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Revisiting Observation System in Astronomy

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ABSTRACT: *Observing astronomical objects is an ancient process, which was power-drifted by Galileo after his discovery of telescope in 16th century. The astronomical instruments over the electromagnetic spectrum that had been perfected after the sudden arrival of Jansky in 1933 and his radio astronomical telescope. In the last century, the improvement of techniques of observations from space, and the exploration of the solar system as well as the rapid improvement of computer and remote technologies have opened up of new possibilities, which have been reviewed by us in this paper.*

I. INTRODUCTION

Variable stars of slow time variation are known since ancient times but interestingly the first pulsar (period 1.377 ms) was not possible to discover until 1968. In fact, investigations on very rapidly varying phenomena have developed from that time as a result of large-scale progress in detector sensitivity. In the mid-1990s, all interactive processing for the acquisition and treatment of astronomical information was started to handle by work stations, UNIX in general. The power of these work stations was significantly increased by increasing the clock speed (can reach up to 200 MHz), besides the advent of parallel computing [1]. The chapter critically focuses the achievements gathered by making use of modern technologies including computer multiplexing and suitable image processing in a complex situation [2].

II. BASIC SETUP OF ASTRONOMICAL OBSERVING SYSTEM

The basic setup of an astronomical observing instrument is shown in Figure 1. By the term observing system, we mean the arrangement of subsystems between the collection of radiation, its processing and storage. The functions of different subsystems to constitute the observing system are as follows [3]:

(i) ***Primary mirror:*** The photon flux from the source is collected by a surface ‘A’, known as the aperture of the detector, usually a mirror called the primary mirror. The area of aperture can be changed several thousand square meters for a radio telescope to a few tens of square centimeters for an X-ray telescope.

(ii) ***Field of view:*** The photons are composed in a solid angle ($\Delta\Omega$), known as the field of view of the system. It can be extensively varied from several square degrees for Schmidt telescopes and γ-ray telescopes to a fraction of a square arc second in the visible.

(iii) ***Side lobes:*** There parasitic side lobes take energy from directions other than the principal direction of observation. Neither the principal lobe nor the side lobes reveal axial symmetry concerning the direction of observation.

(iv) ***Image plane:*** A set of several mirrors, lenses or a combination of an optical system concentrates the received energy to form an image in the image plane or focal plane. Thus, the field of view ($\Delta\Omega$) is decomposed into image elements or pixels. Each pixel is subtended by a solid angle of the source.

(v) ***Device for spectral selection:*** It isolates a particular frequency domain $\Delta\nu$ in the incident radiation where the selection may result from the spectral selectivity imposed by the physical characteristics of the optical system. The selection is also made by the detector itself or from deliberate filtering of the radiation. A set of various frequency domains can be sampled by this way.

(vi) ***Polarizer:*** The polarization of the radiation may be obtained by a polarizing filter. The polarizer selects linear or circular polarization in the incident radiation. Some detectors at radiofrequencies are sensitive only to a particular polarization to combine detection and measurement of polarization.

(vii) ***Detector:*** The incident electromagnetic signal is converted by the detector into a physical quantity which can be measured and stored, such as current/voltage or chemical transformation on photographic plate etc. This may then be stored and measured at convenient time.

(viii) ***Acquisition system:*** For analyzing and recording the signal the detector is followed by a set of electronic devices to make up the acquisition system. If the detector produces an electric signal, the analysis may be done in real time. However, if the receiver is a photographic plate, the analysis cannot do simultaneously.

It should be noted that starting from the basic setup, different observing strategies can be taken. The spectrum of an object can be measured with or without spatial or temporal resolution, i.e. a region can be mapped with or without sensitivity to faint photon fluxes.

