Radioastronomy in France (cm/dm)

Stéphane Corbel

Twitter: stephane_corbel

SRN l'Observatoire de Paris | PSL

Station de Radioastronomie de Nançay

cnrs dépasser les frontières

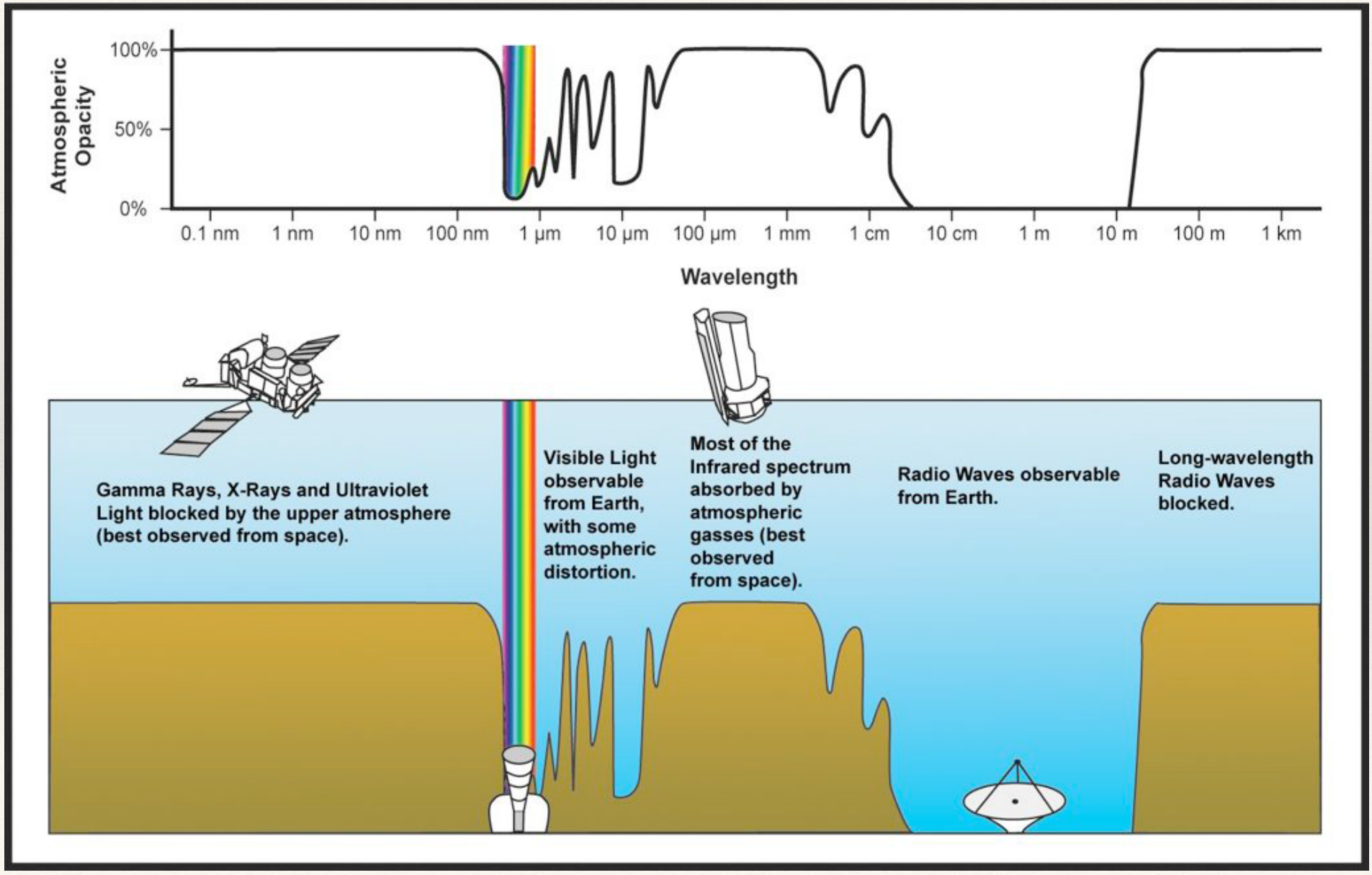
UNIVERSITE D'ORLEANS

Outline

- Radioastronomy in general
- The Nançay Radio Observatory
- The Nançay Radio Telescope (NRT)
- Few research's topics around Paris' Observatory

Radioastronomy ?

Atmosphere's transparency



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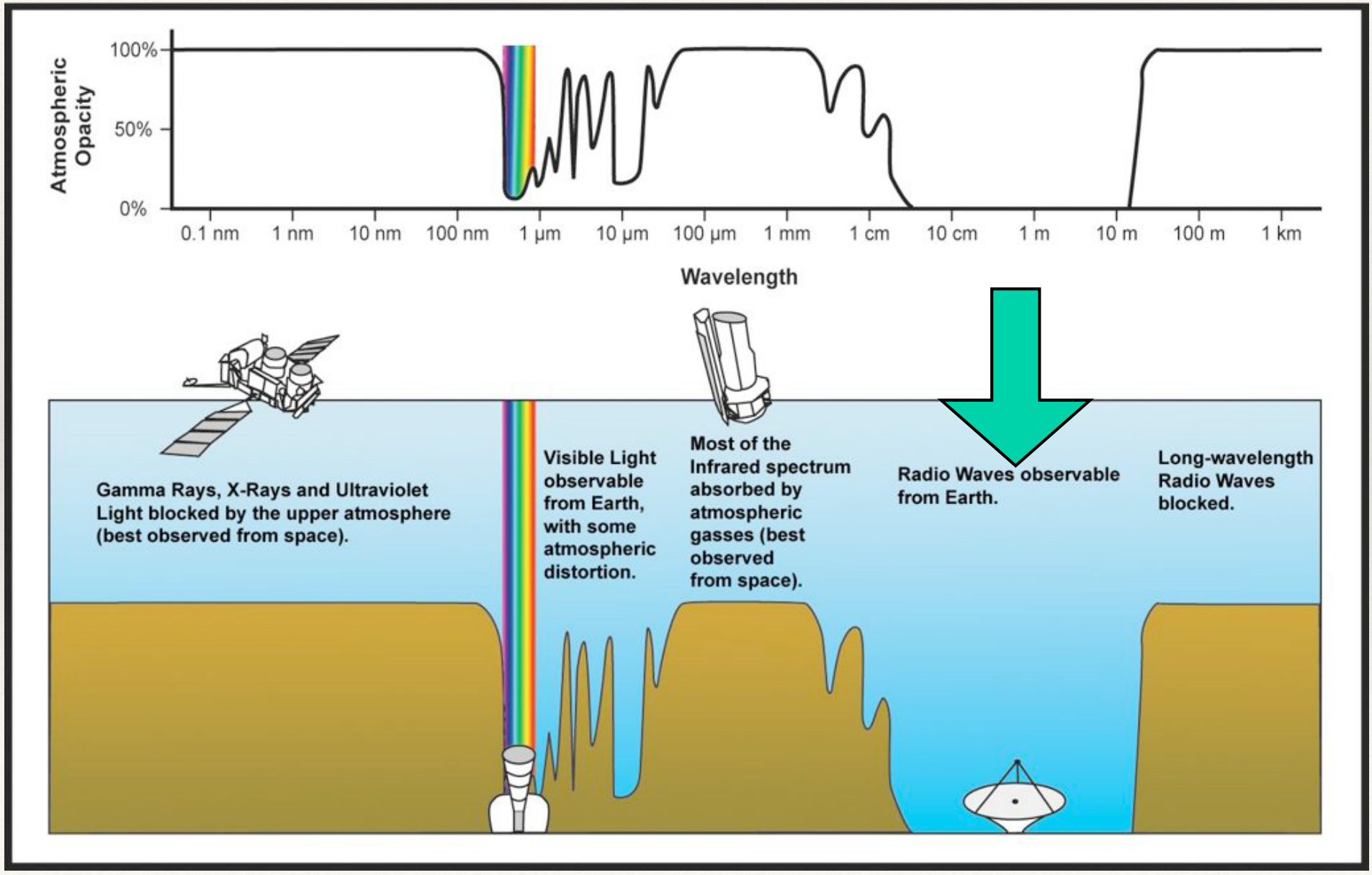
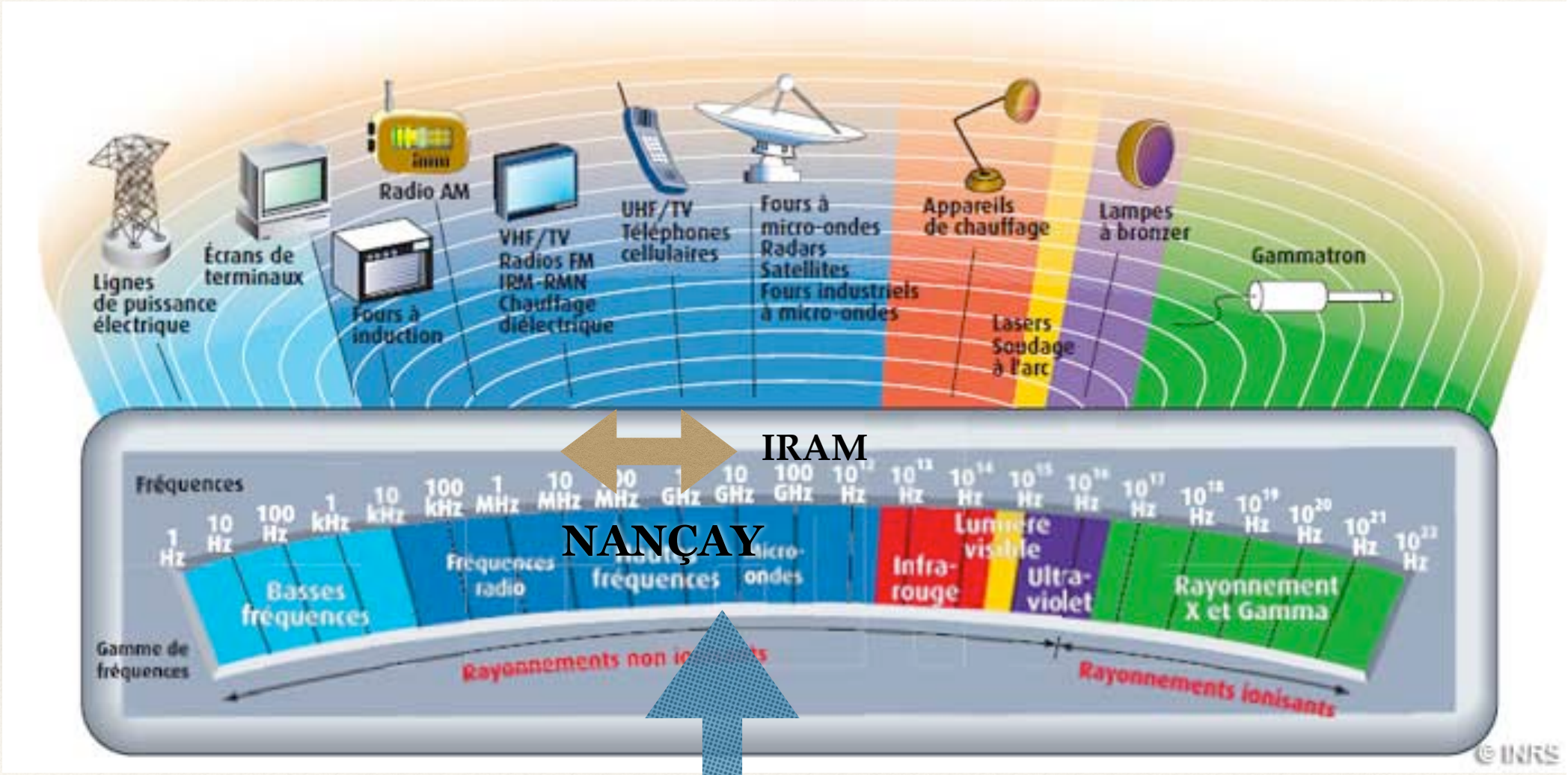
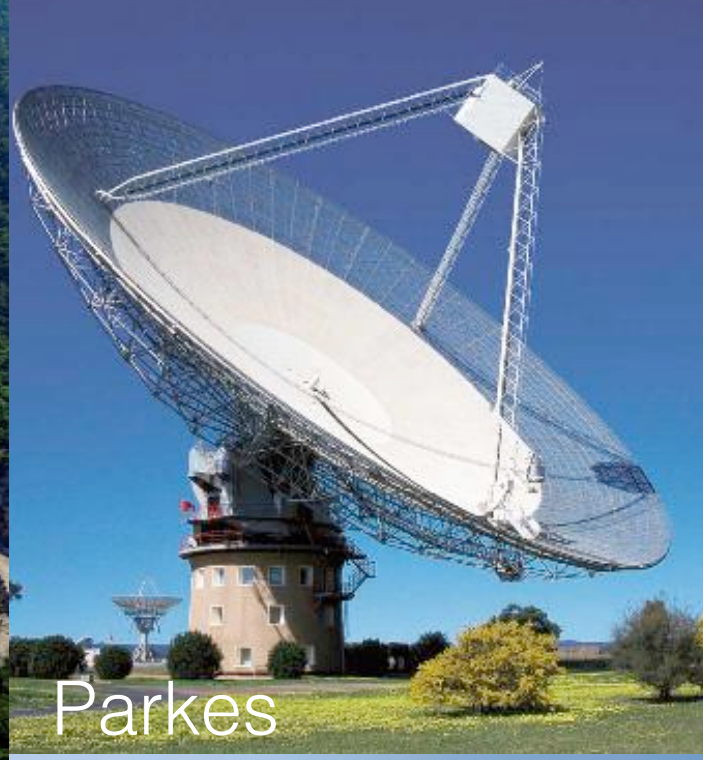


What are we talking about ?



See talk by Philippe Salomé for mm and P. Zarka for m/dam

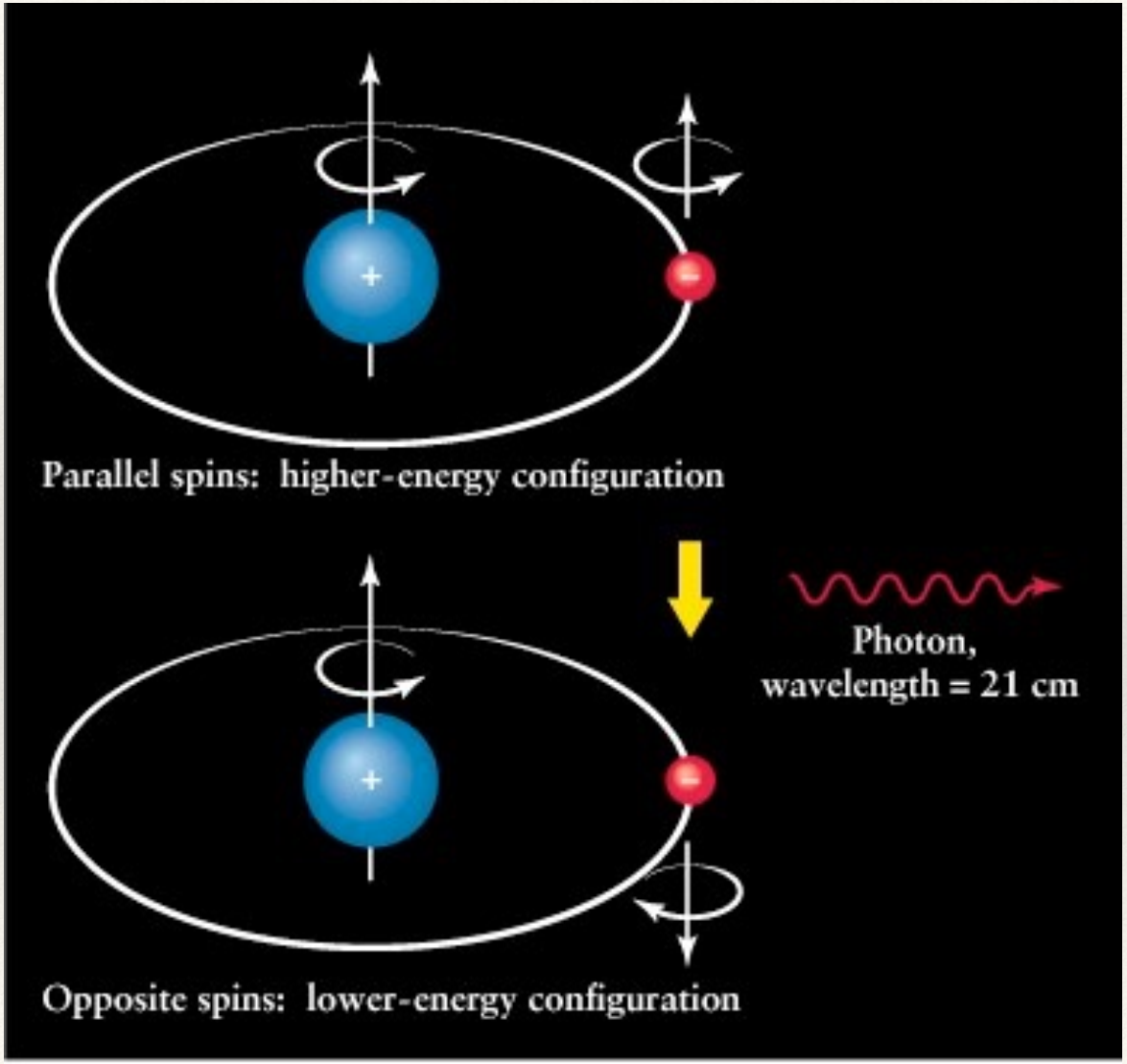

FAST


Parkes


VLA


SKA-LOW

A precious indicator : signature of Hydrogen



b

f = 1420 MHz ⇔ λ = 21 cm

Atome d'hydrogène

Some already great successes!

