AUTHOR: O. La Marle, Astrophysics program scientist
CNES, 2 place Maurice Quentin, 75039 Paris, France.

Astrophysics

Fig. 1

COROT

The COROT mission ended in November 2012, after having doubled its optimal lifetime. COROT recorded the flux of more than 150 000 stars in different areas of the Galaxy, for duration of up to six months. Thirty-four COROT exoplanets have been confirmed and characterized so far, and several hundred candidates are awaiting confirmation. COROT also promoted asteroseismology as a powerful tool for stellar physics and galactic studies.

The COROT exoplanets were systematically "weighted" by radial velocity measures from the ground. The COROT family is very heterogeneous with planets nearing the brown dwarf domain, and others in the range of mini-Neptunes and down to the first telluric super-Earth.

COROT detected and measured solar-like oscillations in various types of stars. The detection of oscillations in red giants opened a new era in galactic studies, with numerous developments ongoing on ground and in space (OGLE, KEPLER II, TESS, PLATO…).

HERSCHEL

The ESA far-infrared observatory HERSCHEL mission ended in April 2013. The HERSCHEL legacy is significant. Star-forming galaxies, the so-called "starburst galaxies", draw their activity from gas infall rather than from mergers; in addition, they evolve according to a common "main sequence". Galactic observation highlighted the cycle of matter, from supersonic flows induced by massive stars explosions up to the collapse of prestellar cores. HERSCHEL detected numerous molecules, in particular water almost everywhere, in the interstellar medium, in Jupiter upper atmosphere where it showed that most of it was brought by comet Shoemaker-Levy 9 in 1994, and unexpectedly, around the Ceres asteroid.

The large contribution of CNRS and CEA laboratories to these results reflect their involvement in the instrument's development and use with CNES support.

PLANCK

ESA's PLANCK mission ended in October 2013, after having doubled its expected lifetime. It completed five sky surveys with its High Frequency Instrument (HFI) and eight with its Low Frequency Instrument (LFI), versus two planned in the original mission. In April 2013, PLANCK delivered the results of the first two surveys: the best map ever of the Cosmic Microwave Background (CMB, the relic of the first electromagnetic emission of the Universe) temperature fluctuations.

Statistical analysis of this map is noticeably in agreement with the theory of the Big Bang with an early inflation period. PLANCK updates the parameters of the model with an accuracy which allows ruling out of a majority of proposed models. The relative amounts of dark energy, dark matter and baryons are revised, as the Hubble constant and the age of the Universe.

Careful retrieval or control of systematics is still going on in order to deliver in 2014 maps of temperature and polarization based on the full set of surveys. CNRS teams which developed and operated HFI are leading this effort, backed by CNES.

Beside these great cosmological results, PLANCK data will provide a unique legacy for various themes through the delivery of a number of additional maps (e.g., polarization of the Galactic microwave emission) and catalogues (e.g., galaxy clusters).

GAIA

ESA's GAIA mission was launched on December 19, 2013 by a Soyouz rocket from the Kourou French Space Port. After the ongoing in orbit test and calibration phase, GAIA will measure the position and velocity of one billion objects of our galaxy with an accuracy of a few millionths of a degree. Its scanning of the whole sky will also provide a priceless database of spectroscopic data for Solar System small objects, stars, galaxies and exoplanets. More than

Fig. 2

400 people from European laboratories, including about 100 members from French research institutes and from CNES, are involved in the challenging GAIA data processing (Fig. 1). The first partial catalogues should be available by 2015 and the final ones will be delivered by 2019.

JWST/MIRI

MIRI (Mid-InfraRed Instrument) is a spectro-imaging instrument with a coronographic mode developed by a consortium of European laboratories, among which several French ones supported by CNES. It will be a key component of the JWST mission, in particular in the field of stellar disks and exoplanets' studies. MIRI, a part of the European contribution to the JWST, was delivered to NASA in May 2012 (Fig. 2). The integration and test phase into the JWST Instrument Module has started with success. JWST is planned to launch in 2018.

EUCLID

EUCLID is the second ESA *Cosmic Vision* program medium mission (M2). It is dedicated to the study of dark matter and dark energy. These unknown components, which stand for respectively 26% and 69% of the content of the Universe, question the validity of Einstein's General Relativity at cosmological scales. Scheduled for launch in 2020, EUCLID will address these issues by probing the large scale structures and probing the galaxies gravitational distortion caused by dark matter. The EUCLID survey will provide unique legacy science in various fields of astrophysics, from the detection of exoplanets and the stellar physics in the Milky Way to the formation and evolution of the galaxies. French laboratories of CNRS and CEA, supported by CNES, are leading the international effort to develop the EUCLID instrumentation and the data processing system.

