PROCEEDINGS OF SCIENCE

Accretion Processes in Astrophysics: Concluding Address

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Before I officially conclude this workshop – and far be it from me to attempt more conclusive remarks than those effected by Jennifer Sokoloski, Dmitry Bisikalo, Paul Mason, and Janusz Ziółkowski – I would like to comment on a few highlights coming from our very fruitful week of discussions about *Accretion Processes in Cosmic Sources*. I make no pretension of completeness in these brief remarks, but I hope to give a clear short summary about my scientific route of course immersed in that larger of my life. I hope that this could be useful for the readers, and especially those who are relatively young.

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[*]Speaker.
[†]A footnote may follow.

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1. Some appropriate historical remarks

When the first theories about accretion disks around compact stars started to be developed around the 1960s, the class of the so-called Cataclysmic Variables (CVs) started to have a leading position in astrophysics. They constituted the perfect laboratories for testing those theories. When the UV window to the universe was opened at the end of 1970s with the advent of the historical IUE (International Ultraviolet Explorer), CVs became really one of the most interesting class of objects of the whole astrophysics.

Previously, essentially two schools of thought born in Cambridge (UK) and in Warsaw (Poland) in order to tackle with the difficult subject of the mass exchange in close binary systems (e.g. Smak, 1962, 1971, 1981a,b, 1984a,b; Paczynski, 1965, 1977; Bath, 1969, 1975, 1976, 1978, 1980, 1984a,b and the references therein; Bath et al., 1974; Mantle & Bath, 1983). However, two fundamental papers about accretion disks appeared at the beginning of 1970s (Shakura, 1972, Shakura & Sunyaev, 1973). These papers marked substantially the development of theories about accretion disks around compact objects in binary systems, until present times. Pringle (1981) reviewed accretion disks in astrophysics (see Giovannelli, 2008).

Figure 1 (upper panel) shows the title of the Shakura's fundamental paper, as it appeared in the journal, and in the lower panel the part in which the α parametrization of the turbulent viscosity is introduced.

2. When I ended up in the lion's den

After the balloon campaign for X-tay astronomy in 1976 (Auriemma et al., 1978), I started probably the first multifrequency campaign of observations of close binary systems, including cataclysmic variables (CVs), X-ray systems with neutron stars and black holes. With fresh data of SS Cygni in which a doubling in the Balmer lines was detected, I went to Poland – under the agreement between Polish Academy of Sciences (PAN) and Italian National Research Council (CNR) – where one of the schools of accretion disk was flourishing.

Marek Abramowicz was the first person I encountered in Warsaw, when I arrived for the first time at the end of May 1978. He was sent by Joe Smak (director of NCAC, not yet inaugurated) to pick up me in the Airport. After 38 years Marek and I met again in this workshop as shown in Fig. 2 (left panel. Not only we changed because of natural reasons, but also Warsaw changed a lot as shown in Fig. 2 (right panel).

Joe Smak was studying CVs and their accretion disks, in particular the shapes of the emission lines from rotating gaseous disks. He looked at my SS Cygni spectra with the doubling in the emission Balmer lines, and used these data for supporting his theoretical results for determining the radius of the accretion disk (Smak, 1981b). Using these data and others coming from different energy regions, I wrote one interesting paper, together with people of my group, about the parameters of SS Cygni system that are standing up to the time passing (Giovannelli et al., 1983).

During my stay in Warsaw, the Nicolaus Copernicus Astronomical Center (NCAC) of the Polish Academy of Sciences was officially inaugurated. This was the reason that allowed me to know all the Polish astrophysicists that invited me to give talks in all the country. Several collaborations

DISK MODEL OF GAS ACCRETION ON A RELATIVISTIC STAR IN A CLOSE BINARY SYSTEM

N. I. Shakura

P. K. Shternberg State Astronomical Institute
Translated from Astronomicheskii Zhurnal, Vol. 49, No. 5,
pp. 921-929, 1972
Original article submitted June 16, 1971