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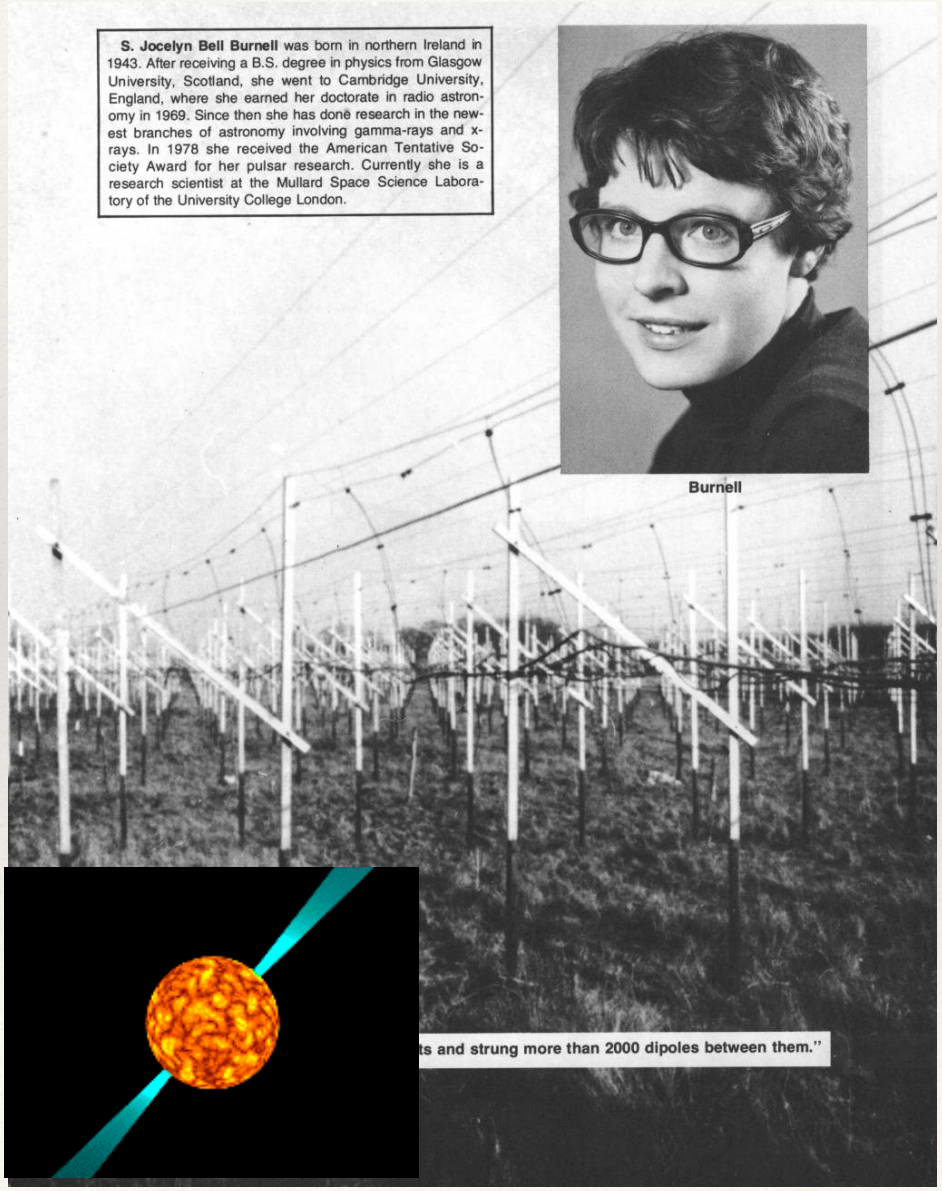

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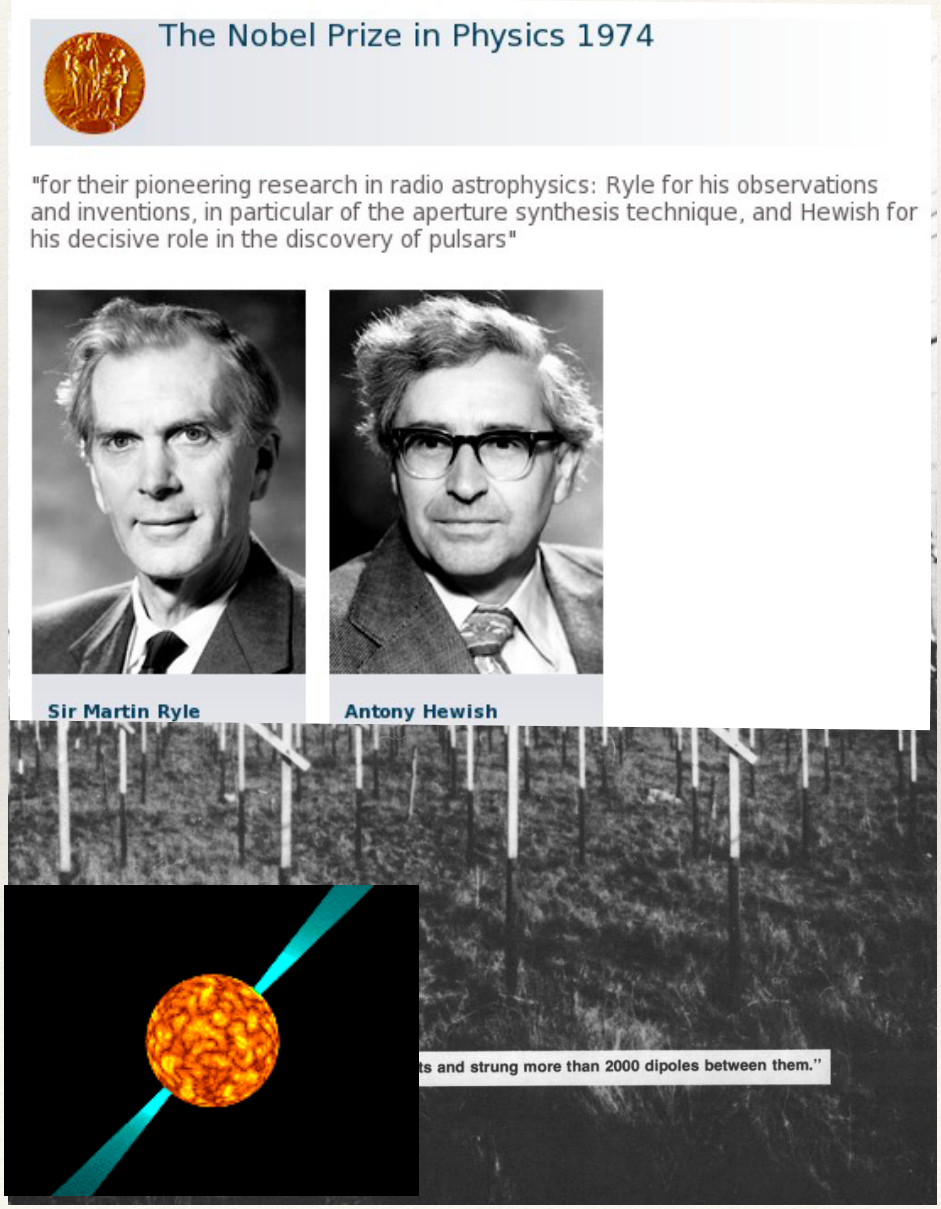

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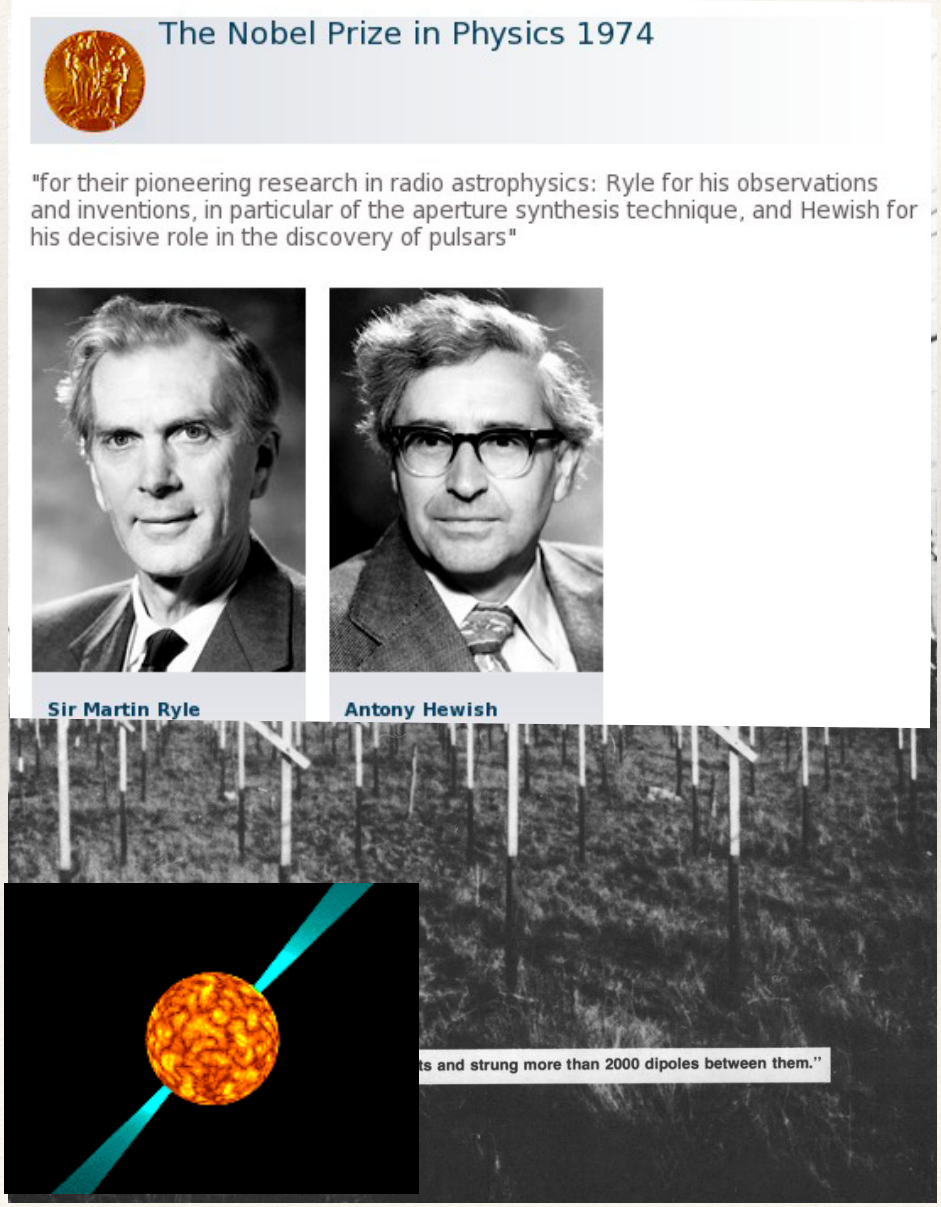

