***Chandra* X-ray Observatory Observations of Dynamically New Comet C/2012 S1 (ISON): First Detection of OVI Emission By the HRC-I From an X-ray Bright Comet.** C.M. Lisse[1], D.J. Christian[2], S.J. Wolk[3], K. Dennerl[4], D. Bodewits[5], M.R. Combi[6], S.T. Lepri[6], T.H. Zurbuchen[6], [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723 carey.lisse@jhuapl.edu [2]California State University Northridge, 18111 Nordhoff Street, Northridge, CA 91330 damian.christian@csun.edu [3]Chandra X-ray Center, Harvard-SAO, 60 Garden Street, Cambridge, MA, 02138 swolk@cfa.harvard.edu [4]Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, 85741 Garching, Germany, kod@mpe.mpg.de [5]University of Maryland, Department of Astronomy, College Park, MD 20742 dennis@astro.umd.edu 6The University of Michigan, Department of Atmospheric, Oceanic and Space Sciences, Space Research Building, Ann Arbor, MI 48109-2143, USA mcombi@umich.edu, slepri@umich.edu, thomasz@umich.edu

Introduction: We present results from the *Chandra* X-ray Observatory's characterization of the x-ray emission from comet C/2012 S1 (ISON), in support of NASA's Comet ISON Observing Campaign (CIOC). Chandra observed the comet in three separate pre-perihelion pointings observations of the comet on Oct. 31.302, Nov. 3.083, and Nov. 6.438 UT. [Note that scheduled post-perihelion observations in Dec 2013 – Jan 2014 were cancelled after the comet disrupted near perihelion on 28 Nov 2013.]

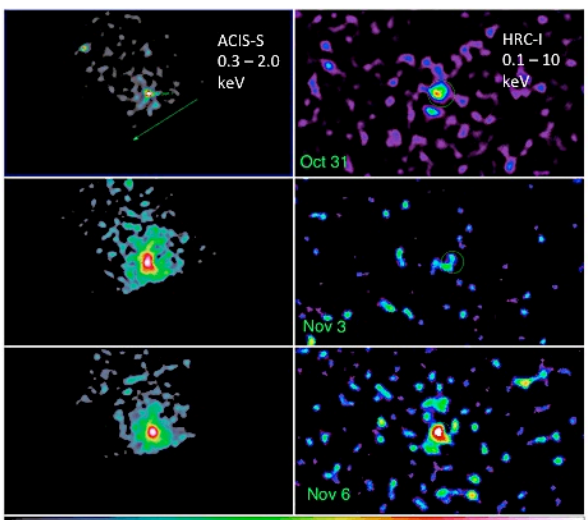

Fig. 1 - Chandra C/2012 S1 (ISON) imaging results. (*Left column*) ACIS-S 0.3 – 2.0 keV measurements taken on 31 Oct (top), 03 Nov (middle), and 06 Nov (bottom). **(*Right column*)** HRC-I 0.1 – 10 keV camera measurements taken contemporaneously with the ACIS-S observations. The Sun is towards the lower left in all images **(Arrow)**. The solar wind state varied from highly mixed and O^{+7} poor on 31 Oct to normal on 06 Nov. It is not clear why the comet is so faint in the 03 Nov HRC-I image.

Observations: Detections were obtained in both the ACIS-S spectro-photometric (0.3-2.0 keV) and HRC-I imaging (0.1-10 keV) cameras in 8700- and 3800-sec duration exposures, respectively. The HRC-I measurements represent the first ever detections of a comet in the broad 0.1 – 10 keV HRC-I bandpass, likely dominated by solar wind charge exchange (SWCX) OVI emission from abundant O^{+6} solar wind ions at 0.05 – 0.10 keV.

The ~5' width of the detected x-ray emission seen in the ACIS-S imagery on Nov. 3 and Nov. 6 corresponds to an emitting region about 260,000 km in diameter, typical for bright x-ray comets [1-3], and consistent with the OH coma radius of > 500,000 km detected by SWIFT on Nov. 7 [4]. The observed x-ray morphology on these "normal" solar wind days is consistent with the usual "kidney-bean" or projected paraboloid emission pattern seen for the brighter comets by *Chandra*.