In the case of the finite perturbations which occur in a binary system, the assumption of developed turbulent motion in the disk presents no difficulty. The maximum turbulence scale is not greater than the disk thickness $z_0(r)$, and since $l \sim z_0(r) \ll r$, the turbulence turns out to be small-scale and isotropic. To describe local isotropic turbulent motion, it is convenient to have the equations derived for laminar flow in which the laminar viscosity is replaced with the turbulent viscosity $\eta_t = \rho v_t l$:

$$\sigma_{r\varphi} = \eta l v_t r \frac{d\omega}{dr}. \qquad (1.7)$$

In this expression $v_t = \alpha v_s$ is the velocity of turbulent motion and α is a parameter which describes the degree of excitation of the turbulence. Since $l = z_0 = 2\, v_s/\omega$, we have

$$\sigma_{r\varphi} = -3\alpha\eta v_s^2. \qquad (1.8)$$

Figure 1: Upper panel: the title of Shakura's fundamental paper about accretion disk around a compact star in a binary systems. Lower panel: the part in which the α parametrization of the turbulent viscosity is introduced.

born, in particular with the Institute of Physics of Łódź University, with Dr Szczepan Karakuła and Dr Wiesław Tkaczyk, and later with the best Szczepan's pupil, Włodzimierz Bednarek.

In that time I met also the young Joseph Patterson who was guest of NCAC as well, working at the computer center of the NCAC sponsored by Bohdan Paczynski and Joe Smak.

During this 40-day stay at the NCAC, I was invited one Sunday to spend the day outdoors at the Warsaw Observatory with many colleagues from the NCAC and the Observatory. During a walk with Bohdan Paczynski we talked about the need to find some sort of HR diagram for extragalactic objects. I was determined to find it, because logic told me that Nature must develop continuously.

Figure 2: Left panel: Marek Abramowicz (left) and Franco Giovannelli (right) in 2016. Right panel: Rynek Starego Miasta (Old Town Market Square) in Warsaw, now.

Bodhan wished me good luck. With the advent of the Einstein satellite, a sample of 297 extragalactic objects emitting X-rays was available. Starting from those data, Vito Francesco Polcaro and I developed a work that gave rise to the Giovannelli-Polcaro diagram, a sort of evolutionary diagram of all the extragalactic objects (Giovannelli & Polcaro, 1986).

One year later, in May 1979, at NCAC I met Dr Gennady Bisnovatyi-Kogan, and with a bottle of Vodka on the table, we started our collaboration, which is still alive and well. Figure 3 shows Gennady and me in 2016, during this workshop.

Figure 3: Left panel: Franco Giovannelli (left) and Gennady Bisnovatyi-Kogan (right) in 2016. Right panel: the famous friendship bottle of vodka.

3. Some important notes on the Vulcano Workshops

With the advent of the IUE, my observations started to explore a wider range of energy, and in 1984 I organized the first historical Frascati Workshop on *Multifrequency Behaviour of Galactic Accreting Sources* – with the technical help of Mr. Massimo Frutti and the administrative help of Miss Lidia Barbanera, who unfortunately left us forever on October 6th 2015 (Giovannelli, 2016) – to which more than 50 participants from all the world actively attended. Among the

many participants I would like to mention Dr James Howard Beall who was invited because his pioneering papers on astrophysical jets. From that event he became a permanent scientist in my workshops, and of course a good friend of mine. However, the record of presences in Vulcano – and later in Palermo – belongs to Dr Janusz Ziółkowski, who jumped only one workshop because he did not receive the passport for leaving Poland during the Communist Era. During the Vulcano workshop 1988, Janusz and I laid the bases for a paper about the presence of two disks (accretion disk around the neutron star and excretion disk around the Be star) in the X-ray/Be system A0535+26/HDE245770 (Giovannelli & Ziółkowski, 1990).

The venue was the "Eolian Hotel" in Vulcano, one of the seven islands of the Aeolian archipelago in Sicily, Italy. Figure 4 shows the cover of the proceedings of that historical workshop (Giovannelli, 1985).

In the mid-80s, Vulcano became home to major international workshops and above all became a point of engagement between scientists from the East and the West, in the middle of the Cold War. Several collaborations emerged despite the different political situations in which the researchers of the two blocks were immersed.

