Modulo 2:

Riferimento a linee guida	**SCHEDA N: 10** AUTOVALUTAZIONE PROGRAMMA
3	Nome programma:
	High-Energy Astrophysics, Cosmology and Planetary Sciences
3	Responsabile programma
	Sabino Matarrese
3	Obiettivi specifici del programma
	The research program is divided into three major research lines: Research Line 1: <u>*Neutron star astrophysics*</u> Goal of this research thread is to exploit observations performed at different wavelengths with new generation ground-based and space-born telescopes to address some of the still open issues in neutron star astrophysics. With magnetic fields in excess of a billion Tesla, central densities above nuclear density and size only a few times the gravitational radius, these objects are the only "laboratories" where current theories of nuclear matter, gravity and electromagnetism can be tested in the strong-field limit. With present-day astronomical techniques the simultaneous measurement of the neutron star mass and radius is within reach. This will make it possible to place tight constraints on the matter equation of state at ultra-high densities. Observations of neutron stars may therefore hold the key to answer such basic questions as if the real ground state of matter is made of free quarks or of hadrons. As time elapses, the neutron star surface temperature, initially as high as several billions Kelvin, decreases and for about a million year the star shines as a X-ray source. Satellite observations have been able to reveal the neutron star emission in X/gamma-rays, while ground-based/space-born telescopes picked up their infrared/optical signatures. This makes neutron stars one of the rare classes of astrophysical sources whose electromagnetic spectrum has been probed over 11 orders of magnitude in frequency, from radio to gamma-rays. The detection of isolated neutron star (INSs) emission at different wavelengths unveiled a complex and very diversified phenomenology. In particular, multi-wavelength observations have been fundamental in revealing the existence of radio-quiet INSs which would have passed undiscovered and unsuspected otherwise. Isolated radio-quiet neutron stars include sources with extremely different properties, from the dim soft X-ray emitters discovered with ROSAT to the soft gamma-ray repeaters, whose giant flares are the most energetic transient events ever observed in the Galaxy. Observations of these sources are of key importance since radiation reaching us comes directly from the star surface and holds unique information about its physical properties. IR/optical observations are required to obtain the star distance through parallax, this being the only way in case of radio-silent INSs. X-ray spectroscopy and timing will reveal the details of the star temperature and magnetic field surface distributions. If distance is known, this will provide a measure of the star radius and, in case spectral features are detected at the same time, also of its mass. Besides, multi-wavelength observations held the potential to unveil the physical/evolutionary differences which are at the basis of INSs vastly different

manifestations. It has become increasingly evident that some INSs have ultra-strong magnetic fields, as large as 100 billions Tesla. However, these alleged "magnetars" may manifest themselves as inconspicuous, dim X-ray sources, as ordinary radio-pulsar or as extremely energetic soft gamma-ray repeaters, spanning something like fifteen orders of magnitude in luminosity. The careful search for similarities/differences in their spectral/timing properties in different energy bands is bound to reveal if indeed they are all ultra-magnetized neutron stars and, if so, which is the physical reason behind their different observational properties, proving or disproving the suspected evolutionary links between the different classes of sources.

Research Line 2: *Cosmology*

This research line covers various aspects of Cosmology, ranging from the physics of the early universe (mostly in connection with the inflationary paradigm) – studying in particular its specific predictions for the properties of the Cosmic Microwave Background (CMB) temperature anisotropy and polarization - to the formation of Large-Scale Structures (LSS) in the universe and, finally, to the fundamental issue of the nature and phenomenological properties of the dark energy component in the cosmos.
In particular, we have analyzed the quantum generation during inflation and subsequent classical evolution of cosmological perturbations, with the specific aim of studying possible deviations from Gaussian statistics arising either from some non-linearity in the generating process or from the non-linear evolution of perturbations. A large fraction of our study has focused on the potential detectability of such primordial non-Gaussian signals, both in all-sky, high-resolution CMB temperature (and polarization) maps, such as those obtainable with the ESA Planck Surveyor satellite, and in the LSS of the universe, as traced by the galaxy distribution in large redshift surveys, such as 2dF and SDSS.
A second direction of investigation concerns specific properties of the Dark Matter (DM) clustering. In particular we have focused on the properties of galaxy bias and we have extracted a robust determination of its value from the 2dF galaxy redshift survey. We have also studied the DM clustering properties at higher redshifts by analyzing not only the clustering of high-redshift galaxies, but also the spatial distribution of the Intergalactic Medium (IGM), as traced by the Ly-alpha forest in the absorption spectra of distant QSO. We have also discussed the possibility to extract information on the warm-hot IGM by studying specific absorption features in the X-ray spectra of bright AGN.
Finally we have analyzed the properties of the Dark Energy (DE) component of the universe. A bunch of independent observations indeed indicates that about two thirds of the present-day cosmic energy budget is contributed by an almost uniform energy component with negative pressure, which has made the Universe undergo a recent phase of accelerated expansion. The nature of this component is still unknown, but a viable possibility is that DE is in the form of a Cosmological Constant. Alternative possibilities have also been analyzed.

