

BINGO: Bispectrum e FRBs

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BINGO Pipeline

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Tópicos

Motivação

BINGO

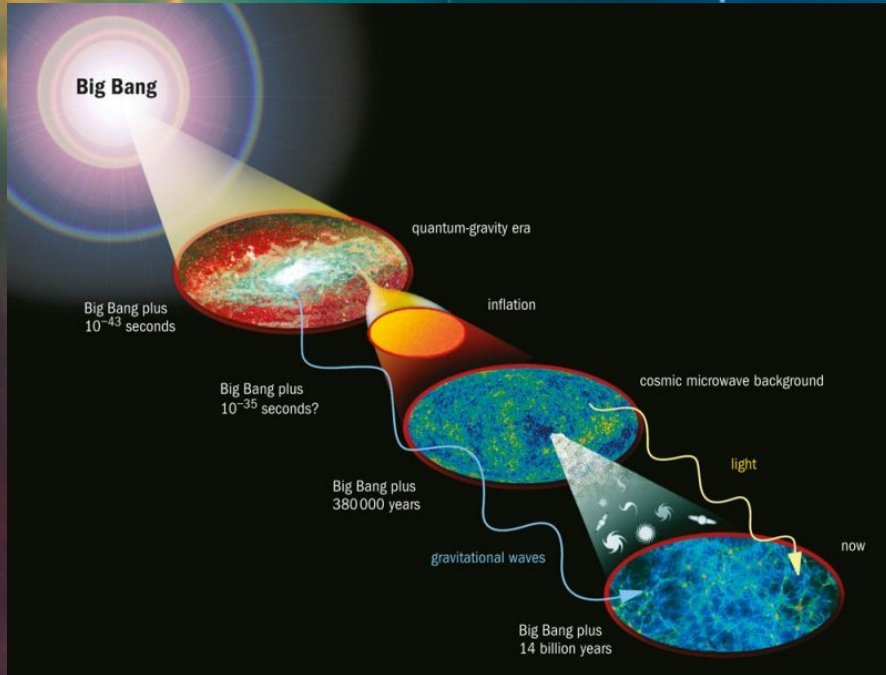
Pipeline

Biespectro

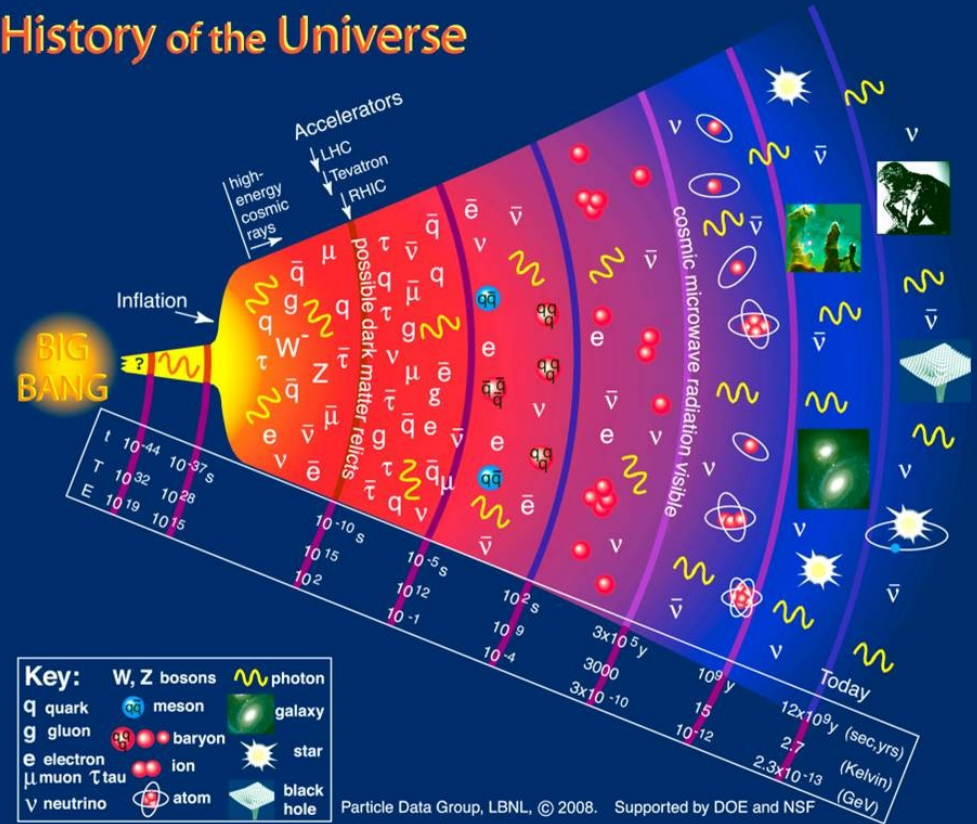
FRBs

Próximos passos

Motivação



History of the Universe

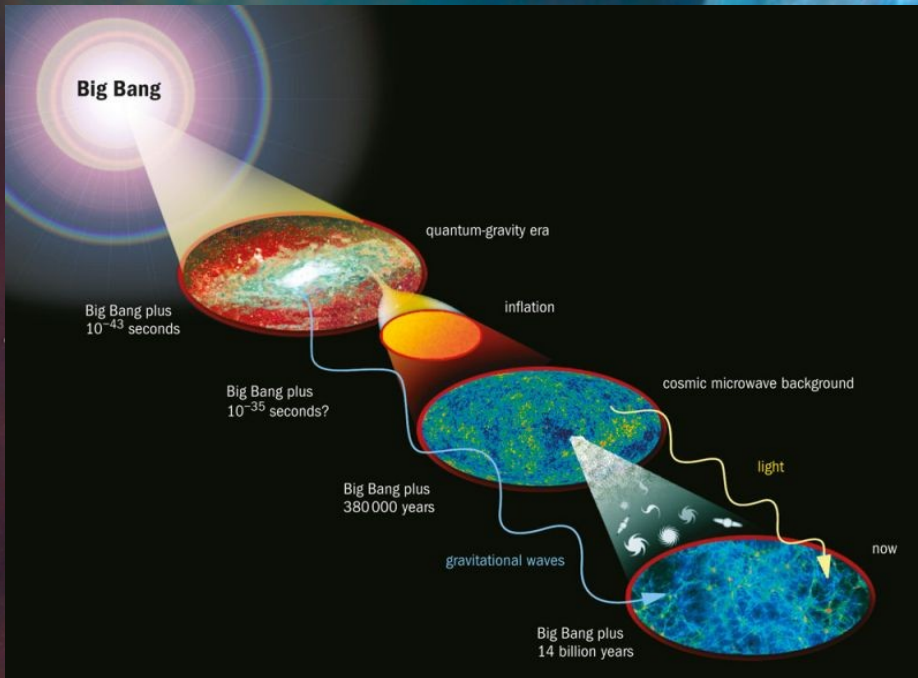


Motivação

Aproximadamente 370 mil anos depois do Big Bang, o universo esfriou o suficiente para permitir que prótons e elétrons se combinassem formando átomos de hidrogênio neutro (que é de longe o átomo mais comum no Universo).

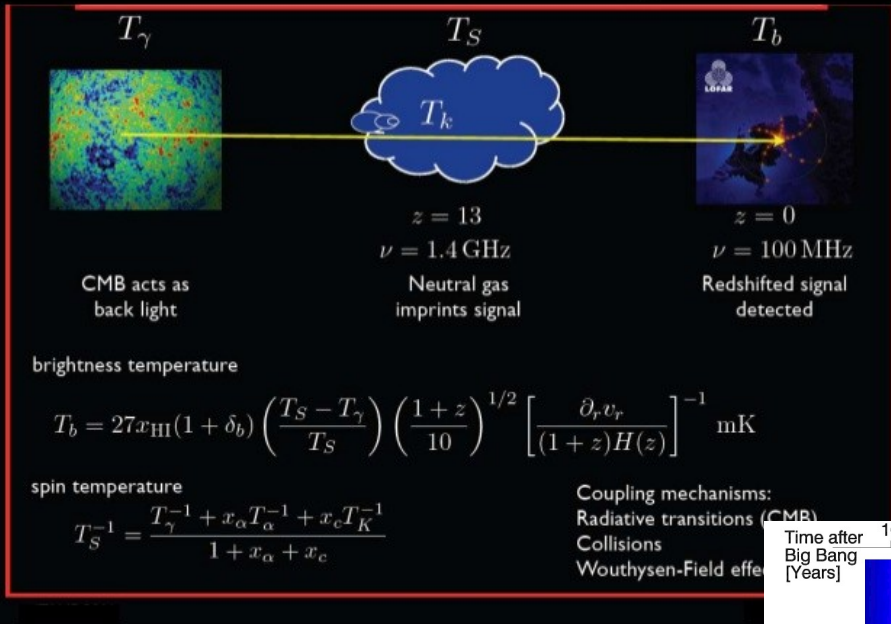
Antes disso, estas partículas constituíam um plasma quente no qual se propagavam ondas de pressão criadas no interior das condensações de matéria escura que começavam a se formar.

Essas ondas foram geradas pela interação dos átomos (ou matéria bariônica) com a radiação. A elas dá-se o nome de oscilações acústicas de bárions.