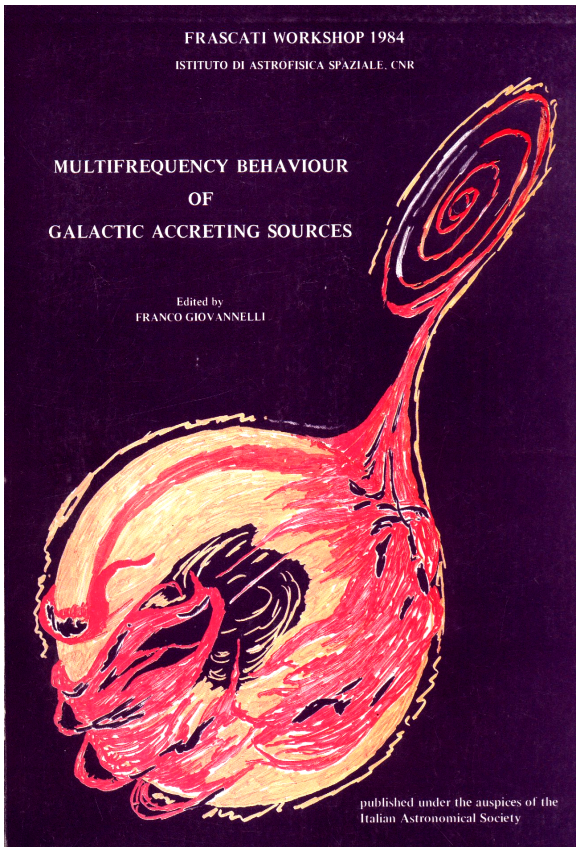

Figure 4: The cover of the proceedings of the first historical Frascati workshop (Giovannelli, 1985).

Vulcano became the venue of our series of workshops: i) *Multifrequency Behaviour of High Energy Cosmic Sources*, now arrived at the XII edition, including the first historical workshop; ii) *Frontier Objects in Astrophysics and Particle Physics* from 1986 to 2012 with biennial cadence. In 2012 the Eolian hotel closed, then we moved to Mondello (Palermo, Italy) and we started with new

series of workshops: i) *The Golden Age of Cataclysmic Variables and Related Objects* now arrived to the III edition, and ii) *Frontier Research in Astrophysics* now arrived to the II edition.

Since part of the international community pushed for organizing a specific workshop on *Accretion Processes in Cosmic Sources*, we organized this workshop in Saint Petersburg (Russian Federation).

4. Some important lessons from the Vulcano workshops

It is impressive to remind the concluding remarks of the first historical Frascati Workshop.

- Wolfgang Brinkmann said: "Let me star with just a few general remarks: roughly one or two years ago one could get the impression that all interest in high energy astrophysics was moving towards the study of extragalactic objects. Therefore it was a great pleasure for me to see on this workshop how much work is still going on in the field of galactic accreting sources. In particular I was very impressed to learn about the enormous efforts put into long term observing programmes in the radio and optical frequency range (for example on A0535+26 or on SS433) which take so much of time but which are in many cases absolutely necessary to get more insight into the physics of these sources.

  I think it became clear in our discussions that there is still a lot of work to be done and, in particular, that many of the 'well established' simplified models for these sources will have to be reconsidered in the light of extended observations over a broad energy range.

  You might have noted as well that we had hardly any new presentations of X-ray results. If you consider that the first results of the TENMA and EXOSAT satellites, mainly concerned with the observations of galactic sources, are just now coming out you can imagine that we will be faced in the next time with an enormous wealth of new data requiring a proper scientific explanation.

  There is certainly enough work to be done, many new (and existing) observational facts to be explained. Therefore I hope that this workshop, so excellently run and organized by Franco, will not be the last one of this kind."

  These last Wolfgang's words were a premonition of the long series of the Frascati Workshops.

- Michael Friedjung said: " ... I would like to end on a note of caution. Novae have been observed for many years, and are still badly understood. Other objects which have been more recently discovered such as gamma-ray bursters and Geminga are much less observed, but this has not stopped a lot of theoretical modeling. There are often fashions in models and a "bandwaggon effect". There can be an almost "political" influence when certain colleagues succeed in imposing their ideas on others ...".

  It seems that it was written just as foresight of the history of GRBs !!!

- Joe Smak said: "... The overall usefulness of a conference defined by the physical process(es) rather than by the type(s) of objects".

  These Joe's words seem now rather obvious!

- Franco Giovannelli said: "... This workshop has clearly demonstrated that the simplified models for the accreting sources must be revisited in view of the simultaneous multifrequency observations, which are the only deep method of analysis of the internal physical processes in these systems". ... And finally to have demonstrated my theorem that says: "**It is possible to work seriously even if smiling**".

We can say that all these remarks are still valid and during the subsequent series of the Frascati Workshops devoted to high energy cosmic sources we have had the continuous proofs.

4.1 The classical T Tauri star RU Lupi

During the first meeting between Gennady Bisnovatyi-Kogan and I in Warsaw at NCAC in 1979, a collaboration born for experimentally verifying the models for outflowing envelopes of T Tauri stars developed by Bisnovatyi-Kogan & Lamzin (1977), and for the case of RU Lupi to experimentally verify the estimated optical, UV, and X-ray emissions from the chromosphere and corona (Bisnovatyi-Kogan & Lamzin, 1980).

