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X-ray Emission Spectroscopy for the plasmas of 153P/Ikeya-Zhang and 46P/Wirtanen Comets.

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Abstract

The present research focuses on composition of comets depending on the process of solar wind charge exchange (SWCX). The chemical composition of cometary nuclei was inferred from measurements of neutral and ionized gases from the coma, tail, and dust grains. Cometary high-energy emission depends on properties of both the comet and solar wind.

Data were obtained from Chandra X-ray space telescope for two comets, one of them come from Kuiper Belt, namely, 46P/Wirtanen and other originating from the Oort cloud namely 153P/Ikeya–Zhang Comet. Observed at energy range (100-10000) eV. The results of present work showed a relation between photons count and energy to estimate the structure of the comets, also we found that the comet come from Oort cloud contain four elements but the other contain eighteen elements furthermore, determined the abundant of each element.

KeyWords

X-ray spectroscopy, Chandra space telescope, 46P/Wirtanen, 153P/Ikeya–Zhang, comets.

1.Introduction

Our knowledge of any celestial objects especially the comets depending on what information we could gather via line emission observed from the interaction like, “visible” light emission. This gives us, limited information about the comets and this leads to limited view of our universe. The opening up of the various other regions of the electromagnetic spectrum like X-ray region has accordingly given us a much more comprehensive and complete picture of the comet and the various processes that operate within it than was ever possible before [1].

The limits of X-ray wavelengths are not sharply defined, there is always an overlap with ultraviolet region towards longer wavelength side and with gamma ray in smaller wavelength side so, we can classify X-ray spectrum depend on wavelength as [2]:

- *Ultraviolet X-ray*: When wavelength is less than (0.1) A.
- *Hard X-rays*: When wavelength is between 0.1 A and 1 A.
- *Soft X-rays:* When wavelength is between 1 A and 10 A.
- *Ultrasoft X-rays:* When wavelength is greater than (10) A.

X-ray and Extreme Ultraviolet (EUV) emission are usually associated with high temperature environments. The discovery that comets are bright emitters in this spectral regime was therefore a big surprise [3], and is in strong contrast to our understanding that comets are dirty snowballs surrounded by a gaseous coma with a temperature of approximately 50 K. After the first discovery by ROSAT of the X-ray emission from Comet C/1996 B2 (Hyakutake), a search through the observatory’s archives proved that in fact all comets (with total visual magnitude mv < 12.0) in the inner solar system (2 AU) had emitted X-rays. The total X-ray power in the 0.2 – 1.0 keV band was between 0.004 – 1.2 GW, the emission was highly variable in time, and many of the observed comets displayed a characteristic crescent shape [3].
Comets emit X-rays via the process of solar wind charge exchange (SWCX). Gas in the coma of the comet donates one or more electrons into an excited energy level of a highly-charged ion of the solar wind. In the subsequent relaxation of the ion, a UV or X-ray photon is emitted [4].

NASA's Chandra X-ray Observatory is a space telescope, which was launched and deployed by Space Shuttle Columbia on July 23, 1999, is the most sophisticated X-ray observatory built to date [5].

It is sensitive to X-ray sources 100 times fainter than any previous X-ray telescope, enabled by the high angular resolution of its mirrors. Chandra consists of two x-ray detecting devices the High-Resolution Camera (HRC) and the Advanced X-ray Astrophysics Facility CCD Imaging Spectrometer (ACIS). There are two sets of CCDs on the device: 4 imaging chips (ACIS-I) and 6 spectrometer chips (ACIS-S), A schematic of Chandra’s ACIS array of CCDs [6].
The Observatory has three major parts:

(1) The X-ray telescope, whose mirrors focus X-rays from celestial objects.
(2) The science instruments which record the X-rays so that X-ray images can be produced and analyzed.
(3) The spacecraft, which provides the environment necessary for the telescope and the instruments to work.

Chandra space telescope observed comets Depending on their properties, which most of them are thought to emit X-ray when the distance from heliocentric is about 2 AU. The emitted X-ray radiation with wavelength between about 0.01 to 10 nm are important for studies of solar system nature and astrophysical applications because the composition of comets can be definitely specified which gives a fair picture about the solar system development in its early stages. Photons are sufficiently energetic to ionize neutral atoms and molecules and the solar wind plays a central role in several of the proposed X-ray production mechanisms [7].

