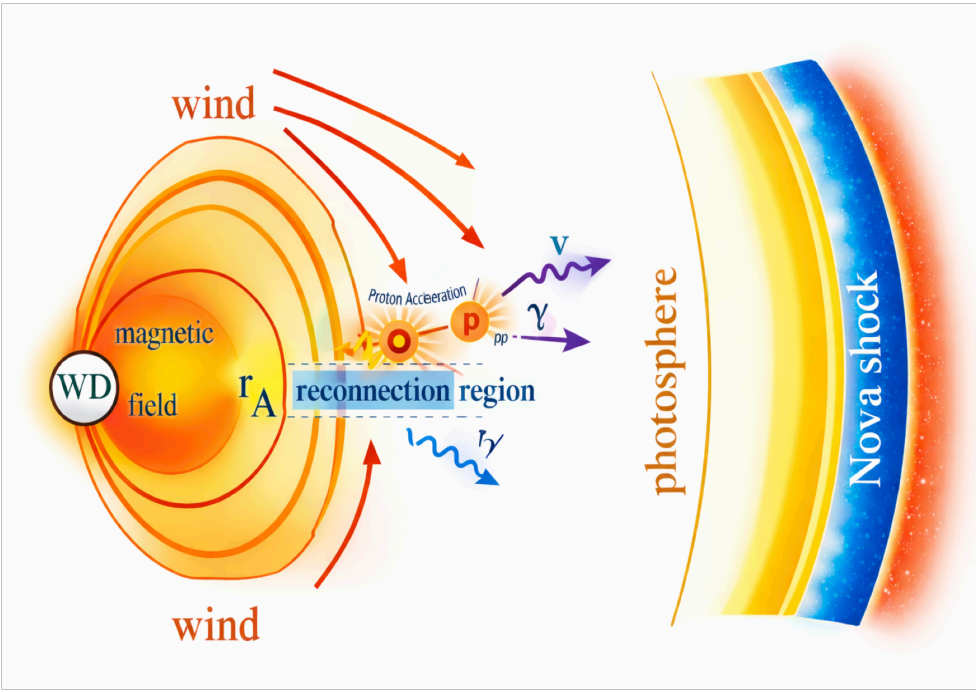
$\alpha_{\rm p}$	2.2	2.0–2.4
$T_{\rm RG}$ (K)	1500	700–5000
$\epsilon_{\rm p}$	10^{-1}	$(1\text{–}20)\times10^{-2}$
$L_{\rm opt}$ ($\rm erg\,s^{-1}$)	10^{38}	10^{37}–10^{39}
$T_{\rm opt}$ (K)	8500	7000–10000





Recurrent Novae: T CrB 202X

Magnetic reconnection (MR) :



Due to dipole magnetic field ~ .
Directs winds towards equatorial plane.

Winds from both poles collide and form a hot plasma ~ 1 MK.

Results in magnetic reconnection at 10^4 km.

