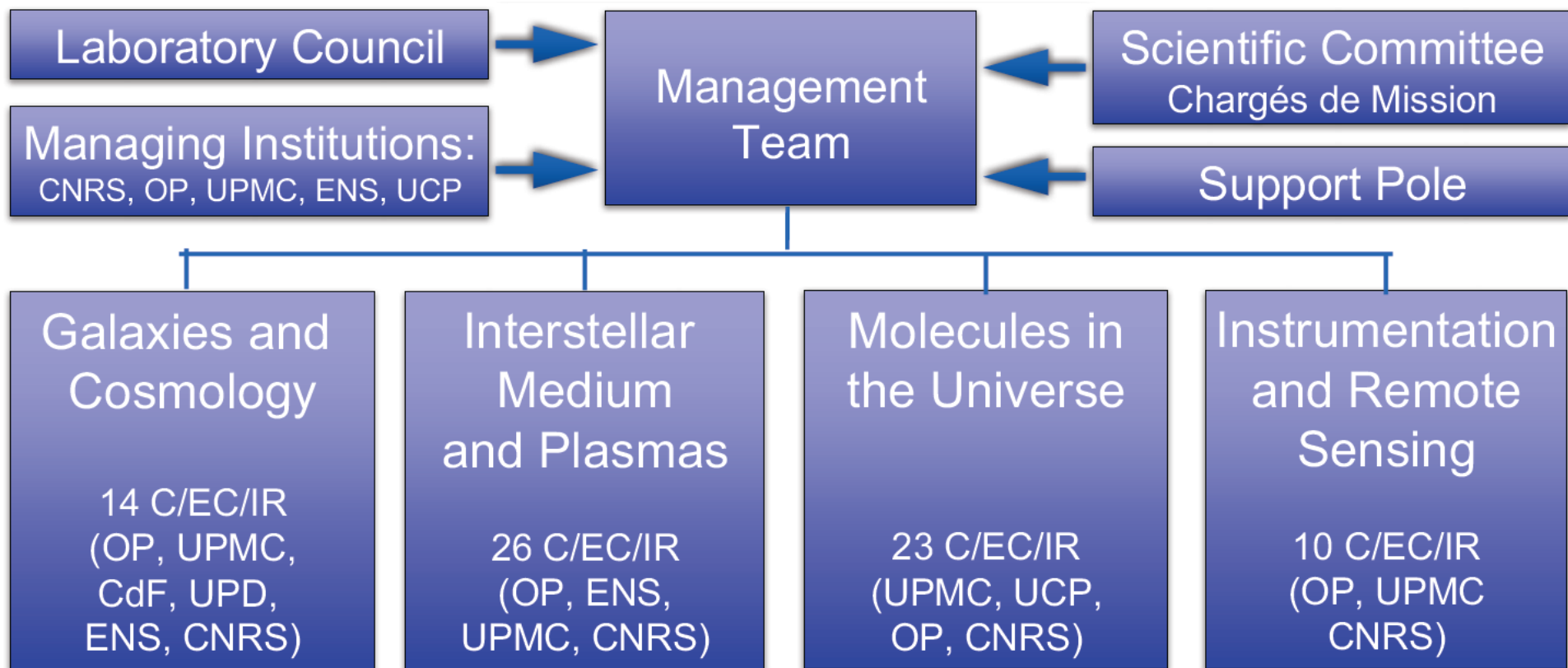


Laboratoire d'étude du rayonnement et de la matière en astrophysique et atmosphères