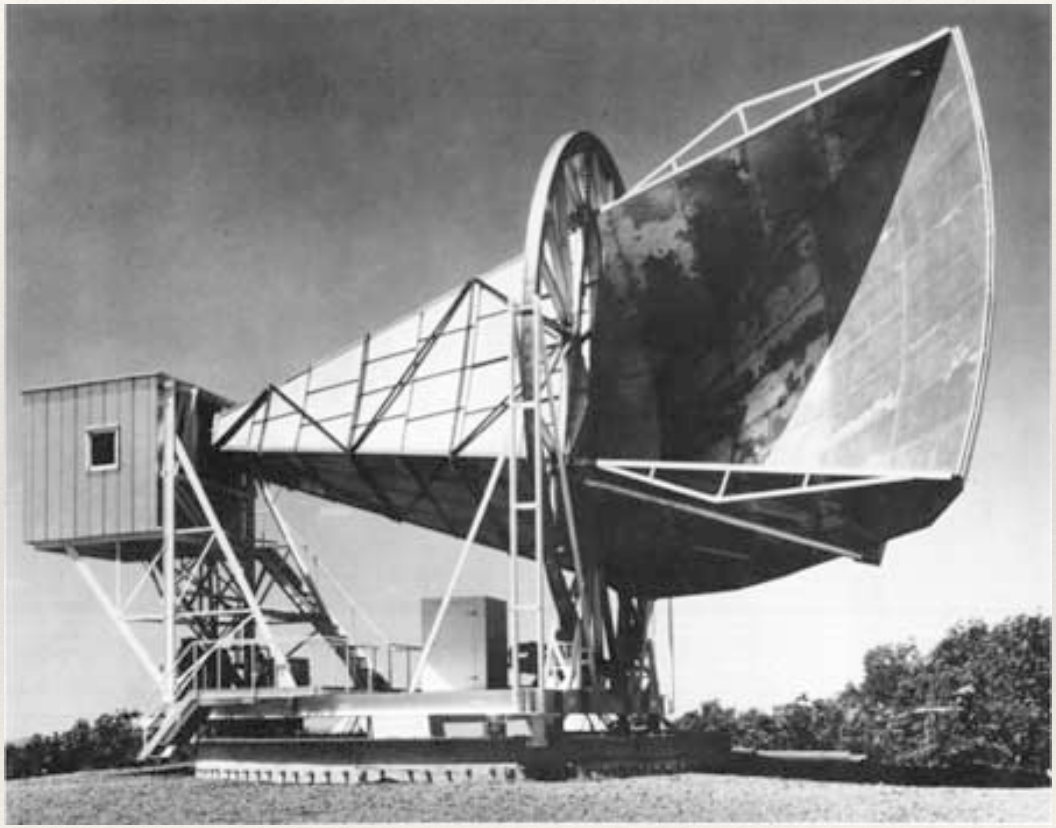

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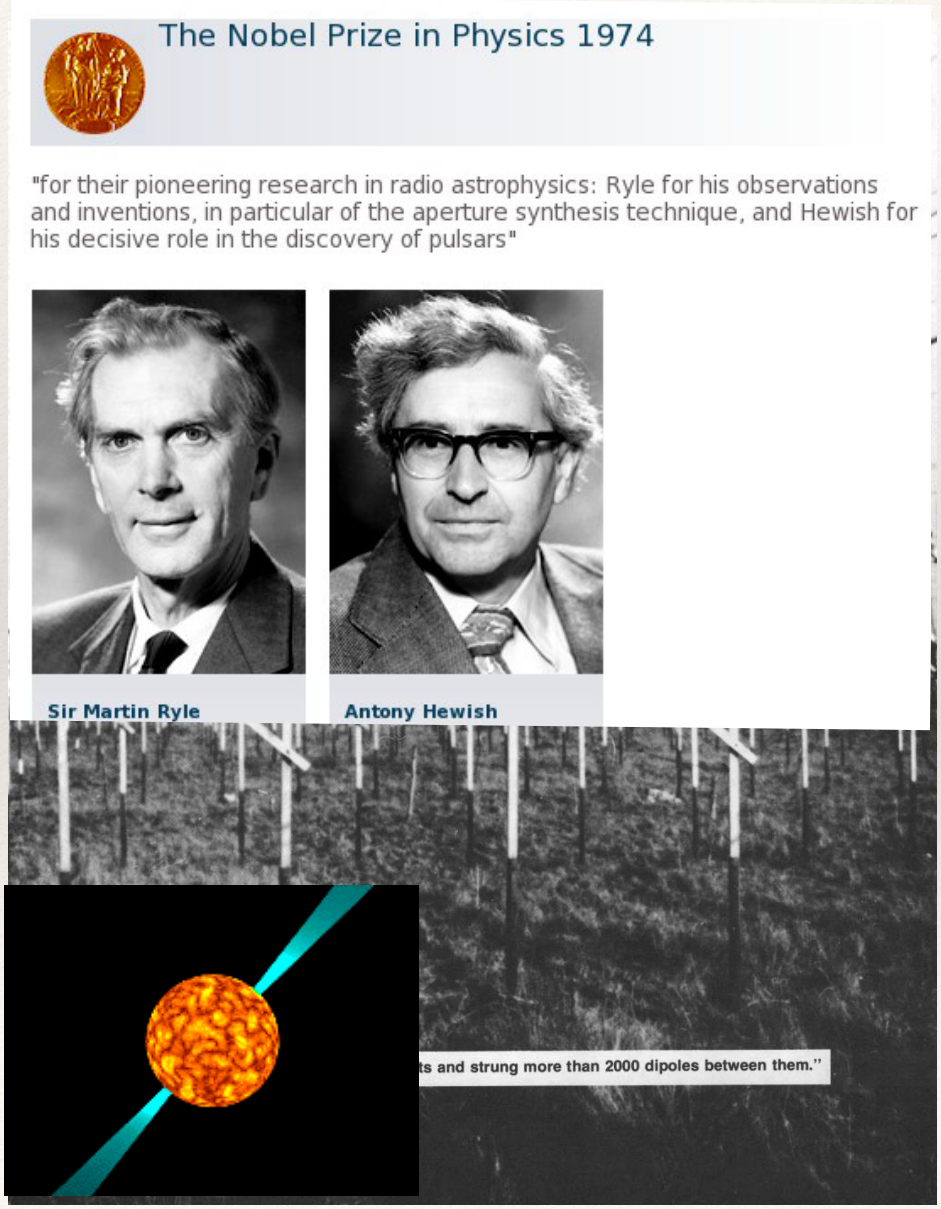

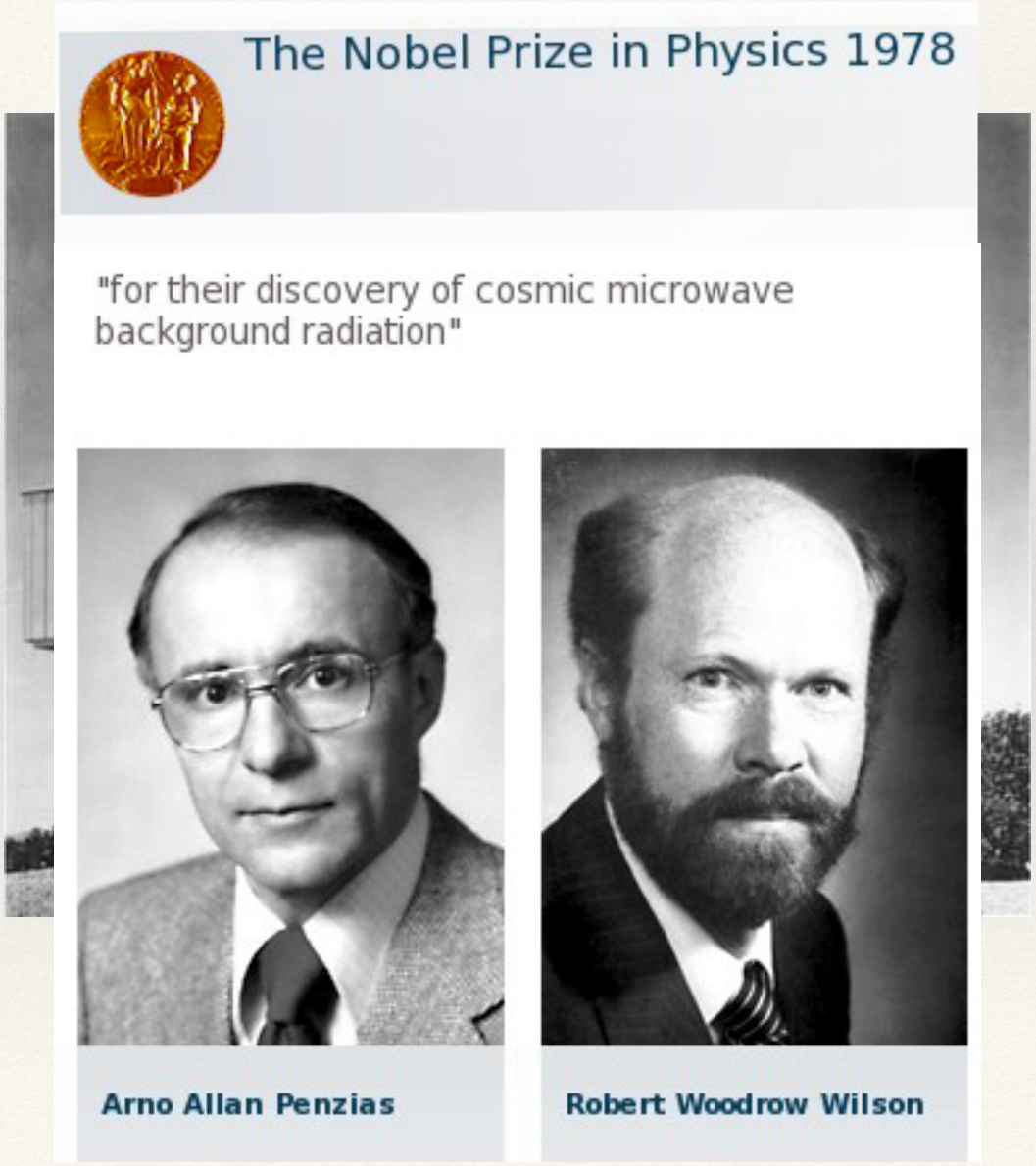

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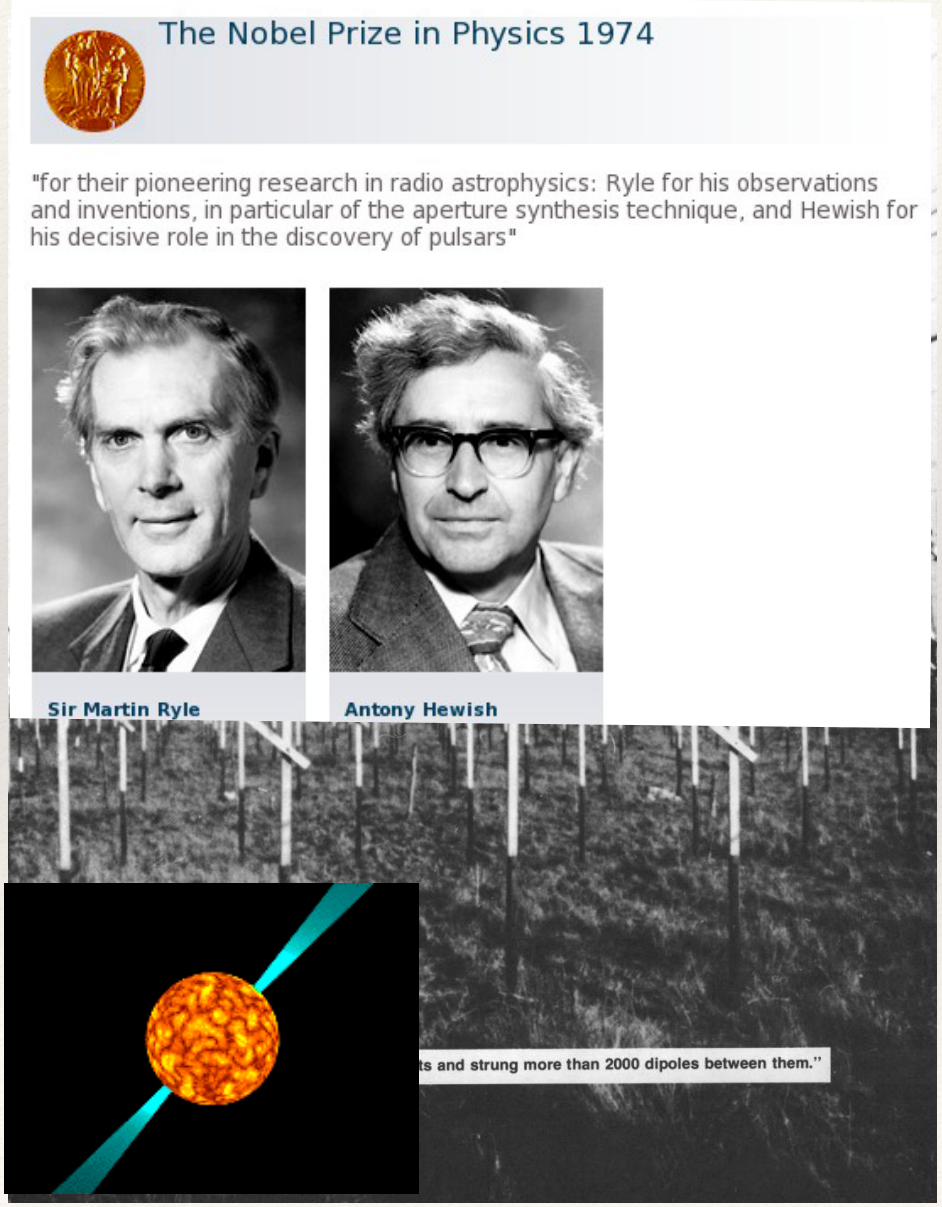

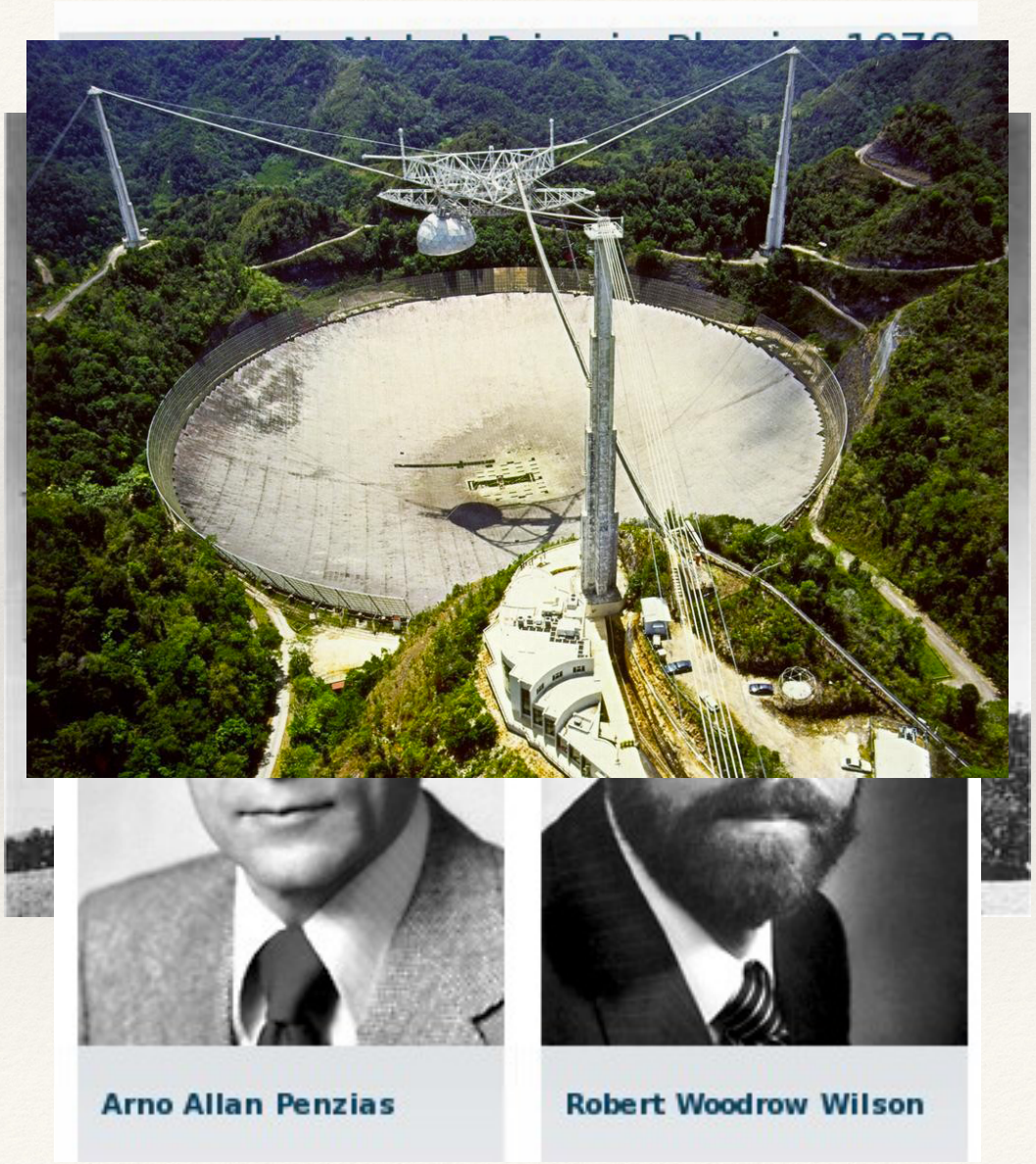

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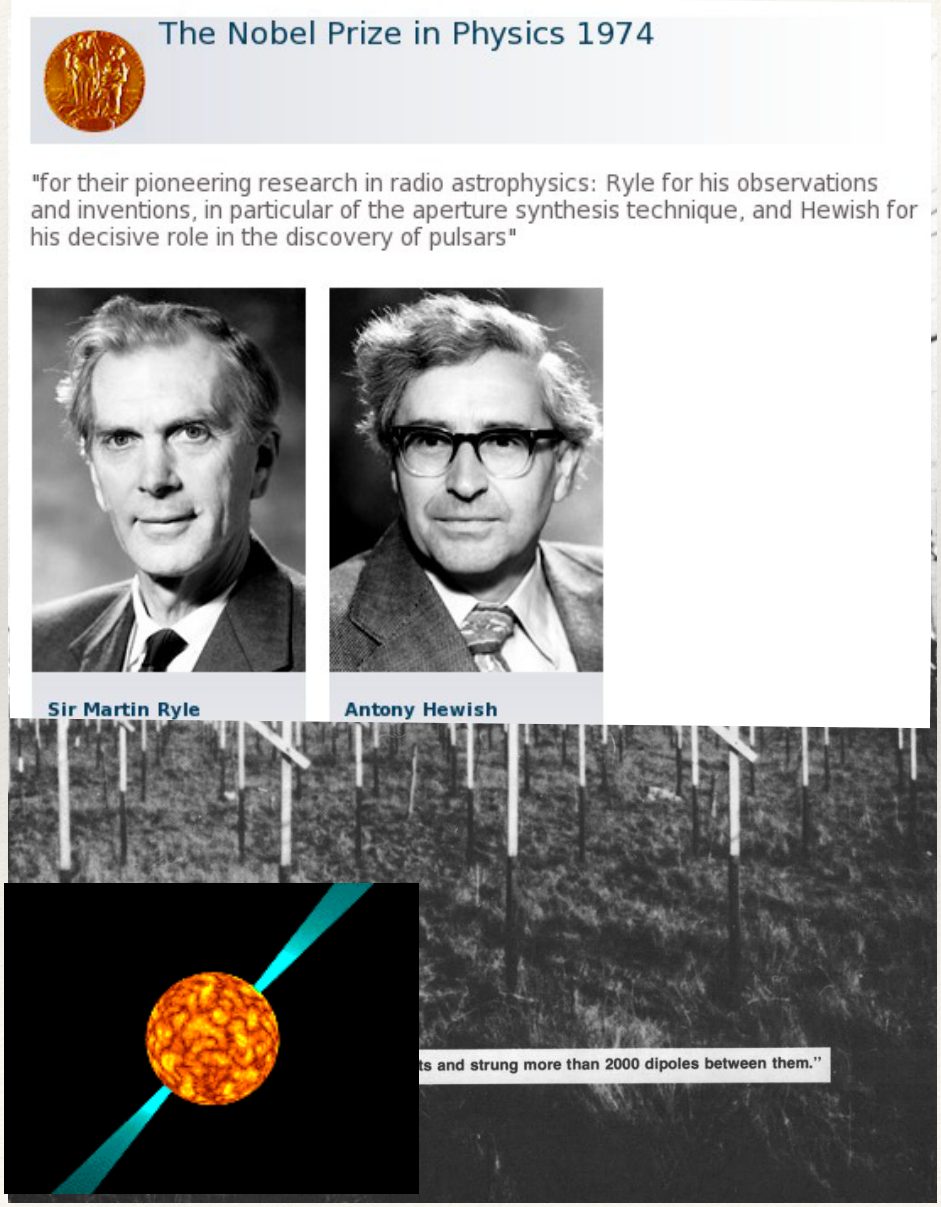

