ATOMDB Atomic Data for Astrophysicists

AtomDB Workshop and Advanced Spectroscopy School
3rd - 5th August 2020

AUBURN UNIVERSITY

Charge exchange emission from comets with NICER

Emanuele Bonamente

Physics Department, Auburn University

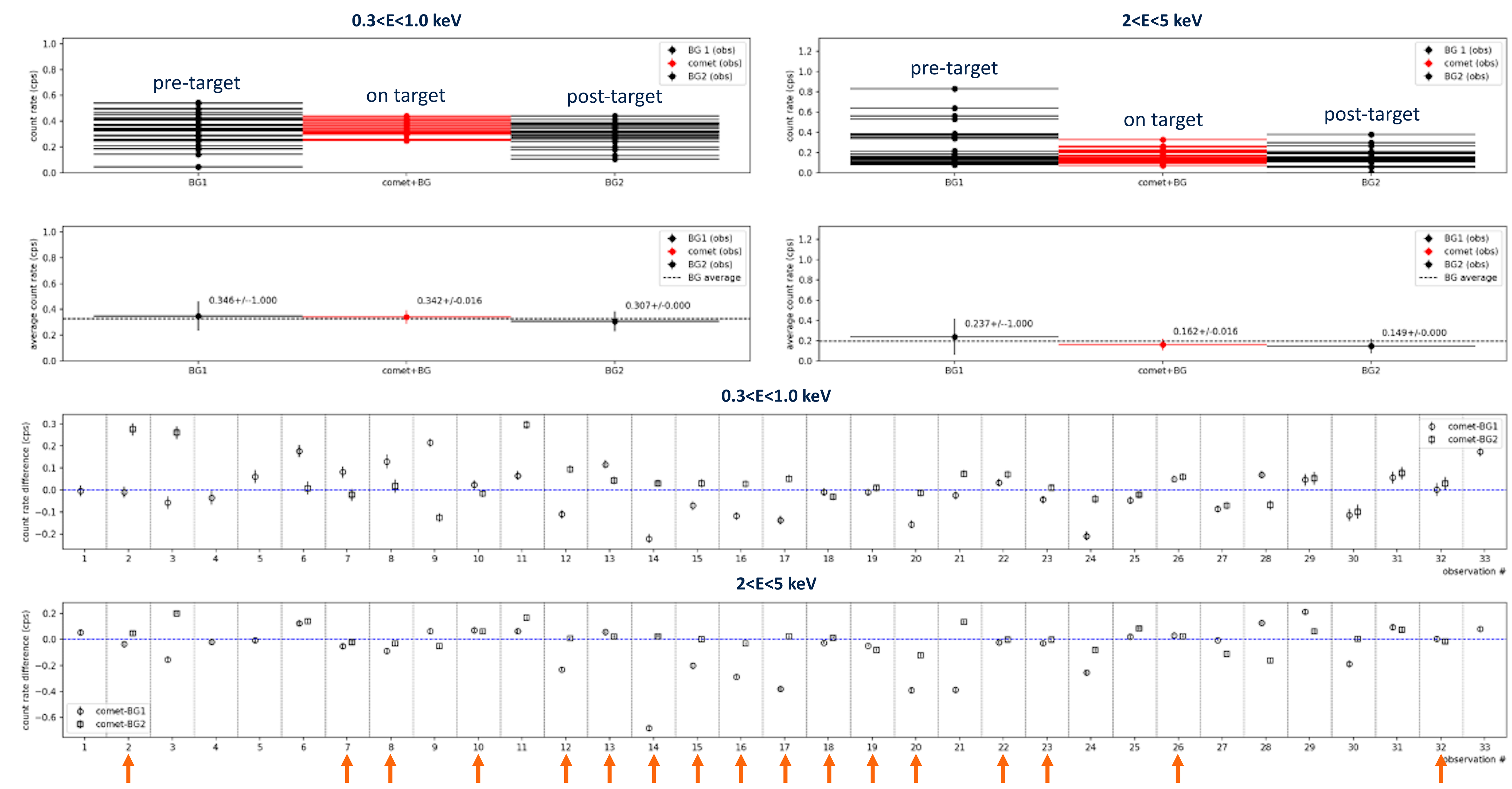
ABSTRACT Preliminary results of the first comet observation with the Neutron Star Interior Composition Explorer (NICER) are presented. C/2017 T2 (PANSTARRS) is an Oort cloud comet that reached perihelion early May, 2020, when it was at high heliographic latitudes and hence in the fast polar wind. The X-ray spectrum was analyzed to find signatures of charge exchange (CX) emission produced by solar wind ions interacting with the gas in the comet coma. As comets are rapidly-moving objects characterized, in general, by low CX fluxes, dedicated observation strategy and background estimate approach were required. The background-subtracted spectrum shows a significant X-ray excess (>5 σ) in the 0.3-1.0 keV. The analysis is still ongoing, however, preliminary attempts to fit CX emission models are consistent with the fast solar wind scenario. There is no evidence of features above 1 keV.

