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Astronomical Data and its Visualization

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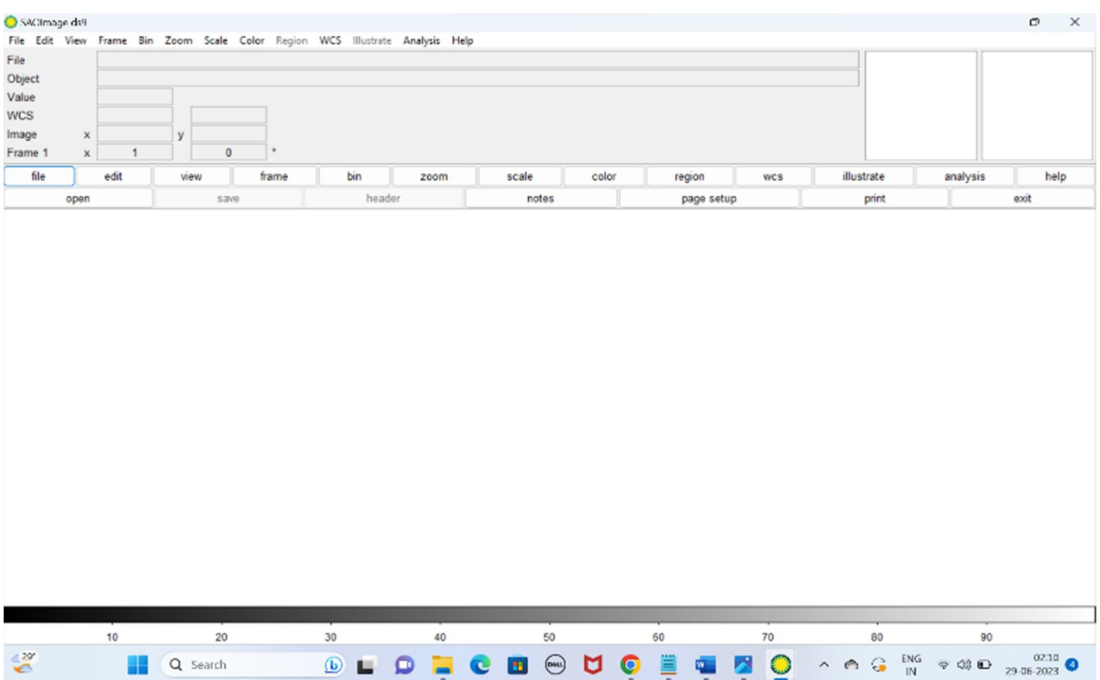
Abstract: The Crab Nebula has been the subject of several studies because to its significance in understanding star formation, supernova remnants, and high-energy astrophysics. In this paper, we present a complete study of astronomical fitting file photos of the Crab Nebula using SAO DS9, a powerful and scalable software tool. Images, spectroscopy, luminosity values, catalogue data, and color mapping techniques are all employed in our investigation. The primary purpose of this research was to employ astrometric and spectroscopic techniques to analyze the intricate details and features of the Crab Nebula. We used SAO DS9 to analyze fits file pictures to reveal the nebula's morphological characteristics, intricate structures, and fine-scale features. I enhanced the nebula's visualization by employing numerous color maps, allowing us to acquire a better understanding of its emission properties and dynamic behavior. As part of our analysis, I also collected spectroscopic data from the fits files. These spectroscopic discoveries shed information on the nebula's physical properties and dynamics, as well as its origins and development. I retrieved and incorporated data from many scientific catalogues to widen the scope of our inquiry. To characterize the fluctuation and energy distribution of the Crab Nebula, we systematically analyze tabular data, including brightness values. I also used photos from multiple sites to supplement our study. These extra photos provided different views and complementing data, allowing us to examine the structure and behavior of the Crab Nebula. I got substantial insights into the Crab Nebula's features, dynamics, and physical qualities by merging photos, spectroscopy, catalogue data, color mapping algorithms, and data from numerous servers. This research adds to our understanding of supernova remnants and lays the groundwork for future high-energy astrophysics research. The special and exclusive to it characteristics and properties of Crab Nebula increase its importance and role in explaining the fundamental processes of astrophysics. The Crab Nebula is also called as Messier 1 and was formed by an explosion in 1054 AD, not to forget that this explosion was observable for humans back then. It has been one of the most studied on object. It is distinguished from a fast-spinning pulsar by the Crab Nebula. Overall, the research study illustrates the use of SAO DS9 as a complete software tool for analyzing astronomical fit file pictures. We got substantial insights into the Crab Nebula's features, dynamics, and physical qualities by merging photos, spectroscopy, catalogue data, color mapping algorithms, and data from numerous servers.



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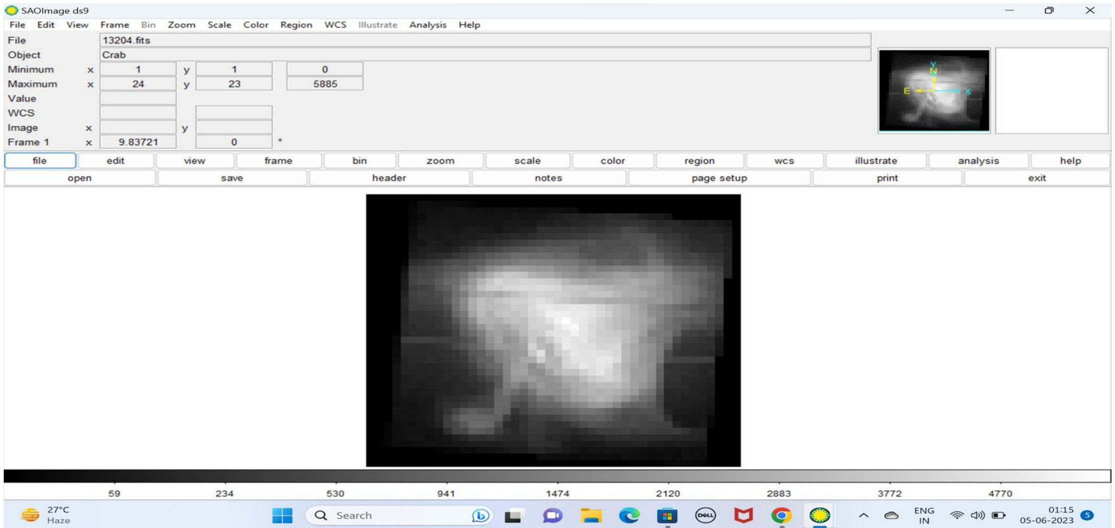
I. MAIN STUDY

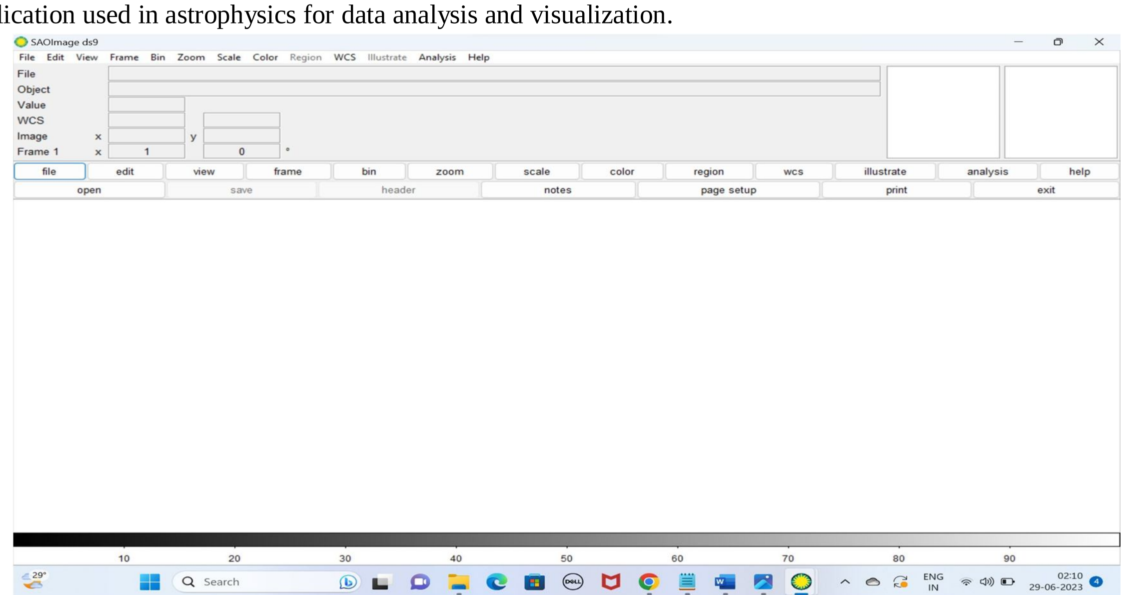


An image of Crab Nebula in the GUI interface of the software to be used.

The Crab Nebula Pulsar is critical for understanding a variety of astrophysical processes, including particle acceleration, magnetic field dynamics, and the nature of compact objects. Furthermore, the Crab Nebula is an ideal laboratory for understanding the causes and repercussions of supernova explosions. The birth of neutron stars.

This is an unparalleled chance to see and study the remains of such an event, which will give insights into the formation of massive stars and the formation of compact stellar remnants. Furthermore, because of its intricate filamentary formations, high-energy emission, and synchrotron radiation, the Crab Nebula is an appealing topic for study into cosmic rays, magnetic fields, and relativistic astrophysics. Because of the nebula's close proximity to Earth, detailed research at many different wavelengths is available, allowing astrophysicists to analyze its properties with remarkable precision.

Overall, the Crab Nebula is a hotspot for astrophysics study due to its unique combination of pulsars, supernova remnants, and intricate emission characteristics. By studying this celestial laboratory, scientists learn more about cosmic explosions, particle acceleration mechanisms, magnetic fields, and the physics of compact objects, which helps to their general knowledge of the universe's fundamental processes. SAO DS9 (Smithsonian Astrophysical Observatory Deep Space 9) is a strong and adaptable software application used in astrophysics for data analysis and visualization.



The beginning GUI interface of SAO DS9.

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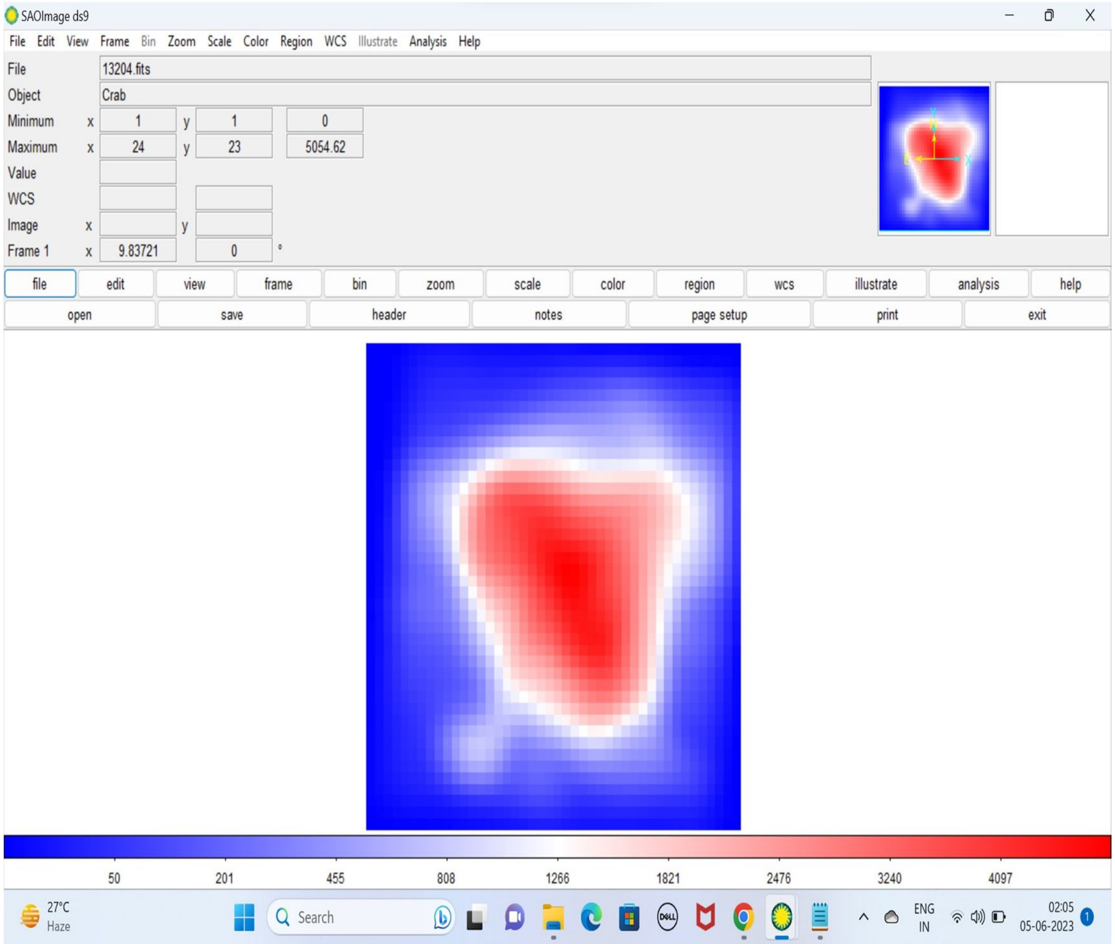
It offers scientists an extensive collection of capabilities and features for studying, processing, and interpreting complicated data sets received from telescopes, satellites, and other astronomical sensors. SAO DS9's capacity to handle a number of regularly used data formats in astronomy, including Flexible Image Transport System (FITS) files, which are the standard data format for astronomical pictures and data cubes, is one of its key assets. It provides multidimensional data visualization and analysis, letting users to view photos, spectra, data cubes, and lists at the same time.



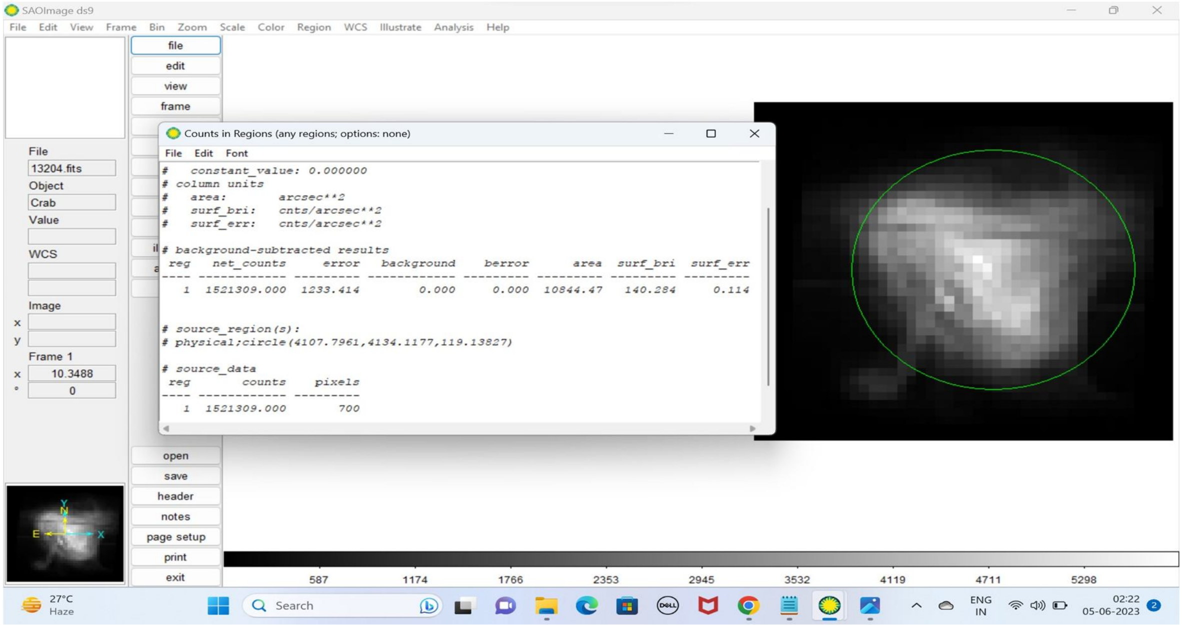
An image of Crab Nebula in “Smooth Luminance Saturation” colormap.

SAO DS9 is a user-friendly graphical user interface that allows for interactive data exploration. Users may traverse through photos and zoom in and out to perform quantitative measurements, modify contrast and color maps, overlay different data sets, and edit locations of interest. It also provides various photometric and spectroscopic analysis tools that allow users to make measurements, extract spectra and analyze line profiles.

All the images captured are astronomical instruments’ images via CCD. A charge-coupled device (CCD) is a photosensitive integrated circuit that captures images by converting photons into electrons. A CCD sensor breaks down pixels into pixels. Each pixel is converted to an electrical charge whose intensity is related to the intensity of light detected by that pixel. This component is a very important component of an astronomical imaging instrument.

II. MONITORING OF THE CRAB NEBULA

The " Counts in Regions" feature of SAO DS9 is a feature that allows users to obtain detailed quantitative measurements and statistics about specific regions of interest within an image or dataset relating it with its photon count primarily. It provides valuable information about the properties and characteristics of selected regions, facilitating a deeper analysis and understanding of astronomical phenomena.



