

Concluding Remarks

Let me first express my warmest acknowledgements to Cesare Barbieri for having taken the initiative of convening this symposium. These two days offered a unique opportunity to celebrate the scientific achievements and the legacy of Galileo Galilei. It allowed not only celebrating the scientist but also the philosopher and the human being. It was a fantastic journey in the past, present and future exploration of our universe and a fantastic retrospection into the Renaissance world which no better city than Padova would be able to offer. During these two days we could listen to a well balanced and well prepared set of excellent papers and presentations. All participants should be congratulated for their very active interactions during the discussions in the aula and also during coffee and lunch breaks.

The first session held in the historical Aula Magna of the University was the occasion of resuscitating Galileo 400 years after his master astronomical work. We were brought back in the universe of an inspired scientist. One who did not really want to be called an astronomer but rather preferred to be considered as an experimentalist. One who was keen to use physics as a tool to understand the world. We had a very sharp hint at the extraordinary talents of this Man who was able to observe Jupiter's moon with an unguided telescope, not only fighting against the diurnal motion which constantly displaced the image of the giant planet in the field of view, but also against the wind, against the mist condensing on the lens of his "cannocchiale" which he had to cleanse regularly during these chilly January nights, even against the beats of his heart, while at the same time using his hands and his eyes to draw on a piece of paper the details of the objects he was just observing. An impossible task indeed that he accomplished with incredible talent and dexterity!

The world of Galileo would not be unfamiliar to that of today's scientists: made of jealousy, of fights with the political authorities (the Church), of detractors. That world was also characterized by the internal dilemma between science and faith, and by the necessary negotiations for money and contracts, when you have to bow and to please often unpleasant people...

The rest of the symposium was devoted to the legacy of Galileo's work 400 years after his historical observations. The core of the presentations of course concerned the Medicean moons as observed from space. The richness of the progress of our observation capabilities could be assessed in perspective through the description of the remarkable production of missions such as Galileo and Cassini. A breathtaking legacy indeed! The meeting also dealt with the other objects that Galileo observed in the Solar System. Then it went on describing future missions to Solar System objects.

Unfortunately for me, the Sun was absent of these future plans. No doubt that if he were living today, Galileo would be exhilarated to see the daily images provided by the SOHO, STEREO and Hinode satellites. He would certainly appreciate the fantastic performance of Ulysses in its journey above the ecliptic plane, as well as the plans to send a Solar Probe diving into the Sun, a project also very dear to the heart of Beppi Colombo, another giant scientist from Padova.

The remarkable observation of the rotation of the Sun through the displacement of sunspots on the solar surface was timely in 1610. A few years later, 3 years after Galileo's death, the so-called Maunder Minimum started and no sunspots could be observed until 1715. A similar situation exists at this very moment, and would Galileo point his telescope today to the Sun, he would just see a pure unspotted disk. In a sense, he was lucky! Luck is often a key ingredient of discovery!

The scientific revolution started by Galileo was followed a little more than 300 years after by a second revolution when Edwin Hubble at Mount Wilson discovered the expansion of the Universe, a revolution amplified by the advent of space astronomy following the historical launch of Sputnik-1 on 4 October 1957. After that successful prowess, we could then on continue observing the same sky as Galileo but now from above the Earth atmosphere which blurred the view of his “cannocchiale” and limited his observations to the visible and near infrared part of the electromagnetic spectrum.

The most emblematic successor to the “cannocchiale” in the space era is undoubtedly the Hubble Space Telescope (HST), nearly more than 100 million times more powerful than its famous predecessor, due to its large mirror of 2.4 m and its using photoelectric detectors. Jupiter and its moons have then been observed in great detail and regularly. The existence of the moons could also be observed indirectly by HST through their signatures appearing as small dots in the Auroral oval around Jupiter’s poles, the effect of the complex interaction between the solar wind, Jupiter strong magnetic field and the channeling of ionized gas flowing out of Io’s volcanoes along the field’s lines of force.