Data Acquisition

2.1 153P/Ikeya–Zhang Comet

153P/Ikeya–Zhang Comet is a periodic comet in the solar system. it has an orbital period 366.51 yr and it was observed in 1661. It was observed by Chandra space telescope on July 22, 2002. It was detected by Astrophysics facility CCD Imaging spectrometer chips (ACIS-S) of Chandra telescope with coordinates as shown in table (1) [8, 9].

Table (1): The coordinates of 153P/Ikeya–Zhang comet

Obs ID	RA	DEC	Instrument	Start data
3447	23 30 26.68	+54 54 45.40	ACIS-S	22-07-2002

The full X-ray image of 153P/Ikeya–Zhang Comet as shown in figure (1).
This image contained a data of comet that observed by space telescope, after that analyzed by Ds9 software [11]. It gave us the spectrum of comet as shown in figure (2).

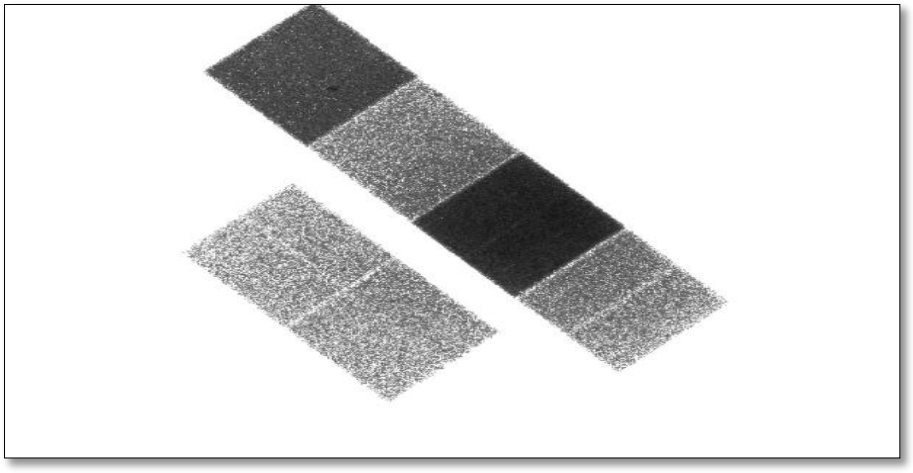

Figure (1): The total X-ray image of 153P/Ikeya–Zhang comet.

2.2 46P/Wirtanen Comet

46P/Wirtanen is a small short-period comet with a current orbital period of 5.4 years it was observed by Chandra space telescope on December 3, 2018. It was detected by Astrophysics facility CCD Imaging spectrometer chips (ACIS-S) of Chandra space telescope with coordinates as shown in table (2)[8,10] .

Table (2): The coordinates of 46P/Wirtanen Comet

Obs ID	RA	DEC	Instrument	Start data
20275	02 43 50.46	-15 27 05.73	ACIS-S	03-12-2018

We can obtain data observation for this comet in a number of steps, start with step one by opened page related with Chandra space telescope; this page provides links to Small Bodies related observations made with the Chandra X-ray Telescope which contain comets name were observed and it's ID [8].

Data observed by Chandra saved as FITS image the total X-ray image of 46P/Wirtanen comet as shown in Figure (2).

