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ASTROMOL: moles de ciencia y divulgación

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Abstract

ASTROMOL is the nickname of the project "Consolider-Ingenio 2010 ASTROMOL, Molecular Astrophysics: The Herschel and ALMA era", a program that comes to an end soon and in which we have obtained important results and both scientific and technological advances. In this presentation we will discuss these results and the tools we have used to spread them to the society.

1 Introduction

ASTROMOL is the nickname of the CONSOLIDER INGENIO 2010 project ASTROMOL, Molecular Astrophysics: The Herschel and ALMA era, funded by the Spanish Ministry of Science and Innovation, MICINN (now the Ministry of Economy and Competitiveness, MINECO). ASTROMOL encompasses 12 interdisciplinary research groups in Astrophysics, Molecular Physics and Physical Chemistry, settled in several public research institutions and universities. The team is made up of more than 100 senior researchers, including permanent positions and tenure-track positions ("Ramón y Cajal" programme). This presentation is structured as follows: Sect. 2 What is Consolider?; Sect. 3 What is ASTROMOL?; Sect. 4 ASTROMOL goals; Sect. 5 ASTROMOL milestones; Sect. 6 Outreach in the ASTROMOL programme.

2 What is Consolider?

Increasing resources invested to create knowledge and improving the mechanisms used to transfer such knowledge so that it benefits society as a whole were top priorities of the European strategy for growth and jobs in 2007. INGENIO 2010, the research, development and innovation strategy, implemented this priority in Spain, being one of the main pillars in its national reform programme. Its objectives were to reduce the technological gap between

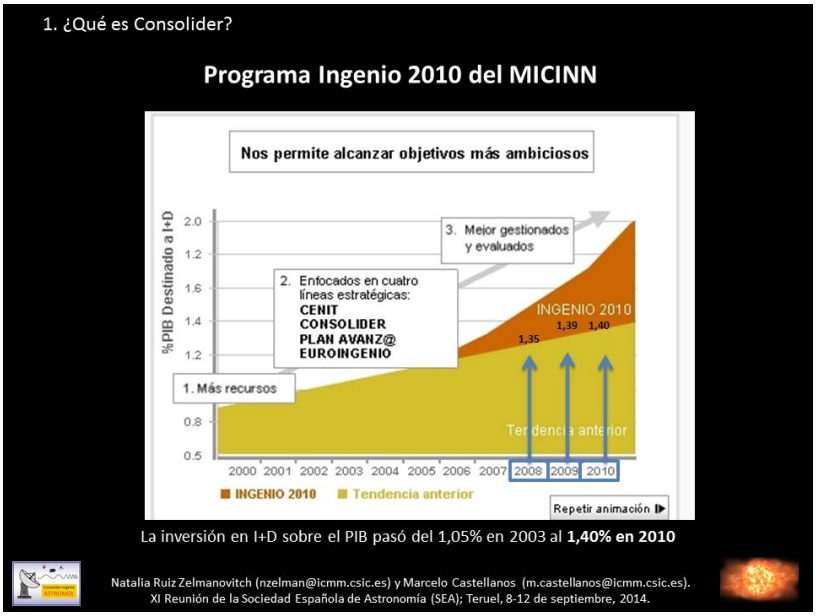

Figure 1: Investment in R&D of GDP grew from 1.05% in 2003 to 1.40% in 2010 [2, 3].

Spain and the rest of Europe and to achieve convergence as regards the information society (see Fig. 1). Measures adopted: More resources dedicated to R&D and innovation in the national budget. New strategic actions: Consolider and Cénit Programmes and Avanza Plan. Goals: Double investment in R&D to 2% of GDP. 1.12% in 2005, interim objective in 2008: 1.6% (it reached 1.35) and the final objective was to reach a 2% in 2010 (getting 1.40%)(see Fig. 2).

Some data:

– Five calls for proposals (2006–2010): EUR 320 M
– His intention was to mobilise EUR 2 billion in 4 years
– Duration of each program: 5 years
– Funding for ASTROMOL: EUR 4.8 M

3 What is ASTROMOL?

The CONSOLIDER-INGENIO project: "Molecular Astrophysics: The Herschel and Alma era" (ASTROMOL), started at the end of 2009. It has obtained an extension of one year (2015). The objective of the project is to make a multidisciplinary approach from different areas of science to increase our understanding of the molecules found in space through the use of the most powerful tools of observation we have at the moment: the Herschel Space Telescope and the ALMA interferometer (Atacama Large Millimeter/submillimeter Array).

