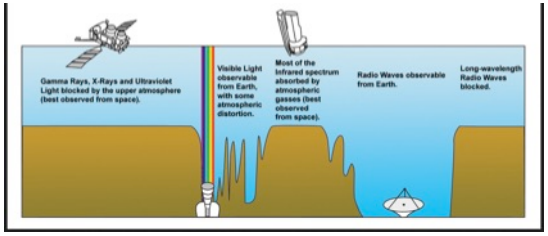
Introduction aux radiotélescopes (sub)millimétriques et leurs récepteurs

Martina Wiedner, LERMA, Observatoire de Paris

Image de la page web d'IRAM

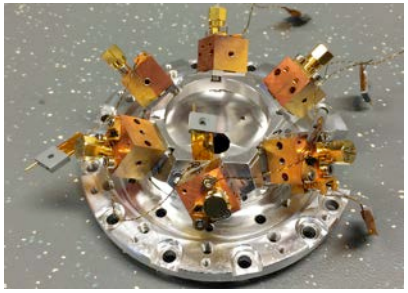
Sommaire

I. Atmosphère

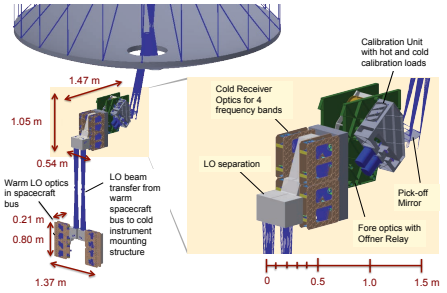


II. Télescopes

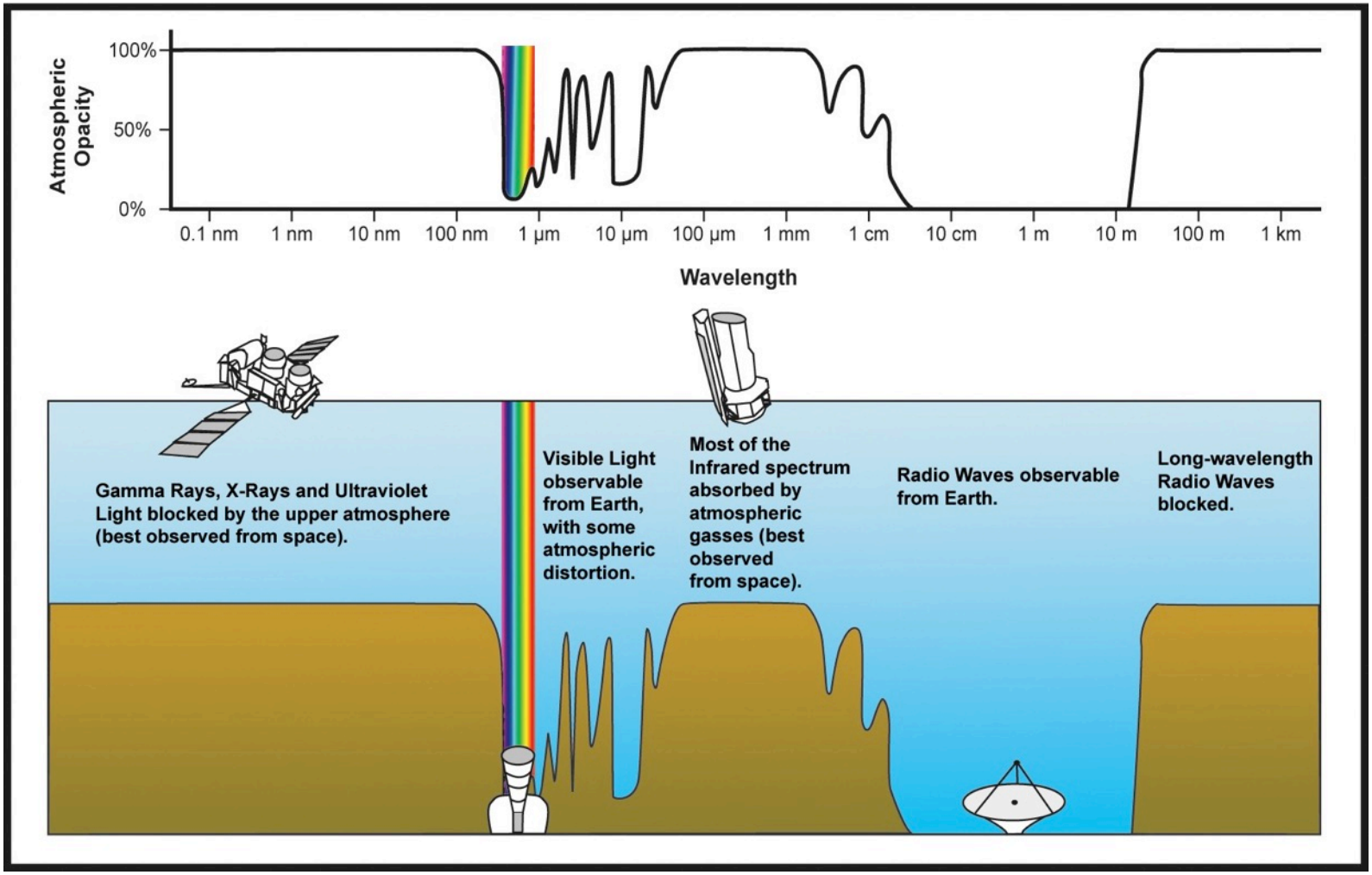
III. Récepteurs



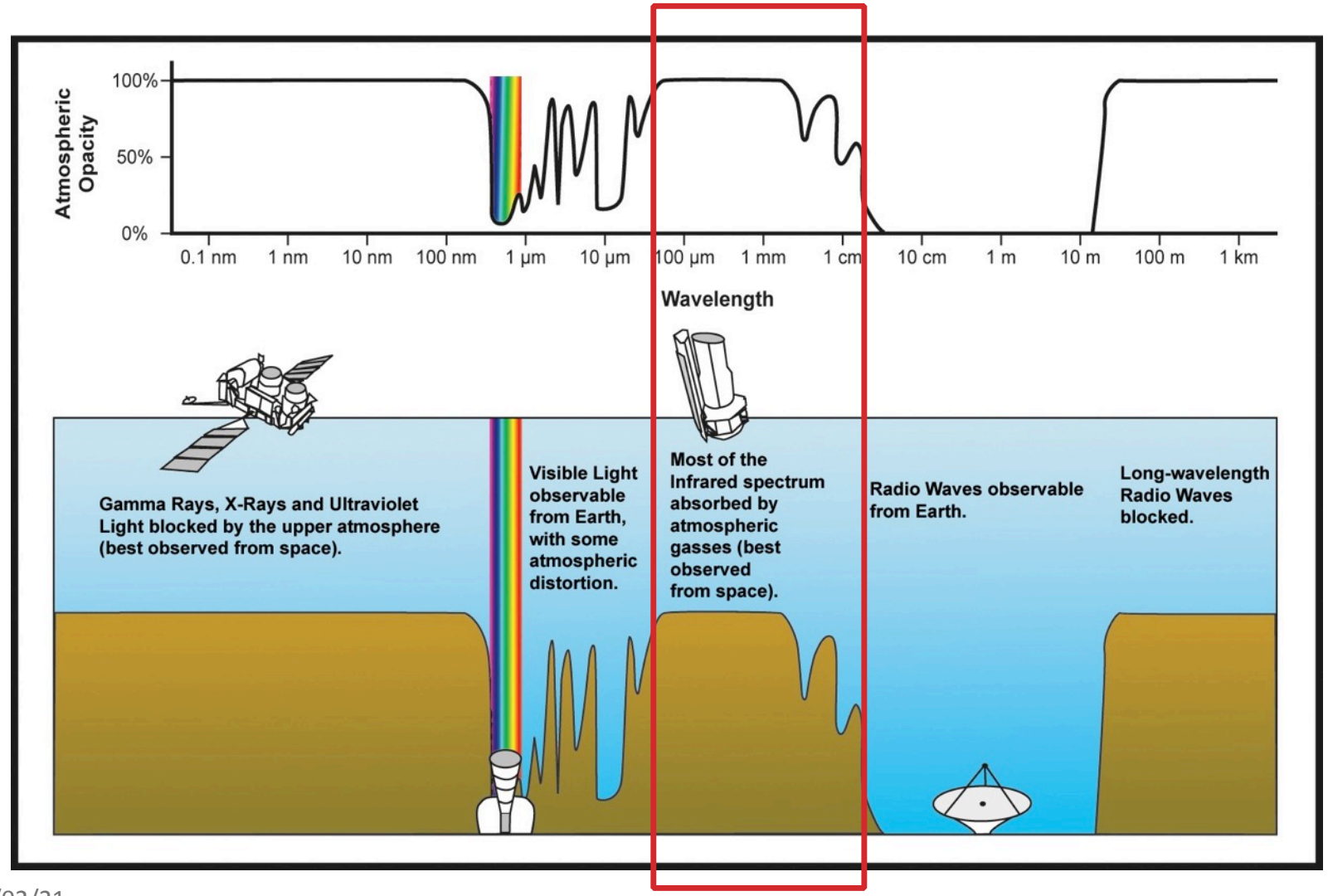
IV. Expertise au LERMA



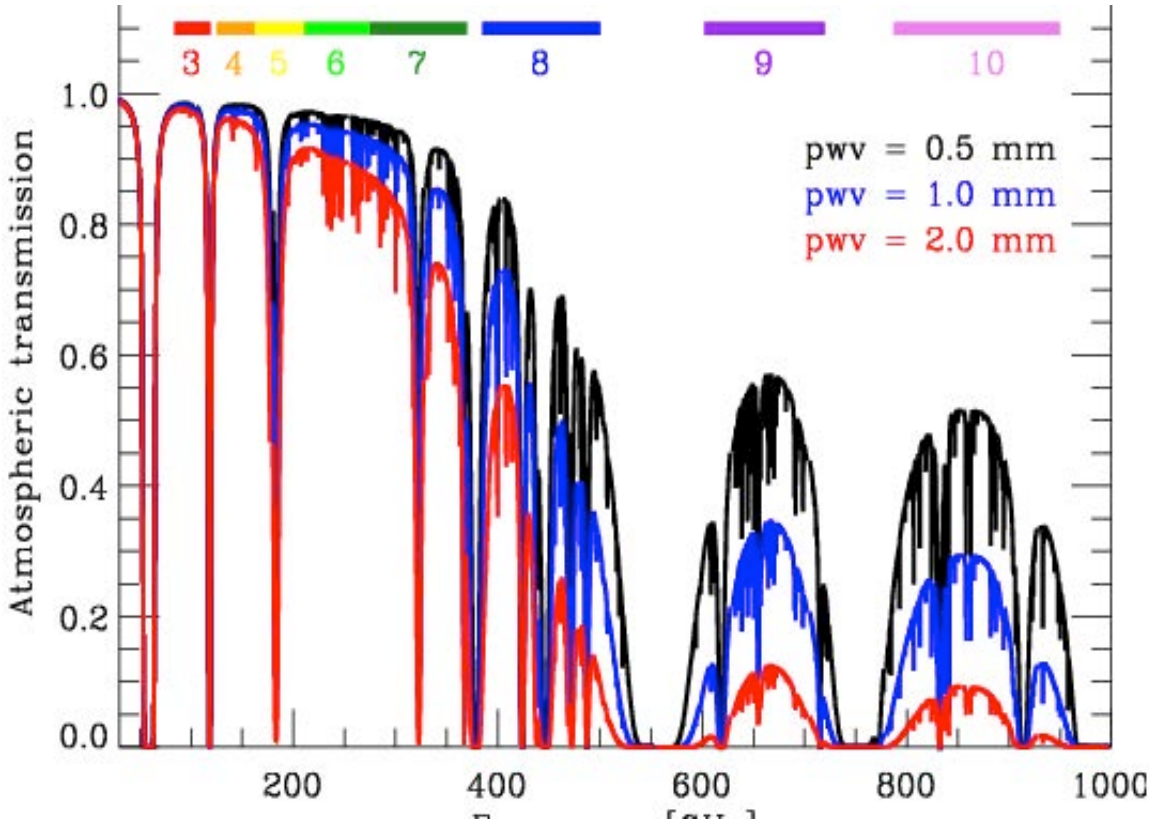
Spectre Electromagnétique



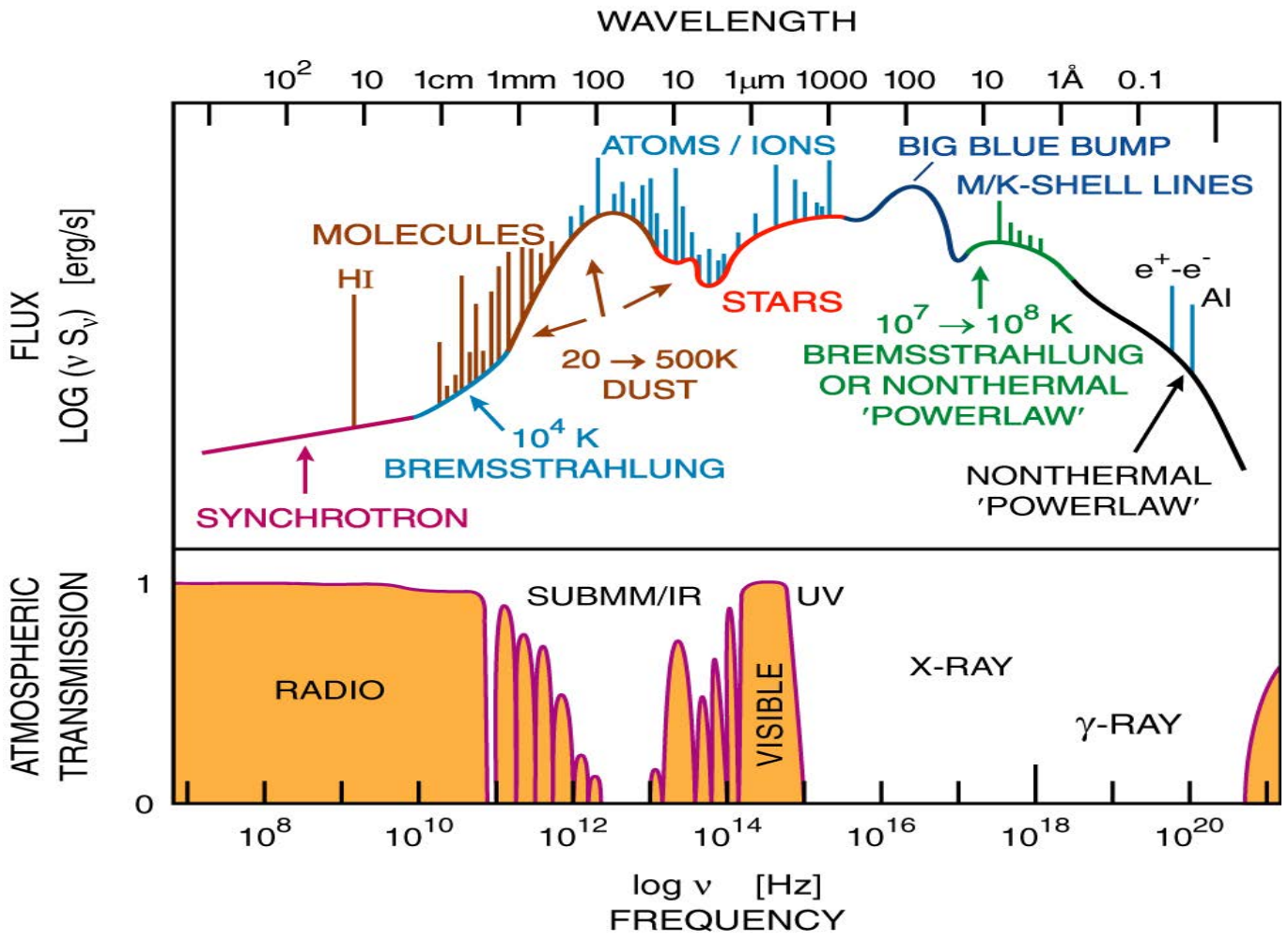
Spectre Electromagnétique



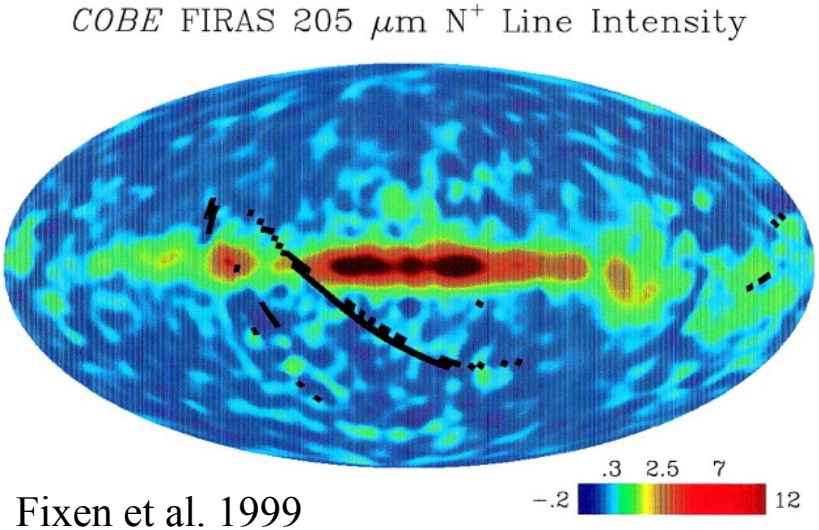
Transmission atmospherique au desert d'Atacama à 5000m