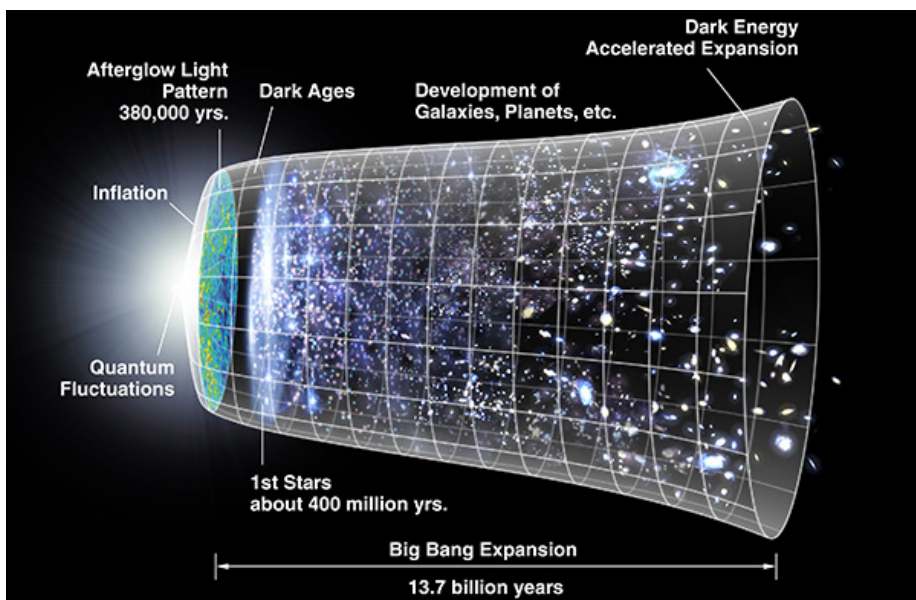


- *Laboratoire d'Études du Rayonnement et de la Matière en Astrophysique (LERMA; UMR 8112)* was created in 2002, by merging *Laboratoire de Radioastronomie Millimétrique (LRA / DEMIRM)* et *Laboratoire Atomes et Molécules en Astrophysique (LAMAp / DAMAp)*
- These two laboratories were at the origin of 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 (SU), 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*

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

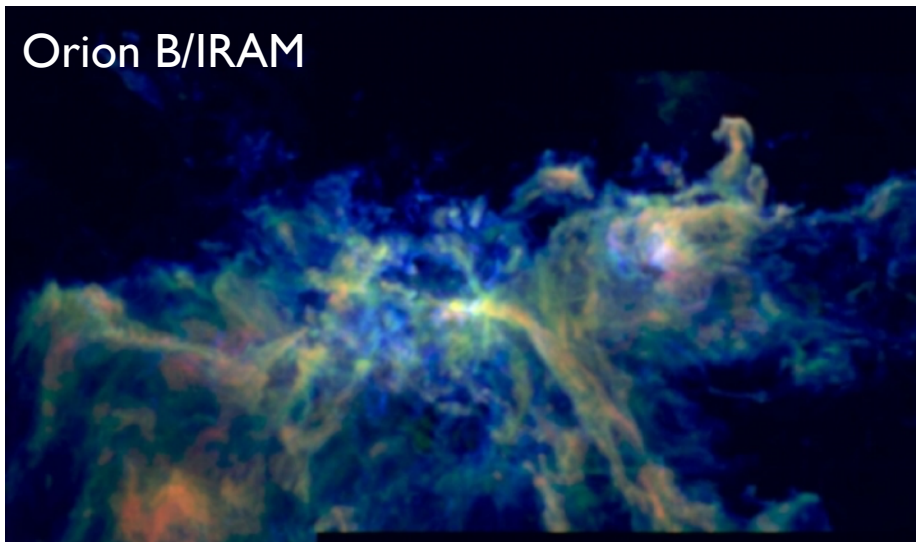


- 7 Labex : [Plas@Par \(SU\)](#), ESEP (PSL), First TF (CNRS), ENS-ICFP (PSL), ILP (SU), MIChem (SU), L-IPSL; 2 EquipEx : REFIMEVE+ et MesoPSL
- Partnerships and collaborations : IRAM, ESO, CEA, CNES, ESA, NASA (JPL), Alcatel/Thalés, EADS/Astrium, RPG, Estellus, C2N (LPN), IPSL...

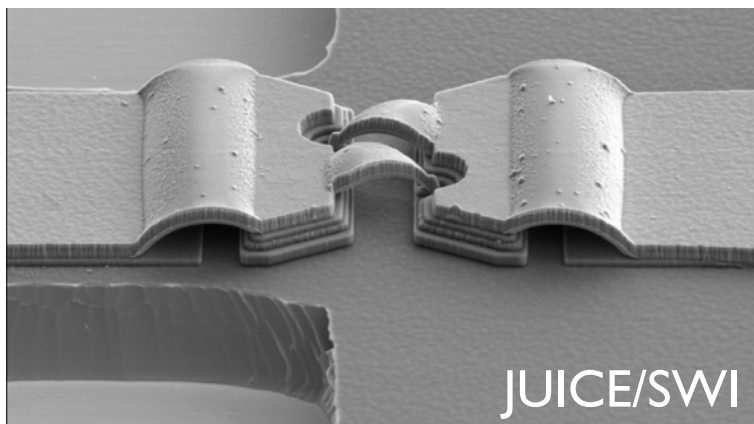
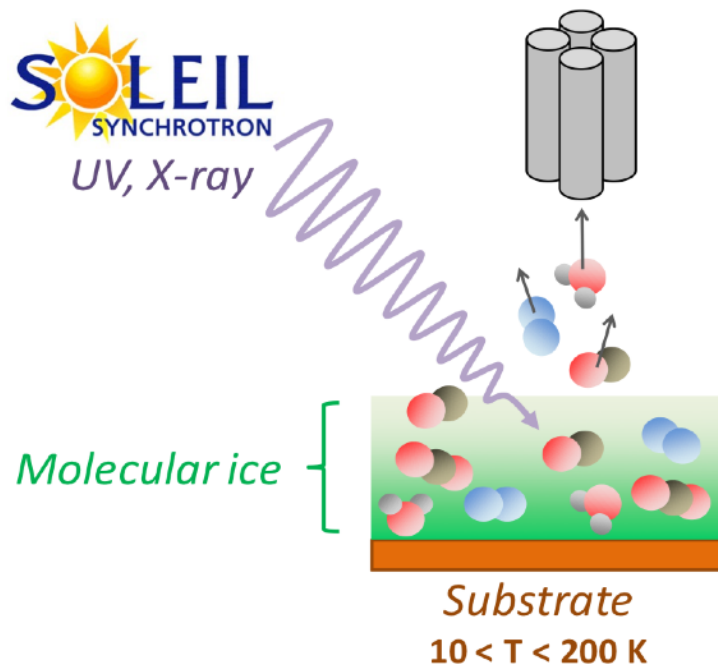


