

Joint Observations of Solar Flares by Konus-Wind and SoLO/STIX

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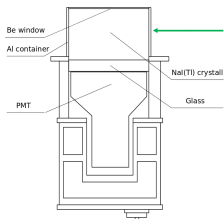
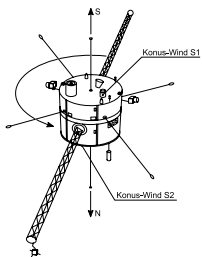
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2023





- Konus-Wind is a joint Russian-US experiment for gamma-ray burst and solar flare studies in hard X-ray and soft gamma-ray ranges (Aptekar et al., 1995).
- Operates since November 1, 1994 till present time.
- Two detectors S1 and S2
NaI(Tl) 13 cm x 7.5 cm are located on opposite faces of the Wind spacecraft, observing correspondingly the southern and the northern ecliptical hemispheres.
- Incident angle for solar flare emission is 90° .
- Continuous observations of all sky.
- ~ 20 keV–15 MeV energy range (present time).
- Since July of 2004 is orbiting around L1 at ~ 5 light seconds from Earth.
- Doesn't suffer from "nights".
- Exceptionally stable background.

- Waiting mode: Time profiles: G1 ($\sim 20\text{--}80$ keV), G2 ($\sim 80\text{--}300$ keV), G3 ($\sim 300\text{--}1200$ keV) with temporal resolution 2.944 s.
- Triggered mode:
 - Time profiles in the same 3 channels with resolution varying from 2 to 256 ms, total duration ~ 240 s.
 - 64 multichannel spectra in two partially overlapping energy ranges ~ 20 keV–15 MeV.

Accumulation time of multichannel spectra varies from 64 ms to 8.192 s.

- After accumulation of energy spectra the instrument is inactive for ~ 1 hour, only count rate curve in G2 channel is available with accumulation time 3.6 s.
- KW-Sun database is available via <http://www.ioffe.ru/LEA/kwsun>. It contains data on >1000 solar flares registered by Konus-Wind in the triggered mode (Lysenko et al., 2022).

Konus-Wind instrument

Konus-Wind is a joint US-Russian experiment launched on November, 1, 1994 to study gamma-ray bursts and solar flares. It consists of two NaCl(Tl) detectors G1 and G2 observing correspondingly the southern and northern celestial hemispheres. The instrument operates in the intermediary space (Cubesat) - near Lagrange point L1, so it does not suffer from "night" and, thus, has a very high duty cycle of about 99%. Thanks to being far from the Earth's magnetosphere it sees an exceptionally stable background.

Konus-Wind works in two modes: waiting mode and triggered mode. In the waiting mode the count rate light curves are available in three wide energy channels G1 ($\sim 20\text{--}80$ keV), G2 ($\sim 80\text{--}300$ keV), G3 ($\sim 300\text{--}1200$ keV) with accumulation time 2.944 s.

Switching to the triggered mode occurs at a statistically significant excess of ~ 5 sigma above a background count rate within an interval of 1 s or 143 ms in the G2 energy channel. In the triggered mode Konus-Wind measures count rate light curves in the three channels with a varying time resolution from 2 to 256 ms and with total duration of 235 s, while in the waiting mode, 64 multichannel spectra are taken in addition to the light curves as follows. The multichannel spectra are measured in two partially overlapping energy bands: low— $20\text{--}250$ keV and mid— $400\text{--}15$ MeV. Each of the bands has 63 energy channels. Accumulation time of the first four spectra is fixed at 64 ms and of the last eight spectra — at 8.192 s. For the remaining 52 spectra the accumulation time is adaptively adjusted from 0.256 s to 8.192 s based on the count rate in the G2 channel; for more intense events the accumulation time is proportionally shorter. After accumulation of energy spectra the instrument is inactive for ~ 1 hour, only light curve in G2 channel is available with accumulation time 2.944 s.

For more detailed instrument description see
 Antonov, L., Anisimov, G. G., Gerasimov, S. V. et al. 1995, *Soviet Sol. Rev.*, 72, 249

Konus-Wind Solar Flare Data

The presented database contains time profiles and energy spectra for solar flares registered by Konus-Wind in triggered mode. For the time period the data are prepared only.

