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Concluding Remarks

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Abstract As every year, the speaker presenting the concluding remarks has the problem of the wealth of too many interesting presentations. It is not easy to select just a few topics among many fascinating ones and any choice will be, necessarily, arbitrary. This year, I decided to make brief comments on astrophysical neutrinos, on cosmology and on gamma-ray bursts. My personal nomination for the hits of the conference goes this year to the **giant flare of SGR 1806–20** (27.12.2004), which threw a new light not only on magnetars, but possibly also on a certain class of short gamma-ray bursts and to **GRB 050509b** – possibly the first short gamma-ray burst with a measured distance.

Key words: cosmology — gamma-ray bursts

1 INTRODUCTION

As stated above (see abstract), this year I decided to present my brief personal impressions concerning three selected topics: astrophysical neutrinos, cosmology and gamma-ray bursts. Such an arbitrary selection is, certainly, unfair. It is unfair to the **Clusters of Galaxies**, to the **Galactic Center** (was Sgr A* much brighter in the recent past?), to **AGNs**, **YSOs**, **magnetars**, **X-ray binaries** (among them **BH binaries**, **microquasars**, **obscured INTEGRAL sources** etc.), **SNe** (and not only type **Ic**), **intermediate mass BHs** (in **ULX sources** and **globular clusters**), **jets** of all kinds, **new results** (**INTEGRAL**, **SWIFT**), **new experiments** & **projects** (among them **robotic telescopes**) and many, many other **exciting topics**.

But the life is unfair and some choice has to be made. And, of course, no choice is perfect.

2 NEUTRINOS

One of the reasons which prompted me to select neutrinos as one of the topics for my concluding remarks was the remark by Giulio Auriemma, who stated that "we have learned a lot about neutrinos from astrophysics and cosmology, but neutrinos, so far, were not very useful for astronomy". Then, later, we heard Jim Beall, who ended his presentation with the statement that we witness "the beginning of a golden era in the neutrino astronomy".

Returning to Giulio's remark: how much the astronomy profited from the neutrinos, so far. First, we got finally (after a long and painful controversy) the beautiful confirmation of the standard solar model. The observed flux of electron neutrinos coming from the direction of the Sun is equal only 0.35$\pm$0.02 of the flux of electron neutrinos predicted by the standard solar model. We know, without any doubts, that the Sun can produce only electron neutrinos. However, we see also μ and τ neutrinos coming from the direction of the Sun! Moreover, the total flux of neutrinos of all flavors coming from the direction of the Sun is equal 1.01$\pm$0.12 of the standard solar model prediction! There is no alternative, but to accept, that neutrinos of other flavors are created from the solar electron neutrinos on their way between the Sun and the Earth.

Secondly, the 24 neutrinos, captured during SN 1987A explosion (out of $\sim 10^{57}$ produced), were fully consistent (energy, distribution of the arrival times) with the present model of core collapse supernova.

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The physics of neutrinos profited from astronomy much more. First, for a long time, the only evidence for the non-zero mass and the mixing of the flavors of neutrinos was coming from astronomy (solar neutrinos). At present, the strongest limit on the neutrino mass ($\lesssim 0.5$ eV) still comes from astronomy (large scale structure). Also, most of our knowledge about mass differences between different species of neutrino still comes from the solar neutrinos (it seems that two species have very similar masses - the difference is $\sim 0.001 \div 0.01$ eV, while the third neutrino has the mass different by $\sim$0.05 eV).

At this point, one is tempted to remind the arguments motivating us to create a "new" (beyond the Standard Model) physics of the elementary particles: • **massive** (non-zero mass) **neutrinos**, • **dark matter**, • **dark energy** and • **inflation**. It is worth to notice, that at least three and a half (out of four) arguments come from astrophysics!

Returning to our main topic: the profits for astronomy from neutrinos. As Jim Beall noticed, the present day situation reminds that of the early days of the X-ray and γ-ray astronomy. We capture single neutrinos (during SN 1987A explosion, three different experiments detected, correspondingly, 11, 8 and 5 neutrinos), similarly as early γ-ray astronomers counting single photons. The X-ray and γ-ray astronomy developed enormously since then. The same will happen with neutrino astronomy. There are many operating and planned experiments. During the next galactic core collapse SN (and it may happen anytime), we will detect not single but hundreds and thousands of neutrinos. They will provide us with valuable information about the process of core collapse and the following phenomena during the SN explosion. We have, also, a good chance of detecting neutrinos from some galactic microquasars. This will tell us about the nature of their jets and about the interaction of these jets with the surrounding matter.