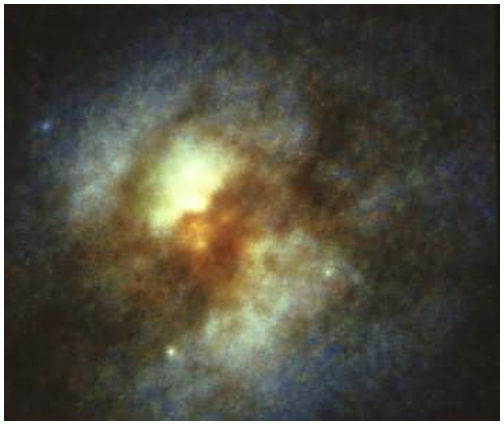
Spectre électromagnétique



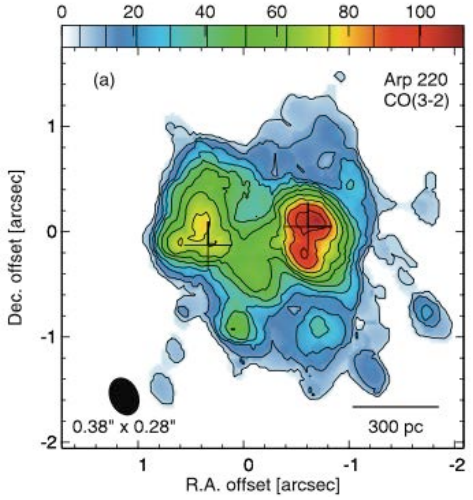
Ciel (Sub)millimétrique



Fixen et al. 1999

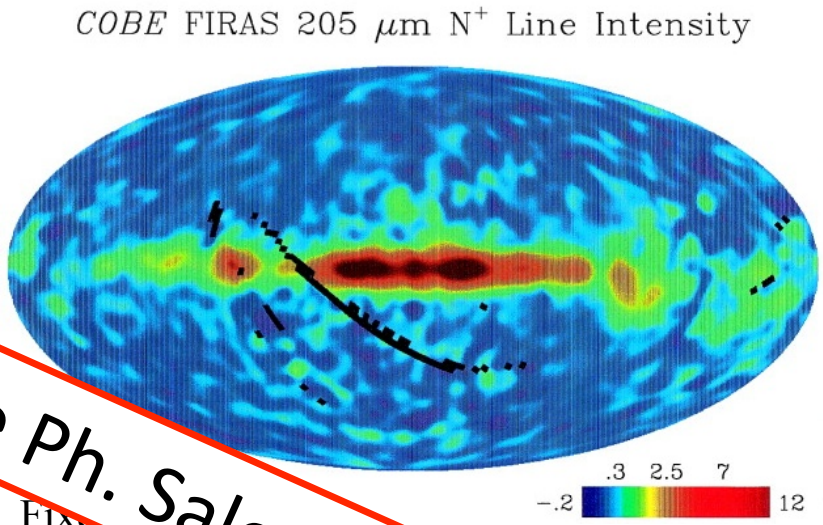


Hubble WFPC, Shaya

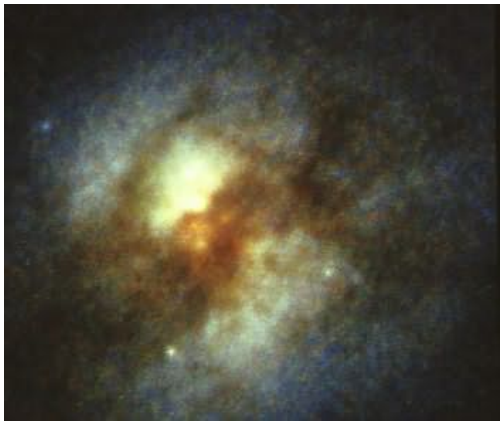


Sakamoto, … Wiedner … 2008

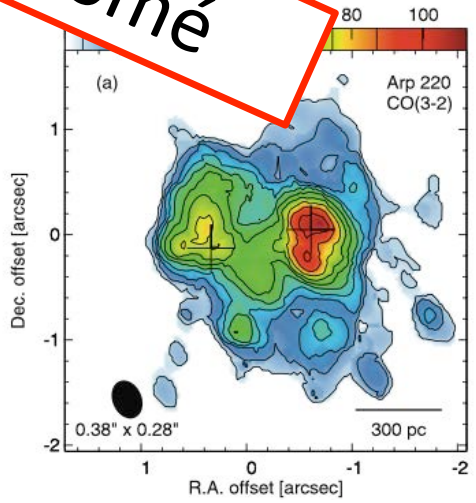
Ciel (Sub)millimétrique



Présentation de Ph. Salomé



Hubble WFPC, Shaya



Sakamoto, …Wiedner … 2008

Quelques télescopes (sub)mm

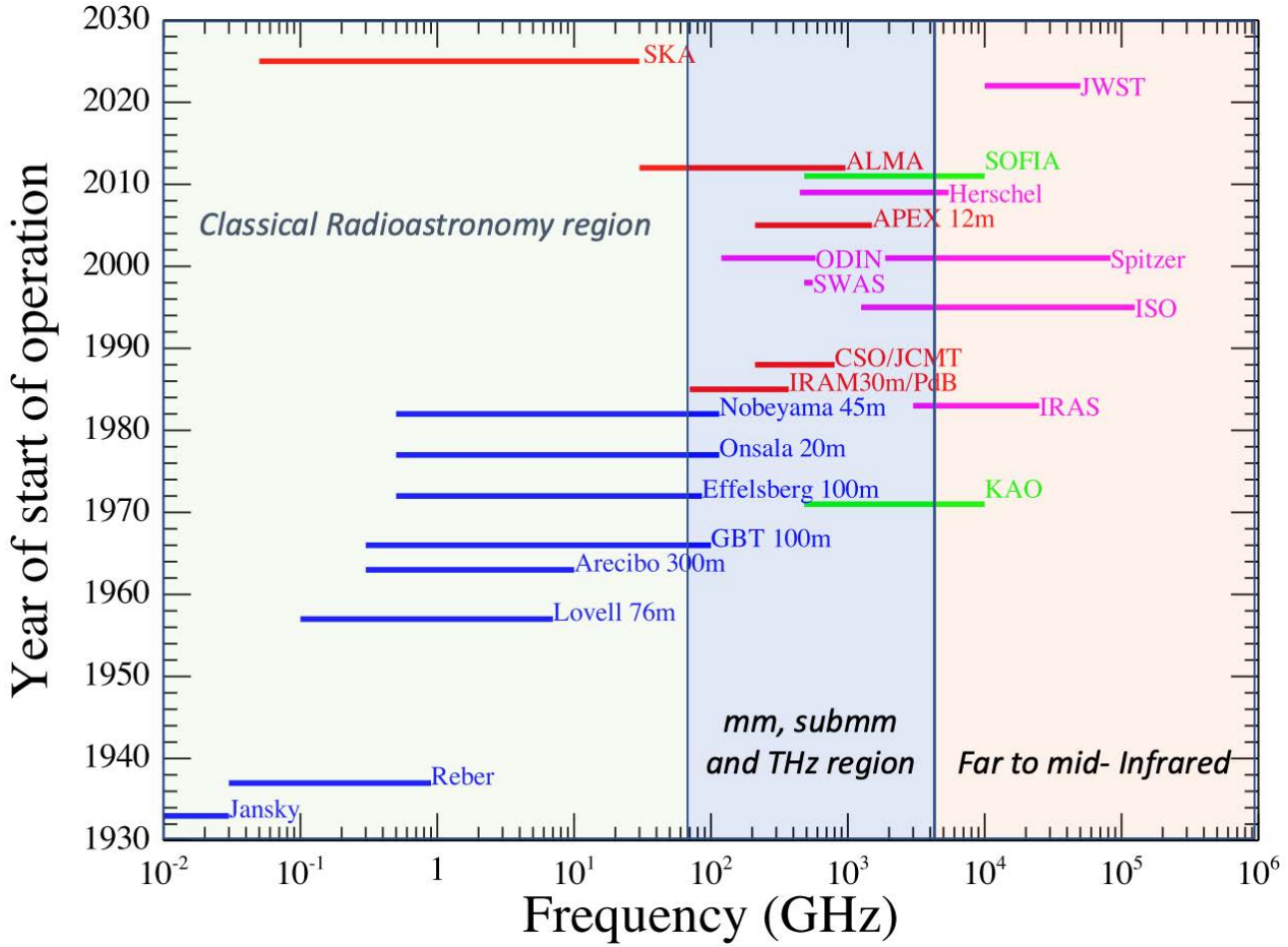


Figure crée par C. Risacher

IRAM 30m
(Institut de Radioastronomie Millimétrique)

NOEMA
(NOrthern Extended Millimeter Array)