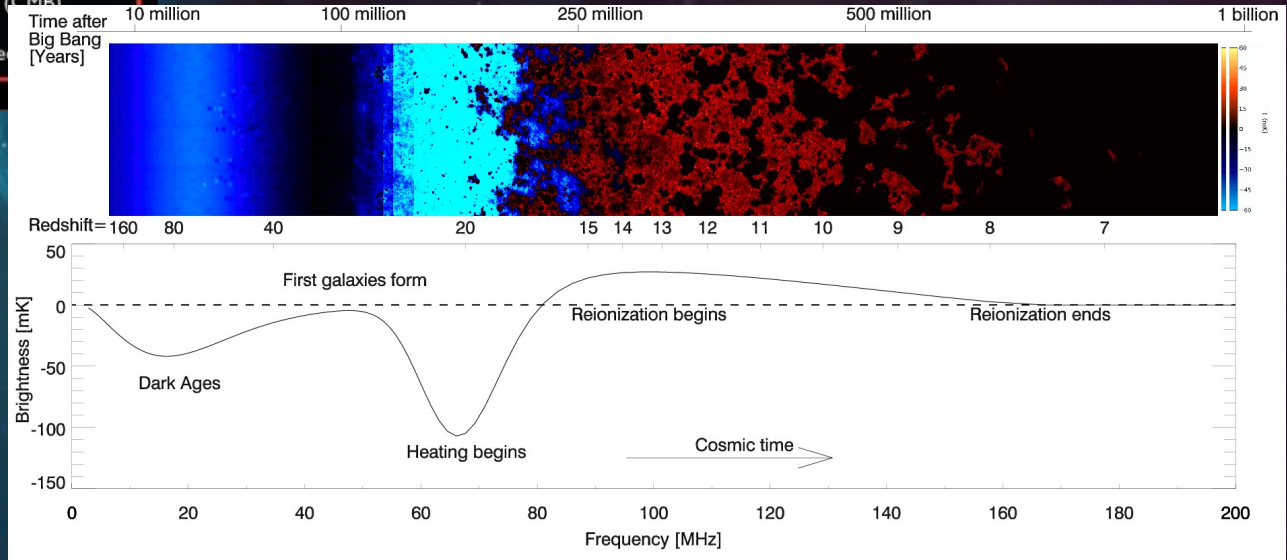


Motivação

21 cm line cosmology



<http://arxiv.org/abs/arXiv:1109.6012>

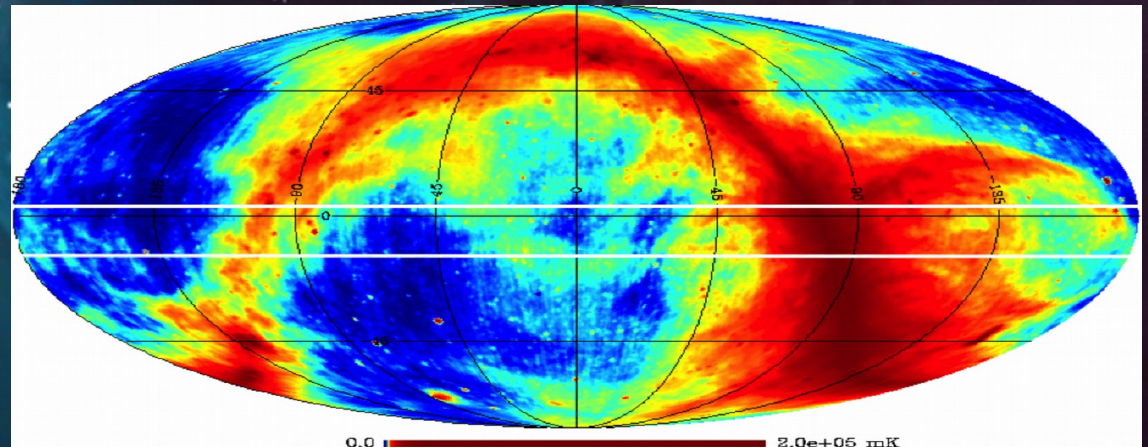
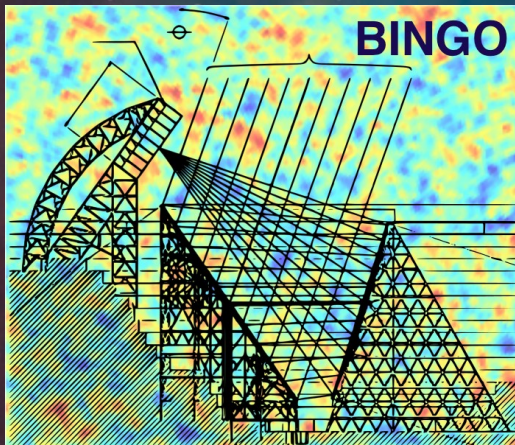


BINGO

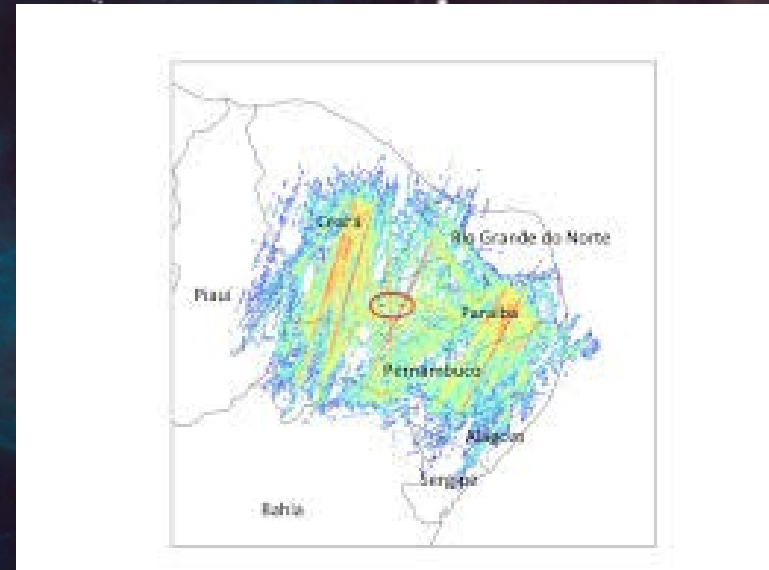
The BINGO (BAO from Integrated Neutral Gas Observations) telescope is a new instrument designed specifically for observing BAO signals, as well as other astrophysical phenomena. These observations will give us the first measurement of the BAO in the radio band and yield a fundamental contribution to the study of dark energy. Our goal is to be the first to detect BAO in the radio domain and to map the 3D distribution of hydrogen, the most abundant element of the Universe, with observations spanning at least two years.

Frequência de estudo – 960 MHz-1260 MHz (ondas de 21cm emitidas por HI dentro de um redshift $0.48 > z > 0.13$)

Resoluções – O BINGO terá resolução espectral de 1 MHz e angular de 40 arcmin.