I believe, that Jim Beall is right. The golden era of neutrino astronomy lies ahead of us.

3 COSMOLOGY

Below, I will briefly mention some highlights of the conference in this field.

• **Blazars contamination problem**

For many years, we lived in the "golden era" of cosmic microwave background (CMB) radiation research. New breakthroughs and enormous improvements of the precision every few years were a standard. Last year, the picture got somewhat greyish. The interpreters of BOOMERANG and WMAP maps were confronted with a serious contamination problem. The main culprits were found to be blazars, as demonstrated by Sergio Colafrancesco. The problem was identified, which is already a half of the success, but it will not be easy to disentangle blazars from CMB fluctuations.

The blazars contamination problem signals a bad news for all CMB polarization measurements projects. Such measurements are very important for cosmology (they might confirm the inflation scenario). Unfortunately, blazars contaminate the polarization measurements even more than the temperature measurements. Predictions for all existing or planned polarization projects indicate that blazars will be a major problem. This becomes a real challenge for CMB community.

• **Optical observation of early ($z \sim$ 10) Universe**

Nino Panagia presented us the preliminary results of the HST Ultra Deep Field. The parameters are impressive. This was really an ultra deep search! The faintest recorded object had the magnitude $31^{\rm m}1$. Several candidates for early structures at $z \sim 6 \div 8$ were identified. One of them is galaxy JD2 at $z \approx$ 6.5 and estimated mass $M \approx 6 \times 10^{11}$ $M_{\odot}$. Objects such as JD2 could be responsible for reionization of the Universe at $z \sim 5 \div 15$.

• **Dark Matter**

The situation was reviewed by Sergio Colafrancesco. The leading candidate is still light neutralino, predicted by the simplest supersymmetric extensions of the standard model of elementary particles. We are able to determine the distribution of dark matter both in the galaxies and in the clusters of galaxies. The annihilation of neutralinos should produce both the observable specific Sunyaev-Zel'dovich effect (SZE) and the observable emission of electromagnetic radiation from radio to γ-rays. The observed SZE for some clusters (Coma, Draco), as well as the observed radio, UV and X-ray emission and the upper limits on the γ-ray emission impose some constraints on the possible neutralino mass. At present, the probable value of this mass seems to lie between ~ 30 GeV and few hundred GeV. Future γ-ray observatories (GLAST) and future SZE projects should provide stronger constraints.

4 GAMMA RAY BURSTS

Gamma Ray Bursts (GRBs) remain one of the most fascinating topics of the Vulcano meetings. This year, we have listened again to many excellent presentations (John Nousek, Kevin Hurley, Massimo della Valle, Filippo Frontera, Lorenzo Amati, Elena Pian and many others). It seems, that a substantial progress is still being made. Since Vulcano 2004 meeting, more than 230 new GRBs were detected, more than 60 new afterglows were seen in different spectral ranges (X-ray, optical and radio) and 10 new redshifts were measured (among them, possibly the first redshift of a short GRB). Below, I shall briefly discuss three areas in which, I believe, a substantial progress was made since last year. All considerations apply to long GRBs (unless explicitly stated otherwise).

4.1 Afterglows

We live now in the SWIFT era (although SWIFT became fully operational only one and a half months ago). One of the important results from SWIFT is that probably all GRBs are accompanied by X-ray afterglows. This is probably not true about optical afterglows, but the fraction of optically dark GRBs is substantially smaller than $\sim 50\%$ implied by Beppo-SAX data. To determine how big is this fraction, we have to wait for more events from SWIFT (better statistics). Another unexpected (and rather disappointing) discovery of SWIFT was that the early (at maximum brightness) optical afterglows are, typically, by $\sim 2^{\rm m}$ fainter than expected. Still another result concerns the distribution of redshifts. This distribution of SWIFT events appears to be different from that of pre-SWIFT GRBs - the distances of SWIFT events were found to be, on average, twice larger ($\langle z \rangle \sim 2.4$ instead of 1.2 for pre-SWIFT events). Again, we will have to wait for better statistics from SWIFT (only 10 redshifts measured so far) to see if this effect will hold.