Research Line 3: *Physics and dynamics of planets and minor bodies*

This research line focuses on the dynamical and physical evolution of solar system bodies and extrasolar planets. A large number (more than 150 up to date) of exoplanetary, extrasolar systems have be discovered in these last years. A major problem from a theoretical point of view arises from their diversity, in terms of

	dynamical properties, in particular with respect to the solar system. An open issue is, for example, the presence of massive planets well inside one astronomical unit from the parent star which do not have counterparts in the solar system. We have developed a model showing how a giant planet can by inserted in inside orbits via gravitational scattering with other planets of the system. This model however, requires theoretical efforts to be worked out and tested. Another aspect of our research concerns planetary formation in binary star systems. In particular we concentrate on the effects of the gravitational interaction of the companion star on the formation of a planetary system around the primary star. We plan to derive the mean distance from the primary at which Earth-like planets and Jupiter-like cores can form, as a function of the binary separation. We are also working at a hybrid algorithm to calculate the formation of planets from an initial population of planetesimals. This algorithm, developed at the Planetary Science Institute of Tucson (USA) uses a Montecarlo statistical code to treat the growth of planetesimals into protoplanets and explicit N-body calculations to follow the evolution of protoplanets into planets. This code will be used to test the effects of dynamical friction on the final eccentricity of terrestrial planets and to model the growth of giant planets. In addition to theoretical studies on planets we are also investigating the dynamical evolution of minor bodies like asteroids and comets. The recent model for the evolution of Jupiter and Saturn through a 2:1 resonance during the initial phases of planetary formation represents a serious challenge in terms of stability of Trojan asteroids during the resonance crossing. Using the Frequency Map Analysis we found that commensurability between the proper frequency of the perihelion of Trojans and that of the migrating Jupiter causes a fast destabilization of Trojan orbits. Further investigation is needed to fully explore the phase space in search of possible regions were Trojans could anyway survive. We are also involved in the ROSETTA mission that will produce within a few years a large flow of data from flybys with two asteroids of the Main Belt (Steins in 2008 and Lutetia in 2010). We will be involved in the planning of the imaging sequence and in the preparation of software for the data analysis.
3	Progetti in corso
	Research Line 1: *Neutron star astrophysics* Project 1.1: *Thermal emission from isolated neutron stars* We take part in a substantial programme of XMM-Newton observations secured in open time, to investigate the properties of X-ray dim isolated neutron stars (XDINSs). These are a rare class of ROSAT sources, characterized by blackbody-like emission at $kT \approx 100$ eV and spin periods of about 5-10 s, with no trace of radio activity. XDINSs offer an unprecedented opportunity to study in detail neutron star surface properties, thanks to their clean thermal spectra, unmarred by the emission from a companion, a surrounding supernova remnant or the magnetosphere. We have first identified the seventh source in the RBS, 1 RXS 2127303.4+065419. Subsequently, a dedicated XMM-Newton observation allowed us to pinpoint the star spin period and to detect a broad absorption feature at ≈ 700 eV. There is increasing evidence that presence of such spectral lines is ubiquitous in XDINSs, as our analysis of XMM-Newton data for RX J0420.0-5022 and RX J0806.4-4123 confirms. Although the nature of the feature is still unclear, the option that this is a proton cyclotron line appears likely. If so, the magnetic field in XDINSs would be about one order of magnitude higher with respect