SVOM

SVOM is a French-Chinese mission aiming to study Gamma-Ray Bursts (GRBs) – the highest energy phenomena observed in the Universe. Launch is expected by 2020. SVOM, complemented by ground follow-up, will provide unprecedented multi wavelength follow-up on the GRBs, especially on very far ones. France, through CNES, CEA and CNRS laboratories, provides key elements of the mission including the wide-field X-ray and gamma-ray camera ECLAIRs and the alert system.

PLATO

PLATO is the third ESA *Cosmic Vision* program medium mission (M3). It will detect and fully characterize planetary systems of all kinds including Earth-like planets around solar-like stars by precise continuous photometry of the latter. PLATO was selected in February 2014 and should be launched in 2024. French laboratories supported by CNES contribute significantly to the scientific payload and to ground data processing preparation.

The hot and energetic Universe, theme of the next ESA large mission

In November 2013, ESA selected the hot and energetic Universe as the science theme for its next *Cosmic Vision* large mission (L2), to be launched in 2028. This X-ray observatory will address some of the most fundamental issues in contemporary astrophysics and cosmology, such as black holes and matter under extreme conditions, formation and co-evolution of galaxies and of their central black holes, clusters and large-scale structures, and life cycles of matter and energy. French laboratories from CNRS and CEA, supported by CNES, are involved in the mission's preparation.

[Fig. 1]
The GAIA Data Processing Center at CNES Toulouse Space Center will harbour about 40% of the overall GAIA data processing. At the end of the mission 6 000 processing cores will be necessary.
© CNES

[Fig. 2]
MIRI Flight Model under inspection at NASA's Goddard Space Flight Center after its delivery.
© NASA/GSFC/Chris Gunn

AUTHOR: F.-X. Désert[(1)]

[(1)] IPAG, UMR 5274, 414 rue de la piscine BP 53, 38041 Grenoble, France.

Astrophysics

Precision cosmology with the PLANCK satellite

La cosmologie de précision avec le satellite Planck

➔ **Abstract:** In March 2013, nine all-sky PLANCK maps were made public. They cover the frequency range of 30 to 857 GHz, and an angular resolution that can reach five arcminutes. These maps reveal, with an unprecedented sensitivity, the angular fluctuations of the temperature of the Cosmic Microwave Background. The only models of the Universe compatible with these data are based on the paradigm of the inflationary Big Bang.

➔ **Résumé :** En mars 2013, neuf cartes couvrant tout le ciel ont été rendues publiques avec des fréquences allant de 30 à 857 GHz, et une résolution angulaire allant jusqu'à cinq minutes d'arc. Ces cartes révèlent, avec une sensibilité sans précédent, les fluctuations angulaires de température du rayonnement fossile à 3 K. Les seuls modèles d'Univers compatibles avec ces données sont fondés sur le paradigme du Big Bang inflationnaire.

The PLANCK satellite is a medium-sized ESA mission. It was launched, along with the HERSCHEL Space Observatory, in May 2009 on an Ariane 5 rocket. It has been in orbit since that day, around the Lagrangian L2 point of the Sun-Earth system. It is dedicated to the precise measurement of the Cosmic Microwave Background (CMB) which is a 2.725 Kelvin black-body relic that emerged from the hot and dense phase at the beginning of the Universe. Small variations of temperature (called anisotropies) have been observed by the two previous satellites COBE and WMAP, from NASA, along with sub-orbital and ground-based experiments. The PLANCK satellite has just achieved the goal of extracting most of the cosmological information that is embedded in the statistics of the anisotropies of the CMB in temperature.

For that purpose, two instruments share the focal plane of the PLANCK 1.5 m telescope. The low-frequency instrument (LFI), led by Italy, has 22 radiometers at 20 K covering the range of 30 to 70 GHz with a black-body reference at 4 K. The high-frequency instrument (HFI), led by France, uses 52 bolometers cooled to 0.1 K. Both provide a sensitivity which is limited in part by the photon shot noise of the 2.725 K background itself. The mission scanning strategy was designed so as to obtain a near full sky coverage every six months. Five surveys have been obtained by HFI during its cold phase. Eight surveys have been gathered by LFI. PLANCK retired in October 2013 on a parking orbit around the Sun, after four and a half years of activity.

The analysis of the data has to come up with solutions concerning three main problems: dealing with calibration, removing or controlling systematic effects and removing or controlling foreground emissions. The 2013 data release is described in Ref. [1] and references therein. It can be accessed at this web page [http://www.sciops.esa.int/index.php?project=planck&page=Planck_Legacy_Archive]. It only concerns the first 15.5 months of survey data called the nominal mission. It deals only with temperature data. No polarization products are given at this stage.