CHARGE EXCHANGE emission is the main physical process making comets visible in X-rays. When ionized atoms in the solar wind meet the cold gas in the comet coma, an electron can be transferred to the ion into an excited level. For high enough ion charges, the successive deexcitation produces electromagnetic radiation in the X-ray range. Spectral features in the CX spectrum from comets (which are also affected by local factors such as collision velocity and neutrals abundancies) can be used as a probe of the solar wind fractional abundances (i.e. fraction of charge states for different elements).

NICER is a non-imaging X-ray spectrometer (0.2-12 keV) located onboard the ISS. It has an unprecedented timing resolution (100 ns RMS) specifically designed to study pulsar emission. The X-ray Timing Instrument (XTI) is an array of 56 concentrator optics and silicon-drift detectors pairs. The sensitivity is 3×10^{-14} ergs s^{-1} cm^{-2} (0.5-10 keV, 5 σ in 10 ksec) and the field of view is 30 $arcmin^2$. NICER is characterized by a variable background that depends on the position (geomagnetic latitude) and the sun (space weather), requiring a specific and detailed estimate for each observation.

OBSERVATIONS of comet C/2017 T2 (PANSTARRS) took place between April 17 and June 28, 2020 and were planned to continuously monitor it during the perihelion passage. During this period, the comet was constantly at high heliographic latitudes (>35 deg) and, being the Sun at the solar minimum, likely within the faster, colder, and more constant, solar wind. Background estimation was expected to play a major role considering the low optical brightness (V~12). The observation strategy was setup to include blank-sky exposures (pre and post) of the same position in the sky where the comet was targeted. The data presented in this analysis makes use of 56 ks exposure at the target after cleanup.

Background analysis and event selection based on low (0.3<E<1.0 keV) and high (2<E<5 keV) energy bands



Observation schedule

- 33 pre-target (BG1, blank sky); *t≃−(10÷12) h*
- 33 on target (comet, t=0); *t = 0 h*
- 33 post-target (BG2, blank sky); *t≃+48 h*

Background estimate

- Systematic difference between pre- and post-target backgrounds. This is found to be a function of the ISS with respect to the Earth and varies with the magnetic rigidity cutoff.
- The X-ray flux at high energies (2<E<5 keV, where no CX emission is expected) is generally stable for periods as long as 2 days.
- 17 target/background pairs (↑) taken out of 33, requiring:
  - similar ISS positions with respect to the Earth magnetic field;
  - consistent count rates in target and post-target observations at high energies.

Background-subtracted spectrum

- Low energy (0.3<E<1 keV) excess: 870±150 counts (>5σ);
- High energy (2<E<5 keV): -14±100 counts.

Goals

- Identification of a reliable and reproducible strategy for future comet observations using NICER.
- Proof of CX spectrum analysis as a reliable probe of space solar wind parameters, especially at high heliographic latitudes where it is not continuously monitored.
- Combine X-ray to optical and ultraviolet information in order to constrain on coma composition and morphology properties.

CX model and fit to data

- A preliminary fit was performed in the 0.3–0.7 keV energy range. There is no definitive evidence of emission features above 1 keV.
- Using the AtomDB Charge Exchange Model version 2 (ACX2), there are preliminary indications of emission from fast solar wind. The background-subtracted spectrum is consistent (75% fit probability) with CX from solar wind having a velocity of v=750 km/s and a plasma temperature of T =10^6 K. The flux is 2.0×10^{-14} ergs s^{-1} cm^{-2} the 68% C.I. is $(1.9\text{-}2.5)\times10^{-14}$ ergs s^{-1} cm^{-2}.

Ongoing investigations and future developments

- Improvements on background estimate and subtraction procedure (i.e. enhanced cuts on good events and good time intervals).
- Refinement of the fitting model and test against alternative hypotheses.
- Scheduled observation of the periodic comet 88P/Howell with NICER starting September 2020. The analysis will allow the comparison between polar and equatorial wind CX emission.

Background-subtracted spectrum (0.3<E<0.7 keV) from comet C/2017 T2 (PANSTARRS)