



DE LA RECHERCHE À L'INDUSTRIE

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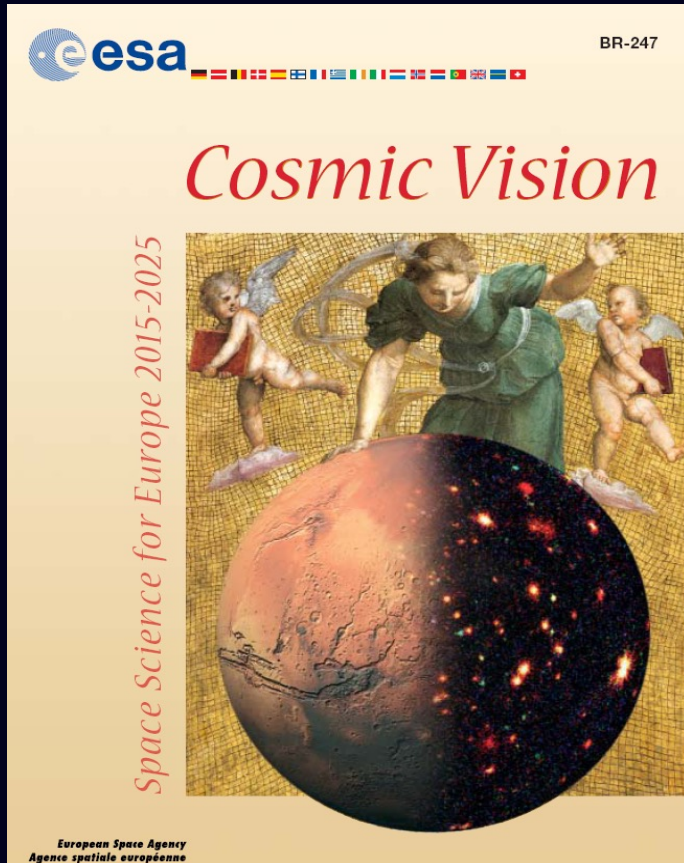
www.cea.fr

THE ASTROPHYSICS DIVISION

Anne Decourchelle

DSM / IRFU / Service d'astrophysique

IRFU SCIENTIFIC COUNCIL, JANUARY 14-15, 2015



Themes:

- What are the conditions for planet formation and the emergence of life?
- How does the Solar System work?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?

Rings, Disks and Planets

Dynamics of Stars and their Environment

Star Formation and Interstellar Medium

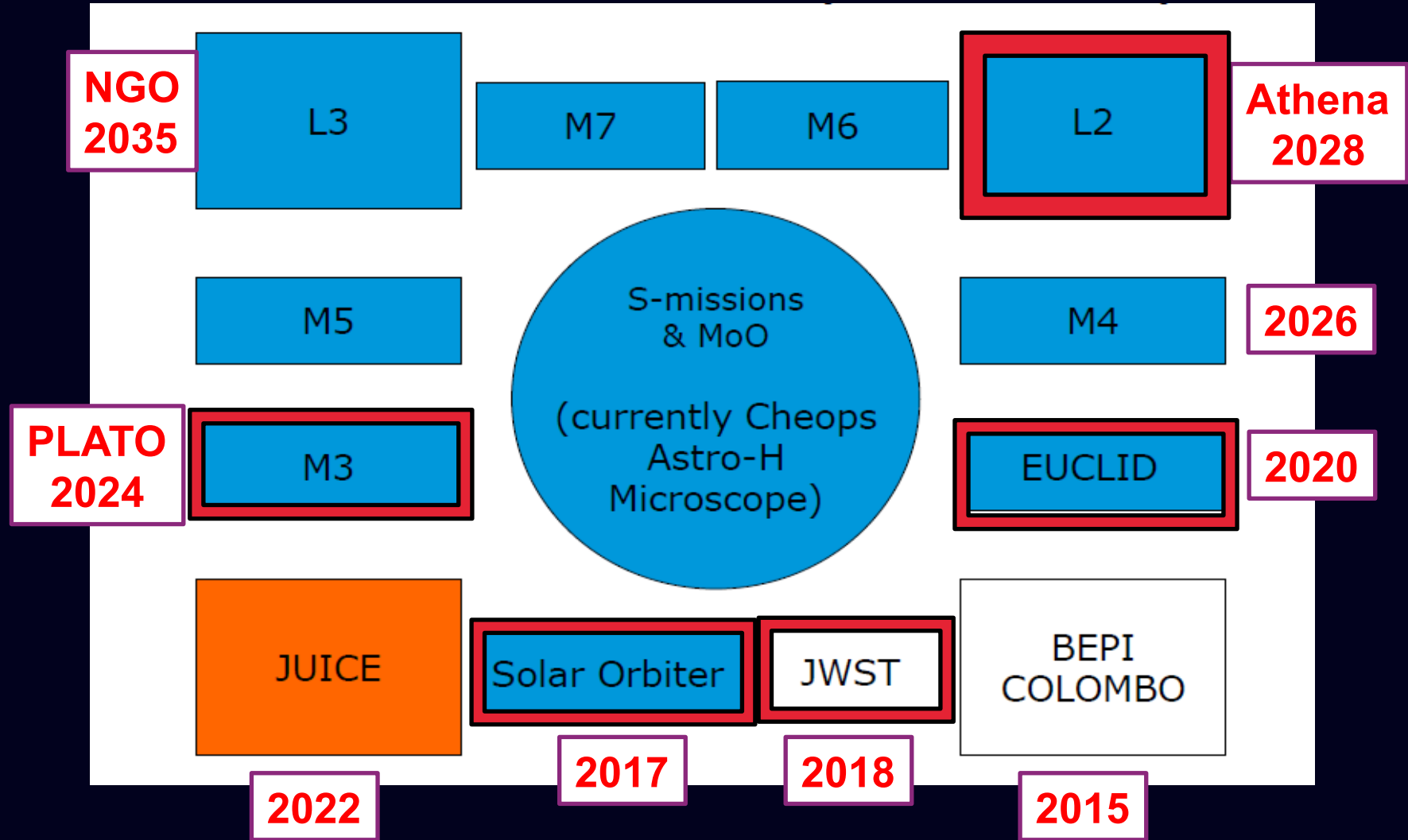
High-Energy Cosmic Phenomena

Cosmology, Galaxy Evolution

Cosmo-Stat

Modelling of Astrophysics Plasmas

FRAMEWORK : ESA COSMIC VISION 2015-2035

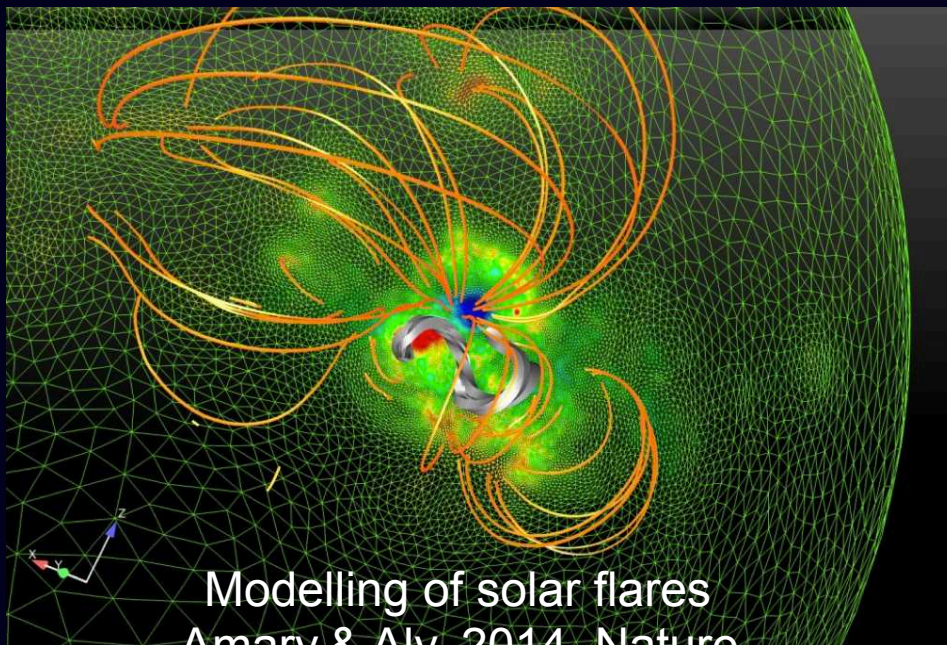


Mission M1 : SOLAR ORBITER (2017)

