# Study of the interaction of cosmic rays and the production of high-energy neutrinos in binary-neutron-star mergers

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16 July 2021

**International Cosmic Ray Conference 2021**

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# BNS-mergers as neutrino sources

## Environment

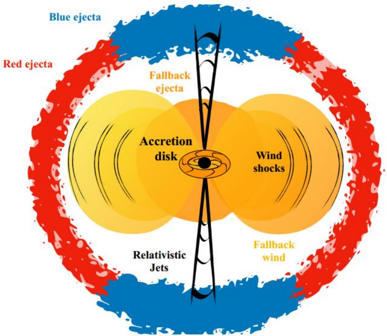
Shock acceleration with ejected matter in the merger.

Nuclei-kilonova interaction BB: $T = 10^4\,\mathrm{K} \div 10^8\,\mathrm{K}$.

Nuclei-non-thermal photon SED interaction.

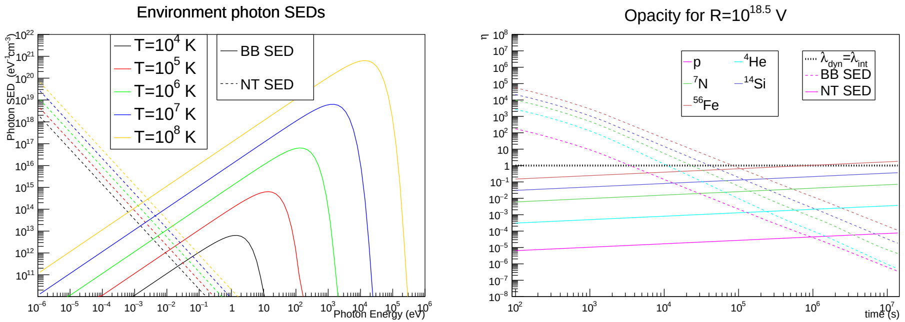
Interaction region $\lambda_{\mathrm{esc}}(t) = \beta_{\mathrm{ej}} c t$, $\beta_{\mathrm{ej}} = 0.3$.

Environment evolution $\log(t) \simeq -0.5 \log(T) + 6$.




*Decoene, V. et al, 2020*

# BNS-mergers as neutrino sources




## Opacity

$$\text{Photon SED } n_j(\epsilon) \quad \Rightarrow \quad \eta_j(t) = \frac{\lambda_{esc}(t)}{\lambda_j(t)} = \frac{\sum_i \tau_{ij}^{-1}}{\tau_{esc}^{-1}}$$

# Simulation code

*SimProp* v2r4

Monte Carlo code for the UHECRs extra-galactic propagation.

*Aloisio, R. et al, 2017*

$\Downarrow$

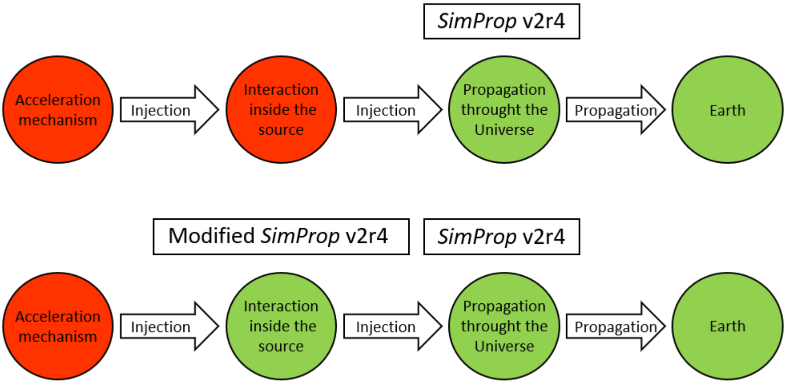
Modified *SimProp* v2r4

Cosmic photons fields replaced by a BB of fixed temperature.

Leaky box model for the CRs escape condition from the interaction region.

# Simulation code

**Several version of the same code for several phases of the "CR life".**



# Simulations

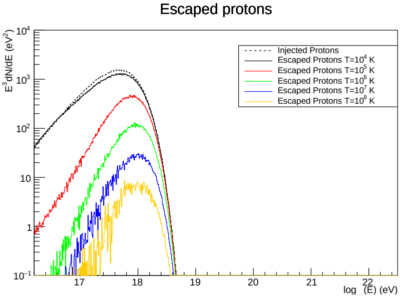
## Injection

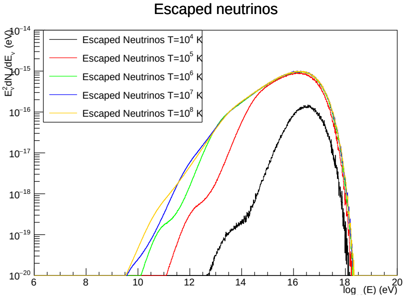
- fixed source temperature
- energy spectrum $\propto \log(E)$
- protons with $10^{14}$ eV $\leq E_p \leq 10^{20}$ eV

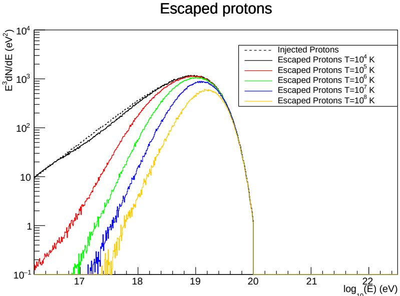
## Post re-weighing

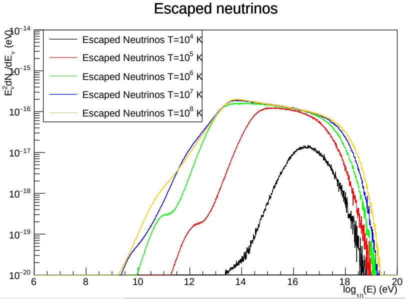
$$J_{\mathrm{inj}}(E) \propto E^{-\gamma} \exp\left(-\frac{E/Z}{R_{\mathrm{max}}}\right)$$

