# Communicating Multi-wavelength Astronomy through Exhibit

*Manash Bagchi*

## Abstract

*Popular perception of astronomical observation is imposing on one to believe that universe is studied only through optical telescopes stationed in terrestrial observatories. Yet, a significant part of the astronomy observation is made in wavelengths spanning other parts of the Electromagnetic Spectrum. And the observation points are bound to be out in space for scanning in certain wavelengths. This expanded nature of astronomy observation was presented in an interactive exhibit* ***Seeing in different lights*** *in the exhibition* ***Messages from the Heaven*** *developed by National Science Centre, Delhi. The exhibit design was conceived through our interaction with the students attending astronomy workshops and they were consulted to conceive the user point-of-view of the possible exhibit addressing this topic.*

## Genesis

'How do we know what is happening all the time in the universe?' we asked the students in the astronomy workshop. 'Observing through Telescopes' - was the unanimous answer. But, light becomes feeble at great distances; Inter-stellar clouds block visible light, earth's atmosphere do not permit all types of radiation to reach the ground, not all astronomical objects emit strong enough visible light. And to know the universe, in its completeness, we must overcome all these problems! Kids did not seem to have the appropriate comprehension of these complications.

We explained them with a scenario - suppose a person goes to a concert and he is so heavily impaired of hearing that he can only listen to sounds made in C-sharp. Can he enjoy the concert? Children seemed to realize his limitation. When all other persons will hear all the sounds from every instrument, the person with hearing impairment will never be able to hear the wholesome music. This analogy helped students in comprehending what one can miss in terms of observational astronomy if we were to restrict our studies solely on observation through optical telescopes.

The visible light - the light we see with our eyes - covers only a small portion of the vast electromagnetic spectrum which also includes gamma rays, X-rays, ultraviolet, infrared, microwaves, and radio waves (Fig. 1) with different types of radiation characterized by

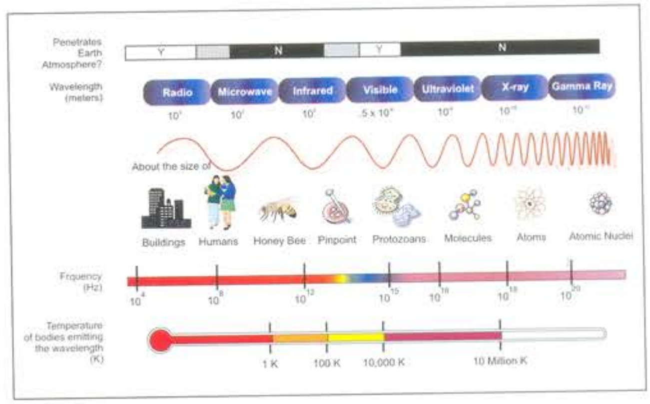



Fig. 1 Electromagnetic spectrum

their wavelength or frequency. Wavelength increases and frequency decreases from gamma rays to radio waves and all these waves travel at the speed of light. Objects radiate energy some of which is visible to our eyes while most of it is not. Even the radiation that is not visible to us has information of the objects' inner physical states. If we can read them properly, we know what is happening inside them.

For a complete picture of the Universe we need to see it all across the electromagnetic spectrum. Technological developments over the past seventy years have led to electronic detectors capable of seeing light that is invisible to human eyes. In addition, we can now place telescopes with special detectors on satellites and on high-flying airplanes and balloons which operate above the obscuring effects of Earth's atmosphere. A black cat in a dark room is missed out by our eyes while the same is seen through the Night Vision Camera with IR Sensor (Fig. 2). Likewise we

Fig. 2 Infrared view of a black cat in a dark room

miss out a lot of the universe if we were to see it only through the visible light. When we discussed these facts, students readily wanted to know how the universe will look in other lights, resulting in our designing the exhibit "**Seeing in Different Lights**" for the exhibition *Messages from the Heaven* to commemorate IYA 2009.

