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OLD AND NEW RESULTS FROM MULTIFREQUENCY ASTROPHYSICS: THE IMPORTANCE OF SMALL TELESCOPES

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RESUMEN

En este artículo vamos a tratar brevemente algunos ejemplos de los resultados, desde el Big Bang a las fuentes galácticas, obtenidos en diferentes rangos de frecuencia por muchos experimentos espaciales y terrestres. Vamos a señalar los problemas fundamentales que nacen a partir de una comparación de los resultados experimentales multirrango y de las teorías. Vamos a tratar también la importancia de contar con una red de telescopios robóticos que pueden proporcionar monitorización óptica a largo plazo de las diferentes clases de fuentes cósmicas para proporcionar datos fundamentales que permitan el progreso en la comprensión de muchos problemas abiertos. Los resultados seleccionados están limitados por nuestros conocimientos y preferencias y se extienden a lo largo de varias décadas, desde la década de 1970, cuando los experimentos espaciales abrieron prácticamente todas las ventanas para investigar el Universo, hasta nuestros días. Hemos tratado este tema muchas veces: en el artículo de revisión "El impacto de los experimentos espaciales en nuestro conocimiento de la física del Universo" (Giovannelli y Sabau-Graziati, 2004) y en sus revisiones posteriores (e.g. Giovannelli y Sabau-Graziati, 2012a).

ABSTRACT

In this paper we will briefly discuss several examples of results, from the Big Bang to galactic sources, obtained in different frequency regions by many space– and ground–based experiments. We will remark the fundamental problems born from a comparison of experimental multifrequency results and theories. We will discuss also the importance of having a network of robotic telescopes that can provide long term optical monitoring of different classes of cosmic sources for providing fundamental data for a progress in understanding many problems still open. The results selected are biased by our knowledge and feelings and extend over several decades, starting from the 1970's, when the space experiments opened practically all the windows for investigating the Universe, up to-date. We discussed about this topic many times (e.g. on the review paper "The impact of the space experiments on our knowledge of the physics of the Universe" (Giovannelli & Sabau-Graziati, 2004) and subsequent revisions (e.g. Giovannelli & Sabau-Graziati, 2012a).

Key Words: early universe — cosmic background radiation — quasars: general — galaxies: jets — gamma-ray bursts: general — X-rays: binaries

1. INTRODUCTION

Multifrequency observations are a typical collaboration task between different 'kinds' of astronomers The idea of collecting them together was born some time ago during the historical first 'Frascati 1984 Workshop' on "*Multifrequency Behaviour of Galactic Accreting Sources*" (Giovannelli, 1985). Traditional observations with a single instrument, sensitive to a given frequency, give only partial knowledge of the observed object. To obtain a complete picture of the object, we need either its multifrequency imaging either its multifrequency spectrum (e.g. Giovannelli & Sabau-Graziati, 2012a). Among celestial objects, high energy (HE) cosmic sources are especially interesting from the point of view of multifrequency observations. Collapsed objects, close binaries, supernova remnants (SNRs), pre-main-sequence stars, AGNs, and GRBs experience particularly violent phenomena of high complexity, and emit radiation along the whole electromagnetic spectrum. Among the HE cosmic sources, XRBs constitute the most rich laboratory for multifrequency observations: they are a cauldron of different physical processes which occur at different frequencies and on different time scales (e.g. Giovannelli & Sabau-Graziati, 2001). Multifrequency astrophysics develops into *Experimental multifrequency astrophysics* and *Theoretical multifrequency astrophysics*. Experimental multifrequency astrophysics develops with

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the study of: a) Simultaneous Multifrequency Observations; b) Coordinated Multifrequency Observations; c) Data base and/or Literature observations; d) Multifrequency Observations (not necessarily simultaneous); e) Multisites Observations. Theoretical multifrequency astrophysics develops with the study of: a) Wide Range Physical Processes; b) Narrow Range Physical Processes.

2. SEVERAL EXAMPLES: FROM THE BIG BANG TO GALACTIC SOURCES

i) Big Bang theory has been proved by several experiments: a) the BOOMERanG experiment (de Bernardis et al. 2000; Netterfield et al., 2002) has shown that the barion fraction is $\Omega_B h^2 = 0.020 - 0.023$. The content of light elements derived by the Big Bang theory (Burles, Nollett & Turner, 2001) is consistent with the latter values of cosmological parameters; b) The existence of the cosmic microwave background (CMB) radiation is a fundamental prediction of hot Big Bang cosmology, and its temperature should increase with increasing redshift. At the present time (redshift z = 0), the temperature has been determined by the COBE FIRAS instrument with high precision to be $T_{CMB(0)} = 2.726 \pm 0.010$ K (Mather et al. 1994), and c) Srianand, Petitjean & Ledoux (2000) reported the detection of absorption lines from the first and second fine-structure levels of neutral carbon atoms in an isolated cloud of gas at z $\sim$ 2.4. They also detected absorption due to several rotational transitions of molecular hydrogen, and fine-structure lines of singly ionized carbon. These constraints enabled them to determine that the background radiation was indeed warmer in the past: they found that $T_{CMB(z\sim 2.4)}$ is between 6.0 and 14 K. This is in accord with the temperature of 9.1 K predicted by hot Big Bang cosmology.

