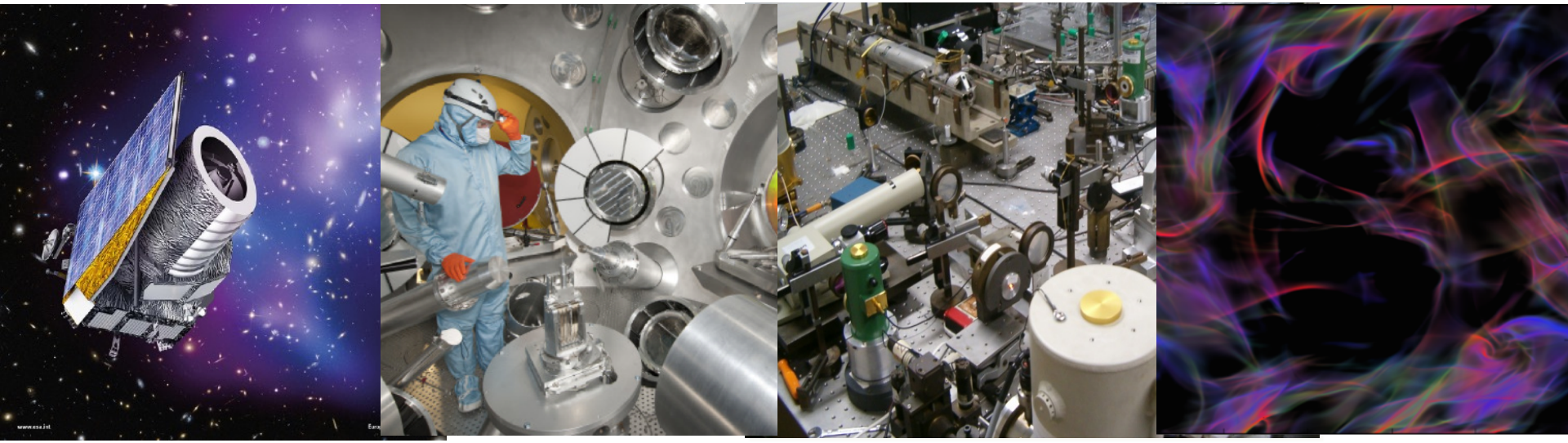


Laboratoire d'étude du rayonnement et de la matière en astrophysique et atmosphères

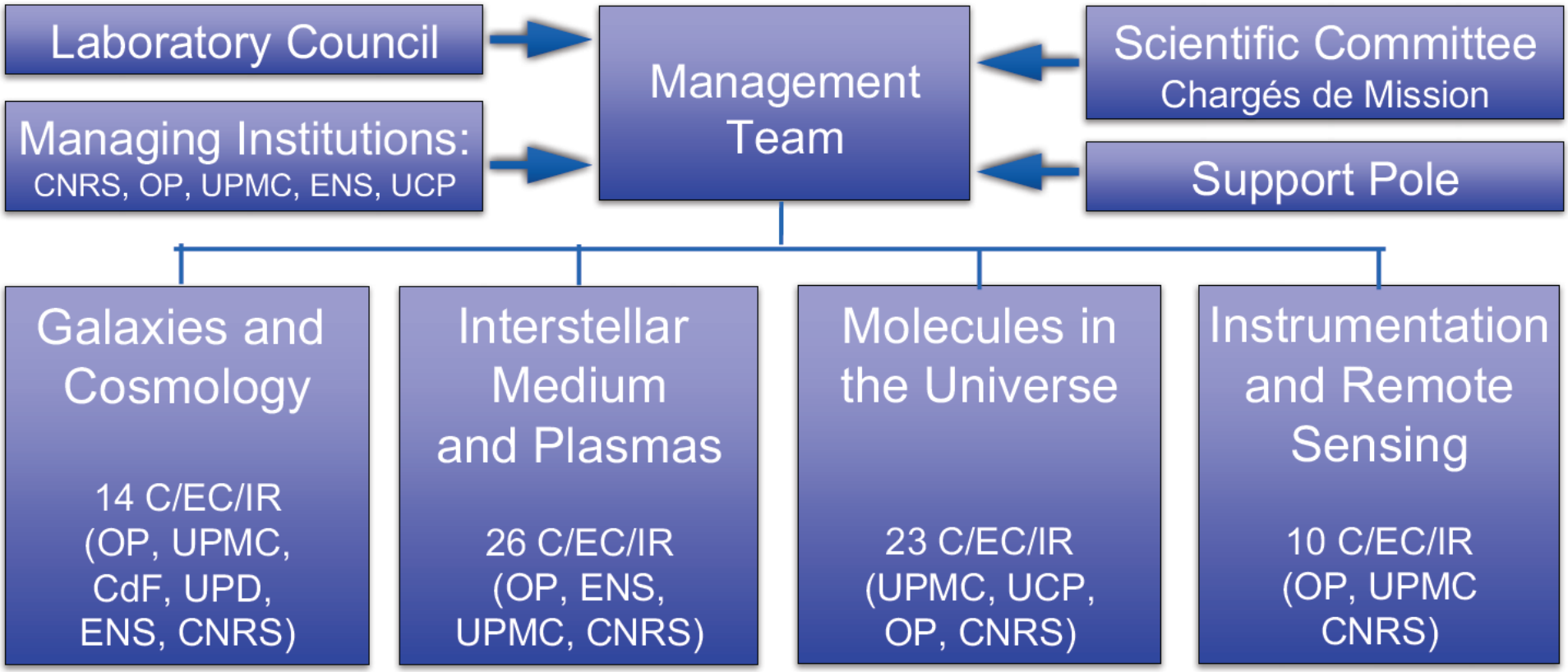
December 2017 J.-H. Fillion — F. Le Petit — D.C. Lis LERMA UMR 8112

LERMA — History

- *Laboratoire d'Études du Rayonnement et de la Matière en Astrophysique (LERMA; UMR 8112)* was created in 2002, by merging *Laboratoire de Radioastronomie Millimétrique (LRA / DEMIRM)* et *Laboratoire Atomes et Molécules en Astrophysique (LAMAp / DAMAp)*
- These two laboratories were at the origin of the molecular astrophysics in France and played a key role in the creation of the *Institut de Radioastronomie Millimétrique (IRAM)* in late 70's
- Another key constituent is the *Laboratoire de Physique Moléculaire pour l'Atmosphère et Astrophysique (LPMAA)* at the UPMC, who has its origins in the *Laboratoire de Chimie Physique de la Faculté des Sciences de Paris* in the 50's et 60's
- This is where molecular lasers were first developed together with the high-resolution spectroscopy