Thus, thanks to the advent of the IUE (International Ultraviolet Explorer), the Soviet ASTRON X-ray/UV satellite, and the facilities of the ESO La Silla Observatory, we started a big multifrequency campaign of observations using as target the classical TTauri-star (CTTS) RU Lupi for essentially three reasons: the first because RU Lupi is inside the Lupus 2 dark nebula (Schwartz, 1977), the second because RU Lupi was the star theoretically studied by Bisnovatyi-Kogan & Lamzin (1980), and the third – fundamental – because it was easily accessible with the ESO telescopes.

A long-term (1982-1988) multifrequency program on Classical T Tauri Stars (CTTSs) was developed by the international group leaded by Franco Giovannelli. The facilities used for such a campaign were the International Ultraviolet Explorer (IUE), the ASTRON X-ray/UV Soviet satellite, and the ESO 0.6-m UBVRI telescope, 1-m IR telescope, 1.5-m telescope for low resolution optical spectroscopy, and 3.6-m telescope for Echelle high resolution spectroscopy.

Figure 5 shows the instruments used for the long term multifrequency program on the CTTS RU Lupi from 1982 to 1988.

The results were published in two main papers, the first with the experimental results (Giovannelli et al., 1995), the second with the interpretation of data and modeling (Lamzin et al., 1996). A review paper about RU Lupi was published by Giovannelli (1994).

One of the main results obtained during the long-term multifrequency program was the simultaneous detection of emissions in different energy bands that allowed to construct the Spectral Energy Distribution (SED) of RU Lupi, as shown in the left panel of Fig. 6.

In two occasions, RU Lupi showed a strong activity (Flare-Like Events: FLEs), much higher than that in "quiescence". Together with the FLEs reported in the literature, these two FLEs allowed to determine their periodicity: $P_{FLEs} = 27.686 \pm 0.002$ days (Giovannelli, 1994). This could be the rotational period of RU Lupi. Indeed, if we use the relationship between the X-ray luminosity (L_X) versus the rotational velocity (v_{rot}) for T Tauri stars, late-type dwarfs, dKe-dMe stars, and RS CVn systems (Bouvier, 1990), the position of RU Lupi fits the relationship $\log L_X = 27.2 + 2 \log v_{rot}$ if $P_{FLEs} = 27.686 \pm 0.002$ days is used, instead of using the "wrong" value reported in the literature of 3.7 days – that simply does not exist (Giovannelli et al., 1991) – whose wrong origin is largely

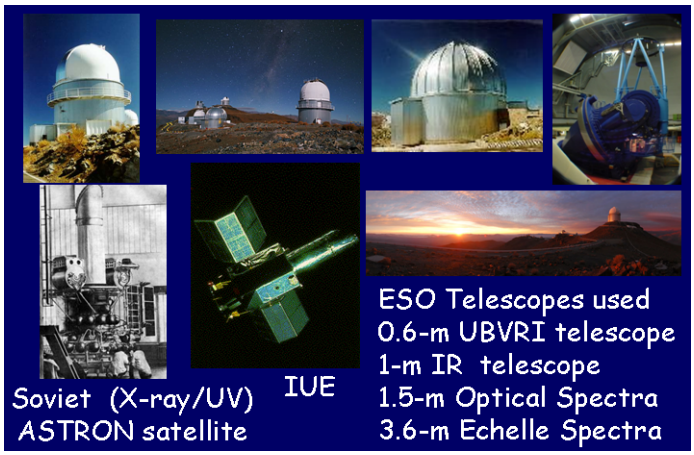

Figure 5: The instruments used for the long term multifrequency program on the classical TTauri-star RU Lupi from 1982 to 1988 (Giovannelli, 1994; Giovannelli et al., 1995; Lamzin et al., 1996).