We will now summarize the main scientific results which are related to the CMB. Detailed results can be read in the 30 papers dedicated to the 2013 PLANCK data release. Fig. 1 shows one of the best renditions of the CMB anisotropies, obtained by PLANCK after foregrounds have been removed using their spectral and spatial diversities. Fig. 2 shows the CMB power spectrum that represents the variance of the brightness fluctuations in bins of angular scales. Seven acoustic peaks are clearly seen, which represent the sign posts of early matter density fluctuations set in motion early on in the Universe. Early gravitational concentrations can rebound and oscillate several times depending on the size of the fluctuations. The generic power spectrum is only explained within the framework of the Big Bang scenario of the Universe.

There are only seven parameters describing the dynamics of the Universe and its energy and matter contents. They are sufficient to provide an acceptable fit to the statistics: a reduced χ^2 statistics of 1.05 ± 0.03 is obtained with 2 450 degrees of freedom. The age of the Universe (13 800 ± 0.037 billion years), its energy (dark energy makes 69% of the critical density) and matter contents (dark matter makes 26% and ordinary matter makes 5%) are determined with a precision at the percent level. The best fit curve in Fig. 2 favors the inflation-motivated cosmologies. In particular, the spatial curvature of the Universe is compatible with zero within 7.10^{-4} and the power law of the initial density fluctuations has an exponent significantly different from 1. The parameters describing the Universe are in broad agreement with those

[Fig. 1]
Mollweide all-sky projection map of the CMB anisotropies as measured by PLANCK in the nominal mission. The galactic plane, that would appear as a middle horizontal line has been inpainted. For the other 95% of the map, the anisotropies that are shown are obtained by combining maps at several frequencies (the most important being the 143 GHz one) so as to null foreground components. The brightness range is less than 2 parts in 10 thousands of the CMB temperature.
© courtesy of ESA & the PLANCK Collaboration

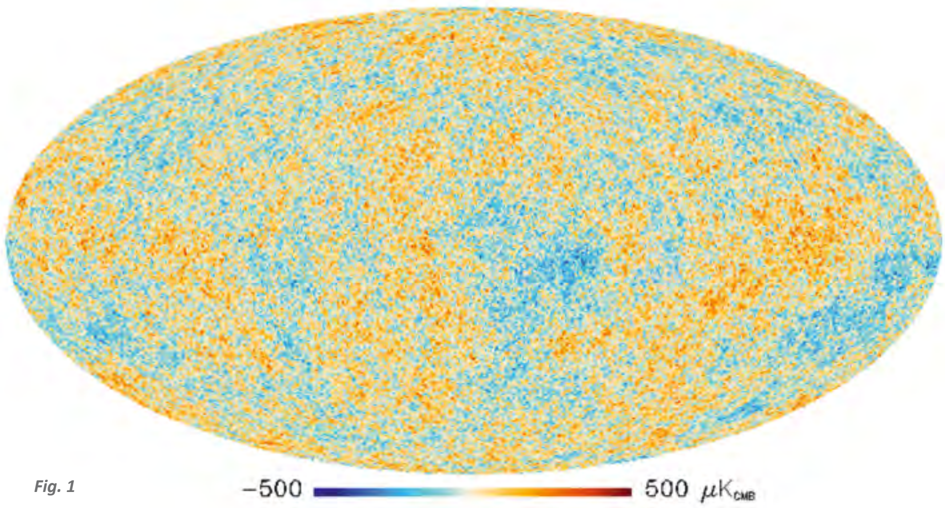

Fig. 1

[Fig. 2]
Statistical analysis of the PLANCK two-point correlation function for the high-galactic-latitude sky. The power spectrum of the anisotropies is shown as a function of the multipole number (red points with error bars, cosmic variance in pale green). It represents the square of the fluctuation rms in bins of angular scales (upper horizontal scale). The best-fit model is shown as the green curve.
© courtesy of ESA & the PLANCK Collaboration

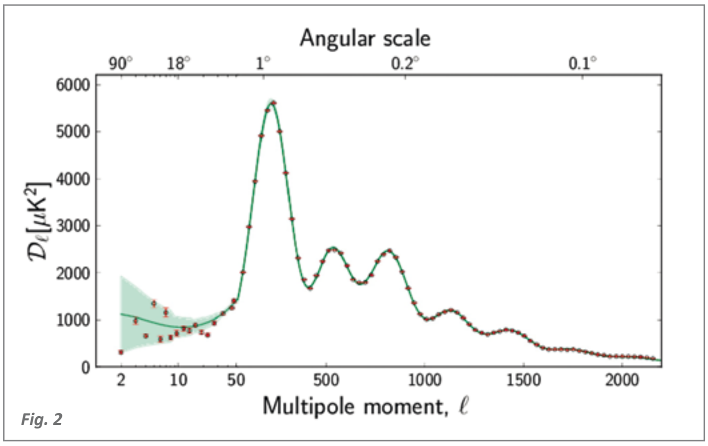

Fig. 2

[Fig. 3]
First submillimeter all-sky map from PLANCK showing the interstellar dust emission in our galaxy. This emission at 857 GHz is used in the foreground removal process leading to the measurement of the CMB anisotropies at lower frequencies.
© courtesy of ESA & the PLANCK Collaboration