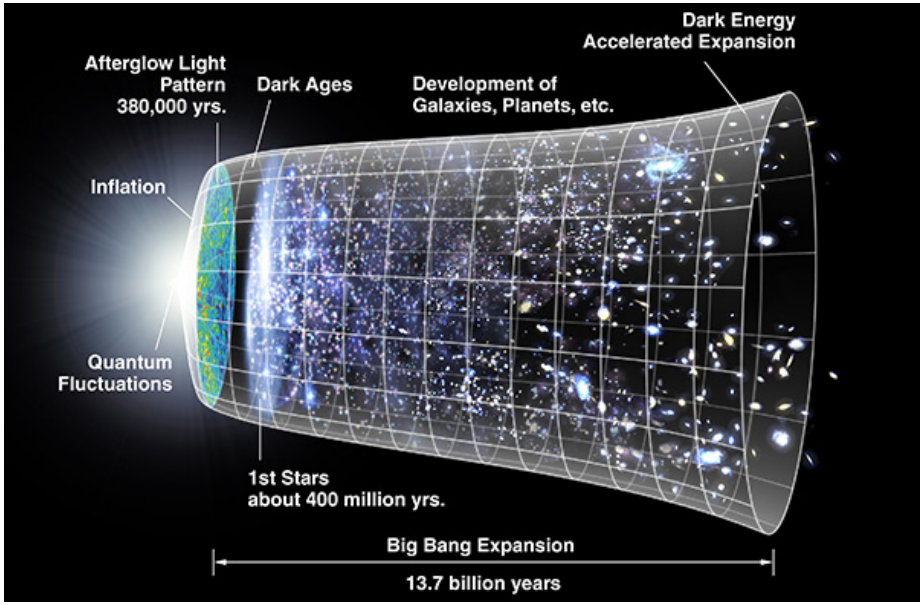
LERMA — A Few Facts

- Created in 2002; enlarged in 2014 (LPMAA and the ISM team of LUTh)
- 2017 arrivals: UPD (Huertas, Mei), ENS (Boulanger, Kaiser, Puget), OP (Casoli)

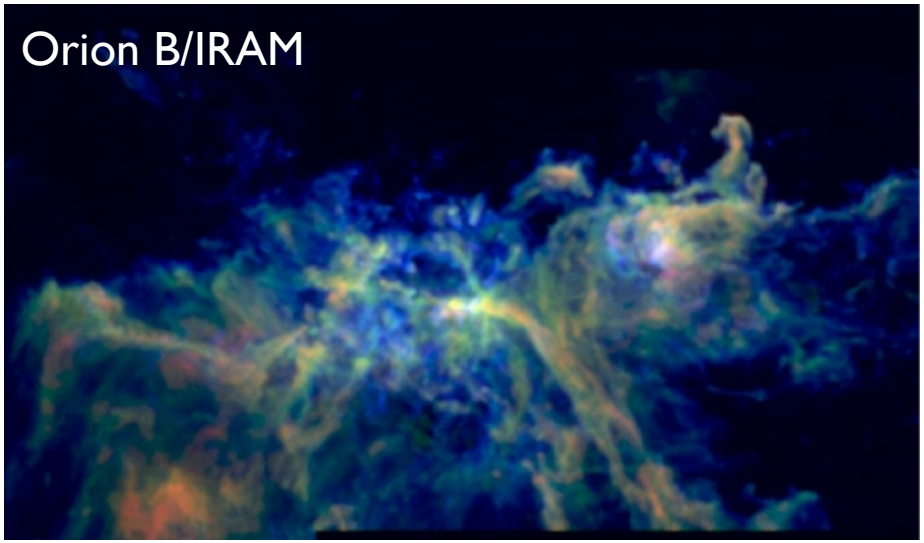


- 7 Labex : Plas@Par (UPMC), ESEP (PSL), First TF (CNRS), ENS-ICFP (PSL), ILP (UPMC), MIChem (UPMC), L-IPSL; 2 EquipEx : REFIMEVE+ et MesoPSL
- Partnerships and collaborations : IRAM, ESO, CEA, CNES, ESA, NASA (JPL), Alcatel/Thalés, EADS/Astrium, RPG, Estellus, C2N (LPN), IPSL…

LERMA Scientific Poles

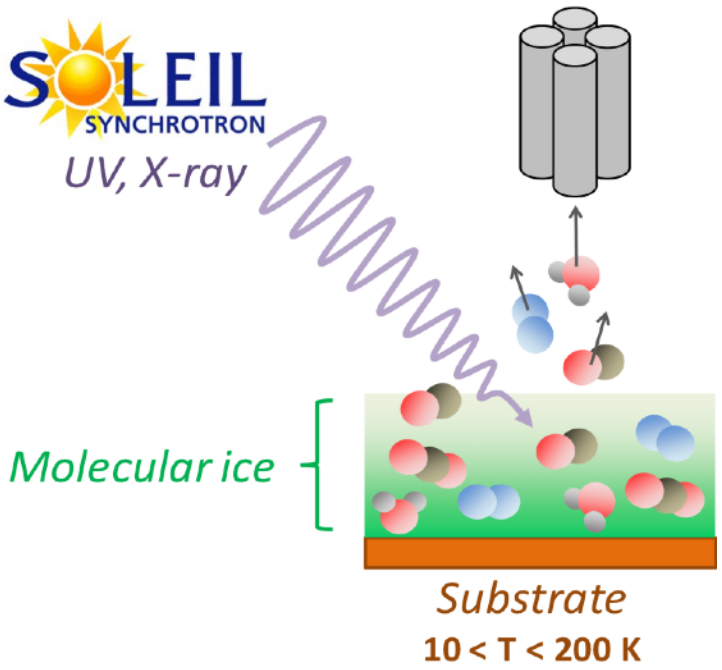


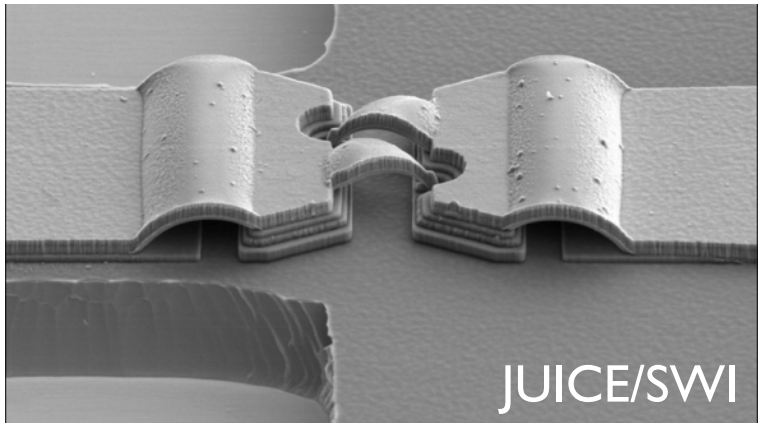
- *Galaxies and cosmology* — baryonic processes in galaxy formation; star formation efficiency, history, and stellar populations; fueling and feedback of black holes; epoch of reionization; large-scale structure of the Universe, nature of dark matter and dark energy, and inflation models