- *Galaxies and cosmology* — baryonic processes in galaxy formation; star formation efficiency, history, and stellar populations; fueling and feedback of black holes; epoch of reionization; large-scale structure of the Universe, nature of dark matter and dark energy, and inflation models

Orion B/IRAM

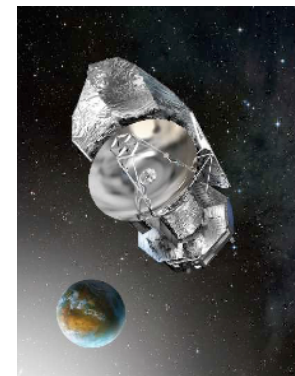
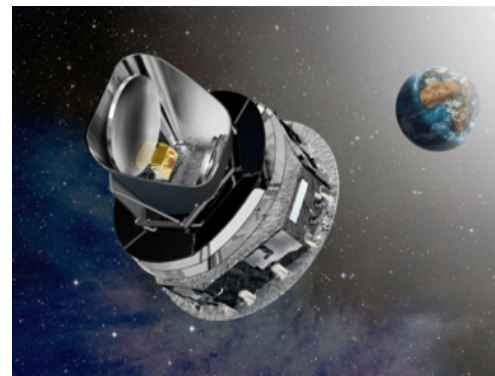
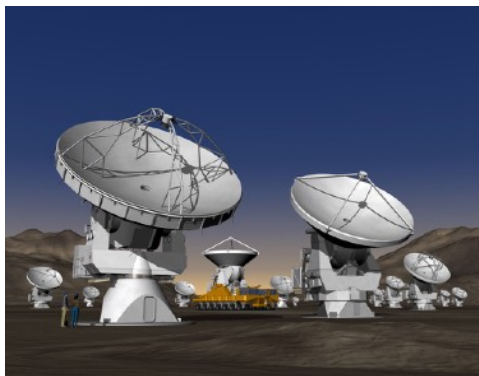
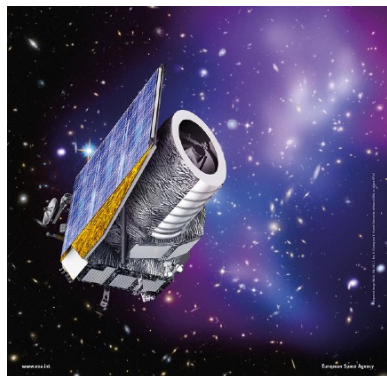


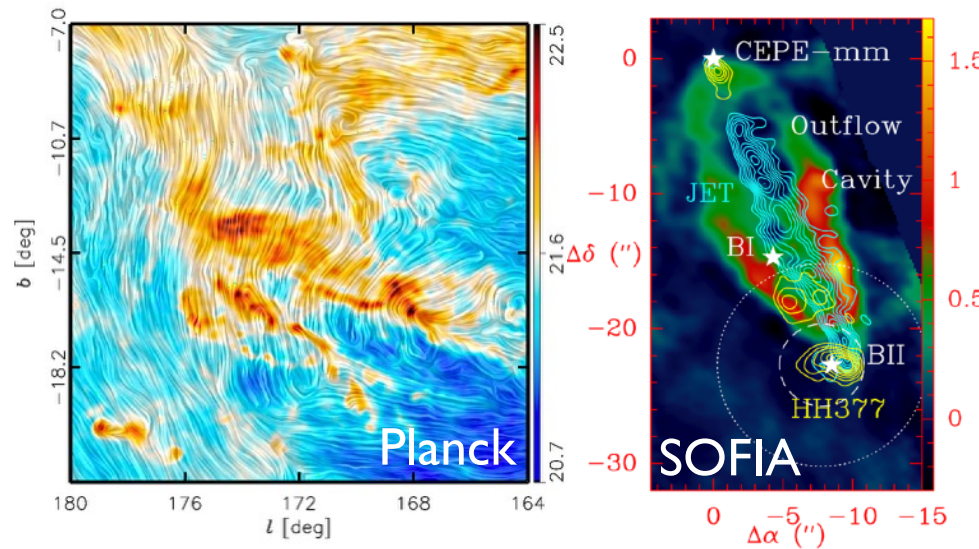
- *Interstellar medium and plasmas* — the complex physical and chemical processes, as well as the dynamics of the various phases of star formation and stellar plasmas; understanding of the effects of the magnetic field, radiation, and non-equilibrium chemistry