BINGO

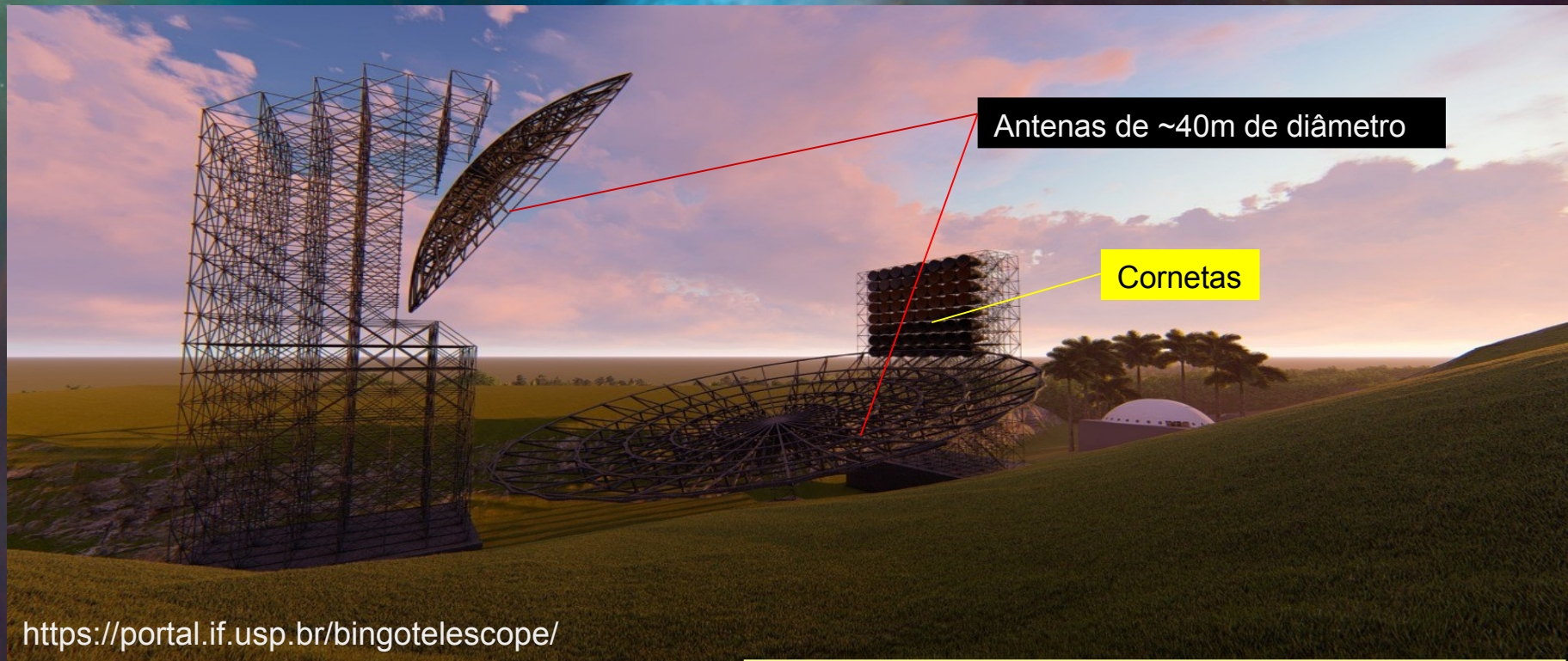


C. A. Wuensche et al. <https://arxiv.org/pdf/1803.01644.pdf>

ELL – Mamutes na Ciência – Lorena -Mar 2019

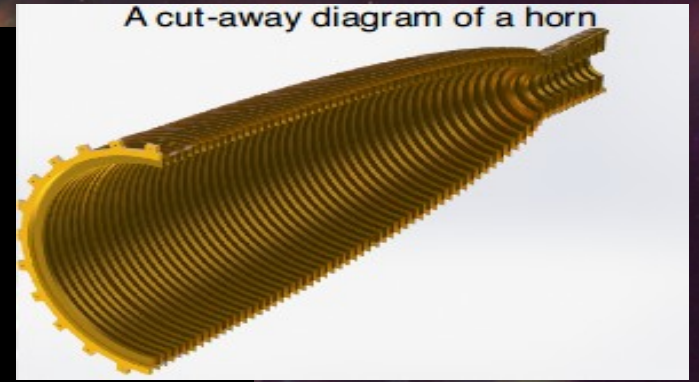
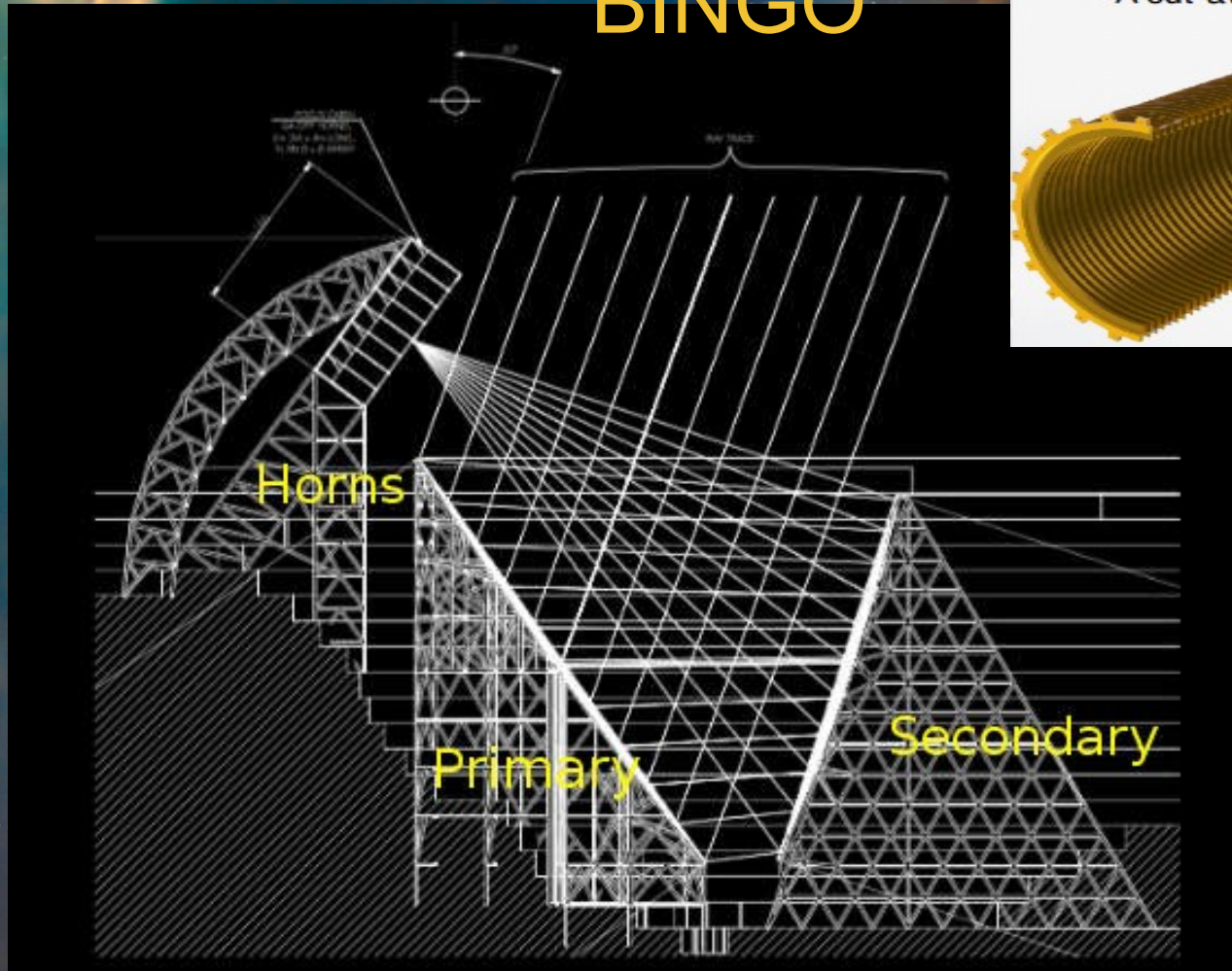


BINGO

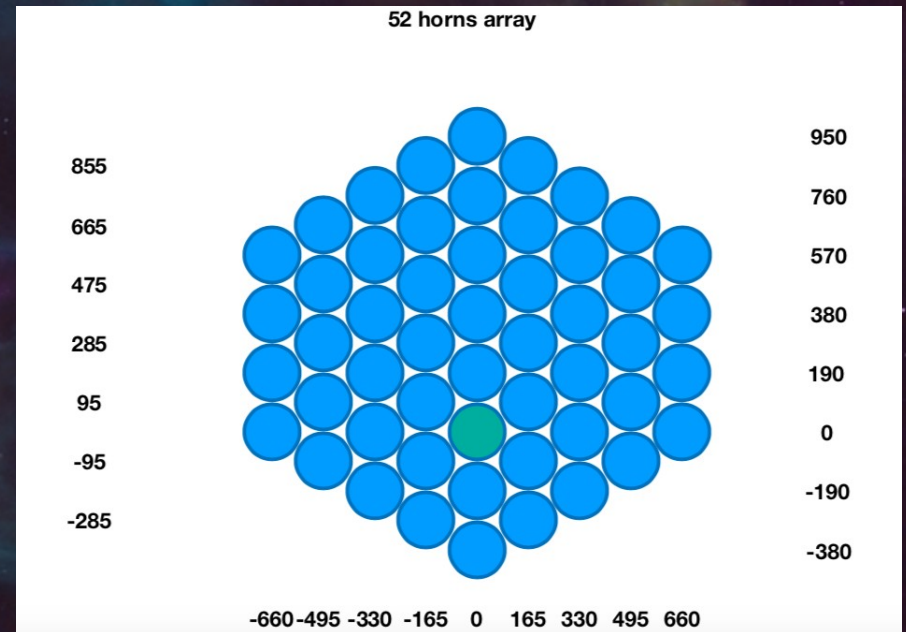


As ondas que chegam, refletirão pelo prato primário para o secundário e serão refletidos novamente, dessa vez para as cornetas.

