Astrophysics in Pisa from the 1960s to the 1980s: personal recollections

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Preliminary remarks

(1) In our country (but not only in our country), as a discipline, Astronomy used to be closer to Mathematics than to Physics. Probably this was the long-term heritage of the perception that Astronomy is best represented by Celestial Mechanics. Of course, this partial picture had already been overcome by many scientists, such as Galileo, Newton, Kelvin, Poincaré, or Fermi, just to name a few. But often, before the 1960s, research activity in Italian observatories had only little appeal to physicists because it was limited to a patient collection and classification of observational data.

(2) A common thought: Astrophysics is not really Physics. Partly true: the paradigm of a theory as a quantitative framework to be tested in laboratory experiments fails in the astrophysical context, with the possible exception of Space Physics, just because we cannot make controlled experiments on the astrophysical scale, but only observations. So why should physicists study Astrophysics? [For a somewhat emotional, but rather realistic answer, see the quotation (*) given at the end of this presentation.]

(3) A widespread belief: "Fundamental Physics" (commonly identified with "Physics of elementary interactions and microscopic phenomena") stands at the top of the Physics Ladder. In reality, understanding elementary interactions is an important and wonderful prerequisite, but in general does not answer the questions posed by the collective behavior of complex systems. The Physics of macroscopic phenomena is often identified as Applied Physics or Phenomenological Physics and thought to lack the depth of the issues addressed by studies of elementary interactions.

(4) Most of the questions raised by astrophysical phenomena refer to mechanisms that determine the behavior of macroscopic systems.

All of the above left many physicists without much curiosity towards the cosmos.

Yet many physicists became attracted by Astronomy and many astronomers became attracted by Physics [a certainly incomplete list may be tried (others will be mentioned later in this presentation): Gino Cecchini (1896-1978), Francesco Zagar (1900-1976), Gilberto Bernardini (1906-1995), Beppo Occhialini (1907-1993), Edoardo Amaldi (1908-1989), Guglielmo Righini (1908-1978), Nicolò Dallaporta (1910-2003), Livio Gratton (1910-1991), Piero Caldirola (1914-1984), Mario Girolamo Fracastoro (1914-1994), Leonida Rosino (1915-1997), Alberto Masani (1915-2005), Marcello Conversi (1917-1988), Giampietro Puppi (1917-2006), Aldo Kranjc (1919-1994), Margherita Hack (1922-2013), Carlo Castagnoli (1924-2005), Marcello Ceccarelli (1927-1984), Livio Scarsi (1927-2006), followed by Bruno Bertotti, Alberto Bonetti, Riccardo Giacconi, Alfonso Cavaliere, Giuseppe Vaiana, Giancarlo Setti, Alessandro Braccesi, Giorgio Sironi, Francesco Melchiorri, Guido Pizzella, Remo Ruffini, Giuseppe Cesare Perola, Guido Chincarini, Giancarlo Noci, Nino Panagia, Duccio Macchetto, Cesare Chiosi, Nanni Bignami, Massimo Tarenghi, Piero Benvenuti,. ...]

Note that many of the physicists at some point attracted by Astrophysics come from studies of cosmic rays or plasma physics.

The beauty and the surprises of Astrophysics

In turn, a number of surprising discoveries, made in the 1960s and 1970s [just to mention some of the most intriguing ones: the discovery of the Cosmic Microwave Background Radiation, the discovery of pulsars soon identified as neutron stars (the binary pulsar discovered by Hulse and Taylor in 1975 eventually provided the first evidence for the emission of gravitational waves by an astrophysical system), the discovery of dark matter still defying a proper identification, and the apparent deficiency of neutrinos from the Sun] made it clear that many astrophysical phenomena are fantastic sources of inspiration, popping up often completely unexpected while astronomical technology progresses, with a tremendous impact on Physics. Our perception of Fundamental Physics may be shaken by some astronomical observations.

