The Third Interplanetary Network

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Abstract. The 3rd interplanetary network (IPN), which has been in operation since 1990, presently consists of 9 spacecraft: AGILE, Fermi, RHESSI, Suzaku, and Swift, in low Earth orbit; INTEGRAL, in eccentric Earth orbit with apogee 0.5 light-seconds; Wind, up to $\sim$7 light-seconds from Earth; MESSENGER, en route to Mercury; and Mars Odyssey, in orbit around Mars. The IPN operates as a full-time, all-sky monitor for transients down to a threshold of about $6 \times 10^{-7}\,\mathrm{erg\,cm^{-2}}$ or $1\,\mathrm{photon\,cm^{-2}\,s^{-1}}$. It detects $\sim$346 cosmic gamma-ray bursts per year. These events are generally not the same ones detected by narrower field of view instruments such as Swift, INTEGRAL IBIS, and SuperAGILE; the localization accuracy is in the several arcminute and above range. The uses of the IPN data are described.

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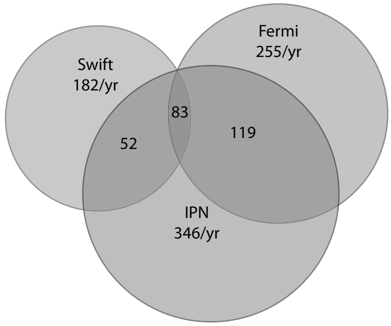

FIGURE 1. The overlap between IPN, Fermi GBM, and Swift bursts during the first year of Fermi operations. The 182 Swift bursts per year are those detected both within the BAT coded field of view and outside it.

INTRODUCTION

The 3rd Interplanetary Network (IPN) came into existence in 1990, with the launch of the Ulysses spacecraft. Its purpose is to derive the positions of fast gamma-ray transients of all kinds by triangulation. Numerous spacecraft and instruments have participated in the network since its inception, but today, it consists of AGILE, Fermi, RHESSI, Suzaku, and Swift, in low Earth orbit; INTEGRAL, in eccentric Earth orbit with an apogee of 0.5 light seconds; Wind, up to 7 light seconds from Earth; MESSENGER, meandering through the inner solar system en route to Mercury, at distances up to about 600 light seconds from Earth; and Mars Odyssey, in orbit around Mars, at distances up to about 1000 light-seconds from Earth. Due to the large number of spacecraft, the roughly isotropic responses of the instruments aboard them, and the fact that three of them (INTEGRAL, MESSENGER, and Wind) view the entire sky without occultation by a planet, the IPN is an all-sky, full-time monitor of fast gamma-ray transient activity. Its limiting accuracy for localization is about 1 arcminute, although only a few events can be localized this well, and its event detection rate is $\sim$346/year, considering only those bursts detected by two or more detectors (i.e. confirmed GRBs). This makes it possible to study a wide variety of events which imaging GRB instruments like the Swift BAT, INTEGRAL-IBIS, and AGILE will seldom detect in their fields of view. These include very intense bursts, short bursts (the IPN detection rate of short bursts is greater than those of imaging instruments), very long bursts, repeating sources (gravitationally lensed GRBs and bursting pulsars like GROJ1744-28 are two examples), soft gamma repeater activity, and possibly other as-yet undiscovered phenomena. The overlap between Swift, Fermi, and IPN bursts is shown in figure 1.

SENSITIVITY

The IPN sensitivity to GRBs is a function of burst duration, energy spectrum, peak flux, and fluence, among other things. It can be defined in various ways, since the experiments

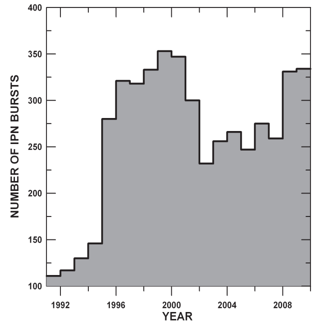

FIGURE 2. The yearly rates of bursts detected by the IPN from 1991 to 2009. Only confirmed cosmic gamma-ray bursts have been counted (i.e., no SGRs or doubtful events). Bursts observed only by BATSE, Swift, or Fermi have not been counted. Counting Swift-only and Fermi-only bursts would bring the current total rate to 440 per year.