Objective: solar and heliospheric physics

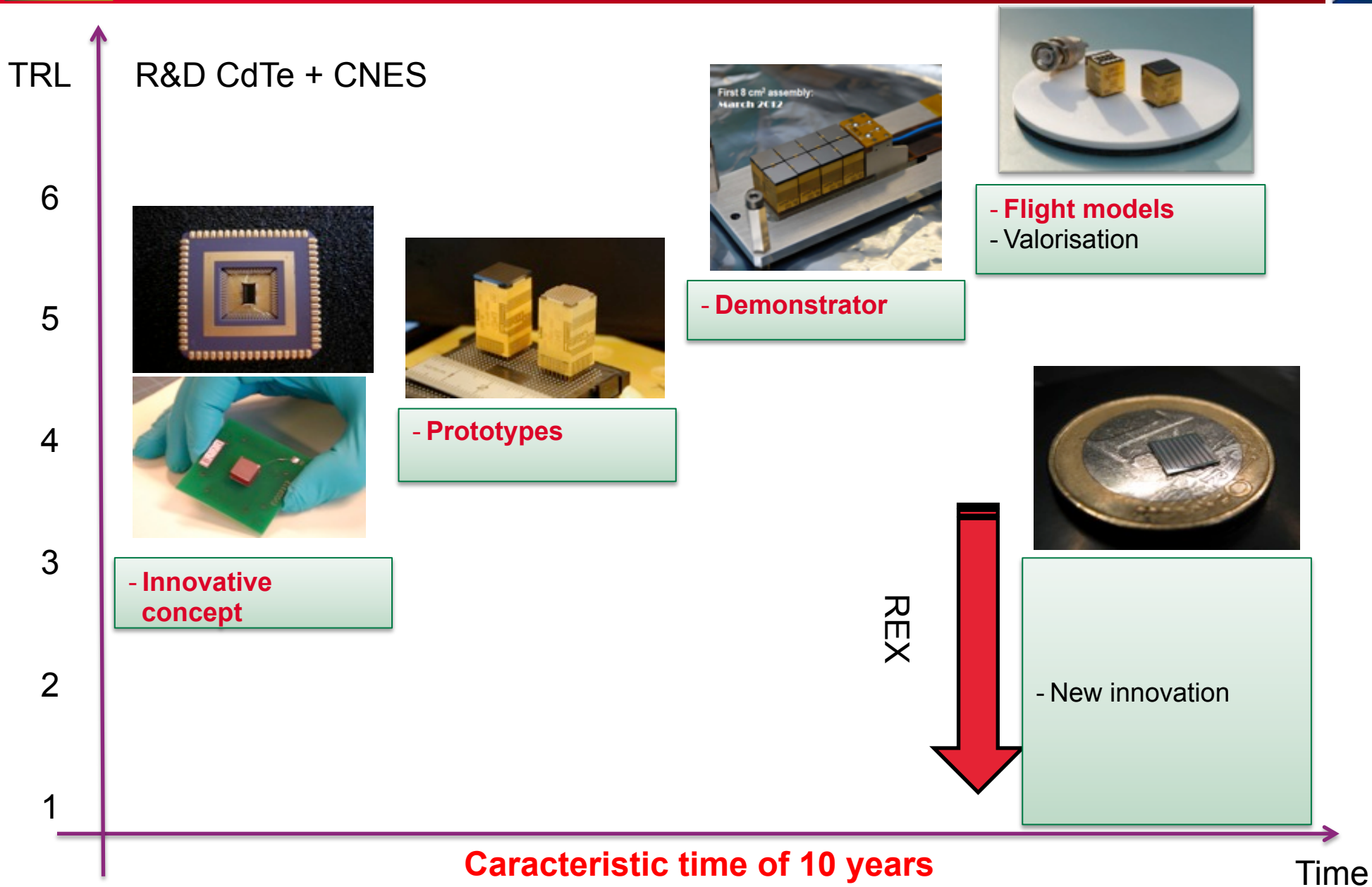
Our contribution :

Camera X- γ Caliste for STIX instrument
Scientific preparation of the mission

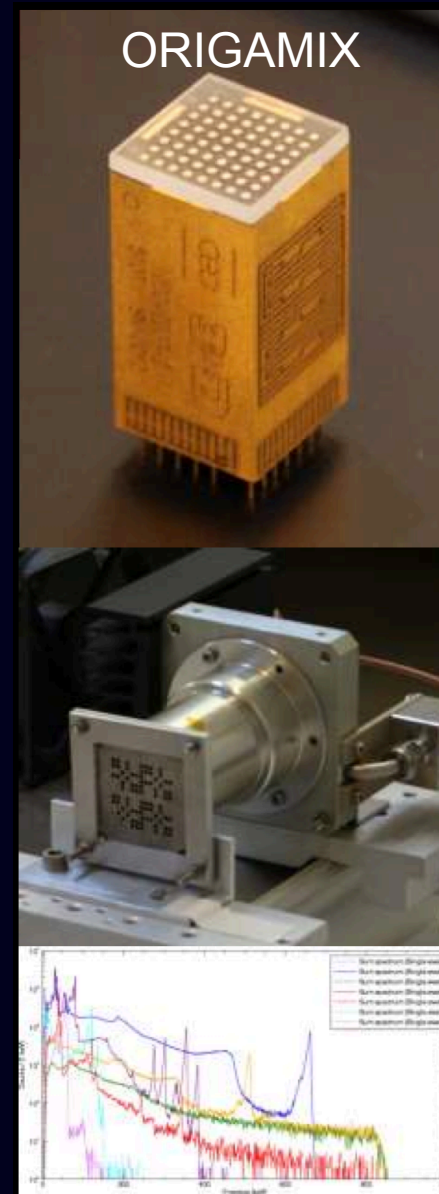
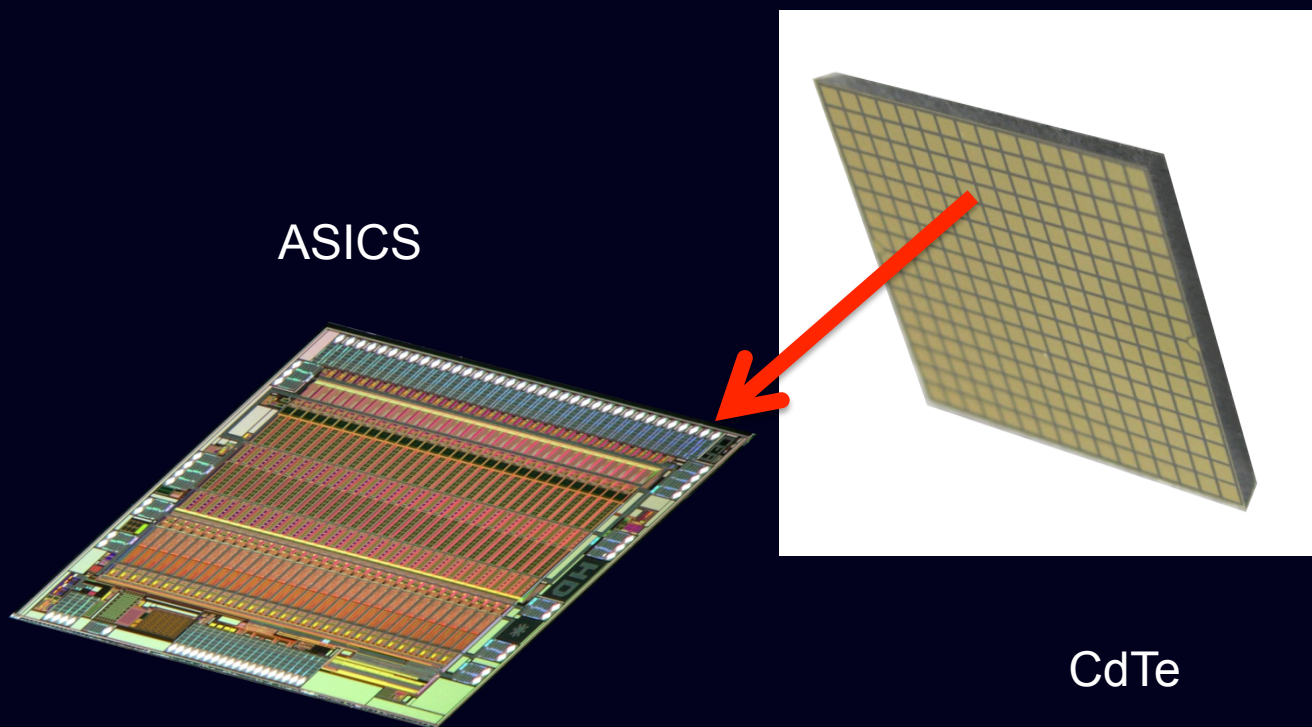