4.2 SNe Connections

First, let me emphasize that there are no longer doubts about these connections. We found, so far, 4 GRBs clearly associated with identified SNe (in all 4 cases of type Ic) and a dozen of probable associations (optical light curve with underlying bump, most likely caused by a SN). Three out of the four identified SNe were so powerful (high luminosity, high kinetic energy) that they could be termed Hypernovae (HNe). From earlier (not necessarily GRB-related) observations, it is estimated that $\sim 5\%$ of all type Ic SNe have parameters of HNe. However, not all HNe are associated with GRBs. It means, that less than 5% of all type Ic SNe are, possibly, associated with GRBs. When comparing with all SNe events, the number of GRBs is by some three orders of magnitude smaller than the number of SNe.

Elen Pian presented a promising “unified” model of GRBs and XRFs (X-ray flashes). The basic feature of this model is the assumption that HNe (and perhaps, generally, all core collapse SNe) explosions are aspherical and, therefore, different viewing angles produce different events. The assumption of asphericity is supported by some observational evidence. The nebular spectrum of SN 1998bw (associated with GRB 980425) indicates that SN explosion was anisotropic. The nebular spectrum of bright SN (HN) 2003jd (not GRB-associated) also indicates aspherical explosion, similar to that of SN 1998bw, but seen at much higher angle ($\sim 70^{\rm o}$ with respect to the axis of the nebula). Neither GRB nor the afterglows were observed in this case, but the X-ray and radio upper limits are not inconsistent with GRB viewed off-axis (so, GRB could be produced, after all). Also X-ray light curves of different core collapse SNe (type Ic and II) are consistent with different viewing angles of the anisotropic explosions. To summarize, let us compare three different type Ic SNe: SN 2003dh (=GRB 030329), SN 1998bw (= GRB 980425) and SN 2003jd (no visible GRB). If the “unified” model is correct, then SN 2003dh was seen along the axis of the jet, SN 1998bw was seen close to the edge of the jet and SN 2003jd was seen far away from the jet. All three could have produced GRBs, but only in the first two cases these events were actually seen.

4.3 The Mystery of Short GRBs

Since last year, there were two important events which should be mentioned at this point.

- **Giant Flare of magnetar SGR 1806–20**

This event happened on December 27, 2004. Like in the case of the previous two giant flares of magnetars in our Galaxy (flare of SGR 0566–60 on March 5, 1979 and flare of 1914–00 on August 28, 1998), the event consisted of the initial, very hard (~ 1 MeV) and very energetic spike lasting less than a second, and subsequent much softer (~20 keV) tail lasting several minutes. Such giant flares of magnetars must be frequent in nearby galaxies. If they occur within $\sim$100 Mpc, only the initial spikes are seen and, therefore, such events *have* to be classified as typical short GRBs (if they occur beyond $\sim$100 Mpc, they are too dim to be observed).

It seems, therefore, that some short GRBs are just giant flares of distant SGRs.

• **GRB 050509b**

This short GRB (which happened less than two weeks before the beginning of this conference) was probably the first short GRB for which it was possible (thanks to SWIFT) to determine its distance. The probable host (an elliptical galaxy reasonably close to the event, so that the exploding object could be just ejected from it) has a redshift equal 0.226. The galaxy has no young stars, so no HN event was possible. Most likely, the event was due to the merger of two compact objects (probably members of a close binary, ejected earlier from the parent galaxy).

• **Conclusion**

The conclusion based on these two events is the following one: probably, the term "short GRBs" is just a sort of an umbrella, under which different types of events are hidden; among them are giant flares of distant SGRs and mergers of compact objects.

5 NOMINATIONS FOR THE CONFERENCE HITS

This year, my personal nominations for the conference hits go to the two events, just described above: the **giant flare of SGR 1806–20** (27.12.2004), which threw a new light not only on magnetars, but possibly also on a certain class of short gamma-ray bursts and to **GRB 050509b** – possibly the first short gamma-ray burst with a measured distance (z = 0.226).

6 ACKNOWLEDGEMENTS

And now, traditionally, let me join Vladimir and thank Lola, Franco and all organizers for their great efforts that led to such a pleasant and successful meeting.