The above image displays the regional information of a region which covers almost all of the portion of the Crab Pulsar selected by the thin green line.

The extracted information is as follows: -

Number of photons in the region: - 15,21,309 counts

Surface Area: - 10,844.47 arcsec^2

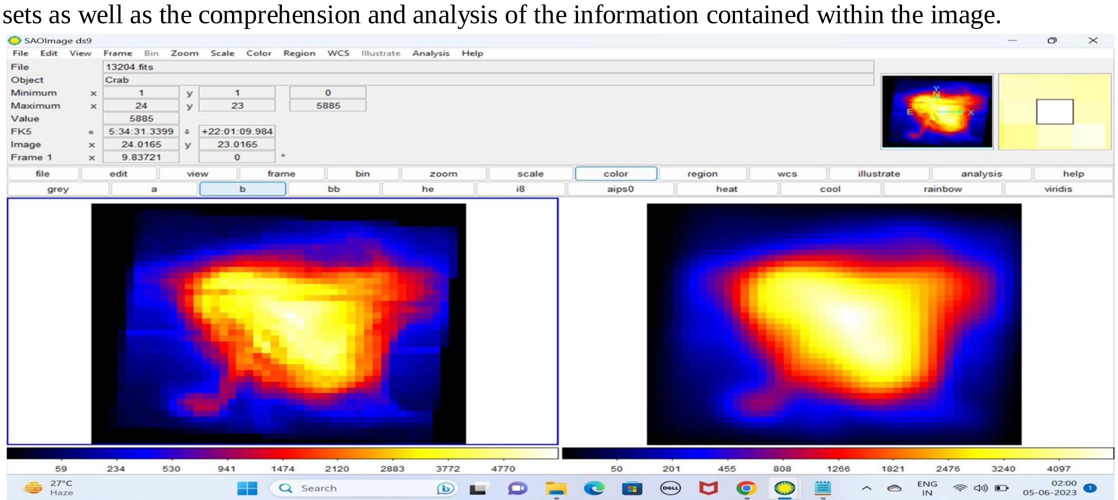
Surface Brightness (it is a measurement of the amount of light energy emitted from the area within the region): - 140.284 counts/arcsec^2

Error associated with the magnitude of surface brightness: - 0.114 counts/arcsec^2

Co-ordinates of the selected region in the image.

This image represents a compilation of several observations taken over a period of time. Monitoring campaigns involve repeated observations of an object to observe changes in its properties, such as changes in brightness, morphology or spectral properties.

Colormaps define how pixel values in an image are mapped to specific colours. They give the intensity or extent of visually observed phenomena. Colour maps can be used to draw attention to certain aspects or components of data. Colour maps can be used to show differences in image intensity, contrast, or spectral features. Scientists can use them to differentiate between different emission components, identify gradients, and highlight specific structures of interest. Colour maps help in the representation of complex data sets as well as the comprehension and analysis of the information contained within the image.

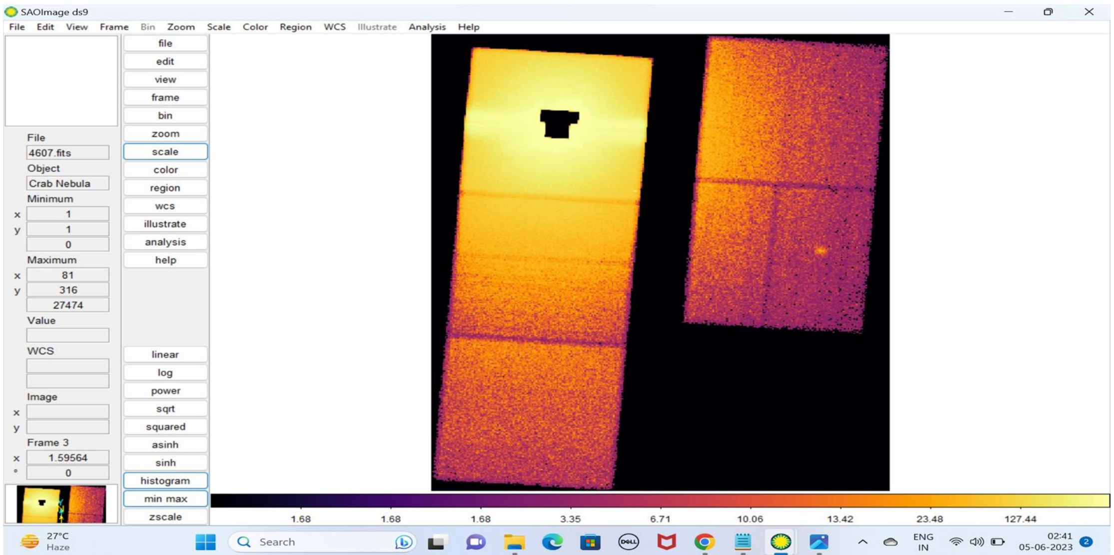


SAO DS9 smoothing is a technique for eliminating noise or improving the attributes of an astronomical image by employing a mathematical smoothing filter. Smoothing is used to improve the visual aspect of a picture, inhibit random changes, and reveal underlying structures or patterns. Smoothing filters help to reduce image noise. Noise can be produced by a number of factors, such as detector faults, air disturbances, and equipment limits. Smoothing procedures can effectively reduce random noise, resulting in a cleaner and more visually attractive image.

SAO DS9 offers a real-time preview of the debug effect, allowing users to observe changes before they are permanently captured. This interactive feature helps users fine-tune debugging parameters to achieve the desired result.

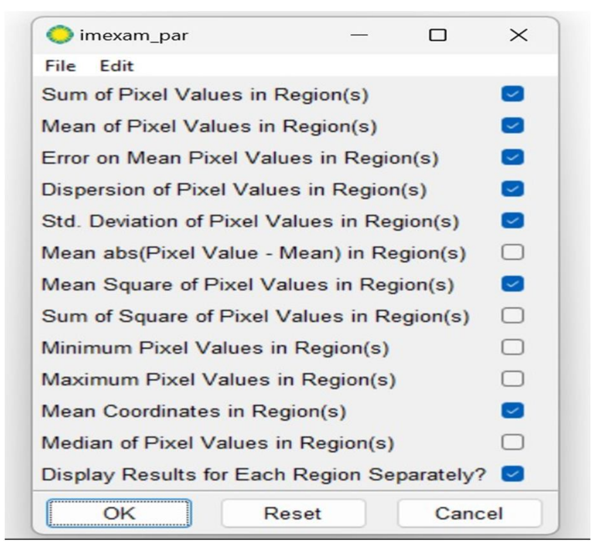
III. THERMAL EMISSION FROM CRAB NEBULA

This image represents thermal radiation emitted by the Crab Nebula.

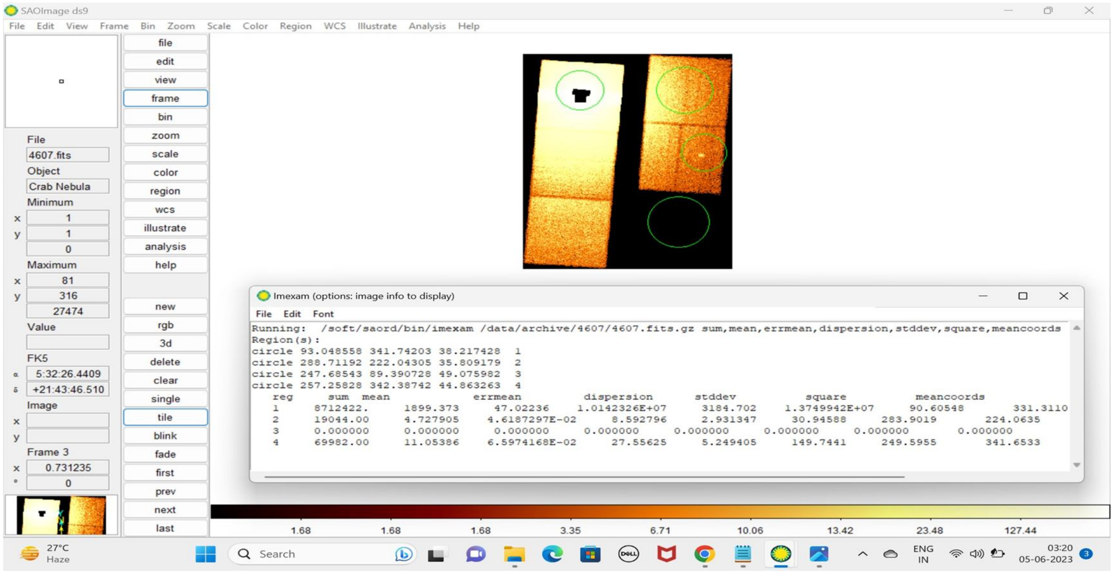


The software application SAO DS9 provides various in-built Chandra Ed-Analysis Tools (Energy Dispersive) for various astrometric, photometric and analytic tasks to be performed on the image in order to extract as much information from the image as possible.

Here we used, IMEXAM operation that tells the user about various light energy related statistics of the image. We have selected a sum of 4 regions in total on the image, from various portions of the image that first hand shows visual difference and then the function allows to explore more.



This is the list of all the different-different options the function provides to uncover more and more statistical data.



In DS9, the high-energy catalog refers to a collection of astronomical sources or objects that are detected in high-energy electromagnetic radiation, usually in the X-ray or gamma-ray wavelength range. These catalogs contain information about the properties and characteristics of these sources, including: positions, currents, spectra, and relationships with other celestial bodies.

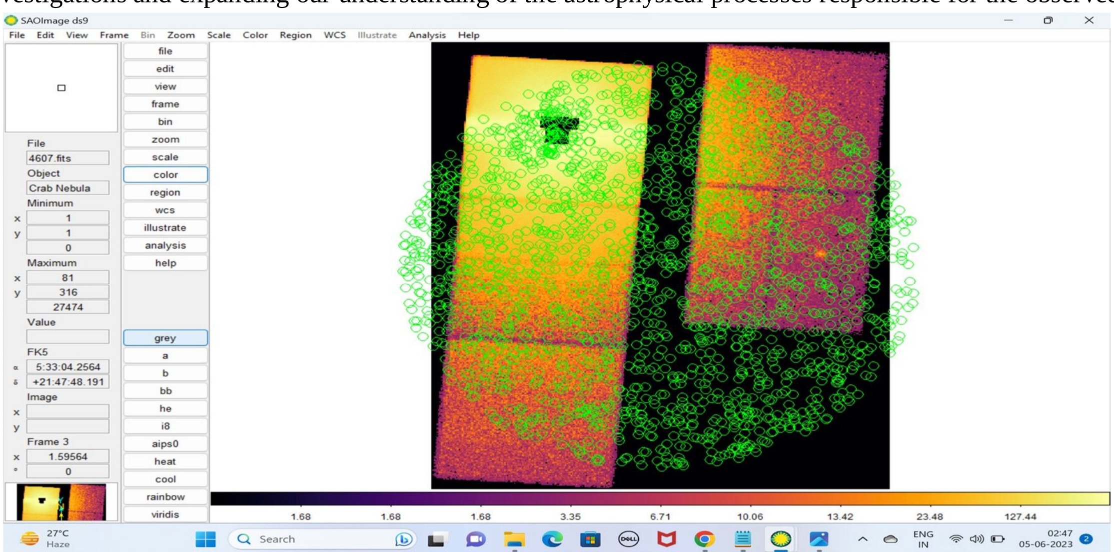
A. Here are some Key Aspects of DS9's high Energy Catalog

Source detection and localization: High-energy catalogs are produced through targeted observations using his space-based X-ray or gamma-ray telescopes such as Chandra, XMM-Newton, Fermi, or Swift. These telescopes are designed specifically to detect and analyze high-energy radiation from a range of astrophysical sources. The collection provides the location and identification of discovered sources, allowing scholars to locate and investigate them.

Luminous Flux and Spectral Data: The High Energy Catalogue defines a light source's luminous flux or intensity at different energy bands or wavelengths. Researchers may use this information to compute the number of high-energy emissions released by each source. Catalogues sometimes include spectral information as well, such as the shape and distribution of radiated energy as a function of wavelength and energy.

Correlation with Multiple Wavelengths: Cross-identification and correlation with sources identified at other wavelengths, such as light, infrared, and radio, are common in the DS9 high-energy catalogue.

This enables researchers to relate high-energy sources to objects detected at various wavelength ranges, allowing for multi-wavelength investigations and expanding our understanding of the astrophysical processes responsible for the observed emissions.



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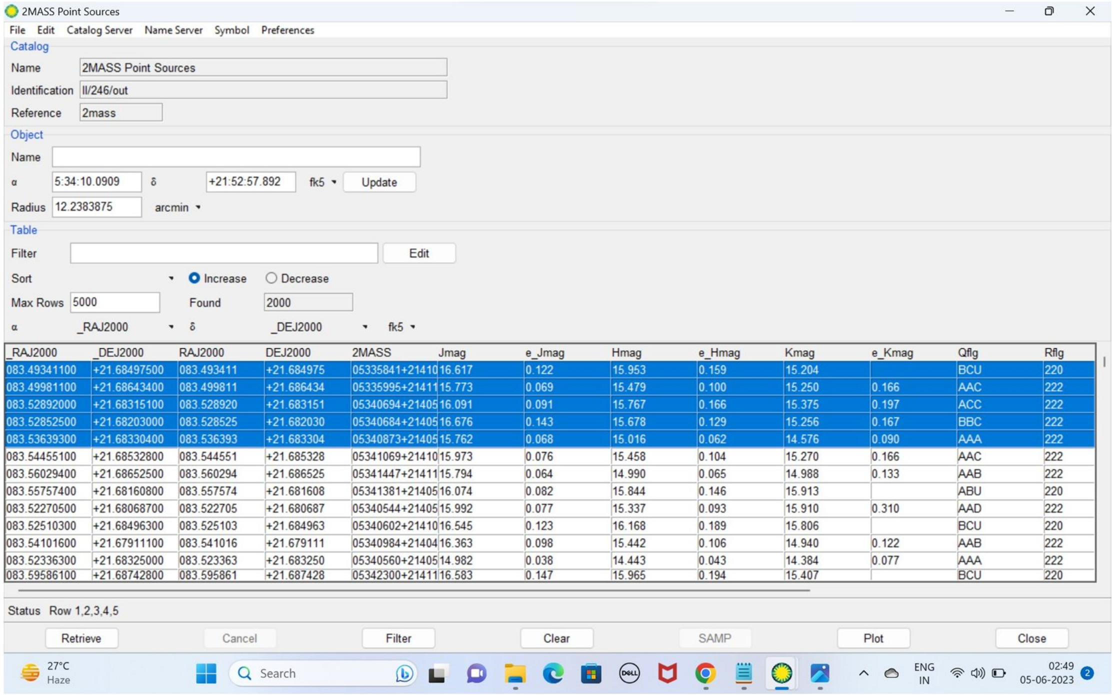
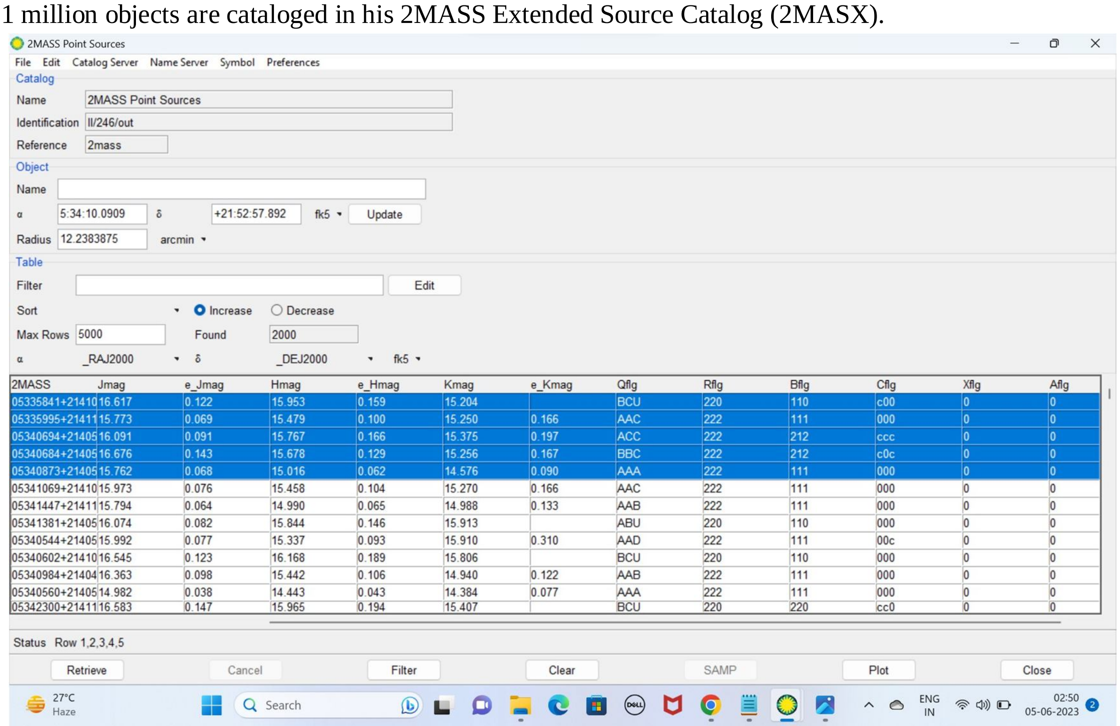
This picture shows all those spots of the image that have the 2MASS identification from the 1997 2 Micron All Sky Survey.