Quelques télescopes (sub)mm

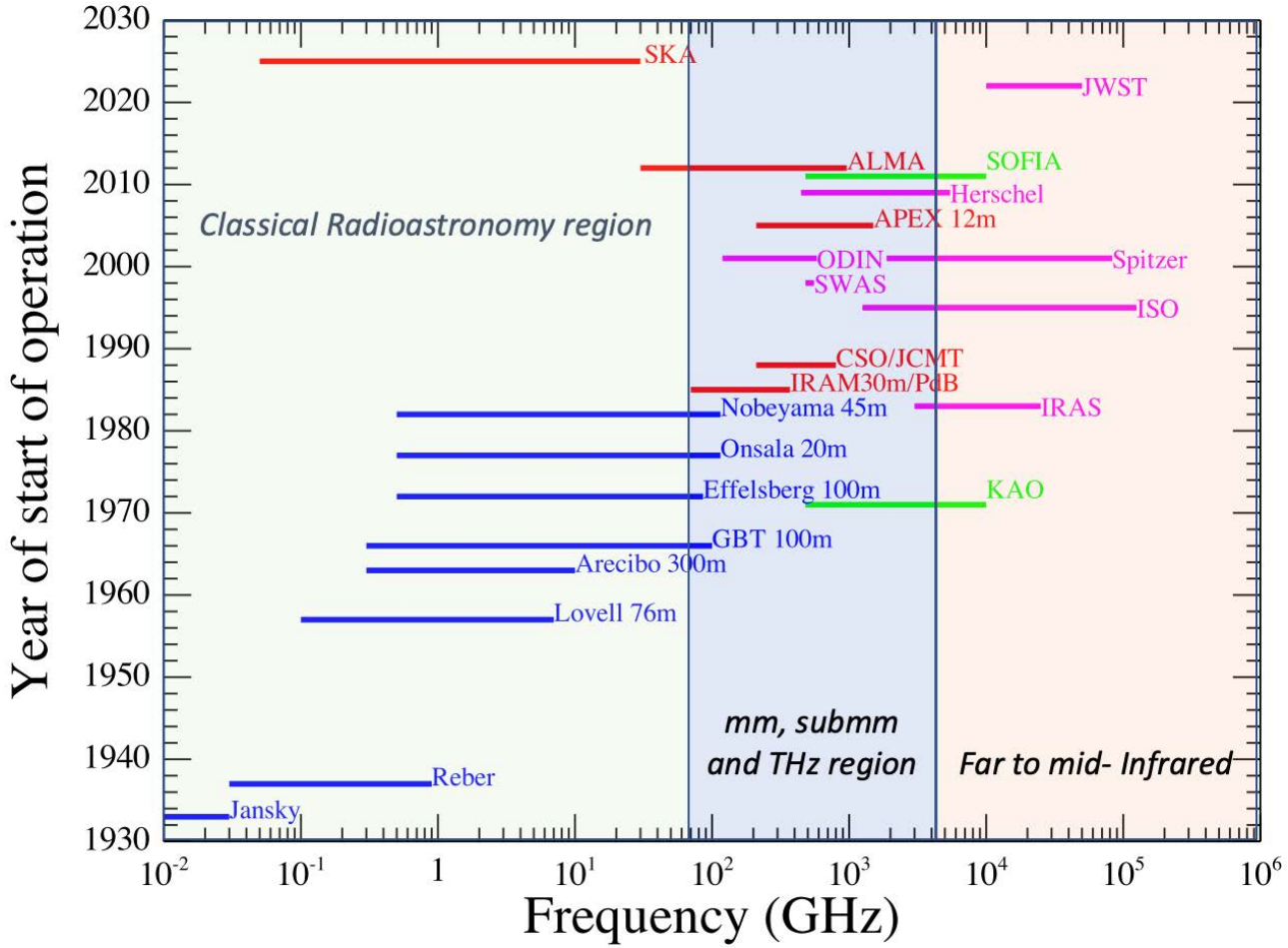


Figure de C. Risacher

Mauna Kea, Hawaii (4200m)

CSO
Caltech Submm Observatory

JCMT
James Clerk Maxwell Telescope

SMA
SubMillimeter Array

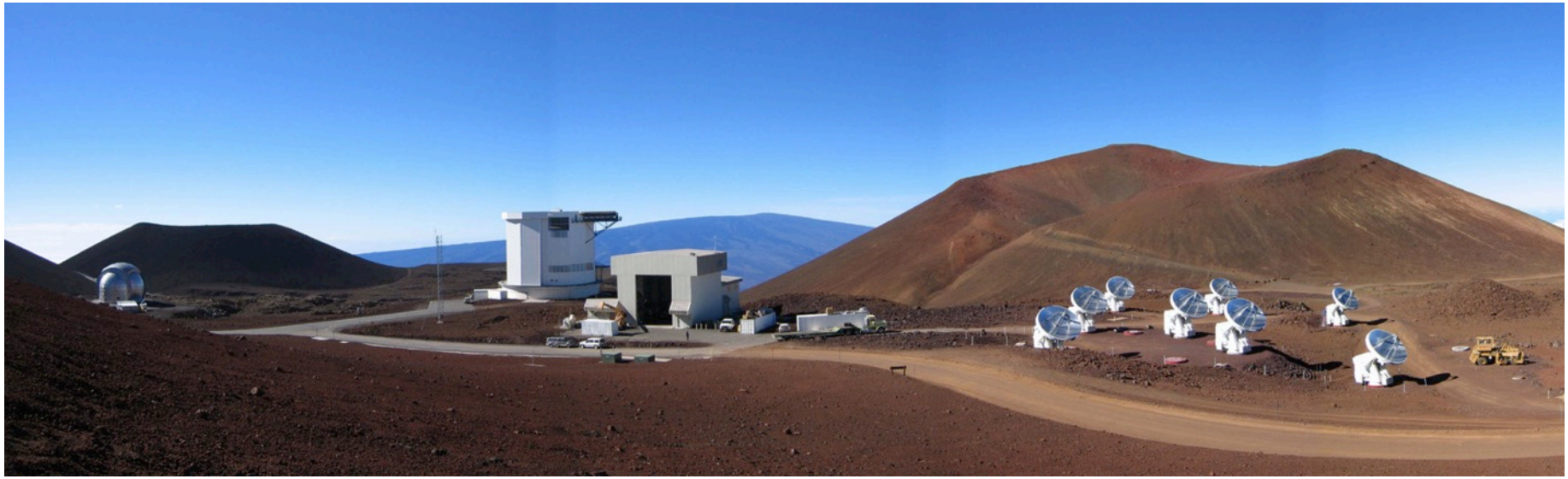


Photo J. Weintraub

Quelques télescopes (sub)mm

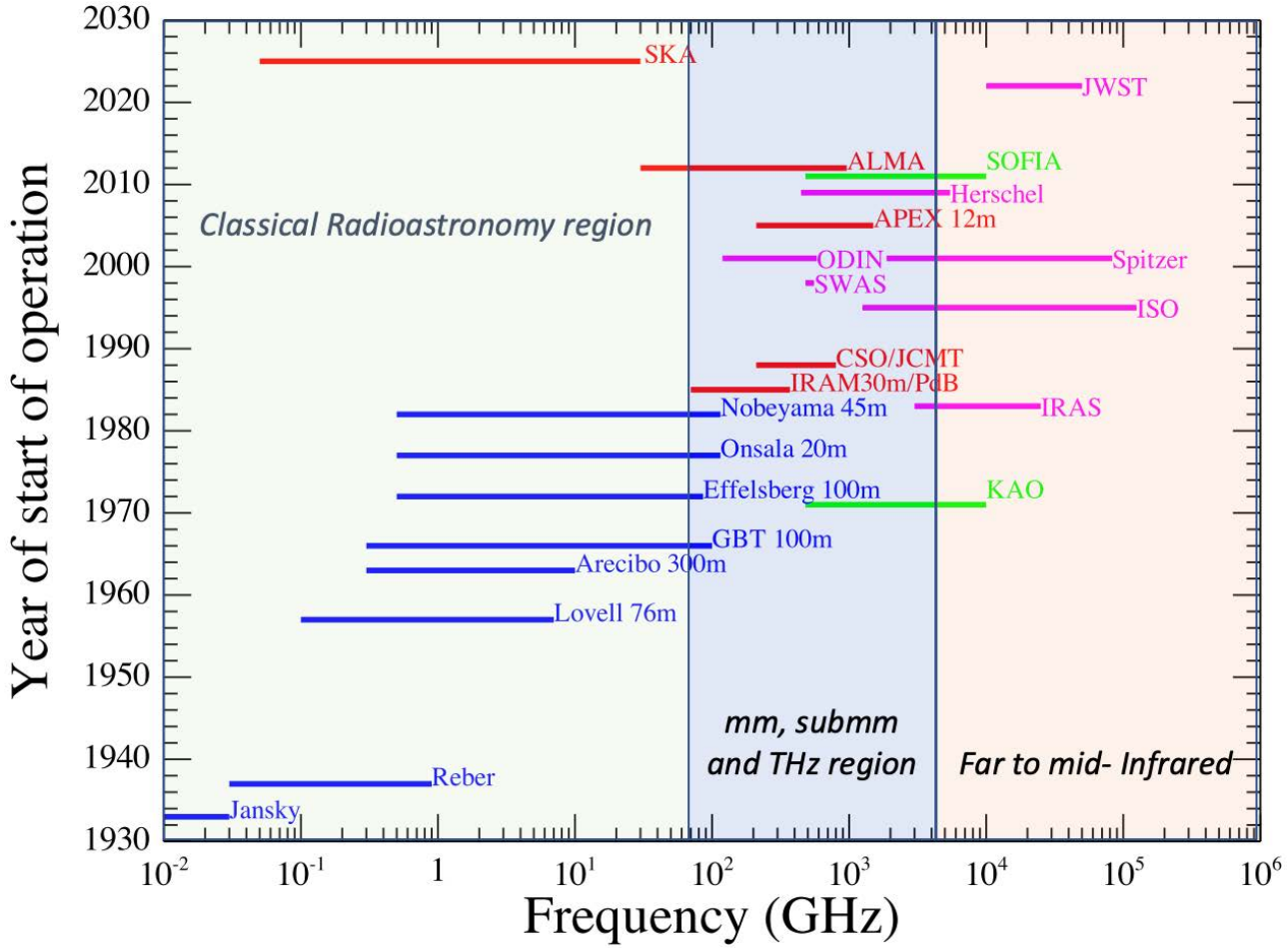


Figure de C. Risacher

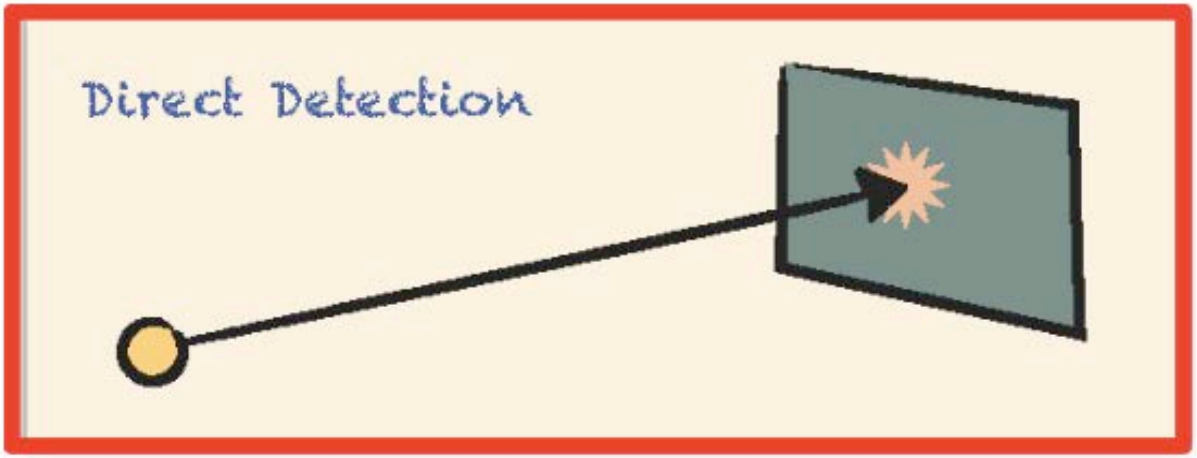
Atacama Millimeter Array

50 antennes de 12m et
16 antennes de 7m

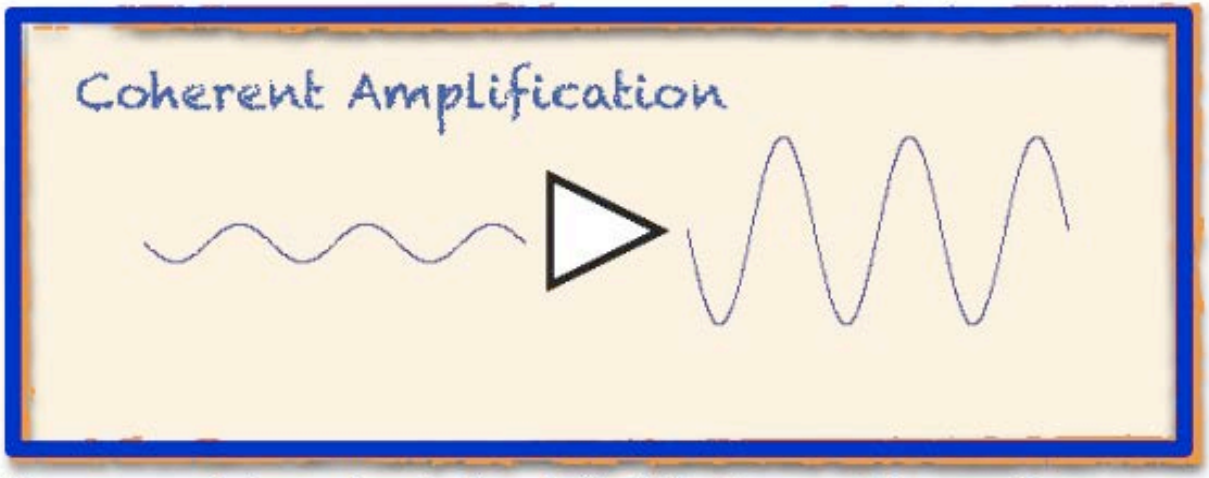
Détecteurs Optiques

Two Fundamental Principles of Detection

Respond to individual photon energy



Photons



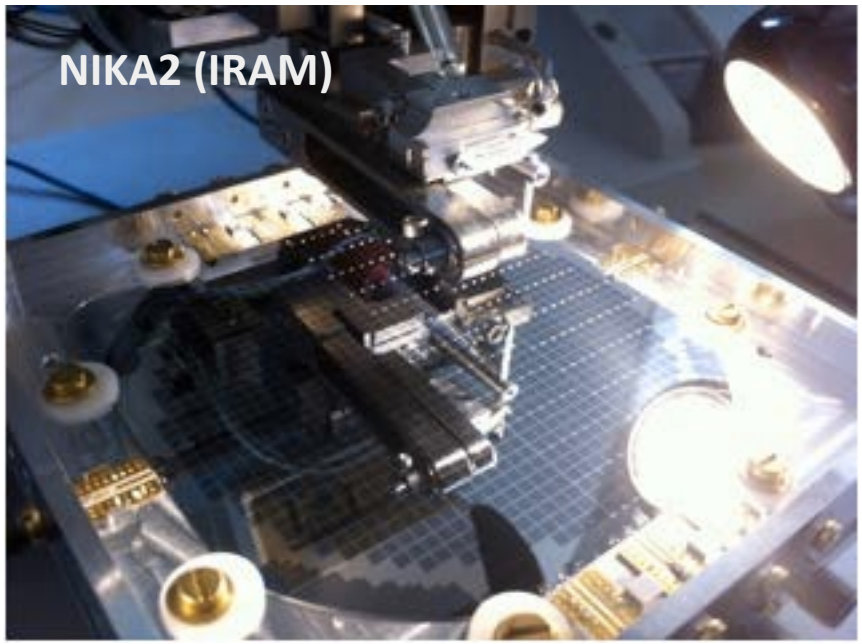
Waves

Respond to electrical field strength and preserve phase

Detecteurs incoherents en (Sub)millimetriques

Types: TES – Transition Edge Sensors
KIDs – Kinetic Inductance Detectors
Quantum Detectors