Modelling of solar flares
Amary, & Aly, 2014, Nature





- **CINEMA** (microsatellite US)
- **Solar Orbiter** : Detectors for the instrument **STIX**
- **ORIGAMIX** : spectro-imager for nuclear post-accidental applications (DRT / DEN / DSM)
- **Future** : **SORRENTO** instrument onboard Solar Helio Probe



M2 mission : EUCLID (2020)

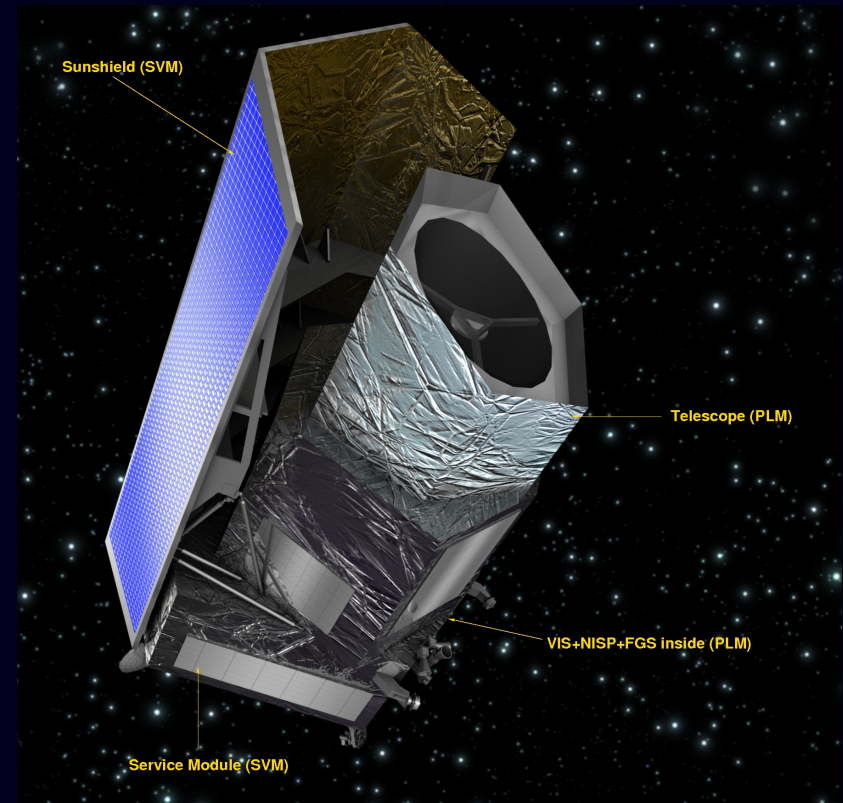
Aim: Characterization of dark matter and dark energy

Method: Survey of the extragalactic sky over 15 000 deg² in 6 years

- **VIS** : Imagery in the visible (shape) and photometry in the infrared (distance) of more than a billion galaxies
- **NISP** : Infrared spectroscopy of 50 millions of galaxies

Strong requirements in terms of:

- **precision**
- **Stability**
- **number of observed objects**

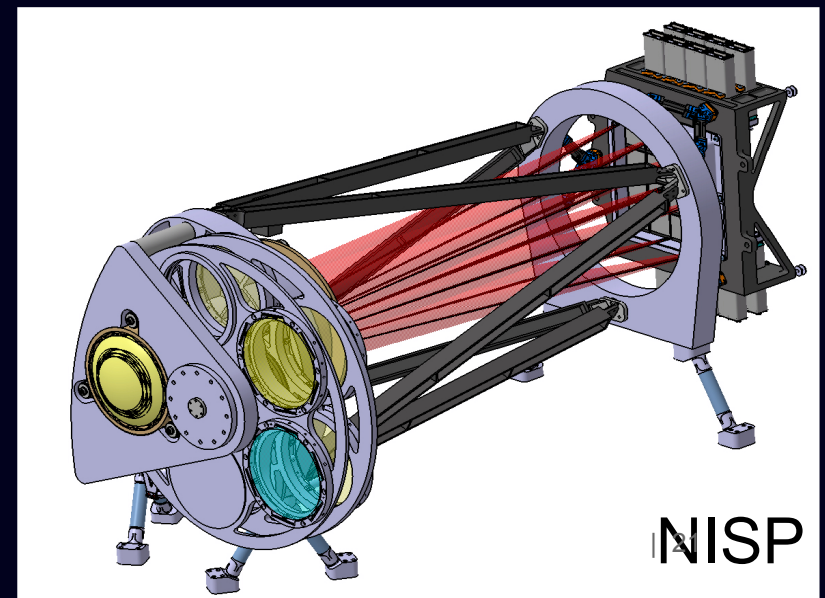
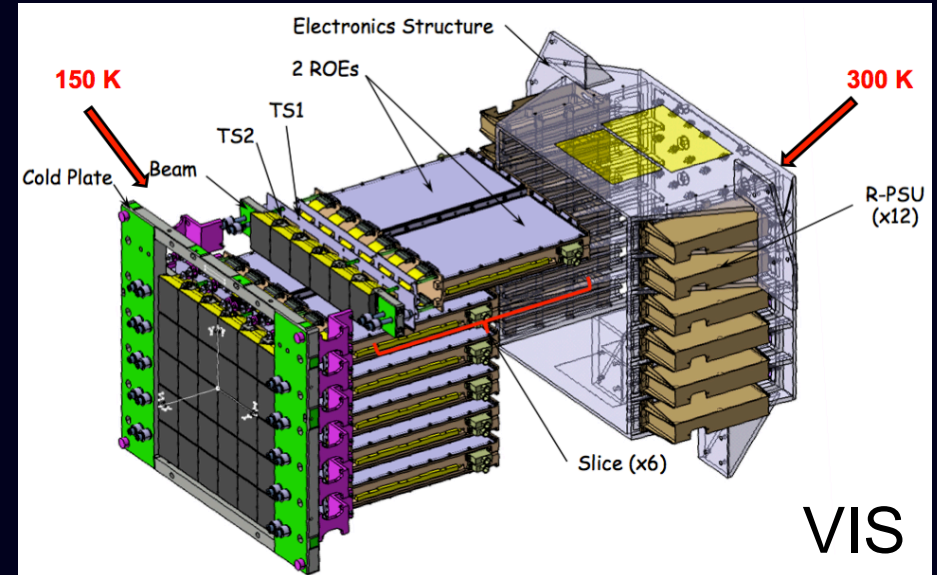