_RAJ2000	_DEJ2000	RAJ2000	DEJ2000	2MASS	Jmag	e_Jmag	Hmag	e_Hmag	Kmag	e_Kmag	Qflg	Rflg
083.49341100	+21.68497500	083.493411	+21.684975	05335841+21410	16.617	0.122	15.953	0.159	15.204		BCU	220
083.49981100	+21.68643400	083.499811	+21.686434	05335995+21411	15.773	0.069	15.479	0.100	15.250	0.166	AAC	222
083.52892000	+21.68315100	083.528920	+21.683151	05340694+21405	16.091	0.091	15.767	0.166	15.375	0.197	ACC	222
083.52852500	+21.68203000	083.528525	+21.682030	05340684+21405	16.676	0.143	15.678	0.129	15.256	0.167	BBC	222
083.53639300	+21.68330400	083.536393	+21.683304	05340873+21405	15.762	0.068	15.016	0.062	14.576	0.090	AAA	222
083.54455100	+21.68532800	083.544551	+21.685328	05341069+21410	15.973	0.076	15.458	0.104	15.270	0.166	AAC	222
083.56029400	+21.68652500	083.560294	+21.686525	05341447+21411	15.794	0.064	14.990	0.065	14.988	0.133	AAB	222
083.55757400	+21.68160800	083.557574	+21.681608	05341381+21405	16.074	0.082	15.844	0.146	15.913		ABU	220
083.52270500	+21.68068700	083.522705	+21.680687	05340544+21405	15.992	0.077	15.337	0.093	15.910	0.310	AAD	222
083.52510300	+21.68496300	083.525103	+21.684963	05340602+21410	16.545	0.123	16.168	0.189	15.806		BCU	220
083.54101600	+21.67911100	083.541016	+21.679111	05340984+21404	16.363	0.098	15.442	0.106	14.940	0.122	AAB	222
083.52336300	+21.68325000	083.523363	+21.683250	05340560+21405	14.982	0.038	14.443	0.043	14.384	0.077	AAA	222
083.59586100	+21.68742800	083.595861	+21.687428	05342300+21411	16.583	0.147	15.965	0.194	15.407		BCU	220

The Two Micron All Sky Survey (2MASS) was an infrared all-sky astronomical survey. The observations were made from 1997 to 2001 at two different locations, the US Fred Lawrence Whipple Observatory in Mount Hopkins, Arizona, and the Cerro Tololo Inter-American Observatory in Chile. Each observatory contained his 1.3-meter telescopes corresponding to the northern and southern hemispheres. This was performed in the near-infrared in three different frequency bands (J, H, K) of his around 2 microns, giving rise to the name of his photometric survey using the HgCdTe detector. 2MASS has produced an astronomical catalog of over 300 million observed objects, including solar system asteroids, brown dwarfs, low-mass stars, nebulae, star clusters, and galaxies. Additionally, 1 million objects are cataloged in his 2MASS Extended Source Catalog (2MASX).



2MASS	Jmag	e_Jmag	Hmag	e_Hmag	Kmag	e_Kmag	Qflg	Rflg	Bflg	Cflg	Xflg	Aflg
05335841+21410	16.617	0.122	15.953	0.159	15.204		BCU	220	110	c00	0	0
05335995+21411	15.773	0.069	15.479	0.100	15.250	0.166	AAC	222	111	000	0	0
05340694+21405	16.091	0.091	15.767	0.166	15.375	0.197	ACC	222	212	ccc	0	0
05340684+21405	16.676	0.143	15.678	0.129	15.256	0.167	BBC	222	212	c0c	0	0
05340873+21405	15.762	0.068	15.016	0.062	14.576	0.090	AAA	222	111	000	0	0
05341069+21410	15.973	0.076	15.458	0.104	15.270	0.166	AAC	222	111	000	0	0
05341447+21411	15.794	0.064	14.990	0.065	14.988	0.133	AAB	222	111	000	0	0
05341381+21405	16.074	0.082	15.844	0.146	15.913		ABU	220	110	000	0	0
05340544+21405	15.992	0.077	15.337	0.093	15.910	0.310	AAD	222	111	00c	0	0
05340602+21410	16.545	0.123	16.168	0.189	15.806		BCU	220	110	000	0	0
05340984+21404	16.363	0.098	15.442	0.106	14.940	0.122	AAB	222	111	000	0	0
05340560+21405	14.982	0.038	14.443	0.043	14.384	0.077	AAA	222	111	000	0	0
05342300+21411	16.583	0.147	15.965	0.194	15.407		BCU	220	220	cc0	0	0

Epoch 2000, also known as J2000.0 or the Julian era, is a specific reference time used in astronomical and celestial coordinate systems. It provides a standardized frame of reference for specifying the positions of celestial bodies on the celestial sphere. Epoch 2000 is defined as the celestial frame of reference corresponding to the beginning of the year 2000, more specifically January 1, 2000 at 12:00 PM (Earth). time. This era was chosen as a practical and widely used reference point for astronomical calculations and measurements. The importance of epoch 2000 lies in its role as a common epoch or starting point for celestial coordinate systems, such as the equatorial coordinate system. Provides a consistent frame of reference for viewing right ascension (RA) and declination coordinates of celestial bodies. These coordinates describe the position of an object on the celestial sphere, similar to longitude and latitude on the Earth's surface. "_RAJ2000" and "_DEJ2000": These columns represent the right ascension (RA) and declination (Dec) coordinates of the source in the International Astrophysical Reference System and ICRS and #41; The values "_RAJ2000" and "_DEJ2000" are usually specified in decimal degrees.

"RAJ2000" and "DEJ2000": These columns provide the right ascension and right ascension coordinates of the source in a more usable format. Right ascension is usually displayed in hours, minutes, seconds and right ascension in degrees, minutes, red seconds.

"2MASS": This column typically contains a unique identifier or catalog name assigned to each source within the 2MASS catalog. Helps differentiate and refer to specific sources of information within the catalog.

'Jmag', 'Hmag', and 'Kmag': These columns represent the illuminant magnitude for the wavelength bands J (1.1-1.4 micrometers), H (1.5-1.8 micrometers), and K (2.0-2.4 micrometers). These bands correspond to near-infrared wavelengths and provide information about the brightness of the source at specific wavelengths. wavelength.

e_Jmag, e_Hmag, and e_Kmag: These columns contain the uncertainties (errors) associated with the size measurements of the J, H, and K bands. These provide an estimate of the accuracy of the magnitude values.

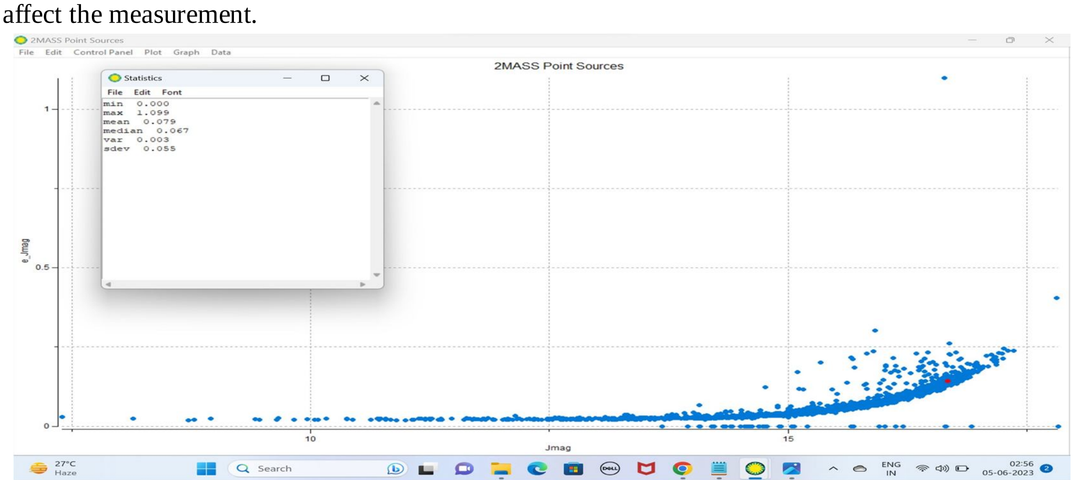
"Qflg": The "Qflg" column represents the photometric measurement quality label. Demonstrate the reliability and quality of photometry taking into account factors such as brightness, congestion and pollution. Flags can contain different values or letter combinations that indicate different quality levels.

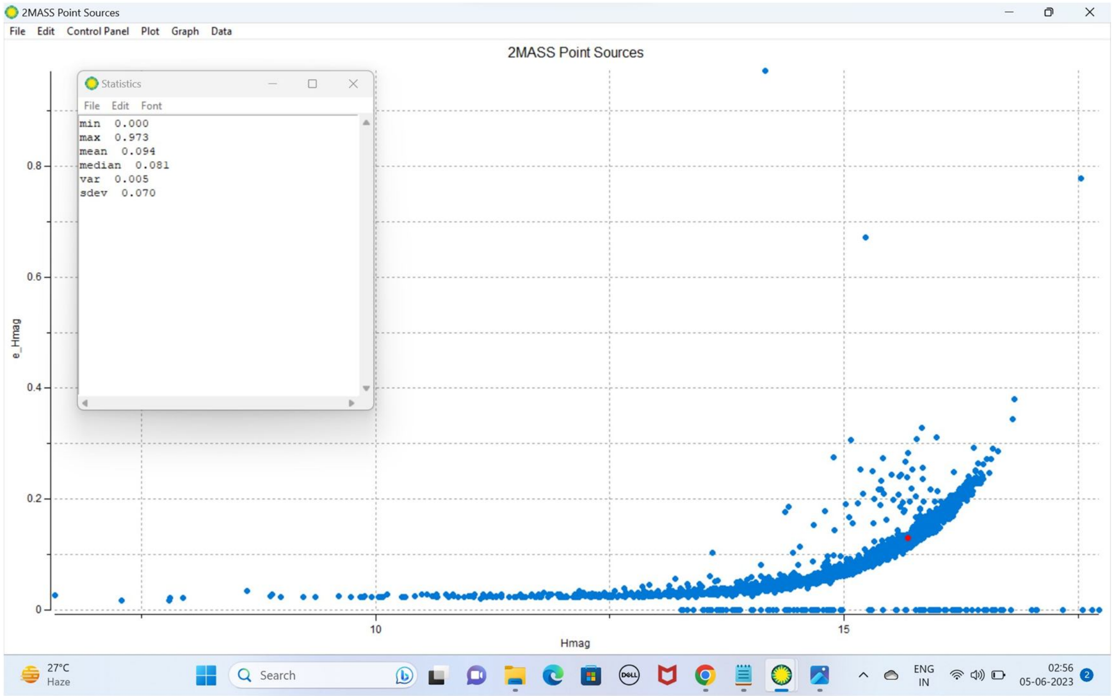
Rflg (read flags): The Rflg column contains flags that indicate potential problems or features related to detecting or reading sources in a 2MASS survey. This can be ``P" (source present), ``C" (source confused), ``S" (source saturated), or any other may contain values such as specific codes for

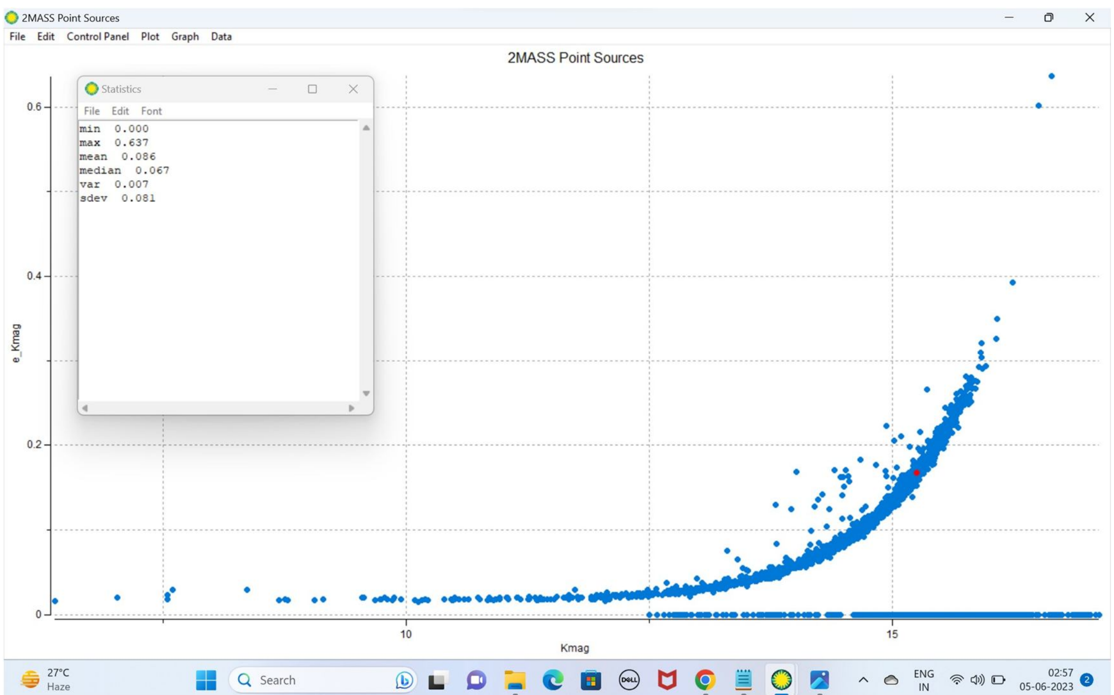
Aflg (astronomical flags): The Aflg column represents flags that provide information about the accuracy of astronomical properties or source positions. This may contain values such as '0' (highest quality astronomical measurements), '1' (high quality astronomical measurements), or other codes that indicate possible astronomical problems or reduced accuracy. there is.

Bflg (photometric flags): The Bflg column contains flags that provide information about the photometric properties or quality of the illuminant measurements. This may include values such as '0' (best quality photometry), '1' (best quality photometry), or other codes that indicate potential problems or reduced accuracy of photometry measurements.

Xflg (extragalactic flag): The Xflg column represents a flag that indicates that the source may be extragalactic (beyond the Milky Way). This may include values such as 'G' (probably galactic), 'S' (stellar), or other codes that indicate its source may be extragalactic. Cflg (Contamination Flag): The Cflg column contains flags that indicate the level of contamination or overcrowding of the source. This may include values such as '0' (no pollution), '1' (low pollution), or other codes indicating levels of pollution or congestion that affect the measurement.