- *Interstellar medium and plasmas* — the complex physical and chemical processes, as well as the dynamics of the various phases of star formation and stellar plasmas; understanding of the effects of the magnetic field, radiation, and non-equilibrium chemistry

LERMA Scientific Poles



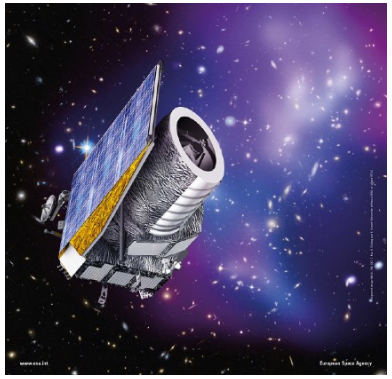
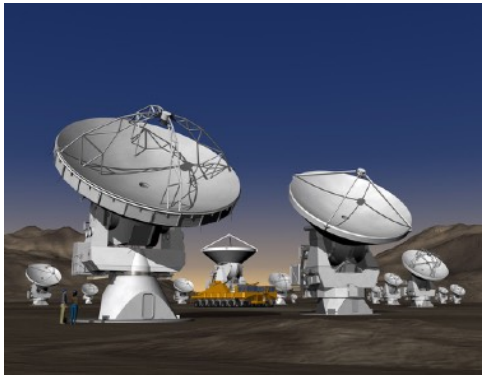
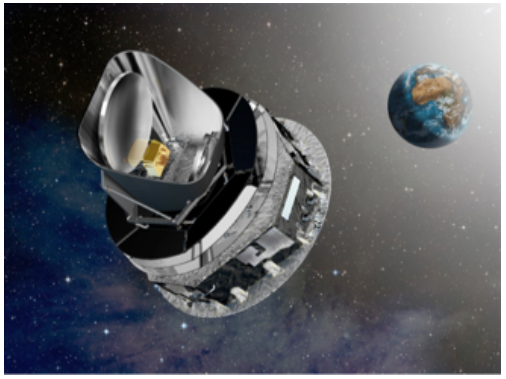
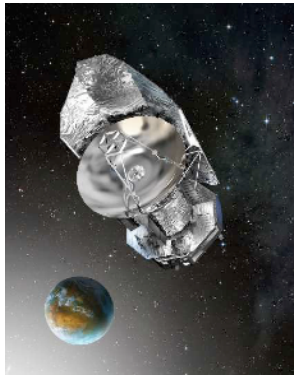


- *Molecules in the universe* — broad range of theoretical and laboratory activities, deeply linked to astrophysics and Earth and planetary science, including both theory and low-temperature molecular physics experiments, and ultra-high-resolution molecular spectroscopy

- *Instrumentation and remote sensing* — design and fabrication of state-of-the-art superconductive and Schottky devices for terahertz heterodyne spectroscopy, with applications to astrophysics and Earth's observations; development of innovative methods for quantifying key variables of the Earth's water and energy cycle using satellite observations

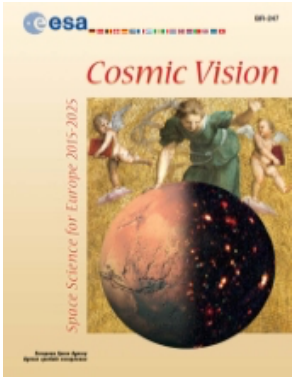
LERMA Research

- Scientific leadership in key areas of modern astrophysics and physics — from cosmology and early universe to Earth science
- Multidisciplinary approach — observations, theory, simulations, laboratory experiments, instrumentation
- Close involvement with large space and ground-based facilities (Herschel, Planck — ALMA, NOEMA, VLT — JUICE, Euclid, SKA, JWST, MetOp-SG — OST…)
- About 190 refereed publications per year

European and National Context

ESA Cosmic Vision 2015-2025:
- What are the conditions for planet formation and the emergence of life?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?



Astronet Science Vision Update "2015-2025 - The Next Decade":
- Do we understand the extremes of the Universe?
- How do galaxies form and evolve?
- What is the origin and fate of stars and planetary systems?

ASTRONET
www.astronet-eu.org

ESA Earth Explorer and Sentinel Programs

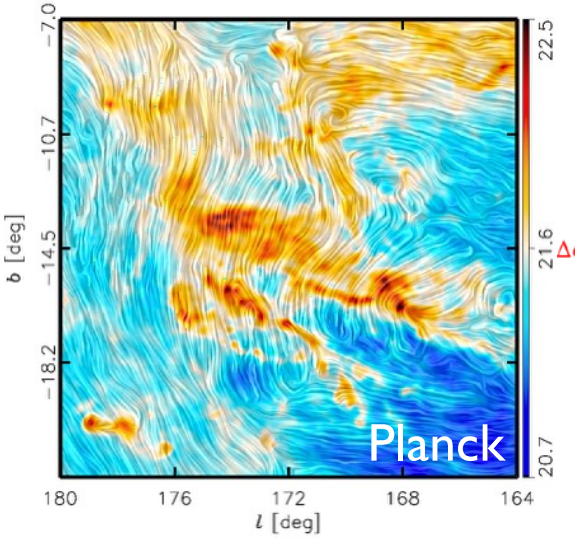
Stratégie nationale de recherche – France Europe 2020:
- Une ambition spatiale pour l'Europe: chaîne de services dans l'observation de la terre ; technologie pour l'observation et l'exploration de l'univers
- Programmes d'actions: big data (applications to astrophysics and Earth observations); système terre : observation, prévision, adaptation

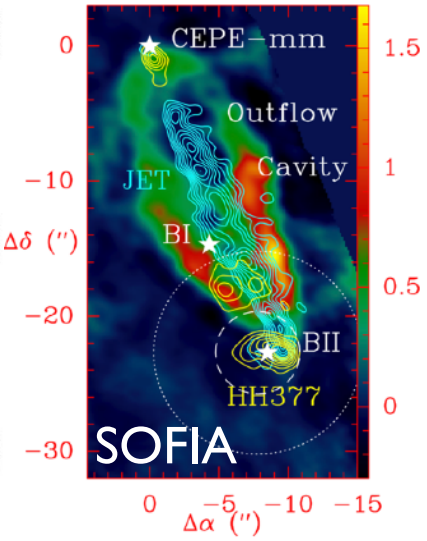
INSU Prospective Astronomie - Astrophysique 2015-2020

