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Concluding remarks

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Abstract. I will start with a remainder that our workshop celebrates a silver jubilee this year. Then, I will very briefly mention some of the highlights of our meetings during the last quarter of a century. Next, I will make brief comments on three arbitrarily selected topics of this year workshop: clusters of galaxies, dark matter and gamma ray bursts. Then, I will announce my personal nomination for the hit of the conference. I will end with traditional acknowledgements and a call to show up at the 2010 Vulcano meeting.

1. Introduction

I have to be very brief here, as an even very concise review of Vulcano workshops highlights would qualify rather for at least one hour long presentation. I will just name few of the memorable events that were exciting us during our 25 years long history.

One should certainly mention the first detection of supernova (SN) neutrinos from SN 1987A. This observation beautifully confirmed the theoretical models for core-collapse SNe.

We were witnessing the first determination of the distance to gamma-ray burst (GRB): z = 0.835 for GRB970508. Then, we were discussing the first (not very strong at that moment) evidence for the association between GRB and SN (SN 1998bw/GRB980425). Few years later, we saw a ”Rosetta stone” GRB - the first case of an undoubtful SN-GRB association (SN 2003dh/GRB030329). Our view of long GRBs was never the same again.

We were truly excited by a beautiful result of Sudbury Neutrino Observatory (SNO): τ and μ neutrinos arriving to us from the direction of the Sun (and we know that the Sun does not produce them!). This observation practically solved the long standing problem of the ”solar neutrinos deficit”.

Few weeks after the launch of SWIFT, we were able to measure the first distance to a short GRB: z = 0.225 for GRB050509B.

During the last year (OK, may be last 14 months) we were witnessing the observations of three truly exceptional GRBSs. First, we saw the first ”naked eye” GRB (GRB080319B, apparent visual magnitude V = 5.3). Then, we had the brightest GRB ever (GRB080916C, isotropic energy $E_{\rm ISO} \sim 10^{55}$ erg). Finally, one month ago we detected the most distant GRB ever (GRB090423, z = 8.2).

We were witnessing the development, successful start and many years of fruitful operation of numerous instruments, both in cosmos and on the Earth surface. Just to mention some of them: HST, CGRO, ROSAT, ASCA, BeppoSAX, RXTE, Chandra, XMM, INTEGRAL, HESS, MAGIC, Auger, SWIFT, Agile, Fermi. Many of these instruments made revolutionary discoveries, that brought a lot of excitement to some of our workshop.

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I am sure that the next 25 years of Vulcano workshops will be equally fruitful and equally exciting.

2. Clusters of galaxies (?)

First, let us note that so called Clusters of Galaxies are clusters of anything but galaxies! In fact, we talk about big clumps of dark matter (DM) with some addition ($\sim 10 \div 20\%$) of intracluster medium (ICM) and a marginal admixture of galaxies ($\sim 1\%$!).

However, even if the name is not the most appropriate, there are no doubts that clusters of galaxies are a powerful tool for cosmological studies. This was demonstrated already several times during our workshops (I would like to remind that clusters of galaxies were my personal nomination for our conference hit in 2002). This year, we were again reminded about it by Julia Weratschnig. In her beautiful talk, she presented some highlights from the recent years. For me, the most fascinating was the determination of the Hubble parameter independent of supernova observations. The method is based on analysis of the X-ray emission from the hot ICM and analysis of the subtle Sunyaev-Zeldovich Effect arising in the same ICM. Applying this method to 38 clusters, Bonamente et al. (2006) obtained values $H_0 = 76.9^{+3.9}_{-3.4}$ km s^{-1} Mpc^{-1} for hydrostatic equlibrium model of the cluster and $H_0 = 73.7^{+4.6}_{-3.8}$ km s^{-1} Mpc^{-1} for isothermal model. It is certainly encouraging that these results (obtained completely independent of the extragalactic distance ladder) agree well with the recent measurement from the Hubble Space Telescope key project that probes the nearby universe ($H_0 = 72 \pm 8$ km s^{-1} Mpc^{-1}).