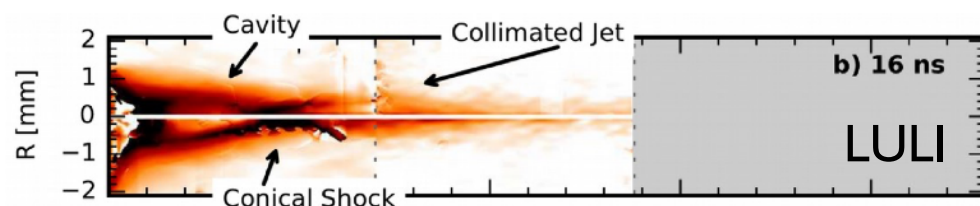
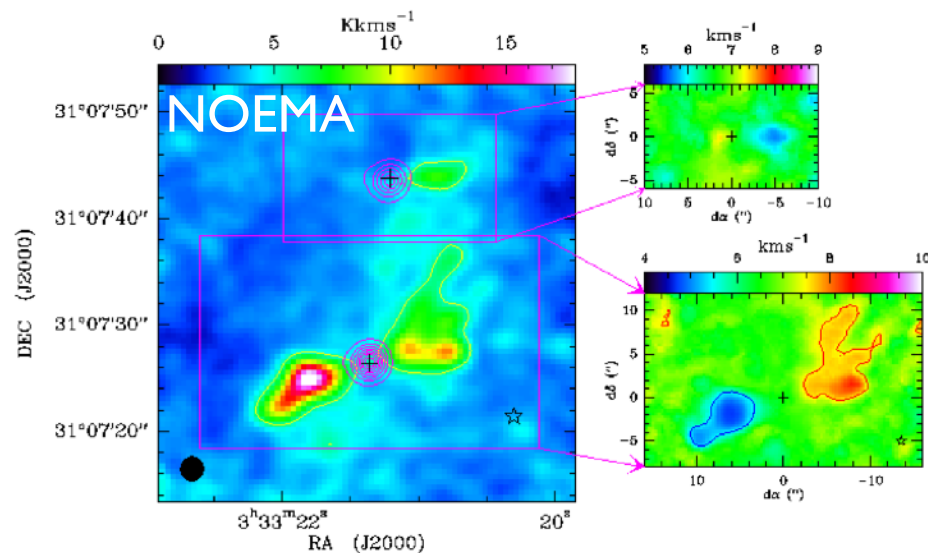
- *Molecules in the universe* — broad range of theoretical and laboratory activities, deeply linked to astrophysics and Earth and planetary science, including both theory and low-temperature molecular physics experiments, and ultra-high-resolution molecular spectroscopy
- *Instrumentation and remote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

- 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





- 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





Observing
Beyond the Light



Following the rise of dust & metals in galaxies and the path of water across cosmic time to Earth and other habitable planets

Tracing the Signatures of Life and the Ingredients of Habitable Worlds

Origins will trace the trail of water through the stages of star and planet formation, to Earth itself and other planetary systems, while also characterizing water and greenhouse gases in potentially habitable worlds.



Unveiling the Growth of Black Holes and Galaxies over Cosmic Time

Origins will reveal the co-evolution of super-massive black holes and galaxies, energetic feedback, and the dynamic interstellar medium from which stars are born.



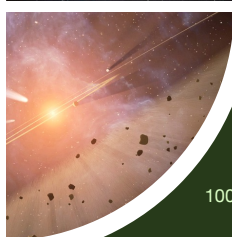
Origins will trace the metal enrichment history of the Universe, probe the first cosmic sources of dust, the earliest star formation, and the birth of galaxies.

Charting the Rise of Metals, Dust, and the First Galaxies



Origins will chart the role of comets in delivering water to the early Earth, and survey thousands of ancient Trans Neptunian Objects at distances greater than 100 AU and down to sizes of less than 10 km.

Characterizing Small Bodies in the Solar System



The Origins Space Telescope is the mission concept for the Far Infrared Surveyor, a study in development by NASA in preparation for the 2020 Astronomy and Astrophysics Decadal Survey.