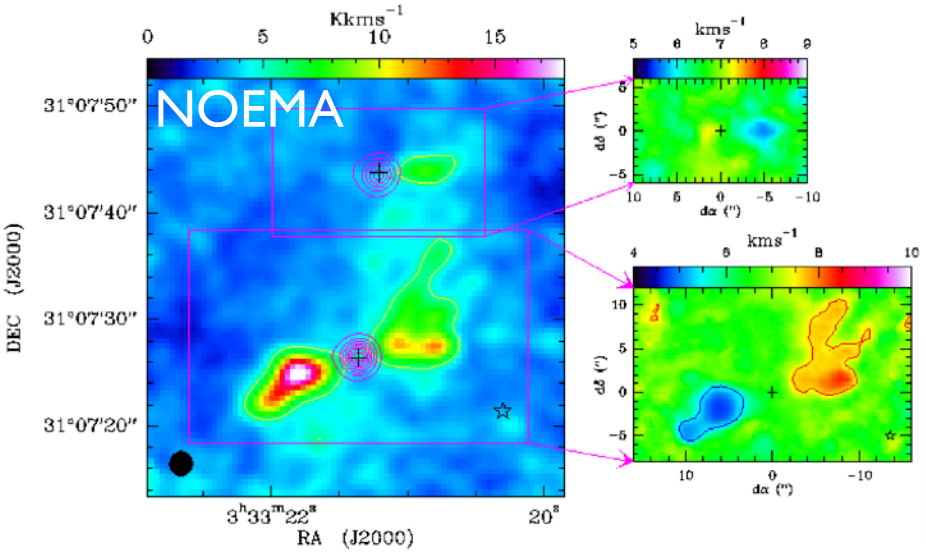
A C A V

Région Île-de-France: DIM-ACAV+ (Astrophysique et Conditions d'Apparition de la Vie), DIM-QI2 (Qualité de l'air)

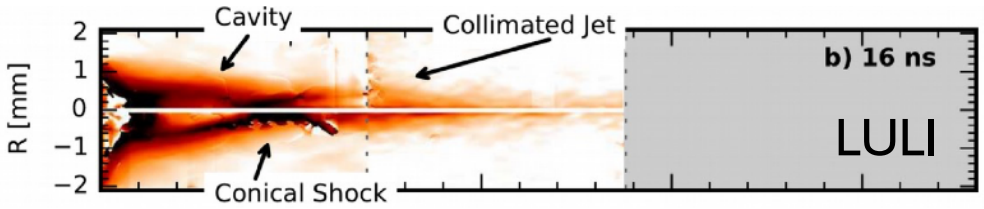
Observations



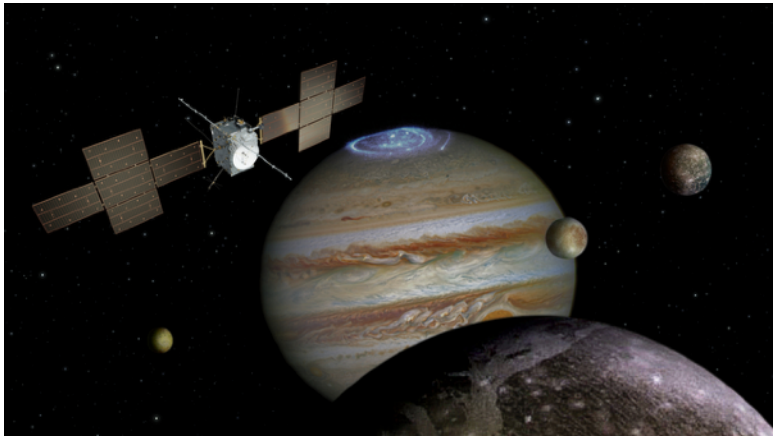




- Leadership of large observational programs: Herschel, Planck, IRAM…
- Exploitation of ALMA, NOEMA, SOFIA
- Preparation of JWST (3 ERS)
- Preparation of Euclid
- Preparation of SKA
- New Federative Action of the Paris Observatory: *Astrochemistry from the Solar System to High-redshift Universe*
- Remote sensing: preparation of ICI on MetOP-SG, SWOT, MICROWAT
- International laser facilities: Orion, LULI, LMJ, Sandia



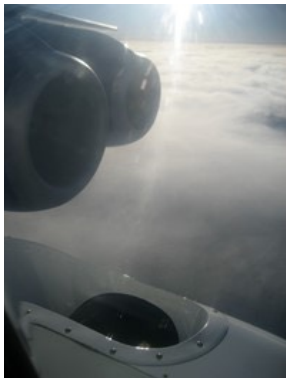
Heterodyne Instrumentation



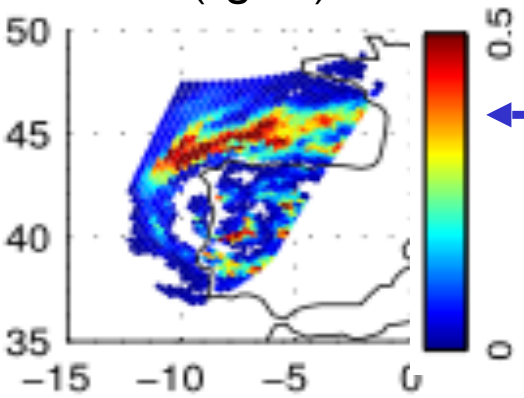
- Herschel/HIFI ➟ SWI/JUICE
- ESA L1, SWI heterodyne 600/1200 GHz
- LERMA: complete 1200 GHz channel
- SOFIA/4GREAT: HIFI band 1+4 legacy mixers
- Origins Space Telescope: NASA FIR Flagship Mission study in preparation for the 2020 US Decadal Survey
- Europe/LERMA: heterodyne instrument
- HSTDM (Chinese Space Station)
- Millimetron: RAS/Roscosmos
- FIRSPEX (M5)

Remote Sensing

The ICI aircraft demonstrator

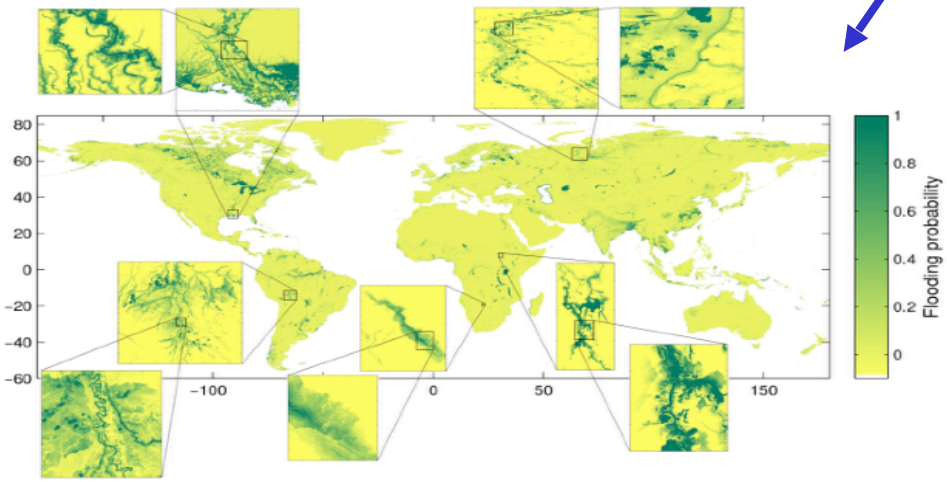


Ice content (kg/m^2)