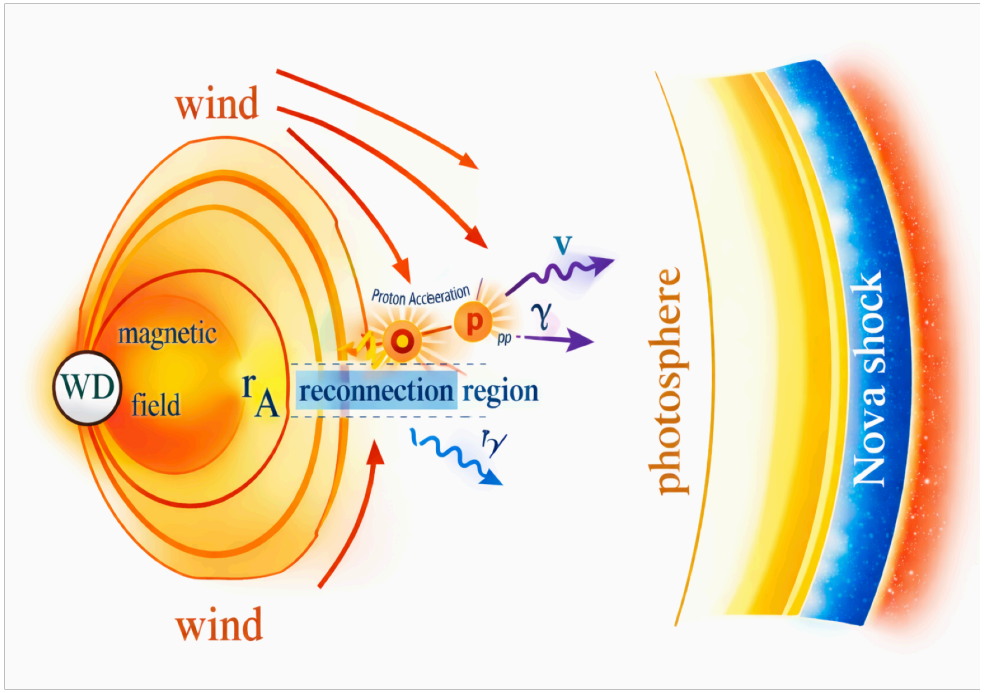
Accelerates protons ~ 100 TeV.

Bednarek & Śmiałkowski 2022

Recurrent Novae: T CrB 202X

Magnetic reconnection (MR) :

$$\phi^S_{\nu/\gamma}(E_{\nu/\gamma}, r) \propto n_{WD}(r) N_p(E_p, r) F_{\nu/\gamma}(E_p, E_{\nu/\gamma}$$



Target protons:

$$n_{\rm WD} \sim 10^{18} \left(\frac{L_{38}}{v^3_{w,3} r^2} \right) \ {\rm cm}^{-3}$$

Accelerated protons:

$$N_p(E_{\rm p}) \propto E_{\rm p}^{-\alpha_{\rm p}} \exp\left(-\frac{E_{\rm p}}{E_{\rm p,max}} \right)$$

Neutrino/gamma-ray spectra:

$\sigma_{\rm pp} F_{\nu/\gamma}(E_{\rm p}, E_{\nu/\gamma})$

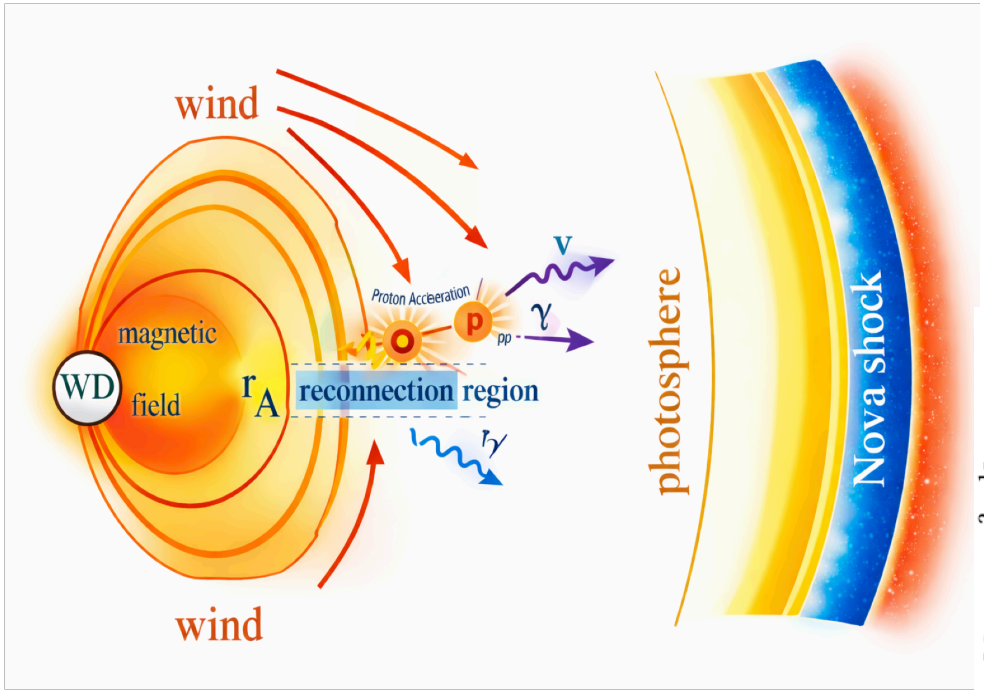
Kelner et al. 2006

No gamma rays, only neutrinos

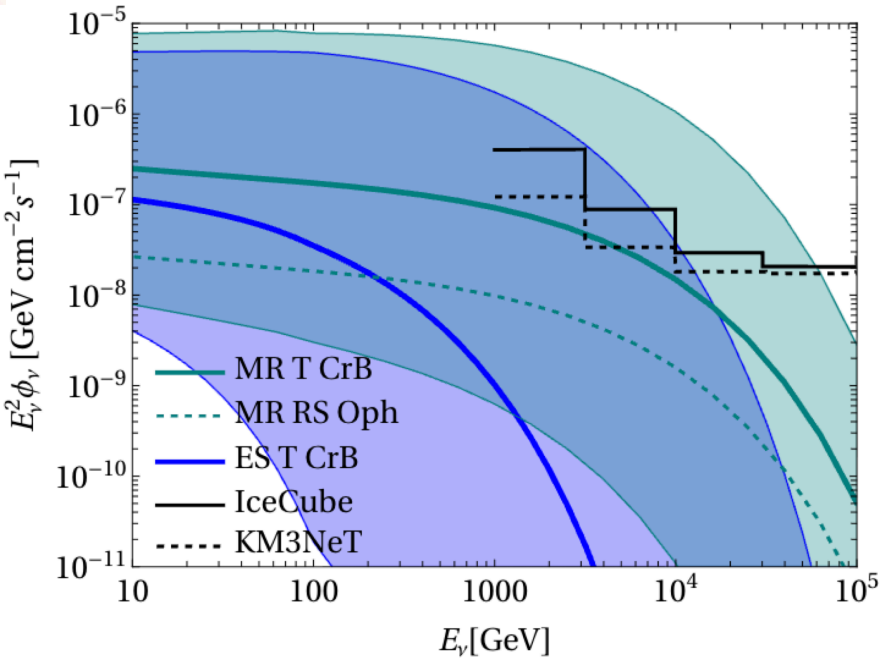
Recurrent Novae: T CrB 202X

Magnetic reconnection (MR) :

P. Sarmah, **S.C** &
X. Wang,
ApJ. Lett. (2026)



Parameter	Benchmark	Range
L_{38}	1	0.5–5
$v_{w,3}$	1	0.6–1.2
B_7	1	0.8–2
α_p	2.2	2.0–2.4
$\epsilon_{p,-1}$	1	0.5–2
Ω_{-1}	1	0.5–2
t_{10}	1.4	1–3



No gamma rays, only neutrinos

Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)

ν and γ flux estimation for ES mechanism

$\int dE_p$ ×

Accelerated protons:
$N_p(E_p) \propto E_p^{-\alpha_p} \exp\left(-\frac{E_p}{E_{p,max}}\right)$ ×

Target protons:
$n_{RG} \sim 10^{10} \left(\frac{10^{13}\ cm}{r}\right)^2$ ×

Neutrino/gamma-ray spectra:
$\sigma_{pp} F_{\nu/\gamma}(E_p, E_{\nu/\gamma})$
Kelner et al. 2006