2007 : IRFU leader of the DUNE proposal

2009 : Merging with the NIR spectrometer
=>EUCLID

Responsibility of CEA/IRFU : key role in the consortium Euclid (> 1000 pers, 100 laboratories)

- support to the PI : project coordinator and system for the mission
- Delivery of sub-systems for the two instruments
 - Focal plane of the VIS instrument
 - Power control unit (PCMU)
 - Cryo-mechanisms for NISP instrument
- Ground segment scientists
- High level data processing for weak lensing
- Strong implication in scientific activities





INSTRUMENTS

- **2011-2014:** Preparatory studies and detailed definition phase
- **June 2014:** **Successful Preliminary Design review (PDR)**
- **October 2014:** **Beginning of the construction phase of Euclid (C/D phase)**

=> delivery of the instrument at ESA in 2017

VIS

=> GROUND SEGMENT

2015: System requirement review (SRR) for the scientific ground segment

JWST (James Webb Space Telescope):

a flagship mission of NASA with ESA contribution

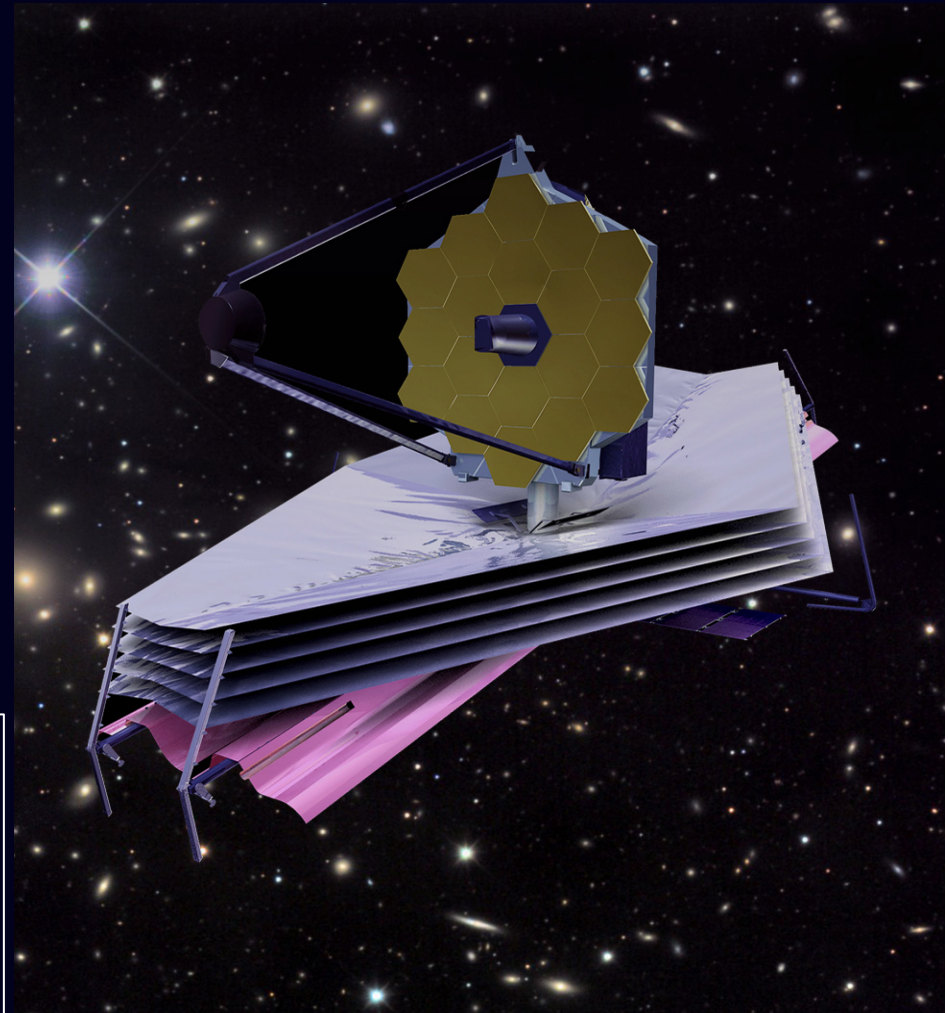
Successor of the Hubble space telescope in the infrared domain : a 6.5 meter InfraRed (0.6 -28 microns) telescope in Space

Launch : 2018

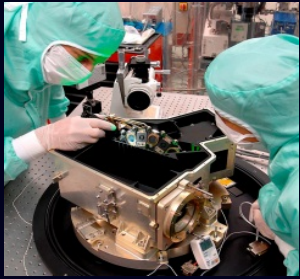
Lifetime : to be in operation for 5 to 10 years

Irfu implication: Co-PI

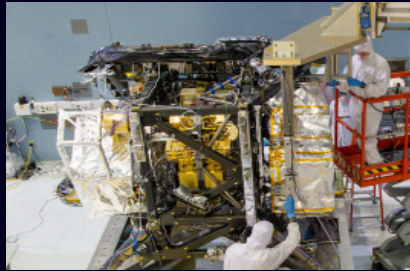
- leading the French contribution
- leading the MIRI imager development at consortium level



CONTRIBUTION TO COSMIC VISION MIRI: THE MID-IR INSTRUMENT FOR THE JWST



Irfu
AIM, SEDI, SIS, SACM



1998-1999
Scientific argumentation
for a mid-IR instrument

2000-2004
Preliminary studies
Phase A

2004-2010
Realisation of the Imager
and Tests at Saclay
Delivered may 2010

2010-12
Tests at RAL, UK
Tests at NASA
Goddard

2013-15
Science: GTO preparation
(coordinating exoplanets program)

Data pipeline:
imager algorithms
to STSCI

Pipeline tests
Leading the development of the
French expertise center:
Help to the users
High level data reduction

2018
Launch

2019-2023 ... 2028
Scientific exploitation
(LCGE, LFEMI, LADP)