Another interesting results discussed by Julia are observations of cold fronts and shocks in some clusters (they provide interesting information about ICM) and observations of filaments joining some clusters (filaments contain baryonic matter).

Still another topic discussed by Julia is relevant both for clusters of galaxies and for dark matter problem. I shall now briefly comment on it.

3. Dark matter

3.1. Interacting clusters of galaxies

Julia recalled several cases of colliding clusters where the collisions led to the separation of DM and baryonic matter. The most famous case is, of course, bullet cluster 1E0657-558. This object is composed of two clusters of galaxies which after a collision are now receding from each other. Analysis indicates that dissipationless components from both clusters (stars and DM), after passing each other, are now well separated. At the same time, the ICM gas from both clusters glued together and now forms one cloud staying between the two clusters. This gas is clearly separated from stellar and DM components of both clusters. This picture is a powerful testimony to the real existence of DM in the Universe. This testimony cannot be removed by MOND-like theories.

Julia presented a new similar case, namely that of merging cluster MACS J20025.4-1222. Also here the ICM gas stays between the two clusters, which are composed of stars and DM. However, the third example shown by Julia - that of the merging cluster Abell 520 - is less obvious to interpret. Also in this case, the ICM gas is seen between the two clusters containing optical galaxies. However, the distribution of DM is very strange. It could be separated (approximately) into three big clumps. Two of them coincide with the clusters (galaxies), but the third coincides with the peak of ICM! It might indicate that DM is not as collisionless as we assume and that the picture of the Universe is not as simple as we would like to believe.

3.2. Spectrum of cosmic gamma-ray background

Jürgen Knödlseder, discussing the early Fermi results, recalled that EGRET found a substantial excess of diffuse gamma-ray emission in a few GeV domain. The observed flux was by a factor of ~ 2 larger than the sum of the all expected contributions (including that from the unresolved sources). This excess was interpreted as due to DM particle annihilations. However, the most recent observations by Fermi agree very well with the theoretically predicted spectrum of gamma-ray background in the GeV domain. Jurgen concluded that the GeV gamma-ray emission excess (hypothetically associated with DM) is gone!

3.3. Spectrum of cosmic ray electrons

Another discovery, hypothetically associated with DM annihilation, was the excess of electrons in the spectrum of Cosmic Rays (CRs) in a few GeV to a few hundreds GeV range. Four experiments (including the very much publicized PAMELA) reported substantial deviations from the standard reference model of the CR electrons spectrum. The most likely origin for the observed excess could be either magnetospheres of nearby pulsars or the annihilations of DM particles. The second possibility created a lot of excitement, up to "DM discovery" news in daily newspapers. Unfortunately, the precise observations by Fermi left no room for any significant excess. Again, Jurgen had to conclude that the evidence for DM particle annihilations, based on the CR electrons spectrum is also gone!

3.4. Summary on dark matter

It seems that there is a strong evidence for the presence of DM in the clusters of galaxies, both from the dynamics of single clusters and from the dynamics of the colliding clusters. However, the evidence (claimed recently on several occasions) for the presence of the products of DM particle annihilations was not supported by the most recent observations of Fermi.

4. Gamma ray bursts

We live in a SWIFT and Fermi era, which means that we live in a "golden era" for GRBs (Lorenzo Amati). We heard several great talks (Eleonora Troja, Lorenzo Amati, Arnon Dar, John Beckman).

4.1. Highlights

I have already mentioned the three exceptional results of the last year: the most distant source visible by naked eye (GRB 080319B, M_V = 5.3, z = 0.937), the most powerful source ever seen (GRB 080916C, $E_{\rm ISO} \sim 10^{55}$ erg, z = 4.35) and the most distant source ever detected (GRB 090423 at z = 8.2).