to that of typical radio-pulsars, enforcing the idea of an evolutionary link with the magnetar candidates, SGRs and AXPs. We obtained HST time to observe RX J1605.3+3249, in order to confirm the optical identification, measure the star proper motion and, set up first epoch for a future determination of the parallax. The more our knowledge of XDINS proceeds, the more the prototype of the class, RX J1856.5-3754, stands out as peculiar. It is the only non-pulsating source and its spectrum is purely blackbody, with no features whatsoever. Its striking features may be accounted for if this is a "bare" neutron star, i.e. a star left without an atmosphere by the condensation of the surface layers produced by the combination of high magnetic field and low temperature, as we proposed. We have started a long-range investigation aimed at confronting the XDINS light curves and spectra with theoretical models. This will allow us to constrain the star thermal map and hence the magnetic field structure. We have shown that the quite large pulsed fractions and light curve asymmetry are not compatible with a simple dipolar geometry, and higher multipoles must be included.

Project 1.2: *Ultra-magnetized neutron stars*

We are involved with a large team in the systematic, long-term X-ray monitoring of both the Soft Gamma-ray Repeaters (SGRs) and the Anomalous X-ray Pulsars (AXPs). These two classes of sources are strongly suspected to host a magnetar, i.e. a neutron star with surface field largely in excess of the QED critical field ($B_{QED} = 4.4 \times 10^{13}$ G).
Although many clues supports the presence of ultra-magnetized neutron stars in SGRs, pellucid evidence in favor of the magnetar scenario came from our detection in Rossi-XTE data of some bursts from SGR 1806-20 of an absorption feature at an energy of ≈ 5 keV. In the likely option this is a proton cyclotron line, the implied magnetic field strength is $B \approx 10^{15}$ G, squarely in the magnetar range. The line properties are in good agreement with theoretical predictions we obtained shortly before. 2004 has been the "annus mirabilis" for SGR 1806-20, since it witnessed the first giant flare from this source, the more energetic transient event recorded so far in the Galaxy. Our XMM-Newton and Chandra observations covered the source at intervals of months both before and after the event. Data clearly show evidence for increased level of activity, enhanced spin-down and spectral hardening in the pre-flare phase, all of which subdued in the aftermath. The emerging observational picture provides support to the "twisted magnetosphere" model for a magnetar.
Long-term monitoring of AXPs is crucial in establishing the link between these sources and SGRs. Although the high spin-down rates measured in both the classes points towards a common magnetar origin, the many differences (lower persistent luminosity, very diverse burst activity) remain largely unexplained. XMM-Newton data of the AXP 1708… have shown that the alleged spectral feature previously reported is not present anymore. A possibility is that the line is intrinsically variable, possibly because its appearance depends on details of the charge flow in the star magnetosphere, again within the twisted magnetosphere model, as also indicated by very recent observations. Within this scenario, the very diverse activity of the two classes might be explained if AXPs and SGRs are both magnetars, but the former are older and dissipated much of the magnetic elicity stored in the star interior.

Project 1.3: *Neutron star population synthesis*

Population synthesis studies helps in shedding light on the origin of the XDINSs and on their relationships with other classes of Galactic neutron stars. Aim of these calculations is to simulate the spatial distribution of a given population of neutron stars

and its evolution. Theoretical predictions are then confronted with observations by comparing the log N-log S curves. This technique allowed us to show that the local density of XDINS exceeds that of radio-pulsars. Their relative large number in the solar proximity is explained taking into account the contribution of the Gould Belt to the XDINS birth rate. Theoretical log N-log S distributions are sensitive to the assumed EOS because the star cooling history is strongly dependent on the interior structure.
As we proposed, the comparison of log N-log S distributions, computed for different EOS, with observations provides a powerful diagnostics for the physics of the star interior and usefully complements the temperature vs. age test commonly used up to now.