×

$\frac{1}{4\pi d_s^2}$
$d_s = 0.9$ kpc, T CrB
$d_s = 2.45$ kpc, RS Oph

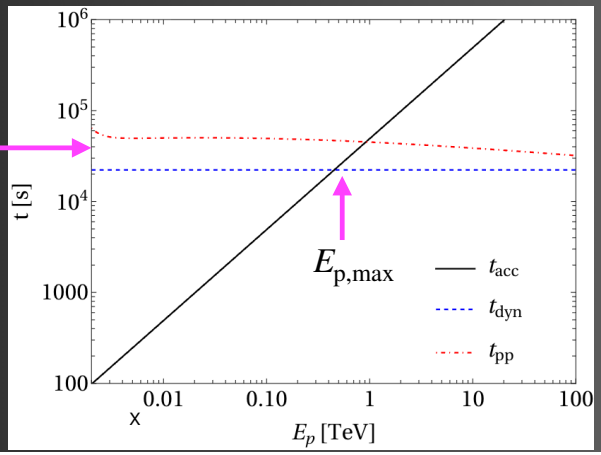
Depends RG mass loss rate ($\dot{M}_{RG}$) and wind velocity (v_{RG}).

Spectral index: 2.0-2.4

A fraction (ϵ_p) of shock kinetic energy.

Maximum proton energy. Obtained by comparing acceleration timescale with different loss timescales.

Depends on:
n_{RG}, Shock velocity (v_{sh}),
RG wind temperature (T_{RG}).



Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)

ν flux estimation for MR mechanism

$\int dE_p$ ×

Accelerated protons:
$N_p(E_p) \propto E_p^{-\alpha_p} \exp\left(-\frac{E_p}{E_{p,max}}\right)$

×

Target protons:
$n_{WD} \sim 10^{18} \left(\frac{L_{38}}{v_{w,3}^3 r^2}\right)$ cm^{-3}

×

Neutrino/gamma-ray spectra:
$\sigma_{pp} F_\nu(E_p, E_\nu)$
Kelner et

×

$\frac{1}{4\pi d_s^2}$
$d_s = 0.8$ kpc, T CrB
$d_s = 2.45$ kpc, RS Oph

Depends on:
L_{38},
ϵ_p: energy transfer fraction,
Ω: solid angle,
t: emission time ~10

Spectral index: 2.0-2.4

Magnetic filed (B_7), L_{38} and $v_{w,3}$.

L_{38}: luminosity in 10^{38} erg/s.
$v_{w,3}$: wind velocity in 10^3 km/s.

x

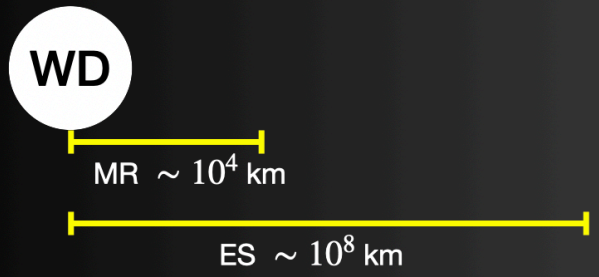
Bednarek & Śmiałkowski 2022

Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)

Summary

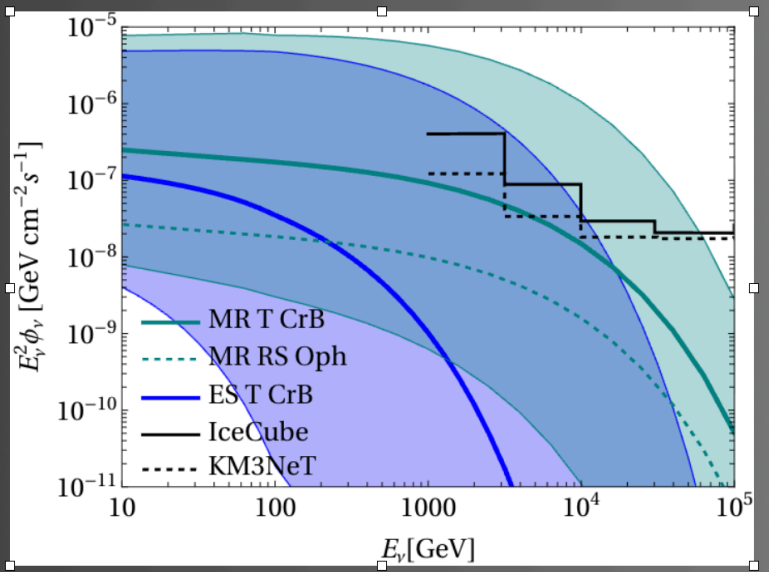
P. Sarmah, S.C & X. Wang, ApJ. Lett. (2026)



