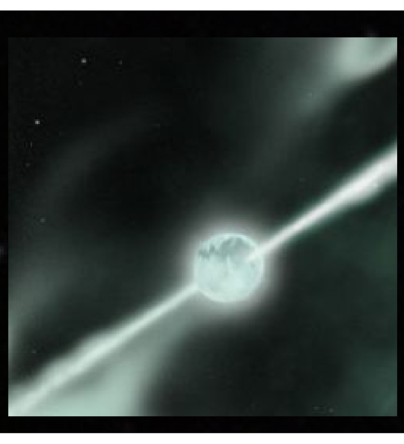

# Detections of Gamma Ray Bursts by Ionospheric Response


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## INTRODUCTION

We report on the independent and indirect detection of GRBs by their ionospheric response (SID – Sudden Ionospheric Disturbance) observed at VLF (Very Low Frequency). Although few such detections have been already reported in the past, the capability of such alternative and indirect investigations of GRBs still remains to be investigated in more details. We present and discuss the examples of further such VLF/SID detections.

## PHYSICS BEHIND IONOSPHERIC DETECTION I

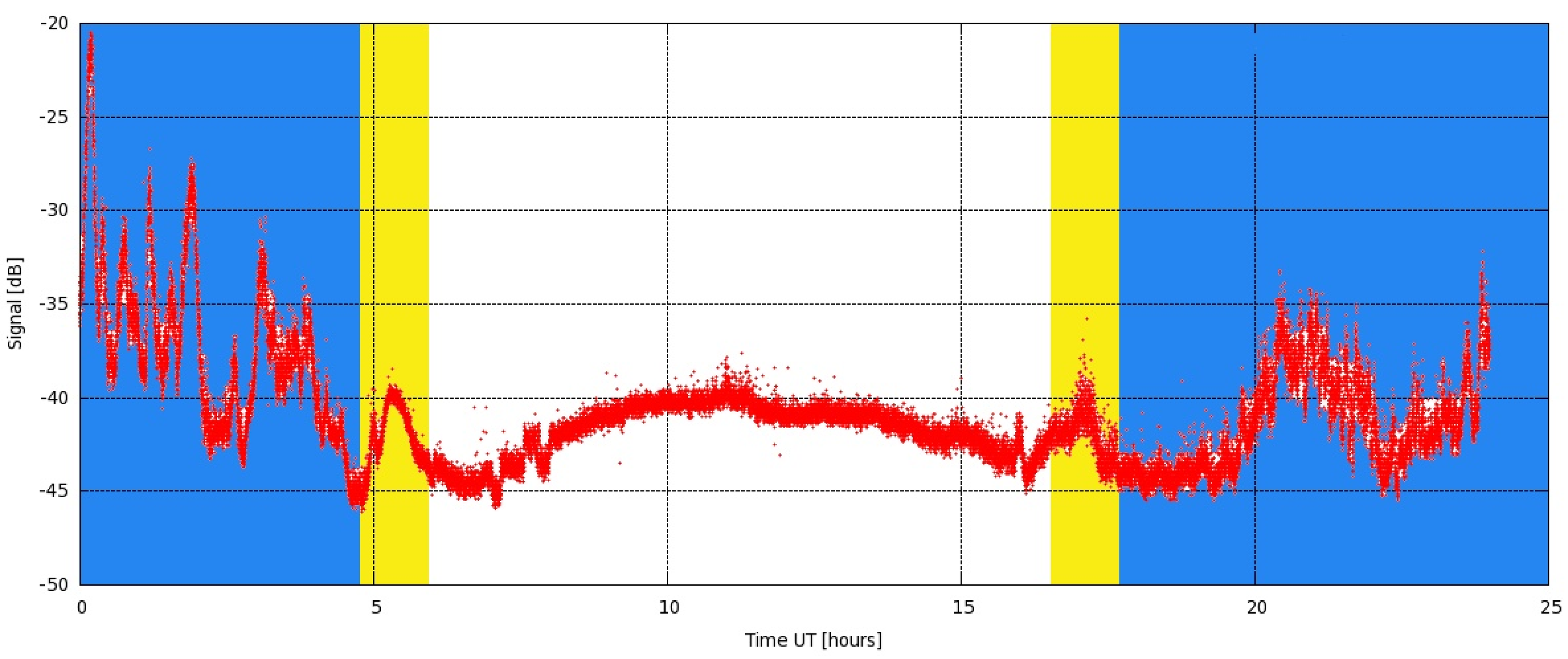
The solar particles stream, solar wind, shapes and controls the Earths, magnetic envelope - the magnetosphere- and increases heat in the aurora zones. But not all ionospheric variability is caused by solar or geomagnetic disturbances. The ionosphere is not a constant 'mirror in the sky'. The E layer (100-200 km above ground) and the F1 layer (170-200 km) usually behave in regular, solar-controlled way, but the F2 layer (250-350 km) does not. It is the F2 layer, which has the greatest density of free electrons, and is potentially the most effective reflector of radio waves. (Rishbeth, Nature Vol. 418, 4 July 2002)