In ASTROMOL scientists from diverse areas work together with a common goal: the

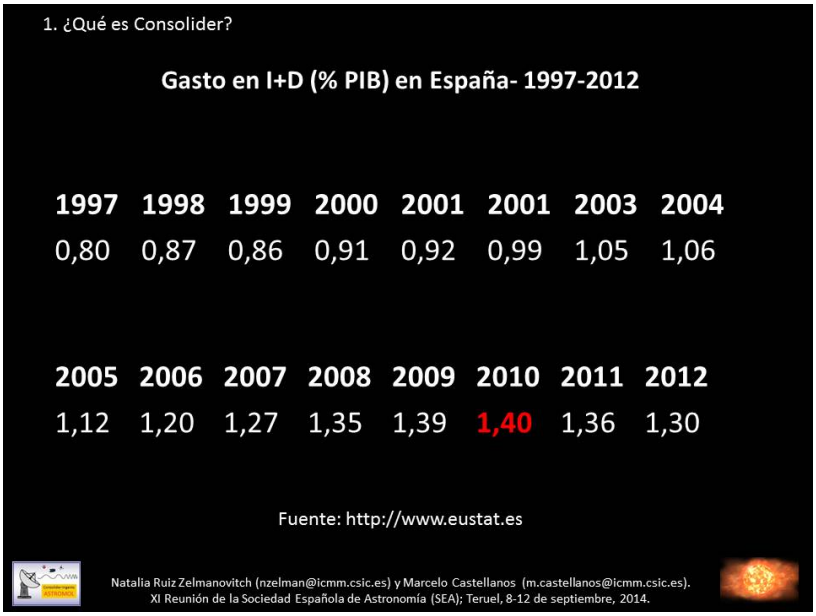

Figure 2: Investment in R&D (% of GDP) in Spain (1997–2012) [1].

understanding of the molecular universe. Molecules play a fundamental role in the evolution of the universe, its abundance and variety, and in the evolution of life by its richness in organic matter. For this reason, we talk about a Molecular Universe. Experts in laboratory spectroscopy, chemists, molecular physicists and astronomers have teamed up to study, with an innovative approach, these molecules found in space, trying to elucidate, not only which species are in each area, but also the implications they have on the physical and chemical processes that govern the universe.

ASTROMOL consists of 12 interdisciplinary groups of research in astrophysics, molecular physics, and physicochemical, established in several public research institutions and universities. The team is composed of more than 100 senior researchers, including permanent positions and tenure-track positions ("Ramón y Cajal" programme).

COORDINATOR: José Cernicharo (ICMM-CSIC). More tan 100 participants. Institutions: Consejo Superior de Investigaciones Científicas (CSIC) through the Instituto de Ciencia de Materiales de Madrid (2014–), the Instituto de Estructura de la Materia (grupo de Física Molecular) and the Centro de Astrobiología (CAB; 2009–2014). Instituto de Física Fundamental (grupo de Cálculos *ab initio* y Dinámicos), Instituto de Astrofísica de Andalucía (Grupo de Atmósferas Planetarias Terrestres), Observatorio Astronómico Nacional (IGN, grupo de Medio Interestelar y Circunestelar), Instituto de Astrofísica de Canarias (grupo de Transferencia de Radiación y Espectropolarimetría), Universidad de Valladolid (Grupo de Espectroscopía Molecular, unidad asociada al CSIC), Universidad Complutense de Madrid (Laboratorio de Dinámica de Reacciones Físicas y Espectroscopía Multifotónica y Grupo de Láseres y Haces Moleculares del Instituto Pluridisciplinar), Universidad Pablo de Olavide (Grupo de Espectroscopía Láser y Espectrometría de Masas), Universidad de Castilla–La

Mancha (Grupo de Química y Contaminación Atmosférica), Universidad de Murcia (Grupo de Láseres, Espectroscopía Molecular y Química Cuántica).