MR νs are 10 hours ahead of ES νs.

How to distinguish?

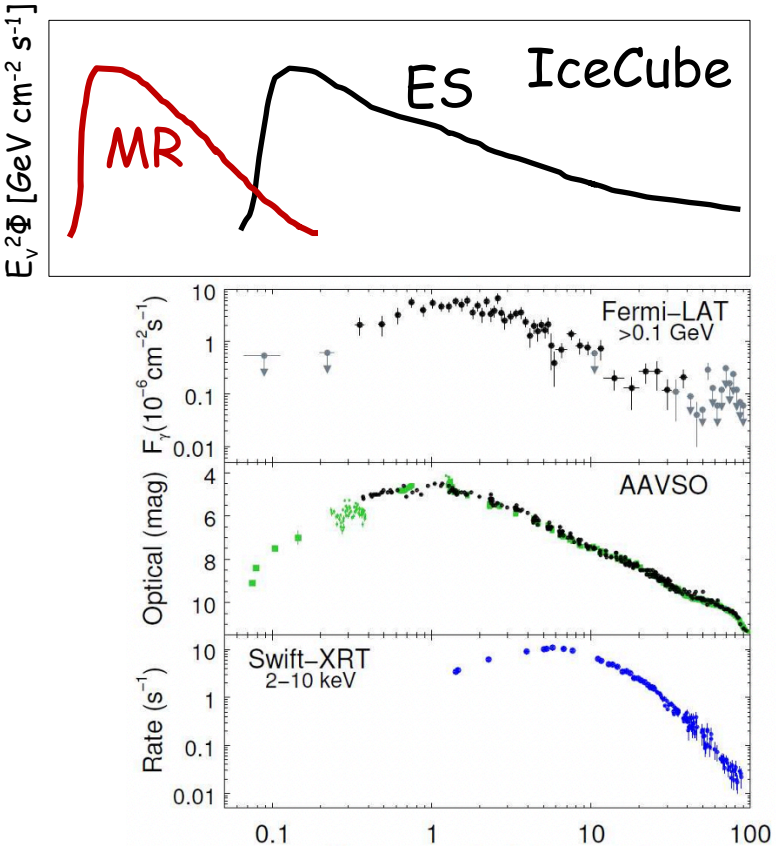
- If neutrinos from both MR and ES detected.
- If there is a delay b/w arrival of neutrinos and gamma-rays.



No gamma rays, only neutrinos during MR

Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)