The concept of "surprises" in Astrophysics is somewhat different from that of the title of the book by Rudolf Peierls "Surprises in Theoretical Physics" (Princeton UP, 1979). In Astrophysics, we just have to wait (but alert, with better and better instrumentation), and surprises will shine on us.
A beautiful example: the detection of 12 neutrinos (Kamiokande II) and 8 neutrinos (IMB) from **Supernova SN1987a**.
An even more beautiful example: the announcement of October 16, 2017 of the observations of the event known as **GW170817**.

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A key mysterious aspect of Physics that is prominently and continually brought to our minds by astrophysical phenomena is gravitational interaction.

In his essay "Science et Méthode" (1908) Henri Poincaré mentions the possible existence of "matière obscure": "*Mais alors, ce que nous donnerait la méthode de lord Kelvin, ce serait le nombre totale des étoiles, en y comprenant les étoiles obscures.....*".

Referring to a picture of a globular cluster and of a spiral galaxy, in chapter 7 of the first volume of The Feynman Lectures on Physics (Addison-Wesley 1963) we find: "*If one cannot see gravitation acting here, he has no soul.*" ..... "*Of course we cannot prove that the law here is precisely inverse square, only that there is still an attraction,...*".

All these statements are dated well before the discovery of dark halos in galaxies. Nowadays we commonly discuss the properties of dark matter and, in this century, of dark energy, but, unfortunately, we do not even know what we are talking about.

Nearby galaxies

NGC 1300 in the near infrared (credit: ESO, P. Grosbol))

A welcome intuition

In Pisa some scientists, in particular, **Luigi A. Radicati** (Università di Pisa 1955-1962; Scuola Normale Superiore 1962-), soon realized the great potential of the beauty of Astrophysics, its major force in generating progress in Physics, and its power in challenging what we call Fundamental Physics.

(Some of the following notes are based on material presented at a meeting in honor of Luigi Radicati at the Accademia Nazionale dei Lincei in Rome on December 9th, 2010.)

As a result, seeds were laid in several research areas that even today are at the forefront of scientific research. The seeds were planted with the collaboration of a number of top scientists invited from outside Pisa, often from abroad, to give a seminar, or a series of lectures, or to make a relatively long scientific visit, or to supervise a thesis or a doctoral thesis project. Pisa was able to attract top scientists and became an enjoyable site for interdisciplinary exchanges. Many young scientists, who started their scientific career in Pisa, then moved to key institutes all over the world; some stayed away becoming leaders in their own field, others returned or at least kept contact with their Alma Mater.

A variety of research topics

Classical astronomy
The observatory and astronomy:
Elio Fabri, **Bruno Barsella**
Planetary astrophysics, rings, celestial mechanics:
Bepi Colombo (SNS Lectures; a precursor of the modern interest in the study of extrasolar planets)
Integrability and chaos:
Donald Lynden-Bell; Louis Michel, Jürgen Moser (Fermi Lectures 1981, Integrable hamiltonian systems and spectral theory), **Vladimir I. Arnold** (Fermi Lectures 1990, The theory of singularities and its applications)

Plasma astrophysics

Pulsar meeting late 1960s:

Subrahmanyan Chandrasekhar, Freeman Dyson, Bruno Coppi, Thomas Gold, Franco Pacini, David Pines, and others

Condensed matter and atoms in very strong magnetic fields:

Biswarup Banerjee, Dan Constantinescu, Pavel Rehák (also in collaboration with Giovanni Moruzzi)

Plasma astrophysics meetings:

1980 (Pisa), 1981 (Firenze + Elba), 1983 (S. Miniato), 1985 (Torino), 1986 (S. Angelo di Drapia), 1987 (Padova), 1988 (S. Gimignano), 1990 (Loiano) .... basically all led by Pisa scientists or scientists educated in Pisa

Plasma physics, solar physics, space physics:

Bruno Coppi (SNS Lectures), **Claudio Chiuderi** (SNS Lectures), **Lo Woltjer**, **Bruno Rossi**