ii) The Diffuse Extragalactic Background Radiation (DEBRA) has been discussed in details by Ressell & Turner (1990) from the radio to γ-ray energy bands. They showed in a unique diagram the flux versus energy or wavelength. This fundamental diagram – reported also in Giovannelli & Sabau-Graziati (2004) review – is now subject to updating thanks to measurements in the TeV region.

iii) Big Bang cosmology was convincingly established, but the Einstein-de Sitter model was showing numerous cracks, under the combined onslaught of data from the CMB, large scale galaxy clustering, and direct estimates of the matter density, the expansion rate (H_0), and the age of the Universe. The universe is probably flat, but there are some discrepancies that comes out from the results of WMAP that are not in complete agreement with those of BOOMERanG. Indeed, BOOMERanG results are in complete agreement with a flat Universe, while WMAP data can be described by a line with a slope less steep, intersecting that of the flat Universe at $\Omega_m \sim 0.3$ and $\Omega_\Lambda \sim 0.7$, being Ω_m and Ω_Λ the density of ordinary matter and cosmological constant, respectively (Schuecker, 2004; Tegmark et al., 2004; Hinshaw, G. et al., 2013). Thus, the problem deserves to be handled with care (e.g. Mortonson, Weinberg & White, 2014).

iv) Coppi & Aharonian (1997) predicted that γ-rays at energies above a few TeV can propagate to a distance $\leq$ 100 Mpc. Therefore most of the VHE universe should not visible to us. On the contrary, with the advent of MAGIC experiment, the detection of 3C 279 at TeV energies demonstrates the transparency of the universe till z = 0.54 (Albert et al., 2008) and later FERMI experiment extended the detection of sources till z $\sim$ 4.5 (Abdo et al., 2010).

v) The main idea (now very popular) that the engine producing high energy radiation is of the same kind for all extragalactic emitters born long time ago (Giovannelli & Polcaro, 1986). Thus, if the energy is produced by the same kind of engine there is analogy among them independent of the factor scales in masses and dimensions, till the galactic collapsed objects. Häring & Rix (2004) found that the mass of a galaxys central black hole is closely related to mass of its bulge ($\log M_{BH} \propto \log M_{centralbulge}$).

vi) Every object rotating with adequate energy produces a jet. There is a formal analogy in jets produced in quasars (QSOs), microquasars and γ-ray bursts (GRBs) (Mirabel, 2003). A general warning in understanding the physical behaviour observed from sources of jets is mandatory. Indeed, as calculated by Bednarek et al. (1990), the angle between the beam axis and the line of observation, as well as the Lorentz factor of the beam particles are fundamental parameters for determining the intensity of the emission from the jets. These two parameters can produce unpleasant misunderstandings about the nature of the sources: the sources are of the same type, but observed with different angles of vision.

vii) High redshift GRBs have been observed (Haislip, 2006; Tanvir et al., 2009), and by the SWIFT observatory up to z = 9.4 (Cucchiara et al., 2011). These results demonstrate that GRBs can be used to trace the star formation, metallicity, and reionization histories of the early Universe if the collapsar/hypernova model is assumed (e.g. Woosley, 1993; Woosley, Heger & Weaver, 2002).

The detection of the most distant QSOs – at z = 6.12 (QSO J1427+3312, Momjian, Carilli & McGreer, 2008), z = 6.23 (QSO J1048+4637, Wang et al., 2008), z = 6.28 (SDSS J1030+0524, Pentericci et al., 2002), z = 6.419 (SDSS J1148+5251, Bertoldi et al., 2003), z = 6.43 (CFHQS J2329-0301, Willot et al., 2007), and z = 7.085 (ULAS J1120+0641, Mortlock et al., 2011) – has opened a new window for exploring the early universe. Indeed, their light can probe the last part of the reionisation era. The detection of high redshift GRBs and QSOs renders experimentally inviting the possibility of detecting the farthest GRBs and QSOs just at the epoch of the formation of Pop-III stars and galaxies soon after the end of the dark age at $z \approx 20 - 25$ (Lamb & Reichart, 2000; Ciardi & Loeb, 2000; Bromm & Loeb, 2002; Tanvir et al., 2013). The use of robotic telescopes is fundamental for the advance in the detection of GRBs, and more. BOOTES network philosophy – identical telescopes (with identical filter sets and identical CCD cameras) spaced around the world – opens a new way to obtain good results in several scientific fields and public outreach (e.g. Castro Tirado, 2011; Castro Tirado et al., 2012). Other important apparatus for detecting GRBs in optical band is the Multicolor Imaging Telescope for Survey and Monstrous Explosions (MITSUME), which is able to start measurements less that one minute after the SWIFT-BAT detection (Kotani et al., 2005; Kawai et al., 2011).