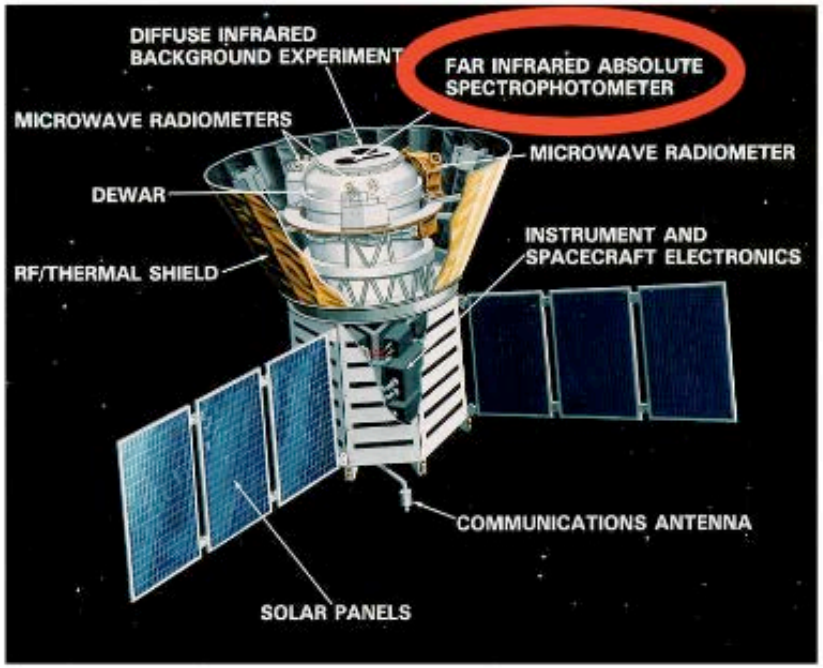
- Refroidis à ~ 50mK,
- très sensible
- Beaucoup de pixels; multiplexage
- Faible résolution spectrale, éléments optiques supplémentaires nécessaires (grating, FTS, FP)

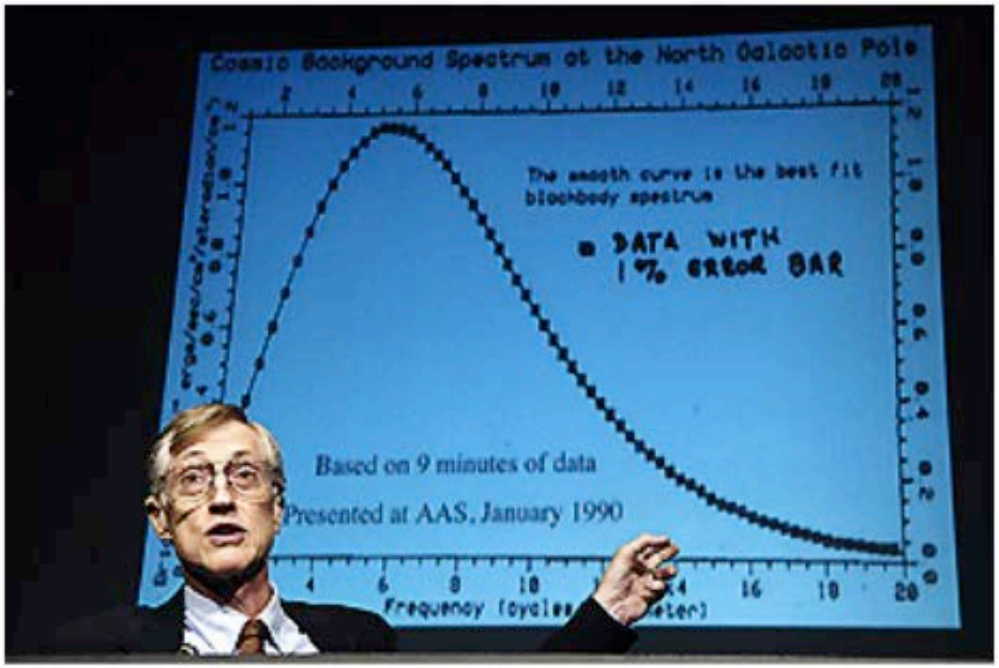


Picture de la page web d'IRAM

A milestone in the History of Bolometers

Many references to John C. Mather (Applied Optics 21, 1125, 1982):





PI for Far Infra Red Absolute Spectrophotometer (FIRAS) on COBE

The Nobel prize in Physics 2006 (with George Smoot)

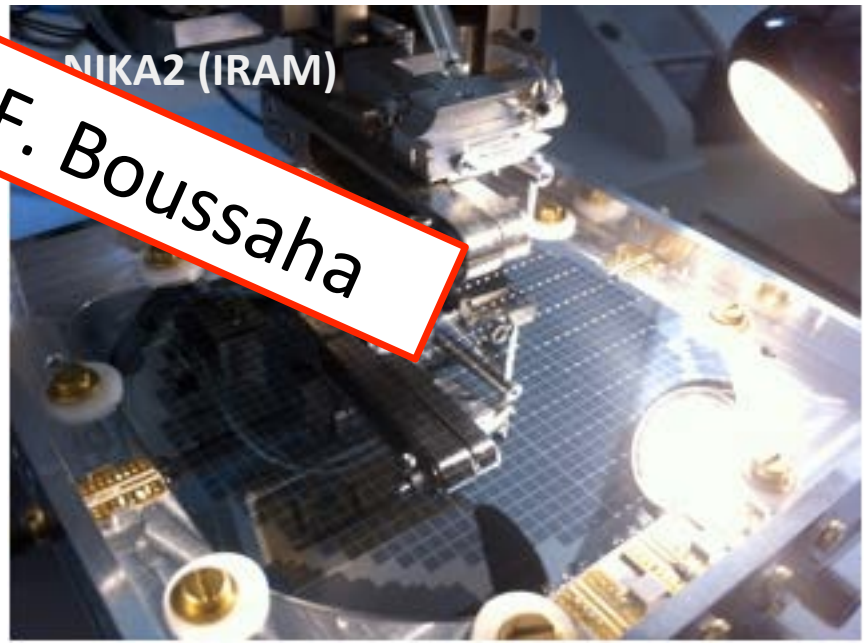
Detecteurs incoherents en (Sub)millimetriques

Types: TES – Transition Edge Sensors

KID – Kinetic Inductance Detectors

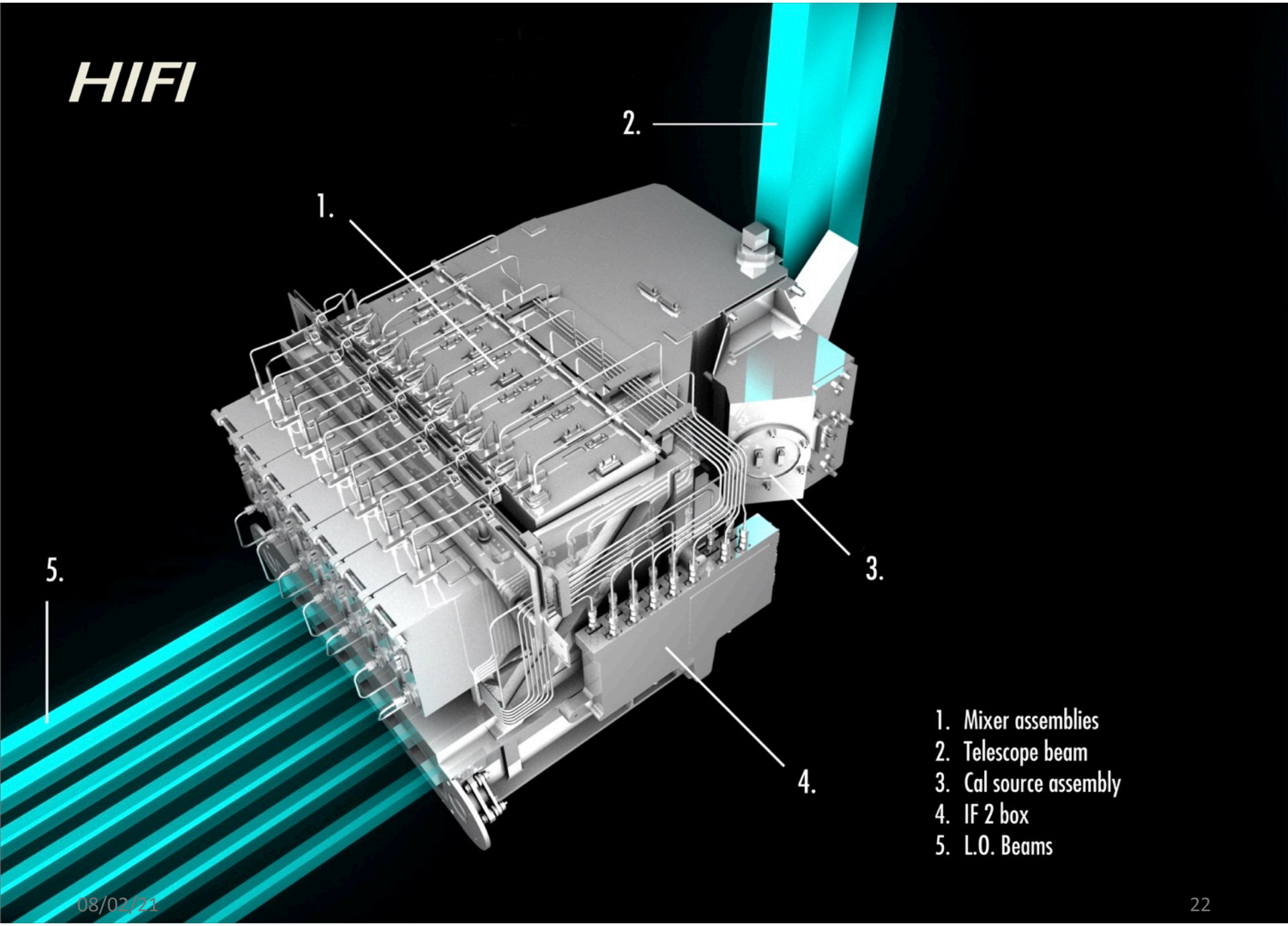
Q[illegible]Detectors

- Refroidis à ~ 50mK;
- très sensible
- Beaucoup de pixels; multiplexage
- Faible résolution spectrale, éléments optiques supplémentaires nécessaires (grating, FTS, FP)