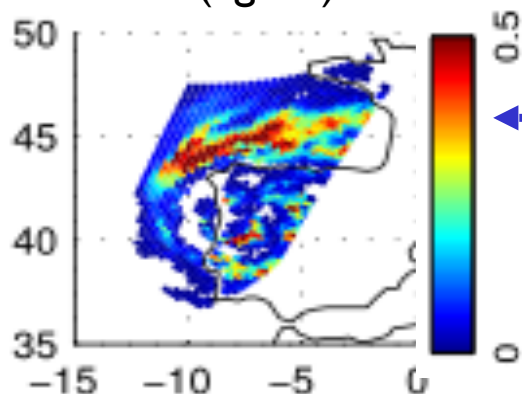


- **Herschel/HIFI → SWI/JUICE**
- ESA LI, SWI heterodyne 600/1200 GHz
- LERMA: complete 1200 GHz channel
- SOFIA/4GREAT: HIFI band 1+4 legacy mixers
- Origins Space Telescope: NASA FIR Flagship Mission study in preparation for the 2020 US Decadal Survey
- Europe/LERMA: heterodyne instrument
- HSTDM (Chinese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

The ICI aircraft demonstrator

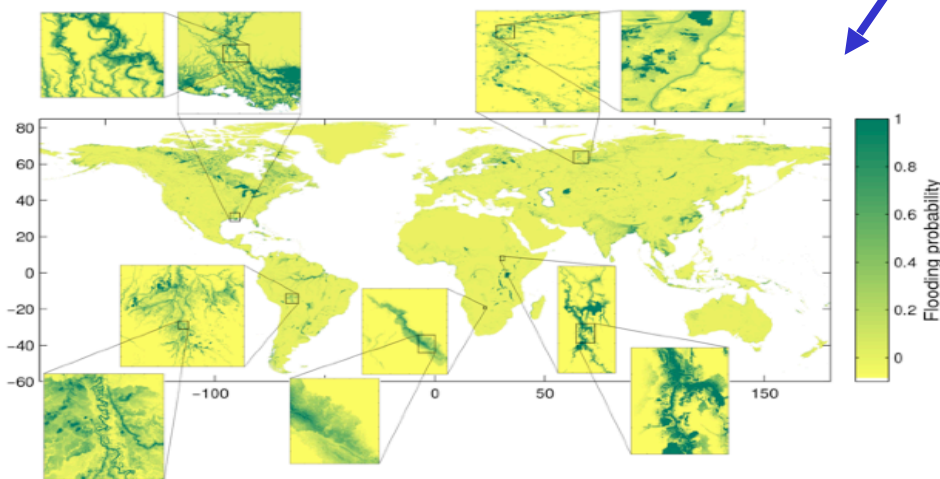


Ice content (kg/m²)

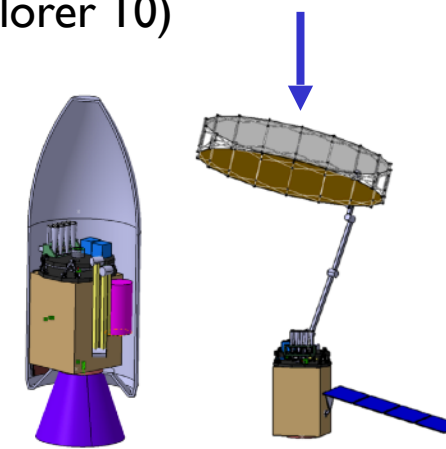


Key variables of the Earth water and energy cycle using multiple satellite observations:

- 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 I0)



Flooding probability at 90m resolution



*MICROWAT
with its 5m
deployable
antenna*

**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

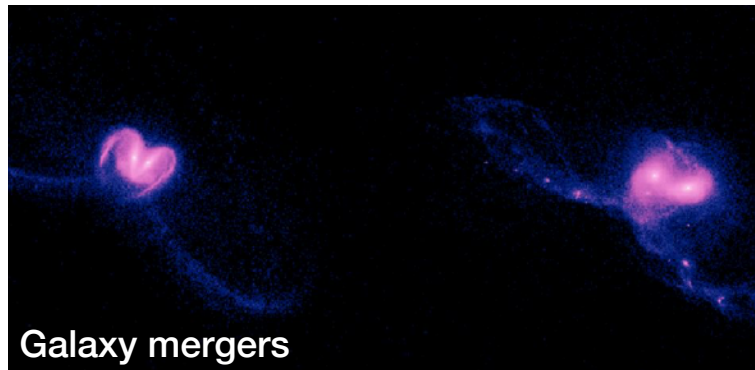
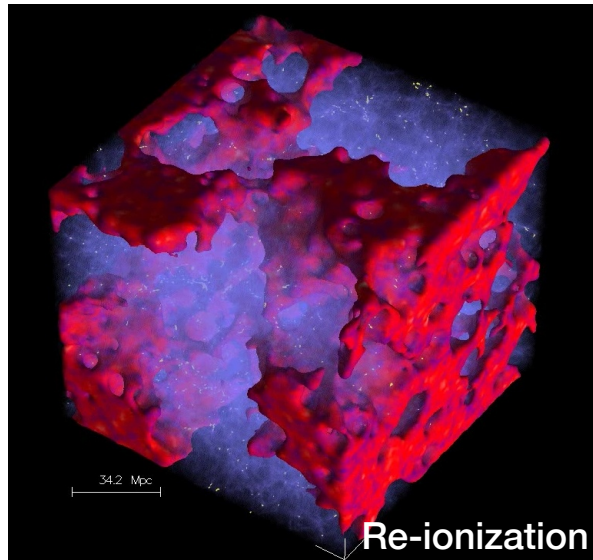