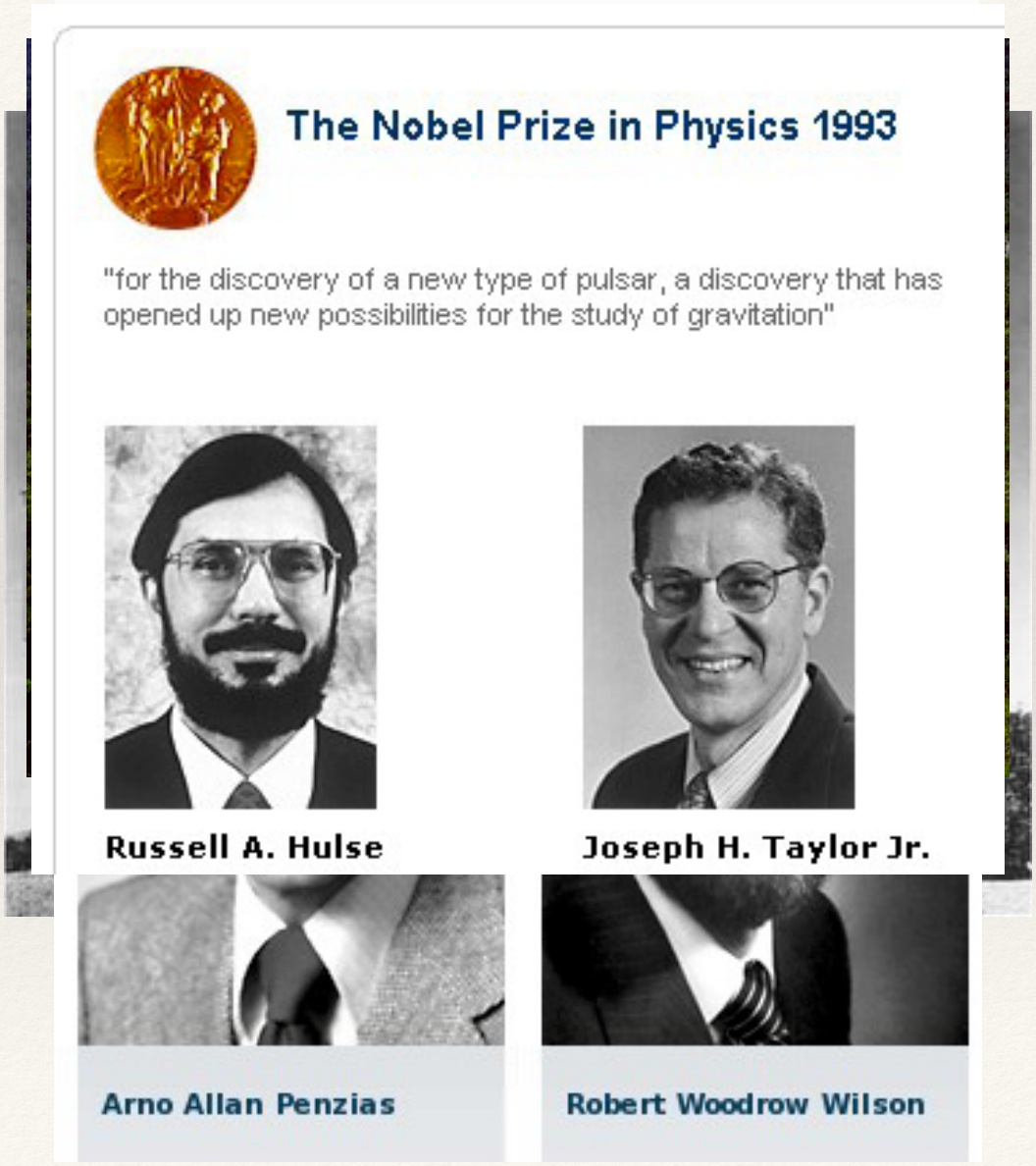

A radio observatory @ Nançay

Une structure dépendant de l'Observatoire de Paris, du CNRS et de l'Université d'Orléans

Where is Nançay ?

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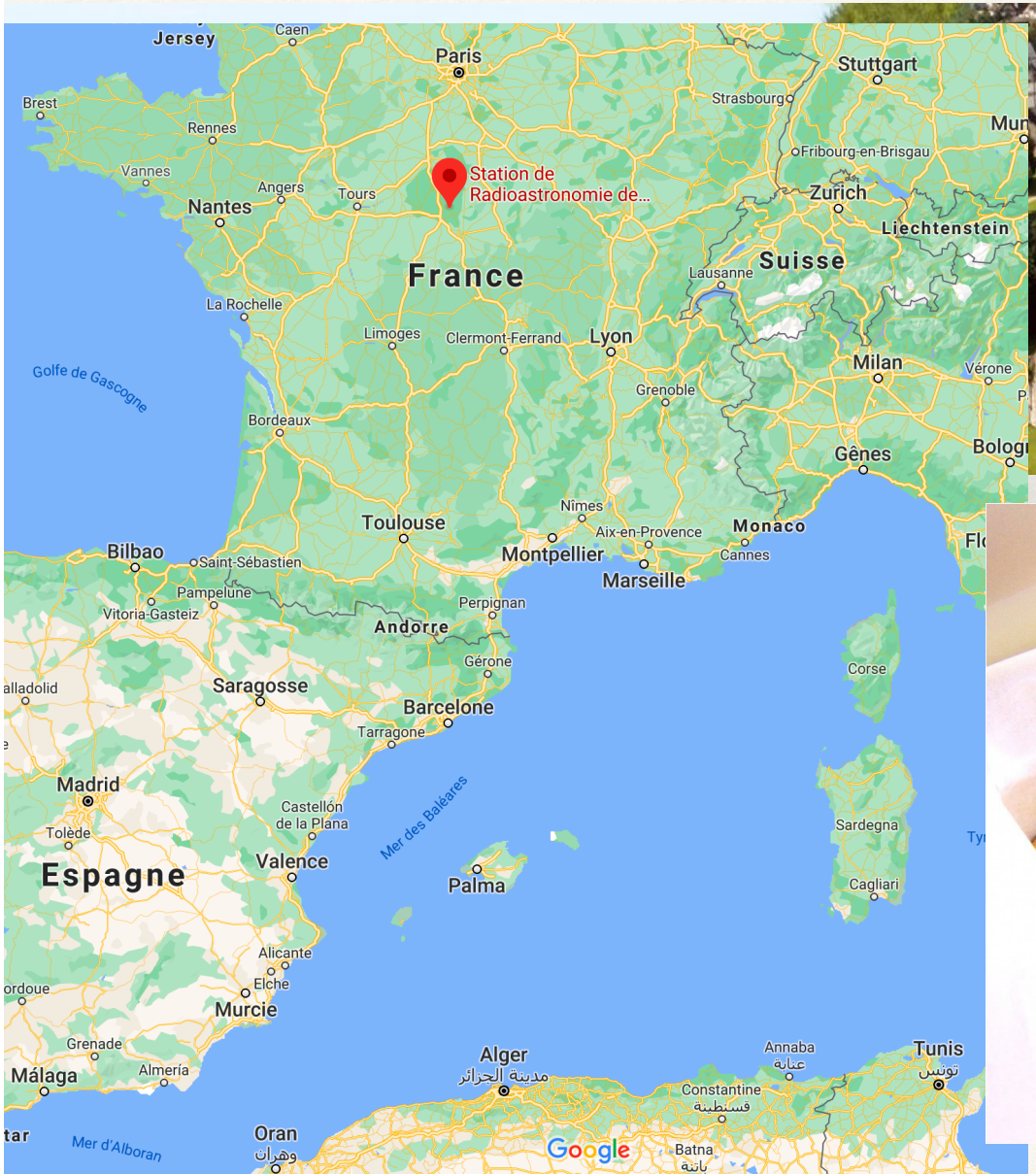

Where is Nançay ?

« Nançay … le lieu du monde que je préférais » Alain-Fournier
(Famous french writter)

Why a radio observatory in Nançay ?

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People at the observatory

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- **~45 FTEs** (~2/3 OP + 1/3 CNRS) + few temporaries grouped en 4 teams: electronic, computing, logistic, administration.
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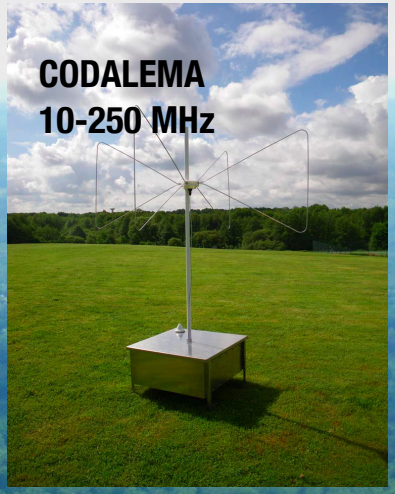
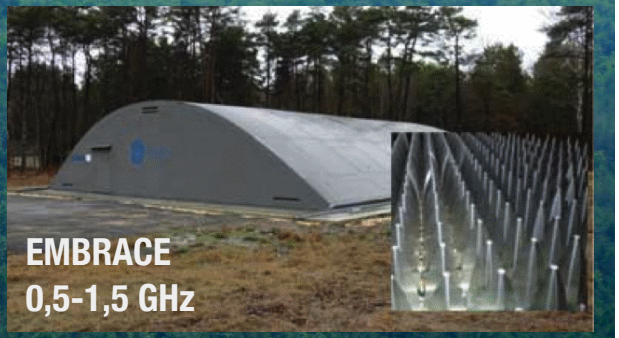
- Several international **collaborations** (ASTRON, Univ. Manchester, Berkeley, …) et **industries** (ALSE, NXP, Eurocircuits, CMP, Intercept Tregor, …).

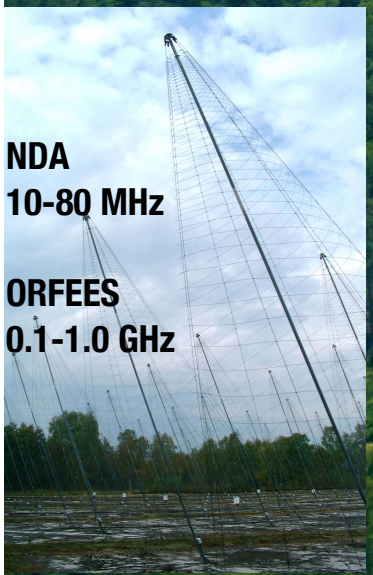
Radio Environment
Monitoring
100 MHz – 4 GHz



