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Concluding remarks

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Abstract. After a canonical disclaimer and some general remarks, I will make brief comments on six arbitrarily selected topics: cosmology, dark matter, gamma ray bursts, X-ray binaries, black holes and gamma-ray sky. I will end with traditional acknowledgements and a call to show up at the next year Vulcano meeting.

1. Introduction

As stated above (see abstract), I have to start with a classical statement that the selection of topics for these concluding remarks is based on personal impressions and as such it has to be arbitrary. Next, I would like to emphasize that we had a really excellent conference, this year. The scope of the conference was very broad, indeed. We covered all windows of astrophysical observations, including the very new ones (note that, nowadays, it is not enough to say "all windows of electromagnetic spectrum"). So, we were discussing the electromagnetic radiation from radio waves to very hard (~ 100 TeV) gamma rays. We were reviewing cosmic rays up to extremely high ($\sim 3 \times 10^{21}$ eV) energies. We were discussing neutrinos from astrophysical sources. And finally, we were considering astrophysical sources of gravitational waves (not detected yet, but the detection is clearly in sight - we have to wait just a few more years). And, as each year at Vulcano, we were discussing the possible astrophysical sources of products of annihilation of dark matter particles (still no convincing evidence).

Continuing the general remarks, I would like to notice some retreat from such topics as dark matter (DM) or ultra-high energy cosmic rays (UHECRs) and a revival of more classical topics such as X-ray binaries (XRBs), black holes (BHs) of all kinds or gamma-ray pulsars. In my opinion, this retreat is due to the fact that topics that yesterday were still exotic (like DM or UHECRs), today became a routine everyday work of astronomers. This is a measure of a rapid progress made by present day astrophysics. Now, more attention is just given to the topic that experienced the relatively biggest progress in recent years. The good example is a big progress in the field of gamma-ray pulsars thanks to FERMI observations.

After these general remarks, I will now briefly discuss the topics listed in the abstract.

2. Cosmology

Among many presentations, I will mention just two that I found particularly striking: the "laboratory" cosmology at LHC and the power hidden in the application of Sunyaev-Zeldovich effect (SZE) to cosmology.

• **"Laboratory" cosmology at LHC**

Gulio Auriemma demonstrated how, with experiments at LHC, we can reproduce the

Send offprint requests to: J. Ziółkowski state of matter (quark-gluon plasma) in ~ 10 μsec old Universe. It is a really amazing birth of a new field of science that one might call a "laboratory" cosmology.

• **Cosmology with Sunyaev-Zeldovich effect**

After listening to the talk by Sergio Colafrancesco, I was really impressed how powerful tool is hidden in applying SZE to cosmology. I was impressed not only by the power of this method but also by the very broad range of different possible ways it can applied for cosmological purposes. We have really no time to review it (even very briefly), but I strongly advice you to to look over this presentation on our conference web page.

3. Dark matter

Let me remind the atmosphere - partially of sensation, partially of triumph, partially of celebration - when Sergio announced during Vulcano workshop five years ago: "a good news - dark matter exists!". Today, we have no doubts that dark matter (DM) exists. The evidence accumulated during these five years is really overwhelming. All components of this evidence were discussed in details during our consecutive Vulcano meetings. However, direct detection of the processes involving DM particles (annihilation) appeared far more elusive than we expected. We witnessed many premature "discoveries" and many premature negative results. Let me recall DAMA, CDMS, CoGeNT, XENON 100, CRESST, PAMELA, ATIC and so on. Let me recall also promises by Aldo Morselli (during Vulcano 2007) that GLAST will detect gamma photons emitted from sites of DM particles annihilation during its first few months of operation. GLAST (renamed FERMI) was launched three years ago. It made many great discoveries (I will mention some of them near the end of my summary), but did not detect DM particles annihilation. Let me recall finally conclusion quoted last year by Marco Regis: "after one year of FERMI LAT observations - no DM discovery". Discussions during this year meeting indicated that there was no breakthrough. I may summarize the situation by stating that "after two years of FERMI LAT observations - no DM discovery".

4. Gamma ray bursts

We still live in a SWIFT and FERMI era, which means that we live in a "golden era" for GRBs. However, similarly as in the case of DM, no major breakthroughs were announced this year in this area.

4.1. Highlights

One highlight, certainly worth mentioning here, is the discovery of the most distant GRB ever detected (GRB 090429B). At $z \sim 9.4$ this is probably the the most distant cosmic source ever seen (with the possible exception of Bouwens Galaxy at $z \sim 10$, but this determination is much less precise).

Let me notice, that the press release announcing this discovery took place during our conference. It was presented to us by Lorenzo Amati just two days after the press release.

4.2. Collimation of GRB emission

Collimation is a topic discussed each year at Vulcano. 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 more than 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. Also for the frequency of the optical/radio orphan afterglows.