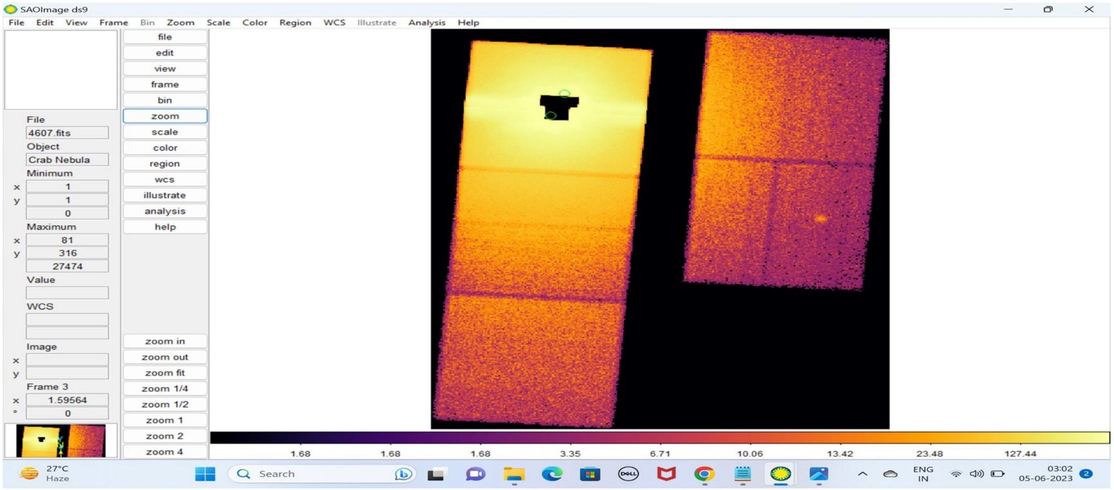




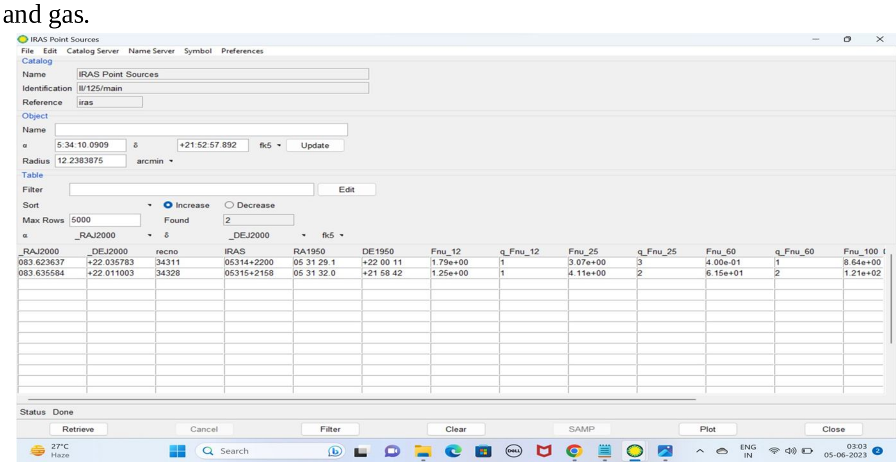


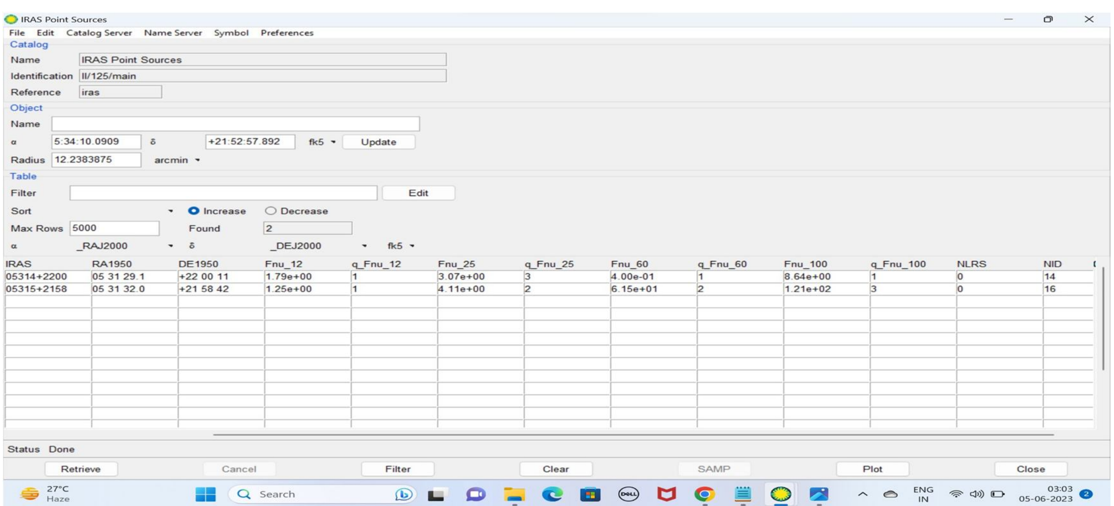
The above 3 images show a graph of the 3 wavelength ranges included in the 2MASS survey namely the Jmag, Hmag and the Kmag, versus their subjective errors. All 3 graphs show a similar trend of the slope heightening towards the ends, that is when the Band Magnitude increases it is likely to be subjected to error, then when the value is low plus there are some that aren’t affected and are precise measurements even at the maximum peak value. When measuring fainter objects, the signal to noise ratio decreases making it more difficult to obtain precise measurements. This uncertainty is very common in astronomical measurements and often doesn’t account to any monumental issues.

Instrumental Artifacts, Background contamination, Calibration Uncertainties, Source Confusions or Point Spread Functions can be a common source for these behaviors.



In the above image the 2 circles display the points in sky thar are listed within the IRAS survey and are present in the Crab Nebula. The Infrared Astronomy Satellite (IRAS) was the first space telescope to study the sky in the infrared. Many infrared wavelengths are blocked by the Earth's atmosphere and cannot be observed from the ground. The IRAS mission showed that the universe is rich in sources emitting these infrared wavelengths. IRAS has discovered about 350,000 infrared sources, an increase of about 70% in the total number of catalogued astronomical sources. The mission made many unexpected discoveries, including six new comets, evidence of dust particles around Vega and Fomalhaut, and strong indications of planetary systems around other stars. Even visible light can penetrate dust and gas.





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B. In the IRAS Catalog

recno: this refers to the record number assigned to each entry in the catalog. Each record corresponds to a specific empty source.

IRAS: Represents the ID of the IRAS source. The IRAS (Infrared Astronomical Satellite) mission was a space-based observatory conducting all-sky surveys at infrared wavelengths.

RA1950: it indicates the right ascension of the source in the B1950.0 coordinate system. Right ascension is the celestial coordinate that measures the angular distance of a source east along the celestial equator.

DE1950: Represents the declination of the light source in the B1950.0 coordinate system. Declination is the celestial coordinate that measures the angular distance of a light source north or south of the celestial equator.

Fnu_12: this indicates the magnetic flux density of the source at a wavelength of 12 microns. Magnetic flux density describes the amount of energy received per unit area per unit time from a light source at that particular wavelength.

q_Fnu_12: Represents the quality flag associated with the magnetic flux density measurement at 12 microns. Quality flags provide information about the reliability or uncertainty of a measurement.

Fnu_25: it represents the magnetic flux density of the source at a wavelength of 25 microns.

q_Fnu_25: it represents the quality flag associated with the magnetic flux density measurement at 25 microns.

Fnu_60: it represents the magnetic flux density of the light source at a wavelength of 60 microns.

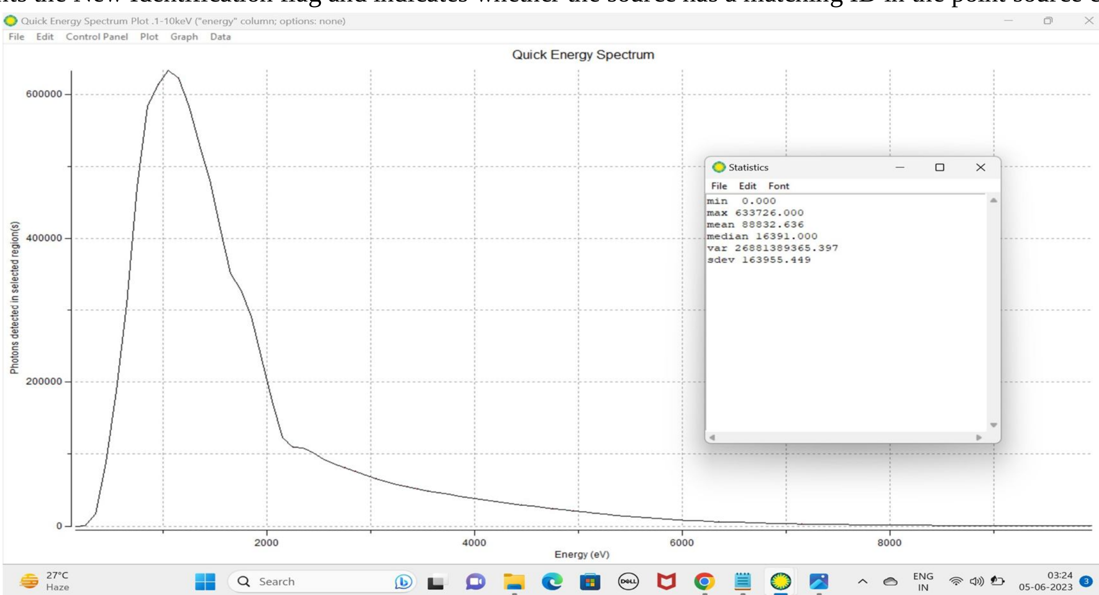
q_Fnu_60: Represents the quality flag associated with the magnetic flux density measurement at 60 microns.

Fnu_100: indicates the magnetic flux density of the source at a wavelength of 100 microns.

q_Fnu_100: Represents the quality flag associated with the magnetic flux density measurement at 100 microns.

NLRS: Short for New Low-Resolution Spectra Flag, indicates whether the source has a spectrum corresponding to the Low-Resolution Spectra catalog.

NID: Represents the New Identification flag and indicates whether the source has a matching ID in the point source catalog.



The Quick Energy Spectrum Plot feature in DS9 is used to display and analyze the energy spectrum of astronomical sources. The energy spectrum describes the distribution of photon number or photon flux as a function of energy or wavelength.

The initial rise followed by a gradual decline with increasing energy suggests a characteristic shape known as the 'turnover' or 'roll-off' of the spectrum. This behavior can occur in a variety of astrophysical scenarios and has specific implications depending on the situation.

At lower energies, a rising slope shows that the photon number or photon flow increases as energy lowers. This behavior might be caused by a number of mechanisms, including thermal radiation from hot plasmas, synchrotron radiation from high-energy particles, and radiation from blackbody sources. The ensuing progressive reduction in slope with increasing energy implies a decrease in photon quantity or photon flow. This can be attributable to a number of reasons, including photon absorption or attenuation by intervening materials, energy distribution of emitting particles and sources, and instrumental effects like as energy-dependent responses and background subtraction uncertainty.

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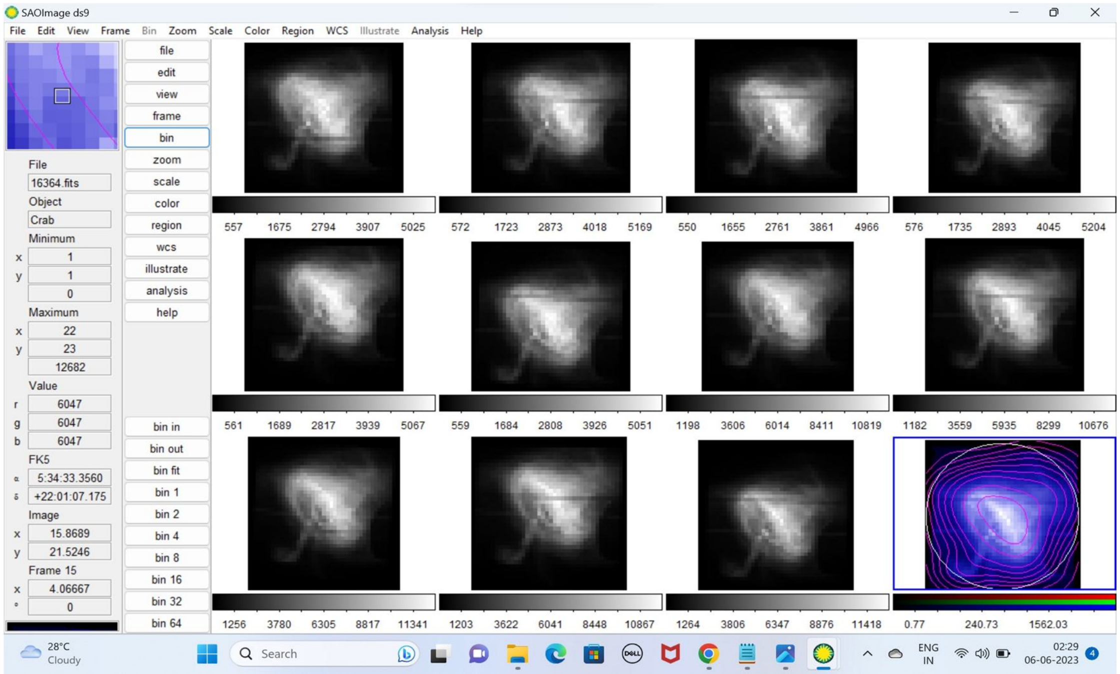
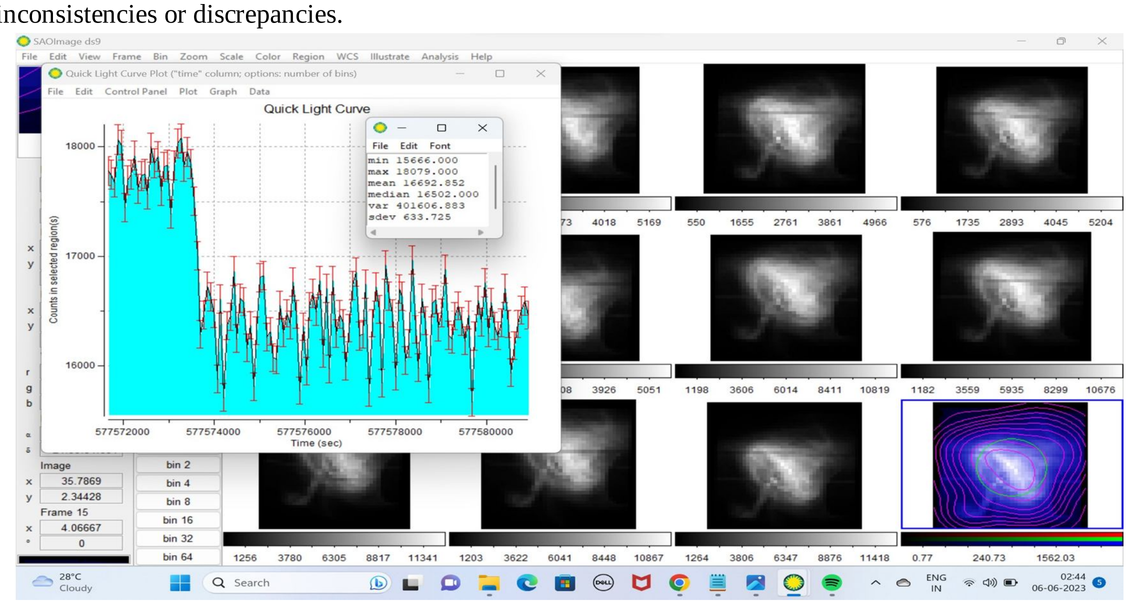
IV. JOINT CHANDRA AND HST MONITORING OF THE CRAB NEBULA



Similar images of a single object with over just a little variance in properties like shown above is a remark of robustness of results and a confirmation of observations.

If several images with small differences in characteristics are obtained of the same object, it helps to ensure the consistency and reliability of the observations. This allows researchers to confirm their observations and ensure that the observed features are not artifacts or errors in the data. Acquiring similar images of an object with minor variations provides an older and more complete understanding of the object's characteristics. By analyzing multiple images, researchers can identify common features and characteristics that allow for more accurate measurements and interpretations. Images with slightly different characteristics can be used to estimate important parameters of an object. By comparing the images, researchers can extract quantitative measurements such as current densities, sizes, shapes and spectral properties. This information can then be used to determine physical parameters and more accurately model the object. By comparing similar images, researchers can distinguish real characteristics of objects and identify any inconsistencies or discrepancies.



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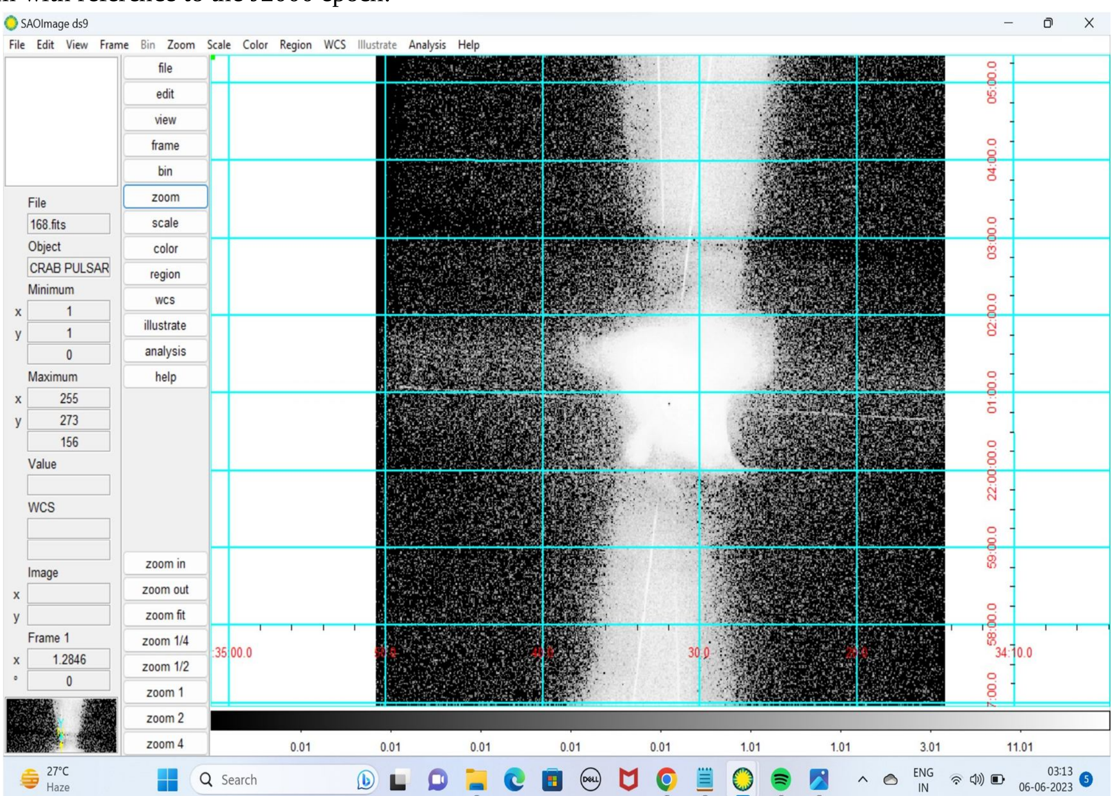
Amongst many Chandra Energy-Dispersive Analysis Tools of DS9, one very smart tool is the Quick Plot Light Curve that demonstrates a graph of time versus photon counts. Quick Light Curve includes statistical data analysis capabilities such as calculating means, standard deviations, and performing periodogram analysis. These statistical approaches aid in determining variability, determining the relevance of periodic signals, or characterizing a source's overall behavior. A rapid light curve aids in identifying the periodic behavior of the source's brightness. Users can seek for repeated patterns and possibly cycles or periodic signals by analyzing the light curve. The rapid light curve describes the temporal fluctuations in the brightness of the source. This enables users to monitor and analyze variations in flow or size over time. Temporal variability can relate to internal source processes like pulsations, periodic fluctuations, or transitory occurrences, as it does here with fog development and the pulsations it creates.