The flare on 6 September 2017, 11:55:23 (42923)

Konus-Wind X-ray light curves:

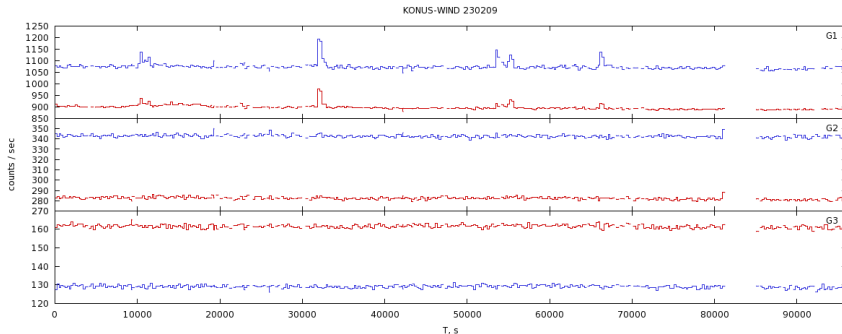
- ASCI1 - 3-ch light curve (ASCII format)
- SAV - 3-ch light curve (IDL SAV format)

Konus-Wind spectral data:

- F150_1 - low-energy spectral data
- F150_2 - high-energy spectral data
- M150_1 - low-energy response matrix
- M150_2 - high-energy response matrix
- ABE - auxiliary response file
- BG150_1 - low-energy background data
- BG150_2 - high-energy background data

[Data format description](#)

- More than 13,000 solar flares are registered in the waiting mode.
- We plan to publish waiting mode data.
- Now waiting mode data are available on request
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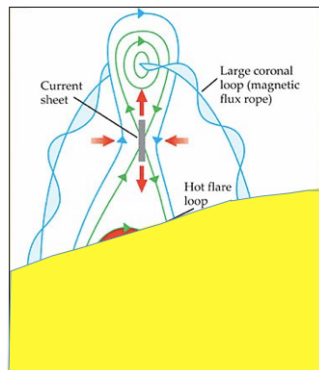


S1 detector (red), S2 detector (blue)

The prospects of joint solar flare observations by Konus-Wind and SoLO/STIX

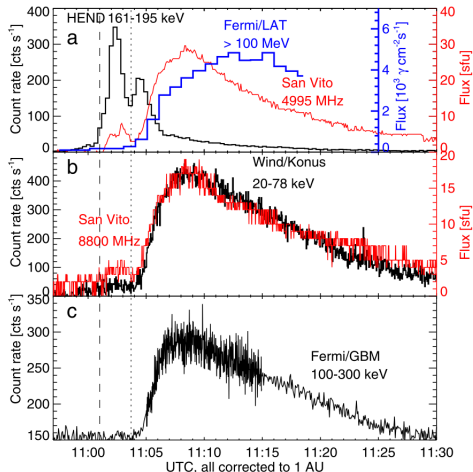
- Studies of solar flares in a wider energy range (up to 15 MeV in the triggered mode).
- Stereoscopic studies of solar flares, first of all, partially occulted and behind-the-limb flares.
- Systematic search for behind-the-limb flares.

- Footpoints of partially occulted flares are located on the far-side of the Sun at longitudes $< 10^{\circ}$.
- Behind-the-limb flares can be located at longitudes up to $\sim 45^{\circ}$ on the far-side.
- A terrestrial observer sees hard X-ray emission from the corona (for the most part).



Stereoscopic observations of behind-the-limb flares

- Behind-the-limb flare SOL2014-09-01 with footpoint at $\sim 45^\circ$ behind the limb;
- Spiky time profile in hard X-ray range from the footpoints (HEND/Mars-Odyssey);
- Smooth time profiles in X-ray range observed from the Earth (Konus-Wind, Fermi-GBM);
- The origin of smooth emission – ? (Ackermann et al., 2017; Grechnev et al., 2018; Jin et al., 2018; Petrosian, 2018; Carley et al., 2017)



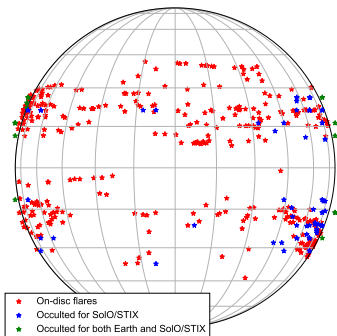
Grechnev et al., 2018

Behind-the-limb solar flare observed by SoLO/STIX – Pesce-Rollins et al., 2022.

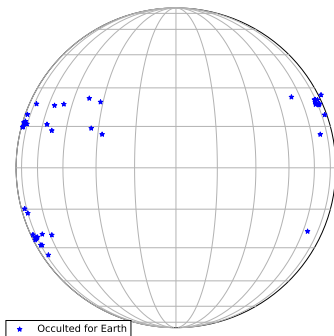
- Thanks to the stable background and almost continuous all-sky observations, Konus-Wind waiting mode data are very suitable for automated search of transient events, in particular, joint observations with other instruments.
- For the search we used list of flares with known locations observed by SoLO/STIX¹. This list contains ~6000 flares between February, 2021 and April, 2023.
- Automated search yielded ~500 jointly observed flares. This flare list is available online http://www.ioffe.ru/LEA/kw_stix/.