# Proton simulations $(1.5, 10^{17.5}\,\mathrm{V}) \oplus (2.1, 10^{19}\,\mathrm{V})$



# Earth propagation

**Original *SimProp* v2r4 for the extra-galactic propagation**

## Set of sources

$$\text{GW170817-like}: \quad T = 10^6 \div 10^4\,\text{K}$$
$$\text{Optimistic}: \quad T = 10^8 \div 10^4\,\text{K}$$

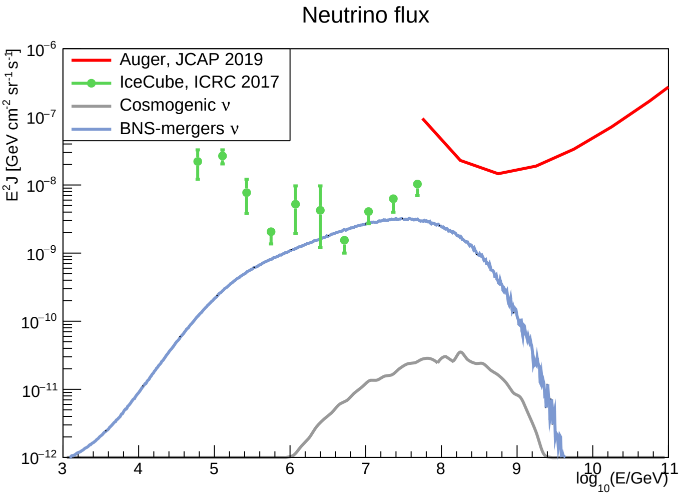
## Sources evolution

$$J_{\text{inj}}(E, z) = J_{\text{inj}}(E, z = 0)(1 + z)^m$$

Assumption: CRs fluxes normalized to the observed CRs flux with $E < E_{\text{ankle}}$.

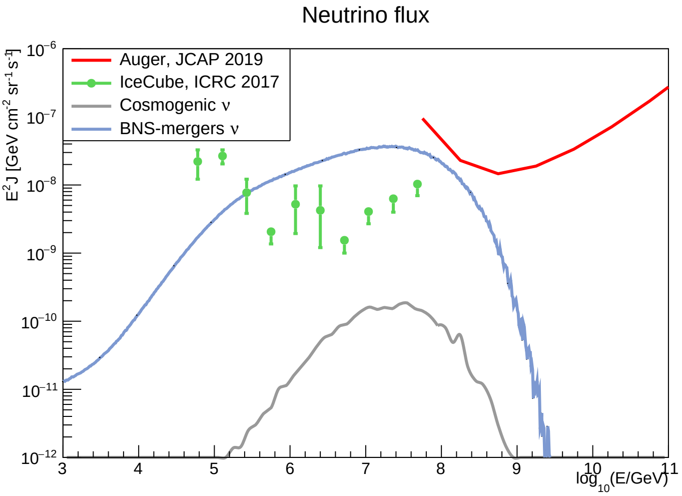
# Neutrino fluxes

Protons , $\gamma = 1.5$ , $R_{\text{max}} = 10^{18.5}\,\text{V}$ , $m = 0$ , GW-like



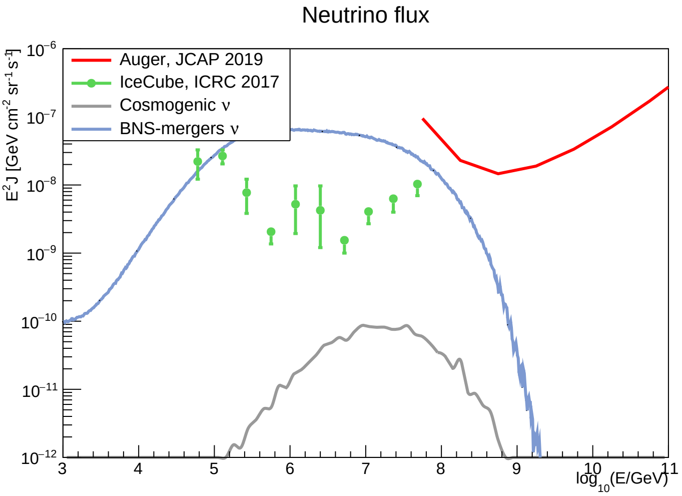
# Neutrino fluxes

Protons , $\gamma = 1.5$ , $R_{\mathrm{max}} = 10^{18}\,\mathrm{V}$ , $m = 3.4$ , GW-like



# Neutrino fluxes

Protons , $\gamma = 2.1$ , $R_{\mathrm{max}} = 10^{18}$ V , $m = 3.4$ , GW-like



# Results and Future developments

## Results

- Cosmogenic neutrinos cannot be responsible of the observed diffuse neutrino flux.
- Nearby sources.
- Colder BNS mergers seem to be most favoured.
- Hard spectral index and and large rigidity better reproduce experimental results.

## Future developments

- Mixed composition (heavier = non-thermal interactions).
- Hadronic interactions.
- Flavour oscillations.
- Population of BNS-merger.