NRT
1,0-3,5 GHz



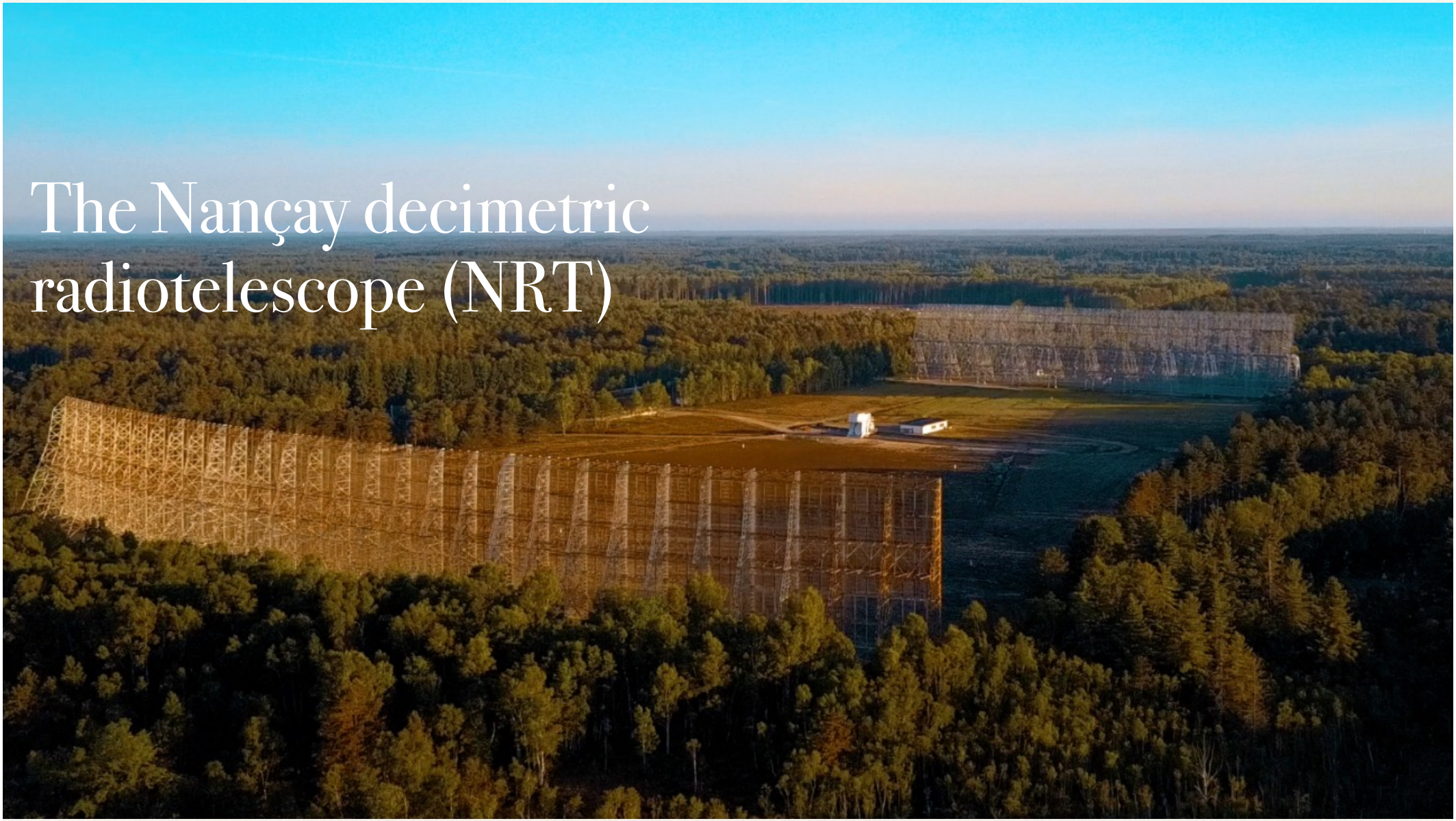
LOFAR
30-250 MHz



HBA

LBA

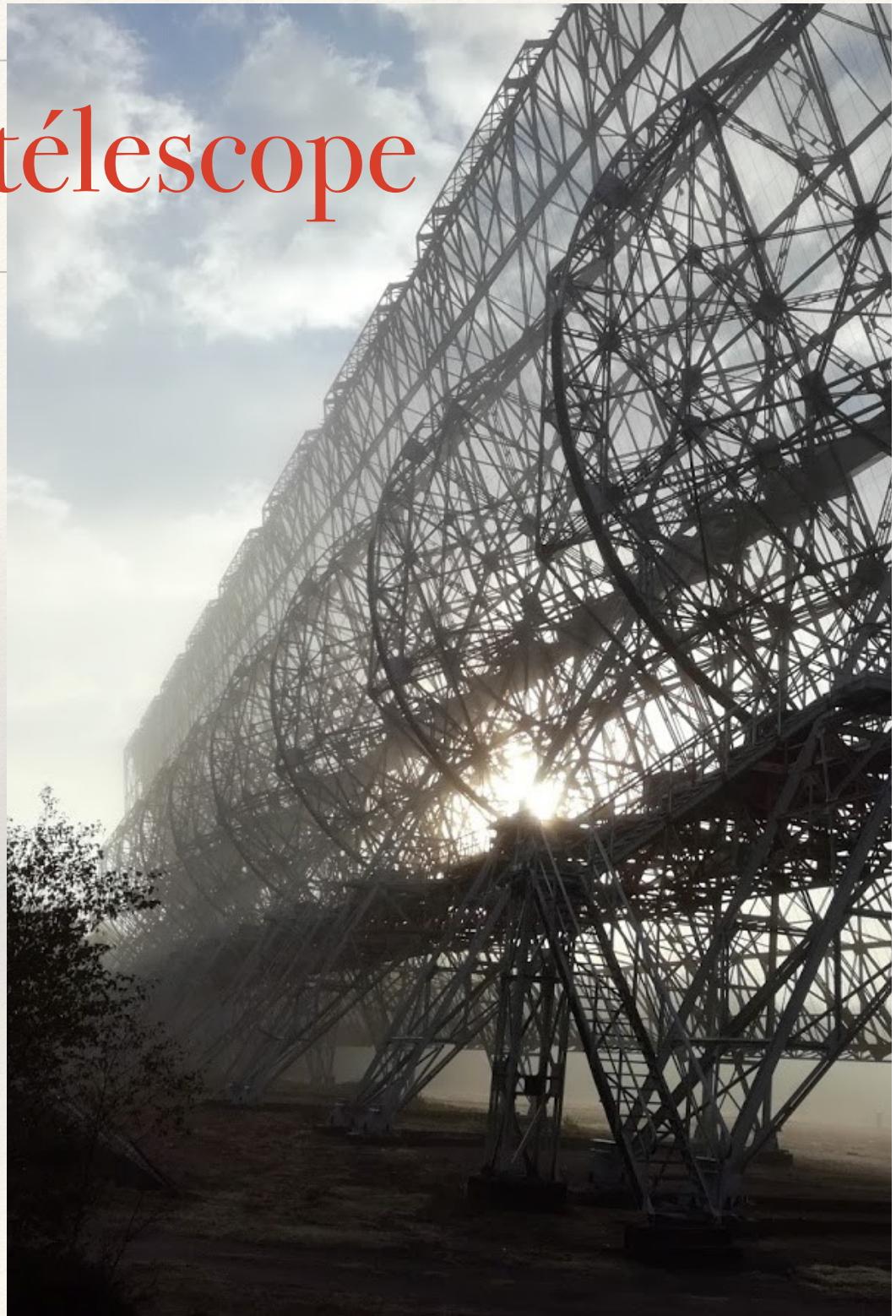
and now also NenuFAR (10-85 MHz)



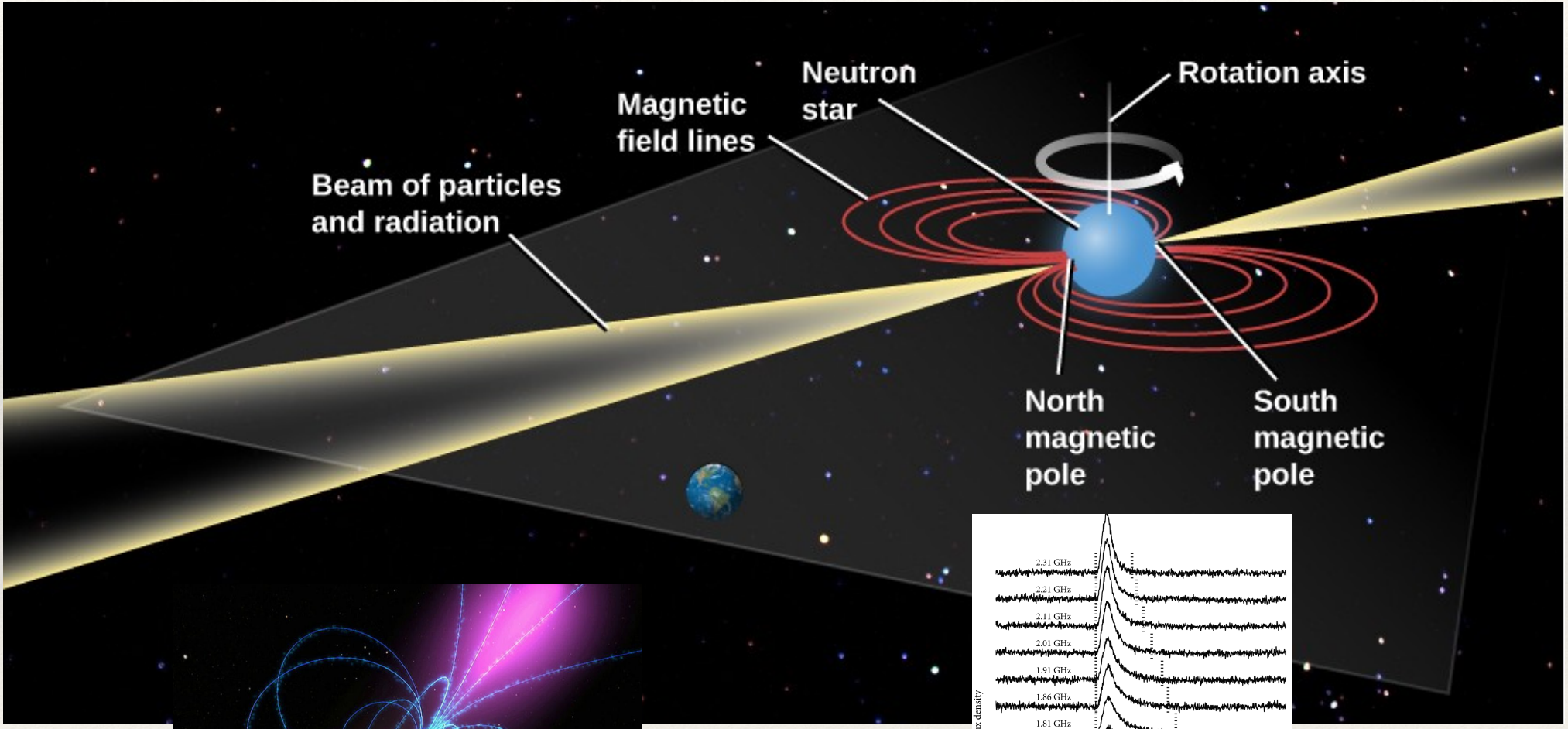
See talk by I. Cognard

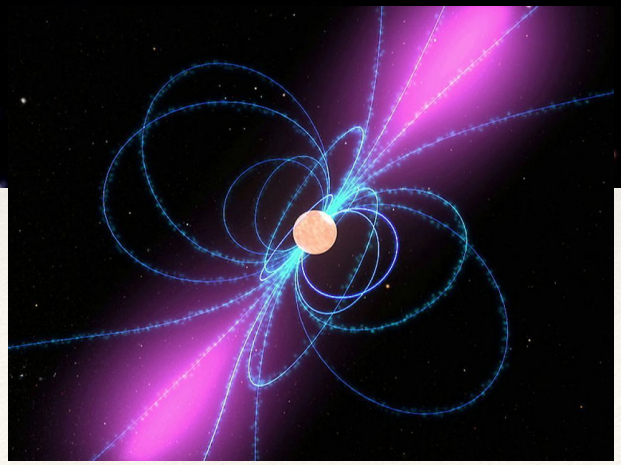
NRT = «big » radiotélescope

- 4th antenna in size in the world (FAST and the big 3). 80 % of time on sky.
- Main receivers: **NUPPI** (Pulsar dispersion in real time for 512 MHz bandwidth (8 GPUs), soon for 2 GHz); WIBAR (600 MHz, ~10^6 channels) +auto-correlator to be upgraded soon.
- ~5 FTE/an.
- **Program committee** (2400 h/sem): dominated by observations of pulsars.



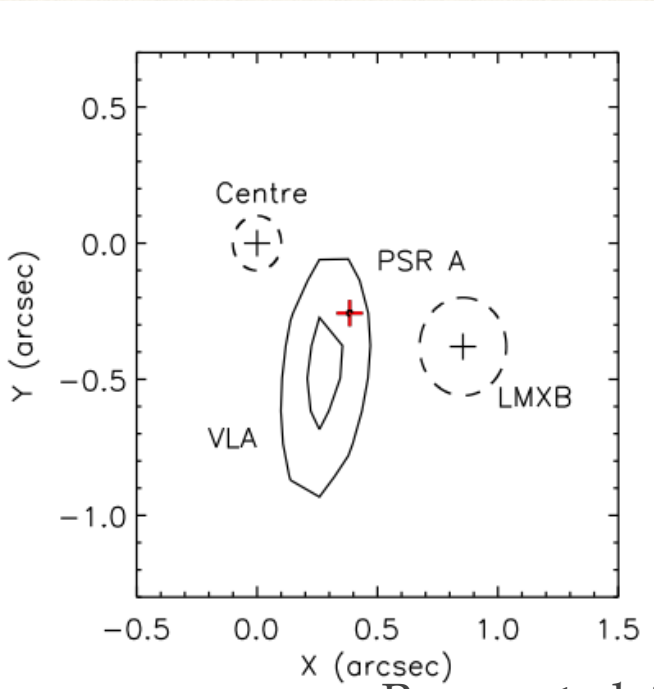
Pulsars


Neutron star
Magnetic field lines
Rotation axis
Beam of particles and radiation
North magnetic pole
South magnetic pole



2.31 GHz
2.21 GHz
2.11 GHz
2.01 GHz
1.91 GHz
1.86 GHz
1.81 GHz
1.76 GHz
1.71 GHz
1.66 GHz
1.61 GHz
1.51 GHz
1.41 GHz
Relative flux density
0.0
0.2
0.4
0.6
0.8
1.0
Pulse phase (turns)

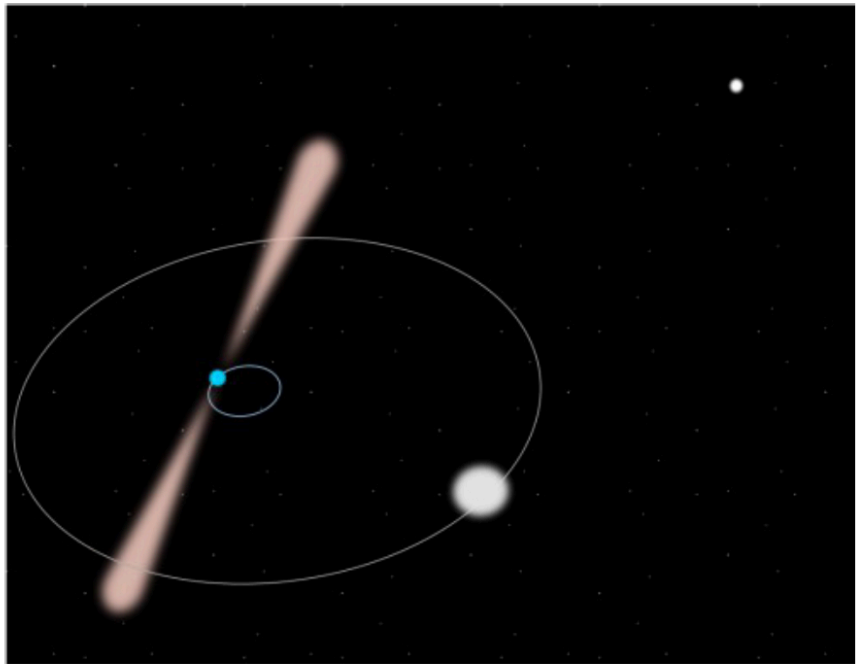
An intermediate mass black hole at the center of the globular cluster NGC6624 ?



Perera et al. 2017, 18

- PSR B1820-30A is located in the globular cluster NGC 6624 and is the closest known pulsar to the centre of any globular cluster.
- 25 years of high-precision timing observations of this millisecond pulsar (NRT, JBO, …)
- The high-eccentricity solution reveals that the pulsar is most likely orbiting around an **intermediate-mass black hole** (IMBH) of mass >7,500M⊙ located at the cluster centre.

Systèmes de pulsars binaires relativistes



Analyse des observations du système triple PSR J0337+1715 (Voisin et al 2020)

Test du SEP $\rightarrow G_{NS\text{-}WD} \neq (1 + \Delta)\, G_{WD\text{-}WD}$

$|\Delta| < 1.8\ 10^{-6}$ **à 95%.**

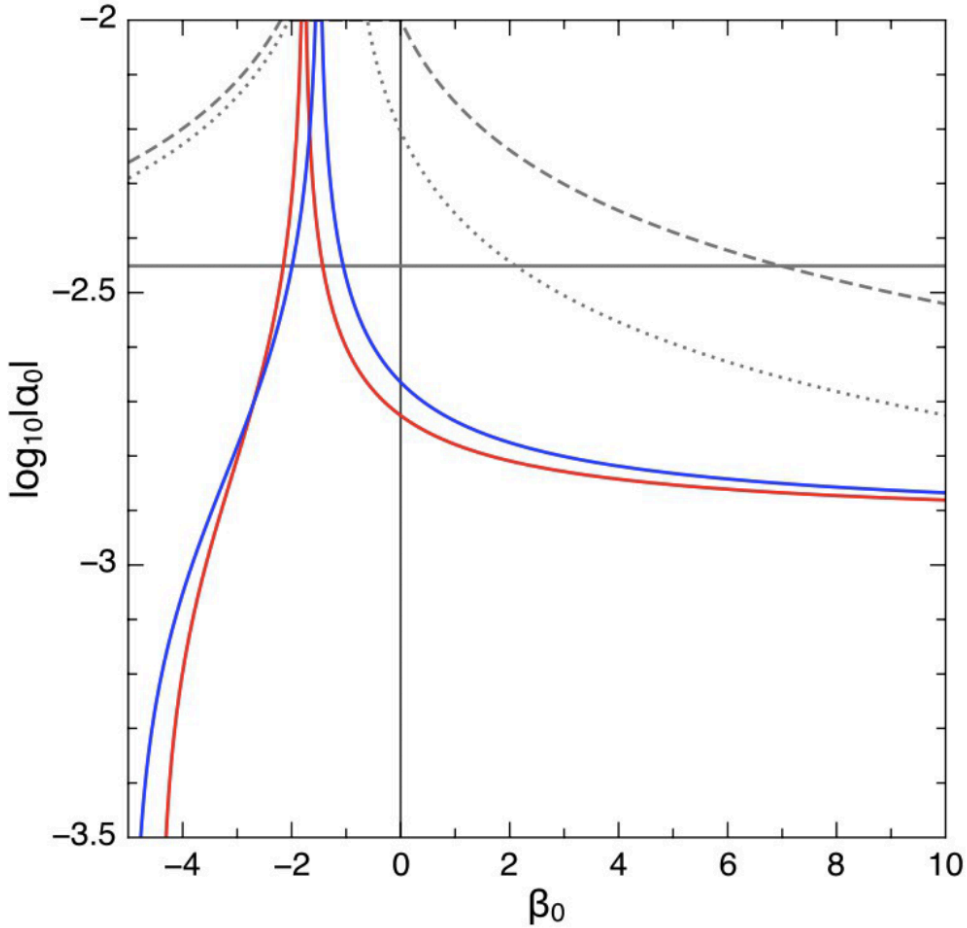
Contraintes sur l'espace α_0-β_0 des théories tenseur scalaire

rouge, **bleu** : contraintes SEP / pulsar système triple

gris : limites à 2σ des expériences dans le Système Solaire

Cassini (pleine),
Laser-Lune (tirets),
MESSENGER (pointillé).