## *Exhibit Design*

Students nurture an idea that profesional astronomy is done through only big-sized reflector and refractor telescopes kept on earth-based observatories. Though the positioning of Hubble Telescope in space were known to them, its purpose was not clear. This called for a means to instill, in them, an idea that astronomy is done throughout the EM spectrum and that every type of telescope cannot work from the earth-base because of the atmospheric shield around the earth. These ideas were too technical and an all encompassing design was elusive, till we zeroed on an interface shown in the Fig. 3. In juxtaposed graphics we presented what is the Electromagnetic Spectrum and how does atmospheric opacity vary with respect to wavelength of the spectrum. The EM spectrum graphic compared dimensions of known things with wavelengths of different types of EM waves differing only in their wavelength. The atmospheric opacity


Fig. 3 The exhibit – *Seeing in different lights* – from the exhibition Messages from the Heaven

graphic (Fig. 4) was intended to simplify the idea that while EM waves from different extraterrestrial sources are coming to us, different wavelengths are blocked at different heights. Two broad windows in the scheme were shown to represent that only EM waves in optical and short wavelength radio wave regions can reach earth surface. So, observations only in those ranges are possible from earth. But, for receiving UV, X-ray and Gamma ray signals, our respective telescopes have to be positioned outside the atmospheric cover. To further elucidate these points, we embedded translite images of appropriate telescopes working in these ranges and coupled them with actuator switches so that pressing them one can see, in a central display, an audiovisual presentation showing the astronomical objects observed in that range of wavelength.

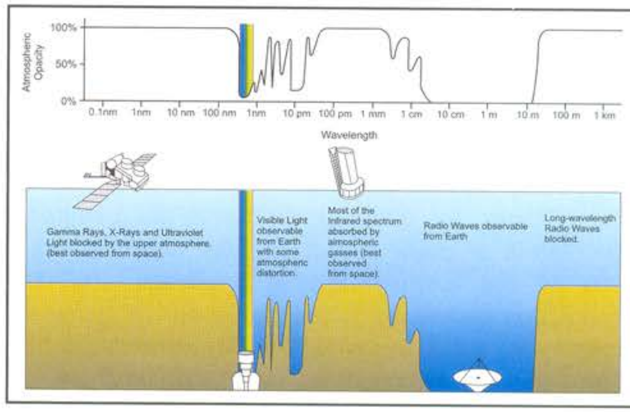



Fig. 4 Variation of atmospheric opacity with wavelength of EM Spectrum

The control circuitry is represented by the block diagram in Fig. 5. Telescope selection switches send signals to a microcontroller that selected and played appropriate media files through a video player. Depending on the telescope selected, the exhibit unfolded in steps, which are the objects that are particularly observed/monitored in that part of the spectrum and how do the commonly known objects look when they are seen through them.

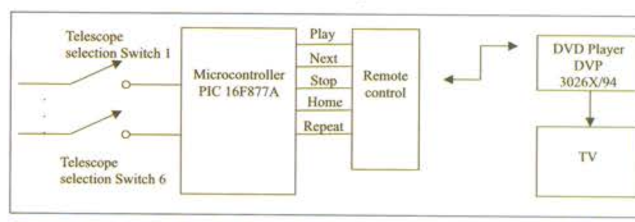
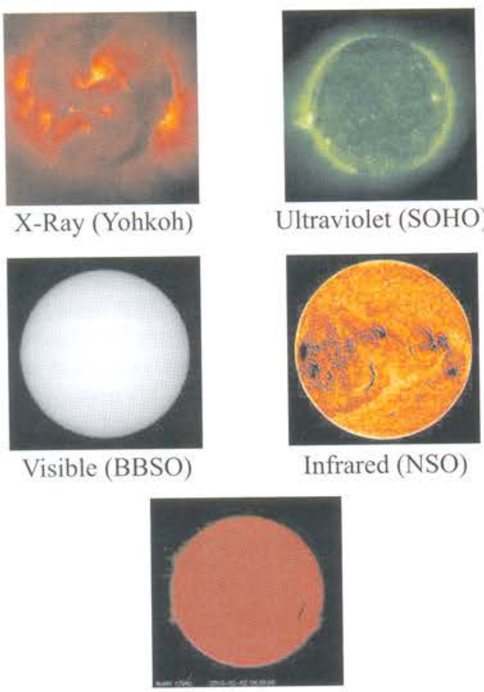



Fig. 5 Control Circuit Block Diagram for the exhibit Seeing in Different lights

## *Content coverage*

By interpretation of the multiwavelength observation of astronomical objects we guess the temperature, energy and type of the objects in a part of the universe. Multiwavelength studies give us information about the different layers in the atmospheres of planets and some of their moons. Observing the Sun in different parts of the spectrum allows us to study details in different layers of the solar atmosphere. Comets emit X-rays and why do they do so is still a mystery. Infrared observations have shown us that our solar system is filled with comet dust and that the giant planets Jupiter, Saturn, and Neptune not only reflect heat from the Sun, but create their own heat as well. Ultraviolet observations have led to the discovery of auroras on both Jupiter and Saturn. We expected our student visitors to go excited about them and also to pursue these mechanisms at the research level when they are beyond their classrooms and ready for their career.