In the next 400 years, what will the next astronomy revolution be? It may start with the contribution of HST’s successor, the James Web Space Telescope (JWST) and be thereafter fed with those of the more gigantic “cannocchiale” that are still on the drawing board today. The first task of these new instruments will be to respond to three presently very challenging problems, still unresolved with present day available instrumentation:

- What is causing the Universe to accelerate since about 7.5 billion years after the Big Bang? In other words, does Dark energy exist and can it explain that acceleration? Are we interpreting present observations rightly?
- What is “holding” the Universe together and what is exactly the nature of that still mysterious Dark matter discovered 80 years ago but which still escapes any real identification.
- Is there life on even a single one of the planets we are now discovering regularly orbiting other stars?

The present successors of Galileo are now designing or imagining the “cannocchiale” of the future that might provide responses to these major questions. Most of their concepts are still in the realm of Utopia: missions impossible? It is certainly the task of the engineers in industry and space agencies to make the impossible come through, exactly like Galileo did when he transformed an optical gadget into a scientific instrument which revolutionized our perception of nature and of science.

This is probably the best occasion for me to celebrate one of these engineers who has done so much for the success of the space missions to the outer planets of the Solar System. I would like that we applaud and acknowledge the unique contribution of John Casani who, at JPL, since the 1970’s had led and managed the most prestigious missions of NASA: the Voyagers, Galileo and Cassini spacecraft among others. John has been sitting here quietly during these two days, enjoying I am sure the enthusiasm of his fellow scientists who thanks to him have got the most stunning insights into the little moons that Galileo observed several hundred years before with his “cannocchiale”.

What lessons can we draw from Galileo’s legacy? What have we learnt from his life and his achievements? There are many but I will concentrate on just a few which I consider as the most important ones.

- Discovery is the fruit of new technologies and new instruments. That has been well analyzed in the famous book of Martin Harwit *Cosmic Discovery: The Search, Scope, and Heritage of Astronomy* (Basic Books, NY, 1981; MIT Press, 1984), some 25 years ago. The problem space astronomers face today is to maintain and ensure the continuity of the expertise in instrument development and experimentation which made space

astronomy the success it is today. That expertise is thinning and threatened of gradually disappearing as it is not regularly replaced.

- Discoveries are the ferment of scientific progress and the mark of the genius of the human brain. Like Galileo: Discover! Discover! Discover!

- The essence of Discovery, with only a few rare exceptions is the result of a scientific intuition and the use of new techniques and systems which integrate them and take advantage of their increased performances.

All geniuses are misunderstood or criticized and subject to jealousy, victims of sarcasms from their competitors or their peers. What affected Galileo is still at play today marking the life of some of the most productive and inventive of our colleagues. As Galileo did 400 years ago, we must resist this aggressiveness and fight as strongly as possible these syndromes. Scientific discovery is also an act of courage!

Although the number of potential “Galileo’s” is increasing in proportion of the global population increase, -the World total population was reaching about 500 millions in 1610, it is presently more than 6.5 billions i.e. more than one order of magnitude higher- the appearance of a new “Galileo” may become a more exceptional event than it was 400 years ago. This is because the “impossible” lies further and further away. A new Renaissance is needed that should be born from the forthcoming dark ages, with very dangerous crisis looming at the horizon of our civilization. The gigantism of missions, which make them look like the cathedrals of the Middle age, with their gestation stretching over longer and longer periods of time, encompassing several generations of scientists, in a context of rapidly evolving technologies, logically will make them more costly and less and less frequent. The gradual disappearance of the synergies with the military will not ease the situation. In that context, international cooperation will become more than ever indispensable. This is another unavoidable effect of globalization. Fortunately, Science by its very nature would strongly benefit from the confrontation of ideas on the broadest basis. Hence, there is some room for optimism.

I would like again to thank Cesare Barbieri for having organized the symposium and for having offered me the opportunity to conclude this very moving and extraordinary meeting.

Roger M. Bonnet