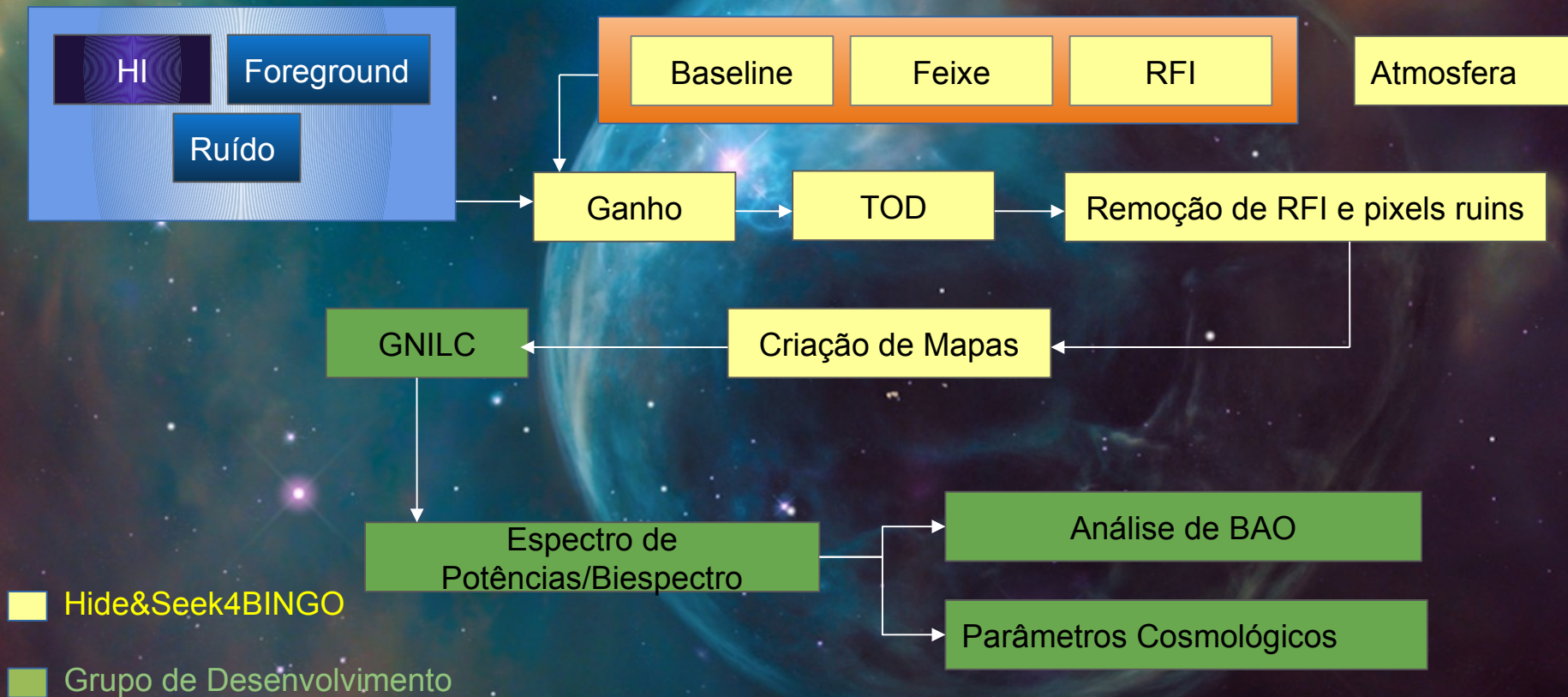
BINGO



BINGO



Pipeline BINGO



Pipeline BINGO

HIDE (HI Data Emulator) & SEEK (Signal Extraction and Emission Kartographer) is a set of two independent software packages that simulate and analyze single-dish radio survey data.

HIDE forward models the entire radio survey system chain:

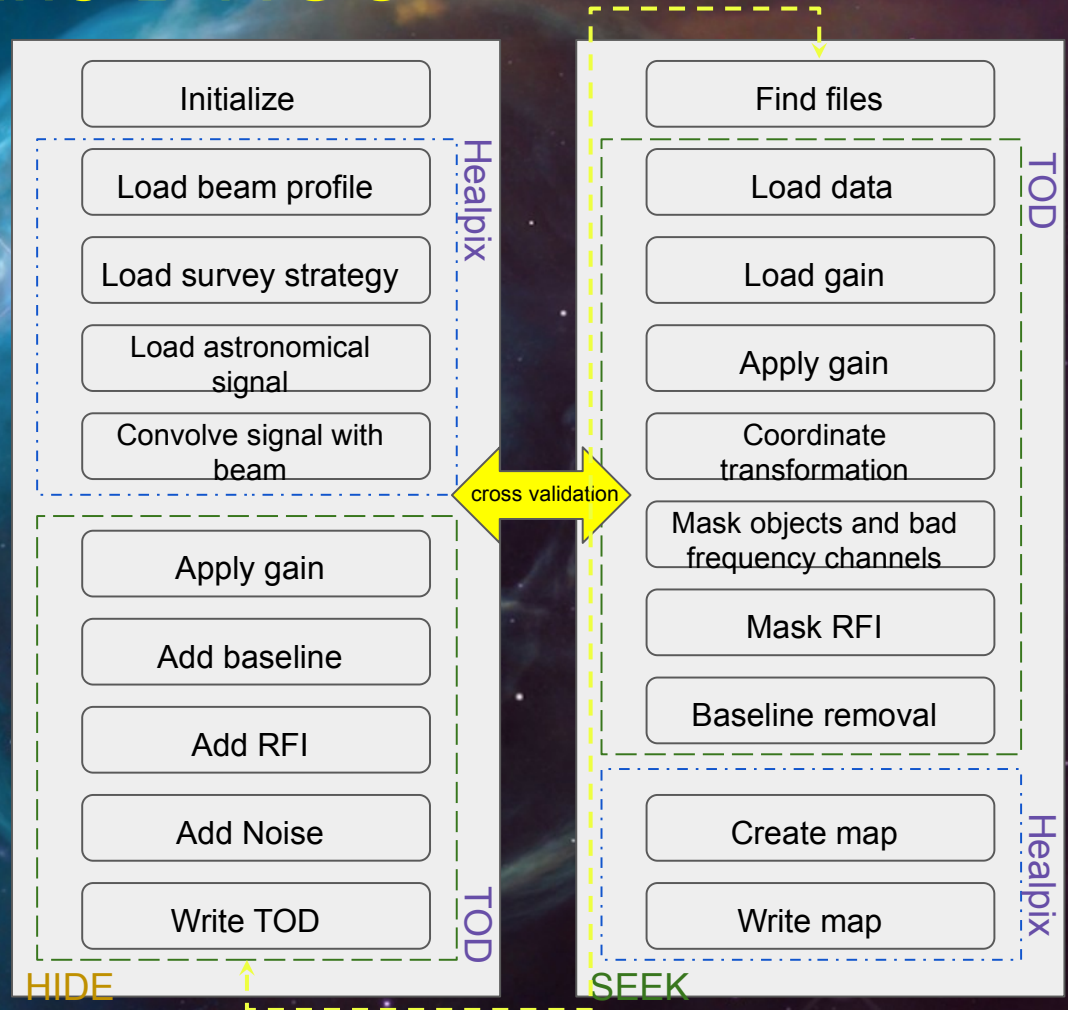
<https://github.com/cosmo-ethz/hide>

SEEK processes simulated (or observed) survey data

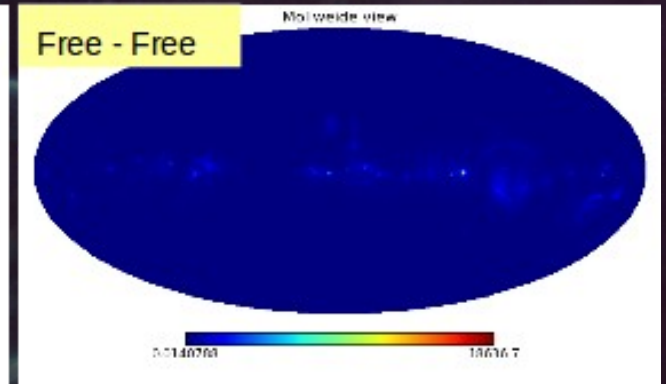
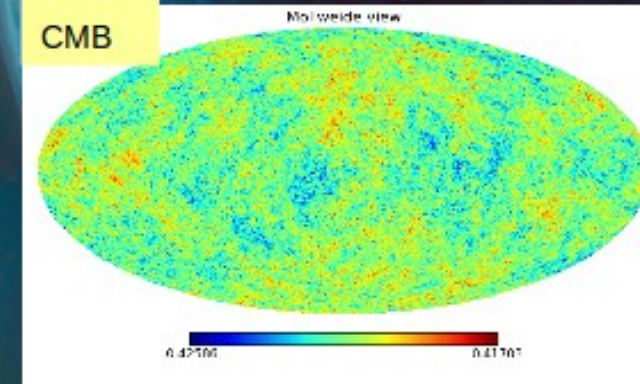
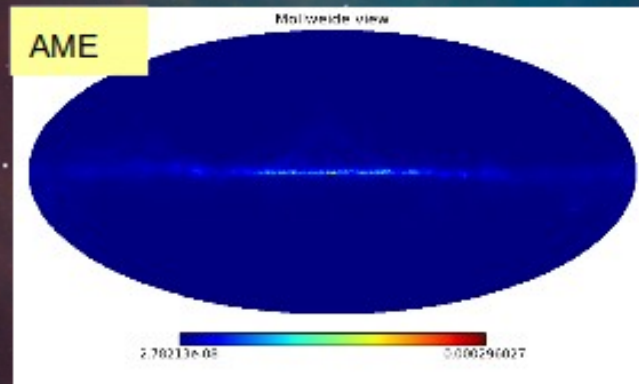
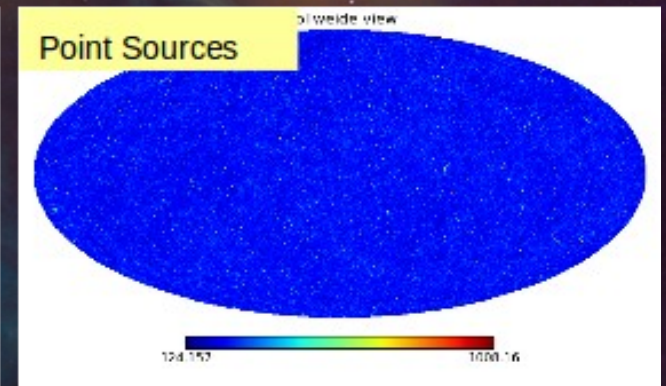
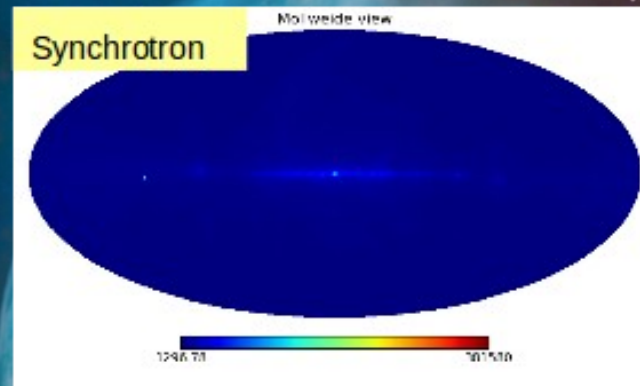
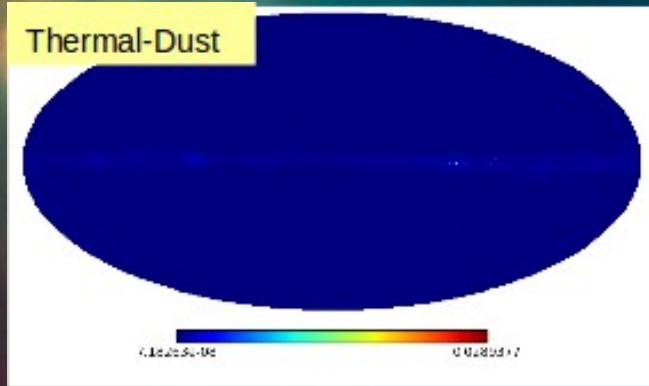
<https://github.com/cosmo-ethz/seek>