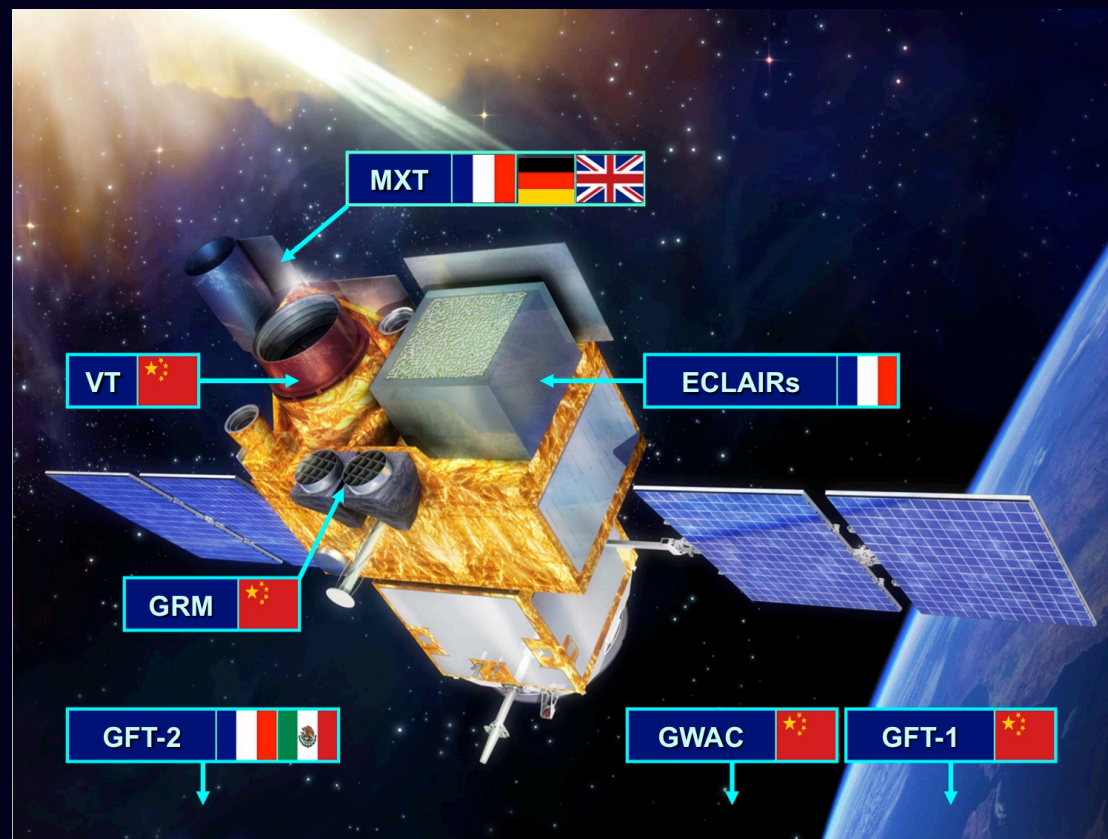
Mission SVOM (2021)

Objective : Study of gamma-ray bursts

Method: Multi-wavelength approach
(hard X-ray instrument ECLAIR, X-ray camera X (MXT),...)

Responsibility of CEA/IRFU :

- Co-PI mission
- PI MXT instrument
- Responsible of the scientific processing unit of ECLAIR
- Scientific PI of French ground segment



IPFU - Starch et al. 2014
SVOM satellite

⇒ **Beginning of phase B in September 2014
after signature of CNES and CSA presidents**

⇒ **See talk by Bertrand Cordier**

Scientific priority

- ARTEMIS (2014, 2015)
- **Cosmic Vision** : Solar Orbiter (2017), Euclid (2020)
- **NASA/ESA** : JWST (2018)
- **CNES/CSA**: SVOM (2021)

- **Mission Cosmic Vision selected in 2014 :**
 - **PLATO (2024) : exoplanets and star**
 - **Athena (2028) : the hot and energetic Universe**
- **ESO : ELT (METIS, 3rd instrument),**

2014: decision of construction of ELT

R&D & innovation :

- **Innovation** with LETI : submm/mm micro-bolometers measuring the intrapixel polarisation
- Development of **IR detectors** with LETI, SOFRADIR, ONERA

A large number of publications expected in 2015:

From large programs and observations

- XMM-Newton : XXL Large Scale Survey, clusters of galaxies
- **Herschel**: GOODS-Herschel ,..
- **FERMI, Herschel/ALMA, ARTEMIS,...**
- **ALMA, IRAM, ...**

From modelling and numerical simulations

- Dynamics of protoplanetary disks, star–planet interaction
- Radiative transfer with adaptative mesh refinement for galaxies simulations
- Supernova mechanism
- Molecular clouds with feedback processes
- ...



From new programs

FP7 programs :

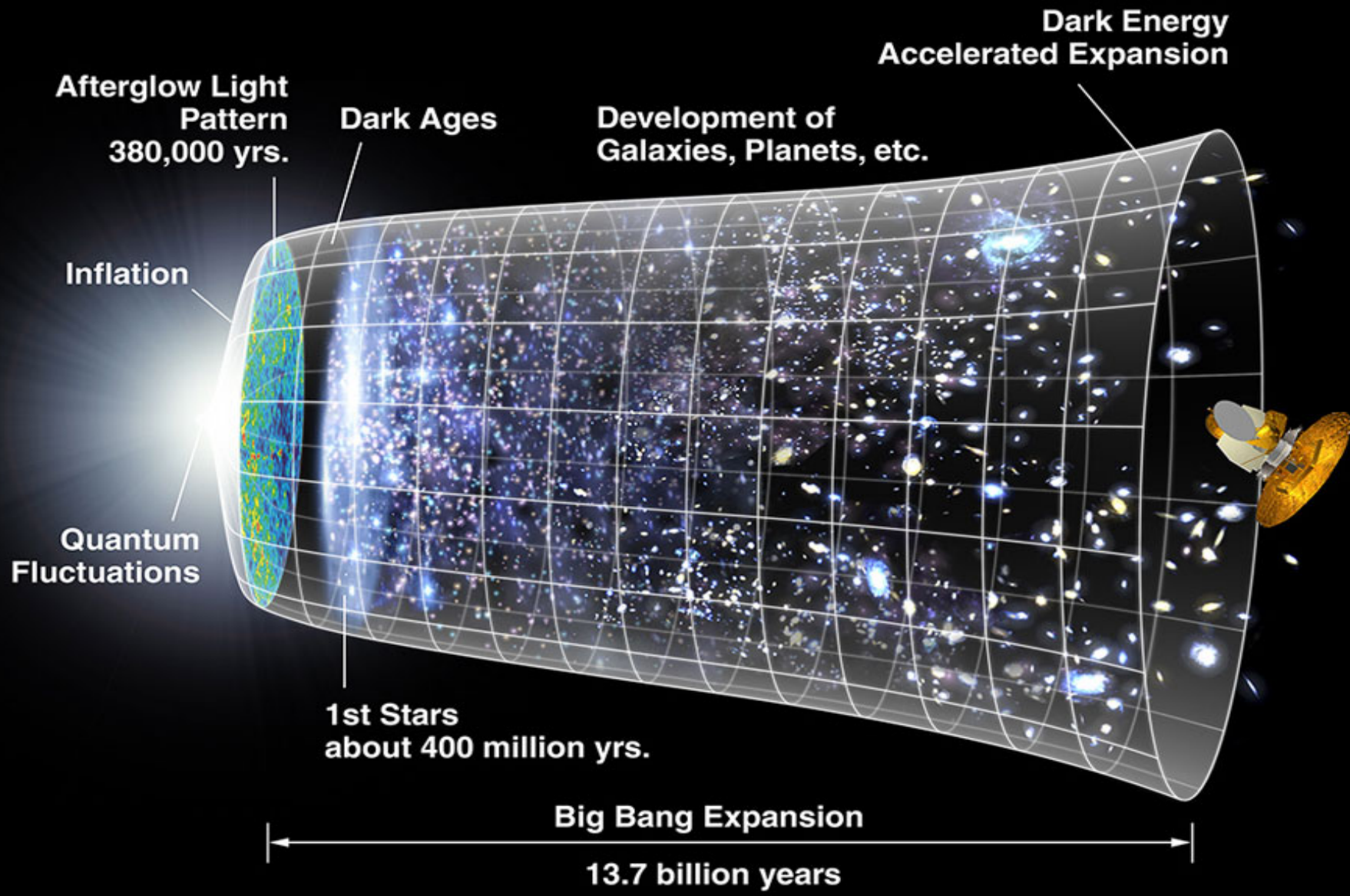
- Sparse Signal Processing Technologies for HyperSpectral Imaging Systems, J.L. Starck
- A Definitive Study of Cosmic Dust in the Local Universe, S. Madden
- ...