- Atomic and molecular precision spectroscopy (MIR – VIS – VUV)
- Isotopic anomalies in oxygen bearing molecules

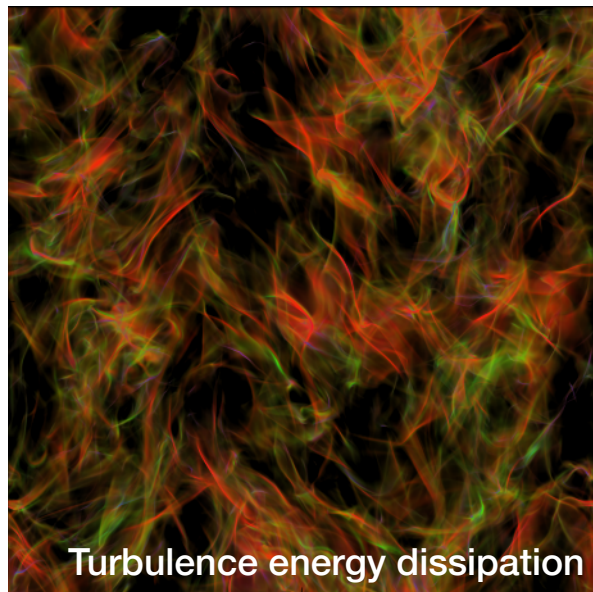
Air Quality



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



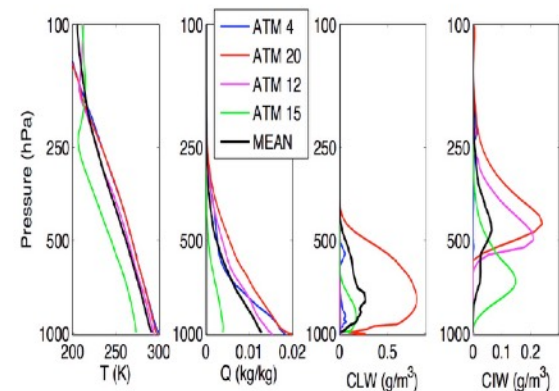
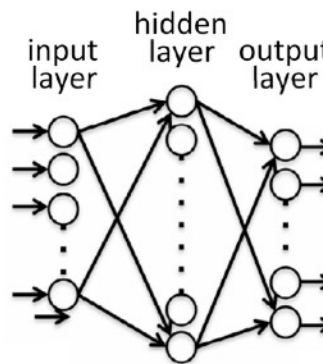
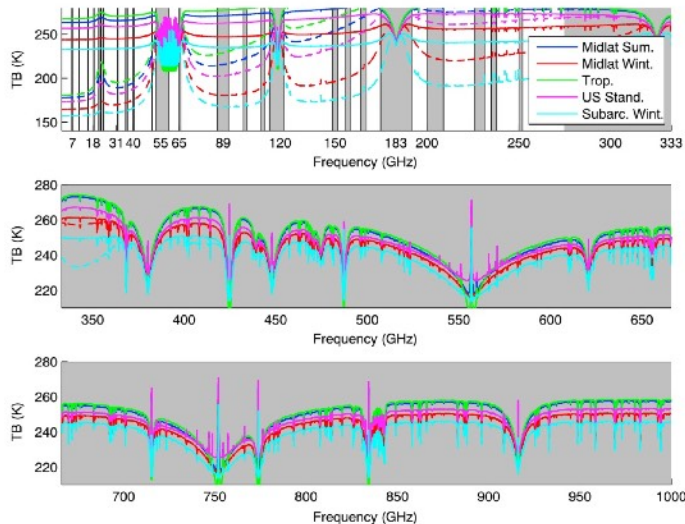
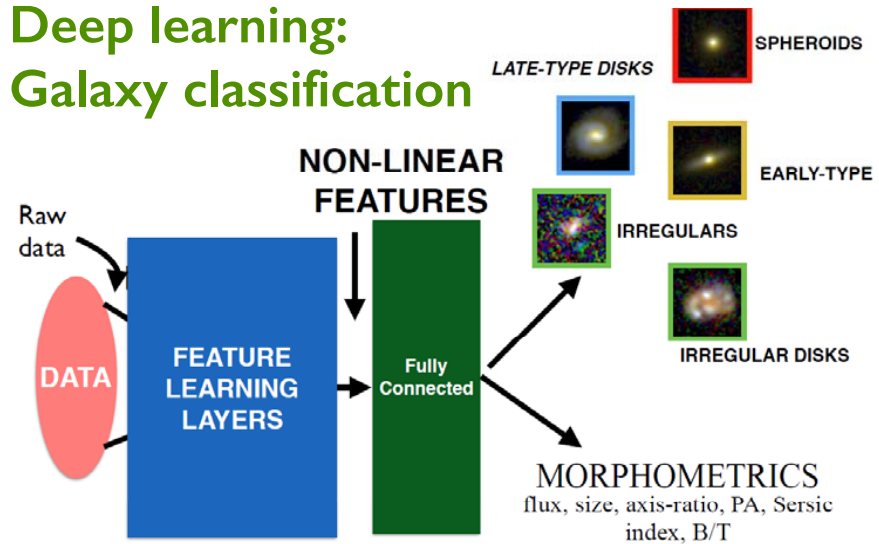
- Numerical codes developed at LERMA (e.g., Meudon PDR code, Paris-Durham shock code) are standards used by the community for interpretation of ISM observations
- Computations of collisional excitation rates
- Large simulations:
 - Dynamical simulations of galaxy formation and history of mass assembly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