comprising it vary widely in their properties. A convenient measure is to consider the fluences and peak fluxes of the GRBs detected by two or more IPN detectors, regardless of duration and spectrum. The thresholds are $\sim 6 \times 10^{-7}\,\mathrm{erg\,cm^{-2}}$ or $\sim 1\,\mathrm{photon\,cm^{-2}\,s^{-1}}$ for 50% efficiency. The IPN is sensitive to bursts with E_{peak} above 20 keV, and durations above tens of milliseconds roughly, with efficiency dropping below these values due to detector design.

DETECTION RATES

The 3rd IPN has detected almost 5000 cosmic gamma-ray bursts to date. However, as experiments come into and leave the network, the burst detection rate changes slowly with time. This is illustrated in figure 2, where the impact of the arrival and departure of missions like Wind (1995 -), GRO (1991 - 2000), and BeppoSAX (1996 - 2002) can be seen in the rates.

THE IPN DATA AND THEIR USES

The IPN data are public. Burst lists can be retrieved at the IPN website (`ssl.berkeley.edu/ipn3`) and are also archived at the HEASARC, where they are available through the “browse” interface (go to Gamma Ray Bursts from the Interplanetary Network). Burst localizations are presently only available at the IPN website. Localization data are being added on a roughly daily basis, but at present the emphasis is on completing the data for the earlier events. For information on bursts which are not yet on the website, contact khurley@ssl.berkeley.edu.

Numerous GCN Circulars have been issued for interesting IPN events, and many Swift ToOs of them have taken place. IPN localizations have been used to refine Swift-BAT positions, confirm BAT bursts outside the coded field of view, and confirm positions found in ground analysis. The short duration, hard spectrum GRB051103, whose

IPN localization suggested a possible origin in M81 or M82, was observed as a ToO by XMM. Other bursts, with only coarse and/or delayed localizations, have found a wide variety of uses. An intriguing ground-based muon detector increase was reported in conjunction with GRB 090315. IPN bursts are being or have been used by the AMANDA and IceCube groups, the ANITA group, and the RICE group to search for neutrino emission associated with GRBs. They have also been used by the Milagro and ARGO YBJ groups to search for 100 GeV - 100 TeV emission in conjunction with GRBs. Because the IPN GRB detection rate is large, and because these bursts are the more intense (and therefore probably, on average, closer) ones, IPN bursts constitute a particularly rich database for these searches. The LIGO group uses them to search for coincident gravitational radiation, and they have been used to search for coincidences with candidate orphan afterglows. IPN data are being studied to determine how many energetic Type Ic hypernovae had gamma-ray emission associated with them. The advantages of the IPN in these searches are its isotropic response and $\sim$ 100% duty cycle. The Fermi GBM team uses them to refine their localization algorithms, and the Fermi LAT team can use IPN localizations to refine searches for high energy emission from coarsely localized GBM bursts. IPN localizations will also be used to support the GRB polarimetry experiment aboard IKAROS. Observations of SGR bursts are also of great interest to many groups for triggering multi-wavelength ToO observations.

THE FUTURE OF THE IPN

The IPN requires at least two interplanetary spacecraft to obtain precise localizations. MESSENGER is the interplanetary mission with the longest "guaranteed" lifetime (through March 2012). Mars Odyssey, the second interplanetary spacecraft, is subject to yearly reviews, and is currently approved through 2012. Most of the near-Earth spacecraft undergo reviews every several years.

In the early days of the IPN, it was possible to propose dedicated GRB experiments for interplanetary missions such as PVO and Ulysses. Today, this is no longer feasible, and GRB experiments must have other primary scientific objectives, such as planetary surface spectroscopy (e.g., Mars Odyssey and MESSENGER). Future interplanetary spacecraft with this capability include the Russian Phobos-Grunt mission in 2011, and BepiColumbo in 2014. Near-Earth spacecraft pose less of a problem. Missions and experiments like NeXT, SVOM, Spectrum XG, and EXIST, among others, will probably provide near-Earth vertices for the foreseeable future.

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