Multi-mission observations of the old nova GK Per during the 2015 outburst

Polina Zemko¹, Marina Orio²,³, G. J. M. Luna⁴

1. University of Padua, Italy
2. INAF-OAPD, Italy
3. University of Wisconsin, Madison
4. Instituto de Astronomía y Física del Espacio, IAFE/Conicet

GK Per

- Magnetic WD accreting from a red dwarf secondary
- $P_{\text{orb}}$ is $\sim 2$ days
- WD spin period is 351 s
- The distance is 470 pc
- Hosts the largest known X-ray emitting nebula centered on a WD binary
- Is detected with the Swift BAT and INTEGRAL during DN outbursts
1901 Feb. 21 Nova explosion

2015 DN outburst

Chandra HETG NuSTAR

Data from the AAVSO database

- Slow rise and decline in optical.
- A long-lasting plateau phase in the X-rays.
**Swift:**
Two exposures per day ~1ks for 2 weeks
One exposure per day ~1ks for 2 weeks

**Chandra HETG:** 69 ks
- HEG: 0.120±0.013 cnts/s
- MEG: 0.0749±0.0010 cnts/s

**NuSTAR:** 42.3 ks
- 3.622±0.009 cnts/s

**0.3 - 1.5 keV**
- 1.5 – 10 keV

**Swift BAT**

**Counts/cm²/sec (15–50 keV)**

**Swift/XRT**
- PC
- WT

**HR**
- Hardness ratio

**AAVSO**
- Outburst
The beginning of the outburst
...SwiO: Two exposures per day ~1ks for 2 weeks
One exposure per day ~1ks for 2 weeks
Chandra HETG: 69 ks
HEG: 0.120 +/- 0.013 cnts/s
MEG: 0.0749 +/- 0.0010 cnts/s
NuSTAR: 42.3 ks
3.622 +/- 0.009 cnts/s

Swift UVOT data
U 3465 A
UVW1 2600 A
UVM2 2246 A
UVW2 1928 A
Swift PC - the first 2 weeks

NuSTAR
On-pulse
Mean
Off-pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR

Swit
PC
	
the
first
2
weeks

NuSTAR
On-
pulse
Mean
Off-
pulse

Chandra
MEG+HEG

Chandra
MEG+HEG
+NuSTAR
Swift PC - the first 2 weeks

Swift WT - the last 2 weeks

NuSTAR
On-pulse
Mean
Off-pulse

Chandra
MEG+HEG

Photons cm$^{-2}$ s$^{-1}$ keV$^{-1}$
A very soft component absorbed only by the interstellar absorber. Will be a case for Chandra LETG.
A two-temperature thermal(?) or photoionized plasma. He-like triplets show strong intercombination lines.
Highly absorbed thermal plasma emission at $T=14$ keV. Modulated at the WD spin period.
Chandra MEG data
2015-04-05
2002-03-27
2002-04-09

normalized counts s^{-1} \, \text{Å}^{-1}

Wavelength (Å)

Chandra MEG data
2015-04-05
2002-03-27
2002-04-09

Ne IX
O VIII
O VII
N VII

0
5 \times 10^{-3}
0.01
0.015
**Swift**

- Power spectrum with three energy ranges:
  - 1.5−10 keV
  - 0.3−1.5 keV

**Spin period**

- 351.35s

**NuSTAR**

- Power spectrum with three energy ranges:
  - 3.0−78 keV

**Spin period**

- 351.35s
The WD spin period is longer comparing with previous observations.

There are no common spikes in the LSPs, corresponding to different data (except for the spin period).
Fe XXVI 6.4 keV

Mg XI 1.35 keV

Si XIII 1.86 keV

Spin phase

Orbital phase

Phase

Counts/s
Conclusions:

The obtained data reveal several distinct regions in the X-ray spectrum:
• a very soft (<0.8 keV) at $T_{bb} \sim 25$ eV
• a soft X-ray component at $T \sim 0.1$ keV
  these components do not show spin modulation
• a hard thermal X-ray component at $T \sim 14$ keV, modulated at the spin period.

The amplitude of the spin pulse is the highest (> 10 cnts/s) in the Nustar energy range -> the modulation is not due to an absorption

The spin period is slightly longer than in previous observations. The proposed spin up is not confirmed.

QPOs are observed in all the data in all energy ranges.
Thank you