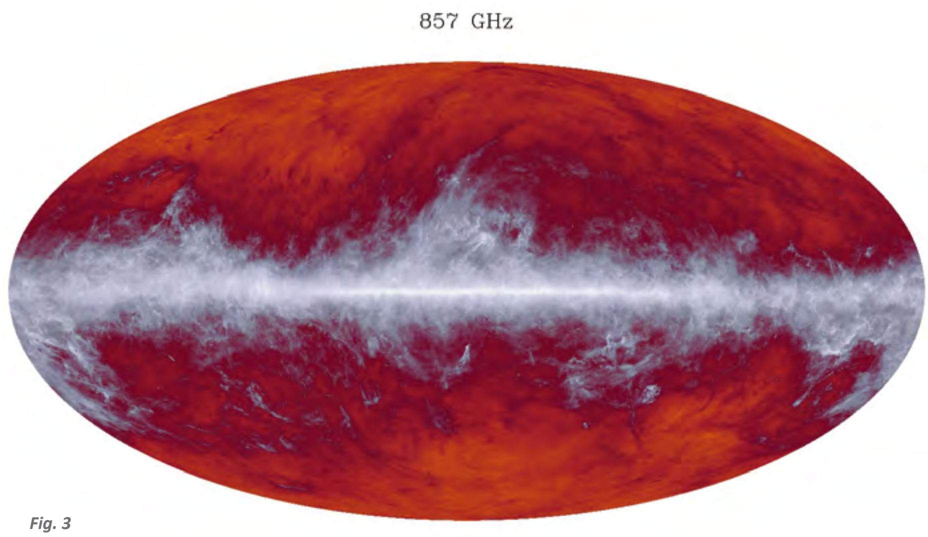

Fig. 3

obtained by other cosmological probes. The PLANCK surveys also bring key contributions to the study of large-scale structures in the Universe via the weak-lensing effect, the cosmic infrared background and the measurement of clusters of galaxies, and to the study of dust (Fig. 3) and synchrotron emission in our galaxy.
The 2014 data release will concern all PLANCK surveys and the polarization information.

REFERENCES

[1] Planck Collaboration: Ade, P. A. R., Aghanim, N., Armitage-Caplan, C., *et al.* (2013), Planck 2013 results. I. Overview of products and scientific results, *Astron. & Astrophys.*, submitted, http://arxiv.org/abs/1303.5062.

AUTHOR: B. Mosser[(1)]

[(1)] *LESIA, UMR 8109, 5 place Jules Janssen, 92195 Meudon, France.*

Astrophysics

Red giant (r)evolution

Évolution/révolution des géantes rouges

➔ Abstract: COROT has revealed that red giant stars sustain solar-like oscillations. Before COROT, ground-based asteroseismic observations gave unclear results. Now, we can use these oscillations to measure stellar masses and radii, identify the stellar evolutionary stages and map the Galaxy. With KEPLER measurements, we have access to the core rotation. Recently, it was made clear that semi-regular variability is also due to such oscillations.

➔ Résumé : Le satellite CoRoT a ouvert de nombreuses voies en physique stellaire, dont l'étude sismique des géantes rouges. De quelques observations au sol, avant CoRoT, posant plus de questions qu'elles n'en résolvaient, on est passé à une étude physique détaillée s'appuyant sur des observables inédites. La mesure des modes mixtes qui sondent le cœur de ces géantes a ainsi permis de mesurer l'état d'évolution des géantes puis, avec Kepler, la rotation de leur cœur.

Red giant seismology is an exquisite surprise provided by the space mission COROT at first, then by KEPLER. The analysis of a wealth of light curves recorded with unique length, continuity and photometric precision has revealed many secrets [1]. The most striking results, up to now, are provided by the observation of mixed modes. Such modes result from the coupling of gravity waves, propagating in the radiative core region, with pressure waves propagating in the stellar envelope. They directly reveal information from the stellar core: the nature of the nuclear reaction and the mean core rotation rate.

From structure homology to seismic scaling relations

Red giants are divided in three main regions: a thin hydrogen-burning shell lies between the dense helium core and the thick, mostly convective envelope. This ensures that the interior structure is highly homologous. This property translates in a very typical solar-like oscillation spectrum revealed by COROT observations and expressed by the concept of universal red giant oscillation pattern [2], as an alternative form to the usual asymptotic expansion. Based on this concept, a method has been suggested to provide an unambiguous identification of the oscillations and a high-precision measurement of the large frequency separation that gives structure to the oscillation pattern. This is highly useful, either for performing ensemble asteroseismology [3] or for modeling individual stars [4].