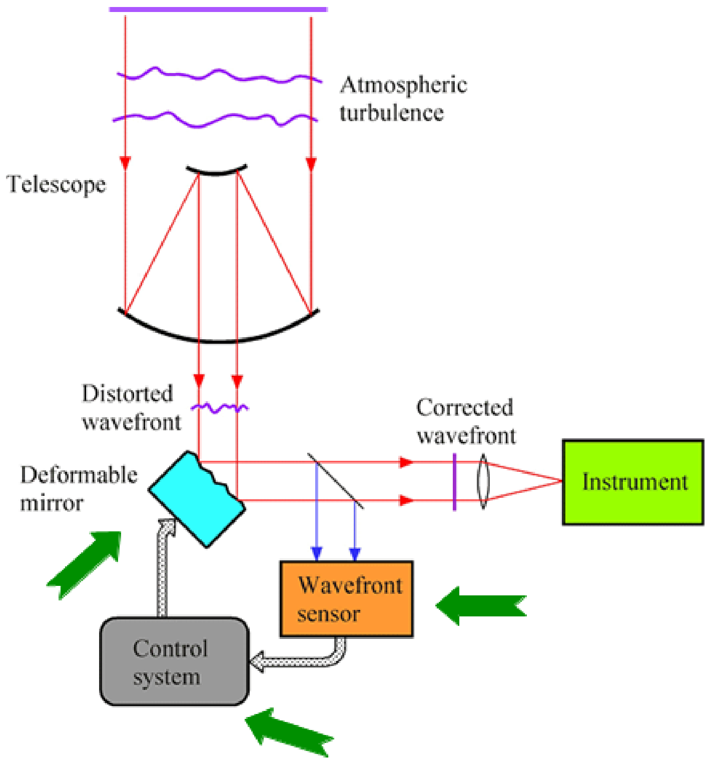

Fig. 1. Illustration of an astronomical system [5]

III. PROGRESSIVE COVERAGE OF E. M. SPECTRUM AND PROGRESS IN TIME RESOLUTION

The historical development of access to the whole electromagnetic spectrum is exhibited in Figure 2. This coverage is, however, not equal with regard to the performance in the domains of sensitivity, angular resolution. The performance level is still a function of the wavelength though the situation is gradually improving with successive space missions. Absorption by the earth's atmosphere is a decisive factor. The wide spectral coverage can provide a full and quantitative view of the relevant object. The photons observed in different spectral regions may be emitted from various sources like images of the galaxy M31, visible stars and dust or cold gases. For a comparative study, the angular resolution of the level of sensitivity of different observations should be taken into account [4].

Transients may originate from nearly all celestial objects including the solar system, star-forming regions, the galactic center, and other galaxies. A combination of increased sensitivity, field of view and algorithmic developments would yield transformational discoveries in a wide range of astronomical fields. Classes of transients are diverse, ranging from nearby stars to cosmological distances (GRBs). Table 1 lists a series of known, hypothesized, and exotic classes of radio transients [6].

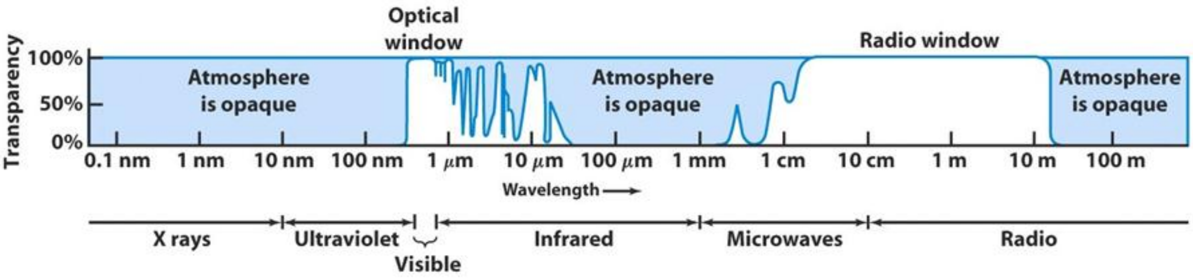

Fig. 2 Progressive coverage of e. m. spectrum by observation [7]

The possibility of observing the time variability of astronomical sources is largely related to detector sensitivity as the measurement time is externally imposed. In fact, the sensitivity improves with increased measurement time. Figure 3 shows the progress in time resolution.

Table 1. Illustrations of Classes of Transients

Known Classes	Extrapolations of known Physics	Exotica
Brown dwarfs, flare stars	**Extrasolar planets**	**Signals from Extra Terrestrial (ET) civilizations**
Pulsar giant pulses, intermittent pulsars, magnetar flares, X-ray binaries	**Giant pulses, flares From neutron stars in other galaxies**	**Electromagnetic counterparts to gravitational wave events**
Radio supernovae, GRB after glows	**Prompt emission from GRB, orphan GRB afterglows**	**Annihilating black holes**
Variability from interstellar Propagation	**Variability from Intergalactic propagation**	

IV. RADIO POWER OUTPUT OF ASTRONOMICAL OBJECTS

Table 2 reveals radio power outputs of some typical astronomical objects [8] while a list of some significant radio sources identified with external galaxies are presented in Table 3.