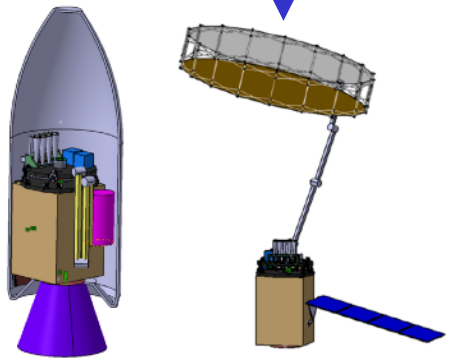


Key variables of the Earth water and energy cycle using multiple satellite observations:

- Millimeter wave observations for Earth ice cloud characterization (operational meteorology in the 2020: ICI on MetOp-SG)
- Satellite-derived surface water extent and dynamics at high spatial resolution, for climate studies and flood warnings (preparation to NASA/CNES SWOT)
- 'All weather' land and sea surface temperature from microwaves. Proposition of a new satellite MICROWAT (ESA Earth Explorer 10)



Flooding probability at 90m resolution



MICROWAT with its 5m deployable antenna

Instrumental Platforms

Unique instrumentation for Laboratory Astrophysics and state-of-the art Spectroscopic Techniques for atmospheric/ planetary applications

Plasma Physics

- Shock waves
- Radiative shocks
- Magnetic reconnection
- Instabilities

Surface Science

- Astrochemistry (low T)
- Gas-grains interactions
- Thermal desorption
- Photodesorption
- Nuclear Spin Conversion

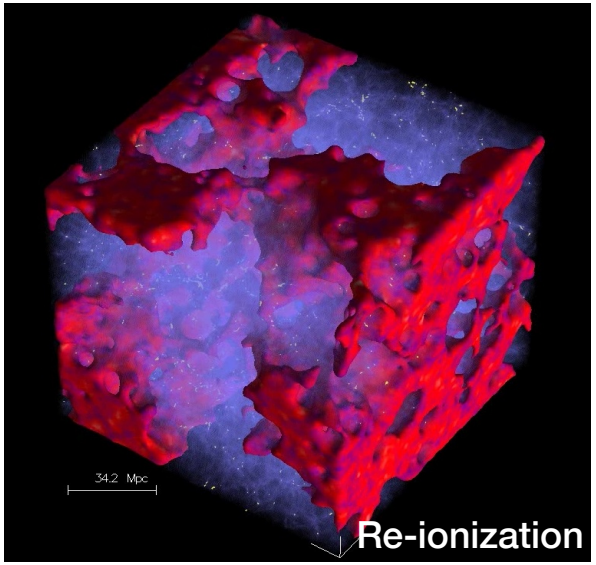
Spectroscopy

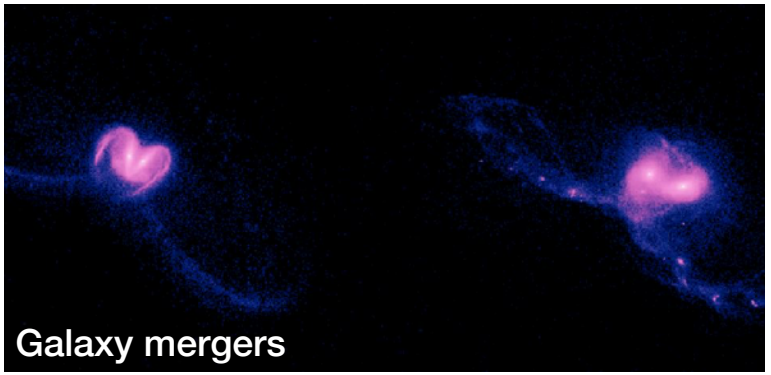
- Atomic and molecular precision spectroscopy (MIR – VIS – VUV)
- Isotopic anomalies in oxygen bearing molecules

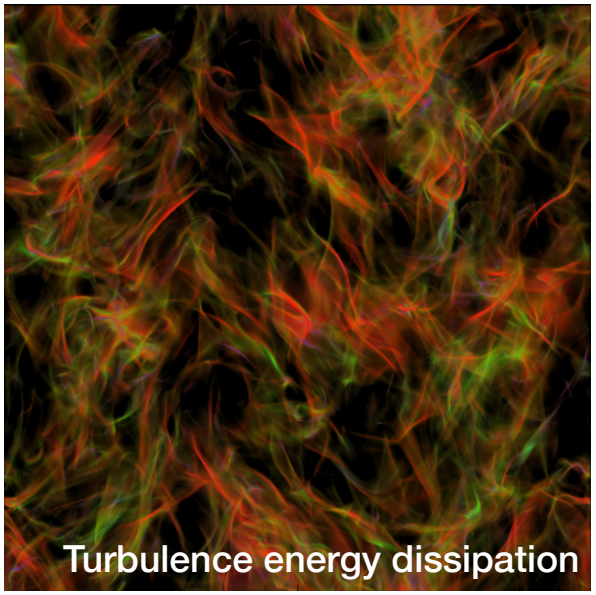
Air Quality

- Greenhouse gas & urban pollutant monitoring in megacity
- Climate & atmospheric composition change

Theory, Simulations, and Modeling







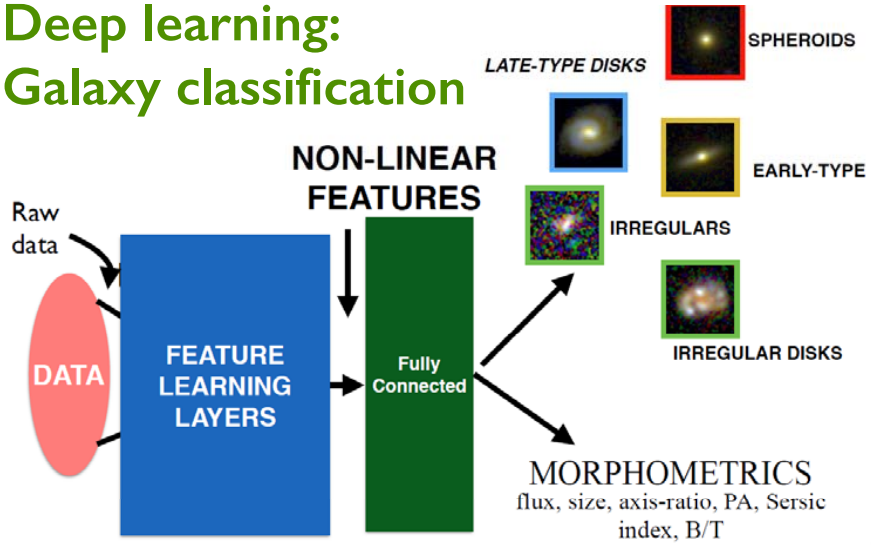
- Numerical codes developed at LERMA (e.g., Meudon PDR code, Paris-Durham shock code) are standards used by the community for interpretation of ISM observations
- Computations of collisional excitation rates
- Large simulations:
  - Dynamical simulations of galaxy formation and history of mass assembly
  - Direct coupling of MHD and chemistry
  - MHD - turbulence energy dissipation
  - Stellar interiors
  - Structure of accretion flows in young stars
- Resources: MesoPSL & national computing centers