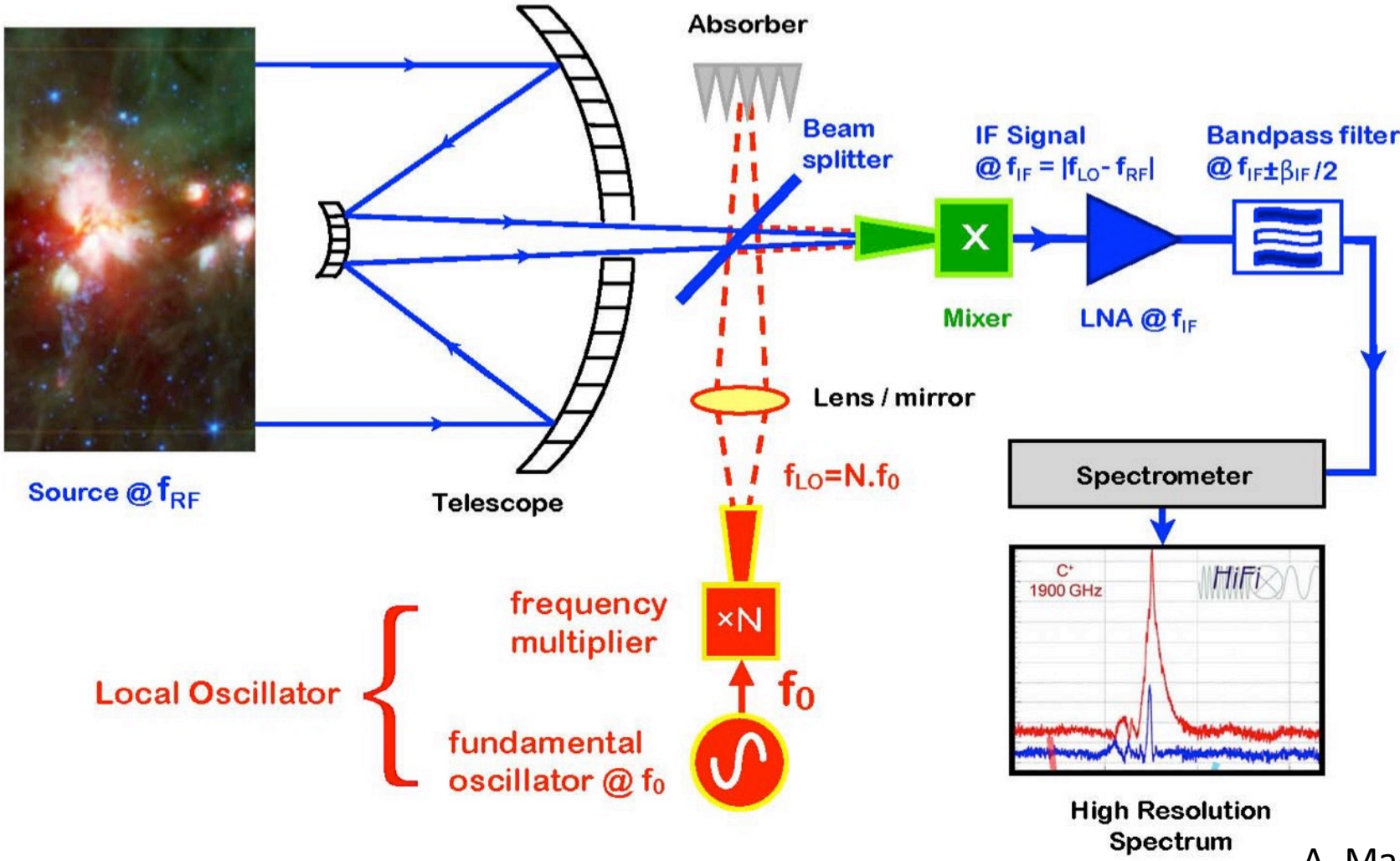


Picture de la page web d'IRAM

Heterodyne Receivers

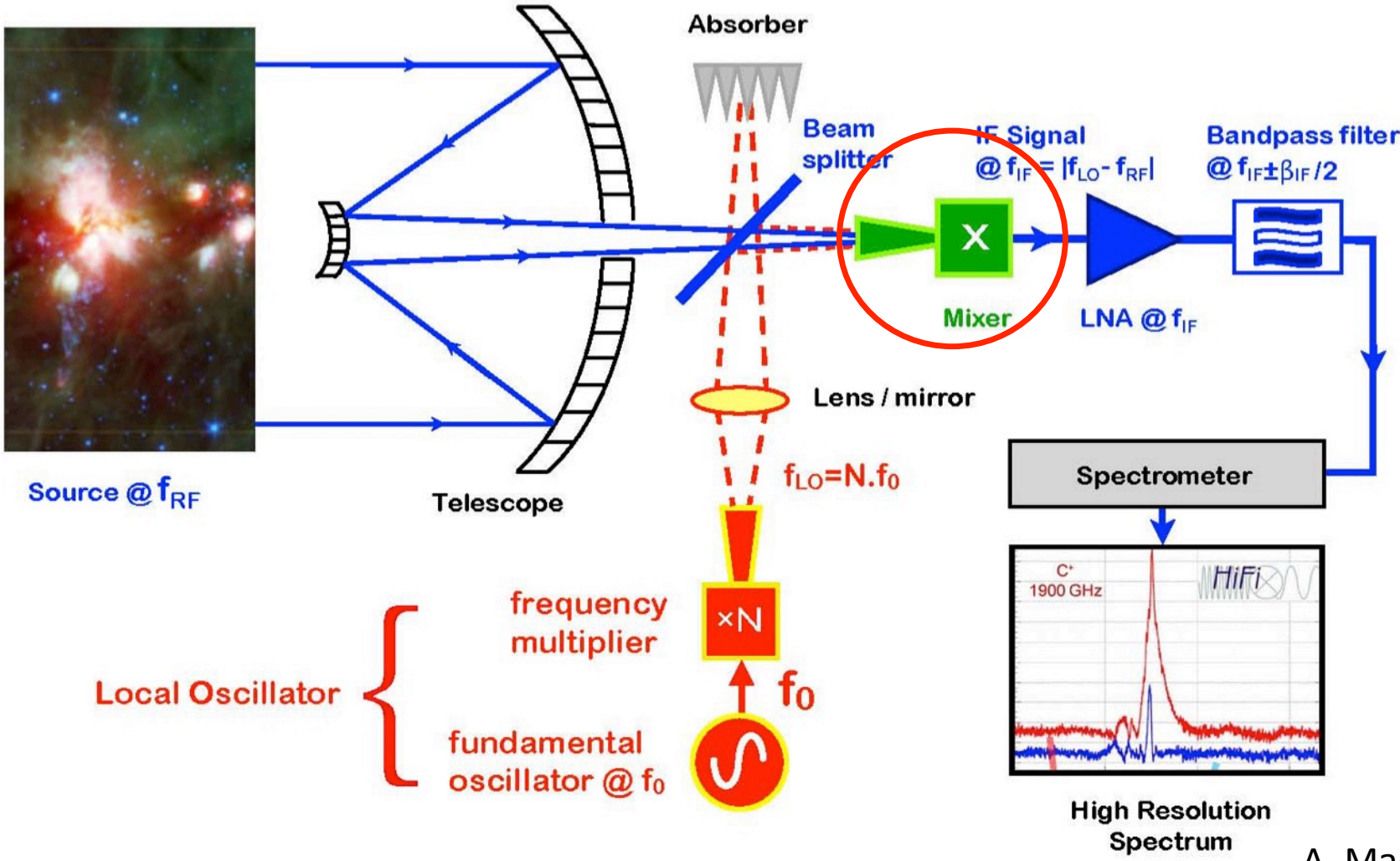

HIFI
2.
1.
5.
3.
4.
1. Mixer assemblies
2. Telescope beam
3. Cal source assembly
4. IF 2 box
5. L.O. Beams

Principe Hétérodyne



A. Maestrini

Principe Hétérodyne



A. Maestrini

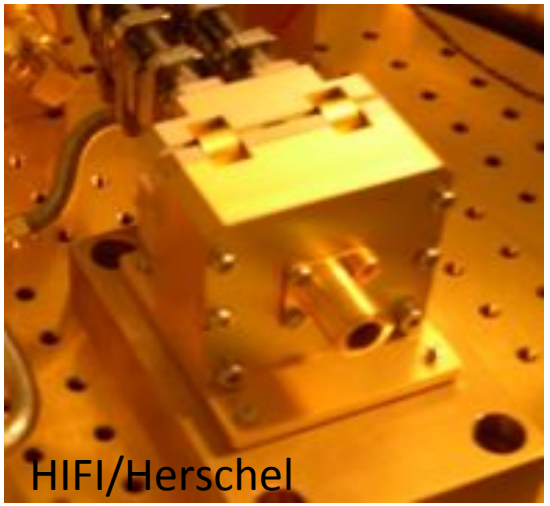
Mélangeurs

Cryogenique:

- SIS – Superconducting Insolating Superconducting

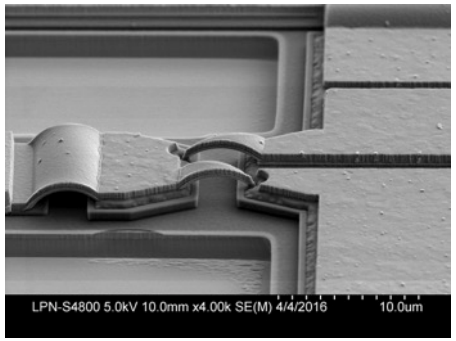
  e.g. HIFI (LERMA-IRAM): Sensibilité à l'état de l'art à 480-640GHz

- HEB – Hot Electron Bolometer


HIFI/Herschel

Température ambiante:

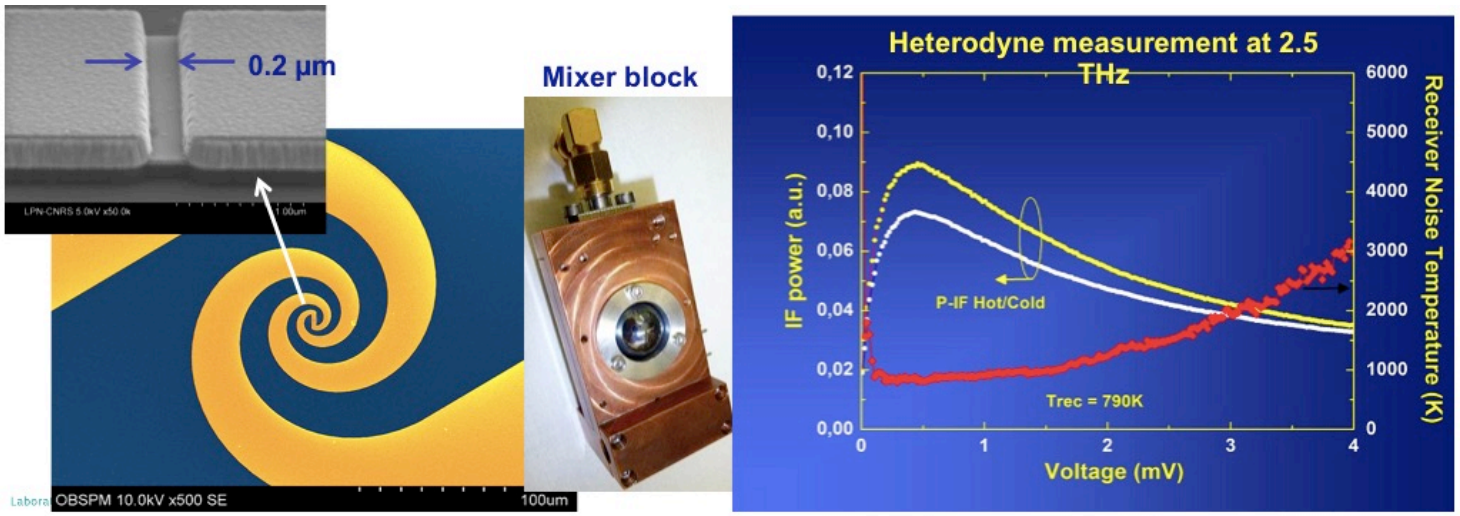
- Schottky → J. Treuttel



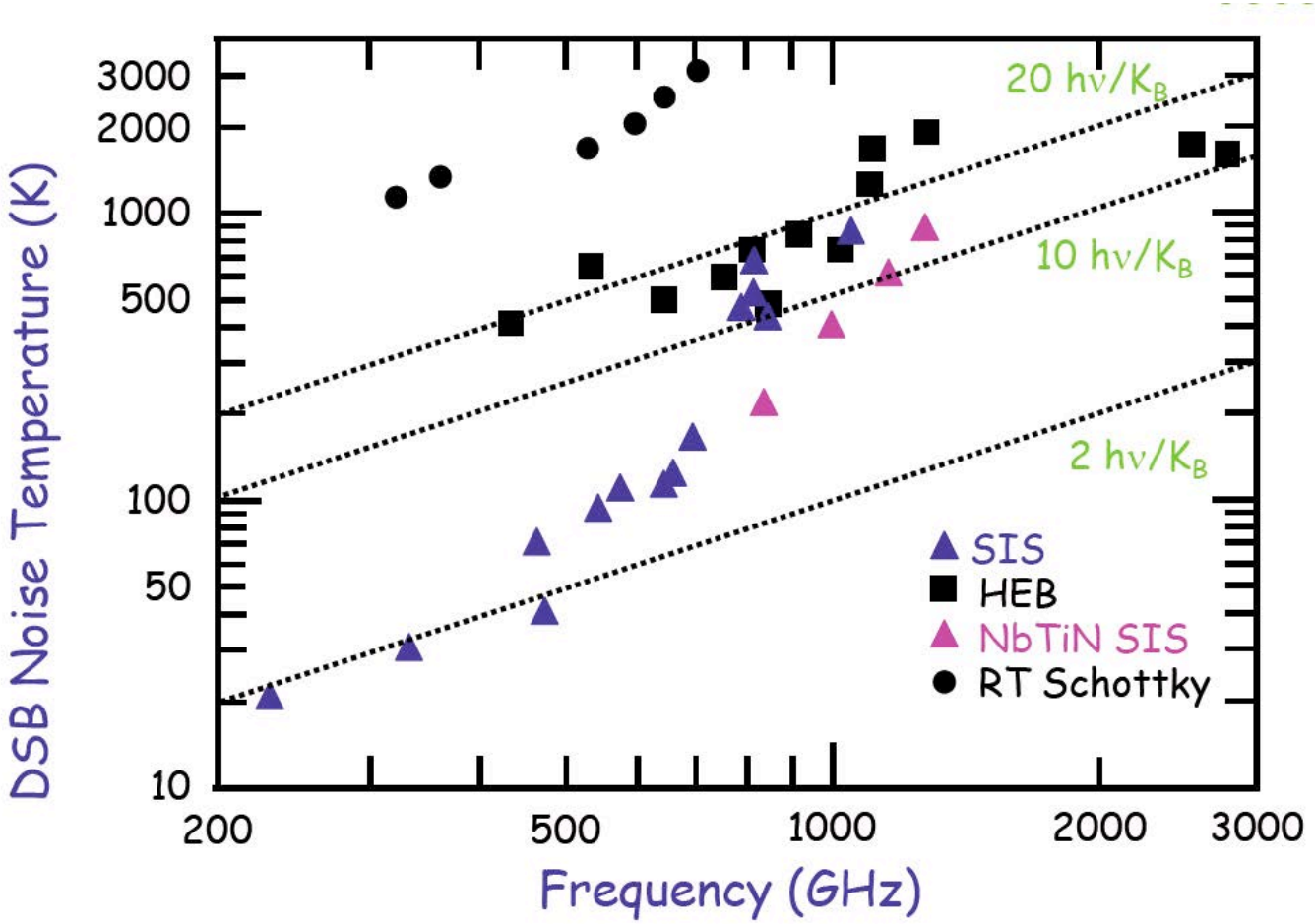
HEB du LERMA

- Mélangeur HEB, NbN (LERMA-LPN)