Table 2. Radio power outputs of Astronomical Objects (assumed isotropic) [8]
(Source: Maarten Schmidt of Mt. Palomar Observatory and Martin Ryle of Cambridge)

Object	Radio Power, Watt
Sun	10^{12}
Flare Star	10^{16}
Supernova remnant	10^{28}
Normal galaxy (10^{11} solar masses)	10^{28}
Seyfert galaxy	10^{32} to 10^{34}
Radio galaxy	10^{35} to 10^{38}
QSO and BL Lac Objects	10^{37} to 10^{39}

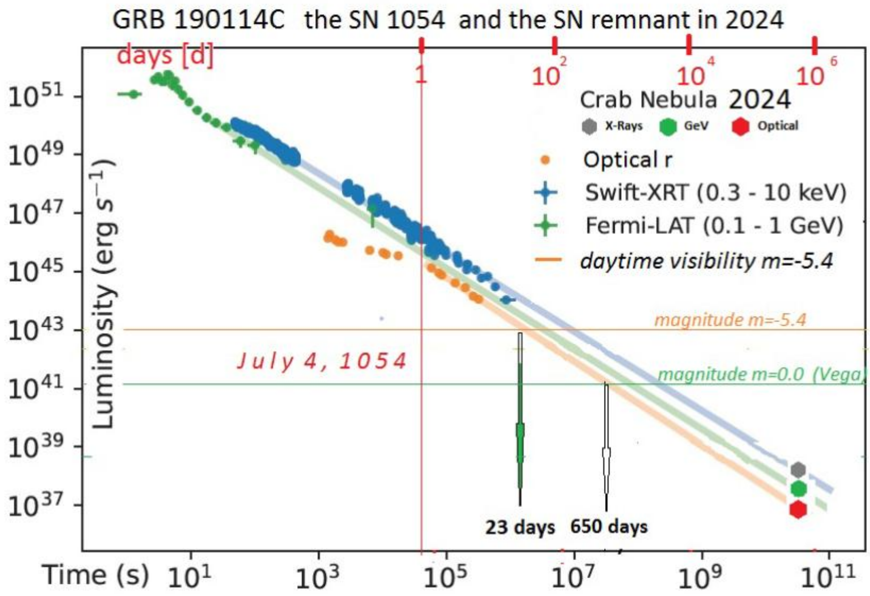

Fig. 3. Progress in resolution of time by observations. The upper part illustrates covering decades or centuries, e.g. observation of the Crab supernova (1054). A few significant discoveries of variable objects are also shown. Cosmic Discovery is completed with dashed line for a period 1985 - 2000 [9].

The radio sources in the table are listed in order of increasing radio power output (or radio luminosity). The list of the objects also results in order of increasing distance with a few exceptions.

Table 3. some significant radio sources identified with external galaxies [10]

Objects considered	Log of radio power ζ (watt)	Distance ş (Mpc)
SMC	29	**0.05**
LMC	30	**0.05**
M 33	31	**0.7**
M 101	31	**3.5**
M 31	32	**0.6**
M 82	33	**3**
M 77	33	**11**
Perseus A (NGC 1275)	35	**55**
Virgo A (M 87)	35	**11**
Centaurus A (NGC 5128)	35	**5**
Formax A	35	**17**
Hydra A	36	**160**
Hercules A	37	**475**
3C 273	37	**475**
3C 47	37	**1300**
Cygnaus A	38	**170**
3C 48	38	**1100**
3c 295	38	**1400**

3C 147	**38**	**1600**

ζ Radio power in watt = 10^N, where N = Number listed in the Table
ş Distance is luminosity, or Hubble distance (= CB/H_o, where H_o = 100 km sec^{-1} Mpc^{-1})

V. SENSITIVITY OF ASTRONOMICAL INSTRUMENT OVER THE E. M. SPECTRUM

Figure 4 reveals the sensitivities attained by the target instruments in various spectral regions [11]. A serious attempt has been made to procure a uniform sensitivity across each different domain emphasizing a spectral distribution as close as possible to that of a source emitting a constant number of photons per frequency interval [12]. A spectral distribution differs only slightly from the typical emission of a quasar across the whole range of the e. m. spectrum.