4.2. Distances

This topic was discussed by Eleonora. The statistics is now based on 118 long GRBs (92 % of all bursts) and 10 short GRBs (8 %) observed by SWIFT. The average distance to long bursts is $<z>$ = 2.2 (the farthest ever seen is at z = 8.2) and to short bursts is $<z>$ = 0.45 (the farthest ever seen is at z = 0.92). This has serious implication for the estimated number of the progenitors of short GRBs: it decreased from $\sim 10^5$ Gpc^{-3}yr^{-1} only three years ago (Nakar et al., 2006) to $\sim$ 10 Gpc^{-3}yr^{-1} (Troja, this workshop). Hosts of short GRBs seem to be representative of the average stellar populations to z = 1 (which is not the case for long GRBs).

4.3. Collimation

The classical estimates of beaming factor based on interpretation of achromatic breaks seen in some GRB afterglow light curves led to the jet opening angles of the order of a few degrees. This translates into the beaming factors of the order of 10^{-3} to 10^{-2}. Arnon Dar on the basis of his cannon balls model argued that this factor must be much smaller (of the order of 10^{-6}). The controversy was not finally solved yet (in a sense of the majority accepted view), but the classical interpretation lost much of its appeal in the light of the substantial amount of data accumulated by now from SWIFT. It is evident now that the achromatic break is a relatively rare phenomenon. In most cases, the breaks are either chromatic or absent (only about 10 out of about 100 GRBs with known redshifts show achromatic breaks).

The degree of the beaming remains one of the fundamental outstanding questions to be solved. The answer to this question has important implications for the energetics of GRBs, their frequency and the number (and the nature) of their progenitors.

4.4. GRBs & cosmology

As noted by Lorenzo, GRBs are potentially powerful cosmological sources. They have huge luminosities and a redshift distribution extending far beyond SN Ia and even beyond that of AGNs (up to $z = 8.2$, at the moment). Moreover, they emit at high energies, so there is no extinction problem. The use of spectrum-energy correlations (Amati relation) for cosmological purposes is indeed promising. However, we need to substantially increase the number of GRBs with known z and $E_{\rm peak}$. We also need calibration with a good number of events at $z < 0.01$ or within a small range of redshifts. With the wealth of new high quality data coming from SWIFT and Fermi, the achievement of these goals looks quite realistic. Therefore, we might expect that in not too distant future, GRBs will become complementary to other cosmological probes (such as CMB, SN Ia, clusters, etc.).

4.5. Summary on GRBs

As Lorenzo pointed out, we live in a golden era for GRBs. A huge observational progress was made during the last 10 years. And, in spite of this, a huge progress still has to be made because several critical issues are still open (e.g., prompt emission mechanism, understanding of the early X-ray afterglow phenomenology, collimation and jet structure, spectrum-energy correlation and GRB cosmology, sub-classes of GRBs, short/long dichotomy).

5. Nomination for the conference hit

This year, my personal nomination for the conference hit goes to the early Fermi results. The highlights justifying this choice were summarized nicely in a fascinating presentation by Jürgen Knödlseder. I have just mentioned two strong (and very important, although, unfortunately, negative) results concerning the evidence for the presence of the products of DM particle annihilations. But this was just a small part of the fascinating results of the new observatory. Fermi detected 205 sources at a detection significance $> 10\ \sigma$ during the first 3 months of observations. Let me remind, after Jürgen, that EGRET found only 31 such sources in its entire lifetime (~ 10 years). Fermi detected 47 new gamma-ray pulsars (16 of them in a blind search!). Fermi achieved the long awaited first ever detection of GeV emission from a globular cluster (47 Tuc). Fermi observed high-energy gamma-ray emission from 7 GRBs (among them GRB 080916C with the largest apparent energy release yet measured: $E_{\rm ISO} \sim 10^{55}$ erg). Finally, Fermi detected > 100 AGNs. And all this, in just a few months. Indeed, a well deserved nomination.

Acknowledgements. And now, traditionally, let me suggest that we thank Franco, Lola, all organizers and all participants. It was their collective effort that made our silver jubilee workshop such a fruitful and memorable event. Let me also to express the hope that I shall see all of you during our next year Vulcano workshop.