→ Sensibilité à l'état de l'art à 2,7 THz

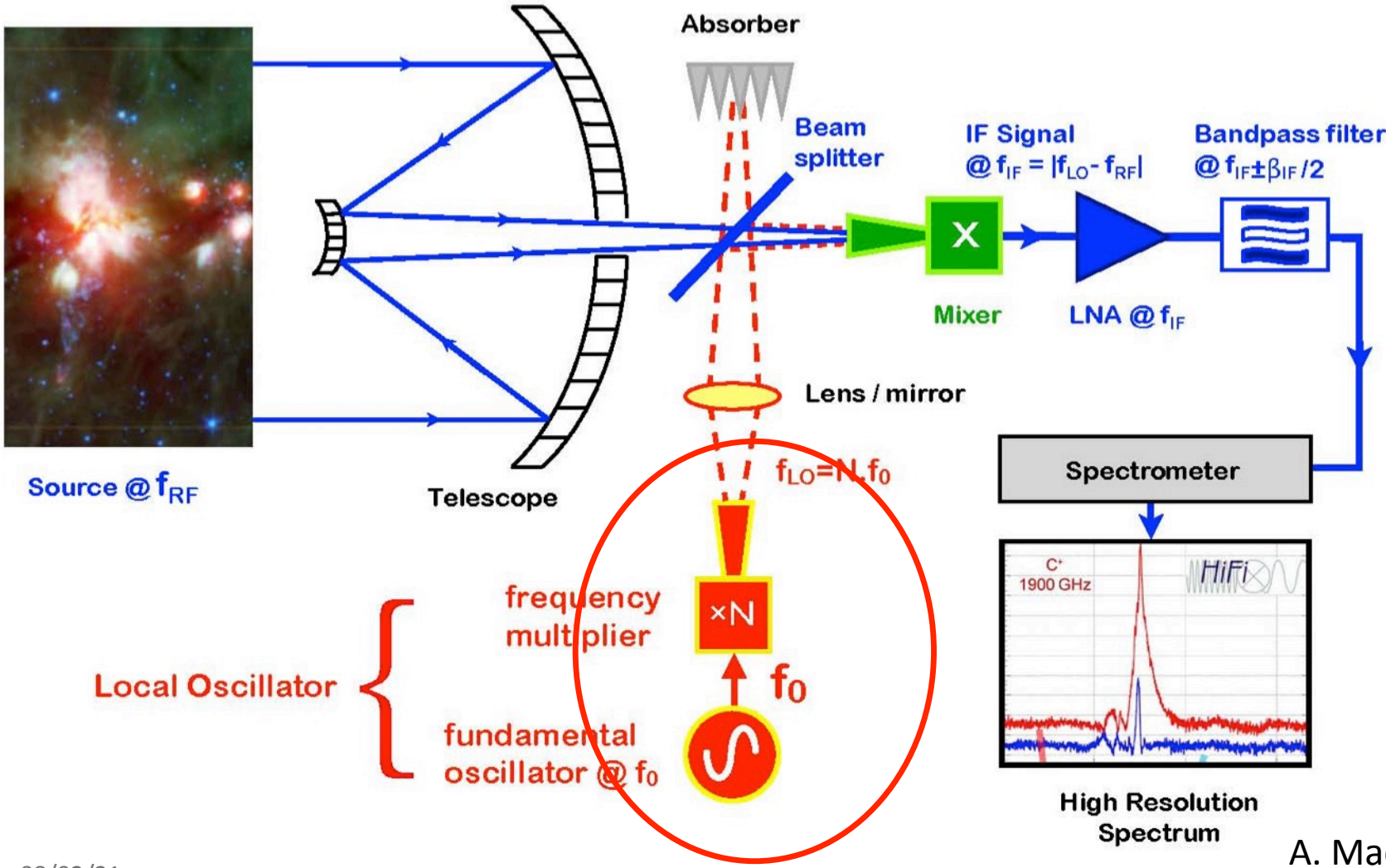


Sensibilité des Mélangeurs



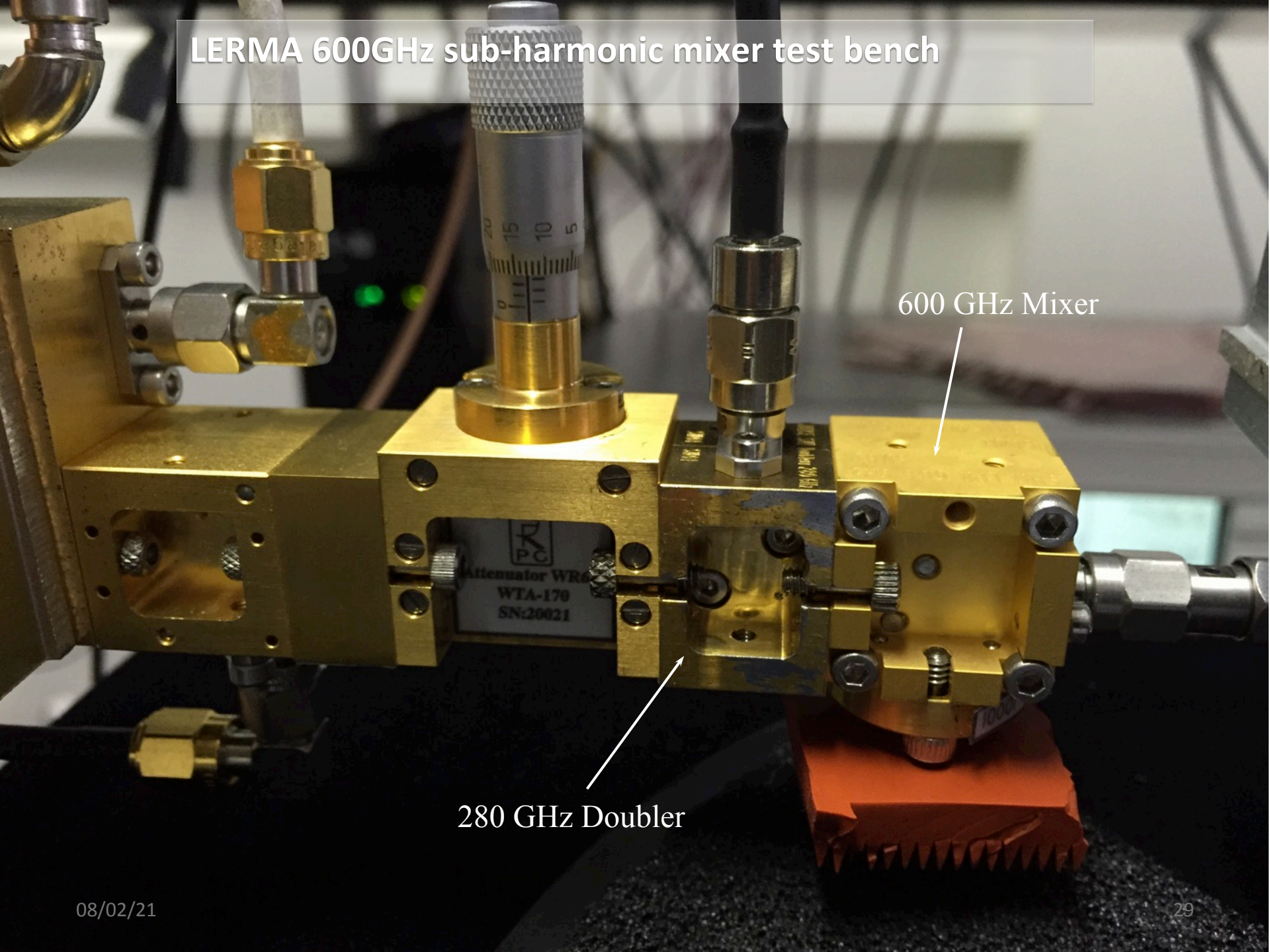
Coutersy Goutam Chattopadhyay

Principe Hétérodyne

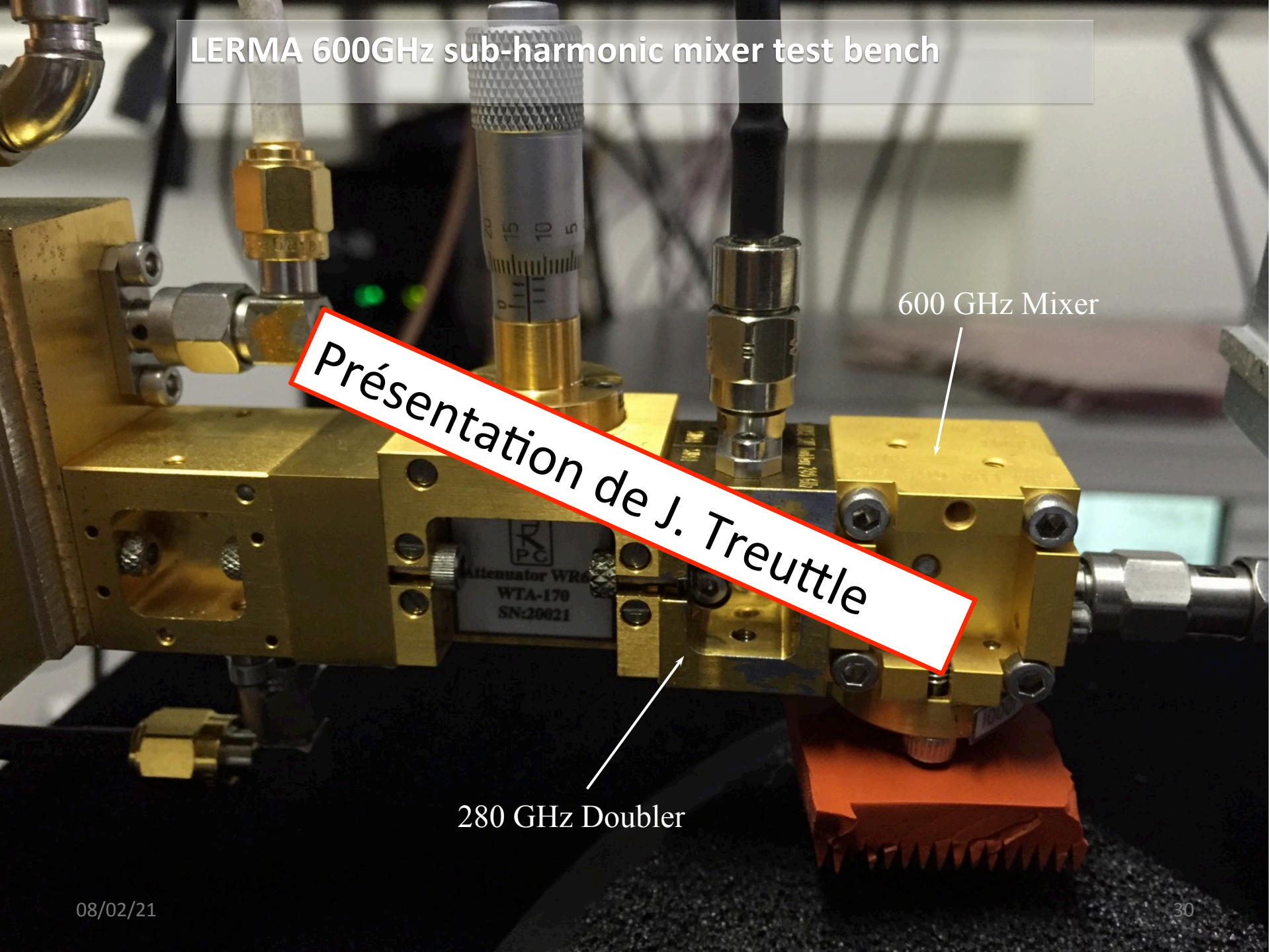


A. Maestrini

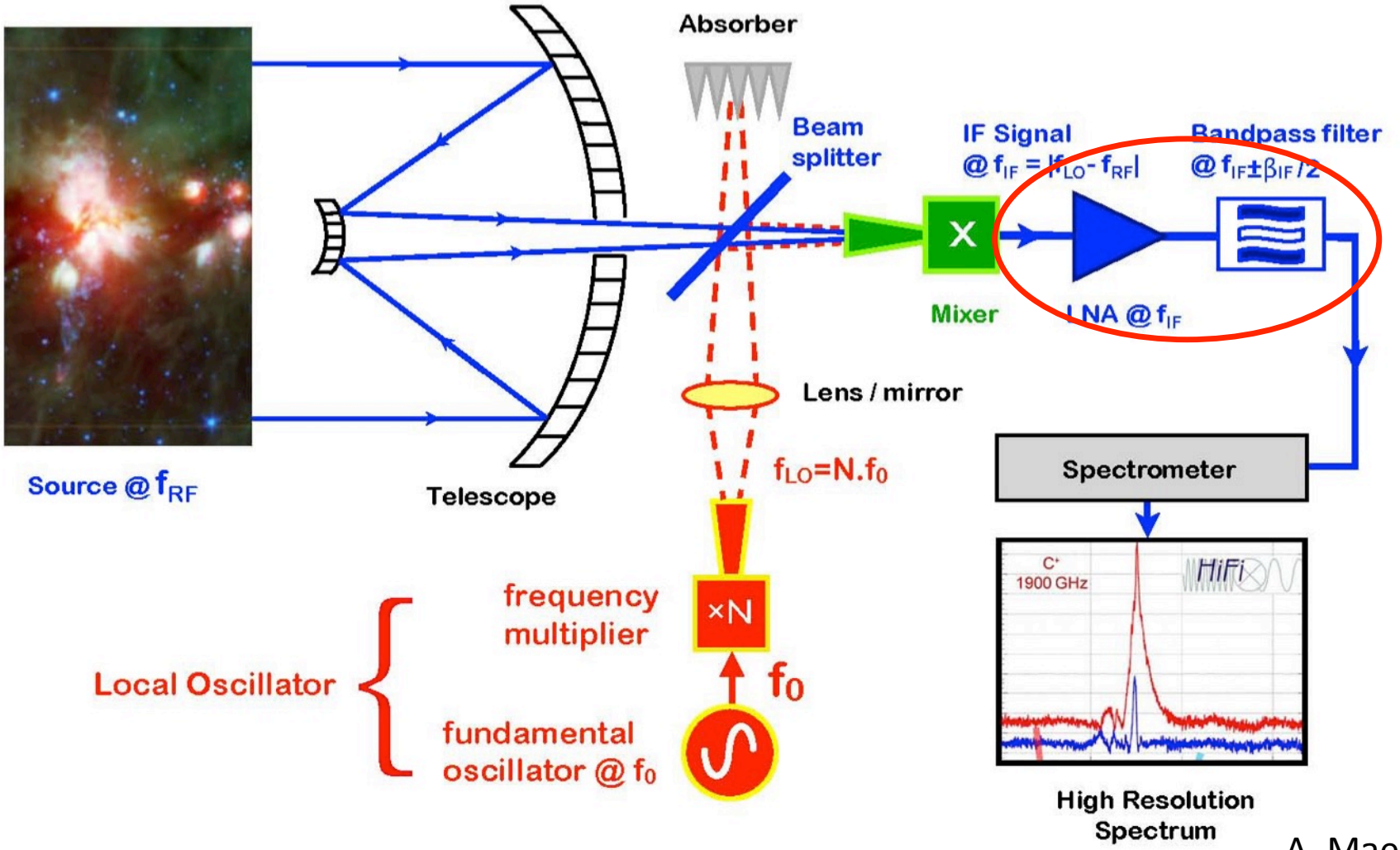
LERMA 600GHz sub-harmonic mixer test bench



LERMA 600GHz sub-harmonic mixer test bench



Principe Hétérodyne



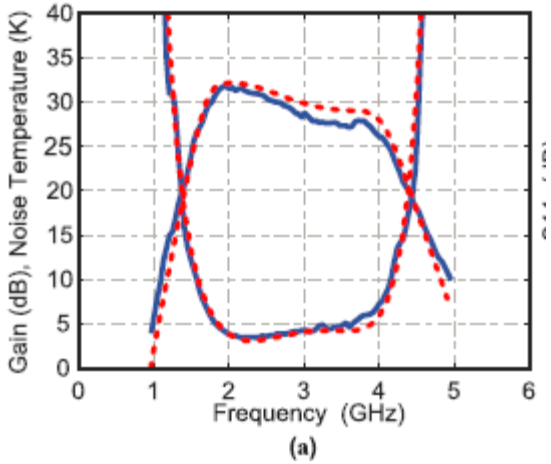
A. Maestrini

SiGe Amplifiers – Innovative technology

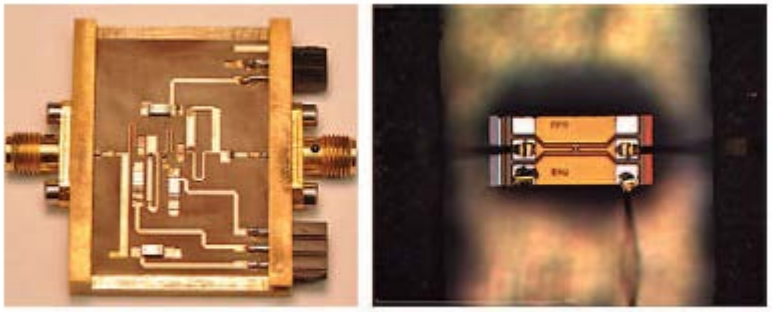
IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 64, NO. 1, JANUARY 2016

Ultra-Low-Power Cryogenic SiGe Low-Noise Amplifiers: Theory and Demonstration