The X-ray image of the Sun shows us the structure of the hot corona – the outermost layer of the Sun. The brightest regions in the X-ray image are violent, high-temperature solar flares. The ultraviolet image shows additional regions of activity deeper in the Sun's atmosphere. In visible light we see sunspots on the Sun's surface. The infrared photo shows large, dark regions of cooler, denser gas where the infrared light is absorbed. The radio image shows us the middle layer of the Sun's atmosphere. In visible light we see sunspots on the Sun's surface – the regions of lesser temperature. All these help us to study the types of reactions going in the Sun, and in turn, they help us understand its course of evolution.



X-Ray (Yohkoh) Ultraviolet (SOHO)

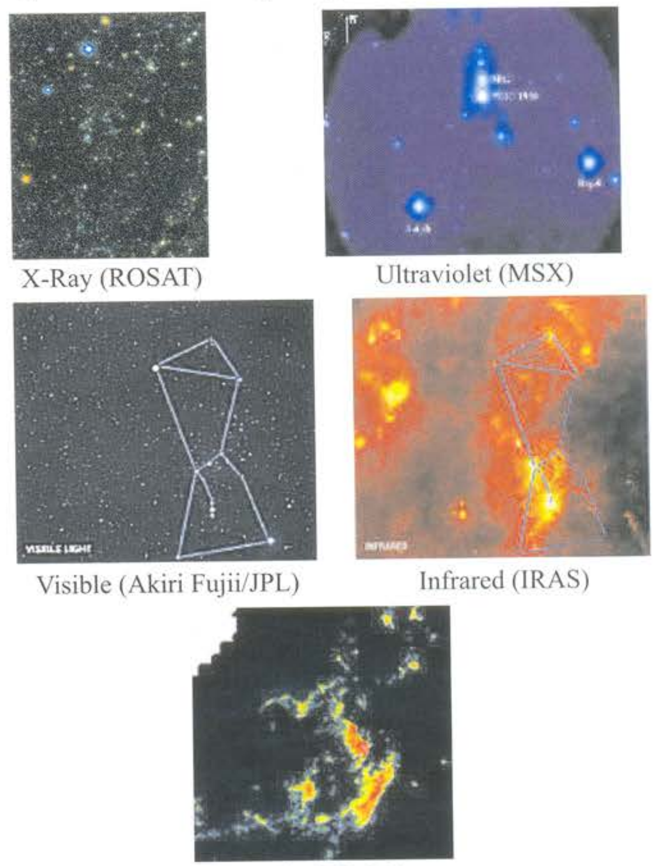
Visible (BBSO) Infrared (NSO)

Radio (Nobeyama)

Fig. 6 Sun observed in different lights

Beyond the sun, within our galaxy, the infrared image shows areas which appear dark and empty in visible light. They reveal bright molecular clouds in which new stars are being formed. Infrared astronomy has revealed disks of material around other stars in which planets may be forming, wisps of warm dust throughout the galaxy, vast numbers of cooler stars, and the core of the Milky Way. X-rays tell us about the hot outer atmospheres of stars and the final phases of a star's life. When a star explodes, it ejects hot shells of gas which radiate strongly in X-rays. This makes the X-ray region of the spectrum a valuable place to learn about supernovae, neutron stars, and black holes. X-ray observations have also led to the discovery of a black hole at the center of the Milky Way. Radio waves also bring us information about supernovae and neutron stars. In addition, radio observations are used to map the distribution of hydrogen gas in our galaxy and to find the signatures of interstellar molecules.

The X-ray photograph in the Orion region of the sky reveals Sun-like stars, white dwarf stars, neutron stars, and supernova remnants in our own Galaxy, and (in the background) nearby galaxies, clusters of galaxies, and distant quasars. The ultraviolet image is a close-up view of the belt/sword region of Orion, including the famous Orion Nebula, and is dominated by emission from hot, young stars.