HIDE & SEEK: End-to-End Packages to Simulate and Process Radio Survey Data [Joel Akeret](#) et al, 2016



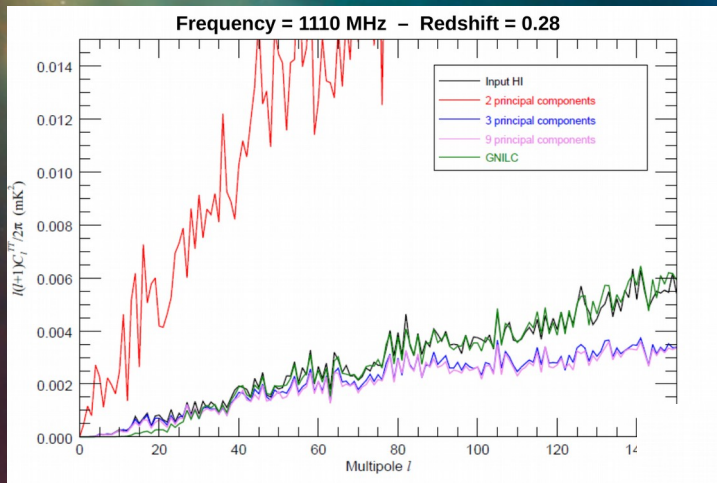
Pipeline HIDE & SEEK-4 BINGO - Module Foregrounds



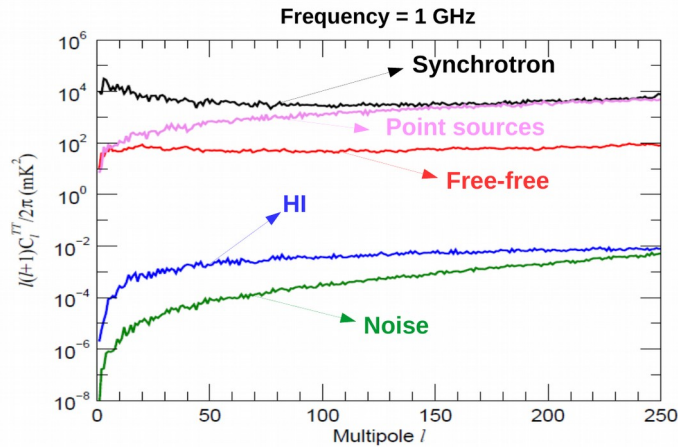
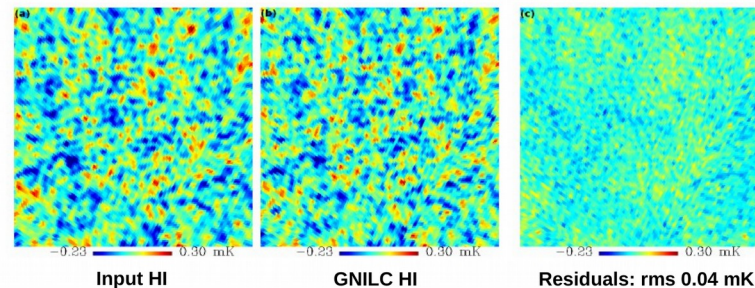
<https://arxiv.org/abs/1707.07647>

Pipeline HIDE & SEEK-4 BINGO - GNILC

GNILC é um módulo que faz a “limpeza” da contaminação atmosférica da observação.



GNILC: Results



Não Gaussianidade e a Função Biespectro

Degenerescência de modelos do universo primordial → estudo de funções espectrais com informações estatísticas adicionais ao espectro de potências do campo de flutuações de temperatura da radiação cósmica de fundo (RCF) → não-Gaussianidade (NG) das anisotropias da RCF.

Dois indicadores estatísticos → mapa da RCF são gerados mapas de “skewness” e “kurtosis”, S e K, respectivamente.

Nós estudamos os momentos da distribuição de probabilidades.

- Ordem 0 – Probabilidade total da distribuição.
- Ordem 1 – Valor médio da distribuição.
- Ordem 2 – Variância da distribuição. (Espectro de potências)
- Ordem 3 – Assimetria da distribuição. (Biespectro)

Não Gaussianidade e a Função Biespectro

$$M_\ell(\Omega) = \sum_{m=-\ell}^{+\ell} a_{\ell m} Y_{\ell m}(\Omega)$$

Onde $a_{\ell m}$ é chamado de coeficiente hamônico

- 1) Decompose the temperature anisotropy into multipoles

$$a_{\ell m} = \int d\hat{n} \frac{\Delta T}{T}(\hat{n}) Y_{\ell m}^*(\hat{n})$$

- 2) The temperature can also be represented in terms of the primordial gravitational potential perturbation and the radiation transfer function

$$\frac{\Delta T}{T}(\hat{n}) = \int \frac{d^3 k}{(2\pi)^3} \sum_{l=0}^{\infty} (-i)^l (2l+1) \Psi(k) \Delta_l(k) P_l(\hat{k} \cdot \hat{n})$$

- 3) We replace the Legendre polynomial with it's spherical harmonic expansion

$$P_l(\hat{k} \cdot \hat{n}) = \frac{4\pi}{2l+1} \sum_{m=-l}^l Y_{lm}(\hat{k}) Y_{lm}^*(\hat{n})$$

- 4) Substituting gives an expression for the multipoles in terms of the primordial gravitational potential perturbation and the radiation transfer function

$$a_{\ell m} = 4\pi (-i)^\ell \int \frac{d^3 k}{(2\pi)^3} \Psi(k) \Delta_\ell(k) Y_{\ell m}^*(\hat{k})$$

Não Gaussianidade e a Função Biespectro

5) The bispectrum is the three point correlator of the alm 's

$$\begin{aligned} B_{l_1 l_2 l_3}^{m_1 m_2 m_3} &= \langle a_{l_1 m_1} a_{l_2 m_2} a_{l_3 m_3} \rangle \\ &= (4\pi)^3 (-i)^{l_1 + l_2 + l_3} \int \frac{d^3 \mathbf{k}_1}{(2\pi)^3} \frac{d^3 \mathbf{k}_2}{(2\pi)^3} \frac{d^3 \mathbf{k}_3}{(2\pi)^3} \langle \Psi(\mathbf{k}_1) \Psi(\mathbf{k}_2) \Psi(\mathbf{k}_3) \rangle \\ &\quad \Delta_{l_1}(k_1) \Delta_{l_2}(k_2) \Delta_{l_3}(k_3) Y_{l_1 m_1}^*(\hat{\mathbf{k}}_1) Y_{l_2 m_2}^*(\hat{\mathbf{k}}_2) Y_{l_3 m_3}^*(\hat{\mathbf{k}}_3). \end{aligned}$$

6) The three point correlator of the primordial gravitational potential perturbation consists of a delta function and a shape function F which only depends on the magnitudes of the k 's

$$\langle \Psi(\mathbf{k}_1) \Psi(\mathbf{k}_2) \Psi(\mathbf{k}_3) \rangle = (2\pi)^3 F(k_1, k_2, k_3) \delta(\mathbf{k}_1 + \mathbf{k}_2 + \mathbf{k}_3)$$

7) We substitute and replace the delta function with its integral representation expanded in Bessel functions and spherical harmonics

$$\begin{aligned} \delta(\mathbf{k}) &= \frac{1}{(2\pi)^3} \int e^{i\mathbf{k}\cdot\mathbf{x}} d^3 x. \\ e^{i\mathbf{k}_1\cdot\mathbf{x}} &= 4\pi \sum_l i^l j_l(k_1 x) \sum_m Y_{lm}(\hat{\mathbf{k}}_1) Y_{lm}^*(\hat{\mathbf{x}}) \end{aligned}$$