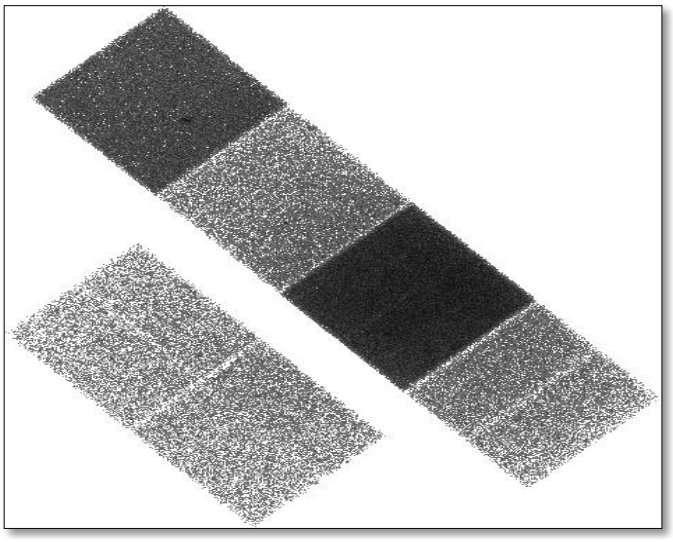

Figure (2): The total X-ray image of 46P/Wirtanen comet

3.Results and Discussion

3.1 The Structure of Two Comets

When highly charged ions from the solar wind collide on a neutral gas in comet, the result is emission one or more photons in the range of X-ray energy. These photons counted per second as a function of energy in eV. This relationship shows the spectrum of the comet, each peak in the spectrum represents a material that we have found in these comets depend on the standard energy of materials which each material has line emission in particular energy. after analyzing the data from figure (1) of the 153P/Ikeya–Zhang comet, and by using ds9 software, the result is the relation between photons count an energy as illustrate in figure (3).

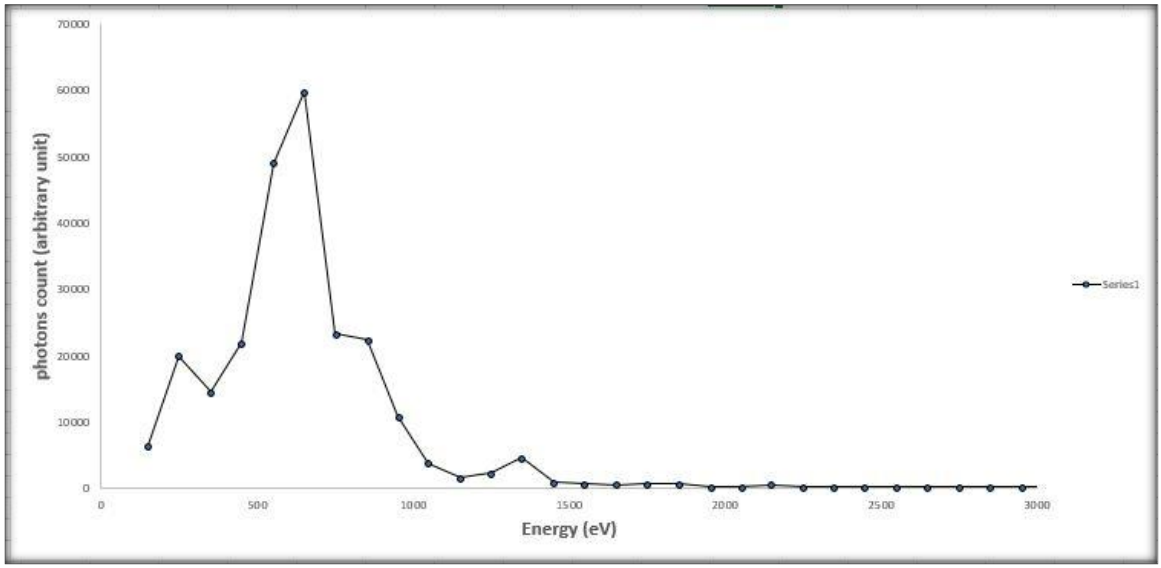

Figure (3): The Relation between Photons count (s) and Energy (eV) for 153P/Ikeya–Zhang comet.

Note in figure (3), that there are four clear peaks and each vertex represented a specific substance, depends on the standard energy of materials, where each material in the universe has specific energy similar to a fingerprint [12].