X-ray astrophysics:

Bruno Coppi (solar flares; ICM as a "perfect plasma"), **Bruno Rossi** (discovery of extrasolar sources and of the ICM in clusters of galaxies), **Craig Sarazin** (physics of the ICM in clusters of galaxies)

Collective phenomena in fluid dynamics

Modern ideas and experiments on the Bénard problem: **Marzio Giglio**, **Albert Libchaber**

Modal and nonmodal behavior of complex dynamical systems: **C.C. Lin**

Gravitation and cosmology

Gravitation, thermodynamics, statistical mechanics:

Freeman Dyson (Fermi Lectures 1970, Neutron stars and pulsars), **Louis Michel** (bifurcations, symmetry break, phase transitions), **Donald Lynden-Bell** (statistical mechanics of self-gravitating systems, gravothermal catastrophe), **Walter Thirring**

Gravitation, black holes, and cosmology, including primordial nucleosynthesis:

Carlo Cattaneo (SNS Lectures), **John Wheeler** (Fermi Lectures 1975, Gravitation and the universe), **Dennis Sciama** (entropy of black holes), **Jerry Ostriker** (Fermi Lectures 1988, Development of large-scale structure in the universe; notes prepared by Roberto Saglia and Massimo Stiavelli)

Gravitation and galactic structure and morphologies:

C.C. Lin (spiral structure in galaxies as density waves), **Renzo Sancisi** (galaxy warps; coherent phenomena in galaxies); **Ennio De Giorgi** (was also fascinated by the structure and morphology of stellar systems, and contributed by means of a number of informal conversations)

Gravitation and galaxy formation:

Tjeerd van Albada (N-body simulations of collisionless collapse), **Donald Lynden-Bell** (violent relaxation in collisionless systems)

Gravitation and dark matter:

Renzo Sancisi (discovery of dark matter in galaxies; galaxy scaling laws), **Tjeerd van Albada** (discovery of dark matter in galaxies; galaxy scaling laws) - landmark article by TvA & RS with John Bahcall and Kor Begeman in 1985

Gravitation, N-body simulations, stability and nonlinear evolution of stellar systems:

Tjeerd van Albada (studies of the process of relaxation and dynamical friction; dynamical evolution of elliptical galaxies, partly in collaboration with Massimo Stiavelli)

21cm radioastronomy:

Renzo Sancisi (rotation curves, dynamics of cold gas in galaxies)

Gravitational waves

Gravitational wave detectors:

Emilio Picasso (three articles on e.m. detectors, with Francesco Pegoraro, Luigi Radicati, Philippe Bernard, and Enrico Iacopini 1978-1979), **Adalberto Giazotto** (VIRGO approved 1993)

Stellar structure

Stellar structure and evolution:

Vittorio Castellani (computations at **CNUCE** in the 1960s; SNS Lectures; Universita' di Pisa since late 1980s)

Interstellar medium

Dust, interstellar medium, star formation, chemical evolution:

Mayo Greenberg (collaboration with Bruno Barsella; chair for laboratory astrophysics in Leiden 1975-1992; comets, astrobiology), **Steve Shore** (collaboration with Federico Ferrini, Francesco Palla, late 1980s)

Major initiatives

Major initiatives from the ground and from space:

Lo Woltjer (Director General of ESO 1975-1987; initiated the construction of VLT), **Lyman Spitzer** (Director of Project Matterhorn, PPPL, early proponent of the Hubble Space Telescope; note that **Massimo Stiavelli**, who obtained his Perfezionamento in Pisa in 1986, is Mission Head of the James Webb Space Telescope, to be launched in the spring of 2019), **Bepi Colombo** (normalista, Tethered Satellite, Mariner 10 mission to Mercury early 1970s, Giotto mission to Halley 1980s), **Bruno Rossi** (Space plasma physics: solar wind, Explorer 10, and the discovery of the magnetopause. X-ray astronomy, 1962 discovery of first extra-solar source, Sco X-1)