## PHYSICS BEHIND IONOSPHERIC DETECTION II

The ionossperic D layer plays in the GRB detections an important role, as the detection of X-ray and gamma-ray triggers is based on the measuremet (monitoring) of reflected radio waves from this layer. The ionospheric D layer is not transparent for radio VLF waves (frequencies 3kHz to 30 kHz) and behaves like a mirror. If the transmitter is at large distance (800 to 2000 km) then the radio waves are guided like in a waveguide consisting of the D layer and the earth surface. Any change in the quality of this waveguide results then in the signal change in the SID monitor. The change can be positive but in some cases such as the sudden phase anomaly also negative.

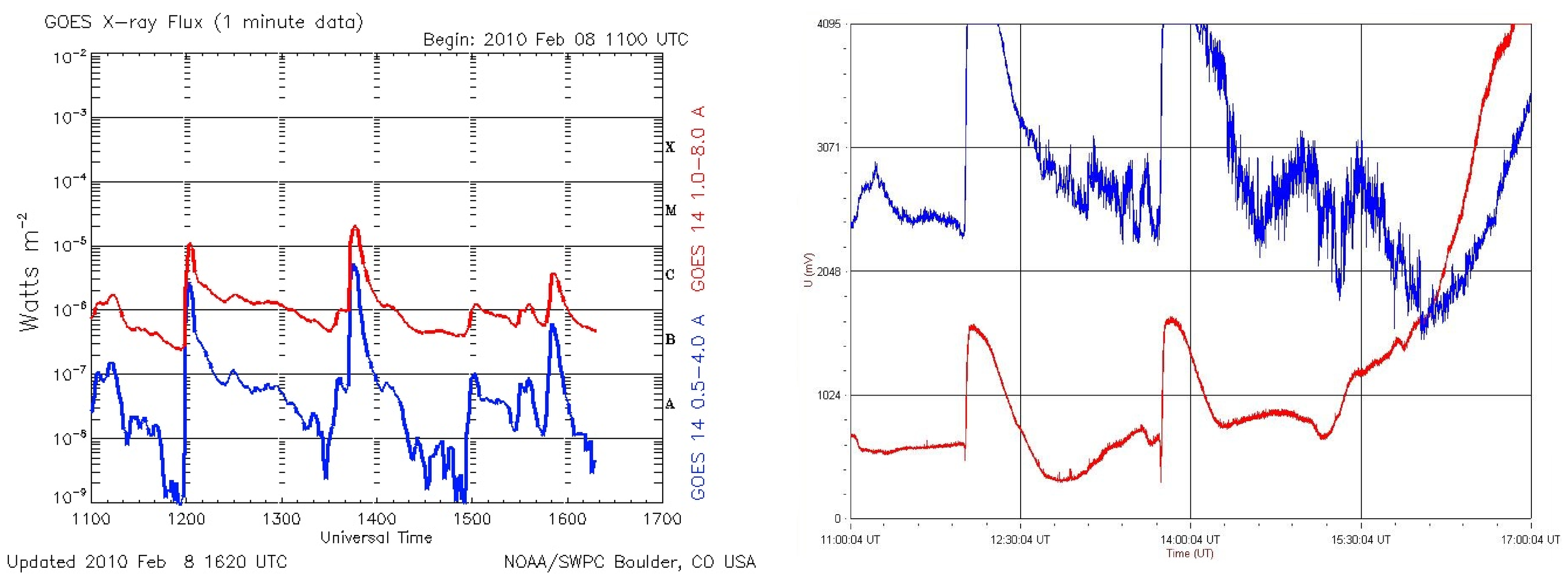
## TYPICAL IONOSPHERIC BEHAVIOUR

Picture below shows the typical behaviour of the ionosphere during the day. The blue part is the night part with absence of the D-layer. The yellow parts are the sunrise and sunset and the white part is day-time.