8) The bispectrum then splits into a geometric factor given by the Gaunt integral times the reduced bispectrum

$$B_{l_1 l_2 l_3}^{m_1 m_2 m_3} = \mathcal{G}_{m_1 m_2 m_3}^{l_1 l_2 l_3} b_{l_1 l_2 l_3}$$

Não Gaussianidade e a Função Biespectro

8) The bispectrum then splits into a geometric factor given by the Gaunt integral times the reduced bispectrum

$$B_{l_1 l_2 l_3}^{m_1 m_2 m_3} = \mathcal{G}_{m_1 m_2 m_3}^{l_1 l_2 l_3} b_{l_1 l_2 l_3}$$

$$\mathcal{G}_{m_1 m_2 m_3}^{l_1 l_2 l_3} = \int d\Omega Y_{l_1 m_1} Y_{l_2 m_2} Y_{l_3 m_3} = \sqrt{\frac{(2l_1 + 1)(2l_2 + 1)(2l_3 + 1)}{4\pi}} \begin{pmatrix} l_1 & l_2 & l_3 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} l_1 & l_2 & l_3 \\ m_1 & m_2 & m_3 \end{pmatrix}$$

$$b_{l_1 l_2 l_3} = \left(\frac{2}{\pi}\right)^3 \int dx dk_1 dk_2 dk_3 (x k_1 k_2 k_3)^2 F(k_1, k_2, k_3) \Delta_{l_1}(k_1) \Delta_{l_2}(k_2) \Delta_{l_3}(k_3) j_{l_1}(k_1 x) j_{l_2}(k_2 x) j_{l_3}(k_3 x).$$

Binned bispectrum estimator

Binned, or coarse-grained, pseudo-bispectrum \rightarrow full-sky spherical harmonic transforms \rightarrow masked sky \rightarrow recovered alm coefficients are a convolution of the real CMB multipole coefficients with the multipole coefficients of the mask.



<https://arxiv.org/abs/1509.08107>

Non-Gaussianity - Bispectrum

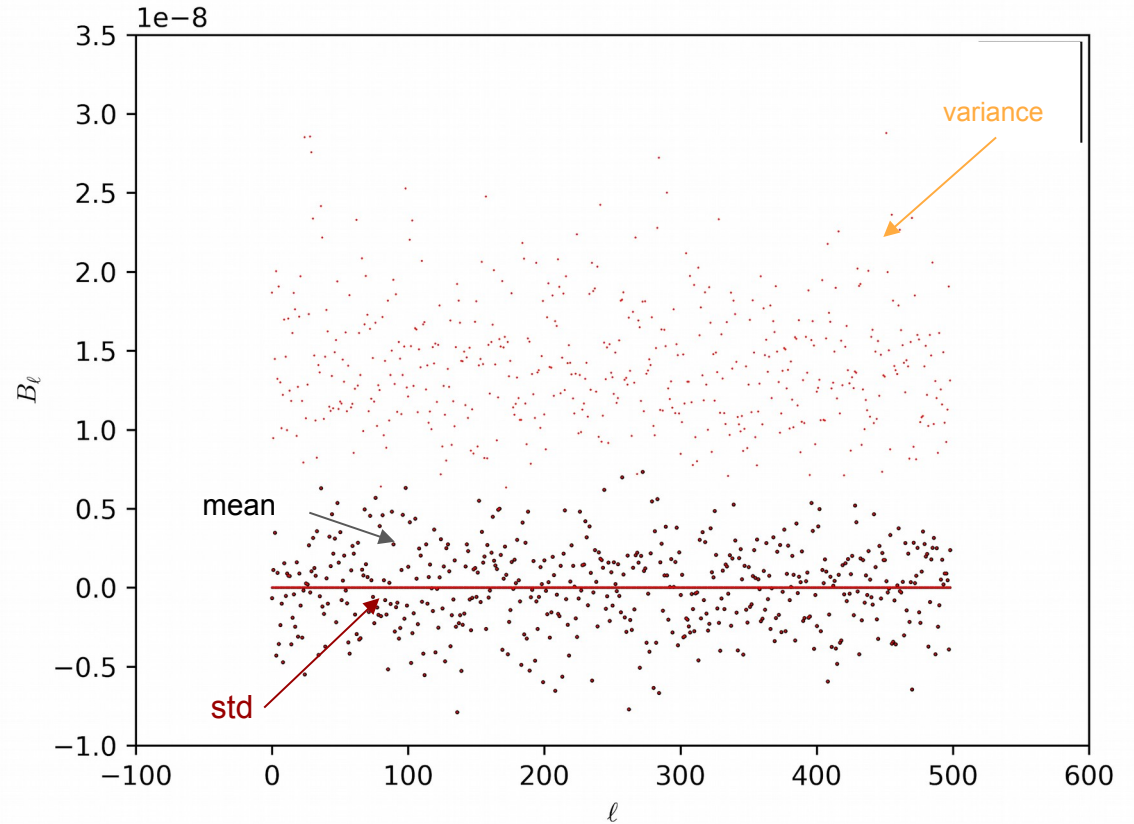
Goals → Not only non-Gaussianity in CMB (as independent module) but, for BINGO case - non-gaussianity of Galaxies (21 cm)

Bispectrum module → by Test Driven Design → refactorate and modulate the code

500 thermal noise maps

$l_{\max} = 30$

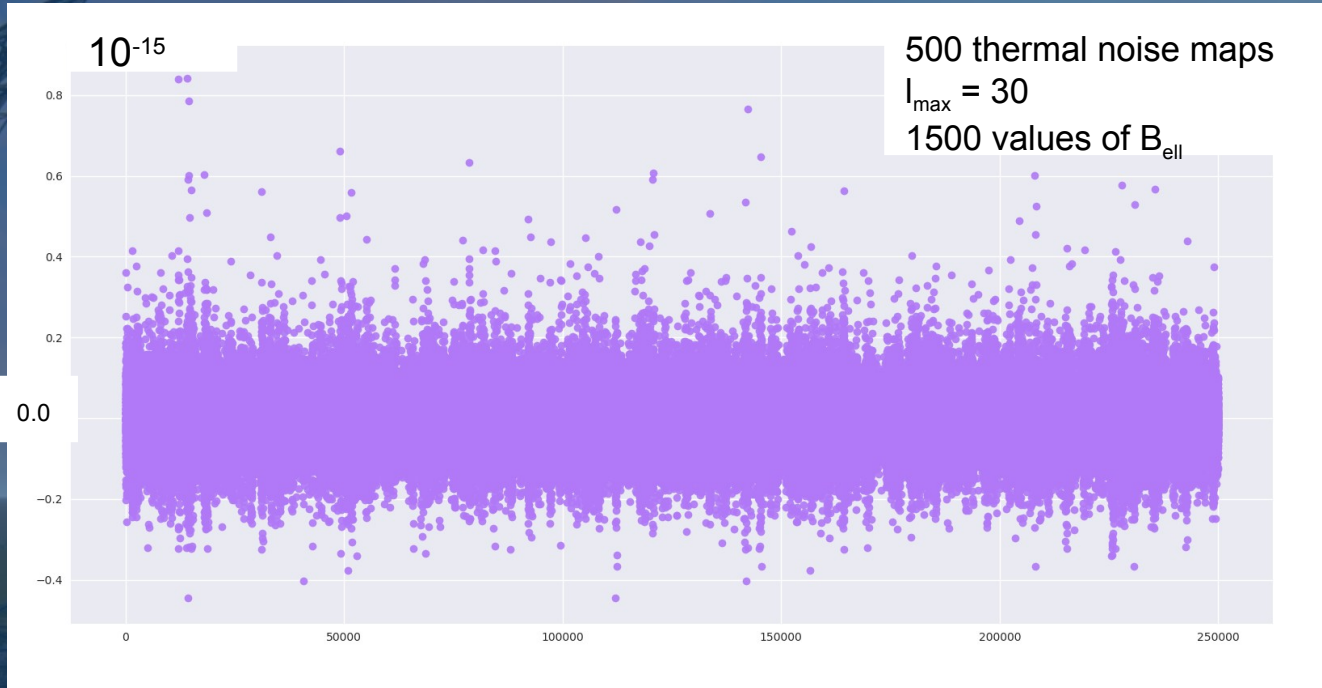
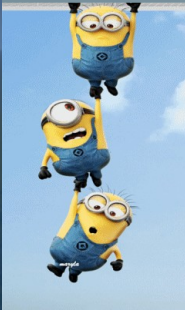
500 values → $B_{\ell\ell}$ mean, std and variance



Non-Gaussianity - Bispectrum

Capacity of all the available cores in the machine → all the calculations simultaneously and we use text files to save the data of each iteration, then another module joined the pieces and can quickly calculate average and standard deviation in addition to plot the graphs

60 hours to approximately 8 hours



Fast Radio Bursts(FRBs)