ERC proof of concept :

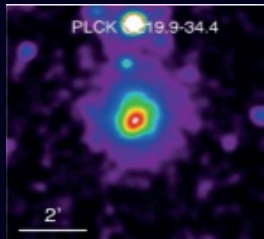
- SolarPredict: An advanced predictive tool and service of the Solar 11-yr Activity Cycle, Sacha Brun

IRFU : Starck et al. 2014
=> Celebration in 2015 of 50 years of astrophysics at CEA





From large scales



To small scales

- Cosmology: structure, origin and evolution of the Universe
- Formation and evolution of galaxy clusters
- Formation and evolution of galaxies
- Formation and evolution of stars and planets

Structuration of the Universe
Energy content of the Universe

To large scales

Feedback processes

Supergalactic winds
starbursts
Galactic winds
Black holes,
Supernovae,
Cosmic rays,
,...

High-energy phenomena

From small scales

ASTROPHYSICS : A SCIENCE OF OBSERVATIONS



**Instruments and
telescopes**

**Multi-wavelengths
observations**

**Statistical signal
analysis**

**Modelling and
numerical simulations**

Multi-wavelengths observations

Technical and scientific excellence

Dedicated instrumentation (Space and ground-based)

Modelling Multi-scales numerical simulations

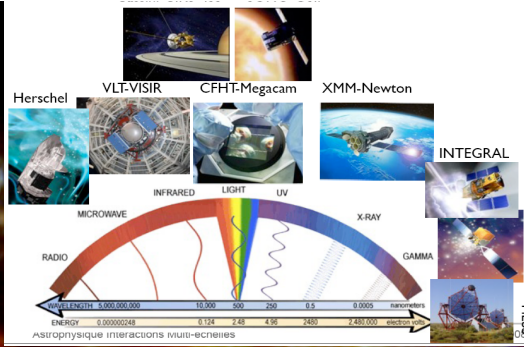
R&D

Dedicated instrumentation (Space and ground-based)

R&D

Modelling Multi-scales numerical simulations

⇒ Long timescale between R&D, realisation of the instruments, interpretation and modelling
⇒ projects in parallel at different phases



APEX/
artemis

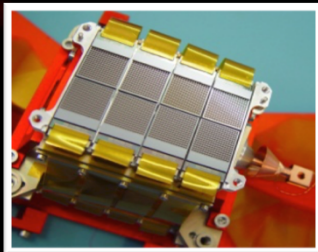
Herschel

Multi-wavelengths observations

Technical and scientific excellence

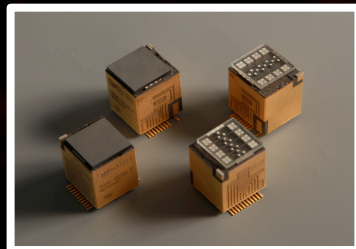
Dedicated instrumentation (Space and ground-based)

Modelling Multi-scales numerical simulations

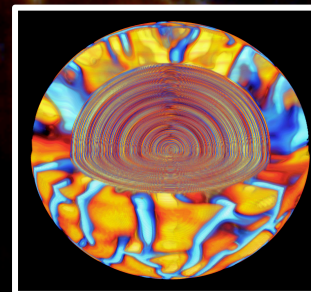


PACS submm bolometers

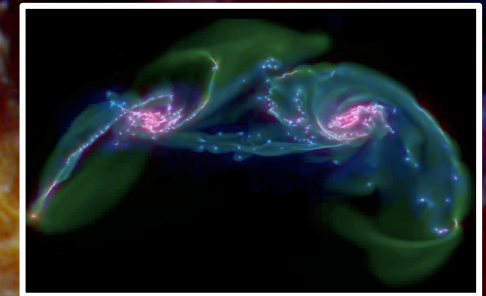
R&D



Hard X-ray Caliste detectors



Sun



Galaxy collisions



Astrophysics division : a joint research unit AIM (CEA - Paris Diderot University - CNRS)
Anne Decourchelle