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

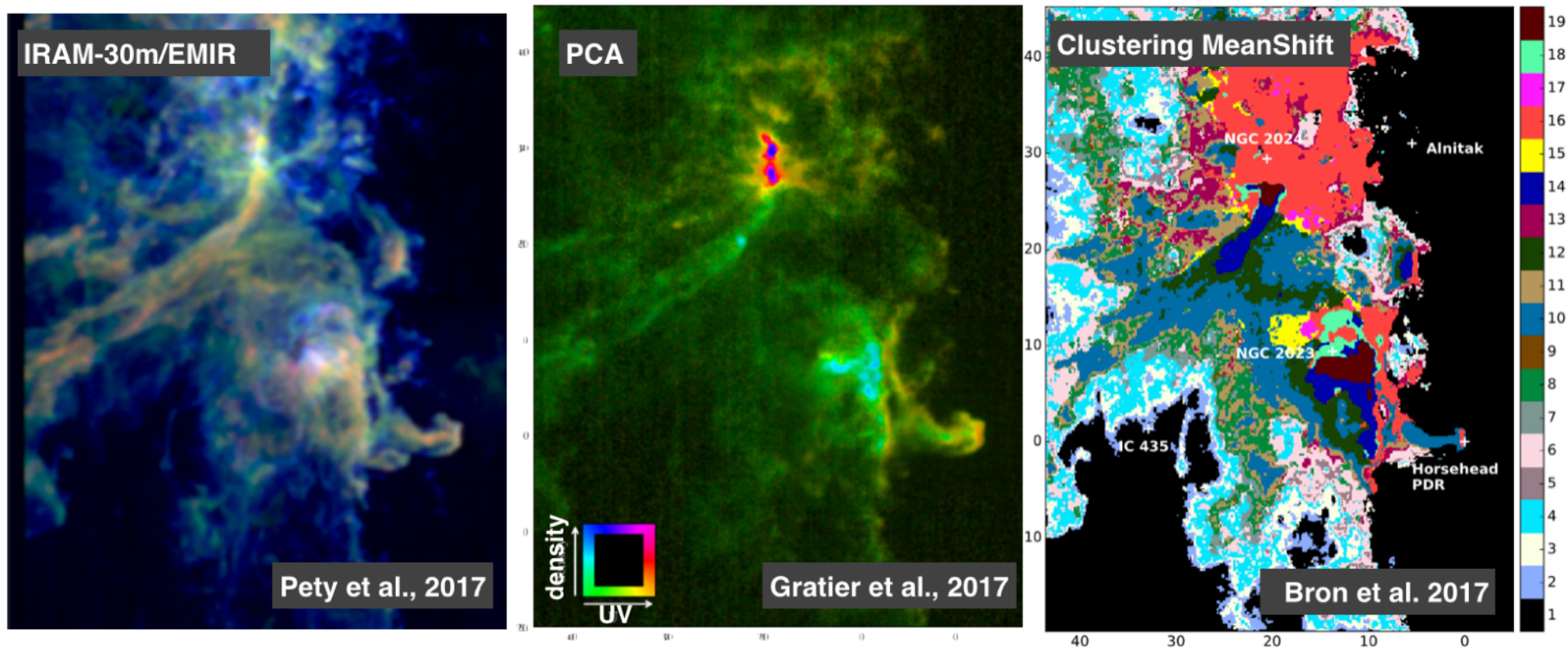
- Optimal sampling of high-dimensional spaces
- Multivariate data analysis
- Channel selection and compression tools
- Artificial neural networks for inverse problems
- Classification algorithms
- Data Assimilation into numerical models