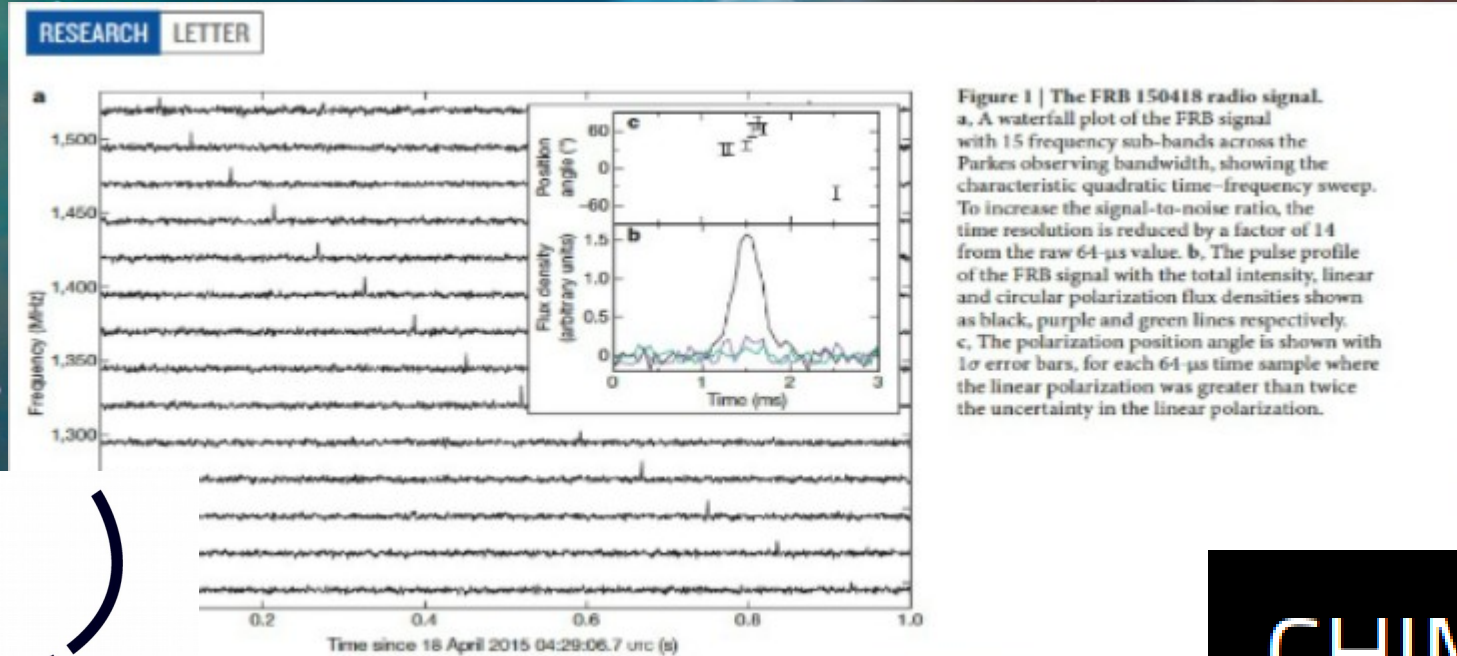


Figure 1 | The FRB 150418 radio signal. **a**, A waterfall plot of the FRB signal with 15 frequency sub-bands across the Parkes observing bandwidth, showing the characteristic quadratic time-frequency sweep. To increase the signal-to-noise ratio, the time resolution is reduced by a factor of 14 from the raw 64- μ s value. **b**, The pulse profile of the FRB signal with the total intensity, linear and circular polarization flux densities shown as black, purple and green lines respectively. **c**, The polarization position angle is shown with 1σ error bars, for each 64- μ s time sample where the linear polarization was greater than twice the uncertainty in the linear polarization.


BINGO

SUL

NORTE

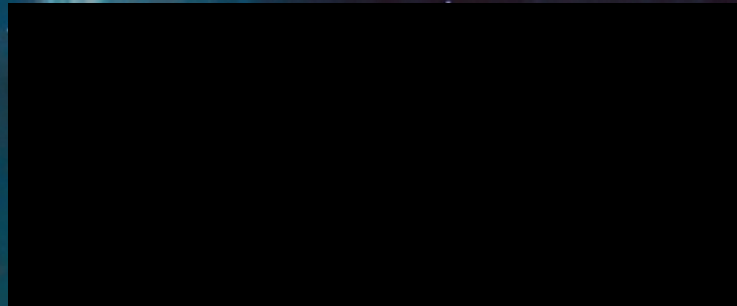
CHIME

arxiv 1811.00605v1

Características das FRBs

Energética: 1 Jy-ms para 1 GHz a uma distância de 1 Gpc é 10^{30} J.

Coerência: A alta temperatura do brilho, em uma FRB, nos dá a informação de que os elétrons no evento não se movem de forma aleatória.

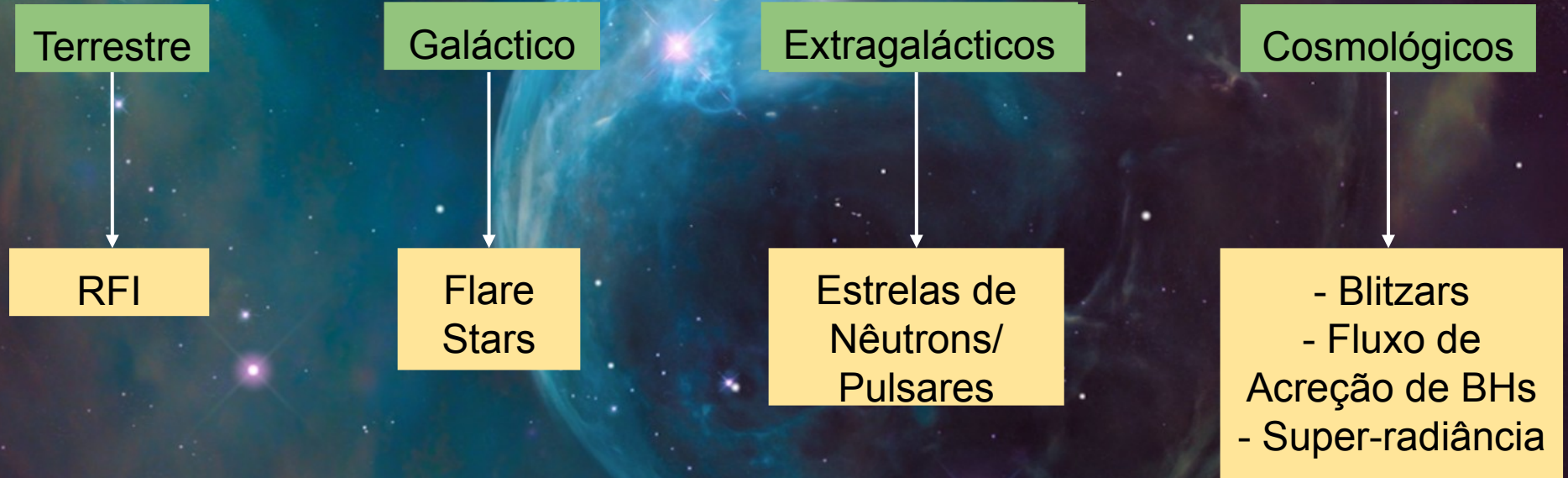


<https://chime-experiment.ca/>

FRBs são altamente polarizados.

arxiv 1811.00605v1

Que modelos usar para estudar FRBs?



Modelos geradores das FRBs:

Terrestre

RFI – Interferência de Radiofrequência: Perytons mostram grande similaridade com a ideia das FRBs.

Galáctica

Flare Stars: Muitas estrelas mostram uma variação de curto período de ondas de rádio, as fazendo serem potencialmente FRBs.

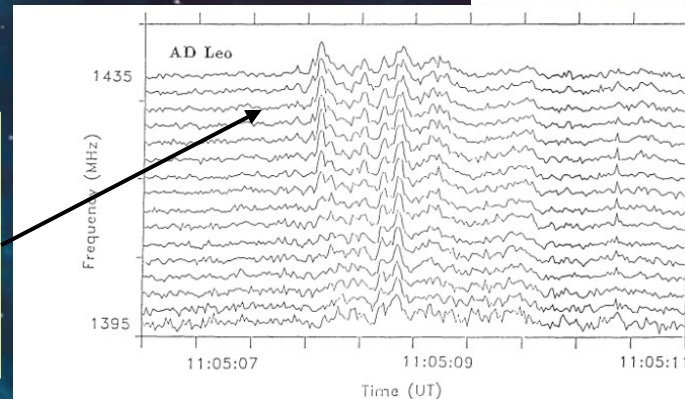
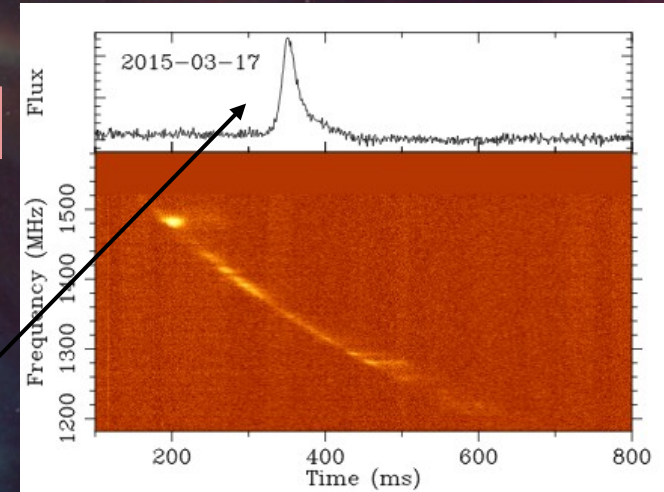