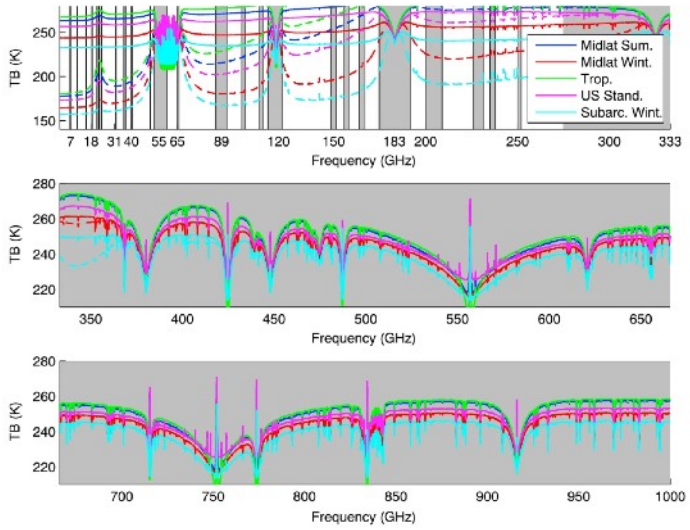
Big Data/Machine Learning

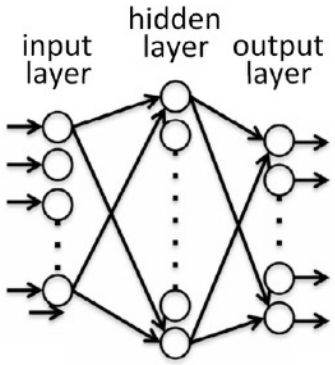
Remote Sensing: Big Data tools to exploit decades of Earth satellite observations:

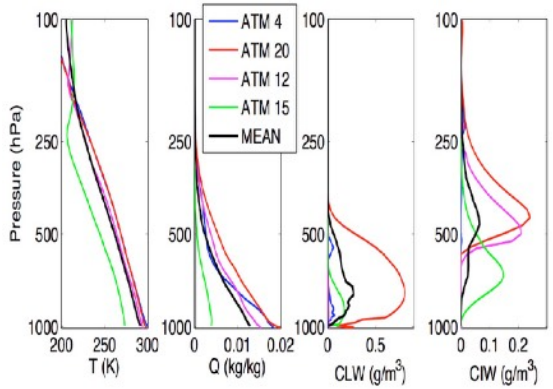
- Optimal sampling of high-dimensional spaces
- Multivariate data analysis
- Channel selection and compression tools
- Artificial neural networks for inverse problems
- Classification algorithms
- Data Assimilation into numerical models