Contacts and collaborations

Major research centers:

European Southern Observatory, European Space Agency, Space Telescope Science Institute

Major academic institutions:

Massachusetts Institute of Technology (**Cambridge, MA**), **Institute for Advanced Study** (**Princeton, NJ**), **Kapteyn Astronomical Institute** (**Groningen, The Netherlands**)

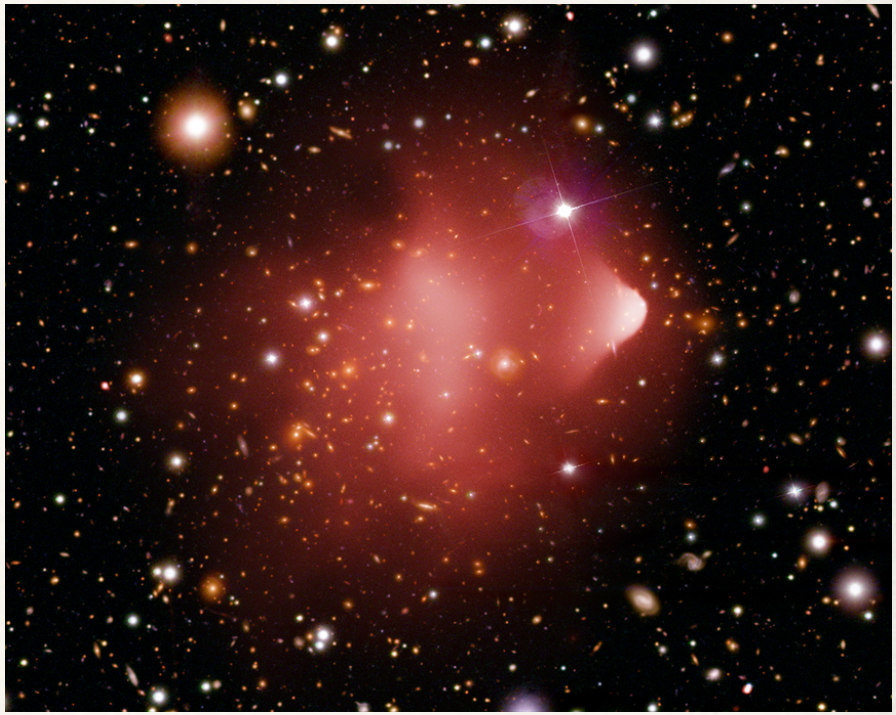
An incomplete but interesting picture of some sprouts from the seeds planted in the period 1960s - 1980s is provided by a booklet "**Seminario di Astrofisica 1994**" (published by SNS), made of contributions by 13 young Pisa scientists (some with well-developed international collaborations) covering a broad spectrum of topics, including gamma-ray astronomy (David Smith; INFN) and studies of high-energy cosmic rays (Daniel O' Connor; INFN).

Another piece of evidence is given by a series of Giornate Lincee on "Internal dynamics of galaxies" held at the Accademia Nazionale dei Lincei and promoted by **Francesco Bertola**, **Alvio Renzini**, and Pisa scientists on a yearly basis (1988-1993; and several international symposia in the following years).