X-Ray (ROSAT) Ultraviolet (MSX)

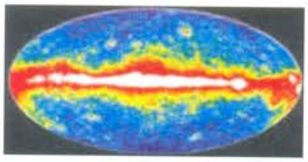
Visible (Akiri Fujii/JPL) Infrared (IRAS)

Radio (NRAO)

Fig. 7 The Orion region of sky in different wavelength

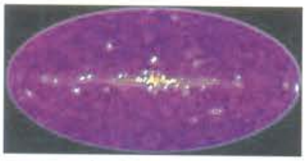
The visible light image shows stars of all ages and temperatures. In the infrared, our view of Orion is dominated by emission from clouds of dust and gas, the materials from which new stars will be born. The radio image maps the distribution of hydrogen molecules in the interstellar medium, with red showing the areas of highest concentration.

All-sky maps portray the entire Milky Way Galaxy (Fig. 8). They are painstakingly formed by taking images of the entire celestial sphere, and then unwrapping and stretching them to fit onto a two-dimensional surface. The Galactic Center is at the center of each image, with the plane of the Galaxy stretching from left to right like the equator on Earth.

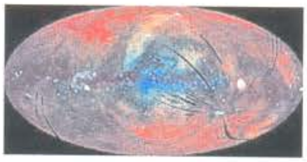


Gamma-Ray >100MeV (CGRO, NASA)

Gamma-Ray (N. Gehrels et.al. GSFC, EGRET, NASA)



X-Ray 2-10keV (HEAO-1, NASA)

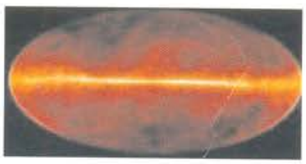


X-Ray 0.25, 0.75, 1.5 keV (S. GSFC, ROSAT, NASA)

Ultraviolet (J. Bonnell et.al. (GSFC), NASA)

Visible (Axel Mellinger)

Infrared (DIRBE Team, COBE, NASA)



Radio 1420MHz (J. Dickey et al. UMn. NRAO SkyView)

Radio 408MHz ©. Haslam et al., MPIfR, SkyView)

Fig. 8 Muliwavelength Milky Way

Each image is dominated by the emission from the disk and central bulge of the Milky Way, where most of the contents of our galaxy are contained.

Gamma-rays have more than a million times the energy of visible light. So, the first gamma range picture shows us areas where high-energy cosmic rays collide with hydrogen in interstellar clouds. The next gamma-ray image highlights the most intense gamma-ray sources. Some of these bright areas have been identified as black holes, neutron stars and quasars. Most of these however, remain a mystery and have not yet been identified with complete certainty.

X-rays are about 1,000 times more energetic than visible light and the first X-ray image shows the brightest X-ray emitters in the Milky Way. These high-energy X-rays are produced in high-temperature environments. They are identified as white dwarfs, black holes, neutron stars, pulsars, supernova remnants, active galaxies, flare stars, and high energy binary star systems. The next X-ray image maps hot gas and show large, looping structures. The gas and dust clouds in the plane of the Milky Way block X-rays and cause this area to appear dark.

The ultraviolet image reveal stars, quasars, external galaxies, supernovae and nebulae. Visible light provides us with a view of the overall distribution of stars. The dark patches along the galactic plane are regions of dense gas and dust which block visible light. In the infrared we see glowing dust which is heated by starlight as well as regions of intense star formation (brightest areas). The remarkable S-shaped blue sash is the structure of zodiacal dust bands which are small pieces of rock and dust orbiting between the Sun and Jupiter. The galactic plane no longer shows dark patches in the infrared. This is because infrared light can penetrate gas and dust clouds causing this region to glow in the infrared.

The higher energy radio image maps the distribution of the hydrogen gas which fills our galaxy. No stars are seen in this image. All we see are vast, diffuse clouds of hydrogen – the most abundant element in the Universe. The next radio view of the sky shows areas where synchrotron radiation (radiation which occurs when charged particles are accelerated in a curved path or orbit), and hence electrons and magnetic fields, are dominant. This image also shows the location of pulsars and supernova remnants.

Beyond our Milky Way galaxy, multiwavelength astronomy unlocks a treasure of information. Visible light images show us the detailed structure of various types of galaxies, while radio images show huge jets and lobes of material ejected from galactic cores. X-rays are used to detect the signature of black holes in the centers of galaxies – the extremely hot material being pulled into a black hole at tremendous speeds. Infrared light has been used to discover thousands of galaxies which are undergoing intense star formation. Radio studies have detected the radiation left over by the Big Bang.