¹https://github.com/hayesla/stix_flarelist_science/

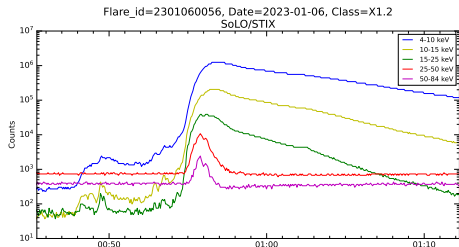
The Sun for terrestrial observer



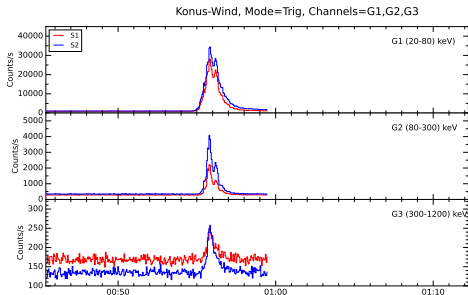
Far-side of the Sun for terrestrial observer



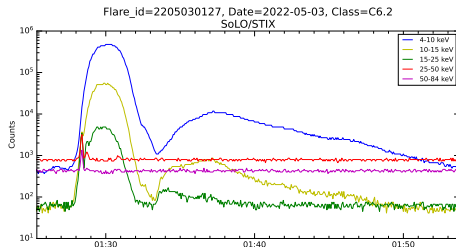
Among 483 jointly observed flares, among them 347 on-disc flares for both Konus-Wind and STIX, 75 flares occulted by solar limb for SoI/O/STIX, 44 flares occulted for Konus-Wind (and the Earth), 17 flares occulted for both spacecrafts.



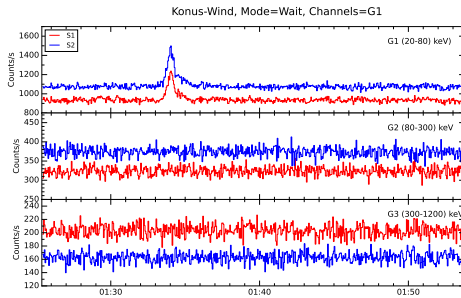
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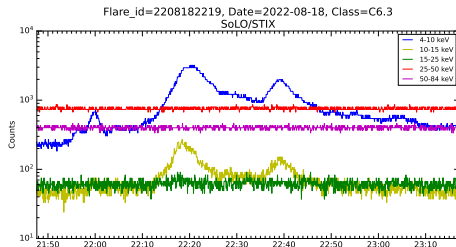
- Konus-Wind observations in the triggered mode (wide energy range, high time resolution).
- Good agreement of time profiles for both instruments.



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- Flare footpoints were observed by SoLO/STIX.
- Coronal emission could be explored by a variety of different instruments (ASO-S, EOVSA...)
- The main role of Konus-Wind is to identify such events.



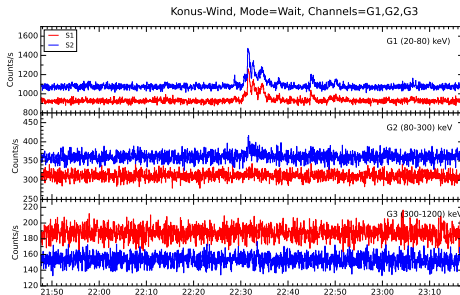
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Earth



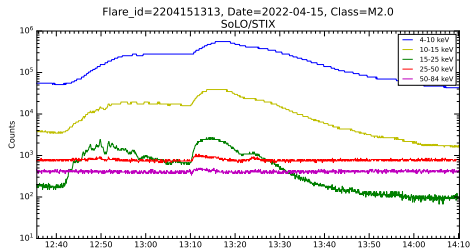
Sun

SoLO



- The study of coronal emission by SoLO/STIX.

Flares occulted for both Earth and SoLO/STIX



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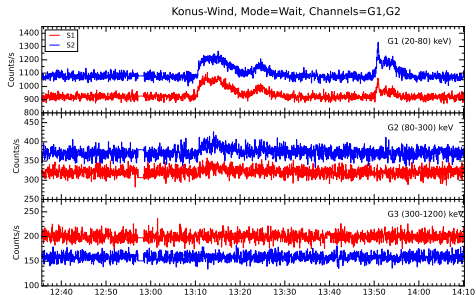
Earth



Sun



SoLO



- The study of coronal emission at different angles.
- Is this valuable?

We developed the technique for the search of solar flares jointly observed by Konus-Wind and SolO/STIX. The automated search yielded ~ 500 jointly observed flares out of ~ 6000 flares with known locations observed by Solo/STIX².

Joint observations can be used for:

- The solar flare study in a wide energy range (4 keV – 15 MeV), which covers the emission from thermal plasma and the emission from accelerated electrons and ions.
- Stereoscopic studies of solar flares.
- The automated search for rarely observed behind-the-limb flares.

The preliminary list of joint Konus-Wind and SolO/STIX observations is available online http://www.ioffe.ru/LEA/kw_stix/.

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Thank you for attention

We thank Hualin Xiao and Andrea Francesco Battaglia for the help with SolO/STIX data.

²https://github.com/hayesla/stix_flarelist_science/