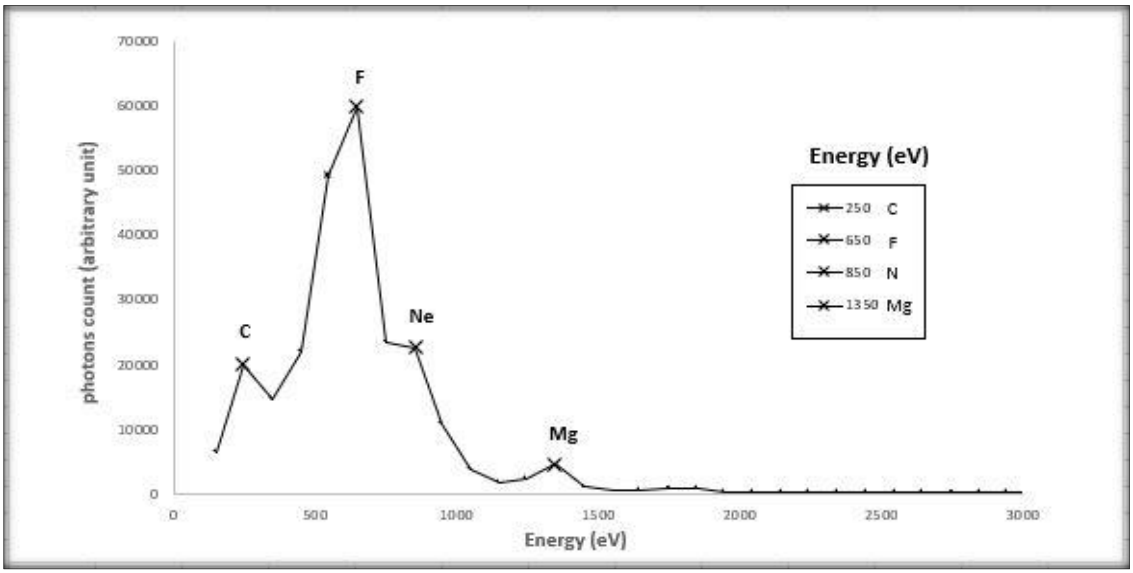

Figure (4): The structure of 153P/Ikeya–Zhang comet.

The structure of 153P/Ikeya–Zhang comet as shown in figure (4), the materials that have been found are Carbon (C) at energy 250 eV $K_{\alpha 1}$, Fluorine (F) at energy 650 eV $K_{\alpha 1}$, Neon (Ne) at energy 850 eV $K_{\alpha 1}$, Magnesium (Mg) at energy 1350 eV $K_{\beta 1}$.

In the same way analyzing the fits image as illustrated in figure (2) for 46P/Wirtanen comet we get the spectrum of comet as shown in figure (5).

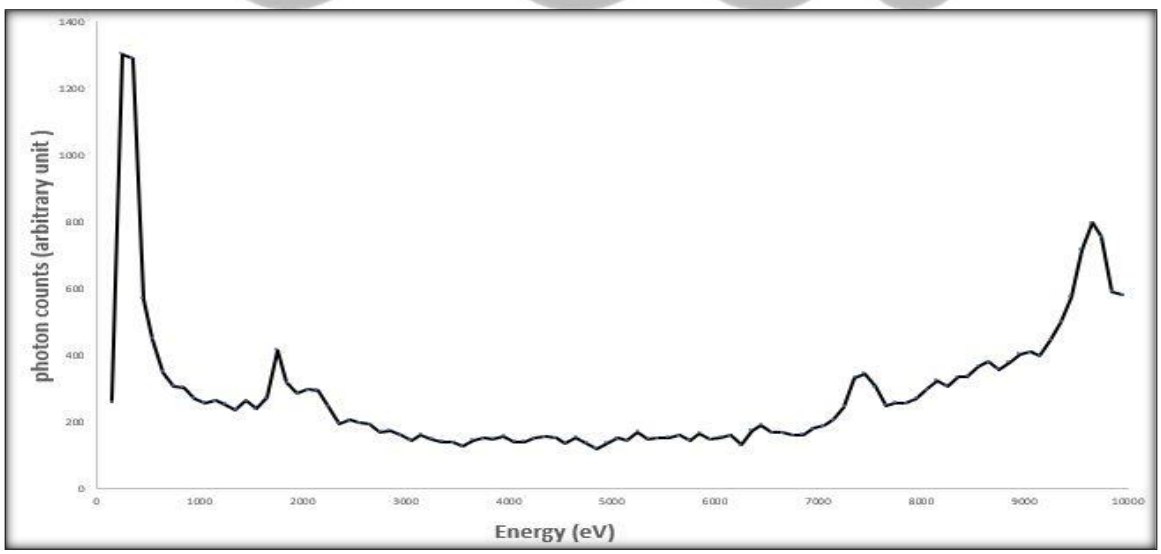

Figure (5): The relation between photons count and Energy (eV).

