Radioastronomy in France (cm/dm)
Outline

- Radioastronomy in general
- The Nançay Radio Observatory
- The Nançay Radio Telescope (NRT)
- Few research’s topics around Paris’ Observatory
Radioastronomy?
Atmosphere’s transparency

- Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).
- Visible Light observable from Earth, with some atmospheric distortion.
- Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).
- Radio Waves observable from Earth.
- Long-wavelength Radio Waves blocked.
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What are we talking about?

See talk by Philippe Salomé for mm and P. Zarka for m/dam
A precious indicator: signature of Hydrogen

Parallels spins: higher-energy configuration

Opposite spins: lower-energy configuration

\[ f = 1420 \text{ MHz} \iff \lambda = 21 \text{ cm} \]
Some already great successes!
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S. Jocelyn Bell Burnell was born in northern Ireland in 1943. After receiving a B.S. degree in physics from Glasgow University, Scotland, she went to Cambridge University, England, where she earned her doctorate in radio astronomy in 1969. Since then she has done research in the newest branches of astronomy involving gamma-rays and x-rays. In 1976 she received the American Astronomical Society Award for her pulsar research. Currently she is a research scientist at the Mullard Space Science Laboratory of the University College London.
Some already great successes!

The Nobel Prize in Physics 1974

"For their pioneering research in radio astrophysics: Ryle for his observations and inventions, in particular of the aperture synthesis technique, and Hewish for his decisive role in the discovery of pulsars."
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The Nobel Prize in Physics 1978

"For their discovery of cosmic microwave background radiation."

Arno Allan Penzias  Robert Woodrow Wilson
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The Nobel Prize in Physics 1993

"for the discovery of a new type of pulsar, a discovery that has opened up new possibilities for the study of gravitation"

Russell A. Hulse
Joseph H. Taylor Jr.

Arno Allan Penzias
Robert Woodrow Wilson
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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« Nançay … le lieu du monde que je préférais »  Alain-Fournier
(Famous french writer)
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.

- 1 scientific on site (head of the observatory). Stronger connection with Orléans, Paris and Nantes.
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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

NDA
10-80 MHz

ORFEES
0.1-1.0 GHz

LOFAR
30-250 MHz

EMBRACE
0.5-1.5 GHz

NRH
150-450 MHz

CODALEMA
10-250 MHz

LBA
and now also  NenuFAR (10-85 MHz)

HBA
The Nançay decimetric radiotelescope (NRT)

See talk by I. Cognard
NRT = «big » radiotélescope

- 4\textsuperscript{th} 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, \sim 10^6 channels) +auto-correlator to be upgraded soon.
- \sim 5 FTE/an.
- Program committee (2400 h/sem): dominated by observations of pulsars.
Pulsars
An intermediate mass black hole at the center of the globular cluster NGC6624?

- 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 \[ G_{\text{NS-WD}} \neq (1 + \Delta) G_{\text{WD-WD}} \]

\[ |\Delta| < 1.8 \times 10^{-6} \text{ à 95\%}. \]

Contraintes sur l'espace \( \alpha_0 - \beta_0 \)
des théories tenseur scalaire

- rouge, bleu : contraintes SEP / pulsar système triple
- gris : limites à 2\( \sigma \) 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

PSR J0030+0451 (Raaijmakers et al 2020)
Pulsars as a tool for gravitational waves
EPTA: European consortium
IPTA: International consortium
NRT, pulsars, GW, supermassive binary black holes

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

The NRT provides 55% of EPTA data.

Une série de 5 papiers contenant les données NRT BON (bv=128MHz): Taylor et al, PhysRev L 115, 4, 041101, 201

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 présentées 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 répétiteur FRB121102 observées 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.
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 fine).

| 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, % |
|                 |         |                 | $I$ | $Q$ | $U$ |                  |
| 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 |
| 8.04.2020       | 1665   | −10.45          | 2.80 | 0 | −0.20 | 7 | −45 |
|                 | 1667   | −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
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