V. CALIBRATION OF HETGS USING THE CRAB PULSAR AND THE NEBULA

The Crab Pulsar and Nebula will be used as calibration targets for the HETGS gadget in this investigation. HETGS is a high-resolution X-ray spectrograph that uses beams to scatter X-rays and obtain detailed spectra of celestial entities. By examining the Crab Pulsar and Crab Nebula using HETGS, scientists may evaluate the features of their X-rays, monitor the instrument's reaction, and characterize its performance. The research will most likely include analysis of the produced spectra, comparison to known emission patterns, and calibration of the instrument's energy and wavelength scales. Calibration of the HETGS with the Crab Pulsar and Crab Nebula is critical for precise X-ray measurements in future missions. This enables scientists to create a consistent reference point and calibrate the instrument's measurements to enable precise interpretation of the X-Ray data.

The following image shows the targeted image and a with a World Co-ordinate System of FK5 grid on it. FK5 is an equatorial co-ordinate system with reference to the J2000 epoch.



The x-axis shows the Right ascension co-ordinates and y-axis shows the Declination ones.

HETGS is an acronym that stands for High Energy Transmission Grating Spectrometer. It is a sophisticated X-ray astronomy device designed to analyze the high-energy radiation produced by celestial bodies. HETGS employs perfectly aligned transition states to scatter X-rays, allowing for high-resolution spectroscopy. The fundamental function of HETGS is to divide entering X-rays into sub-wavelengths, allowing for thorough measurements of the X-ray spectrum.

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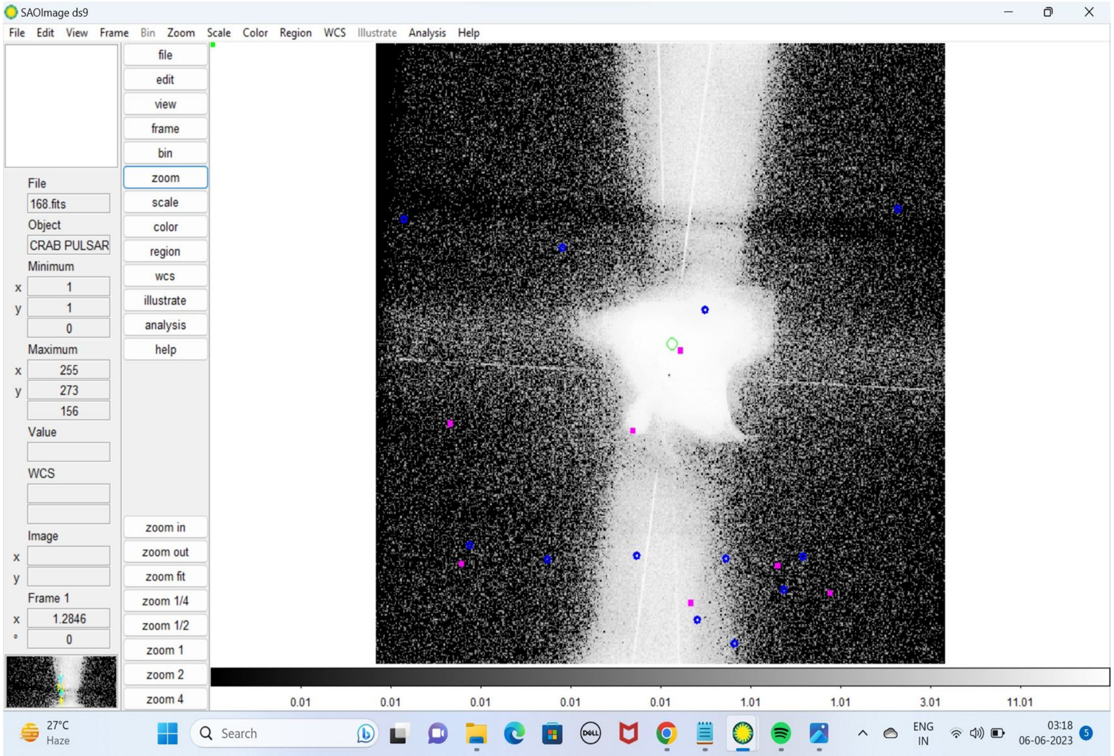
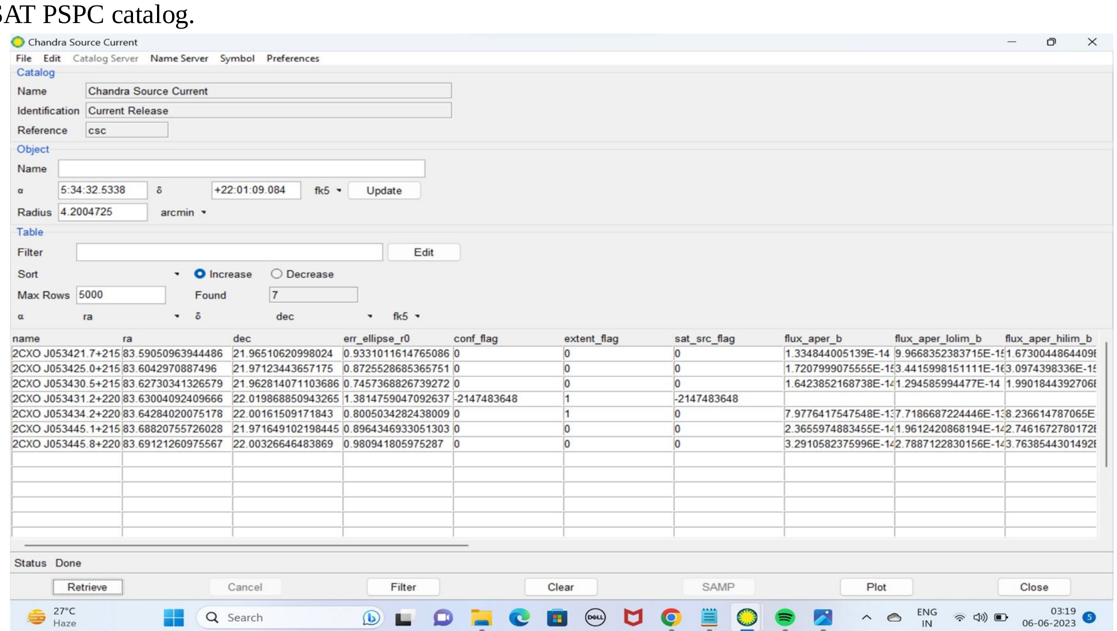


The above image shows various High Energy sources in crab nebula under different catalogs.
The DS9 high-energy catalogues are collections of astronomical sources discovered and characterized at high-energy wavelengths such as X-rays or gamma rays. These catalogs contain information about the locations, currents, spectral properties and other relevant parameters of the observed sources. High-energy catalogs are compiled from observations made with space telescopes and instruments specially designed to detect and study high-energy radiation. DS9, is a versatile astronomical data visualization and analysis software that provides the tools and functionality to access and analyze these high-energy catalogs.
The blue circles indicate 2xMMiSource Catalog, the magenta boxes denote Chandra Source Current catalog and the green circle is from the ROSAT PSPC catalog.



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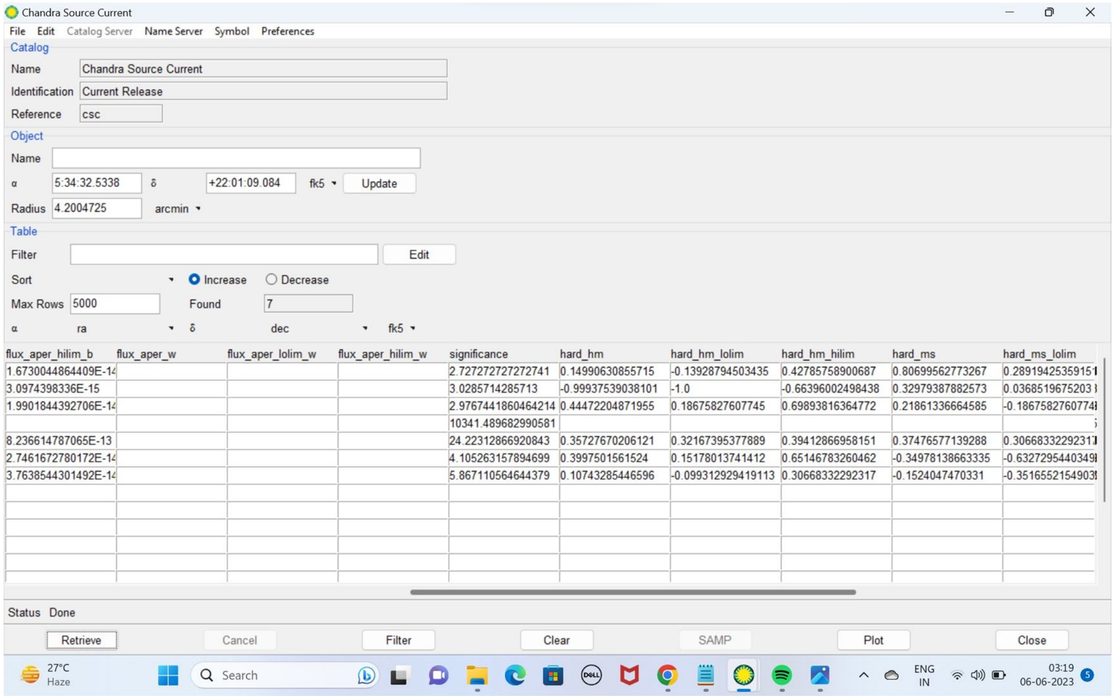
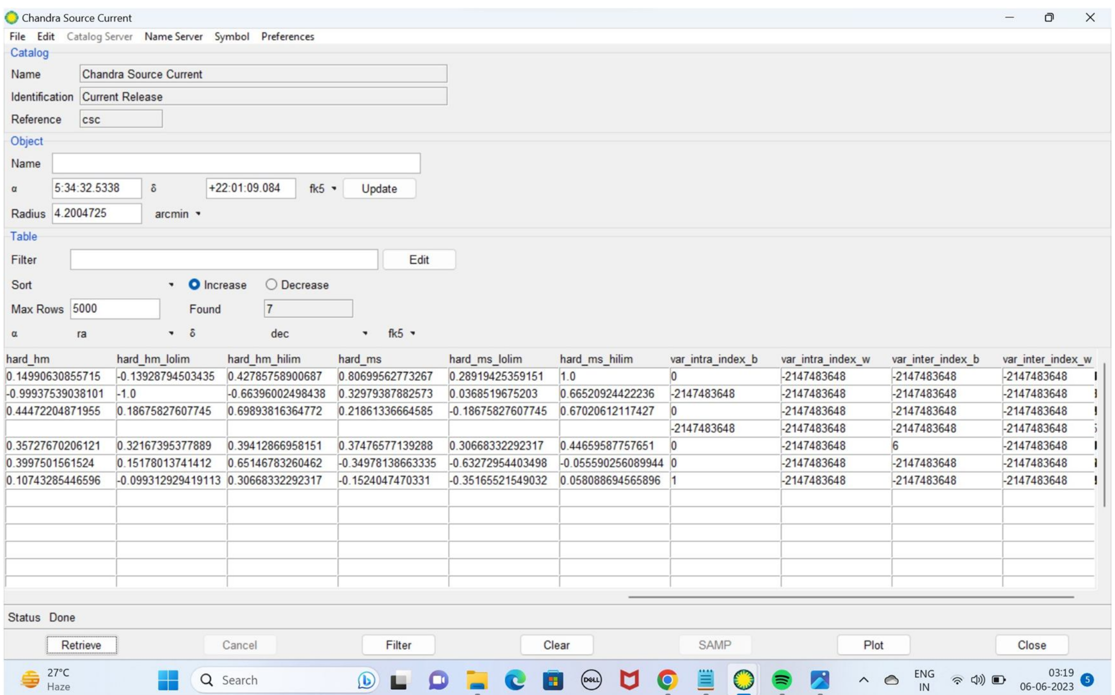




err_ellipse_r0: This represents the positional error in arcseconds of the ellipse's semimajor axis.

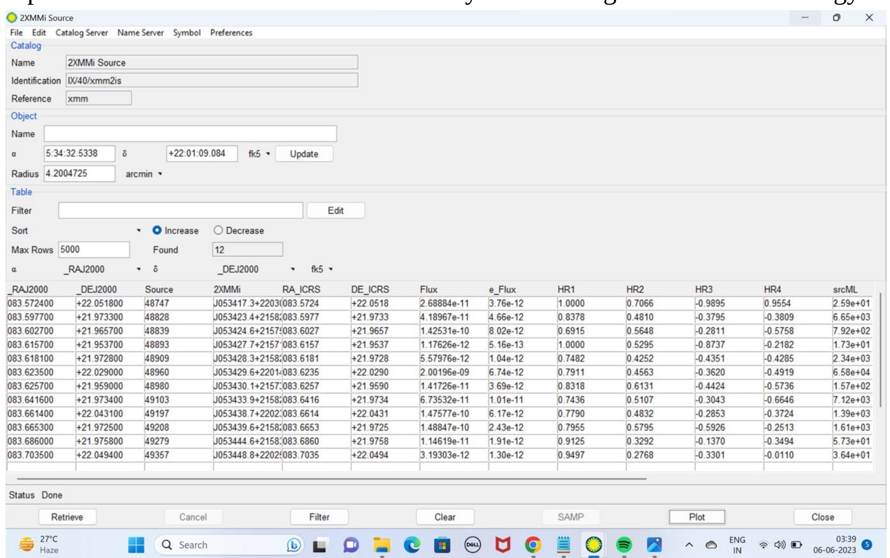
conf_flag: This flag indicates the level of confidence associated with source identification and characterization. It provides information about the reliability of the source parameters.

extent_flag: Indicates whether the source is considered extended or point based on its spatial extent.

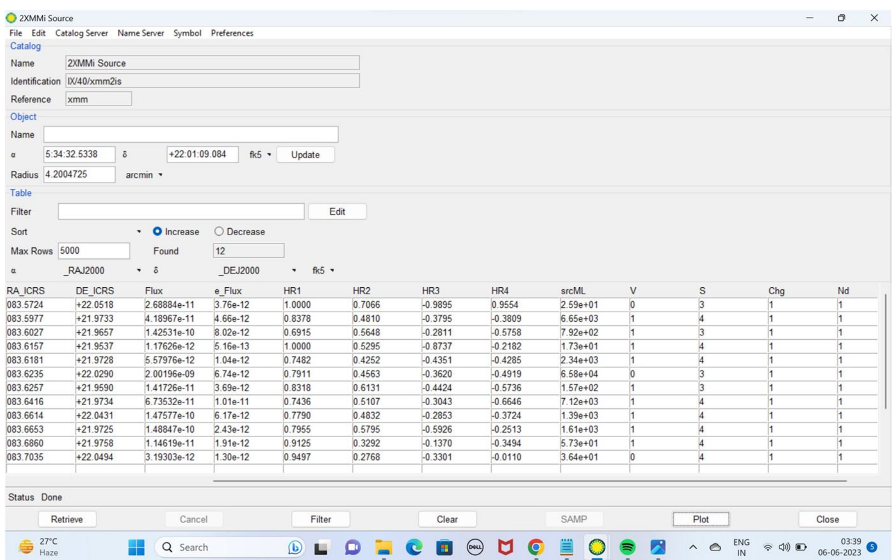
sat_src_flag: This flag indicates whether the source is affected by saturation, which occurs when the detected X-ray intensity exceeds the dynamic range of the detector. F

flux_aper_b: This represents the flux based on the aperture of the source in a given energy band (e.g., soft, medium hard, hard) using a predefined aperture size.

flux_aper_lolim_b: This parameter indicates the lower limit of the gap-based flux in the corresponding energy band.
flux_aper_hilim_b: This indicates the upper limit of the gap-based flux in the corresponding energy group.
significance: This represents the statistical significance of the source detection and measures how reliably the source is detected above the background noise.
hard_hm: This parameter represents the hardness ratio between the high and medium energy bands, indicating the relative intensity of X-rays at higher energies.
hard_hm_lolim: This indicates the lower limit of the hardness ratio between the high and medium energy bands.
hard_hm_hilim: This parameter indicates the upper limit of the hardness ratio between the high and medium energy ranges.
hard_ms: It is the hardness ratio between high and soft energy bands indicating the relative intensity of the X-rays at higher energies.
hard_ms_lilim: This parameter indicates the lower limit of the hardness ratio between the high and soft energy bands.
hard_ms_hilim: This represents the maximum hardness ratio between the high and soft energy bands.
var_intra_index_b: This parameter specifies the source's internal variable index in the provided energy band.
var_intra_index_w: It is the average of energy bands that express intrasource variability.
var_inter_index_b: This parameter specifies the source's interband variable index in a specified energy band.
var_inter_index_w: This represents the source's inter-band variability as an average of the various energy bands.