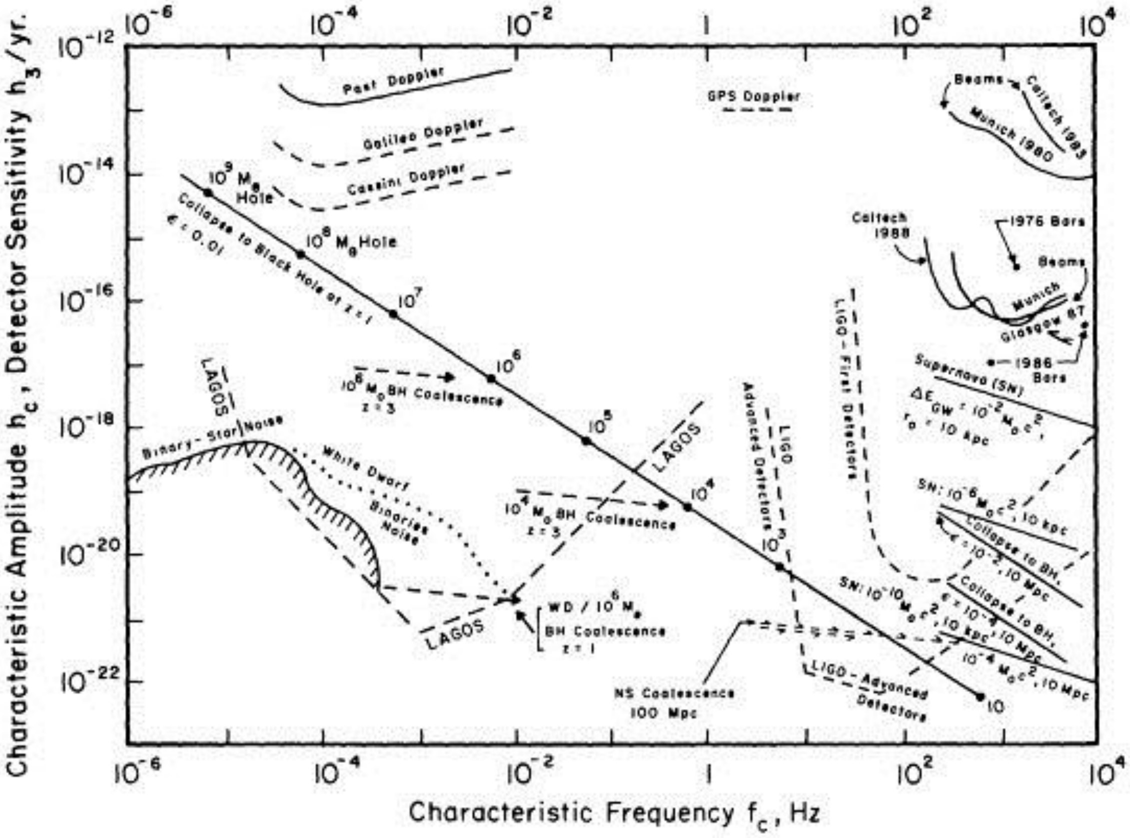

Fig. 4. Sensitivity of astronomical instrumentation over the electromagnetic spectrum, for the best existing instruments. The straight line shows the spectrum of an object emitting a constant number of .photons per frequency interval of 1 Hz, right across the spectrum [12]

The sensitivity in the measurement is obtained from the minimum flux detectable by the instrument for its maximum integration time, i.e. a few minutes to hours or days, depending on the instrument. The measured spectra shown by continuous curve or estimated spectra as presented by broken curve of some typical sources like the Crab Nebula (a galactic supernova remnant), quasar 3C 273, [13-17] and a similar quasar at a much greater distance (red shift z = 4). 'S' indicates a spectrographic method, of resolution R = 103 - 104 and 'I' indicates wide band imaging (R from 1 – 10).

VI. CONCLUSION

For a successive experiment starting from the basic set up various strategies can be chosen. The spectrum of an object can be measured with or without spatial or temporal resolution, i.e. a region may be mapped with or without sensitivity to faint photon fluxes. Statistical functions in the arrival of photons largely restrict the precision of any photometric observation of an instrument for a given observing time [18-19. The synthesized view obtained in practice is very rich and so for any basic observational projects on the earth or in the space, careful attempt is to be taken for using observatories of comparable performance in terms of angular and temporal resolution in the required ranges of wavelength. It may be pointed out that photometry is the measurement of received radiation intensity and is not strictly related to the reference objects like galaxies and standard stars. For this type of observation, it is utmost important to apply the techniques of absolute calibration. The great difficulty in presenting the physical methods as derived from observational astronomy is the high degree of interrelationship between all the elements of the observing system and the properties of the source being studied. Strong interdependence of different aspects may provide a somewhat arbitrary appearance of a phenomenon and for that any astronomical research programs are made very cautiously with a wide range of skills and know-how [20-22].

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