Research Line 2: Cosmology

Project 2.1: *Constraining/measuring the spectrum and the non-Gaussianity of primordial perturbations with the Cosmic Microwave Background*

The possibility of measuring deviations from Gaussianity in the statistics of primordial cosmological perturbations has received growing attention during the last few years. Such a measurement would in fact allow to better discriminate among competing scenarios (such as e.g. slow-roll single-field inflation, curvaton, inhomogeneous reheating, multi-field inflation, etc. …) for the origin of the primordial seeds of CMB anisotropies and LSS formation in the universe.
Mild deviations from the purely Gaussian behavior of primordial density fluctuations are indeed expected, owing to either the possible presence of sizeable non-linearities in the non-inflaton sector of the theory, or due to the evolution of perturbations in the post-inflationary era. Our study has then focused both on the inflation generating mechanism, accounting for possible variants to the simplest single-field inflation scenario, such as the curvaton and the inhomogeneous reheating scenarios, and on the modifications induced by the non-linear evolution after inflation. This analysis has required the use of a fully relativistic and gauge-invariant higher-order perturbation theory approach to the dynamics of matter irregularities in the Universe. To deal with the comparison of theoretical (inflationary) predictions with presently available and future CMB temperature anisotropy datasets, we have developed the first (and so far the only) numerical code able to produce synthetic maps of the CMB sky at the maximum Planck resolution, including quadratic non-Gaussianity. Our approach is characterized by an accurate treatment of the radiation transfer function on all scales. Our numerical code and the resulting maps are now included in the so-called "reference sky" for the Planck satellite mission. The standard goal of these studies is to constrain the so-called non-Gaussianity strength parameter f_{NL}, setting the amplitude of quadratic non-Gaussianity in the primordial gravitational potential. Available data constrain this parameter within a fairly broad range around zero (the Gaussian limit), while Planck temperature anisotropy data are expected to set more stringent limits ($|f_{NL}|<5$). The use of our simulated CMB maps and of optimal statistical estimators might further improve this lower limit.

Project 2.2: *Modeling and constraining the properties of Dark Energy*

Maximum likelihood analyses of many independent datasets clearly indicate the existence of a considerable dark sector in the energy budget of our universe. There is indeed wide consensus on the fact that about two thirds of the present energy density of our Universe is in the form of a quasi uniform component with negative pressure, which caused its accelerated expansion, as indicated by the analysis of the magnitude-redshift relation of Type Ia Supernovae. The simplest interpretation of this Dark Energy fluid is that it is constituted by a Cosmological Constant with unnaturally low value. A viable alternative is that DE is explained by a slowly-rolling scalar field, named "Quintessence". In this respect, we have also examined the intriguing possibility that such a Quintessence field could have the properties of the scalar sector in the so-called Jordan-Brans-Dicke ("scalar-tensor") theories of gravity, discussing the observational properties of these models, in connection with CMB anisotropies, LSS formation and the magnitude-redshift relation of distant Type Ia Supernovae. We have dubbed this new class of models "Extended Quintessence" (Perrotta et al. 2000). Precision measurements of CMB anisotropies, such as those that will be achieved by Planck, and future SN data from SNAP will place interesting limits on this theory. Finally, we have investigated the observational evidence for DE from a radically different perspective, that of the possible role of the "back-reaction" of cosmological inhomogeneities within our Hubble radius on the background evolution of the underlying cosmological model. The key open issue here remains that of unambiguously determine the strength of the relevant back-reaction terms, which would require a fully relativistic non-perturbative calculation.

Project 2.3: *The formation of Large-Scale Structures in the Universe*

This study follows from previous studies of our group on modeling the DM halo bias and its evolution with redshift. Using higher-order statistics (the bispectrum) we achieved a precise measurement of the galaxy bias of 2dF galaxies (Verde et al. 2002), which allowed an indirect determination and of the matter (DM and baryons) density parameter, in full agreement with independent estimates. We also studied the redshift evolution of galaxy bias. Next, we have obtained original results on a related problem, that of reconstructing the initial distribution of galaxies from their present location in redshift space (Frisch et al. 2002). Our procedure (named MAK), which is based on optimal mass transportation algorithms, may also have interesting applications in other fields of physics. also Lyman-alpha forest. Finally, our group has been working on semi-analytic modeling and full numerical simulations of the IGM, studying in particular the Lyman-alpha forest in the absorption spectra of distant QSO. Using the LUQAS sample obtained with Keck data, we recently succeeded to place interesting constraints on the mass of Warm Dark Matter candidates and sterile neutrinos (Viel et al. 2005).