SEMINARIO DI ASTROFISICA 1994

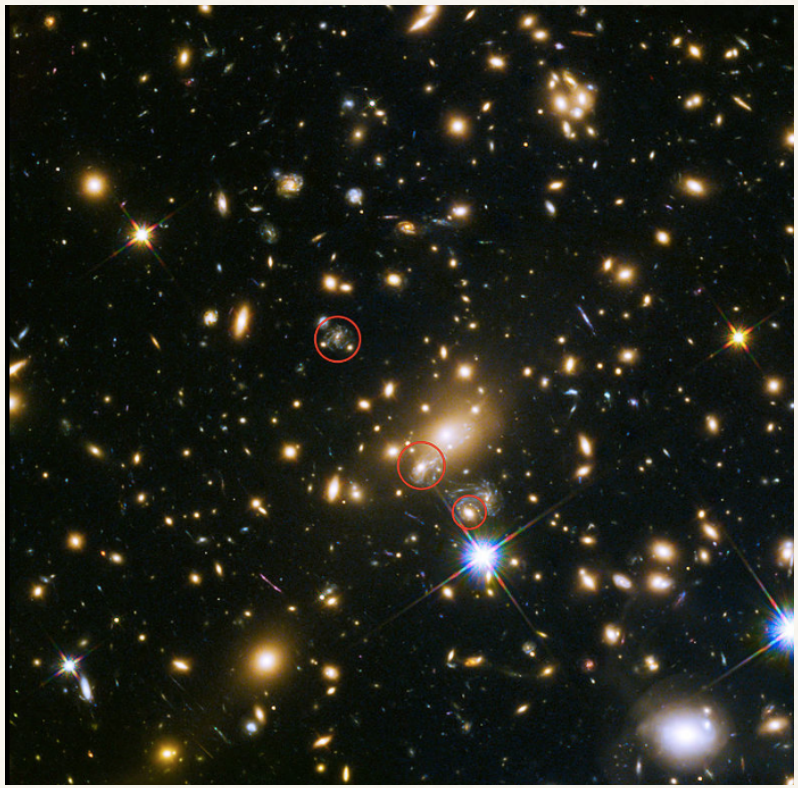
Dark matter and gravitational lensing

Cluster Abell 2219, arcs by gravitational lensing on distant galaxies (credit: NASA, ESA, R. Ellis, J-P. Kneib)



The Bullet Cluster seen by *Chandra* (M. Markevitch et al.) and *Magellan* (D. Clowe et al.)

Gravitational lensing and the Hubble constant



SN *Refsdal* (inset picture) and galaxy cluster MACS J1149.6+2223 (credit: Hubble/NASA/ESA/STScI/UCLA)

Treu, T. et. al 2016, The Astrophysical Journal, 817, 60. "Refsdal meets Popper: comparing predictions of the reappearance of the multiply imaged supernova behind MACS1149.5+2223"