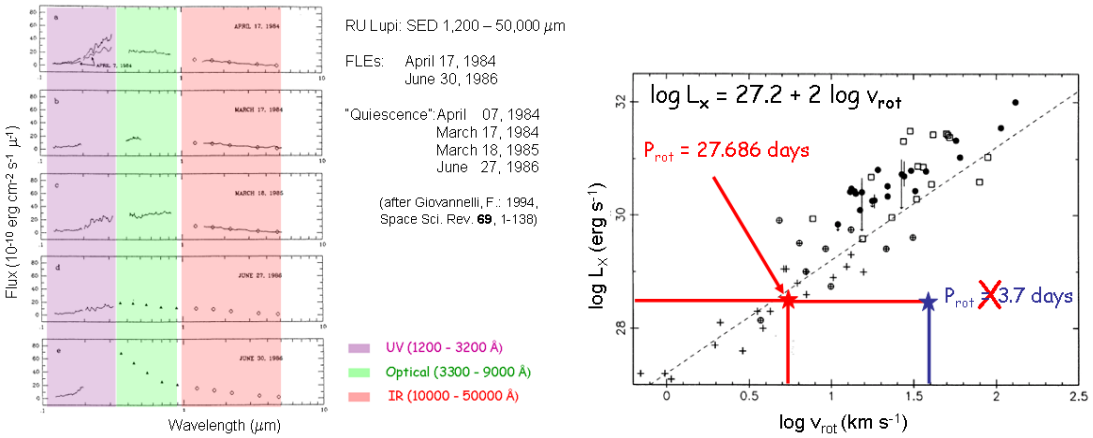

Figure 6: Left panel: SED (1,200-50,000 μm) of RU Lupi in different epochs (after Giovannelli, 1994). Right panel: X-ray luminosity vs stellar equatorial velocity for TTS (•), late-type dwarfs (+), dKe-dMe stars ($\oplus$), and RS CVn systems (square). The right position of RU Lupi is marked with a red star, and the wrong position is marked with a blue star (Giovannelli, 1994 after Bouvier, 1990).

commented in the paper by Giovannelli (1994). Right panel of Fig. 6 shows the diagram of the X-ray luminosity (L_X) versus the rotational velocity (v_{rot}) where the "correct" position of RU Lupi is overlapped with a red star, and the "wrong" position with the blue star.

5. Habitable Zone in the Milky Way and Exoplanets

In the last few years during our workshops on *Frontier Research in Astrophysics*, the problem of exoplanets and habitable zone in the Milky Way has been discussed by several authors. A deep discussion about this fundamental problem has been published by Giovannelli & Sabau-Graziati (2016a) and references therein, and in this workshop (Giovannelli & Sabau-Graziati, 2016b).

The research of potential habitable exoplanets has been strongly supported during last two decades. Indeed, this field of astrophysics is now probably the most exciting since the discovery of

planets Earth-like could open a serious debate about the possibility of life outside of solar system.

The presence of numerous exoplanets in the vicinity of solar system – within a distance of ~ 0.8 pc – plays an important role in speculating about the possible number of such exoplanets within the whole habitable zone of our galaxy. Such habitable zone has an internal radius of ~ 4 kpc and an external radius of ~ 11 kpc, as shown in Fig. 7, where the habitable zone in a Milky Way-like galaxy is represented in green. The number of stars contained in this zone is $\approx 10\%$ of the total number of stars in the Galaxy. Taking into account that the thickness of the disk is ≈ 1 kpc, as evaluated by the differential rotation of the Galaxy, the habitable volume is ~ 330 kpc^3. Therefore, if in a volume of ≈ 2 pc^3 there are 808 Earth-like planets detected, in the habitable zone of our Galaxy we could expect $\approx 133 \times 10^6$ Earth-like planets. It is evident that the probability of finding numerous habitable planets becomes very high. Next generation instruments ground– and space–based will provide valuable information about this intriguing problem.

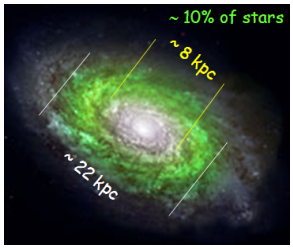

Figure 7: Habitable zone of a Milky Way-like galaxy (Giovannelli & Sabau-Graziati, 2016a after Lineweaver, Fenner & Gibson, 2004).

After the paper by Cleeves et al. (2014) it is understood that the water now present in Earth's oceans, and is present in other solar system bodies, has remained virtually unchanged with respect to that in the interstellar medium. This means that this water has not changed during the process of planet formation. This allows us to understand that the initial conditions that have favored the emergence of life are not unique, i.e. not dependent on the unique characteristics of our solar system. They can, however, be common in space.

An intriguing question about the probability of finding a number of civilization in the Galaxy arises. It is now evident that Drake's formula (Drake, 1962) must be object of a robust revision.