P. Delbourgo, L. Rodriguez, I. Grenier, P.-A. Duc

ASTROPHYSICS

Cosmology, Galaxy Evolution
D. Elbaz

Star Formation and
Interstellar Medium
M. Sauvage

Dynamics of Stars and
their Environment
S. Brun

Rings, Disks and Planets
C. Ferrari

High Energy Cosmic Phenomena
J. Rodriguez

Cosmo-Stat
J.-L. Starck/J. Bobin

Modelling of
Astrophysics Plasmas
T. Foglizzo

Staff ~130

**SPACE
TECHNOLOGIES**

Product Assurance
Integration
J. Fontignie

System , Architecture
M. Berthé

Spectro-Imagers
O. Limousin

Space Electronics
C. Cara

Interface Science and
Instrumentation
A. Claret

Staff ~60

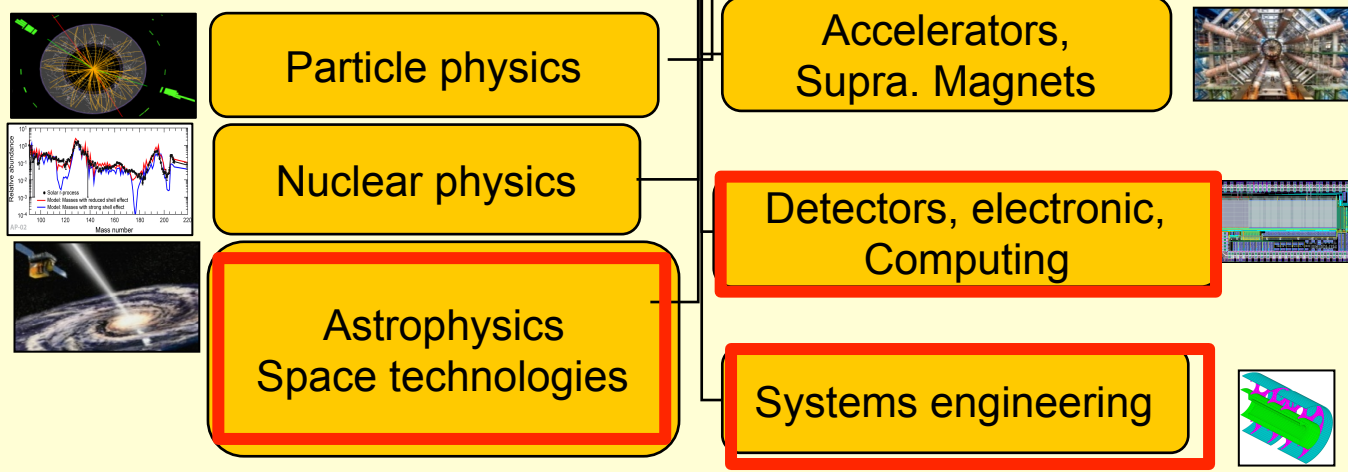


Capacity to manage
the development of
a space instrument

Total staff ~190
Permanent ~ 120
Post-docs₆ ~40
PhD students ~30

CEA / DSM / IRFU

Institute of Research into the Fundamental laws of Universe



**CNES, ESA,
ESO, EU
(FP7, H2020),
ANR**

**National
and local
funds
labex :
FOCUS,
Univearth, P2IO, DIM
ACAV**

**Pôles
spatiaux et
plateformes
Paris-
Saclay
university**

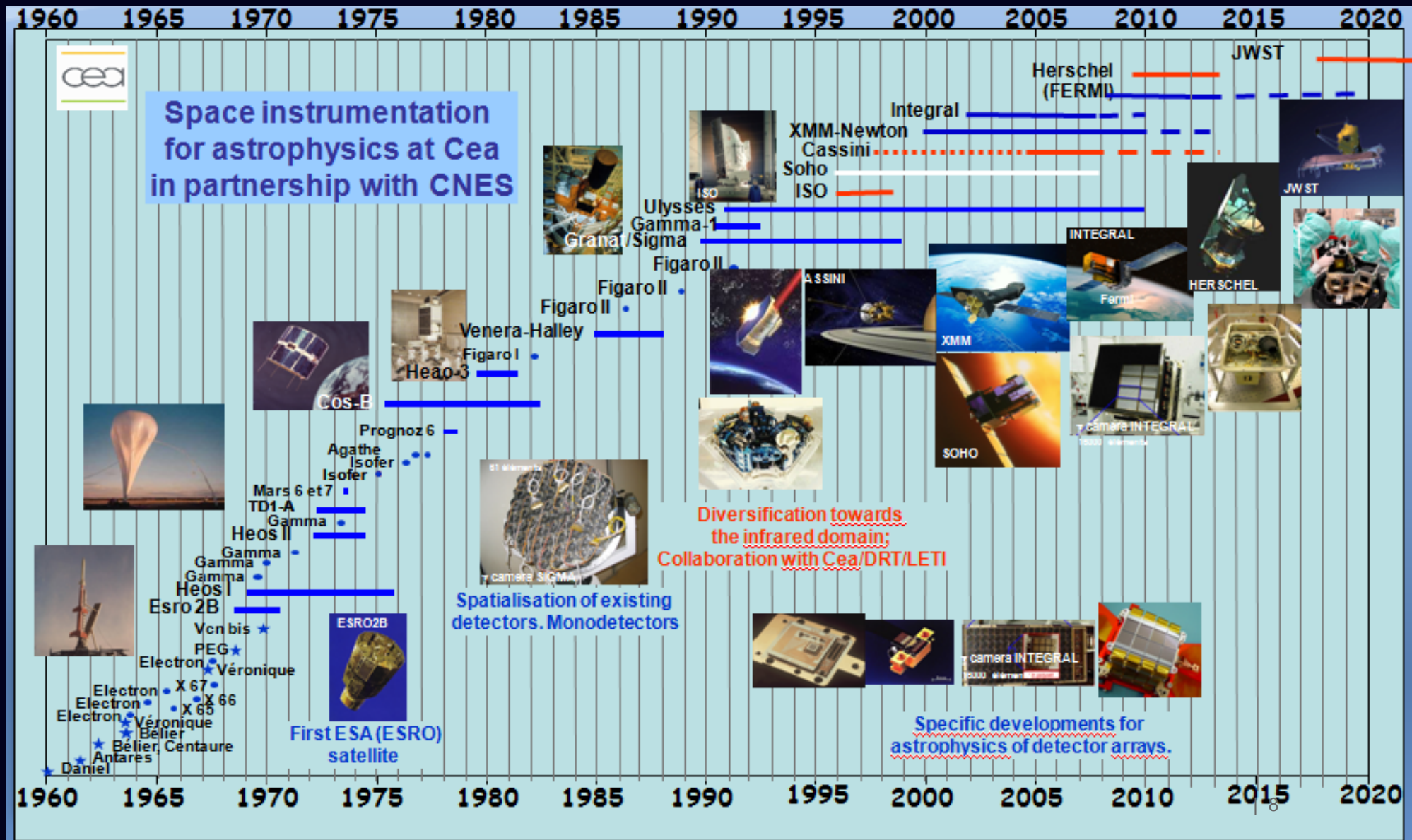
**Academic
partners**

**DRT / LETI
detectors**

**Industrial partners
3D+, ASTRIUM,...**

**DSM / INAC / SBT
Cryogenics**

2015 : 50 YEARS OF ASTROPHYSICS AT CEA IN PARTNERSHIP WITH CNES



SPACE INSTRUMENTATION IN CEA : FROM HIGH ENERGY TO INFRARED DOMAIN



Observations from space required :

- In **gamma-rays, UV, IR and submillimeter** (atmosphere is opaque)
- To avoid **atmospheric turbulence** in optical and in a few infrared bands
- To get **very high sensitivity** in the mm and submm domain

HIGH ENERGY DOMAIN

- *HEAO* (1978-), NASA
- *SIGMA* (gamma rays), French-Russian mission (1990-2000)
- *Ulysse*, NASA mission (1995-2010)
- ***XMM-Newton*** (X-rays), cornerstone of de l'ESA (1999-)
- ***INTEGRAL*** (rayons gamma), satellite de l'ESA (2002-)

INFRAROUGE and SUBMILLIMETER OBSERVATIONS

1990 : technical developments at **CEA/LETI**

- Caméra ***ISOCAM*** (infrarouge) du satellite **ISO** de l'ESA (**1995-1998**)
- Spectromètre ***CIRS*** (IR moyen) de la mission NASA **Cassini** vers Saturne (1997-)
- Photomètre ***PACS*** (60-210 microns) de la mission **Herschel** de l'ESA

To increase sensibility : instruments needs to be at low temperature (**CEA/INAC⁹/SBT**)

Scientific exploitation of the data

Space : Herschel, Planck, XMM-Newton, Integral, Fermi, Cassini

Ground : CFHT/megacam, VLT/VISIR, HESS, HESS2

Ground segments

Herschel, FERMI

In prep. : JWST/MIRI, EUCLID, SVOM

Instrument developments

Space : JWST/MIRI, Solar Orbiter/STIX, EUCLID, SVOM

Ground : ARTEMIS, PILOT, IRAM/NIKA 2

Preliminary studies

Space : PLATO, ATHENA

Ground : CTA, ELT/METIS

Proposals for new missions and instruments concepts

=> M4 missions : Core+, Ariel, LOFT, ARAGO, Theseus, ..

R&T

- Submm bolometers, mini gamma/hard X-rays cameras, X-ray microcalorimeters, intrapixel characterization of detectors, IR detectors, TALC deployable telescope

PACS :

- Responsible for the PACS imager
- Detectors (bolometers LETI), electronics, cryo-cooler (SBT), mechanics, tests and space qualification

⇒ Most used instruments of Herschel

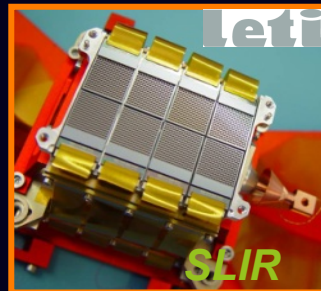
SPIRE

- Electronics, cryo-cooler (SBT)

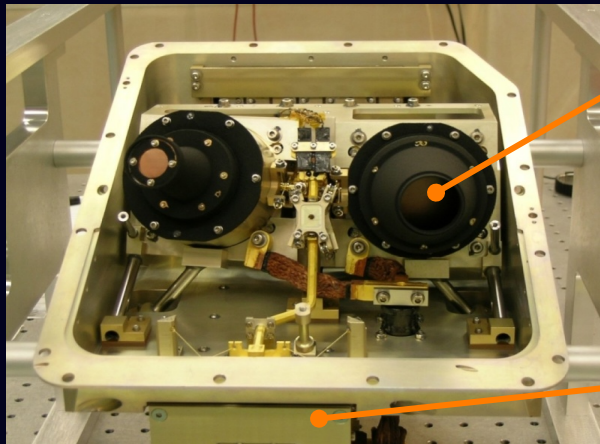
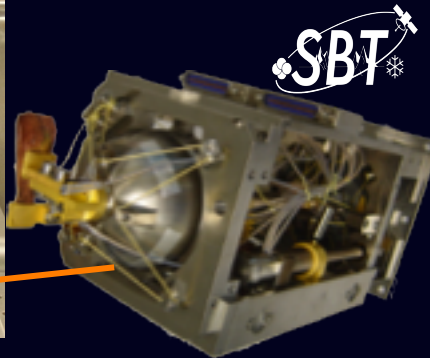
Development time : 13 years (1996, 2009)