_RAJ2000	_DEJ2000	Source	2XMMi	RA_ICRS	DE_ICRS	Flux	e_Flux	HR1	HR2	HR3	HR4	srcML
083.572400	+22.051800	48747	J053417.3+2203	083.5724	+22.0518	2.68884e-11	3.76e-12	1.0000	0.7066	-0.9895	0.9554	2.59e+01
083.597700	+21.973300	48828	J053423.4+2158	083.5977	+21.9733	4.18967e-11	4.66e-12	0.8378	0.4810	-0.3795	-0.3809	6.65e+03
083.602700	+21.965700	48839	J053424.6+2157	083.6027	+21.9657	1.42531e-10	8.02e-12	0.6915	0.5648	-0.2811	-0.5758	7.92e+02
083.615700	+21.953700	48893	J053427.7+2157	083.6157	+21.9537	1.17626e-12	5.16e-13	1.0000	0.5295	-0.8737	-0.2182	1.73e+01
083.618100	+21.972800	48909	J053428.3+2158	083.6181	+21.9728	5.57976e-12	1.04e-12	0.7482	0.4252	-0.4351	-0.4285	2.34e+03
083.623500	+22.029000	48960	J053429.6+2201	083.6235	+22.0290	2.00196e-09	6.74e-12	0.7911	0.4563	-0.3620	-0.4919	6.58e+04
083.625700	+21.959000	48980	J053430.1+2157	083.6257	+21.9590	1.41726e-11	3.69e-12	0.8318	0.6131	-0.4424	-0.5736	1.57e+02
083.641600	+21.973400	49103	J053433.9+2158	083.6416	+21.9734	6.73532e-11	1.01e-11	0.7436	0.5107	-0.3043	-0.6646	7.12e+03
083.661400	+22.043100	49197	J053438.7+2202	083.6614	+22.0431	1.47577e-10	6.17e-12	0.7790	0.4832	-0.2853	-0.3724	1.39e+03
083.665300	+21.972500	49208	J053439.6+2158	083.6653	+21.9725	1.48847e-10	2.43e-12	0.7955	0.5795	-0.5926	-0.2513	1.61e+03
083.686000	+21.975800	49279	J053444.6+2158	083.6860	+21.9758	1.14619e-11	1.91e-12	0.9125	0.3292	-0.1370	-0.3494	5.73e+01
083.703500	+22.049400	49357	J053448.8+2202	083.7035	+22.0494	3.19303e-12	1.30e-12	0.9497	0.2768	-0.3301	-0.0110	3.64e+01



RA_ICRS	DE_ICRS	Flux	e_Flux	HR1	HR2	HR3	HR4	srcML	V	S	Chg	Nd
083.5724	+22.0518	2.68884e-11	3.76e-12	1.0000	0.7066	-0.9895	0.9554	2.59e+01	0	3	1	1
083.5977	+21.9733	4.18967e-11	4.66e-12	0.8378	0.4810	-0.3795	-0.3809	6.65e+03	1	4	1	1
083.6027	+21.9657	1.42531e-10	8.02e-12	0.6915	0.5648	-0.2811	-0.5758	7.92e+02	1	3	1	1
083.6157	+21.9537	1.17626e-12	5.16e-13	1.0000	0.5295	-0.8737	-0.2182	1.73e+01	1	4	1	1
083.6181	+21.9728	5.57976e-12	1.04e-12	0.7482	0.4252	-0.4351	-0.4285	2.34e+03	1	4	1	1
083.6235	+22.0290	2.00196e-09	6.74e-12	0.7911	0.4563	-0.3620	-0.4919	6.58e+04	0	3	1	1
083.6257	+21.9590	1.41726e-11	3.69e-12	0.8318	0.6131	-0.4424	-0.5736	1.57e+02	1	3	1	1
083.6416	+21.9734	6.73532e-11	1.01e-11	0.7436	0.5107	-0.3043	-0.6646	7.12e+03	1	4	1	1
083.6614	+22.0431	1.47577e-10	6.17e-12	0.7790	0.4832	-0.2853	-0.3724	1.39e+03	1	4	1	1
083.6653	+21.9725	1.48847e-10	2.43e-12	0.7955	0.5795	-0.5926	-0.2513	1.61e+03	1	4	1	1
083.6860	+21.9758	1.14619e-11	1.91e-12	0.9125	0.3292	-0.1370	-0.3494	5.73e+01	1	4	1	1
083.7035	+22.0494	3.19303e-12	1.30e-12	0.9497	0.2768	-0.3301	-0.0110	3.64e+01	0	4	1	1

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2XMMi catalog stands for the Second XMM-Newton Serendipitous Source Catalog.

The 2XMMiS catalogue is a collection of X-ray sources identified during research at the XMM Newton Observatory. The European satellite Agency's XMM-Newton satellite observatory is designed to investigate high-energy cosmic events. The 2XMM library contains an exhaustive list of X-ray sources detected by XMM-Newton, including both point and extended sources. Sky locations, X-ray fluxes, X-ray hardness ratios, spectrum characteristics, and variability indicators are all included.

RA_ICRS: This provides the source's accurate altitude (RA) in the International Sky Reference coordinate system. RA is one of the celestial coordinates used to calculate an object's east-west location on the celestial globe.

DE_ICRS: This is the source's declination (DEC) in the International Celestial Reference Coordinate System. DEC is one of the celestial coordinates used to calculate an object's north-south location on the celestial globe.

HR1: HR1 is the hardness ratio, which is determined as the ratio of the two energy bands. It displays the relative emission levels in different energy bands and offers information about the source's spectral structure.

HR2: Like HR1, HR2 is a hardness ratio that compares the computed rates of various energy bands. This offers more information about the source's spectrum qualities.

HR3: HR3 is a hardness ratio that measures the ratio of two energy band numerical indices and offers information about the source's spectral properties.

HR4: HR4 is a hardness ratio that expresses the ratio of two energy bands and offers information about the source's spectral properties.

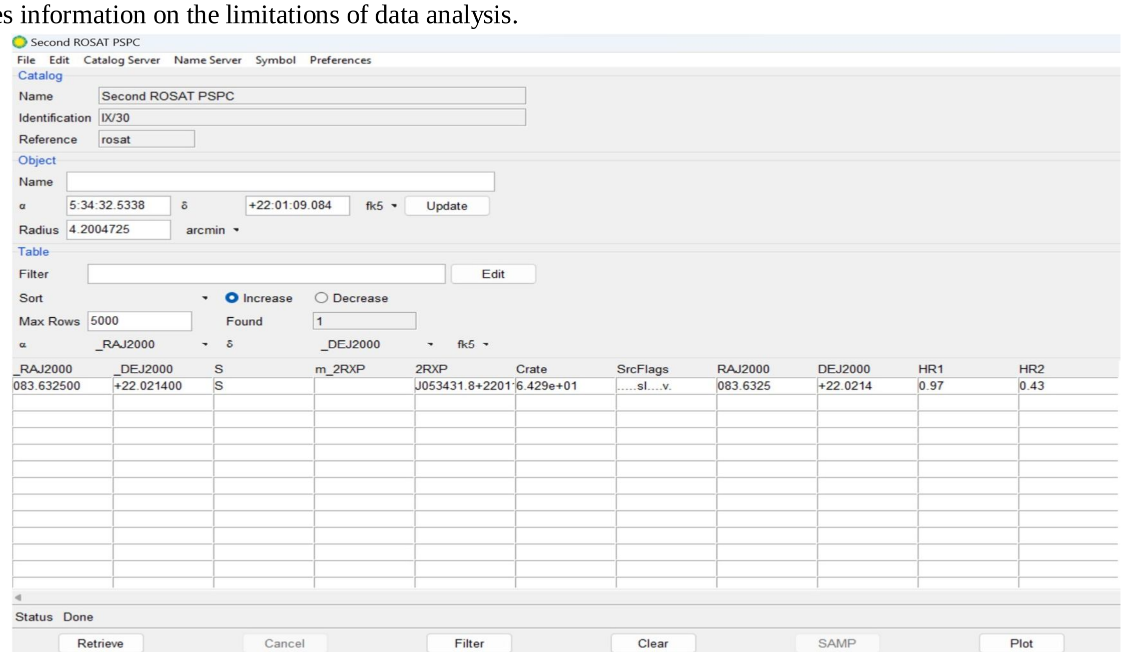
V: The "V" parameter denotes the source's variability. Based on the measured X-ray emission, this shows if the source is changeable.

S: The "S" parameter denotes the statistical importance of source discovery.

srcML: srcML is an abbreviation for Source Maximum Likelihood. It is a statistical measure of source detection probability that represents the amount of confidence in source detection.

Chd: The Chisq/DOF ratio, which represents the decreased Chi-square value. It is a statistical metric used to assess the fit between observed data and a certain model.

Nd: The number of degrees of freedom, or the number of independent data points utilized in the statistical analysis, is represented by Nd. This gives information on the limitations of data analysis.



The DS9 ROSAT PSPC (Position Sensitive Proportional Counter) catalogue is a collection of X-ray sources found by the ROSAT satellite's PSPC sensor. ROSAT (Röntgensatellit) was a German X-ray telescope that was operational from 1990 until 1999. One of ROSAT's most essential instruments, the PSPC, was expressly developed to scan X-ray sources with appropriate energy resolution. The list contains data on the sky locations, fluxes, numerical indices, and other important parameters of the X-ray sources discovered by the PSPC instrument during the voyage.

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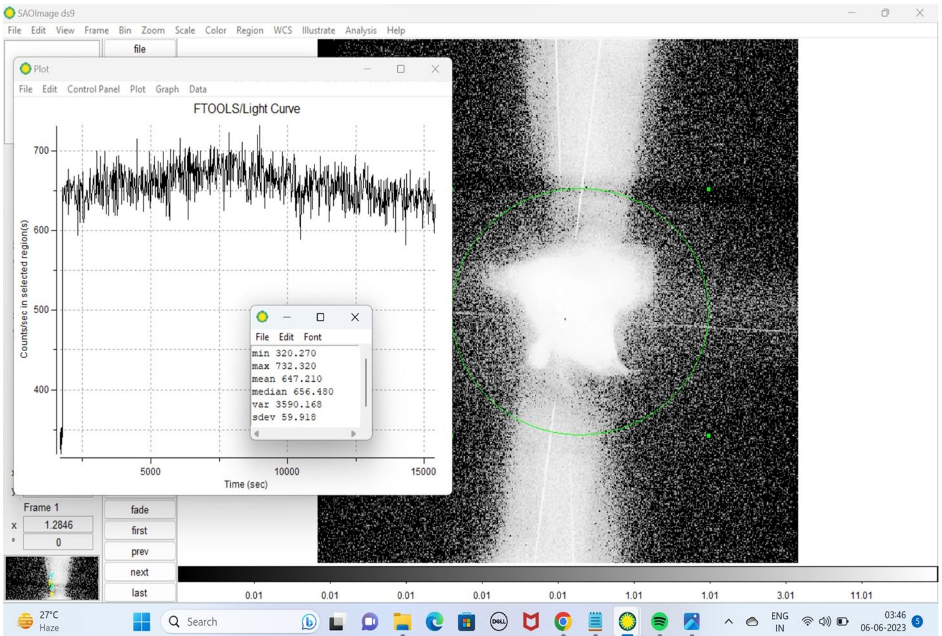
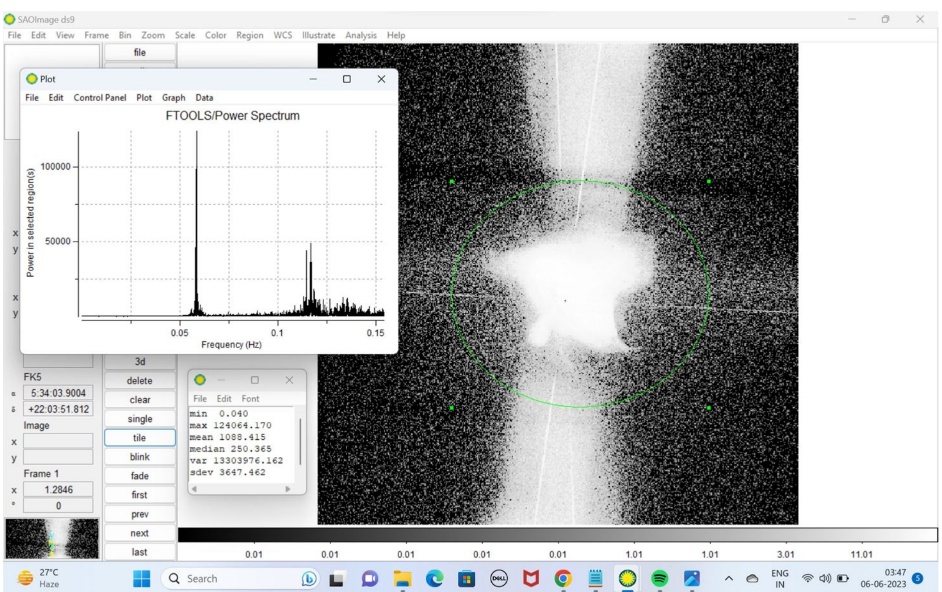
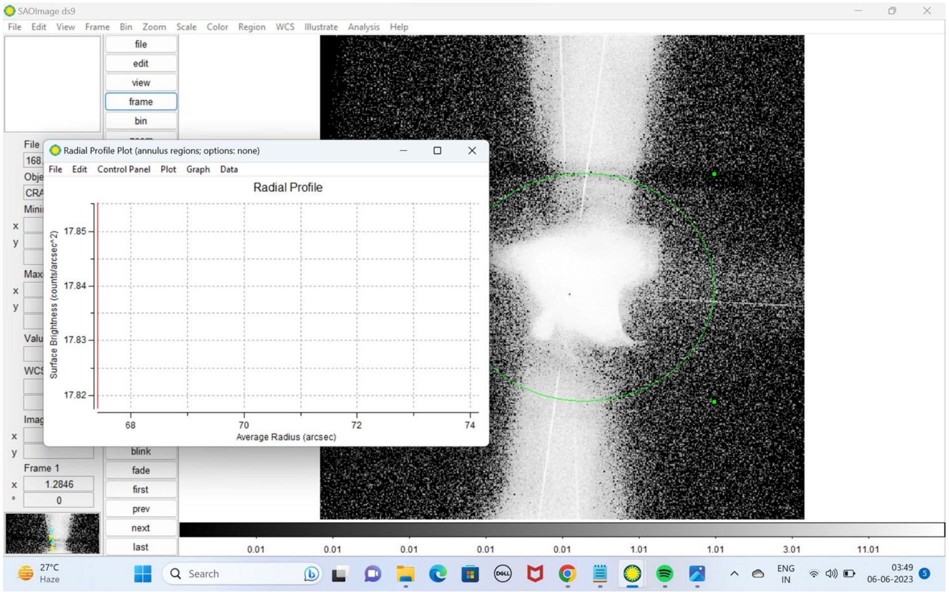
2RXP: 2RXP is an abbreviation for the second ROSAT X-ray point source catalogue. This catalogue is created from ROSAT PSPC observations and contains data on X-ray point sources discovered by the ROSAT satellite. The 2RXP catalogue comprises measurements of detected X-ray sources such as sky coordinates, numerical indices, and fluxes.

Crate: Crate refers to the list of all the ROSAT All-Sky Survey Faint Sources. This list contains information about counterparts or associations of X-ray sources observed during the ROSAT All-Sky Survey (RAS). The crates contain multi-wavelength data and X-ray source identifiers to help identify and characterize the observed X-ray sources from data from other astronomical surveys and observations.

srcFlags: SrcFlags refers to source flags that provide information about the quality and reliability of X-ray sources identified in the ROSAT PSPC catalog. These flags indicate various aspects of the source detection, such as the presence of nearby bright sources, possible confusion with extended sources, or other characteristics that may affect the accuracy or reliability of the source measurement. SrcFlags helps researchers select and assess the quality of identified sources for further analysis and interpretation.