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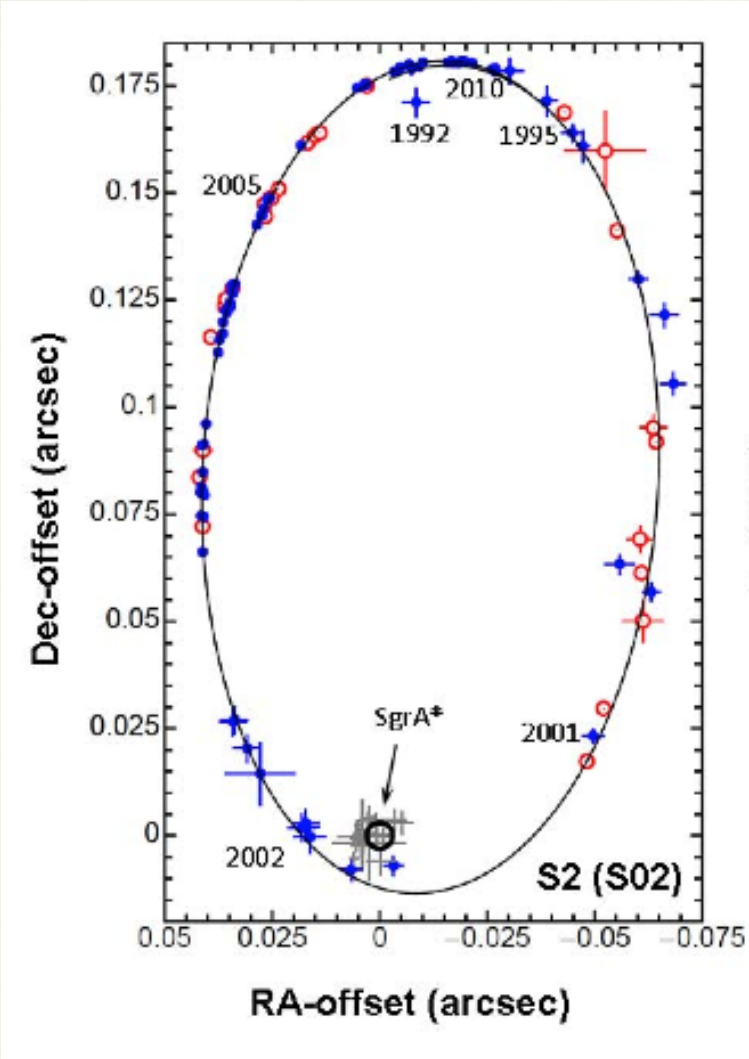
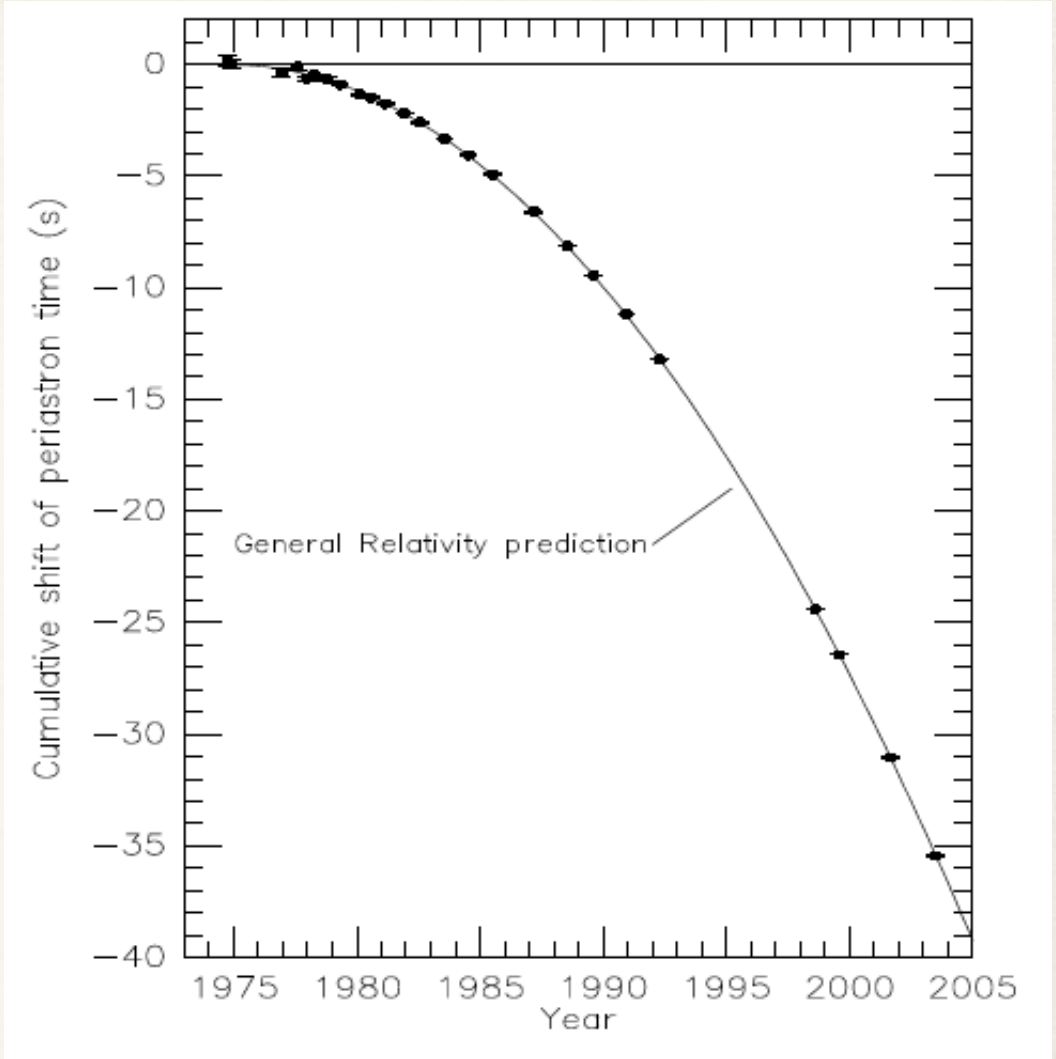
Supermassive black hole and gravitational radiation from binary pulsar