Deep learning: Galaxy classification





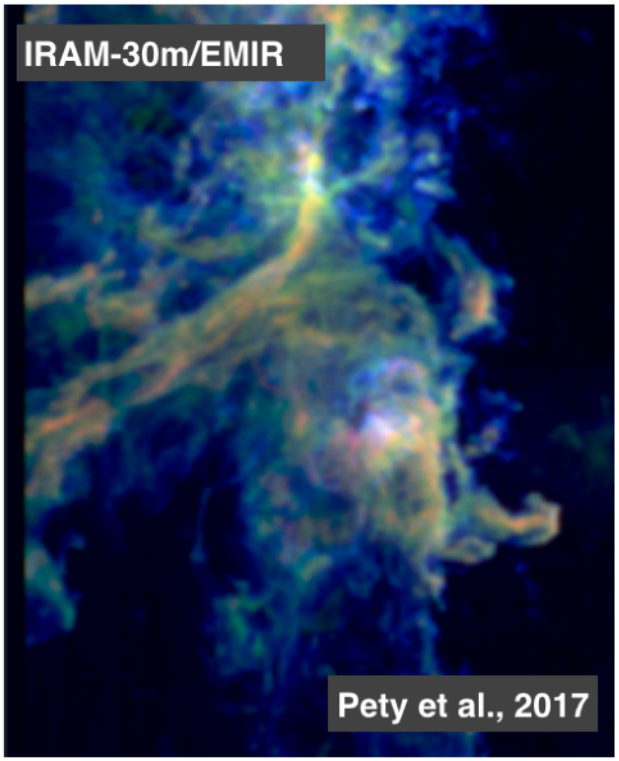


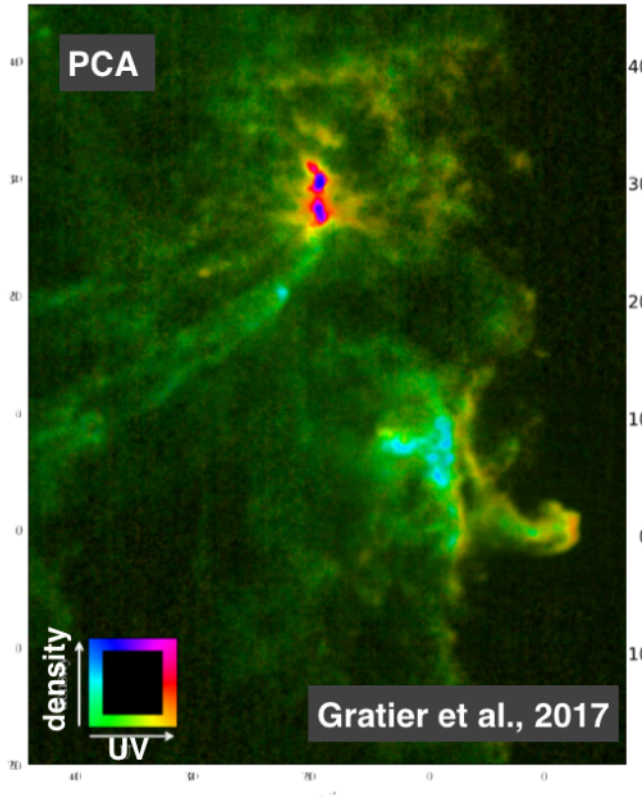


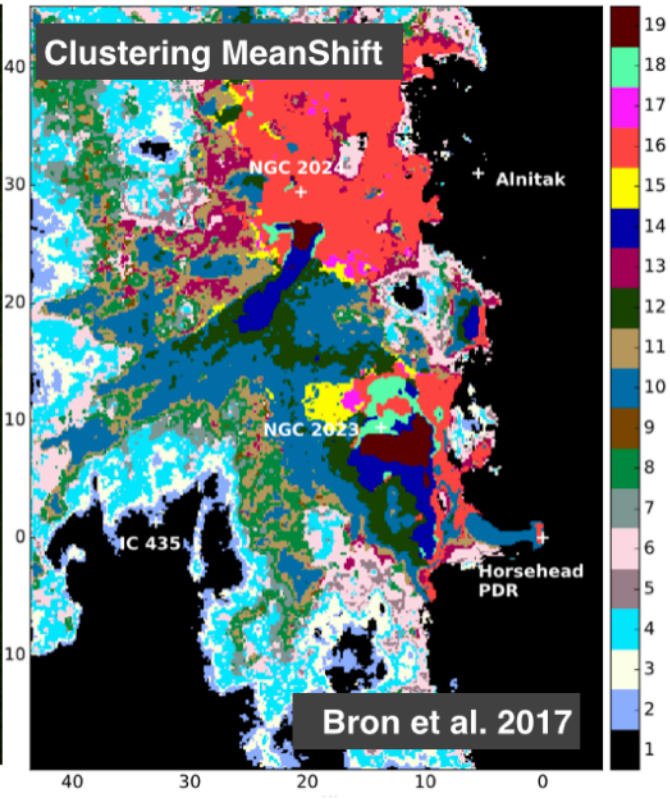
An exemple: Retrieval of atmospheric hydrometeors from hyper-spectral observations in the microwaves

Big Data/Machine Learning

- Orion B: Large IRAM 30-m/EMIR program (141k pixels, 12 lines)
- Adaptation of Machine Learning technics to ISM observations: clustering (MeanShift…), unsupervised







- Exploration of other methods to reveal the anatomy of molecular clouds

Observation Services

ANO5 BASECOL

http://basecol.obspm.fr

Data base of molecular collision rates for Interstellar medium & comets

Collision rates & Spectroscopy of molecules:

- About 240 collisional systems
- About 900 references
- Versioning of data

- Access via VAMDC portal and SPECTCOL Tool

Projects:

- Automatic Ingestion
- New Interface

ANO5 F-VAMDC

http://www.vamdc.eu

Interoperable platform to exchange atomic & molecular data

The VAMDC Consortium is :

- Built on a Memorandum of Understanding
- Currently composed by **17** members who signed the MoU.
- Leadership: Paris Observatory
- About **30** interconnected Databases
- Services : http://portal.vamdc.eu
- Standards: vamdc.eu/standards
- Software: vamdc.eu/software

Project:

- **Inclusion in an ESFRI**

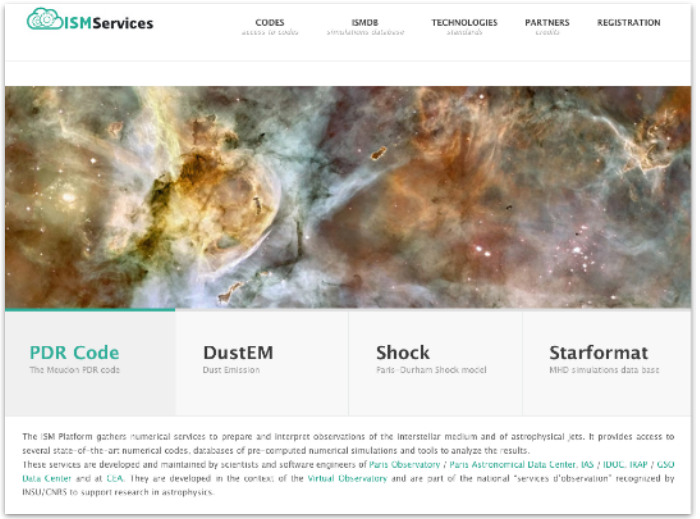
- ANO5 Pôle thématique national: **Diffusion des données physique atomique & moléculaire**
- ANO5: F-VAMDC, Basecol, KIDA

Observation Services

ANO5 Plateforme MIS & Jets

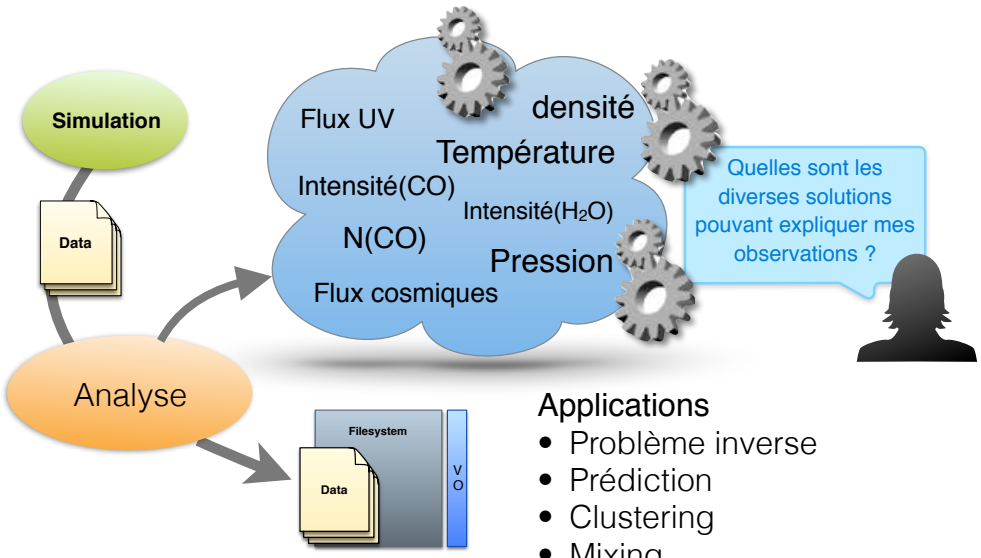
(P.I. LERMA - Partners: LUTH, CEA)

http://ism.obspm.fr



Goal: **Theoretical tools to prepare and interpret observations from world-class telescopes**
(IRAM/Noema - ALMA - JWST - SPICA - GUSTO…)

- Diffusion of **ISM reference codes** (PDR, shocks, TDR, …)
- **Tools** to analyze **ISM observations**
- **Database** of numerical models with **data mining tools**
- Development of **VO standards** for Theory (**IVOA**)



Applications
- Problème inverse
- Prédiction
- Clustering
- Mixing

Projects:
- **Machine Learning** / Artificial Intelligence to provide advanced services
- Direct **interpretation of line intensity maps**
- **Data mining** in N-dimensional space
- New codes & tools