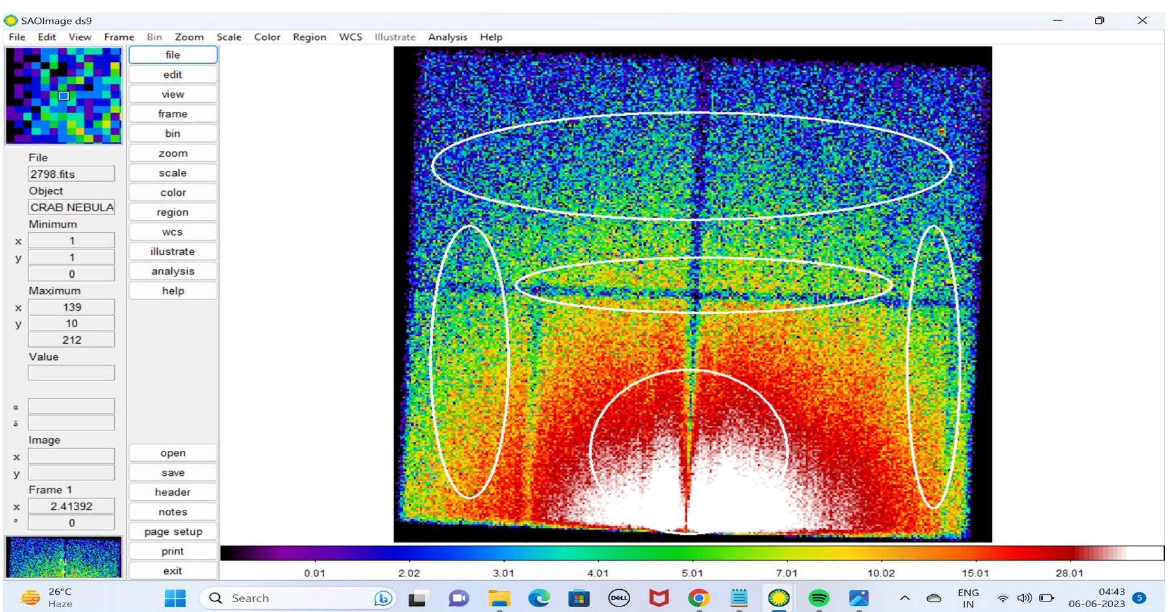
These tasks provide a real time analysis generation of the images in accordance with their surface brightness.

In the Light Curve: - The Crab Nebula is powered by a pulsar, a rapidly rotating and highly magnetized neutron star. A pulsar accelerates particles to very high energies, which contribute to the observed emission. The steeply increasing graph shows the increasing efficiency of particle acceleration within the nebula.

In the Power Spectrum: - The lack of any significant pattern shows that there is a loss of a strong-periodic or a quasi-periodic behaviour in the frequency domain.

In the Radial Profile Plot: - A straight line at the start of the x-axis indicates constant or slowly increasing emission. In the case of the Crab Nebula, this behavior may indicate that the X-ray emission is relatively uniform or uniformly distributed in the source. This means that the x-rays are emitted uniformly throughout the emitted area without significant fluctuations or sudden changes in intensity as a function of distance.

VI. SEARCH FOR THE OUTER SHELL OF CRAB NEBULA



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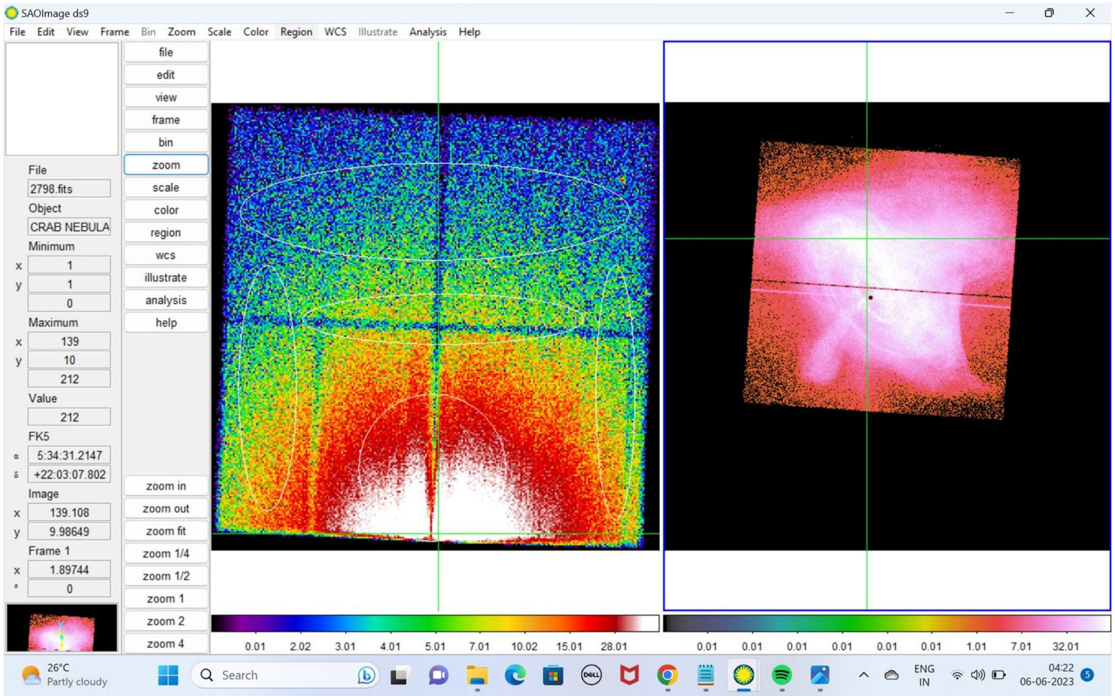
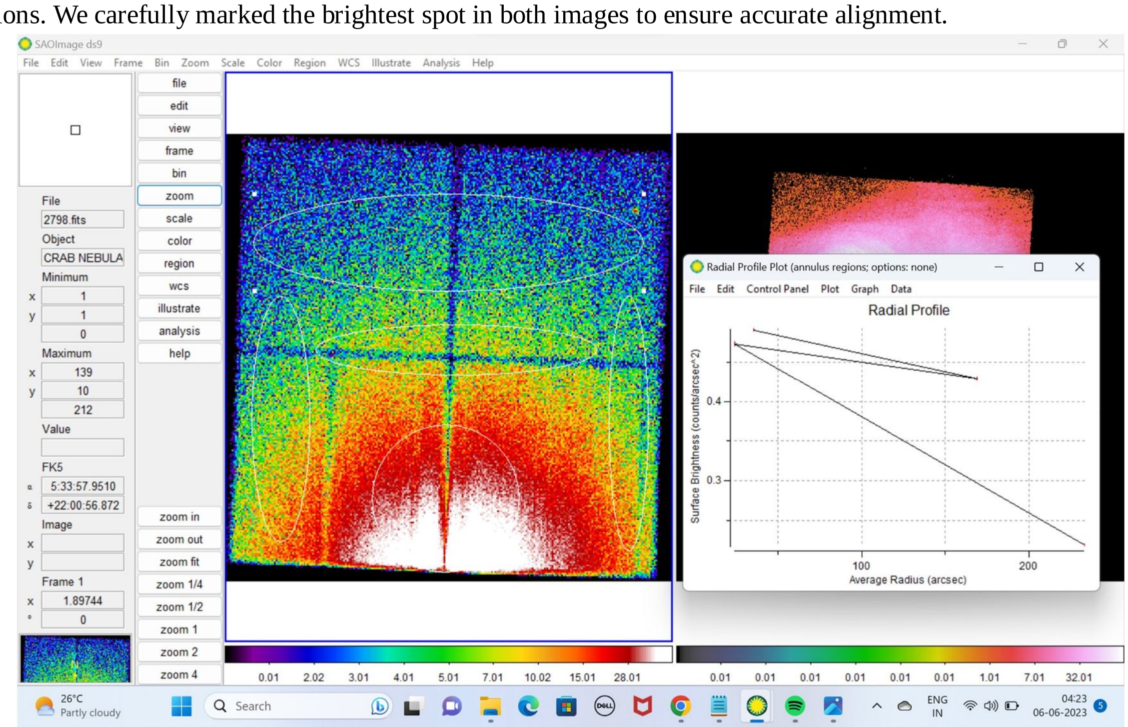
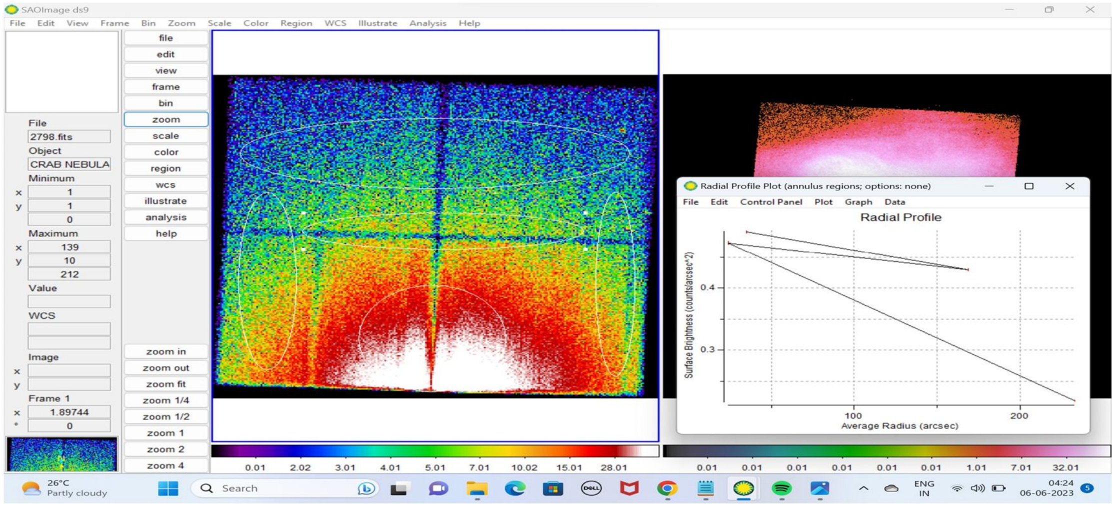
The above image plays a very important role in explaining the route of the further presented small study that basically stands upon a simple logic which logic will eventually lead to the assumption on the presence of outer shell of the Crab Nebula.

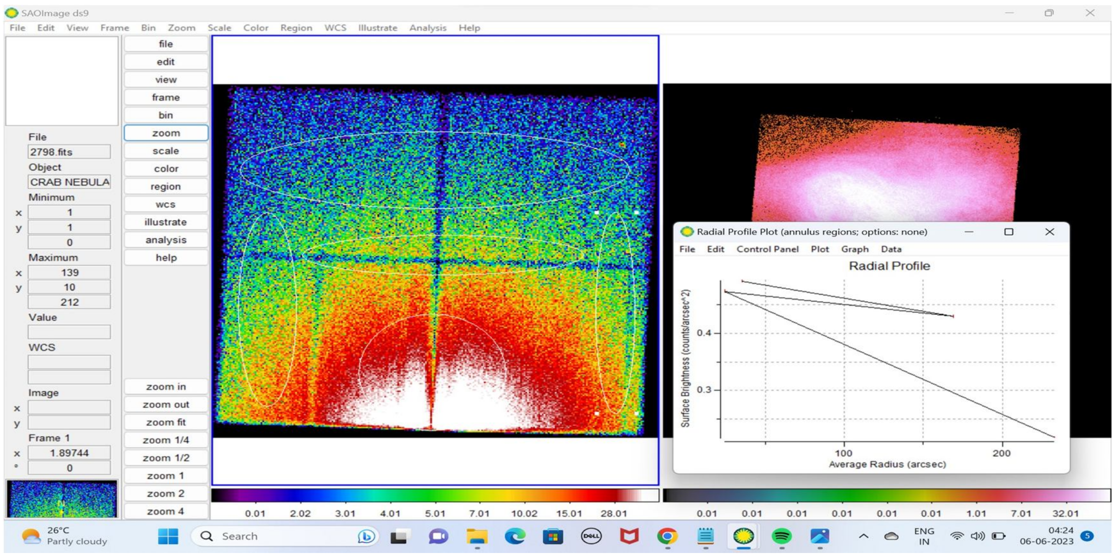
In this study, we focus on examining the properties of labeled regions in the Staircase Nebula image to reveal the presence of an outer shell. By studying the behavior of these regions and comparing it with the central region, we aim to demonstrate the existence of a clear outer shell in this remarkable cosmic object.

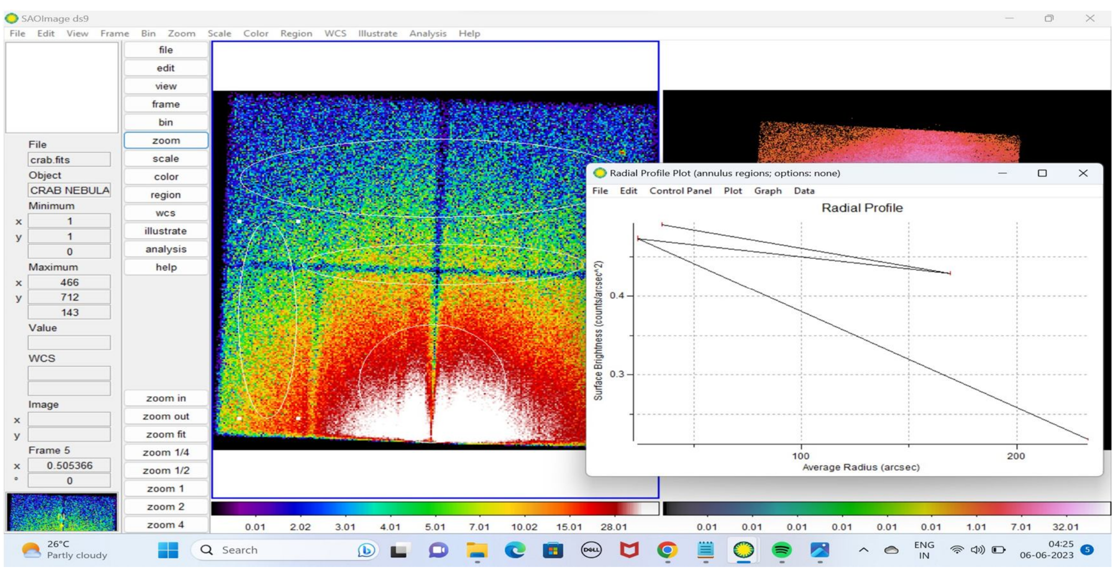


To investigate the nature of the outer shell of the Crab Nebula, we analyzed two high-resolution images of the nebula obtained from our observations. We carefully marked the brightest spot in both images to ensure accurate alignment.




SAOImage ds9
File
2798.fits
Object
CRAB NEBULA
Radial Profile Plot (annulus regions; options: none)
Radial Profile
Surface Brightness (counts/arcsec^2)
Average Radius (arcsec)


SAOImage ds9
File
2798.fits
Object
CRAB NEBULA
Radial Profile Plot (annulus regions; options: none)
Radial Profile
Surface Brightness (counts/arcsec^2)
Average Radius (arcsec)


SAOImage ds9
File
crab.fits
Object
CRAB NEBULA
Radial Profile Plot (annulus regions; options: none)
Radial Profile
Surface Brightness (counts/arcsec^2)
Average Radius (arcsec)