La gravité JFBD correspond à $\beta_0 = 0$ (fine ligne verticale).



Slide : Gilles Theureau

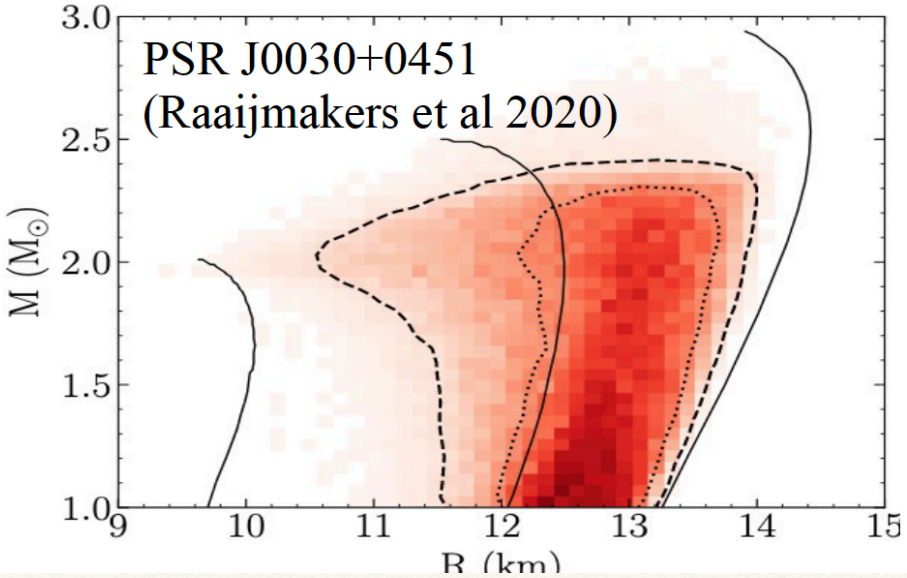
Pulsars multi-λ

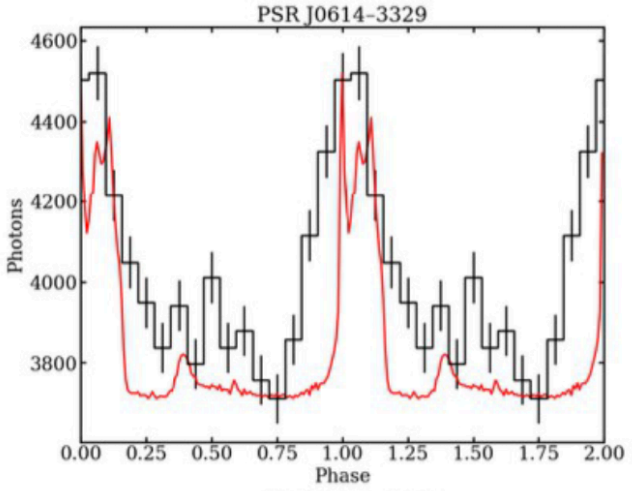
Support NICER (X-ray)
(Guillot et al 2019)

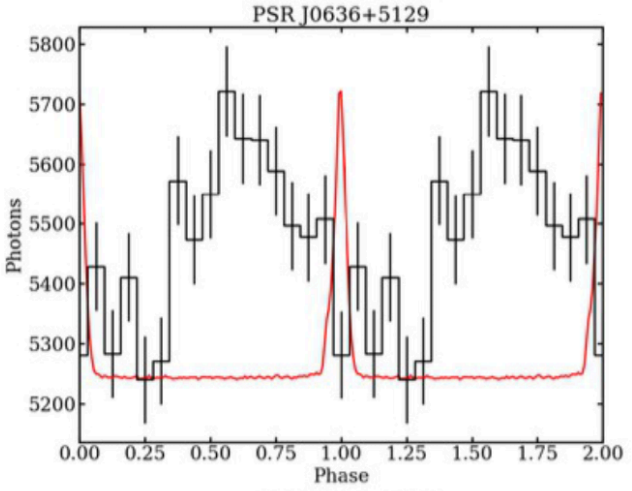
Détection de cinq pulsars millisecondes à partir des éphémérides radio

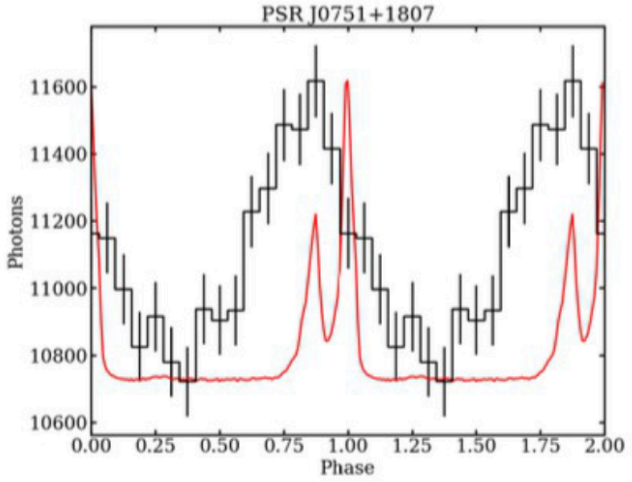
Émission thermique X
de la calotte polaire

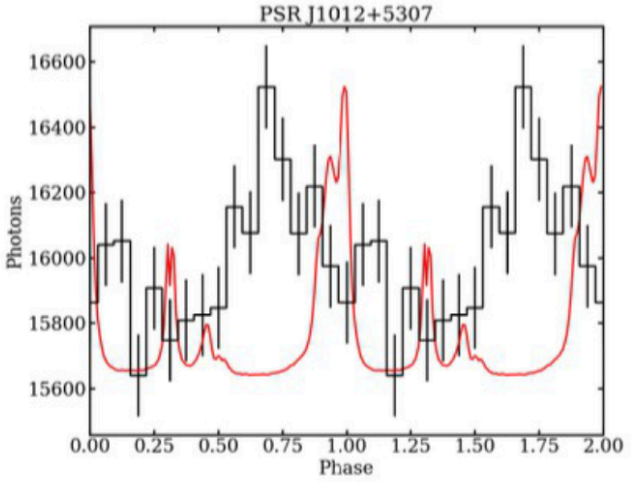
Futures contraintes
sur la relation masse-rayon
et sur l'équation d'état
de la matière dense

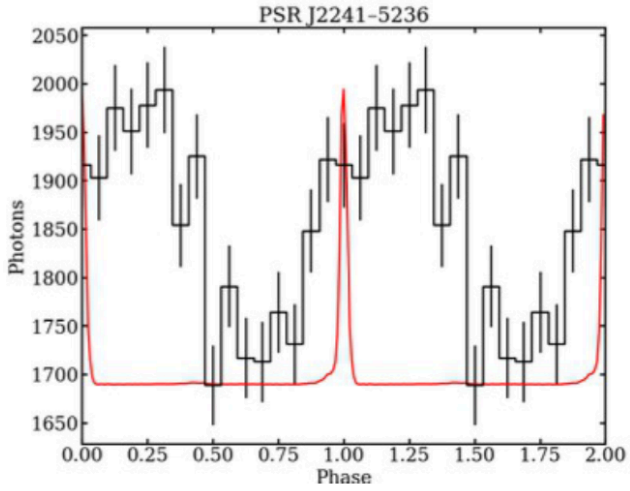






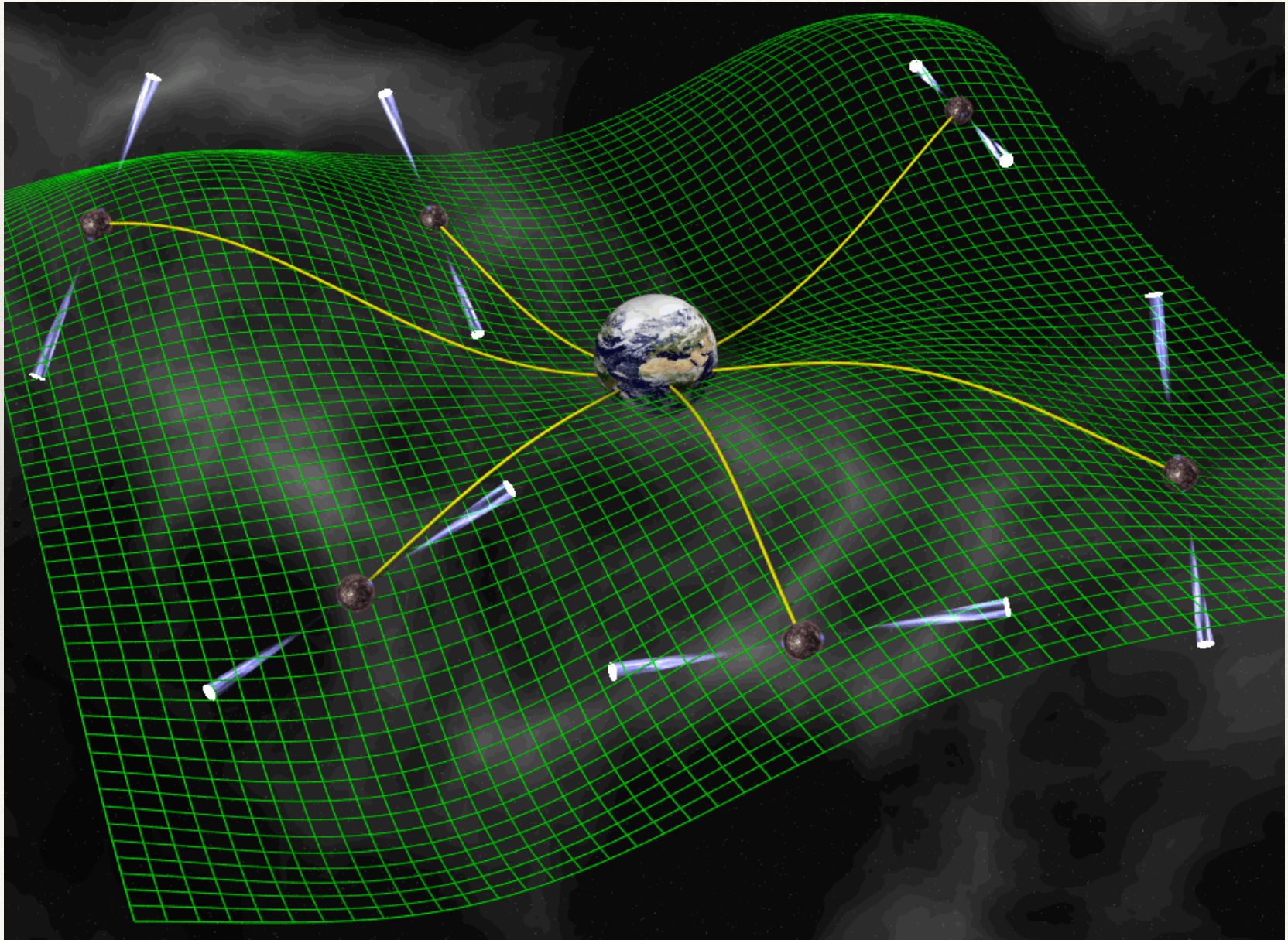




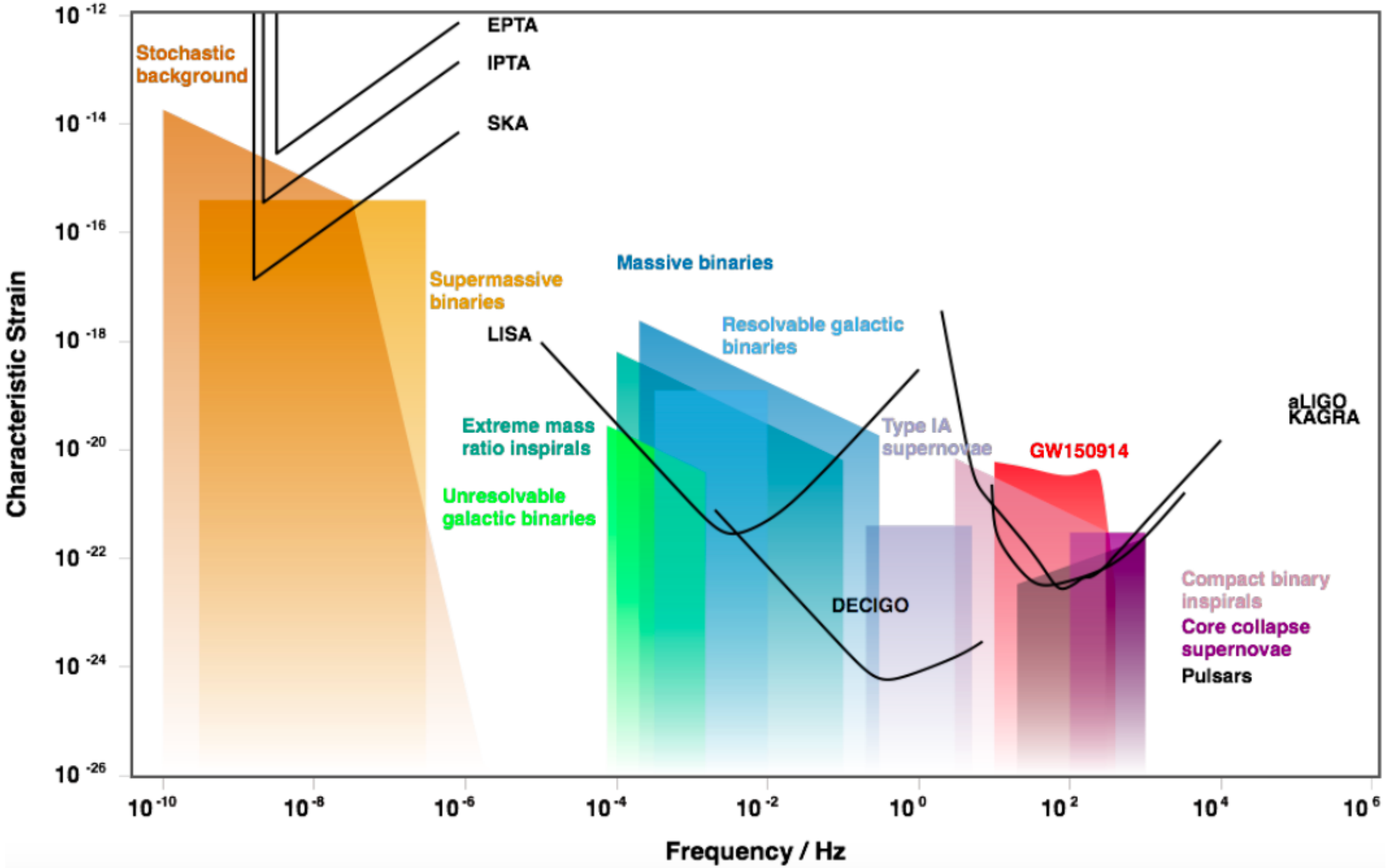


Slide : Gilles Theureau

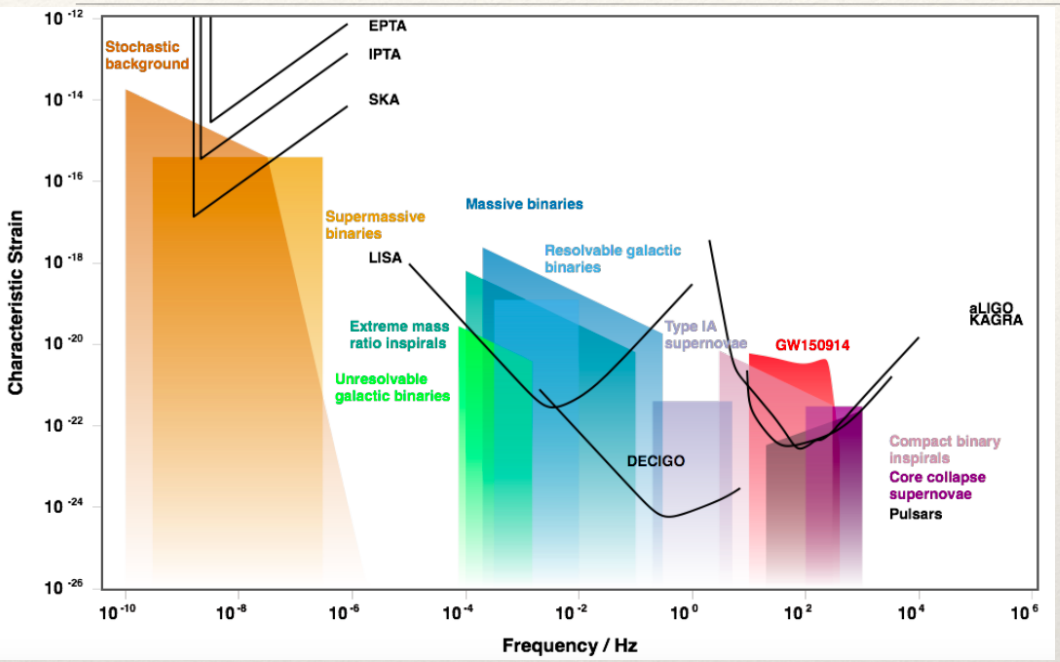
Pulsars as a tool for gravitational waves