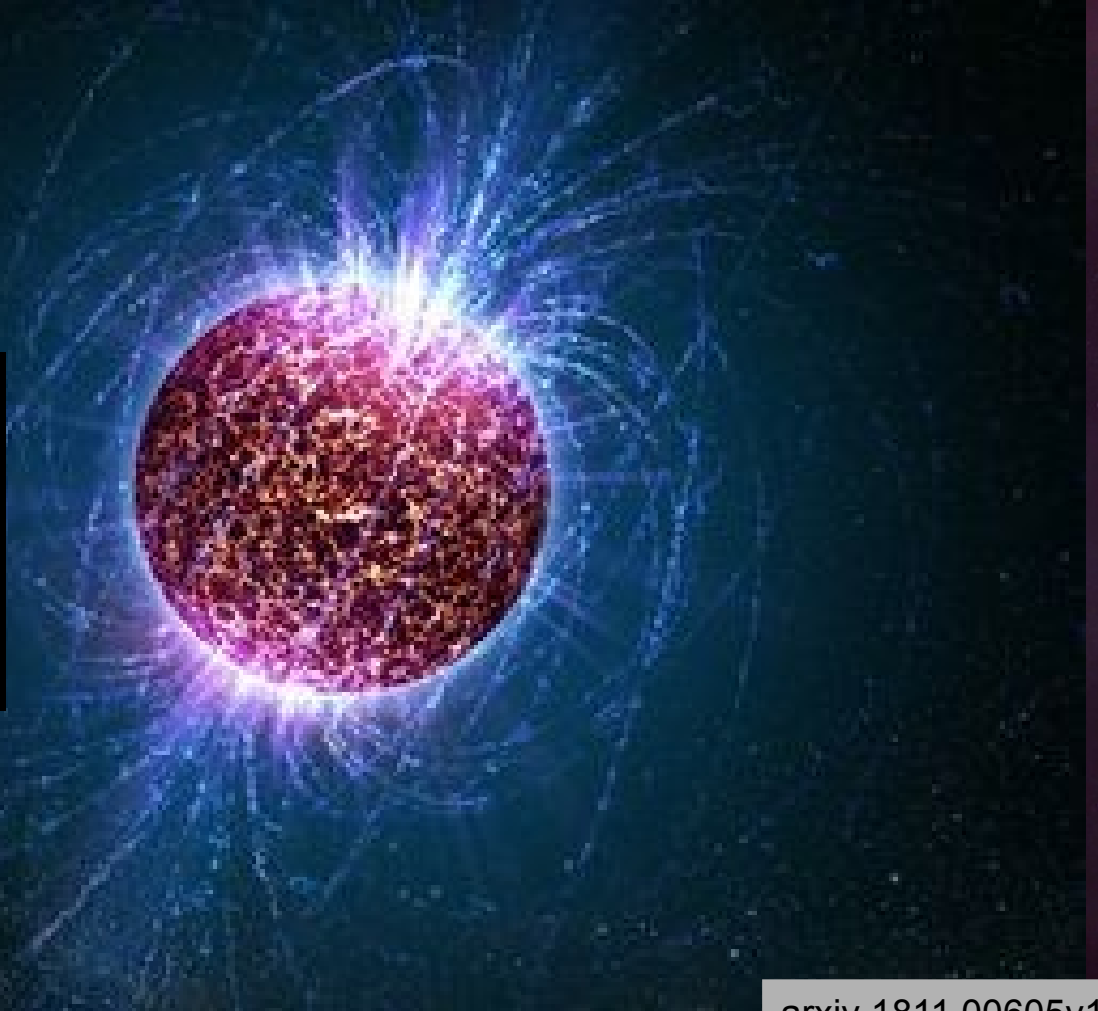
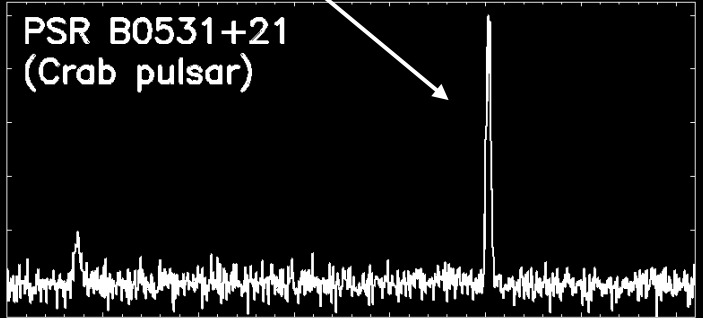
Fig. 6. Spectrum of ≈ 4 s of a 1.4 GHz burst on AD Leo as observed by the Arecibo 305 m telescope, 1987 November 4. Each of the 16 traces represents a bandwidth of 2.5 MHz. Note the presence of spikes and narrow-band features (from Bastian *et al.*, 1990).

rytons generated during the test m^{-3} pc. RFI monitor data at the Figure 3

Extragaláctico

Estrelas de neutrons/pulsares:

PSR B0531+21
(Crab pulsar)



arxiv 1811.00605v1

Cosmológicos

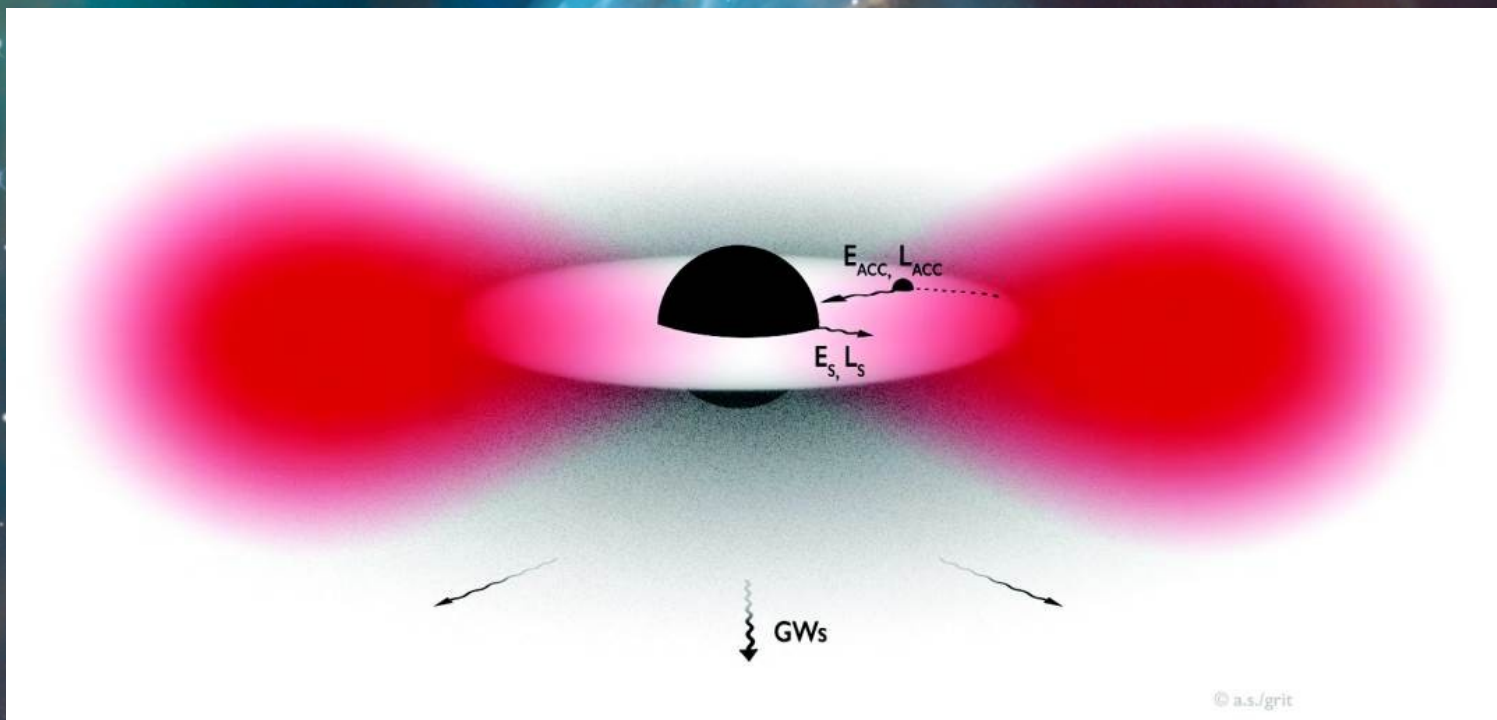
Blitzars: Buracos negros formados pelo colapso de estrelas de neutrons.

Fluxo de acreção de buracos negros.



arxiv 1811.00605v1

Super-radiância.



Próximos passos

- Aplicação do módulo de biespectro para mapas com não-gaussianidade.
- Melhora do módulo de biespectro e ampliação para todos os tipos de análise.
- Estimar o f_{NL} .
- Escolha de um modelo de FRB a ser estudado com maior prioridade.
- Modos de aplicar o modelo que for escolhido no BINGO.

Obrigado !

Dúvidas?

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<https://portal.if.usp.br/bingotelescope/>