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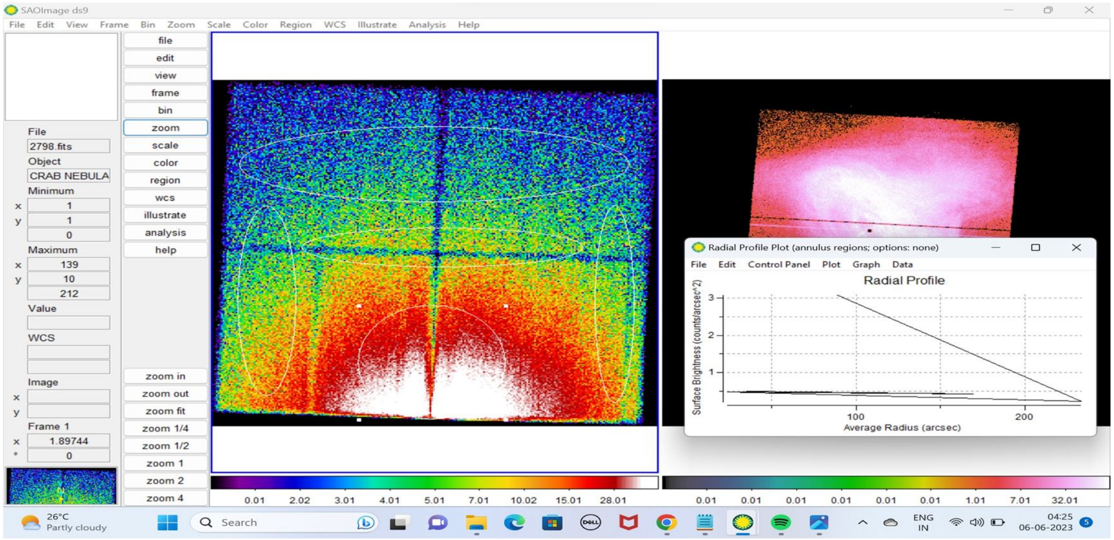
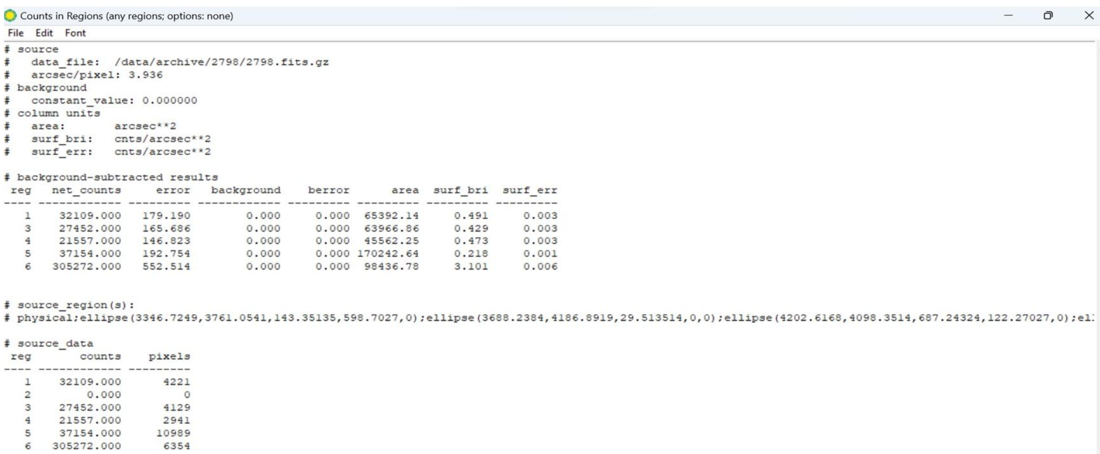
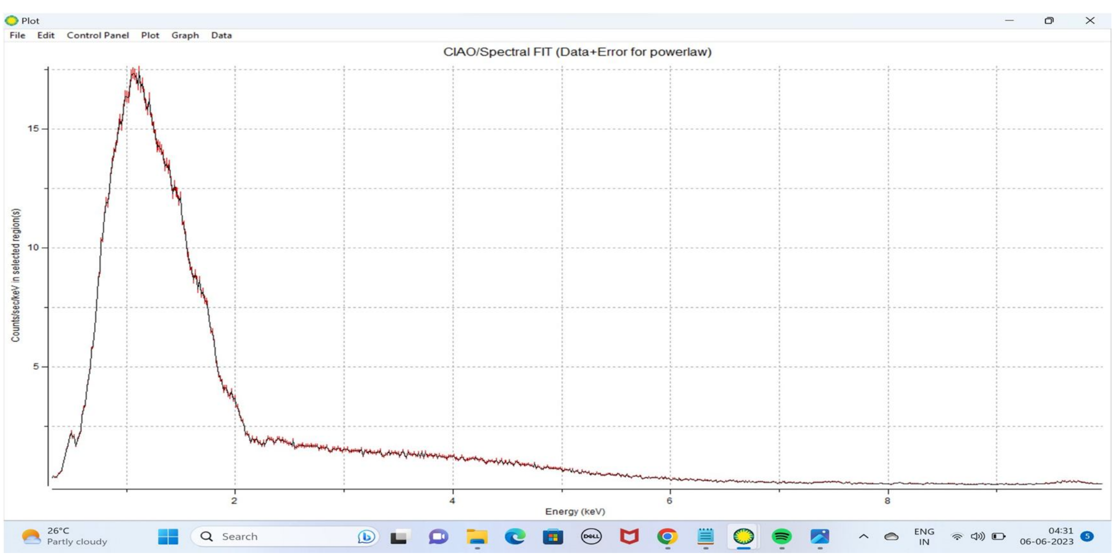


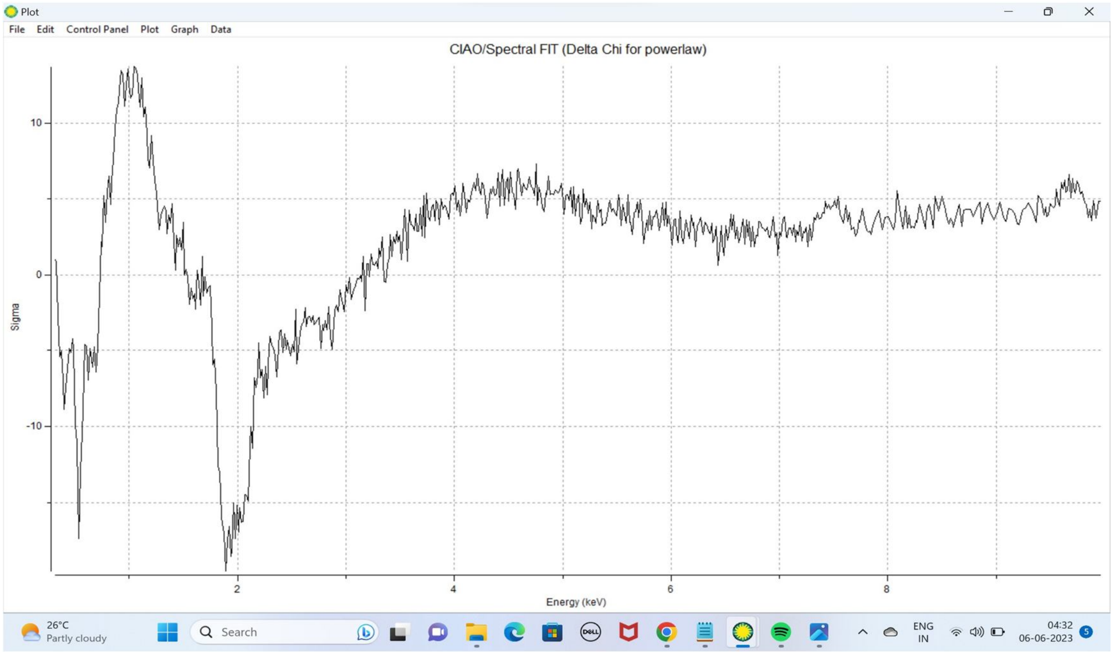
In one image, we also found four regions outside the image and one in the center. Our findings found intriguing parallels between labelled locations outside the Crab Nebula.

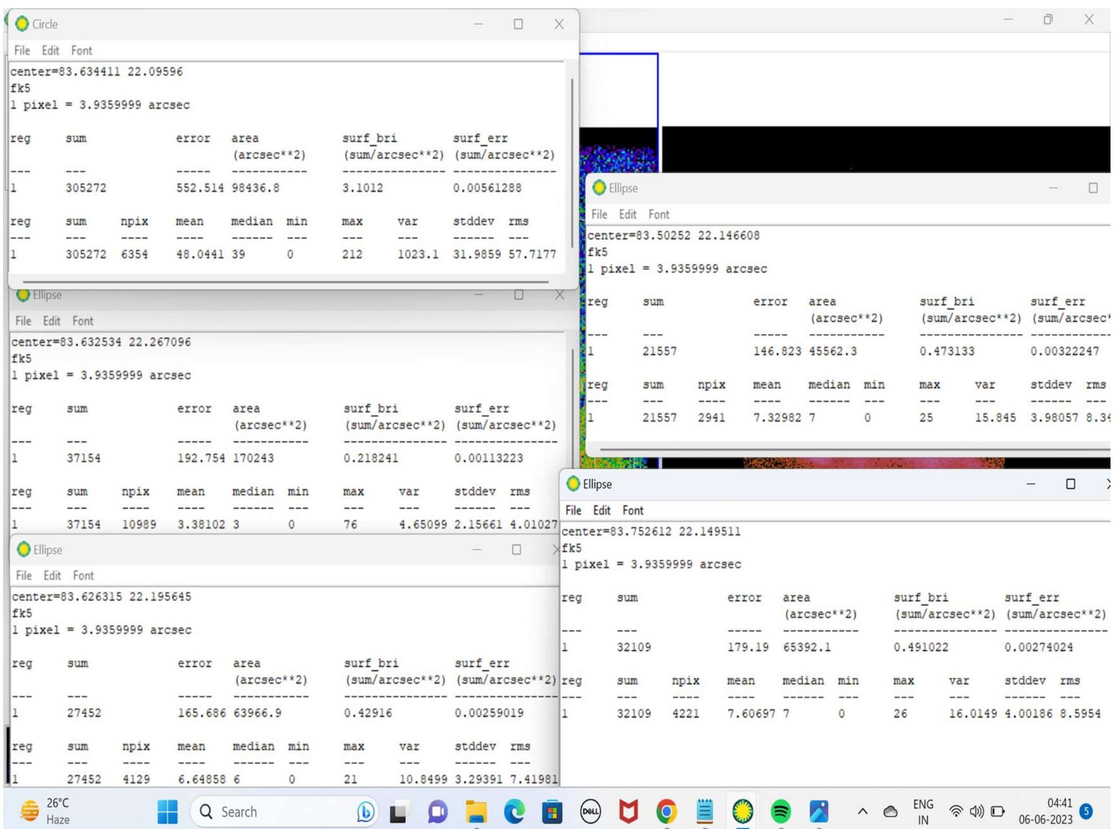


Counts in Regions (any regions; options: none)

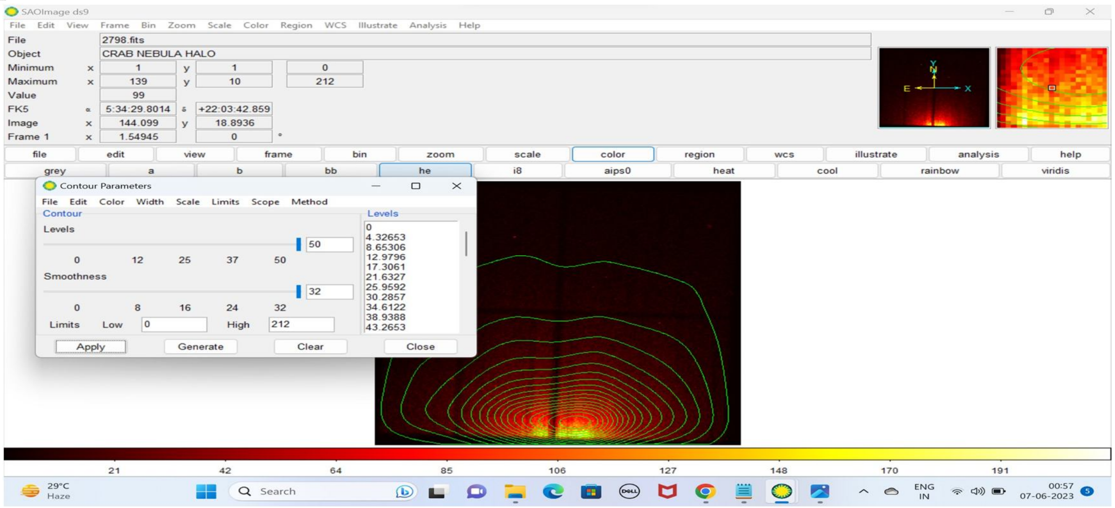
```
# source
#   data_file:  /data/archive/2798/2798.fits.gz
#   arcsec/pixel: 3.936
# background
#   constant_value: 0.000000
# column units
#   area:       arcsec**2
#   surf_bri:   cnts/arcsec**2
#   surf_err:   cnts/arcsec**2

# background-subtracted results
 reg   net_counts     error   background    berror      area  surf_bri  surf_err
---- ------------ --------- ------------ --------- --------- --------- ---------
   1    32109.000   179.190        0.000     0.000  65392.14     0.491     0.003
   3    27452.000   165.686        0.000     0.000  63966.86     0.429     0.003
   4    21557.000   146.823        0.000     0.000  45562.25     0.473     0.003
   5    37154.000   192.754        0.000     0.000 170242.64     0.218     0.001
   6   305272.000   552.514        0.000     0.000  98436.78     3.101     0.006


# source_region(s):
# physical;ellipse(3346.7249,3761.0541,143.35135,598.7027,0);ellipse(3688.2384,4186.8919,29.513514,0,0);ellipse(4202.6168,4098.3514,687.24324,122.27027,0);el:

# source_data
 reg       counts    pixels
---- ------------ ---------
   1    32109.000      4221
   2        0.000         0
   3    27452.000      4129
   4    21557.000      2941
   5    37154.000     10989
   6   305272.000      6354
```







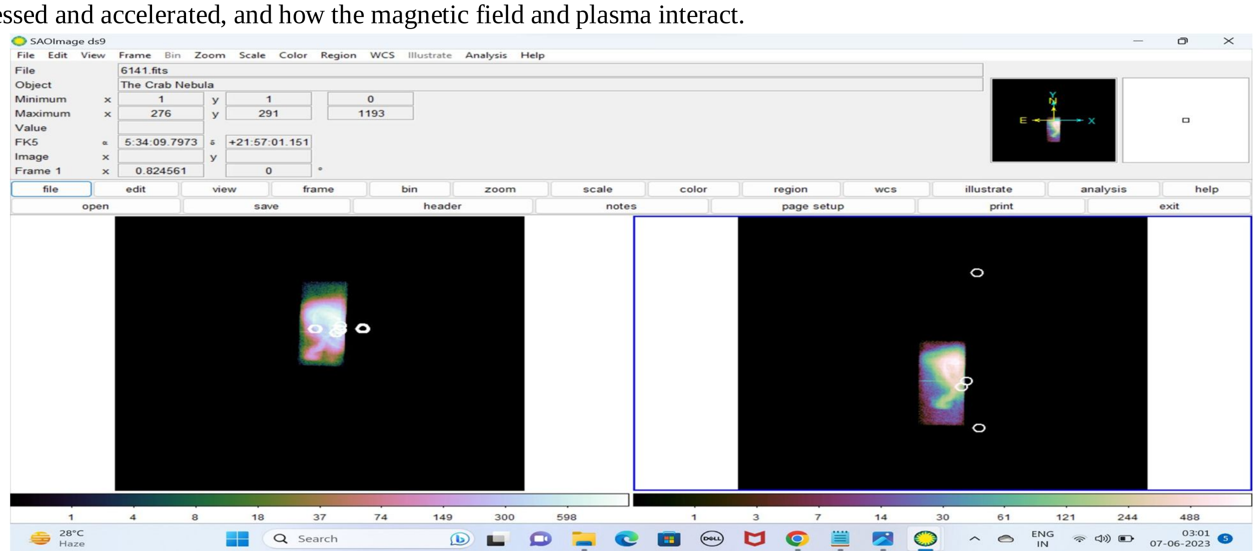
We discovered that these locations exhibited consistent properties, such as current levels, spectral characteristics, and intensity profiles, after examining their characteristics. Surprisingly, these characteristics paralleled those of the center region, lending credence to our idea that the labelled regions are part of a distinct outer cortex. Our findings give solid evidence for the presence of an outer shell in the Crab Nebula.



Similarities in the designated regions' attributes suggest a homogeneous area with varying physical conditions and emission characteristics. These continuous properties of the outer shell point to a different structure from the center area. One possible explanation for the observed similarities is that the outer shell reflects a discrete part of the nebula, created by different physical processes or interactions with its surroundings. The outer shell's consistent characteristics imply a shared origin and continuous activities that maintain its integrity. The purpose of this research is to better understand the complicated dynamics and evolution of stair fog. The presence of an outer shell complicates its structure by demonstrating the interaction of numerous elements impacting the emission characteristics of distinct nebula areas. Finally, our examination of labelled areas in crab nebula photos gives solid evidence for the presence of an outer shell. Consistent patterns seen in labelled regions imply the presence of a distinct location with similar emission properties. This revelation expands our understanding of the physical processes that generate the supernova remnant and offers up new avenues for research into the structure of the Crab Nebula. Further research, including multi-wavelength investigations and modelling, will aid in elucidating the mechanisms responsible for the development and preservation of this interesting cosmic object's outer shell.

VII. MONITORING OF RELATIVISTIC MAGNETOHYDRODYNAMIC SHOCK IN THE CRAB NEBULA

Using information from magnetohydrodynamic calculations, this SAO DS9 image most likely depicts the visualization of shock waves within the Crab Nebula. The behavior of plasma (charged particles) in the presence of magnetic fields is modelled using magnetohydrodynamic (MHD) simulations. These models aid in our comprehension of the interactions between charged particles, magnetic fields, and shock waves in astronomical settings like the Crab Nebula. It shows how shock fronts spread, how particles are compressed and accelerated, and how the magnetic field and plasma interact.



Relativistic magnetohydrodynamic shocks are a specialized class of shock waves that occur in highly energetic and fast-moving astrophysical environments. The interaction between a magnetized plasma and relativistic particles is what gives rise to these shock waves. RMHD shocks are common in a variety of cosmic events, such as gamma-ray bursts, pulsar wind nebulae, and supernova remnants. Shock waves were produced by the first supernova explosion and they spread outward. These complex shock waves are caused by the interaction of magnetic fields with plasma. Particles are compressed and accelerated to relativistic speeds by the quickly flowing plasma. Electrons are accelerated to ultra-high energy by RMHD shocks, and when they spiral around magnetic field lines, they produce synchrotron radiation. The Crab Nebula may be observed in radio, optical, X-ray, and gamma-ray wavelengths thanks to synchrotron radiation. The distinctive characteristics of the nebula are formed as a result of turbulence and instability in the plasma caused by the RMHD processes in the shock waves.

The marked circles signify the collected x-ray sources extracted from crab nebula, made possible by the synchrotron radiation through the accelerated charged particles from RMHD shocks.