from the spectrum of the comet illustrated in figure (5) many peaks appear in the spectrum

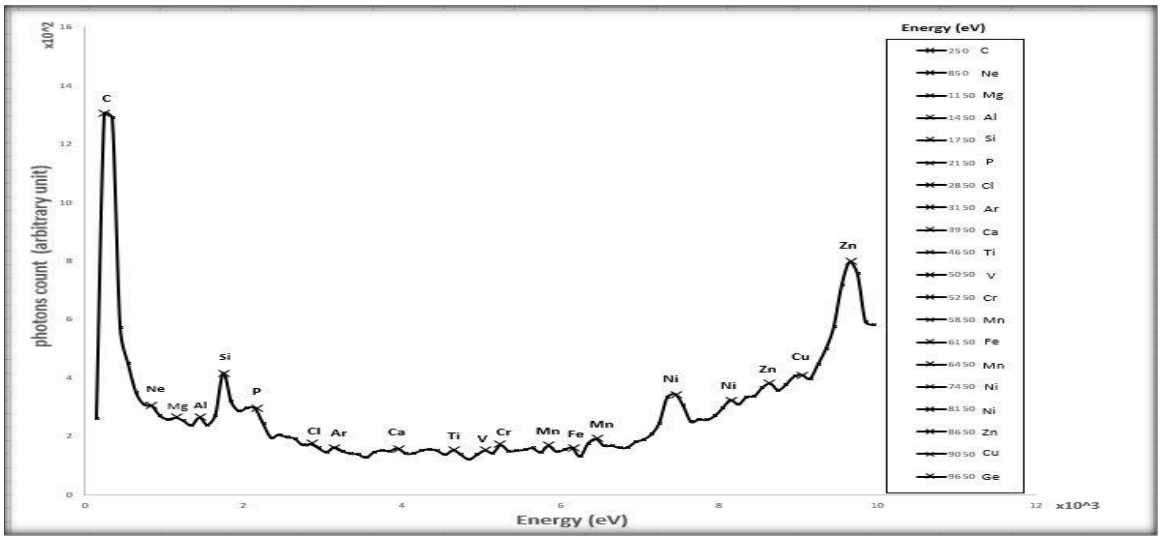

Figure (6): The structure of 46P/Wirtanen Comet.

Figure (6) demonstrates the spectrum of 46P/Wirtanen Comet. The materials that have been found are Carbon (C) at energy 250 eV $K_{\alpha 1}$, Neon (Ne) at energy 850 eV $K_{\alpha 1}$, Magnesium (Mg) at energy 1350 eV $K_{\beta 1}$, Aluminum (Al) at energy 1450 eV $K_{\alpha 1}$, Silicon (Si) at energy 1750 eV $K_{\alpha 1}$, Phosphorus (P) at energy 2150 eV $K_{\beta 1}$, Chlorine (Cl) at energy 2850 eV $K_{\alpha 1}$, Argon (Ar) at energy 3150 eV $K_{\beta 1}$, Calcium (Ca) at energy 3950 eV $K_{\beta 1}$, Titanium (Ti) at energy 4650 eV $K_{\alpha 1}$, Vanadium (V) at energy 5050 eV $K_{\alpha 1}$, Chromium (Cr) at energy 5250 eV $K_{\alpha 2}$, Manganese (Mn) at energies (5850 $K_{\alpha 2}$, and 6450 $K_{\beta 1}$) eV , Iron (Fe) at energy 6150 eV $K_{\alpha 2}$, Nickel (Ni) at energies (7450 $K_{\alpha 2}$, and 8150 $K_{\beta 1}$) eV , Zinc (Zn) at energies (8650 $K_{\alpha 1}$, and 9572 $K_{\beta 1}$) eV. Copper (Cu) at energy 9050 eV. The materials of 46P/Wirtanen comet and their standards energy shown in table (3).

3.2 The Abundant of Materials in The Two Comets

From the relation between photons count (s) and Energy (eV), found that the 153P/Ikeya–Zhang comet contain 4 elements, we can estimate the abundance of each element as shown in figure (7).