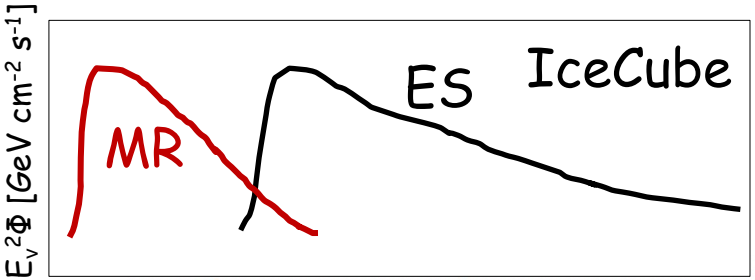
About 10 to 100 Neutrinos in IC

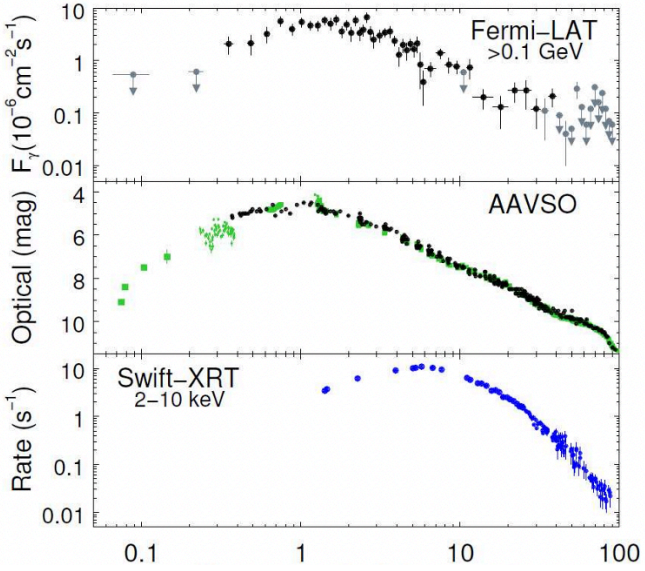
P. Sarmah, **S.C** & X. Wang, ApJ. Lett. (2026)

No gamma rays, only neutrinos during MR

Recurrent Novae: T CrB 202X

T Coronae Borealis (T CrB)





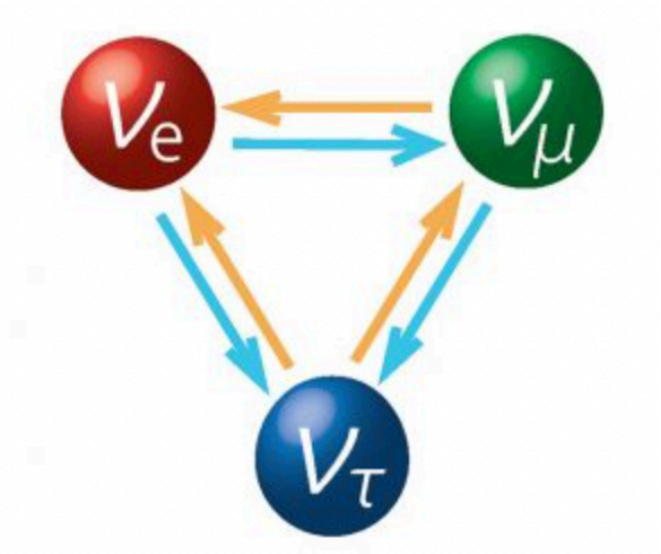
About 10 to 100 Neutrinos in IC

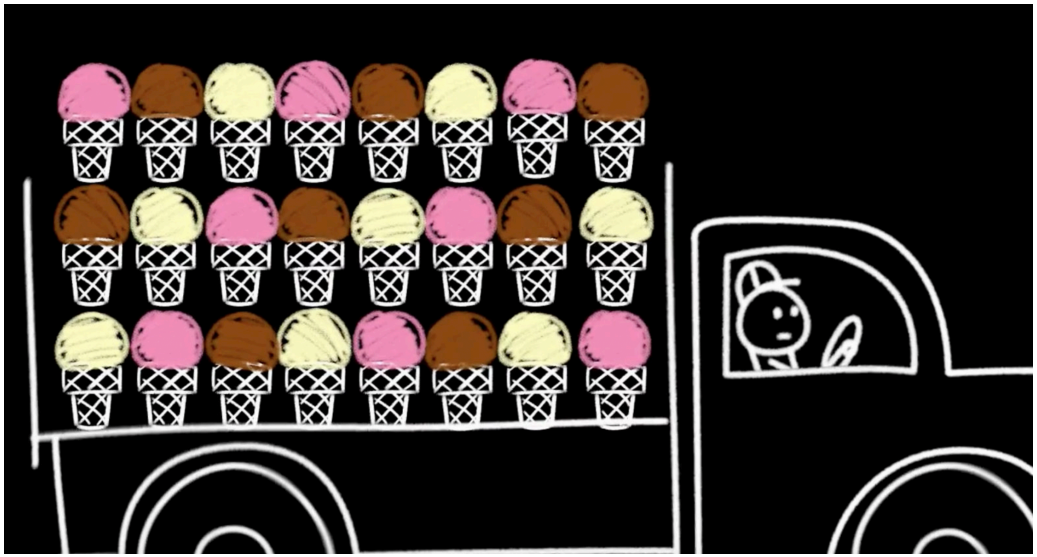
P. Sarmah, **S.C** & X. Wang, ApJ. Lett. (2026)