Research Line 3: *Physics and dynamics of planets and minor bodies*

Project 3.1: *Extrasolar planets formation and dynamics*.

There are many intriguing aspects of the newly discovered extrasolar planets like their orbits so different from those of the planets in the solar system. With the "Jumping Jupiter" model we have shown how gravitational scattering can produce eccentric orbits consistent with those observed and how the tidal dissipation could circularize the orbit near periastron distance and explain the close and circular orbits of 51 Peg type systems. Thus far we have, of necessity, examined only a very limited parameter space of the possible range of planetary masses, initial orbits, and planet/star mass ratios. We intend to explore in more details the implications of the Jumping Jupiter model by considering different initial configurations of the system. The goal is to compare the final outcome of the numerical simulations with the observations to derive possible

	constraints on the starting conditions and then on the planetary formation process. We are also exploring the dynamical evolution of multi-planet systems with two bodies in mean motion resonance like 55 CNC and Gliese 876. The trapping mechanism and the long term evolution will be explored with numerical tools for the detection of chaotic behaviour. Different migration models will be used to test the probability of capture in resonance. Project 3.2: *Evolution of minor bodies populations in the Solar System* A natural question about Trojan asteroids is: did they form where they are now and did they survive to the orbital evolution of their host planets? A recent model proposed at the Observatory of Nice assumes that both Jupiter and Saturn migrated away from their original formation site at the end of the planetesimal phase. During this migration the planets would have crossed a 2:1 mean motion resonance that might have destabilized the Trojan asteroids. Via numerical integration we are evaluating the odds that such an event really occurred in the solar systems and the possible consequences on a primordial Trojan population of Jupiter. Project 3.3: *Scientific support to Space missions ROSETTA and BepiColombo* As co-Investigators of the ROSETTA mission on the short term we are involved in the planning of the asteroidal flybys in 2008 and 2010. The data analysis will reveal the density and superficial composition of the asteroids and the possible presence of a satellite. These data will be of paramount importance for modelling the collisional evolution of asteroids. We are also co-investigators in the Bepi-Colombo mission to Mercury. This ESA mission is still in its initial phase and it requires scientific support in the definition of the mission goals. The science requirements will direct the technical design of the instruments on board of the spacecraft.
4.b	Risorse personale
	[professori ordinari, associati, ricercatori e dottorandi, borsisti post dottorato, assegnasti, personale tecnico-amministrativo] **STAFF** Francesco Marzari (RU) Sabino Matarrese (PO) Luciano Nobili (PA) Ornella Pantano (RU) Roberto Turolla (PA) Vittorio Vanzani (PO) **POST DOCTORAL FELLOWS** Luca Zampieri (A) Sergei B. Popov (PD) **PHD STUDENTS** Nicola Bartolo Valentina Bianchin Michele Liguori Matteo Viel Valentina Granato