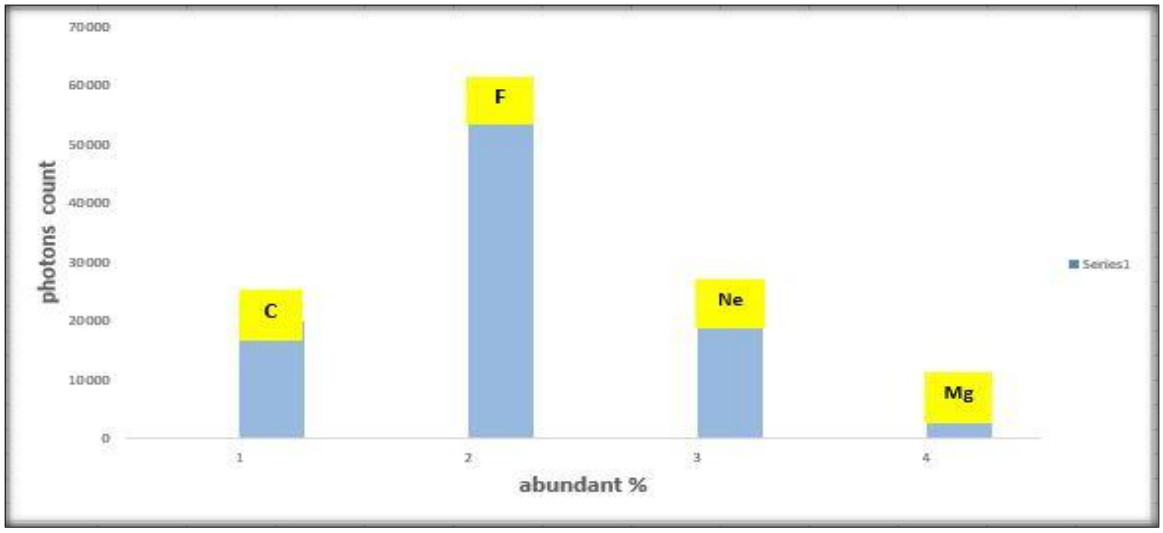

Figure (7): the abundant of 153P/Ikeya–Zhang comet.

From the figure (7), the abundant of elements C, F, Ne, and Mg are 18.67526, 55.99768, 21.05204, and 4.275025 percentage respectively.

Furthermore, found that the 46P/Wirtanen Comet contain 18 elements as shown in table (3). Also, we can estimate the abundance of each element for the comet depending on the photons count as shown in figure (8)