ANO5 Pôle thématique national

Diffusion des modèles de référence pour la matière interstellaire

- ANO5: Plateforme MIS & Jets
- ANO5: DustEM (IAS)

Observation Services

ANO3 **ALMA Regional Center** (partner)

ARTEMIX database

Goals:

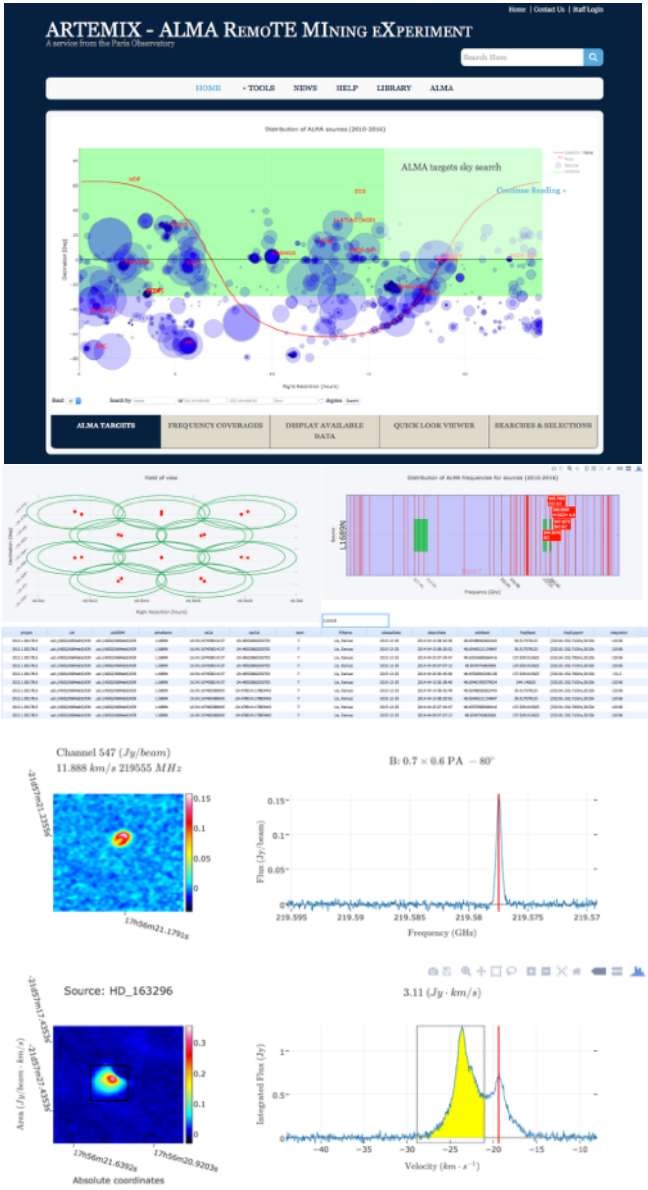
- **Develop remote visualization tools** to ease data mining : (i) meta-data **visualisation** : what has been observed : position / frequency setups (ii) science products : what is in the science data cube ?

Deliverables:

(i) sky coverage, selection tools, (ii) frequency / line observed for a given source (iii) remote data cube fast visualizer

Projects:

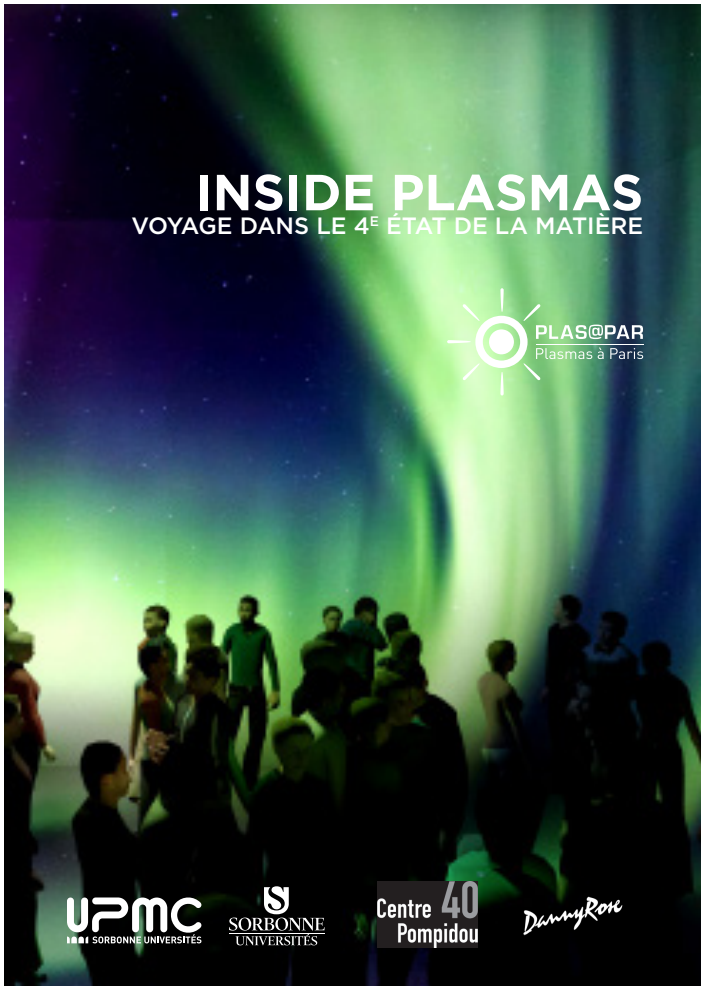
- **Automated signal search methods** (collaboration with P. Teuben) - ADMIT (ALMA DataMining Toolkit) : ALMA-dev supported by NRAO
- **Cross-match** with external catalogue, tools to build subsamples



ANO3 **JUICE** (partner)

- Participation to the development of JUICE / SWI
- SWI: Schottky heterodyne instrument

Education and Outreach



- Strong university presence provides access to high-quality students
- Trained: 78 PhD students, 40 postdocs, and 241 interns
- Management responsibilities in doctoral schools (Le Bourlot, Mei, Dulieu)
- Participation in Science Fairs and Festivals
- Project Inside Plasmas (Centre Pompidou)
- Hands on Universe
- Astronomical Platform at UPMC
- Inflatable planetarium at Cergy
- La Maison du Soleil, Saint-Véran

Summary

- LERMA is a modern research laboratory with demonstrated scientific and technical leadership in many key areas of astrophysics, physics, and Earth science
- The unique aspect and the strength of the laboratory is its multidisciplinary approach, including observations, theory, computer simulations, laboratory experiments, and instrumentation
- Our combined expertise in all these fields enables leadership of ambitious observational programs using state-of-the-art international space and ground-based facilities
- The astrophysical observations, in turn, stimulate new laboratory, theoretical, and technical activities
- Laboratory responds very well to the constant changes in the research environment and can evolve, as needed, to stay at the forefront in its four key research areas