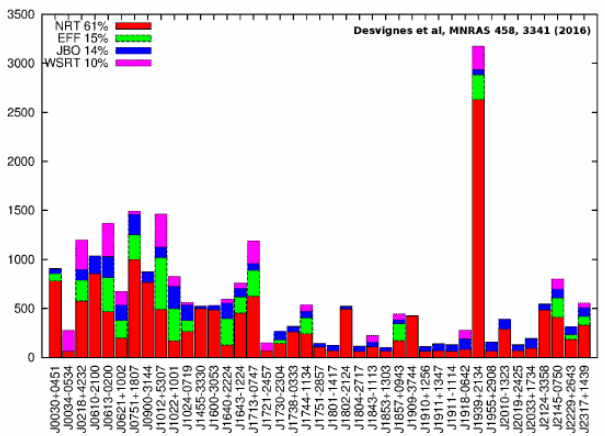


EPTA: European consortium
IPTA: International consortium



NRT, pulsars, GW, supermassive binary black holes





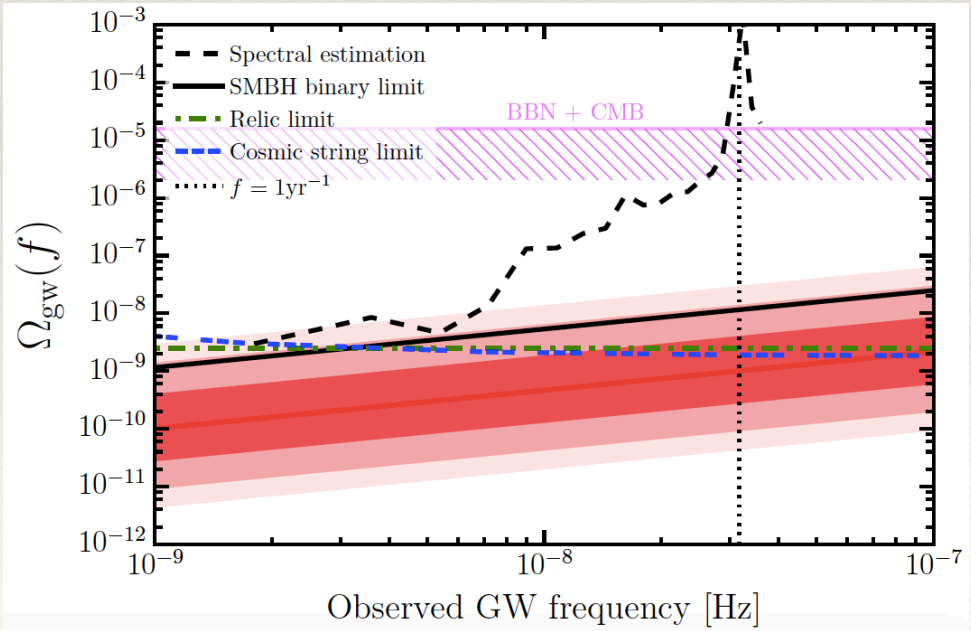
The NRT provides 55% of EPTA data.

Une série de 5 papiers contenant les données NRT BON (bw=128MHz) :

Taylor et al, PhysRev L 115, 4, 041101, 201
Lentati et al, MNRAS 453, 2576, 2015
Babak et al, MNRAS 455, 1665, 2016
Caballero et al, MNRAS 457, 4421, 2016
Desvignes et al, MNRAS 458, 3341, 2016

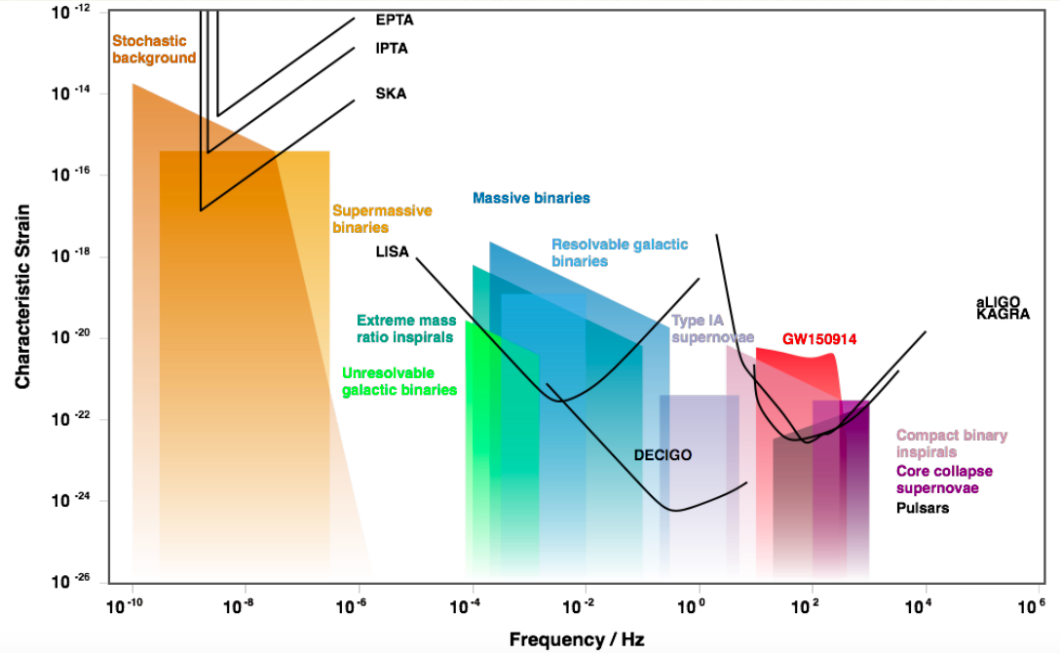
Analysis of the 6 best EPTA pulsars (Desvignes et al, 2016)

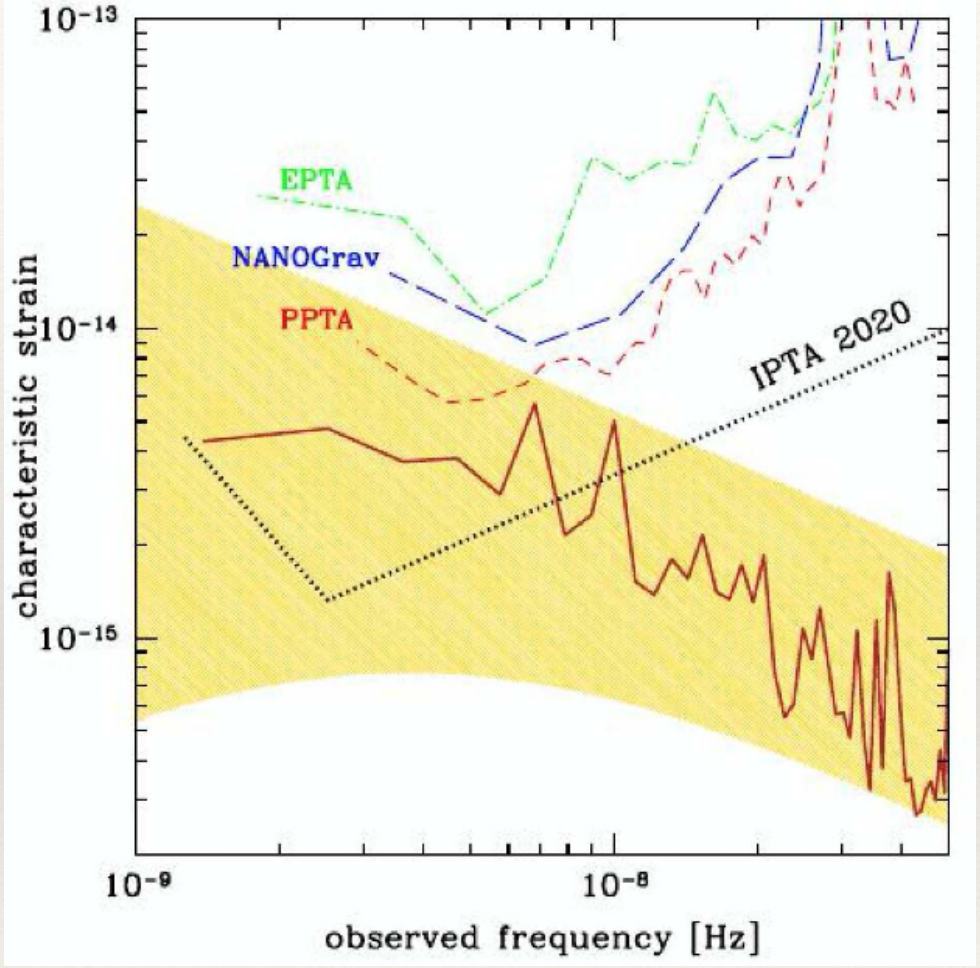
Dashed : no hypothesis on the nature of the population
Black : Power-law with index 13/3 corresponding to stochastic background of binary supermassive black holes