viii) All the compact objects independent of their nature can be clearly described as *Gravimagnetic Rotators* by using only physical parameters, namely spin period (P_{spin}), magnetic moment (μ), mass accretion rate ($\dot{M}$), and the gravimagnetic parameter $y = \dot{M}/\mu^2$ (Lipunov, 1987). In this framework, in the plane $\log P_{spin}$–$\log y$, all the compact objects occupy different areas according to their physical conditions: accretors, propellers, ejectors, superaccretors, super-propellers, super-ejectors, georotators, and magnetors, as discussed by Lipunov (1987).

The cataclysmic variable (CV) SS Cyg, whose nature as intermediate polar (IP) or non magnetic CV (NMCV) is largely disputed in the literature, lies just in the place of the IPs, like for instance the well known IP EI UMa. This renders virtually certain the nature of SS Cyg as IP (e.g. Giovannelli & Sabau-Graziati, 2012b,c and the references therein).

ix) Important results have been obtained by means of multifrequency observations of the transient X-ray source A0535+26/HDE245770. X-ray data were obtained with many satellites since 1975, and the optical data with many telescopes of medium and small sizes (e.g. Giovannelli & Sabau-Graziati, 1992). The optical behavior of the Be star shows that at periastron the luminosity is typically enhanced by 0.02 to a few tenths mag, and the X-ray outburst occurs eight days after the periastron (Giovannelli & Sabau-Graziati, 2011). Giovannelli, Bisnovatyi-Kogan & Klepnev (2013) constructed a quantitative model for this event based on a nonstationary accretion disk behavior, connected with a high ellipticity of the orbital motion. They explain the observed time delay between the peaks of the optical and X-ray outbursts in this system by the time of radial motion of the matter in the accretion disk, after an increase of the mass flux in the vicinity of a periastral point in the binary . This time is determined by the turbulent viscosity parameter $\alpha = 0.1$–0.3. The increase of the mass flux is a sort of flush that reaches the external part of the accretion disk around the neutron star, which enhances the optical luminosity. The subsequent X-ray flare occurs when the matter reaches the hot central parts of the accretion disk and the neutron star surface. This discovery and the subsequent model could be valid for all the eccentric X-ray binary systems. Moreover, this model may be valid also for AGNs. Indeed, Nandra et al. (1998) found a delay of $\sim$ four days between UV and X-ray emissions in NGC 7469; Maoz, Edelson & Nandra (2000) found a delay of $\sim$ 100 days between optical and X-ray emissions in the Seyfert galaxy NGC 3516; Marshall, Ryle & Miller (2008) found a delay of $\sim$ 15 days between optical and X-ray emissions in Mkr 509, and Doroshenko et al. (2009) found a delay of $\sim$ ten days between R, I and X-ray luminosities in the Seyfert galaxy 3C 120.

x) After this short discussion the importance of Multifrequency Astrophysics appears evident, but there are many problems in performing Simultaneous Multifrequency, Multisite, Multiinstrument, Multiplatform Measurements due to: 1. Objective technological difficulties; 2. Sharing common scientific objectives; 3. Problems of scheduling; 4. Problems of budgets; 5. Politic management of science. However, there are no doubts about the importance of the small telescopes (SmTs), better if ROBOTIC. SmTs – including those belong to amateurs – are the unique capable of doing long-term observations of selected sources. SmTs – distributed at different longitudes and grouped in specific programs (e.g. WET, MUSICOS, BOOTES, GLORIA) – can provide continuous long-term monitor of a source (i.e. sdB stars for stellar seismology, RS CVn stars, XRBs, CVs, GRBs, survey of asteroids,). Obviously any telescope independent of its size could perform long-term observations of selected sources, but medium and large size telescopes are never scheduled for this purpose. Therefore, SmTs are unreplaceable tools complementary to larger telescopes and to ground- and space-based Multifrequency experiments.

3. CONCLUSIONS

With the short presentation of several important results from the Big Bang to galactic sources we hope to have given the proofs of what a network of robotic telescopes – complementary tools of bigger telescopes ground- and space-based – can provide for improving and accelerating our knowledge of the physics of the Universe.

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