For years, the search for manifestations of extraterrestrial civilizations has been one of humanity's most ambitious projects. Major efforts are now focused on the interception of messages from extraterrestrial civilizations, and the millimeter range is promising for these purposes (Dyson,1960). The Millimetron space observatory is aimed at conducting astronomical observations to probe a broad range of objects in the Universe in the wavelength range 20 μm to 20 mm, including the search for extraterrestrial life (Kardashev et al., 2014, and the references therein).

6. Some reflections

We are going to study $\sim 50{,}000$ Clusters of Galaxies (Thomas Boller, 2017), and we have millions more. We know now more than 4000 planets clearly recognized in the Milky Way (Mullally, 2015). We know the lower limit of the extrapolated number of Earth-like planets in the habitable

zone of our Galaxy that is $\approx 133 \times 10^6$ (Giovannelli & Sabau-Graziati, 2016b). Thus I can dare to say that we are approaching to the philosophical results obtained by two great free thinkers:

- Siddhartha Gautama also known as Shakyamuni (the sage of Shaka – between the VI and V century B.C.) who exposes a grandiose vision of the universe: through the concept of "major system of worlds", a concept on huge scale that implies both the existence of countless galaxies and the possibility of sentient life on other planets other than our own (from the Lotus Sutra – the central text of Mahayana Buddhism).

- Giordano Bruno (Nola 1548 – Roma 17th February 1600) (see Fig. 8 left) who was burned alive in Campo dei Fiori by the "Saint Inquisition" because of his thought – summarized in *De l'infinito, universo e mondi* (Giordano Bruno, 1584) (see Fig. 8 right)– that produced the same conclusions of Siddharta. Moreover he was saying that "*Whether we like it or not, we are the cause of ourselves. Being born in this world, we fall into the illusion of the senses: we believe in what appears. We ignore that we are blind and deaf. Then the fear attacks us and we forget that we are "divine". We can change the course of events*". These philosophical lucubrations were not exactly in agreement with the position of the Roman (Catholic) Church!

Figure 8: Left: Image of Giordano Bruno. Right: Frontispiece of the original publication of *De l'infinito, universo e mondi* (Giordano Bruno, 1584).

Of course we must wait for the scientific confirmation for "alien life". We must wait even more for the discovery of "intelligent life". But, the number of discovered planets is growing very fast. Thus, I can reasonably affirm that the **Universe is full of life**, hoping to avoid to be burned alive like Giordano Bruno.

7. The Vulcano Theorem

During this fruitful workshop, we hope to have demonstrated once more the "Vulcano Theorem" enunciated in 1984 in my concluding address of the first historical workshop on "Multifrequency Behaviour of Galactic Accreting Sources" (Giovannelli, 1985): **It is possible to develop science seriously even if smiling**.

But, as you probably suspected, this workshop has been organized under peaceful and friendly surroundings, as also shown in Fig. 9, representing one scene of the performance of Anna Lisa and Flavia.

Figure 9: Flavia Giovannelli (left) and Anna Lisa Amodio (right) in a scene of their performance: *TeleMoon: It all started with the Big Bang*.

In this workshop, the presence of women has been particularly pleasant and intentional as well as the presence of many young colleagues, some of them still PhD students.

This is the age of the youth. Young people do not depend on anyone or draw strength from others. The courage of young people is unparalleled. It fears nothing. The courage of youth is boundless, is the strength to never give up (Daisaku Ikeda, 2001a).

And I would like to remind one famous sentence of Leonardo Da Vinci: *Tristo è lo discepolo che non supera lo maestro suo!*, that in English is *Grim is the disciple who does not exceed his master!*

And finally, I would like to conclude with few wonderful words of Dr Daisaku Ikeda (2001b), president of the Soka Gakkai International (SGI), and reported in the booklet entitled *For Today and Tomorrow* as the thought of the 30th of May: "*The one who has many friends has greater opportunities for growth. In this way, one both makes society a better place, and lives happier and more satisfied. In all cases, human relations, the inter-personal interaction and communication are of vital importance. We must establish and nurture friendship and contacts with many people, both in our environment, and in society in general. In this manner our life will open up and will flourish*".

We could go back to early childhood when we were as the "Little Prince", who says that One sees clearly only with the heart. What is essential is invisible to the eye (from *The Little Prince* by Antoine de Saint Exupéry, 1943).