Lentati et al. 2015

NRT, pulsars, GW, supermassive binary black holes

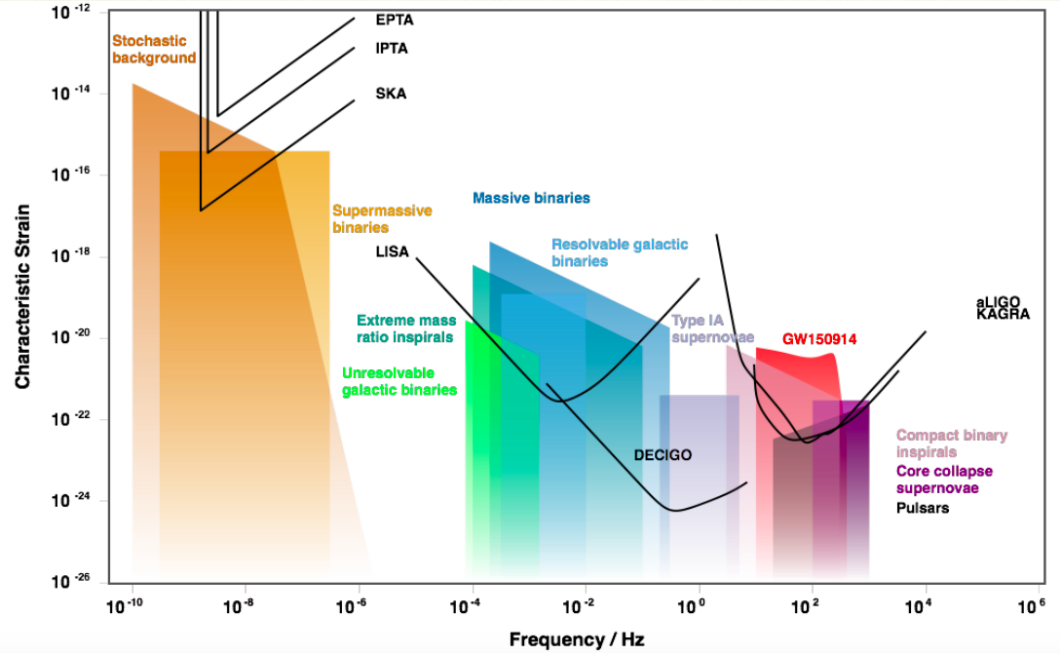


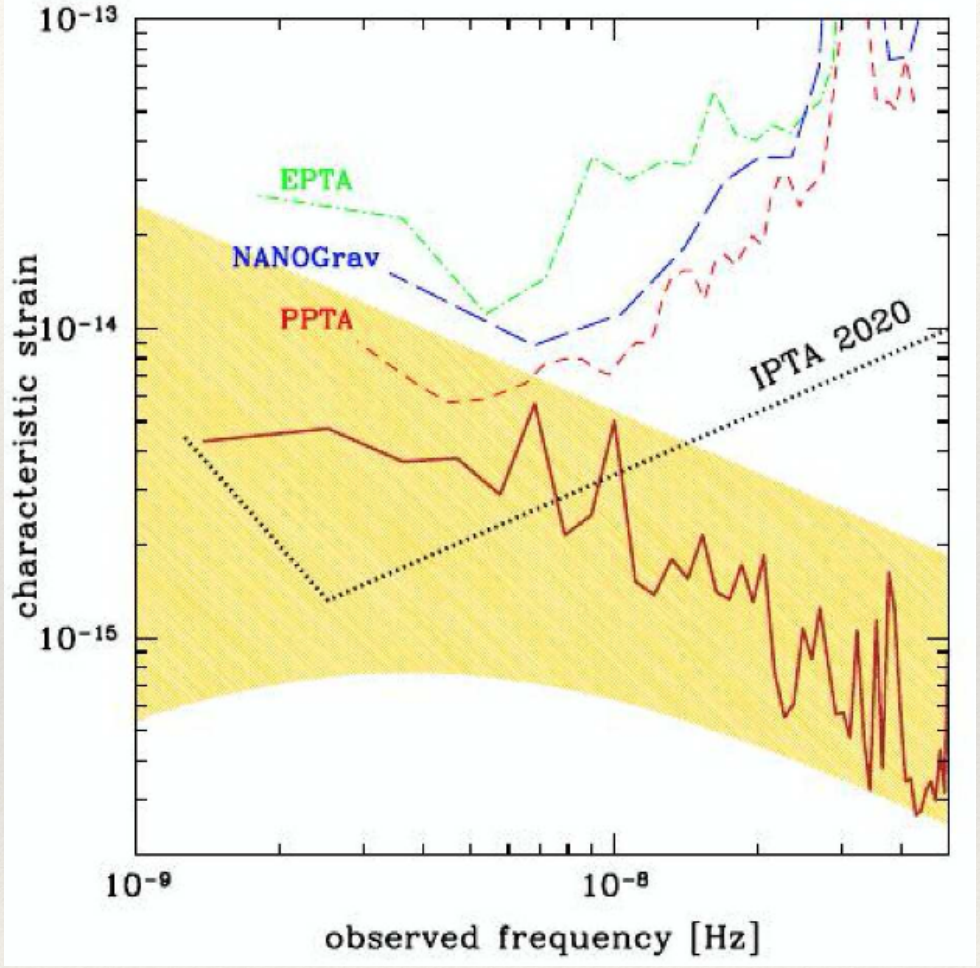


PTA's : synthesis of last results
and projection for current IPTA analysis

Hobbs et al. 2017

NRT, pulsars, GW, supermassive binary black holes





PTA's : synthesis of last results
and projection for current IPTA analysis

A major update in 2021

Hobbs et al. 2017

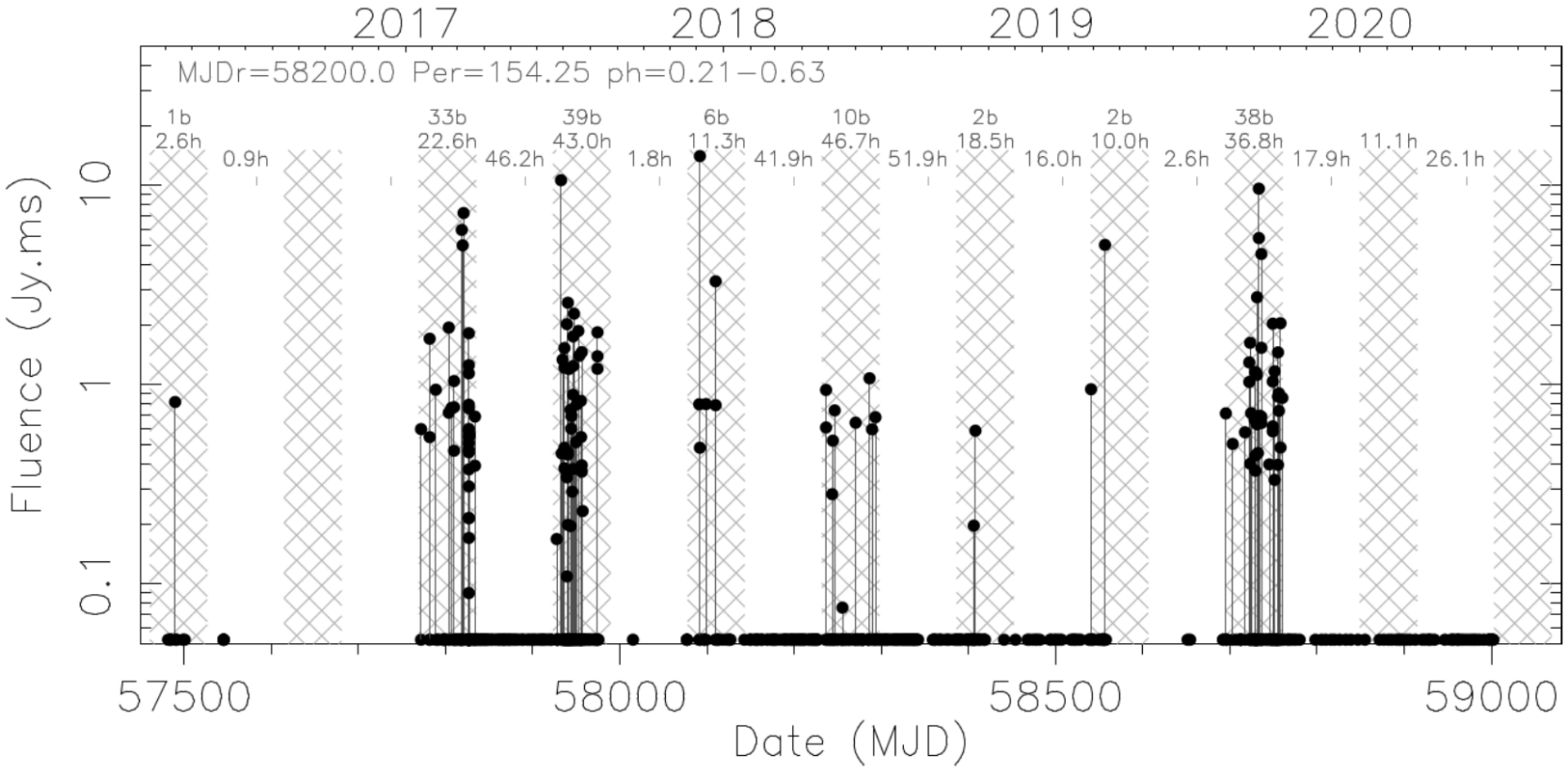
Le FRB « repeater » FRB121102

Plus de 130 impulsions d'intensité très variable ont été recensés sur plus de 400 heures d'observation

Campagne coordonnée multi-télescope (Arecibo, Green Bank, Effelsberg, FAST, SRT, ALMA + INTEGRAL)

Quatre impulsions détectées simultanément entre MeerKAT et le NRT sont présentés dans Caleb et al (2020).

Une analyse détaillée de la séquence des impulsions détectées à Nançay est en cours (Cognard et al in prep) et semble confirmer l'existence d'une périodicité agrémentée de variations plus lentes de l'activité



Périodicité des impulsions du répéteur FRB121102 observés au NRT (Cognard et al in prep).
Chaque impulsion est représentée par un point noir selon intensité
(et chaque observation repérée par un point noir le long de l'axe des dates MJD),
la périodicité de ~150 jours et les fenêtres d'activité sont en hachuré.

Slide : Gilles Theureau

Régions de formation stellaire

Evolution of the OH Maser Emission in the Active Star-Forming Region IRAS 05358+3543 (S231)

Ashimbaeva, Colom et al 2020a
(6 autres papiers « stellaires » depuis sept 2019)

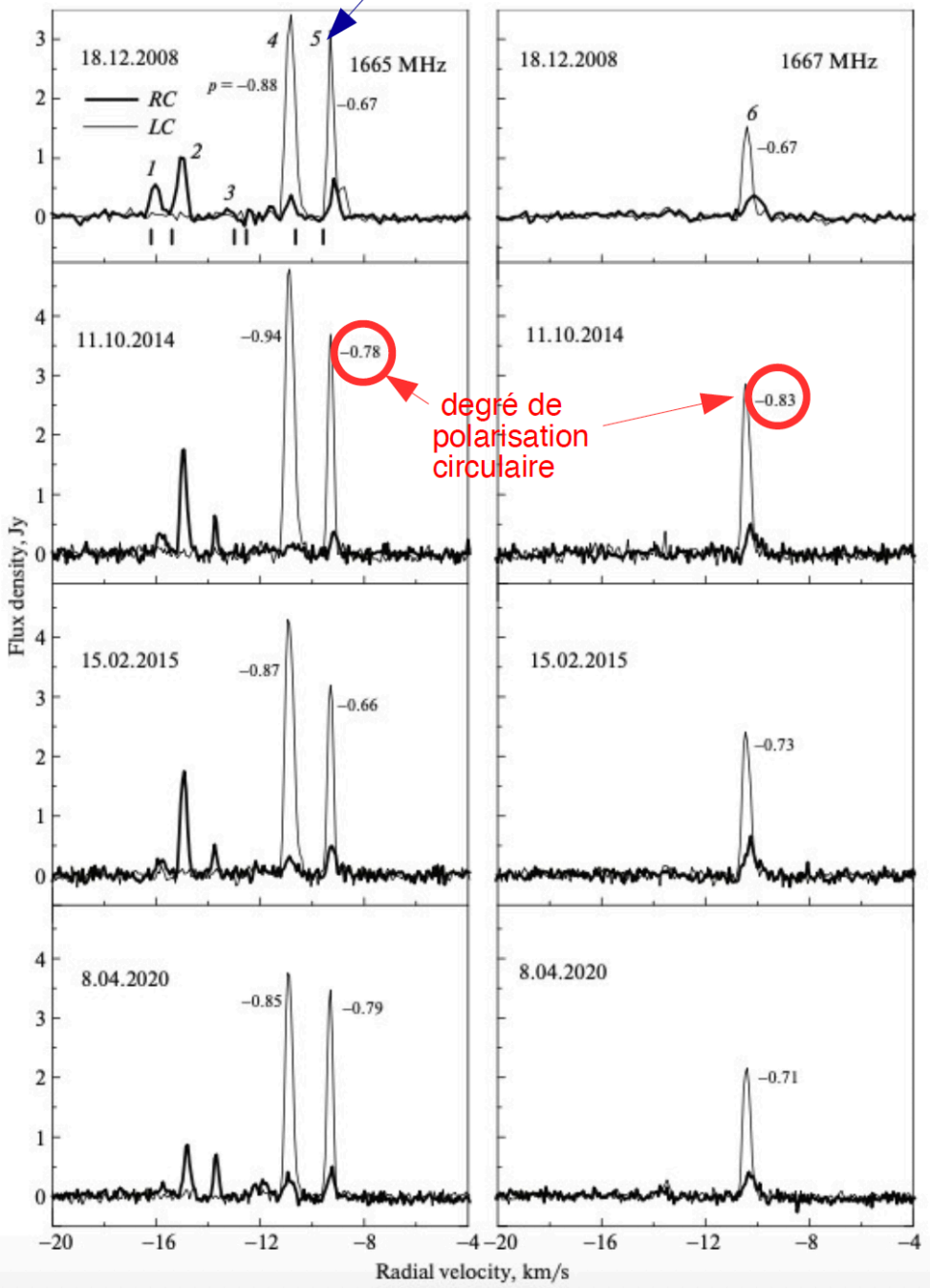
Ci-contre :
Émission de OH à 18 cm dans les raies principales en polarisation circulaire droite (ligne épaisse) et en polarisation circulaire gauche (ligne f ne).

Table 1. Parameters of the main features in the OH spectra in the source S231

Epoch of observations, day month year	Line, MHz	V_{LSR}, km/s	Stokes parameters, Jy			Degree of polarization, %	Position angle, deg
			I	*Q*	*U*		
18.12.2008	1665	−10.82	4.06	0.74	−0.36	20	−26
	1665	−9.32	3.60	0.17	0	5	0
	1667	−10.40	1.84	0.10	−0.04	6	−22
11.10.2014	1665	−10.88	4.95	0.56	−0.29	13	−27
	1665	−9.27	4.0	−0.15	0	5	0
	1667	−10.35	3.35	0	−0.37	11	−45
15.02.2015	1665	−10.88	4.6	0.66	−0.35	16	−28
	1665	−9.29	3.8	0	0	0	
	1667	−10.45	2.80	0	−0.20	7	−45
8.04.2020	1665	−10.90	4.3	0.58	−0.18	14	−17
	1665	−9.31	3.5	0	0	0	
	1667	−10.40	2.40	0.10	−0.13	16	−38

Stokes I, Q et U, degrés de polarisation linéaire
et PA pour quelques raies et époques.
La variabilité est relativement faible pour la polar linéaire.

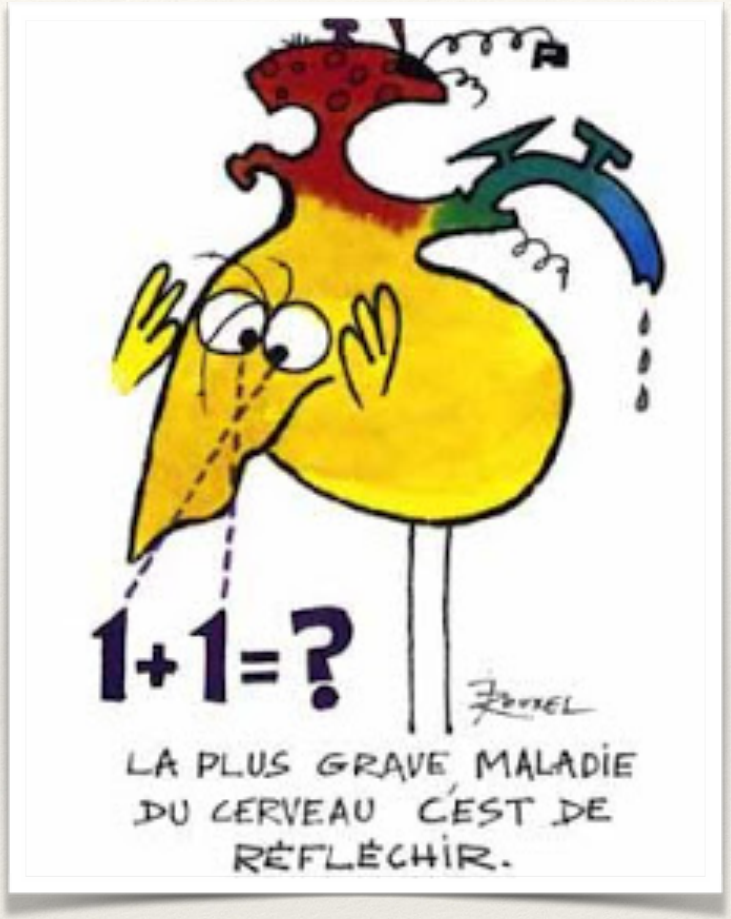
La polar circulaire pour une des raies à 1665 MHz montre un "Zeeman splitting" et a permis de mesurer le champ magnétique projeté sur la ligne de visée et son évolution entre 2008 et 2020



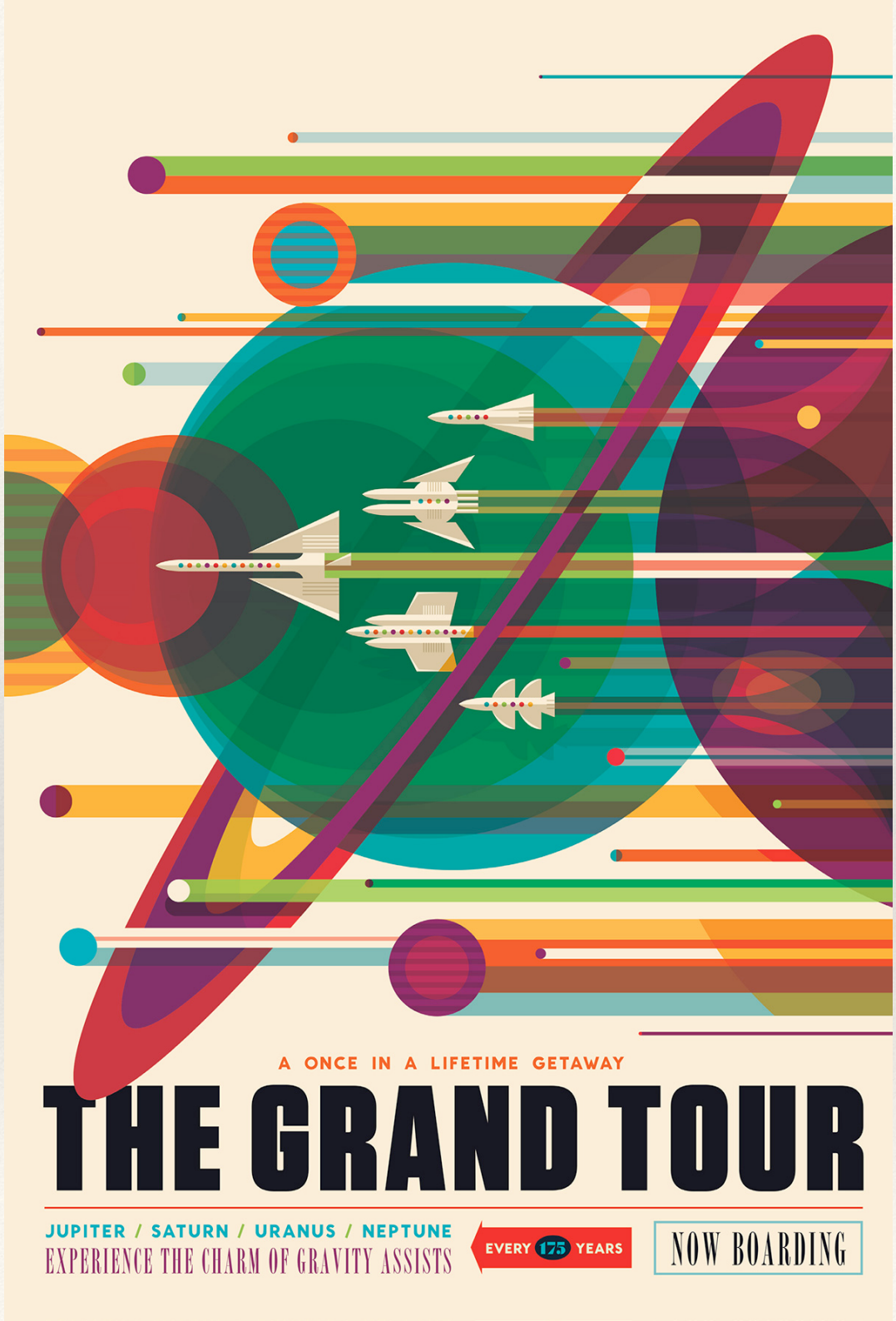
Slide : Gilles Theureau

Radio astronomy across the Paris's Observatory

Few examples



- **NRT Science** : pulsars under scrutiny (the pulsar itself, the environnement with precise measurements of its metrics , multi-wavelength emission, …), HI in galaxies, comets, star forming regions, …
- Radio observations of **accreting objects** : galactic black holes (Corbel), AGNs (Zech, Sol, …) and synergies HE, gamma-ray burst (Vergani), …
- **EHT** (team from LUTH/LESIA)
- Evolution of **galaxies** and big structure (Combes, …)
- **Interstellar medium** (synergies with mm obs.)
- And much more….



Merci beaucoup
de votre attention

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