Thank you!

No gamma rays, only neutrinos during MR

Neutrino flavor oscillations





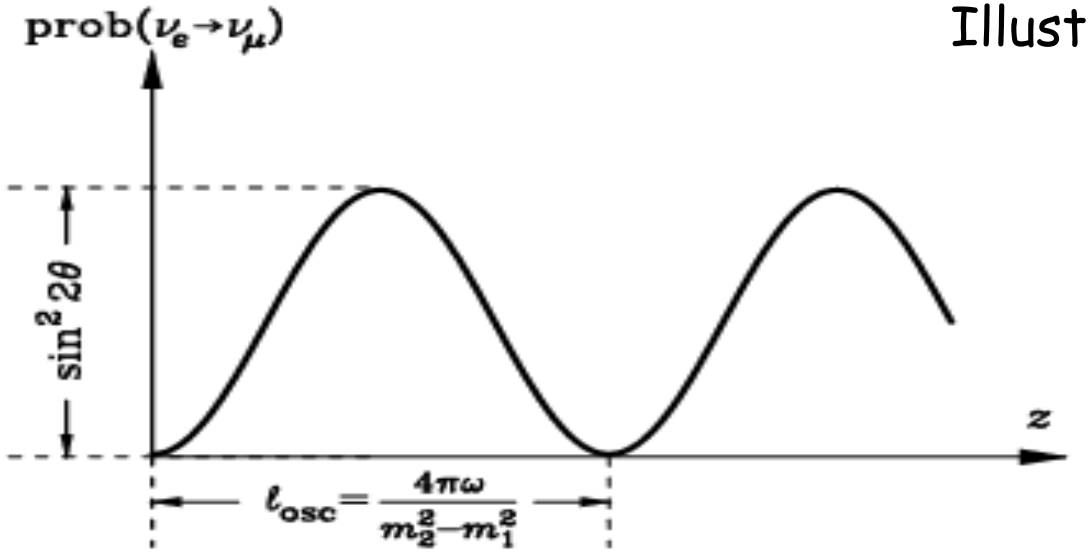


Illustration by Fermilab

NEUTRINO FLAVOR OSCILLATIONS

- **Two flavor mixing** $\begin{pmatrix} \nu_e \\ \nu_\mu \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \end{pmatrix}$

Each mass eigenstates propagates as e^{ipz} with $p_i = \sqrt{E^2 - m^2} \approx E - \frac{m_i^2}{2E}$

$$\left|\nu_\mu(z)\right\rangle = -\sin\theta\, e^{-ip_1 z}\left|\nu_1\right\rangle + \cos\theta\, e^{-ip_2 z}\left|\nu_2\right\rangle$$

- **2 n oscillation probability** $P(\nu_e \to \nu_\mu) = \left|\left\langle \nu_\mu(z) \middle| \nu_e(0)\right\rangle\right|^2 = \sin^2 2\theta \sin^2\left(\frac{\Delta m^2 L}{4E}\right)$