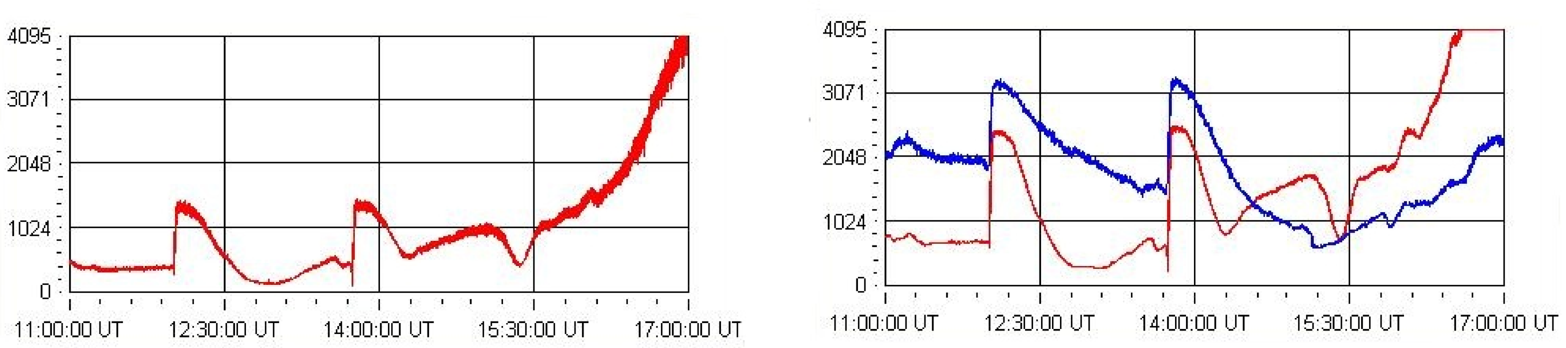



## DETECTION OF SOLAR FLARES

Beautiful and copybook example of detection of solar flare is from the 8th February 2010. Three SID-monitors from observatories Hlohovec, Partizanske and Bojnice detected the M class solar flare. Pictures below show the detection and the same event detected by one of GOES satellites.

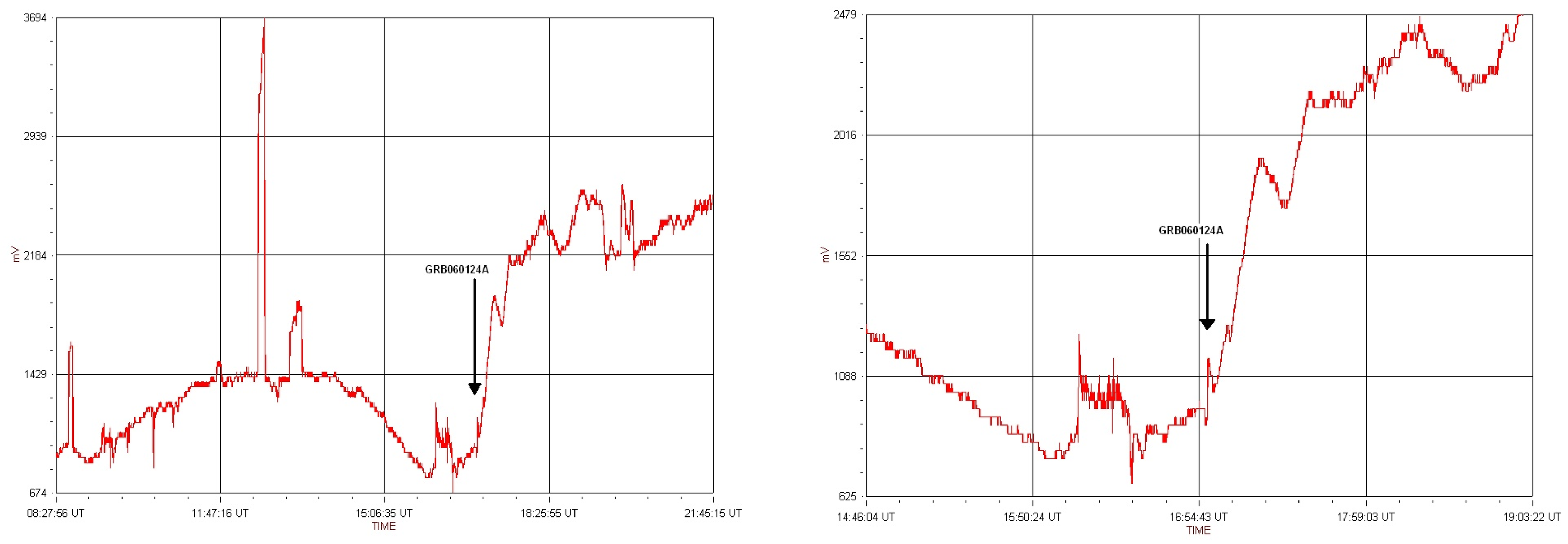



FIGURES: GOES X-ray data (top-left), detection from the Hlohovec Observatory (top-right), detection from the Partizanske observatory (bottom-left) and detection from the Rudy BASE observatory in Bojnice (bottom-right)