5.b	Risorse finanziarie [media quinquennale]
	[la somma di finanziamento ordinario d'Ateneo finanziamenti specifici d'ateneo, finanziamenti specifici da enti di ricerca locali, nazionali e internazionali, finanziamenti da contratti con enti privati.] Research line 1: *Astrophysics of Neutron Stars* (2001-2005) MIUR, PRIN: 13.0 k€ (2001-2005) INAF, PRIN: 1.0 k€ (2001-2005) ATENEO, ex60%: 6.5 k€ (2001-2005) TOTAL: 20.5 k€ Research line 2: *Cosmology* (2001-2005) MIUR, PRIN: 10.0 k€ (2001-2005) INAF: 2.0 k€ (2001-2005) INFN: 4.8 k€ (2001-2005) ASI: 3.0 k€ (2001-2005) ATENEO, ex60%: 6.5 k€ (2001-2005) TOTAL: 26.3 k€ Research Line 3: *Physics and dynamics of planets and minor bodies* (2001-2005) MIUR, PRIN: 11.0 k€ (2001-2005) ASI: 3.0 k€ (2001-2005) ATENEO, ex60%: 6.5 k€ (2001-2005) TOTAL: 20.5 k€
7	Rapporti con altri istituti di ricerca a livello locale, nazionale e internazionale
7.a	*[specificare concretamente quanto indicato sotto collaborazioni istituzionalizzate indicate al punto 1 della scheda di Dipartimento]* INFN, ASI, INAF
7.b	*[Indicare collaborazioni personali non istituzionalizzate ma rilevanti per il programma]* International collaborations: Max Planck Institut für extraterrestrische Physik, Garching, Germany; Mullard Space Science Laboratory, University College London, UK; Goddard Space Flight Center, NASA, Greenbelt, USA; Smithsonian Astrophysical Observatory, Cambridge, USA; Observatoire Astronomique, Strasbourg, France; Sternberg Astronomical Institute, Moscow, Russia; National Institute for Space Research, Utrecht, The Netherlands; Institute of Astronomy, Cambridge, UK; Institute for Astronomy, Edinburgh, UK; Department of Astrophysics, University of Oxford UK; Astronomy Centre, Sussex UK; Institute for Cosmology and Gravitation, University of Portsmouth UK; Institute of Theoretical Astrophysics, University of Oslo, Norway; Department of Astronomy, University of Texas at Austin, USA; Fermilab, Batavia, Illinois USA; Physics Department, University of Chicago, Illinois USA; Physics Department, McGill University, Montreal Canada; CERN, Geneva, Switzerland; Centro Atomico, Bariloche Argentina; Max Planck Institut für Astrophysik, Garching, Germany; Department of Physics and Astronomy, UPENN, Philadelphia USA; Princeton University Observatory, Princeton USA; Observatoire de la Cote d'Azur, Nice, France;

	International Center for Theoretical Physics “Abdus Salam”, Trieste, Italy; Planetary Science Institute, Tucson, USA; Dept. of Aerospace Engineering, University of Michigan, Ann Arbor, USA; Observatoire de Nice, Nice, France; Obsevatoire de Paris, Meudon, France. National collaborations: Istituto Nazionale di Astrofisica, sezione di Padova; Istituto Nazionale di Astrofisica, Sezione di Roma; Istituto Nazionale di Astrofisica, Sezione di Milano; Università dell’Insubria; Università di Milano-Bicocca; SISSA, Trieste; Università di Roma, Tor Vergata; Università di Roma TRE; Università di Bologna; Scuola Normale Superiore, Pisa; CNUCE-CNR, Pisa; Dipartimento di Ingegneria Meccanica, Padova; Dipartimento di Fisica, Pisa; Istituto Nazionale di Astrofisica, sezione di Trieste.
9	Altre attività rilevanti per la ricerca, a livello di Programma
	[organizzazione di seminari e convegni, partecipazione a seminari e convegni, ecc..] ORGANIZATION OF CONFERENCES **Sabino Matarrese:** Chair of the Session on Dark Energy, National Meeting on “Problemi Attuali di Fisica Teorica”, Vietri sul Mare, April 2001 Co-Director First INAF-INFN National School on Astroparticle Physics, Bertinoro, October 2001 Member of the Scientific Organizing Committee VII National Cosmology Conference, Monteporzio, November 2002 Member of the Scientific Committee Pisa Week on Large Scale Structures and Cosmic Microwave Background Radiation, Pisa, May 2003 Member of the Scientific Organizing Committee, International School on Cosmology and Gravitation “The Polarization of the Cosmic Microwave Background”, Villa Mondragone, Frascati, September 2003 Member of the Scientific Organizing Committee International Conference “New Directions in Physics Beyond the Standard Model”, Pisa, May-June 2004 Co-Director National School in Astrophysics (VII cycle) , Asiago, September 2004 Member of the Scientific Organizing Committee, International (UCLA-SNS) Workshop “Cosmic Connections”, Quarrata, April 2005 INVITED TALKS S. Matarrese: “Non-standard aspects of inflationary perturbations”, invited talk at the CMBnet Workshop, Villa Mondragone, Frascati, June, 2001 S. Matarrese: “Cosmology and Particle Physics”, invited talk at SIF at LXXXVII National Conference, Milano, September 2001