As a result of homology, the red giant global seismic parameters conform to a large number of scaling relations (Fig. 1). Two parameters are especially important: the frequency large separation $\Delta\nu$ provides an estimate of the mean stellar density. The frequency ν_{max}, which corresponds to the maximum oscillation signal, is proportional to the stellar surface gravity. From spectroscopy, gravity is measured with a poor precision (200 or 300%), whereas it is constrained to the 1% level by asteroseismology. As a consequence, seismic relations with $\Delta\nu$ and ν_{max} can be used to provide proxies of the stellar masses and radii, with typical precisions about 10 and 5%, respectively [3].

An important consequence of the measurement of asteroseismic radii for field stars is the capability of estimating stellar distances. Miglio *et al.* [5] have shown that red giants represent a well-populated class of accurate distance indicators, spanning a large age range, which can be used to map and date the Galactic disk in the regions probed by observations made by COROT and KEPLER. They have determined precise distances for about 2 000 stars spread across nearly 15 kpc of the Galactic disk, exploring regions which are a long way from the solar neighbourhood (Fig. 2).

A direct view into the stellar core

In the Sun, asteroseismology performs very efficiently, except in the central region since pressure modes do not probe the core efficiently. In red giants, gravity modes are not present, but appear clearly through the coupling of gravity waves propagating in the core with pressure waves propagating in the envelope. A wealth of information has been provided by their analysis. The different mixed-mode patterns help distinguish helium-core burning giants in the red clump from hydrogen-shell burning giants on the RGB [6-7].

The capability of mixed modes to probe rotation in red giants is unfortunately limited by the observation length of COROT. The frequency resolution achieved with five-month-long runs has turned out to be insufficient to measure rotation.

[Fig. 1]
Superimposition of solar-like oscillation spectra, from the Sun to a semi-regular variable, showing that red giant oscillation spectra are governed by different scaling relations. All stars with a large separation (indicated in μHz) less than 40 μHz are red giants. The scaling relations concerning the background (dashed line) and the maximum oscillations signal (dotted line) show evidence of the close connection between seismic and convective properties.
© B. Mosser.

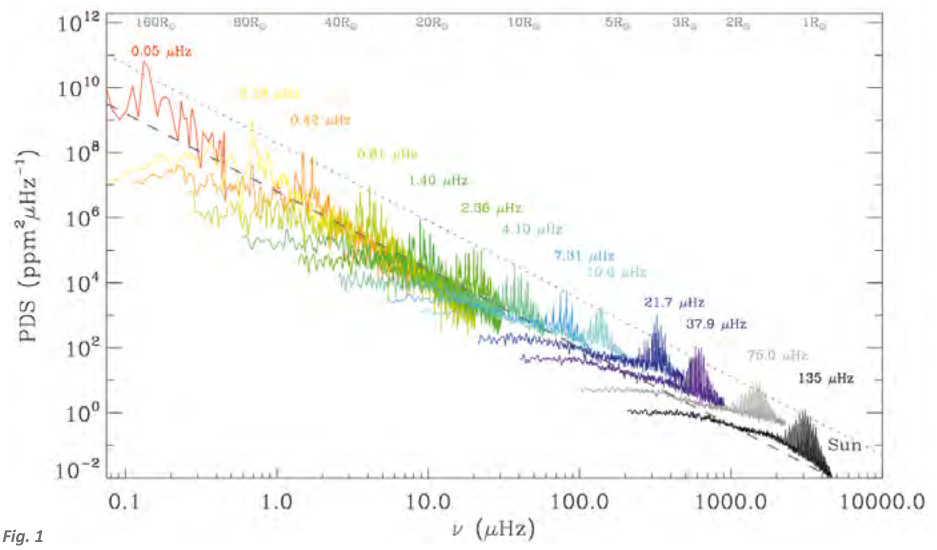

Fig. 1

[Fig. 2]
Solar-like oscillating G-K giants observed in several COROT fields of view and by Kepler: projection on the x-z plane perpendicular to the Galactic plane.
© from 2012EPJWC.1905012M.

