Neutron Star Astrophysics at the Crossroads: Magnetars and the Multimessenger Revolution
Proceedings IAU Symposium No. 363, 2023
E. Troja & M. G. Baring, eds.
doi:10.1017/S1743921322000801

RNO-G detection perspectives of binary neutron star mergers

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Abstract. The Radio Neutrino Observatory Greenland (RNO-G) is currently being deployed and it is currently gathering data. As a precursor and complementary detector to the future radio array of IceCube-Gen2 in Antarctica, it will explore mainly the Northern sky via in-ice radio detection technique. The total array configuration includes 35 radio stations and will be fully completed within three years from now. The antennas will register the radio signals produced by the Askaryan effect in cascades generated in ice by neutrinos. RNO-G's scientific purpose is to detect UHE neutrinos at energies above 10 PeV. Due to the attenuation length of radio waves in ice (order of 1 km) the radio detection allows to address neutrino energies above several PeV. The detector will reach unprecedented sensitivity in the scale from tens of PeV up to EeV. Models predict GRBs induced by binary neutron star mergers as likely transient sources of such highly energetic neutrinos. The current study of NS-NS mergers will therefore possibly be complemented by future RNO-G detections through multimessenger temporal and spatial coincidence, including an alert system. In this presentation, we will describe the instrument capabilities and explore the possibility of detection of such sources with RNO-G.

Keywords. acceleration of particles, neutrinos, stars: neutron

1. Radio Neutrino Observatory Greenland

Neutrinos make the perfect astrophysical messengers. Unlike cosmic rays, they are neutral particles so they do not get deflected and point directly to their source. They are weakly interacting so they do not undergo the attenuation that gamma-rays encounter and can therefore travel for long distances reaching the Earth from the remotest parts of the Universe. Therefore neutrinos provide crucial information in order to answer many open questions. IceCube has provided spectral measurements above 1 PeV however its size limits the possibility of observing higher energies. Models predict several types of astrophysical sources of neutrinos in the energy range above 10 PeV and one of the purpose of Radio Neutrino Detector in Greenland (RNO-G) is to target these sources.

RNO-G's station design is based on previous radio neutrino in-ice detectors: mainly ARA and ARIANNA. It includes both a surface component and a deep component. The deep part consists of three strings at which are attached two different types of antennas. It is mainly intended for energy and direction reconstruction and gives the largest part of the effective volume. The surface antennas are LPDAs (3 per string) and their main purpose is vetoing cosmic rays and noise events. They also contribute to enhancing the effective volume closer to the surface. RNO-G's stations will detect neutrinos through the radio signals produced by Askaryan effect (Askaryan (1961)). Neutrinos that interact

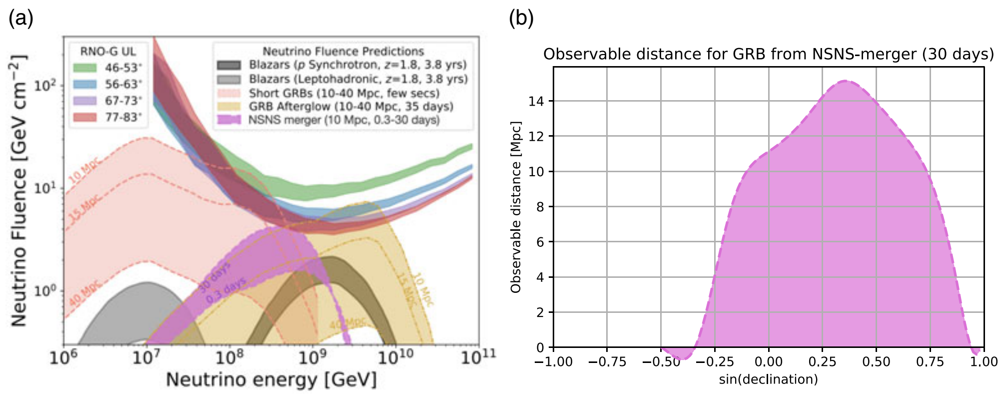

Figure 1. 95% CL fluence sensitivities of RNO-G full array compared to energy spectra of transients (see text) (Aguilar et al. (2021)). Observable distance of 30 days-long GRBs produced after Binary neutron star mergers (as in Fang & Metzger (2017)).

with the atoms of ice produce secondary particle that lose energy through cascades. The cascades that propagate in ice gain a net negative charge that develops in the medium and emits radiation in the radio frequencies. This is called Askaryan emission. Due to Earth absorption of UHE neutrinos, RNO-G observes Earth skimming and downgoing neutrinos and represents the first neutrino detector sensitive to the Northern sky at UHE energies with a sufficient sensitivity to approach now predicted fluxes.

2. Detection perspectives of binary neutron star mergers

According to model predicted emission at energies above PeV and up to 100 EeV, RNO-G has the potential to constrain the neutrino fluence from GRB afterglows, short GRBs, and GRBs from long-lived magnetars (such as the ones generated after binary neutron star mergers) which are located within tens of Mpc. Fig. 1a shows the 95% CL fluence sensitivities for trigger levels at 1.5σ and 2.5σ noise calculated for the four most sensitive zenith bands centered at 50°, 60°, 70°, and 80°. For comparison the plot also presents model-predicted fluences from these transient source classes: bright gamma-ray blazars (Rodrigues *et al.* (2021)), short GRBs (Kimura *et al.* (2017)), GRB afterglows (Murase (2007)), GRBs from NS-NS mergers with duration from 0.3 to 30 days (Fang & Metzger (2017)). In Fig. 1b is shown the observable horizon for 30-days-long GRBs produced by NS-NS mergers (with fluence as the magenta upper line in Fig. 1a) as a function of the declination. This kind of GRBs appears to be visible by RNO-G full array up to around 15 Mpc. This is especially promising considering the future radio array of IceCube-Gen2, which will cover an almost 10 times larger surface area with deeper antennas. This will provide a roughly 10 times better sensitivity (around 1 EeV) (Hallmann et al. (2021)). Hence, with IceCube-Gen2, we expect to be able to extend the observable distance up to 150 Mpc.

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https://doi.org/10.1017/S1743921322000801 Published online by Cambridge University Press

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