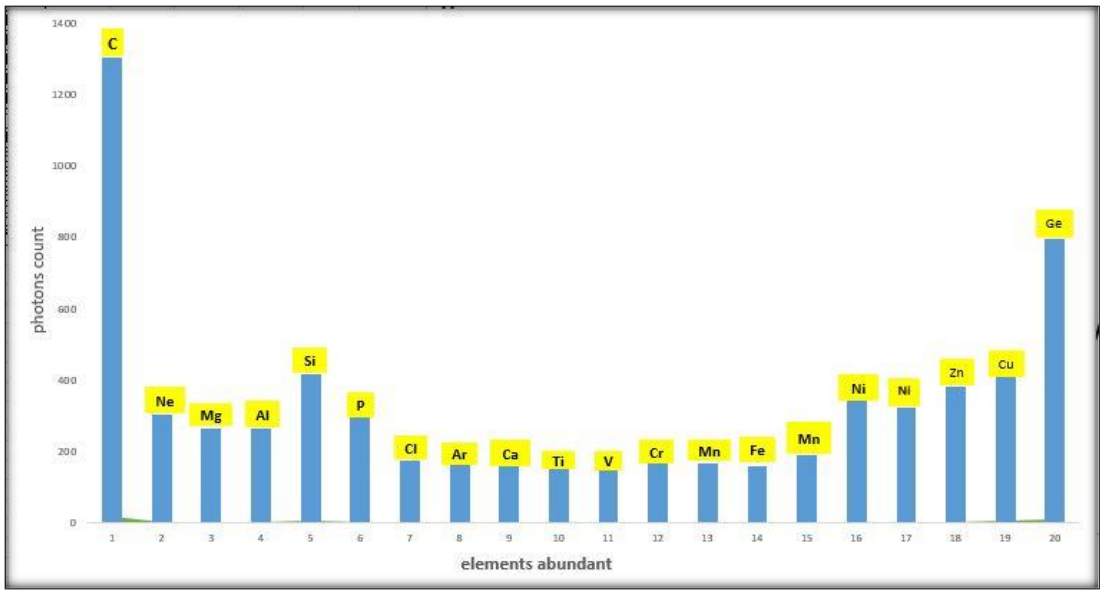

Figure (8): the abundant of 46P/Wirtanen Comet.

From figure (8), found that the abundant of elements, C, Ne, Mg, Al, Si, P, Cl, Ar, Ca, Ti, V, Cr, Mn, Fe, Mn, Ni, Ni, Zn, Cu, and Ge are 19.76973, 4.605363, 3.999394, 4.014543, 6.317225, 4.484169, 2.635964, 2.469323, 2.408726, 2.317831, 2.302681, 2.575367, 2.52992, 2.439024, 2.90865, 5.226481, 4.923496, 5.771853, 6.226329, and 12.07393 percentage respectively.

The most common elements in the milky way are Hydrogen, Helium, Oxygen, Carbon, Neon, Iron, Nitrogen, Silicon, Magnesium, and Sulfur and the dominant chemical elements found in comets are (Hydrogen, Carbon , Oxygen, Nitrogen, Sulfur, Silicon) forming the different components [26], in spite of Hydrogen percent is very high, Hydrogen atom doesn't appear in results because A hydrogen atom has one proton and one electron. So, we can calculate exactly what energy of electron has in each shell. But hydrogen is also the least energetic element. Even the most energetic line hydrogen emits (when an electron drops down from the second shell to the first) has only enough energy to be an ultraviolet photon. So, hydrogen atoms do not emit X- rays. But other elements have more electrons, so it can be emitted photons in the range of X-ray spectrum, like Carbon has six electrons emitted X-ray in the low energy as shown in spectrum of **46P/Wirtanen Comet.**

Elements found in the two comets are shown in Tables (3), where there is a difference between the observed and standard energy. This difference because these materials do not exist in a free chemical state, but as composition with other elements arrived in the state of stability because they are not saturated.

Table (3): the observed and standard energy for materials

Materials	symbol	Energy observed (ev)	Standard (ev) [13]
Carbon	C	250	277
Neon	Ne	850	848.6
Magnesium	Mg	1350	1486.7
Aluminum	Al	1450	1486.7
Silicon	Si	1750	1739.98
Phosphor	P	2150	2139.1

Sulfur	S	2250	2307.8
Chlorine	Cl	2850	2815.6
Argon	Ar	3150	3190.5
Calcium	Ca	3950	4012.7
Titanium	Ti	4650	4510.84
Vanadium	V	5050	4952.20
Chromium	Cr	5250	5405.5
Manganese	Mn	5850	5887.6
	Mn	6450	6490.4
Iron	Fe	6150	6390.8
Zinc	Zn	8650	8638.8
		9650	9572
Nickel	Ni	7450	7460.89
		8150	8264.6
Copper	Cu	9050	8905.29

CONCLUSION

When highly charged ions from the solar wind collide on a neutral gas of comet, the ions get partially neutralized by capturing electrons into an excited state. These ions subsequently decay to the ground state by the emission of one or more photons at X-ray Energy. By analyzing the X-ray emission of the 153P/Ikeya–Zhang and 46P/Wirtanen comets in the interaction region between the solar wind and the comets nuclei at a distance 0.89 and 1.25 AU respectively, From the spectra that have been observed from two comets provides us information on the composition of the region where the comet came from, which the elements for comet 153P/Ikeya–Zhang come from Oort cloud different with 46P/Wirtanen comet come from Kuiper belt, also we found that the two comets have the same light element like (C, Ne), the most abundant element in 153P/Ikeya–Zhang is Fluorine 55.997% but in 46P/Wirtanen is Carbon 19.76973%. furthermore 46P/Wirtanen comet have heavy element is **Zinc** with high abundant is equal to 12.07393 %

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