Deep learning: Galaxy classification



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

- 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

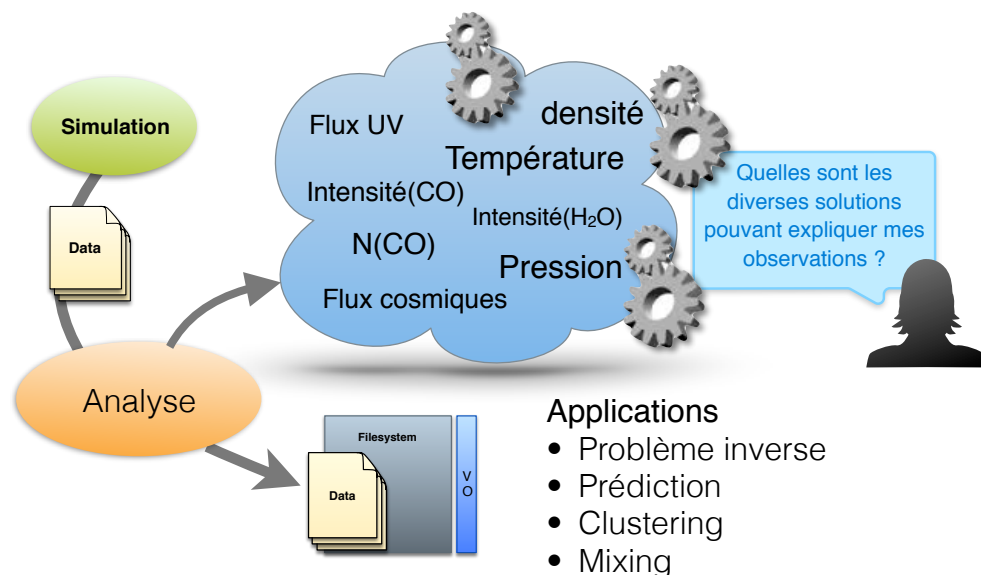
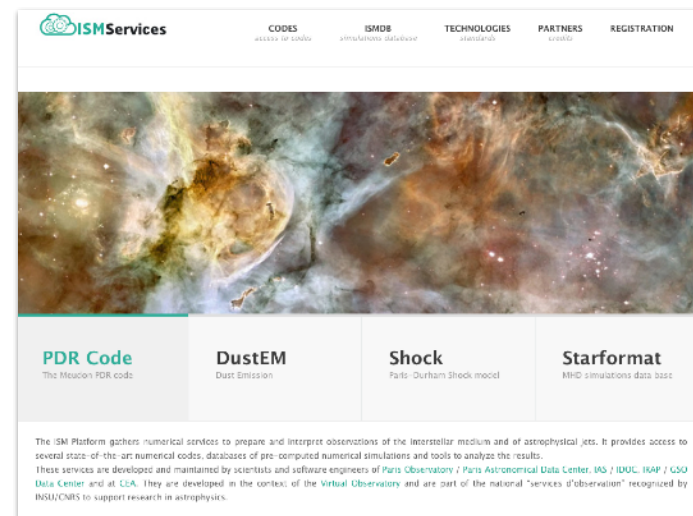
ANO5 Plateforme MIS & Jets

<http://ism.obspm.fr>

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

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**)



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)

- 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

Séminaires du LERMA

LERMA seminars are scheduled 2 or 3 times per month, on Friday at 2p.m. at Observatoire de Paris in salle de l'Atelier.

Speakers are scientists from other departments of Observatoire de Paris and from french or foreign laboratories.

Topics discussed are related to the broad spectrum of astrophysical issues of concern at LERMA ; from cosmology to microphysics of interstellar grains.

For instance , next seminar on Friday November 30th is entitled : « Multiscale star-formation in the Ophiuchus Molecular Cloud: from molecular clouds to brown-dwarfs formation », by Bilal LADJELATE, post-doc at IRAM.

Typically, a seminar lasts 45 minutes + 15 minutes questions ; it starts with a 15 minute long introduction that should be understandable by a student or a non-expert, and then it turns to more detailed results of the study presented.

When not directly related to one's own research topics, a seminar remains a unique opportunity to broaden one's vision (culture) of the vast field of astrophysics. Everyone is encouraged to attend.

Séminaires du LERMA

Seminars are announced through a mailing list and posters.

If you don't receive these mails, please let jean-francois.lestrade@obspm.fr know and you will be added to the list.

If any question, contact jean-François Lestrade (Observatoire de Paris Bat A 6th floor).