The search for the essential is of extreme interest to a large number of men of great learning. These are in agreement with Paul Salahuddin Armstrong, who said in his 2014 talk "*Human Family; Past, Present and Future*", at the "*New Humanity Movement-Event*" (Paul Salahuddin Armstrong, 2014): *Today we travel the world, making connections, doing business, and building relationships in person or online with fellow members of our Human Family from all parts of the Earth. We are becoming more conscious that what happens in one place affects people everywhere. We are not alone... We are not isolated... Only through building bridges of Love and Understanding can we ensure the well-being of everyone in our Human Family*.

The search for the essential is so important that even famous, noble-minded scientists try to attempt the difficult way of the possible convergence of science and life in its more sublime meaning. For instance, Pier Luigi Luisi founded in 1985 the *International Week of Cortona "Science and the Wholeness of Life"*, dedicated to the integration of Scientific Disciplines and Humanities. Later he published the book "*The emergence of Life. From Chemical Origins to Synthetic Biology* (Luisi, 2006) in which he resumed the consecutive stages from prebiotic chemistry to synthetic biology, uniquely combining both approaches. Indeed, the origin of life from inanimate matter has been the focus of much research for decades, both experimentally and philosophically. Friedrich Rolle, a German philosopher and biologist, wrote "*The general reasons for this assumption are so categorical that I have no doubt that sooner or later it will be possible to demonstrate such an assumption in an unambiguous and scientific way, or even repeat the process experimentally* (Rolle, 1863).

In the book "*The Systems View of Life: A Unifying Vision*" (Capra & Luisi, 2014) the authors integrate in a single framework of coherent thought the ideas, models and theories that are the foundation of the systemic vision of life, highlighting its the economic, ecological, political and spiritual implications.

Personally, I would like to reiterate and underscore some fundamental concepts in the book which I completely share.

Life is a network of complex and inseparable relationships that renders the understanding of an individual phenomenon indivisible from the understanding the entire ecosystem in which it occurs. Therefore the answers can not be found by relying exclusively to the scientific method. A "holistic" approach is now required, one that is able to reflect on connectivity, relationships and contexts as well as properties and functions of the individual parts.

The discipline that best reflects the systemic vision of life is ecology, which reconnects the life sciences with the earth sciences and studies the interaction of organisms with each other and

with the surrounding environment. The new ecological science - that has emerged from organismic biology only in the late twentieth century, when the concept of ecosystem developed - is not anthropocentric but eco-centric, that is characterized by the awareness that all living things are tied together in networks of interdependence.

Ecology is the ideal bridge between science and spirituality. In fact, within the systemic view of life, it is essential the concept of balance between science - responsible for the material and technological progress - and spirituality, responsible for the internal growth of individuals and ethical limitations imposed by the excessive consumption of resources of the planet. The balance between science and spirituality determines the welfare of society.

The bridge between the Big Bang and Biology ferries us from the original point to the biologically active side where sentient life and then science start. But to close correctly the “run" of it, it is necessary to cross one bridge more: The bridge between science and spirituality. If this bridge is properly covered, our society will flourish.

Personally, I feel obligated to point out some observations that seem fundamental about the philosophical and social implications of contemporary science. These observations lead to interesting conclusions about the origin of life and self-organization of natural and synthetic systems. These findings are in keeping with the Buddhist view of the universe. It is understood as a living organism being composed of myriads of components all related and interacting with one another. Life can be seen as a system of interconnected autopoietic systems. The organism interacts with the environment in a "cognitive" way. At the same time, the organism "creates" its own environment and the environment allows the creation of the organism. But this is the concept of dependent origin. According to this concept, every phenomenon is the product of the interaction of every other phenomenon in the universe.

The consequence of this view are of extraordinary importance, above all in ethics: it asserts that all living beings and their environment are inextricably linked, and that their essence is not absolute but "of relationship." It leads us to respect every individual being and its inherent rights. In other words, this view leads us to live and act without distinguishing our own happiness from that of others. Ultimately this view leads to the **TOTAL RESPECT OF LIFE** in the most general meaning.

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- Franco Giovannelli - INAF - Istituto di Astrofisica e Planetologia Spaziali, Roma, Italy (Co-Chairperson)
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- ALL SPEAKERS, who rendered this workshop very interesting
- ALL PARTICIPANTS, who breathed life into the workshop with their question-answers, and for the friendly atmosphere they provided
- The FOUR COLLEAGUES and FRIENDS (Jennifer Sokoloski, Dmitry Bisikalo, Paul Mason, and Janusz Ziółkowski) who kindly accepted the not so easy task of making the concluding remarks of the workshop.
- Flavia Giovannelli and Anna Lisa Amodio for their Superb Performance *Tele-Moon: It all started with the Big Bang*.
- The staff of the Hotel Ambassador.