	S. Matarrese: "Inflation and Dark Energy", invited lectures at the VIII-th Argentinian Symposium of Theoretical Physics of Particles and Fields, Bariloche, January 2003 S. Matarrese: "Inflation and non-Gausssianities", invited talk at the 2-nd CMBnet Workshop on Science and Parameter Extraction, Oxford, February 2003 S. Matarrese: "New developments in inflationary cosmology", CERN Theoretical seminar, invited, March 2003 S. Matarrese: "Dark Energy in the Universe: theory vs. observations", invited talk at the X-th International Workshop on Neutrino Oscillations, Venice, March 2003 S. Matarrese: "The Early Universe", invited talk at SAIT National Conference, Trieste, April 2003. S. Matarrese: "Non-Gaussian Signals from Inflation", invited talk at Scuola Normale Superiore, Pisa, April 2003 S. Matarrese: "Introduction to Numerical Cosmology", invited talk at the School on Applications of Numerical Computing to Science and Engineering, Padova, July 2003 S. Matarrese: "Non-Gaussian signals from the Early Universe", invited talk at the Non-Linear Cosmology Programme Workshop, Nice, July 2003 S. Matarrese: "Inflation", lectures at the International School on Cosmology and Gravitation "The Polarization of the Cosmic Microwave Background", Villa Mondragone, Frascati, September 2003 S. Matarrese: "Modern Cosmology: The Legacy of Christian Doppler", invited talk ar the International Symposium on Christian Doppler's Legacy, Venice, November 2003 S. Matarrese: "Materia ed Energia Oscura nell'Universo: evidenze osservative e modelli teorici", Physics Colloquia 2003, Physics Department, Milano, December 2003 S. Matarrese: "The Quest for Primordial non-Gaussianity oin CMB data", invited talk at the 2-nd Planck Symposium and Consortium Meeting, Orsay, January 2004 S. Matarrese: "Primordial non-Gaussianity" invited talk at the 20th IAP colloquium on Cosmic Microwave Background physics and observation, July 2004 A. Masiero, S. Matarrese & A. Riotto: "Dark Matter and Dark Energy as a window to new physics", invited talk at the COSPAR Meeting, Paris, July 2004 S. Matarrese: "The quest for non-Gaussianity in initial data", invited talk at Large-Scale Reconstruction Workshop, Nice, August-September 2004 S. Matarrese: "The Quest for non-Gaussian Primordial Fluctuations", Astrophysics Seminar at the ETHZ Institute of Astronomy, Zurich, November 2004 S. Matarrese: "Energia Oscura: Una sfida per la cosmologia teorica", invited talk at the Meeting of the "Accademia detta dei Quaranta", Roma, May 2005

S. Matarrese: "Surprises from Second-Order Cosmological Perturbation Theory", invited talk at the VIII Paris Cosmology Colloquium "WMAP and the Early Universe", December 2004

S. Matarrese: "Dynamical effects of non-linear cosmological perturbations", invited talk at the ICTP Meeting on Non-Linear Cosmology: Turbulence and Fields, Trieste, May 2005

S. Matarrese: "Cosmic Acceleration without Dark Energy", invited seminar at ESO Garching, June 2005

S. Matarrese: "Cosmic Acceleration without Dark Energy", invited talk at the IX Paris Cosmology Colloquium "Physics of the Early Universe confronts Observations", July 2005

S. Matarrese: "Four Lectures on Inflation", lectures given at "Novicosmo, International School", Novigrad, September 2005

S. Matarrese: "The Early Universe", invited talk at the Workshop "40 Years of Cosmic Microwave Background", Villa Mondragone, Frascati, October 2005

S. Matarrese: "Dark Energy", invited talk at XCI SIF National Conference, Catania, September 2005

Roberto Turolla:

ORGANIZATION OF CONFERENCES

Co-Chair of the session "Radiative Transfer in Relativistic Astrophysics" at the 9th Marcel Grossmann Meeting, Rio de Janeiro, Brazil, July 20-26, 2003

Member of the Scientific Organizing Commitee, "III Congresso Nazionale Oggetti Compatti", Osservatorio di Roma, December 9-11, 2003

Chair of the workshop "IV Congresso Nazionale Oggetti Compatti", Dipartimento di Fisica, Università di Padova, November 23-25, 2005

Co-chair of the conference "Isolated Neutron Stars: from the Interior to the Surface", London, UK, April 24-28, 2006