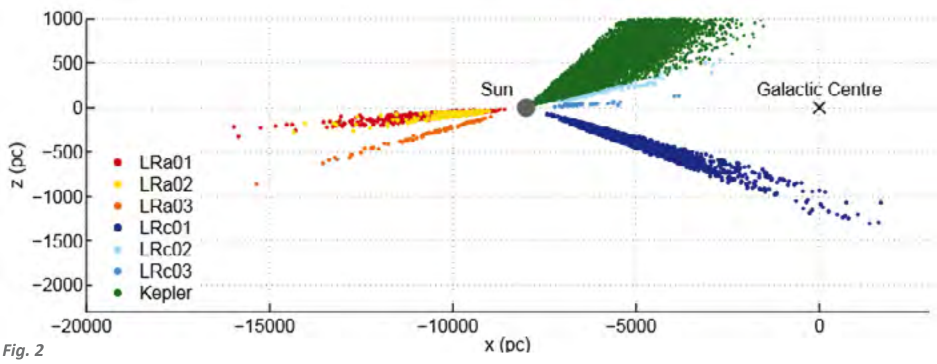

Fig. 2

Rotational splittings measured with KEPLER have highlighted a significant radial differential rotation [8]. Further observations reveal a small decrease of the mean core rotation rate of stars ascending the RGB [9]). Alternatively, an important spinning down is observed for red-clump stars compared to the red giant branch.

Semi-variability in evolved M giants was suspected to be due to solar-like oscillation. However, until recently, only indirect information was available to sustain this hypothesis. The question concerning the nature of these oscillations is now solved with KEPLER four-year-long observations [10]. According to scaling relations, such oscillations occur at very low frequency: at the tip of the RGB, oscillations periods are as high as 50 days. Such observations provide improved distance measurements and open the way to extragalactic asteroseismology, with the observations of M giants in the Magellanic Clouds. This work, as others, has highly benefitted either from the COROT observations or from the methods developed for COROT observations.

REFERENCES

[1] De Ridder, J., Barban, C., Baudin, F., *et al.* (2009), Non-radial oscillation modes with long lifetimes in giant stars, *Nature*, **459**, 398.

[2] Mosser, B., Belkacem, K., Goupil, M. J., *et al.* (2011a), The universal red-giant oscillation pattern. An automated determination with CoRoT data, *A&A*, **525**, L9.

[3] Mosser, B., Belkacem, K., Goupil, M. J., *et al.* (2010), Red giant seismic properties analyzed with CoRoT, *A&A*, **517**, A22.

[4] Baudin, F., Barban, C., Goupil, M. J., *et al.* (2012), Modeling a high-mass red giant observed by CoRoT, *A&A*, **538**, A73.

[5] Miglio, A., Chiappini, C., Morel, T., *et al.* (2013), Galactic archaeology: mapping and dating stellar populations with asteroseismology of red-giant stars, *MNRAS*, **429**, 423.

[6] Bedding, T. R., Mosser, B., Huber, D., *et al.* (2011), Gravity modes as a way to distinguish between hydrogen- and helium-burning red giant stars, *Nature*, **471**, 608.

[7] Mosser, B., Barban, C., Montalban, J., *et al*. (2011b), Mixed modes in red-giant stars observed with CoRoT, *A&A*, **532**, A86.

[8] Beck, P. G., Montalban, J., Kallinger, T., *et al.* (2011), Fast core rotation in red-giant stars revealed by gravity-dominated mixed modes, *Nature*, **481**, 55.

[9] Mosser, B., Goupil, M. J., Belkacem, K., *et al.* (2012), Spin down of the core rotation in red giants, *A&A*, **548**, A10.

[10] Mosser, B., Dziembowski, W., Belkacem, K., *et al.* (2013), Period-luminosity relations in evolved red giants explained by solar-like oscillations, *A&A*, **559**, A137.

AUTHOR: L. Vigroux[1]

[1] CEA, route Nationale, 91191 Gif sur Yvette Cedex, France.

Astrophysics

HERSCHEL opens new windows on the Universe

Herschel ouvre de nouvelles perspectives sur l'univers

➔ **Abstract:** With its three instruments, PACS, SPIRE and HIFI, and its 3.5 m diameter telescope, the HERSCHEL Space Observatory launched in 2009 has provided observations leading to transforma-tional science in several domains, such as star formation, early galaxy evolution and chemistry of the interstellar matter.

➔ **Résumé :** Avec ses trois instruments et son télescope de 3,50 m de diamètre, l'observatoire spatial Herschel, lancé en 2009 a fourni des observations qui ont permis des avancées considérables dans de nombreux domaines, et plus particulièrement pour la formation des étoiles, l'évolution des galaxies et la chimie du milieu interstellaire.