Shirin Montazeri, *Student Member, IEEE*, Wei-Ting Wong, *Student Member, IEEE*, Ahmet H. Coskun, *Student Member, IEEE*, and Joseph C. Bardin, *Member, IEEE*

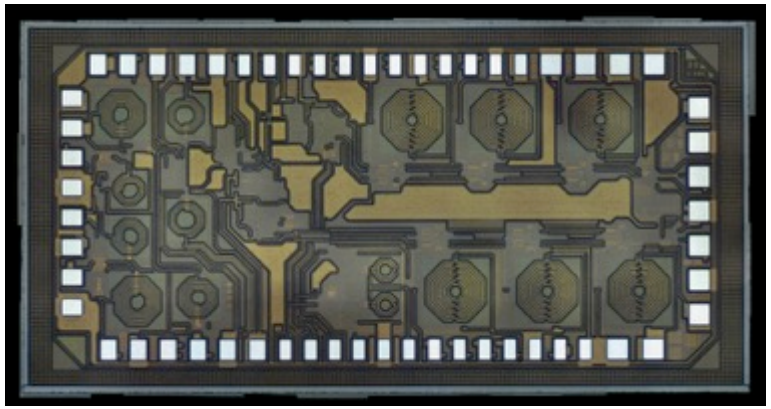


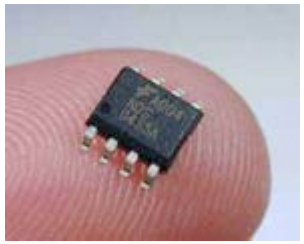
Band= 1.8-3.6 GHz
Pdis= 0.3 mW
IBM BiCMOS8HP

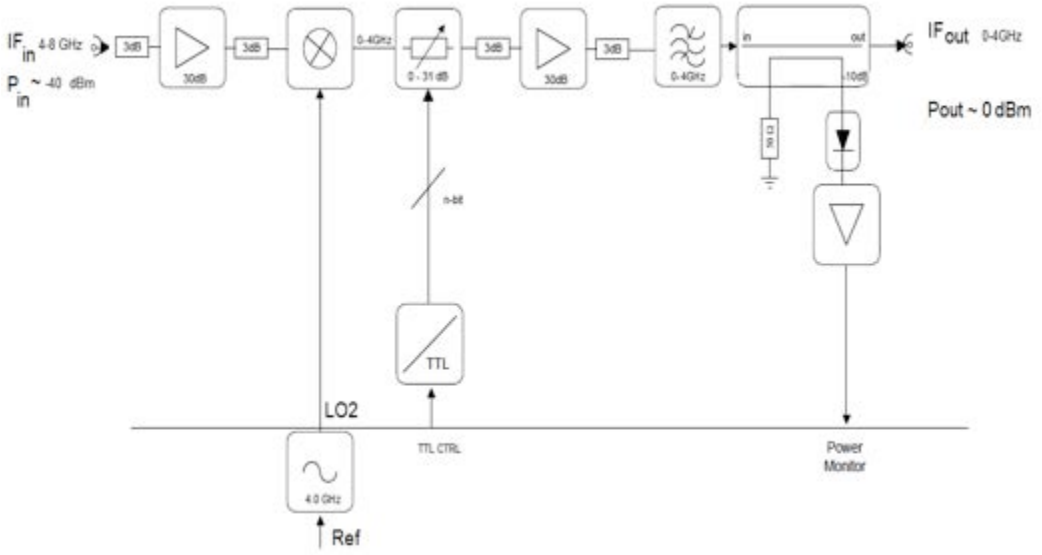


Warm IF chain

- For many channels WIFC using IC instead of individual components
  - built on one Complementary Metal-Oxide Semiconductor (CMOS) chip that is approximately 1.5mm x 1.5mm in size.

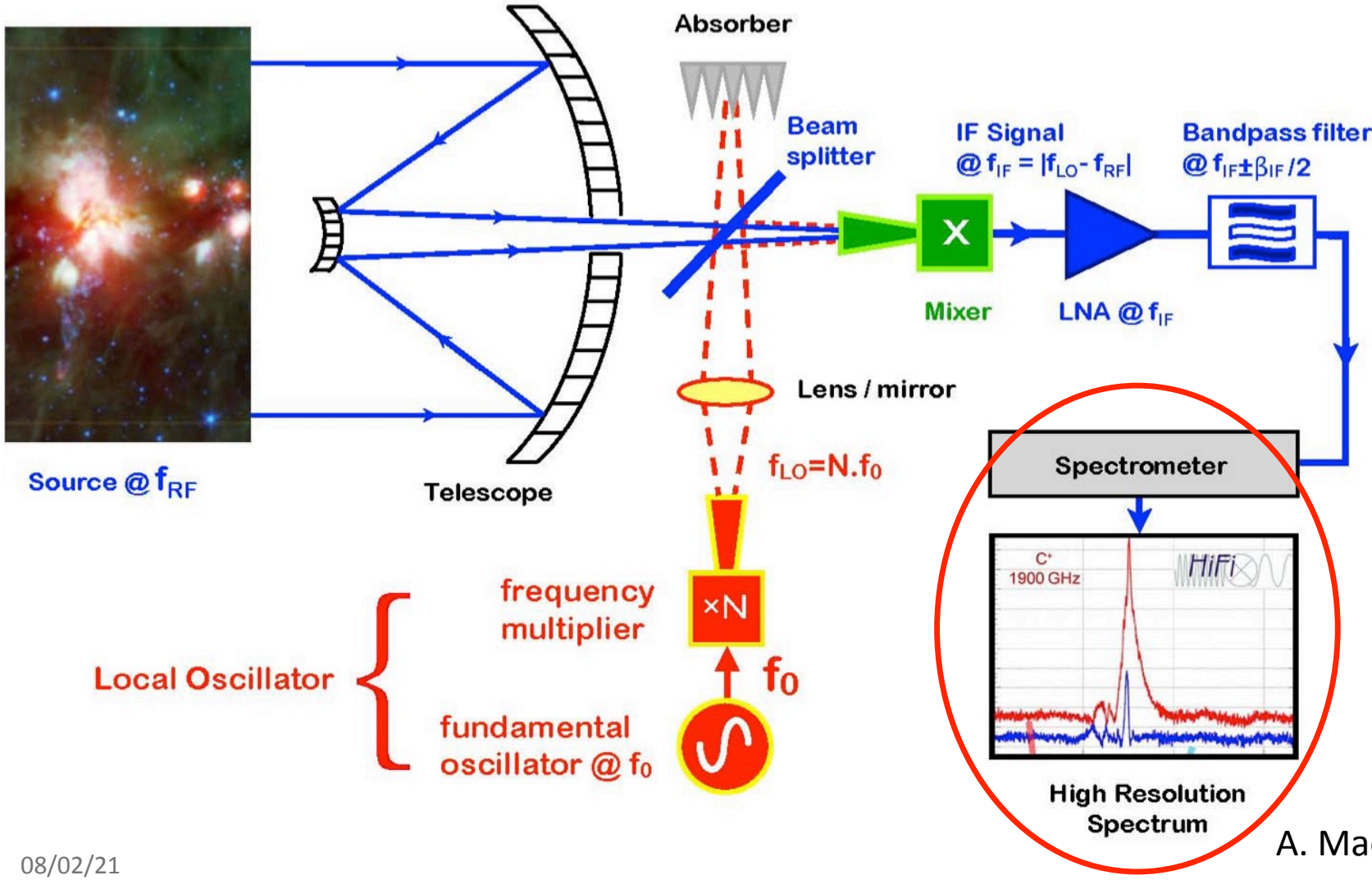






Slide by R. Plume

Principe Hétérodyne



A. Maestrini

Max-Planck-Institut
für Radioastronomie

digital Signal Processing dSP

MPIfR dFFTS4G spectrometer

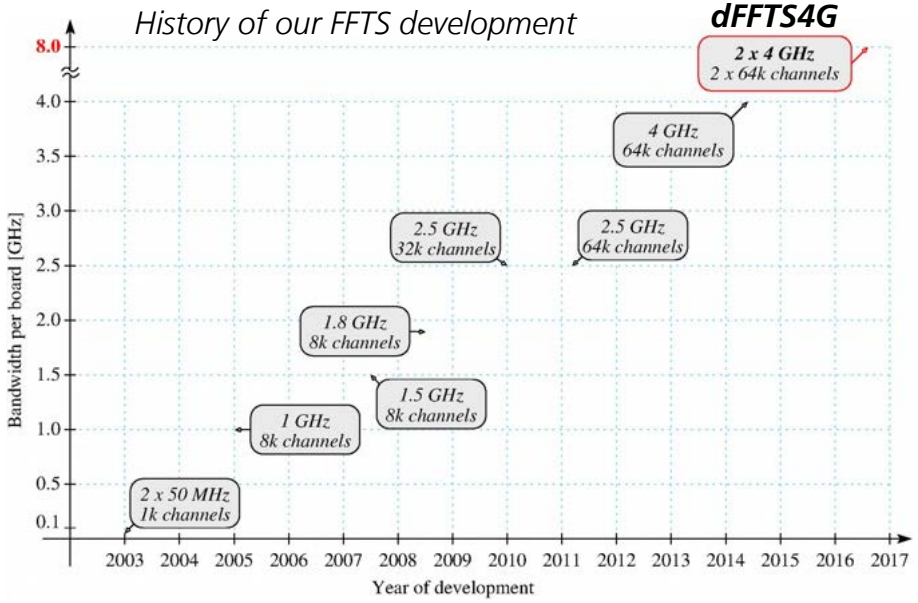


Photo: dFFTS4G spectrometer crate

Technical data of a dFFTS4G board:

- Input bandwidth: 2 x 4 GHz (0 – 4 GHz)
- Spectral channels: 2 x 64k
- Spectral resolution: 71 kHz (ENBW)
- Power consumption: max. 70 W (~9 W / GHz)

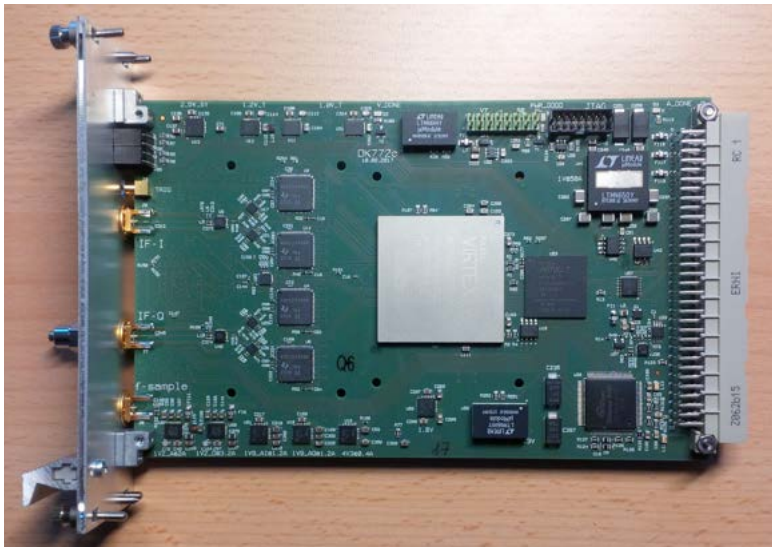
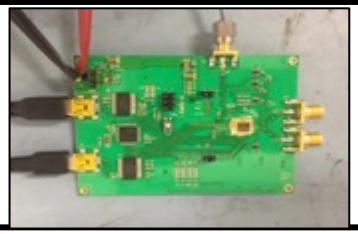
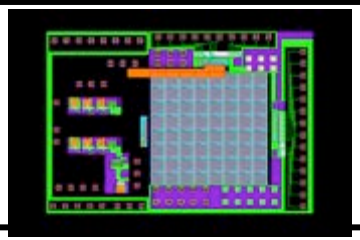


Photo: dFFTS4G spectrometer board

Technical specifications of a dFFTS4G 19" crate :

- Total bandwidth: 8 x 2 x 4 GHz = 64 GHz
- Spectral channels: 8 x 2 x 64k = 1 Million (1024k)

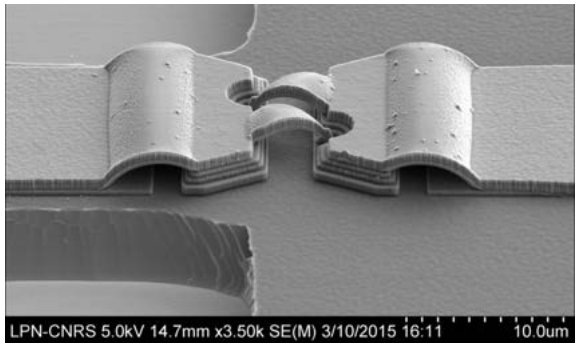
Existing Spectrometer Comparison

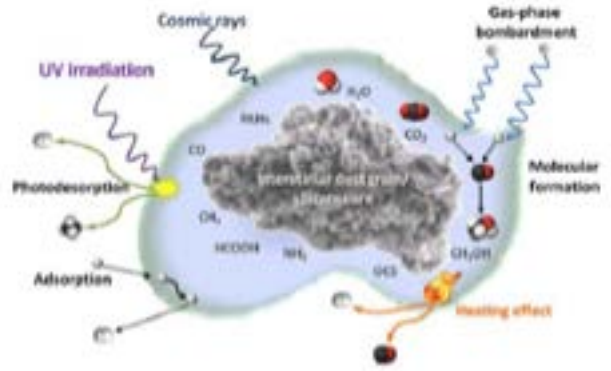
Design Parameter	Demonstrated CMOS Spectrometer System	
	Spectrochip SVII Spectrometer (UCLA/JPL) 2017 [3]	Spectrochip SVIII Spectrometer (UCLA/JPL) Available Late 2018
Processor Bandwidth (MHz)	3000	6000
Channel Count (#)	4096	8192
FFT Window Type	Hanning	PFB
FFT Format	Real	Real
Bit Resolution (#)	3	3
Power (W)	1.75 W	1.65 W
Size (cm^3)	10x8x2 cm	6x8x2 cm
Packaging Technique	Ribbon-Bond	Flip Chip
Weight (Kg)	0.12 Kg	0.12 Kg
Core Technology	65nm CMOS	28nm HPC CMOS
		

Adrian Tang

Expértise aux LERMA

- Instrumentation pour l'astronomie
  - mélangeurs cryogéniques
  - Récepteurs de réseau, phase grating
  - Technologie Schottky: multiplicateurs, mélangeurs
- Molécules dans l'Univers
  - Expériences de laboratoire

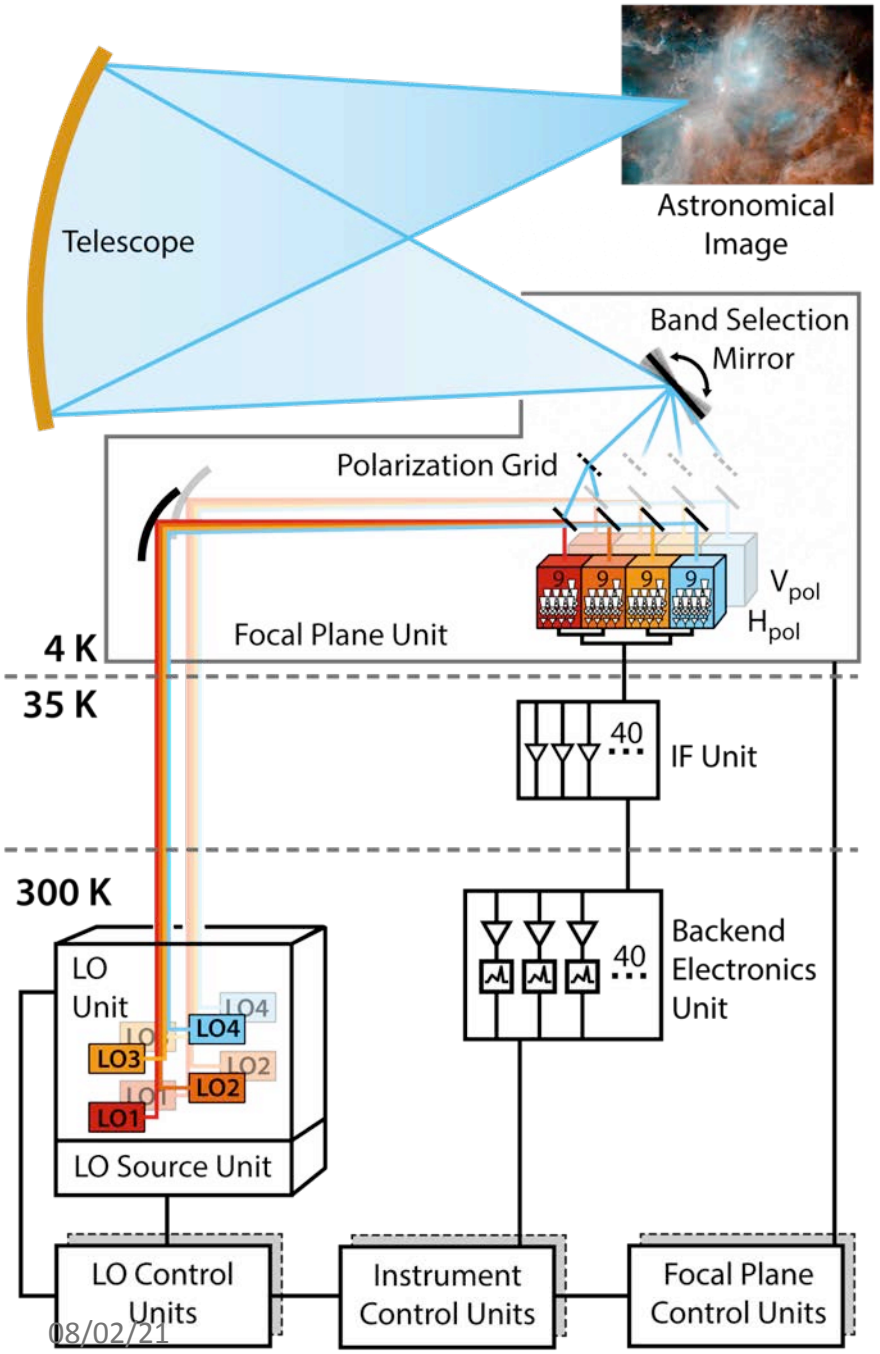




ORIGINS
Space Telescope

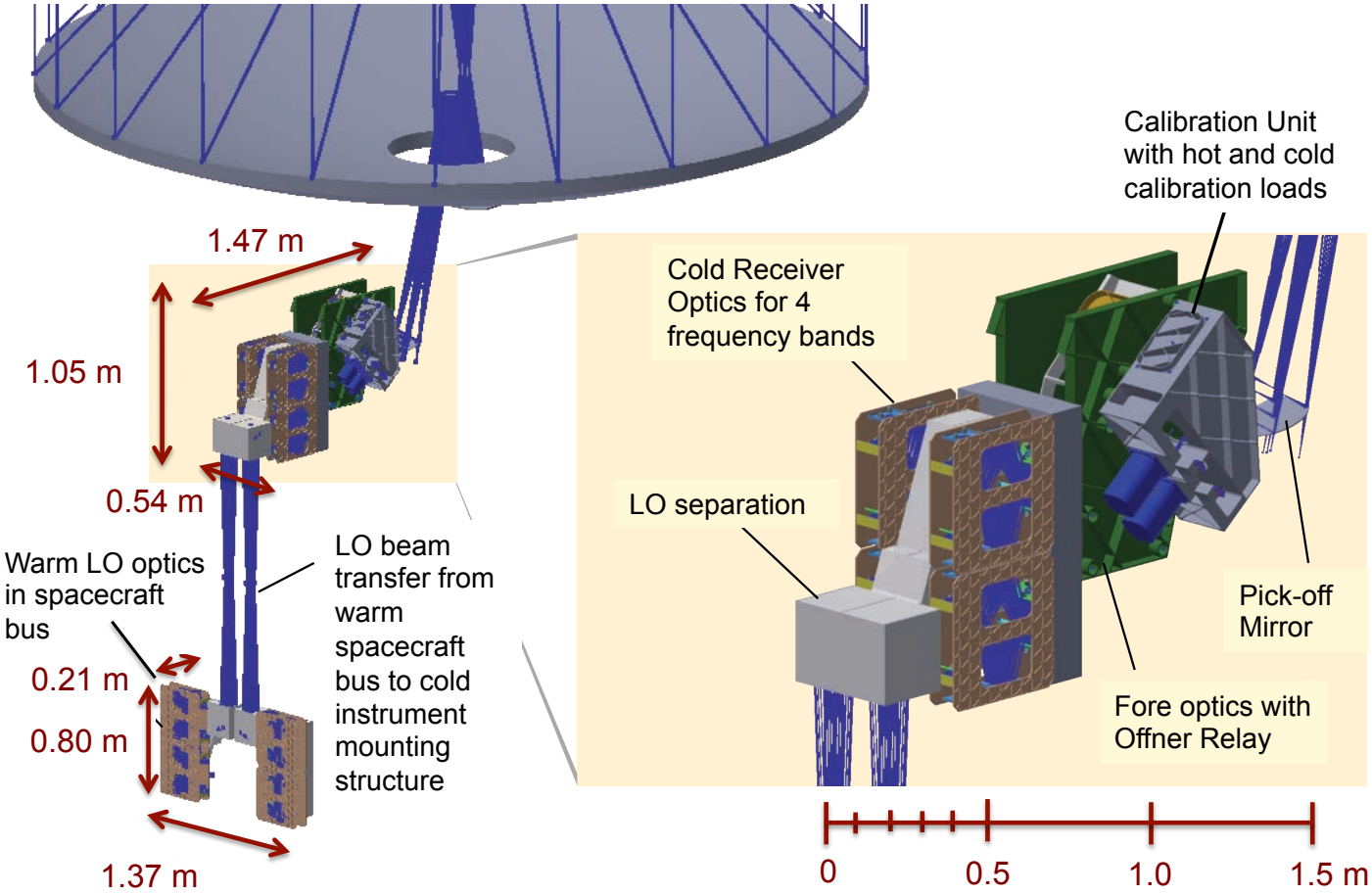
- 2.8-590 microns
- 5.9m aperture (same collecting area as JWST)
- Cooled to 4.5K
- Up to 1000 more sensitive than anything before
- 5 year minimum; 10 year design goal
- Minimal Deployment, Spitzer-like architecture

HERO pour Origins



	Component	HERO
LO	**Multiplied LO Technology**	Cascaded Multipl. + On-chip. Power Combining +. 3D integ.
	DC power/pixel	2 W
	Fractional Bandwidth	45 %
Mixer + HEMT	**Mixer Technology**	SIS, HEB
	LNA Technology	Low-power SiGe HEMT
	DC power/pixel	0.5 mW
	Mixer. Assembly	Waveguide
Back end	**IF Processing**	GaAs HEMT ampl
	Spectrometer Tech.	CMOS based SoC
	DC Power/pixel	2W
	IF Bandwidth	8 GHz
Total DC power per pixel		4 W

Conception de HERO



Merci pour votre attention!