Member of the Scientific Organizing Committee, 36th COSPAR Scientific Assembly, Session "Different Manifestations of Neutron Stars", Beijing, China, July 16-23, 2006

INVITED TALKS

R. Turolla, "Spectral Signatures of Super-strong Magnetic Fields", invited talk, 15th SIGRAV Conference, Monte Porzio (RM), Italy, September 9-12, 2003

R. Turolla, "Radiative Transfer in Astrophysical Sources: Future Perspectives", invited talk, session APT7, 9th Marcel Grossmann Meeting, Rio de Janeiro, Brazil, July 20-26,

	2003 R. Turolla, “Getting to Grips with Neutron Star Surface”, invited talk at the workshop “Neutron Star: Structure and Cooling”, Trento, Italy, September 20-25, 2004 R. Turolla, R. Turolla, S. Merereghetti, A Tiengo, P. Esposito, D. Gőtz, L. Stella, GL. Israel, N. Rea, M. Feroci, S. Zane, “SGR 1806-20 in the pre-Giant Flare Epoch”, invited talk at the workshop “Neutron Stars at the Crossroad of Fundamental Physics”, Vancouver (Canada), August 9-13, 2005 R. Turolla, “SGR 1806-20: A Journey into Frenzy and Back”, invited talk at the workshop “Quarks, Leptons and Hadrons in Compact Stars”, Trento, Italy, September 12-17, 2005 INVITED TALKS **Francesco Marzari:** F. Marzari, “Dynamics of Trojans”, invited talk at the workshop on “Search for Trojans with ASTROVIRTEL”, Garching, Germany, September 2001. F. Marzari, “Spacecraft dynamics around a comet”, invited talk at the workshop on “ROSETTA mission, the OSIRIS camera”, Lindau, Germany 2002. F. Marzari, “Stabilità degli asteroidi Troiani”, IV Convegno Nazionale di Scienze Planetarie. Bormio, 20-26 Gennaio, 2002.
11	Prodotti della ricerca
11.b	*[per ogni anno del quinquennio la quantità totale dei prodotti del programma secondo la tipologia CINECA, indicare anche eventuali prodotti che non rientrano in questa tipologia.]* Research line 1: *Astrophysics of Neutron Stars* Publications in international refereed journals (2001-2005): **31** 2005 – 10 2004 – 8 2003 – 5 2002 – 2 2001 – 6 Conference proceedings (2001-2005): **20** 2005 – 3 2004 – 7 2003 – 0 2002 – 4 2001 – 6 Research line 2: *Cosmology*

	Publications in international refereed journals (2001-2005): **58** 2005 – 14 2004 – 14 2003 – 10 2002 – 14 2001 – 6 Conference proceedings (2001-2005): **5** 2005 – 1 2004 – 1 2003 – 1 2002 – 0 2001 – 2 Research Line 3: *Physics and dynamics of planets and minor bodies* Publications in international refereed journals (2001-2005): **28** 2005 – 7 2004 – 6 2003 – 4 2002 – 9 2001 – 2 Conference proceedings (2001-2005): **41** 2005 – 8 2004 – 14 2003 – 8 2002 – 4 2001 - 7
11.c	*[indicare i prodotti più rappresentativi con un massimo di 5 per l'intero quinquennio]* *U. Frisch, S. Matarrese, R. Mohayaee & A. Sobolevski, "A reconstruction of the initial conditions of the universe by optimal mass transportation", Nature **417** (2002) 260-262* *N. Bartolo, E. Komatsu, S. Matarrese & A. Riotto, "Non-Gaussianity from Inflation: Theory and Observations", Phys. Rept. **402** (2004) 103-266* *R. Turolla, S. Zane & J.J. Drake, "Bare quark stars or naked neutron stars ? The case of RX J1856.5-3754", ApJ **603** (2004) , 265-282* *S. Zane, R. Turolla, L. Stella & A. Treves, "Proton cyclotron line in thermal spectra of ultra-magnetized neutron stars", ApJ **560** (2001), 384-389* *F. Marzari & S.J. Weidenschilling, "Eccentric Extrasolar Planets: The Jumping Jupiter Model", Icarus **156** (2002), 570-579*