## GRB DETECTIONS BY SID-MONITORS

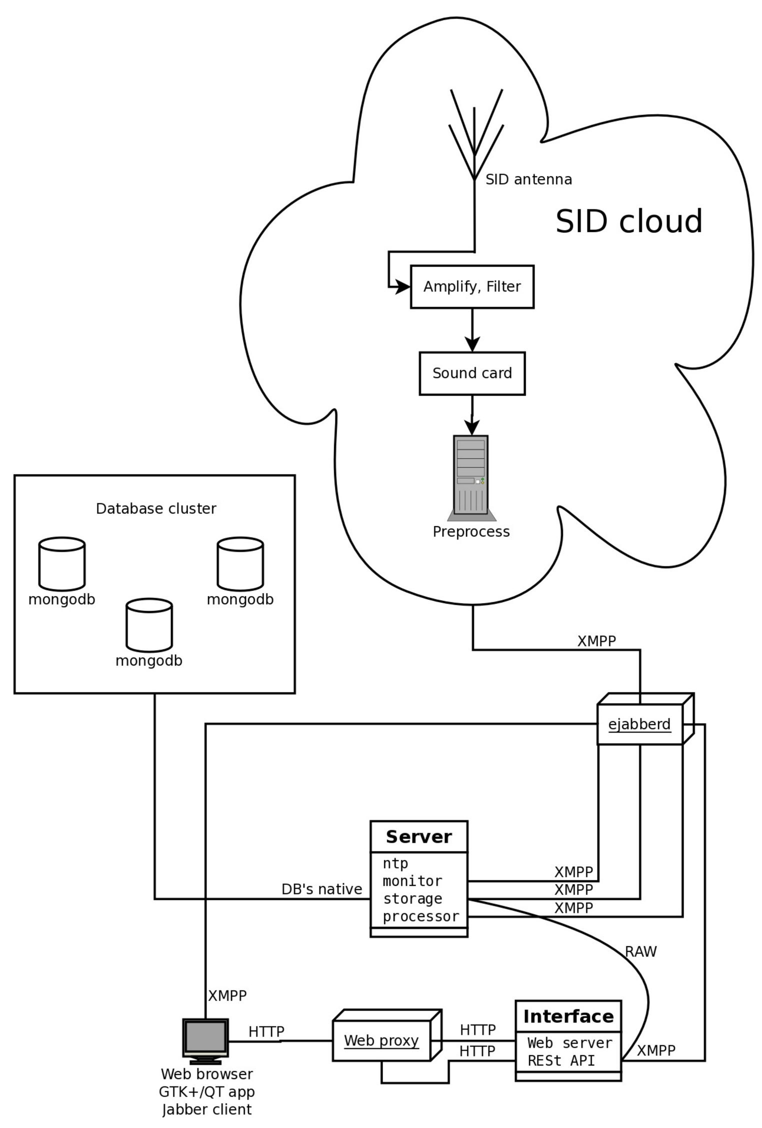
We already know that SID-monitor is sensitive enough to detect such faint ionospheric events like GRBs. As you can see on detection of GRB 060124A (images below). Weakness of this method is noise coming from different sources mostly relatively close to SID-monitor antenna, like close factories, electronics devices or for example neon light tubes. For elimination of this kind of noise we want to build SID-monitor network.




## NETWORK OF SID-MONITORS

We have two ideas. First is to build several SID-monitors not so close each others. This will eliminate local disturbances from industry and electronics. We already have three SID-monitors in Slovakia (Hlohovec, Partizanske, Bojnice). The distance is ~70km. Two SID-monitors in Czech Republic, one in Brno and one in Ondrejov and several more will be build in 2011.

The second idea is to create an autonomous network. Inside this network will be one server and each SID-monitor computer will send the data using jabber (XMPP) to this server. On the picture bellow-left is diagram of this network. On the pictures bellow-right are the SID-monitor and antenna. All data from SID-monitors network will be immediately accessible by web-server.




## REMARKABLY FAINT DETECTION

During GRB100212 we observed very interesting behaviour. In the same time GOES14 detected a solar flare. The SF from Rudy BASE SID-monitor is plotted below. In the middle of SF event we detected small disturbance. This very small disturbance is exactly in the time of GRB100212. The very same disturbances we found in data from all three SID-monitors (Partizanske, Hlohovec, Rudy BASE Bojnice). Because all three SID-monitors detected the same disturbance in same time, we assume that we possible detected GRB100212.

This detection clearly shows how important is SID-monitor network and how sensitive it can be.