I hope to meet all of you once again during our next Saint Petersburg Workshop.

9. Imagine

Imagine there's no heaven – It's easy if you try – No hell below us – Above us only sky – Imagine all the people living for today – Imagine there's no countries – It isn't hard to do – Nothing to kill or die for – And no religion too – **Imagine all the people living life in peace** (John Lennon, 1971).

Imagine all the people singing (Fig. 10). Imagine all the people dancing (Fig. 11).

You may say I'm a dreamer – But I'm not the only one – I hope someday you'll join us – And the world will live as one (John Lennon, 1971).

Figure 10: Amateur Singers after the Official Banquet. Upper left panel: Francesco Reale & Anna Lisa Amodio. Upper right panel: Anna Lisa Amodio & Franco Giovannelli. Down left panel: Nazar Ikhsanov and in the background: Pieter Meintjes. Down right panel: Kei Tanaka (left) & Keisuke Isogai (right).

Figure 11: Left panel: David Buckley happily dancing because of the "New Modulated Polarization of AR Sco" (in the background from left to right: Paolo Persi, Pieter Meintjes, Solen Balman). Right panel, from left to right: Edward Sion, David Buckley, Kulinder Pal Singh.

10. Conclusions

After this interesting week of full immersion in problems connected with the **accretion processes in cosmic sources** we have clearly seen that the accretion regulates the growth and evolution of all objects in the Universe, and this process is really general, as shown in Fig. 12 (courtesy of Jaime Sanchez Calleja, 2016).

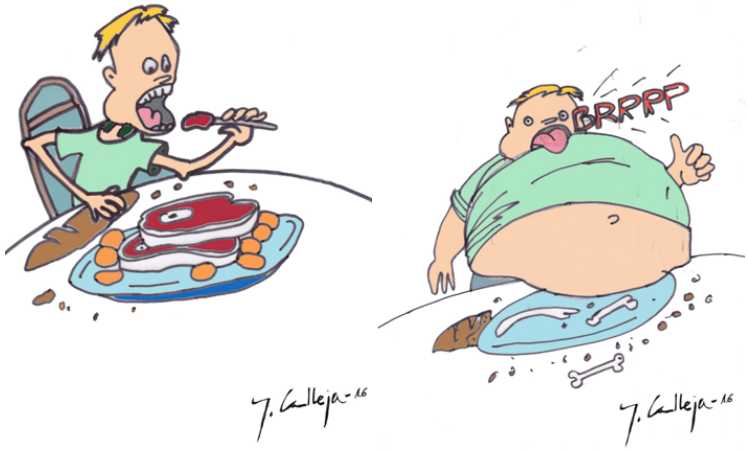

Figure 12: Accretion is a universal phenomenon (courtesy of Jaime Sanchez Calleja, 2016).

And also the inverse process of mass loss is really working, as demonstrated by Sergio Colafrancesco (2008) who experimentally found the proof of the Dark Matter annihilation in the living laboratory, as shown in Fig. 13.

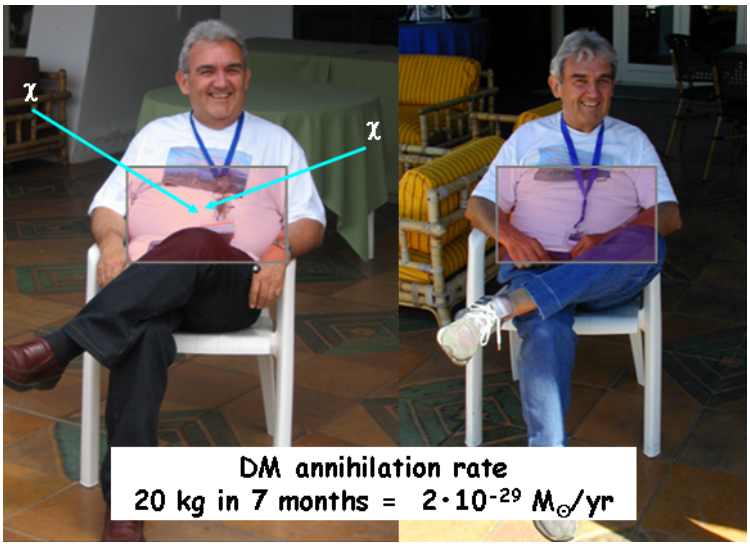

Figure 13: The living laboratory for Experimental proof of Dark Matter annihilation (Colafrancesco, 2008).

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