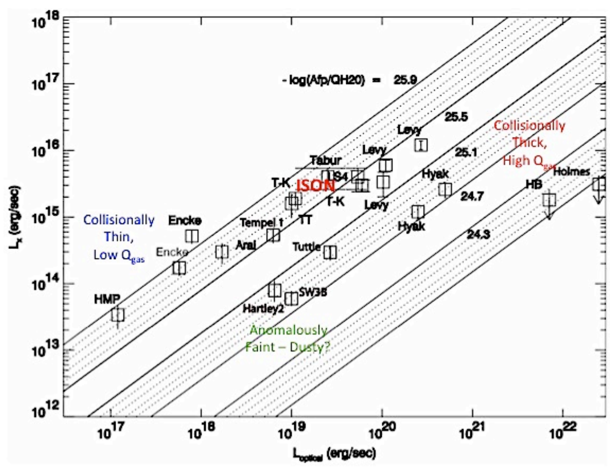

Fig. 2 - Comet ISON's relative optical and x-ray luminosities in early Nov 2013. At L_{opt} ~ 4 x 10^{19} erg/sec, L_x ~ 3 x 10^{15} erg/sec, and Q_{gas} ~ few x 10^{28} mol/sec, C/2012 S1 (ISON) appeared as a typical x-ray bright, collisionally-thick-to-SWCX comet emitting ~ 10^{-4} of its energy in the x-ray.

Total count rates of 0.24, 0.36, and 0.30 counts per sec were found for C/2012 S1 by the ACIS-S when the comet was at r_h = 1.0, 0.94, and 0.87 AU from the Sun, and at Δ = 1.25, 1.17, and 1.08 AU from the Earth/Chandra. During this time, C/2012 S1 exhibited a neutral gas-emission rate, Q_{gas}, of 1 to 3 x 10^{28} molecules/s [5-6] and a moderately low dust-to-gas ratio of about 0.7. Assuming a 1/Δ luminosity dependence, the comet's 0.3- to 1.0-keV x-ray luminosity was 3.1, 3.5, and 3.9 x 10^{15} ergs/s and its L_x/L_{opt} ratio was ~10^{-4}, typical of the brightest Chandra-detected comets [1-3].

The low resolution ACIS-S pulse height spectra show evidence for the typical cometary x-ray OVII emission complex at 0.50 – 0.70 keV [2,3,7], and the normal ACIS-S instrumental background peak at 0.20 – 0.30 keV. Unexpectedly, though, an apparent peak at 0.05 – 0.10 keV that varies consistently with the HRC-I imaging photometry was also found.

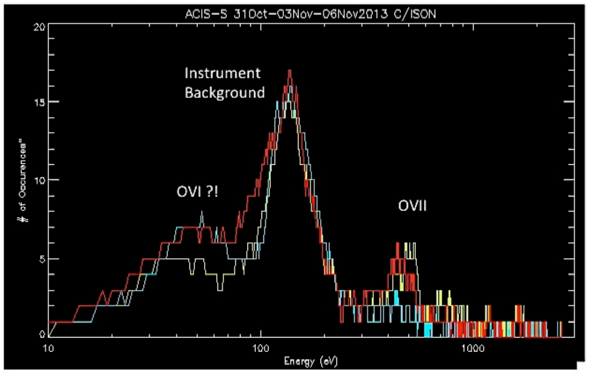

Fig. 3 - C/2012 S1 (ISON) CXO/ACIS-S low resolution pulse height x-ray spectra using preliminary pipeline energy calibration. Blue – 31 Oct 2013 pointing. Yellow – 03 Nov 2013 pointing. Red - 06 Nov 2013 pointing. The OVII emission is strong on 03/06Nov, and an apparent extremely soft OVI peak is strong on 31 Oct/06 Nov, consistent with the imaging results of Fig. 1.

The relative ratio of OVII/ OVI emission in the ACIS-S vs. HRC-I cameras flipped between 31 Oct and 03-06 Nov, due to a change in the ion (O^{7+}/O^{6+}) abundance ratio in the solar wind impacting the comet on those days. This in turn likely reflects a change in the source (O^{7+}/O^{6+}) ratio of the solar wind emitted 3 to 7 days prior from the solar corona, a change between a wind dominated by material from a coronal mass ejection or a coronal hole [8] on Oct. 31 and a mostly normal low equatorial solar wind on 03-06 Nov.

Implications: We had employed the HRC-I camera's larger sensitivity at low x-ray energies in an attempt to detect potentially ubiquitous OVI emission [9], and we appear to have been successful. Detection of OVI emission in the ACIS-S spectra was unexpected, but, if real, has important implications for the possibility of finding OVI emission in archival Chandra comet observations. Without major changes in the solar wind content and the comet's concomitant x-ray response, though, it is unlikely we would have made a concrete detection of the OVI emission.

Another important finding comes from ISON's relatively high x-ray luminosity L_x. ISON's G_{as} of ~1 to 3 x 10^{28} mol/sec is the lowest measured yet for an x-ray bright, collisionally thin to SWCX coma, and pushes the lower limits of the required coma density in current charge exchange models [7]. On the other hand, as ISON was a notably dust poor comet with a very large, extended gas coma [10], the high x-ray luminosity is in line with the hypothesis suggested in [9] that coma dust density anti-correlates with cometary x-ray production.

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Acknowledgements: Support for this work was provided by NASA through Chandra GO Award Number 15100583 issued by the Chandra X-ray Observatory Center and the NASA ACE project via mission grant 44A-1085637.