4 ASTROMOL goals

- Water vapour in Space. Fundamental studies on the excitation conditions and spectroscopy of this key molecule and detailed astronomical models including chemistry and radiative transfer will be performed.
- Molecular complexity in Space. Explore the evolution and the physical and chemical characteristics of large carbon chains and Polycyclic Aromatic Hydrocarbon molecules in space by combining laboratory and theoretical studies into astronomical models of interstellar sources.
- Deuterium Chemistry. A concerted research effort will be directed towards identifying the chemical routes, the spectroscopy of deuterated species and their excitation.
- Gas phase and surface chemistry. Study of key gas-phase reactions of interest in the interstellar medium at 70–300 K, laboratory measurements and *ab initio* calculations. The chemistry of interstellar ice surfaces will be studied in the ultravacuum chambers of the CAB.
- Nitrogen and Oxygen chemistry. Studies of the reactivity and excitation of nitrogen-bearing and O-bearing species (including atomic oxygen), as well as their spectroscopy, may provide the only way to determine the physical conditions and dynamics of the phase preceding the collapse phase of star formation.
- Molecules as probing tools. The collisional rates for these species (first priority will be CO, H_2O, and OH) will be derived from laboratory experiments and *ab initio* calculations (if not already available).
- Planetary atmospheres. Adaptation of spectral databases and new laboratory measurements of the frequencies of combination bands of the most abundant species in Titan, Venus and Mars atmospheres.
- Radiative transfer models. Development of powerful radiative transfer codes for the interpretation of the spectroscopic and spectropolarimetric observations we will be able to carry out with the present and future telescopes, such as HERSCHEL, ALMA, SKA, and ELT.
- Technological developments ⇒ Development of state-of-the-art techniques for laboratory production and detection of species of astrophysical interest, high resolution spectroscopy and new *ab initio* methods: New instrumental developments will grant access to a series of experiments whose results will be most relevant for the interpretation and analysis of the data obtained with the new astronomical observatories coming on line. Hence, these developments cross-correlate with all astronomical activities related

to chemical modelling, radiative transfer and data interpretation of molecular species of astrophysical interest.

5 ASTROMOL milestones

- In the laboratory: experimental development and characterization of molecules, which has enabled the detection of various compounds in the interstellar medium. Patent developed: "Electro-optical device and method for ion beam of low energy and big intensity", Grupo de Láseres y Haces Moleculares del Instituto Pluridisciplinar de la Universidad Complutense de Madrid.
- In space: Detection of various molecular species in various astrophysical environments of the circumstellar and interstellar medium, some of which have been previously characterized in the laboratory (phosphine, radical methoxyl, etc.)
- Theoretical developments: from a theoretical point of view, the team characterized the H_{5+} (surfaces of potential energy, bounded states and infrared pre-dissociation spectrum) as well as the rovibrational spectrum of linear triatomic molecules of astrophysical interest: CO_2, N_2O and HCN, FCN.
- Development of models: development of different chemical models and radiation transfer models.
- More than 400 publications in peer-reviewed journals (especially relevant those between experimental-laboratory groups with groups of Astrophysics (5%)).
- Meetings organised:
  – The Molecular Universe – IAU280 (Toledo, 2011) – 450 participants
  – 2° Congreso de Astrofísica Molecular y de Laboratorio (Sevilla, 2012) – 150 participants

6 Outreach in the ASTROMOL programme

The importance of publishing scientific results based on ASTROMOL in the scientific literature goes without saying. But it is also important and a stated ASTROMOL objective to disseminate the achievements of ASTROMOL and its scientific and technological results to a wider audience.

Of course, scientific, technical, business, institutional and governmental audiences are all prime targets. But, because ASTROMOL is supported by public funds, there is an equal responsibility to show citizens that these monies are being spent to good effect. Fulfilling the societal objectives of spreading education and generating an enthusiasm for science also implies a need to reach the public at large, using all available means. In order to do this, it is important to create win-win situations for ASTROMOL scientists, their institutes, national organisations, funding agencies, mass media and general public.

Figure 3: ASTROMOL Scitech portal.

The World Wide Web has become a major information channel. This success is explained by the variety and multitude of information it makes available to a wide number of people at any time with a few clicks of a mouse. This is why the most common form of science communications proposed is by means of writing, posting, and widely disseminating web news and releases based on scientific results. The news come in two flavours, one aimed at the special interest community, posted on a specific ASTROMOL SciTech portal (see Fig. 3) (`http://auditore.cab.inta-csic.es/consolider-ingenio-astromol/`), and another intended for the media and the general public posted on a ASTROMOL Outreach Portal (`http://www.icmm.csic.es/astromol/`). Both are key tools to raise the image of the project and improve dissemination to specialists, potential users of the technologies being developed, politicians and public funding authorities, as well as the general public.

The ASTROMOL Outreach portal hosts the news and press releases, focused depending on the subject: science-release, techno-release, hot news, photo-release, etc. (see Fig. 4).

Social accounts were created in facebook, twitter and Google+ to spread all the news and information generated in the website. Fully-fledged press conferences can be considered, but are reserved for exceptional circumstances.

ASTROMOL has a "Communication team", composed by the Manager and the Public Information Officer (PIO)(see Fig. 5). They are the contact points for the ASTROMOL community to spread all the information created by the project teams. Once the scientist/engineer has a ASTROMOL result or considers any advance interesting to a wider audience, the team, through the Principal Investigator, should bring this to the "Communication team" attention that will be in charge of developing the information. The interaction can mainly be by email.

Figure 4: ASTROMOL Outreach blog.

Figure 5: "The social contract is not complete until the results are not communicated", Jacqueline Mitton, 2001 [4].

Acknowledgments

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