The situation did not change substantially since last year meeting. Lorenzo has shown us the most up to date (March 2011) presentation of his famous relation. It was shown in the original $E_{\mathrm{peak}} - E_{\mathrm{iso}}$ form; the correcting for beaming was abandoned already three years ago (Lorenzo (2008): "let us make a step backward and focus on the $E_{\mathrm{peak}} - E_{\mathrm{iso}}$ correlation"). The most recent relation contains 126 long GRBs, 13 short GRBs and 4 X-ray flashes (XRFs). It confirms that XRFs follow the same relation as long GRBs, but the relation for short GRBs lies clearly above in the $E_{\mathrm{peak}} - E_{\mathrm{iso}}$ plane (by about one and a half orders of magnitude).

4.3. GRBs & cosmology

This is also a topic discussed each year at Vulcano. And, again, the situation did not change substantially since last year meeting. The effective application of GRBs to cosmology lies still ahead of us (we need still more GRBs with determined redshifts), but it is approaching fast. As noted by Lorenzo, the cosmological potential of GRBs is really great: they have huge luminosities, which permit them to cover much larger range of redshifts than SNeIa (at present up to z=9.4 as opposed to z=1.7 for SNeIa) and their emission is in high energy band, which helps to avoid extinction problems. Unfortunately, GRBs are not standard candles. We have to investigate much better their properties to find ways to standardize them or to collect many more objects to obtain a good statistics. This is still the future. However, even today, Lorenzo demonstrated the cosmological use of GRBs. If we assume that part of the scatter in the Amati relation (E_{peak} - E_{iso} correlation) is due to choice of cosmological parameters used to calculate E_{iso} and if we assume flat geometry of the Universe and then adjust Ω_{matter}, so as to minimize the scatter,then we obtain $\Omega_{\mathrm{matter}} \sim 0.2 \div 0.35$.

5. X-ray binaries

We witnessed a clear revival of the interest in this field. We listened to a lot of excellent presentations concerning X-ray pulsars (Joern Wilms), supergiant fast X-ray transients (Pietro Ubertini, Pere Blay), microquasars (Manel Perucho Pla), TeV XRBs (Valenti Bosch-Ramon), dipping low mass XRBs (Monika Bałucińska-Church) and populations of XRBs in nearby galaxies (Frank Haberl). I will briefly comment only on the last topic (due to my personal interest). It was well known for some time that there is a significant over-abundance of high mass XRBs in both Magellanic Clouds. The recent studies have shown that the number of high mass XRBs in different regions of Small Magellanic Cloud correlates well with the star formation rate during the burst that took place 42 Myr ago.

6. Black holes

Tom Boller, in his very interesting review, demonstrated that, indeed, we observe emission originating very close to BH horizon! In addition to some well known cases of supermassive black holes, Tom discussed two new examples: 1H 0707-495 and Ark 564. The first source is unique, because we see two relativistically distorted iron lines in its X-ray spectrum: Lα line and Kα line. Analysis of these lines indicates that they are emitted from the matter very close to the central black hole - at a distance of only about one and a half of gravitational radius ($R_g = GM/c^2$). In the case of Ark 564, this distance is even smaller - only $\sim 1.2\ R_g$.

The angular resolution of the present day VLBI observations is so high that, in the case of our Galaxy central black hole - Sgr A*, we can resolve the structures of the size comparable with the diameter of BH horizon! In near future, the improved VLBI observations and the X-ray observations with GRAVITY probe (launch in 2014) will permit us to image the "shadow of BLACK HOLE"! If it agrees with the theoretical predictions, it will be one more confirmation of the general relativity.

7. Gamma-ray sky

The gamma-ray sky is observed today by several excellent instruments: two gamma-ray telescopes on the orbit (FERMI and AGILE) and three TeV telescopes on the Earth surface (HESS, MAGIC and VERITAS). The most spectacular achievements belong recently (last two years) to FERMI. They were nicely reviewed by Jean Ballet. FERMI performs sky survey every three hours since August 2008. During that time, it detected more than 1000 blazars (up from ~ 200 known in pre-FERMI era). It detected 88 gamma-ray pulsars (up from 6 known in pre-FERMI era). It observed regularly several GeV-TeV XRBs. Fermi observed high-energy gamma-ray emission from several GRBs (among them GRB 080916C with the largest apparent energy release yet measured: $E_{\rm iso} \sim 10^{55}$ erg). FERMI discovered hadrons in several old SNRs. Just to illustrate the efficiency of FERMI observatory, Jean noticed that more than 100 papers based on FERMI data were published in May 2011 alone!

8. Acknowledgements

And now, traditionally, let me suggest that we thank Franco, Lola, all organizers and all participants. It was their collective effort that made again our 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.