LETI

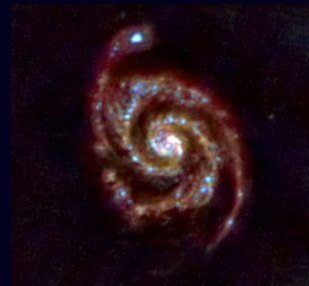
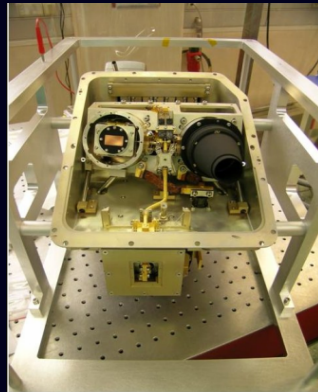


SBT



Rosetta molecular cloud, 11
Herschel/PACS/SPIRE

Innovative technology and scientific excellence

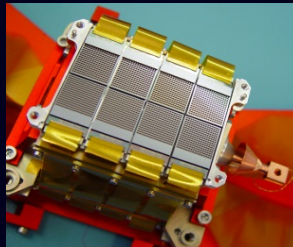


2009 – 2014+

Scientific exploitation

Participation to the ground segment

Realisation of PACS imager



R&T : new matrix of detectors

CEA/LETI

~ 1990

Scientific questions
Star formation,
interstellar medium

Scientific exploitation

Major scientific results, among the most cited on Herschel

- Elbaz et al. 2011
Star forming galaxies
- André et al. 2010
Star formation
- A lot of other articles



Numerical simulations

Numerical simulation

- **Galaxy interaction**
Bournaud et al. (2014)
-
- **Star formation**
=> See talk by Patrick Hennebelle

ARTEMIS:

- Ground-based telescope APEX (ESO, Chili)
- Focal plane of matrix of bolometers at 350 microns (2014) and 450 microns (2015)

SBT : cryogenics

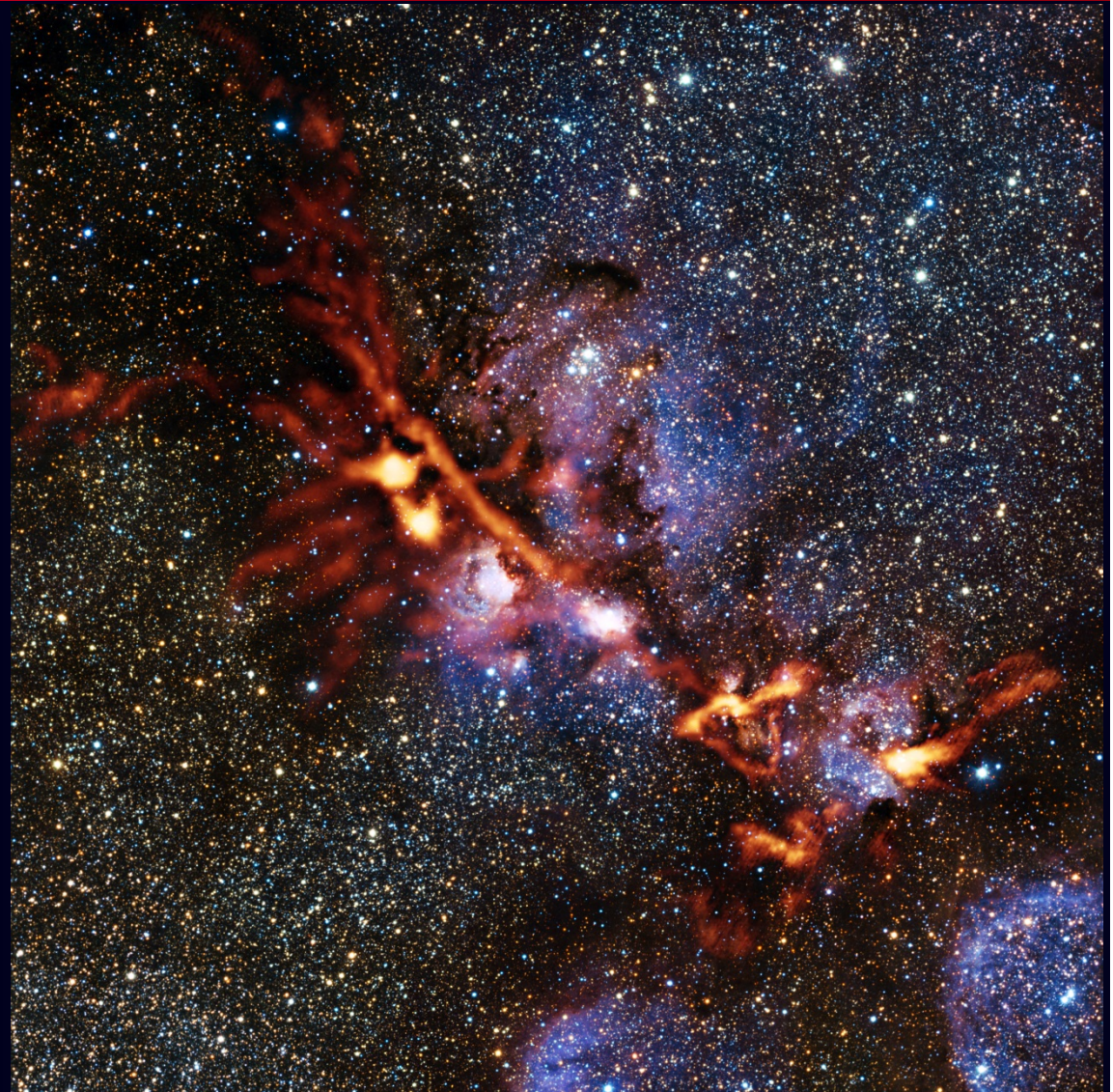
LETI : PACS detectors

PILOT : measure of the polarisation
Stratospheric balloon

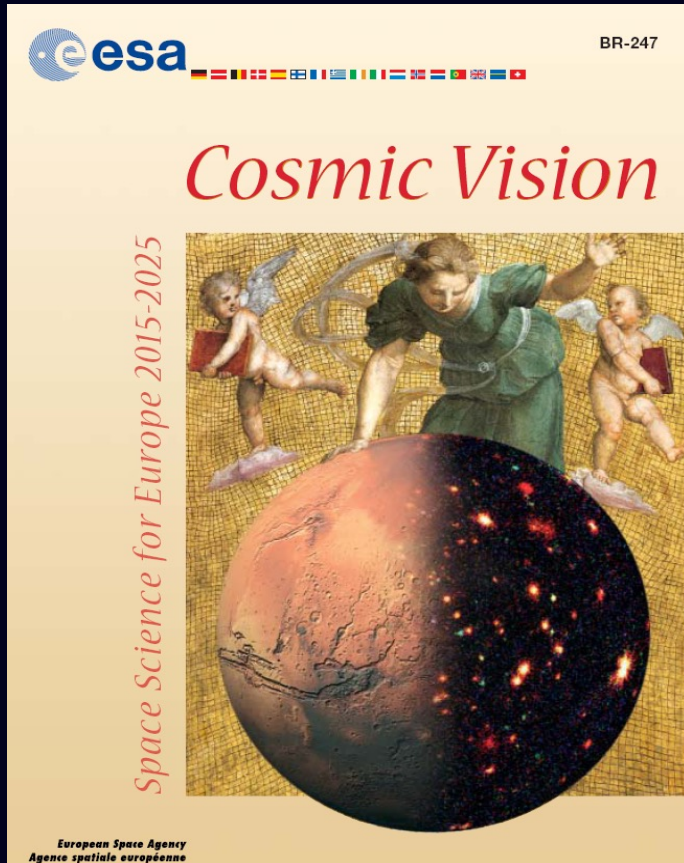
Focal plane of matrix of bolometers at
240 microns

⇒ Flights in 2015, 2017, 2018

LETI : PACS detectors



Cat's paw nebula
VISTA / ArTéMiS Image



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