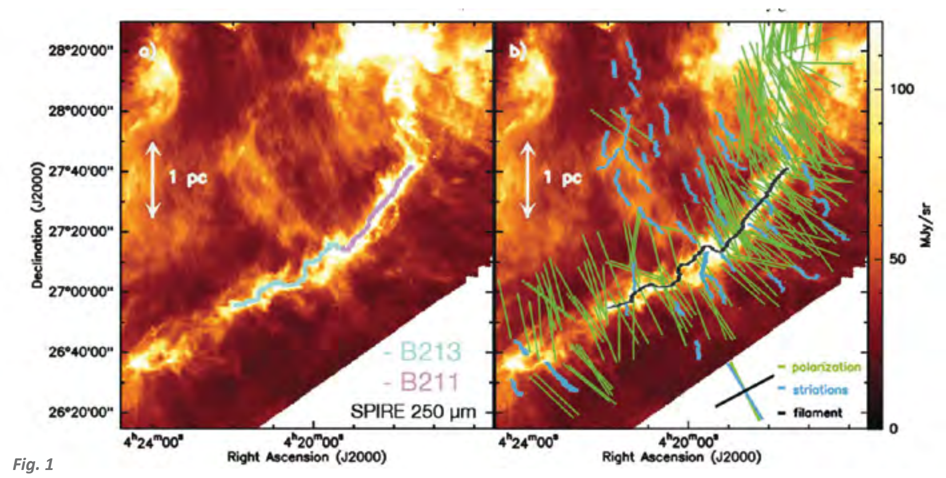

Fig. 1

[Fig. 1]
a) HERSCHEL/SPIRE image of star forming region in Taurus. The light blue and purple curves show the crests of filament.

b) Display of polarization vectors tracing the magnetic field orientation, overlaid on the HERSCHEL/SPIRE image. The magnetic field appears to be oriented perpendicular to the filament and roughly aligned with the general direction of the striations overlaid in blue.
© From [2]

The HERSCHEL Space Observatory has a long story. The first document describing what could be a mm space observatory were presented in the early 80s. Selected as one of the corner stone of the *Horizon 2000* ESA program, HERSCHEL was launched on May 14, 2009. Five years later, a good assessment of the HERSCHEL achievement can be made. Today, more than 900 scientific papers have been published, on almost every domain of astrophysics, from Solar System to Cosmology. In this short paper, it is not possible to report on all the results obtained from HERSCHEL's observations. I will focus on some of them, which I consider are breaking frontiers. Readers who would like a full overview can go to the Universe explored by HERSCHEL symposium web page (ESTEC/ESA, October, 15-18, 2013, http://HERSCHEL.esac.esa.int/TheUniverseExploredByHERSCHEL.shtml).

For a long time, there was a lack of information on the first steps in the formation of stars. Parent molecular clouds could be observed in radio and protostars, in infrared, but cold core phases, when molecular clouds fragments start to collapse to give birth to protostars, remained hidden: cold cores are very cold, a few tens K, and hidden by dust. HERSCHEL was the first observatory to observe these cold cores and the structure of molecular clouds on a small scale. The main surprise was that cold cores are all lying in filaments that design a skeleton inside the star forming molecular clouds. In addition, it was possible to map these filaments and to demonstrate that they have all a typical width of 0.1 pc, whatever star forming region is observed. This was totally unexpected, and most star formation theories assumed star formation to be randomly distributed in molecular clouds. The 0.1 pc scale corresponds

[Fig. 2]
Nearby galaxies spanning the whole galaxy Hubble sequence observed in the far infrared with the instrument PACS and SPIRE onboard the ESA HERSCHEL Observatory, and the MIPS instrument onboard the NASA SPITZER mission. Colors are created by combining a blue image from SPITZER, a green from PACS and a red from SPIRE. These observations have been obtained in the framework of the HERSCHEL KINGFISH key program (PI. R. Kennicutt, http://www.ast.cam.ac.uk/research/kingfish).
© Courtesy of M. Galamatez.