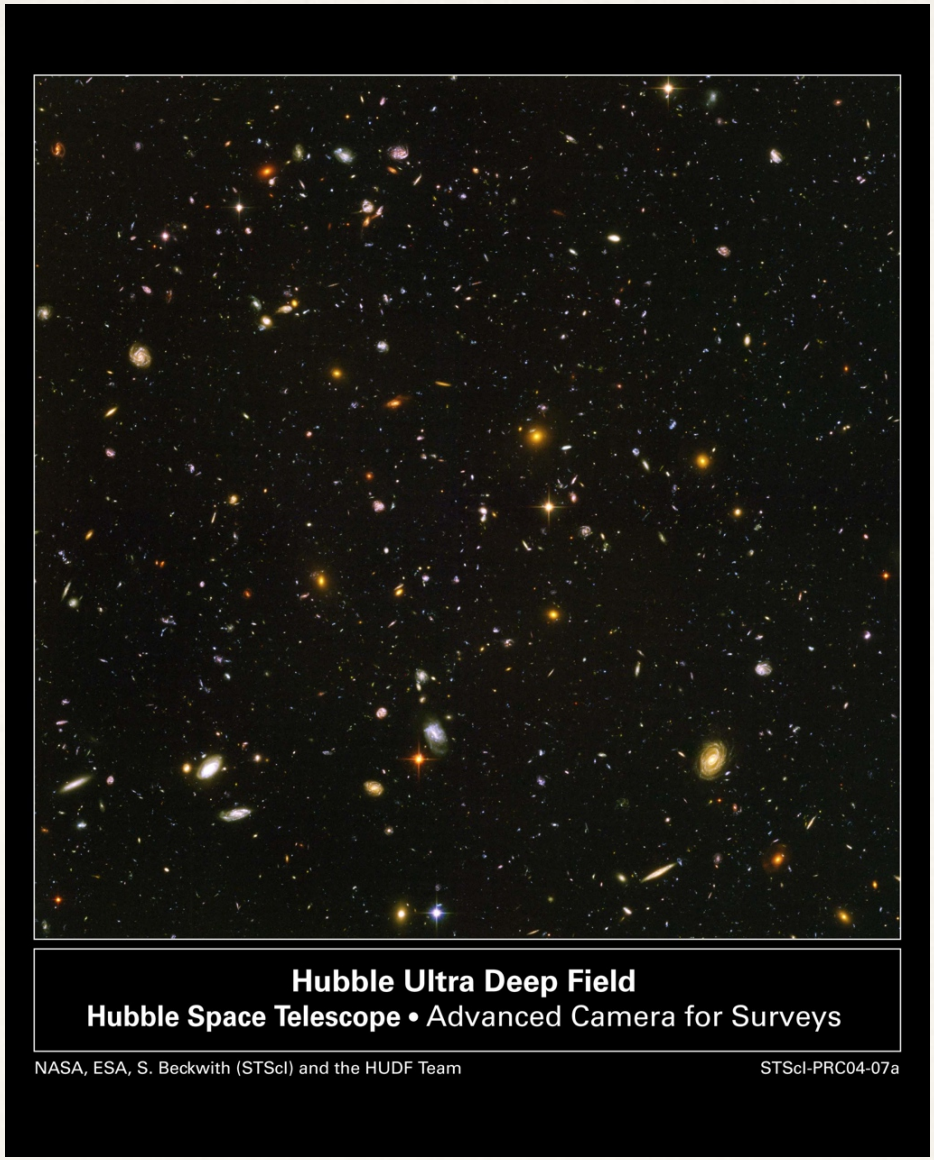


Genzel, R., Eisenhauer, F., Gillessen, S. 2010, Rev. Mod. Phys., 82, 3121



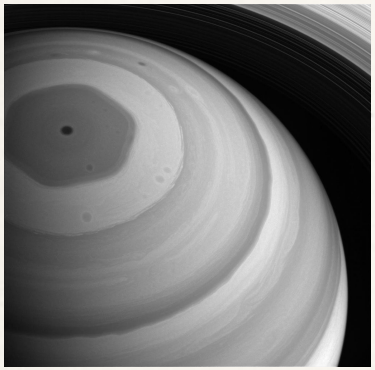
J.M. Weisberg, J.M., Taylor, J.H. 2005, ASP Conf. Ser., 328, 25

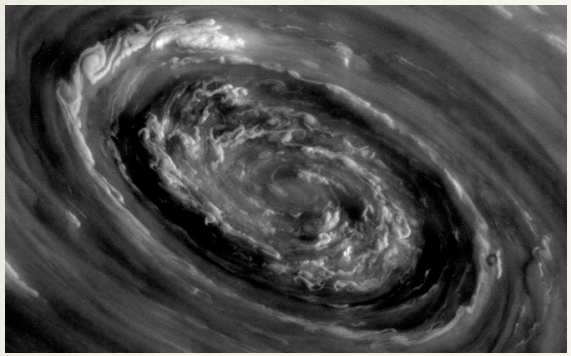
Distant galaxies out to z ~ 10



S.V.W. Beckwith, M. Stiavelli, et al. 2006, Astron. J., 132, 1729

Hurricane on Mars (*Viking*, 1978)

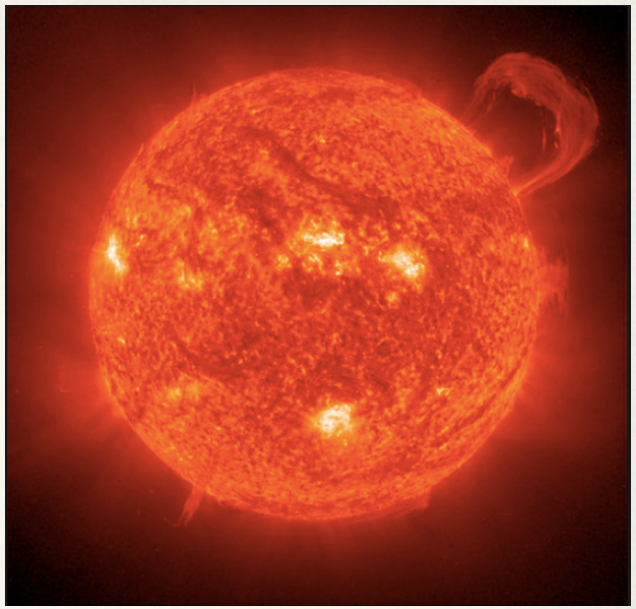




Saturn's polar region (*Cassini-Huygens* **2012**)

Space physics

(*Soho*)



Parker Solar Probe
(to be launched in 2018)

At closest approach, Parker Solar Probe hurtles around the sun at approximately 700,000 km/h.

At closest approach to the sun, the front of Parker Solar Probe's solar shield faces temperatures approaching 1,400 C. The spacecraft's payload will be near room temperature.

On the final three orbits, Parker Solar Probe flies to within 8.5 solar radii of the sun's surface.

(*)

“Many years ago the great British explorer George Mallory — who was to die on Mount Everest — was asked why did he climb it. He said, ‘Because it is there.’ Well, space is there, and we’re going to climb it. And the moon and planets are there. And new hopes for knowledge and peace are there.” – John F. Kennedy

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