A multiwavelength look at the Whirlpool Galaxy (Messier 51), 37 million light years from Earth, reveals a face-on spiral galaxy gravitationally interacting with a smaller companion galaxy.

The X-ray image highlights the energetic central regions of the two interacting galaxies. Much of the diffuse glow is from multi-million degree gas. Many of

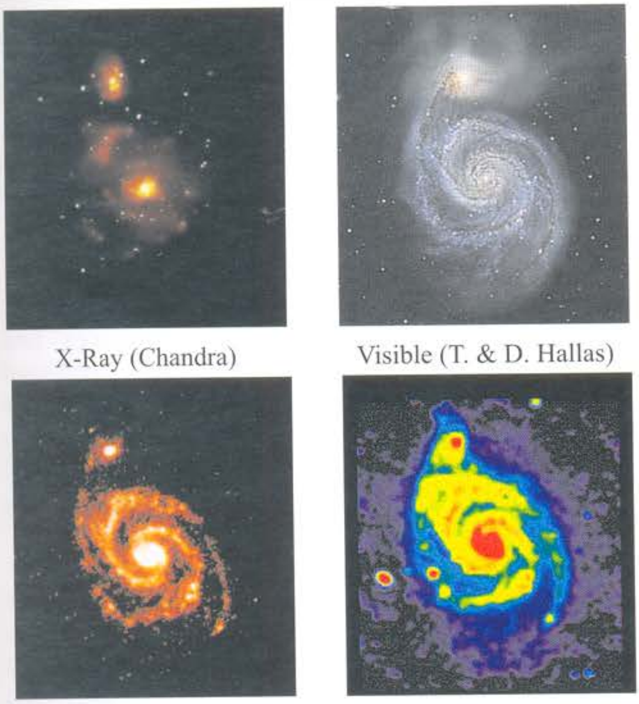



Fig. 9 Whirlpool Galaxy in different lights

the point-like sources in the x-ray image are black holes and neutron stars in binary star systems. Visible light clearly reveals the sweeping spiral arms which include patchy knots of star formation. The companion galaxy, classified as an irregular galaxy, lacks the well-defined structure of a spiral galaxy and appears "attached" to the end of a spiral arm in the "Whirlpool Galaxy". Infrared is well-suited to studying star formation and tracing dust in spiral galaxies. The infrared image not only shows the galaxy cores and spiral arms, but nicely illustrates the knots of star formation occurring in the arms. The spiral arms extending from the galaxy center and the companion galaxy are clearly seen at radio wavelengths. A modest-sized red blob appears to be connected to the end of the southern spiral arm, located about the 8 o'clock position. This is interpreted as a probable background quasar.

## Conclusion

The information discussed above was presented to the visitor in the exhibit in an interactive way with a message that rapid advances in technology have made the future of multiwavelength astronomy extremely bright. In the coming years and decades, we will continue to hear about many new discoveries being made across the spectrum. So the exhibit *Seeing in Different Lights* seemed to address an important area of cutting-edge astronomy. During one and half month of the exhibition at the National Science Centre, from our interaction with the visitors to the exhibition, it transpired that the objects observed in different wavelength gained good popularity and the fact that most distant objects like Pulsars and the farthest objects observed like the Gamma Ray Bursts (GRBs) can only be observed by high frequency region of the EM spectrum were established well with the visitors. Students showed great interest in the interpretations of the multiwavelength views of the Milky Way galaxy.

## Exhibit collaborators

S Sen, N R Iyer, V Sharma, M Bagchi, K Khemnani, N Rajani, Bharti.

## References and Sources

1. Gribbin John, *Hyperspace - our final frontier,* (BBC Worldwide Limited, 2001)
2. Henbest Nigel, Henbest Nigel, *The New Astronomy*, (Cambridge University Press; 2nd edition, 1996)
3. http://imagine.gsfc.nasa.gov/docs/science/know_11/multiwavelength.html
4. http://imagine.gsfc.nasa.gov/docs/science/know_12/multiwavelength.html
5. http://mwmw.gsfc.nasa.gov/mmw_edu.html
6. http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/observing.html
7. http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_astronomy/index.html

Manash Bagchi, Curator, National Science Centre, NCSM, New Delhi.