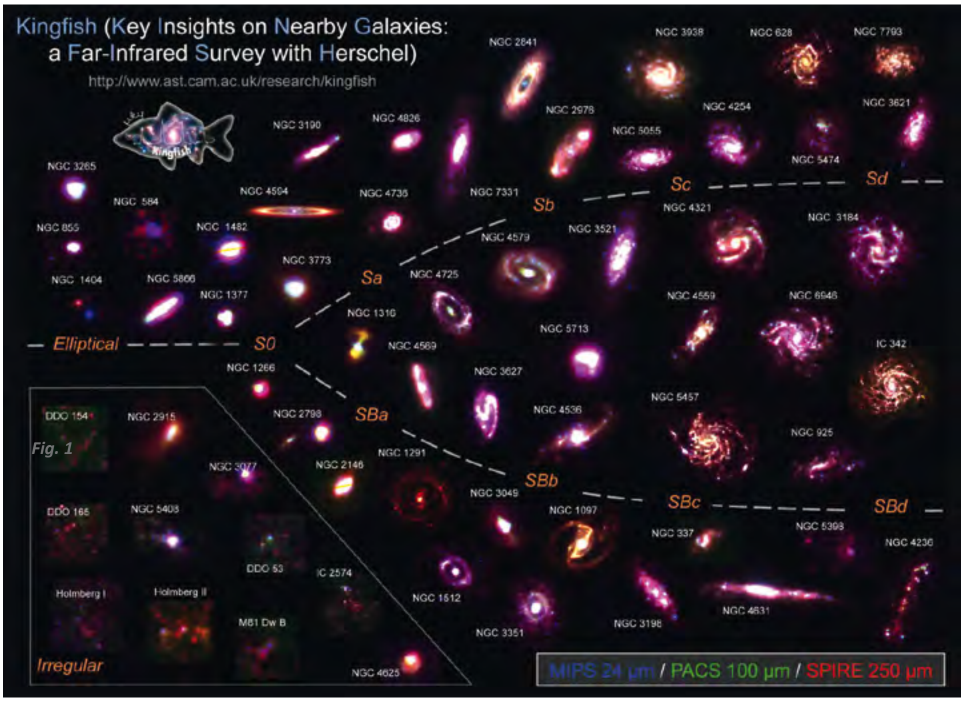

Fig. 2

to the transition from supersonic turbulence to subsonic turbulence in these clouds. Other observations have demonstrated that these filaments created by magnetic turbulence are growing by infall driven by gravity. Clouds become filamentary due to magnetic turbulence; filaments grow by gravitational infall, and when they reach a critical linear mass, they start fragmenting creating cold cores and coeval of similar masses along one filament (Fig. 1 a and b). The mass function of these cold cores is very similar to the mass function of protostars, which turn to be different from the mass function of molecular clumps and clouds. These results have given the solution of an old problem, the fight between turbulence and gravity. Theoreticians explained the long life-time of molecular clouds by turbulent pressure to sustain the cloud, while others claimed that gravity and fragmentation were required to form stars. These two opposite views are now included in a single process, where filaments are the tool to move from a turbulence-dominated regime to a gravity-dominated regime. A new paradigm has emerged from the HERSCHEL observations ([1-2] for a review).

Since IRAS in the early 80s, we have known that star forming galaxies radiate more energy in the far infrared than in the visible, due to heating of the interstellar dust to temperature ~20 K, which radiates in the far IR. HERSCHEL was the first infrared space observatory with enough sensitivity to probe galaxies from our neighbourhood (Fig. 2) to cosmological distances. Contrary to the canonical view of hierarchical merging of galaxies triggering strong starburst, HERSCHEL has demonstrated that mergers are playing a minor role, while the bulk of star formation is due to large galaxies sustaining a large star formation rate thanks to infall of cool gas falling along the filaments delimited by the web structure of the dark matter distribution [3]. Previous infrared missions have identified a Cosmic infrared Background due to the sum of the emission of unresolved galaxies. For the first time, HERSCHEL was able to resolve the galaxies emitting this CIB, and as a by-product, it is now possible to trace the history of star formation in the Universe in an unbiased way [4]. Deep surveys made with HERSCHEL allowed us to discover lensed distant galaxies with redshift from 4 to 6. More than a hundred of these galaxies have been identified, while only a few were known before HERSCHEL. Thanks to the gravitational lensing effect, they are bright enough for a follow up with mm interferometers, IRAM and ALMA, providing us for the first time with a possibility to study in details these primeval galaxies [5]. HERSCHEL observations are at the origin of a revolution in our understanding of early evolution of galaxies.

The spectrographic capabilities of HERSCHEL were used to study in detail the chemistry of the interstellar gas. Water has been found in many objects, either as vapour or as ices. For the first time, it was possible to follow the water trail along the stellar formation process, from ices to vapour. These measurements provide a clue to understand the origin of water in the Solar System and on Earth [6].

REFERENCES

[1] André, P., *et al.* (2013), From Filamentary Networks to Dense Cores in Molecular Clouds: toward a New Paradigm for Star Formation, *Astro-ph.*, arXiv:1312.6232.

[2] Palmeirim, P *et al.* (2013), HERSCHEL view of the Taurus B211/3 filament and striations: evidence of filamentary growth? *A&A*, **550**,38.

[3] Rodhighiero, G, *et al.* (2011), Lesser Role of Starbursts in Star Formation at z = 2, *ApJ*, **739**, 40.

[4] Béthermin, M., (2013), The redshift evolution of the distribution of star formation among dark matter halos as seen in the infrared, *A&A*, **557**, 66.

[5] Omont, A., *et al.* (2013), H_2O emission in high-z ultra-luminous infrared galaxies, *A&A*, **551**, 115.

[6] Karska, A, (2014), Far-infrared molecular lines from low- to high-mass star forming regions observed with Herschel, *A&A*, **562**, 45.