

# COSMO BIT

## Towards Simultaneous Global Fits of Particle Physics and Cosmology

Janina Renk  
Oskar-Klein Centre, Stockholm Universtiy

*on behalf of the GAMBIT collaboration*



02.09.2019

Janina Renk

# Inflation → primordial power spectrum



**Inflation** → primordial power spectrum

**Big Bang Nucleosynthesis** → light element abundances



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**Decoupling** → CMB

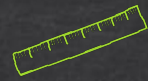


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**Structure formation**



→ BAO scale



→ gravitational lensing

→ recession velocities of SNe Ia



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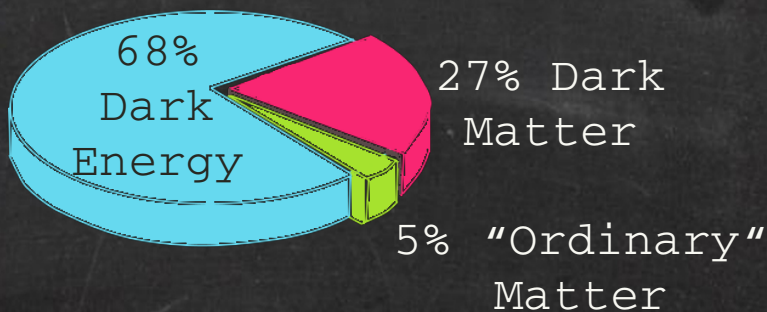
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Standard Model  
of Cosmology

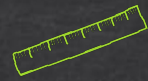


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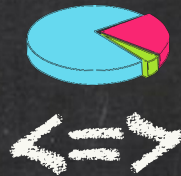
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Dark Matter?

Dark Energy?

"Ordinary"  
Matter?



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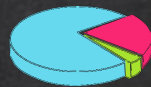
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**Galaxies**

→ indirect detection

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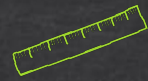
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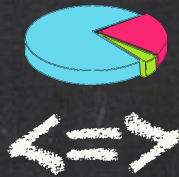
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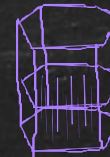
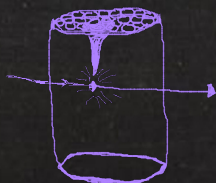
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→ **direct detection**

→ **particle collider**

→ **neutrino experiments**

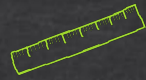


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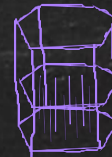
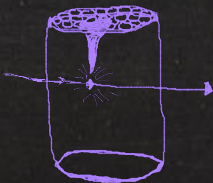


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- Tool(s) to compute cosmological predictions/observables
- Tool(s) to compute cosmological likelihoods
- Tool(s) to compute DM relic density abundance & cross-sections
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- Keep track of all models & model-dependent assumptions
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Does something like this exist already?

⇒ YES, GAMBIT!!

# GAMBIT: The Global And Modular BSM Inference Tool

[gambit.hepforge.org](http://gambit.hepforge.org)

EPJC 77 (2017) 784

arXiv:1705.07908

- Extensive model database – not just SUSY
- Extensive observable/data libraries
- Many statistical and scanning options (Bayesian & frequentist)
- *Fast* LHC likelihood calculator
- Massively parallel
- Fully open-source
- Fast definition of new datasets and theories
- Plug and play scanning, physics and likelihood packages



## Members of:

ATLAS, Belle-II, CLiC, CMS, CTA, *Fermi*-LAT, DARWIN, IceCube, LHCb, SHiP, XENON

## Authors of:

DarkSUSY, DDCalc, Diver, FlexibleSUSY, gamlike, GM2Calc, IsaTols, nulike, PolyChord, Rivet, SoftSUSY, SuperISO, SUSY-AI, WIMPSim

## Recent collaborators:

Peter Athron, Csaba Balázs, Ankit Beniwal, Sanjay Bloor, Torsten Bringmann, Andy Buckley, José Eliel Camargo-Molina, Marcin Chrzęszcz, Jonathan Cornell, Matthias Danninger, Joakim Edsjö, Ben Farmer, Andrew Fowlie, Tomás E. Gonzalo, Will Handley, Sebastian Hoof, Selim Hotinli, Felix Kahlhoefer, Anders Kvellestad, Julia Harz, Paul Jackson, Farvah Mahmoudi, Greg Martinez, Are Raklev, Janina Renk, Chris Rogan, Roberto Ruiz de Austri, Pat Scott, Patrick Stöcker, Aaron Vincent, Christoph Weniger, Martin White, Yang Zhang

**40+ participants in 11 experiments and 14 major theory codes**



# FACT SHEET

*all links work!*  
(except this one ↑)

## CosmoBit:

Inflation:

MultiModeCode ([Price+, '14](#))

BBN:

AlterBBN ([Arbey, '18](#))

Boltzman solver:

CLASS ([Blas+, '11](#))

+ [exo\\_class \(Stöcker+, '18\)](#) [[+ hi\\_class \(Bellini+, '19\)](#)]

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COMING SOON!

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Relic abundance: `WIMPs` [`DarkSUSY` ([Bringmann+, `18](#)) `micrOMEGAS` ([Belanger+, `18](#))],  
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## NeutrinoBit:

Oscillations: NuFit ([Esteban+, '18](#))  
Direct detection: DELPHI, ATLAS, CMS, NuTeV, ..  
Indirect searches: Lepton Flav Violation&Universality, Nu-less double  $\beta$  decay

## SpecBit:

Phase Transitions: Vevacious++ ([Camargo-Molina+, '13](#))

## ScannerBit:

Scanners: GreAT ([Putze+, '14](#)), MultiNest ([Feroz+, '13](#)), Polychord ([Handley+, '15](#)),  
T-Walk ([Christen+, '10](#)), Diver + PostProcessor ([Martinez+, '17](#))

# EXAMPLE: ALPs

## *keV-scale Axion-Like Particles*

→ Mass range  $1 \text{ keV} \lesssim m_a \lesssim 1 \text{ MeV}$

→ Interactions with SM via effective coupling to photons

$$\mathcal{L} = \frac{g_{a\gamma\gamma}}{4} a F^{\mu\nu} \tilde{F}_{\mu\nu}$$

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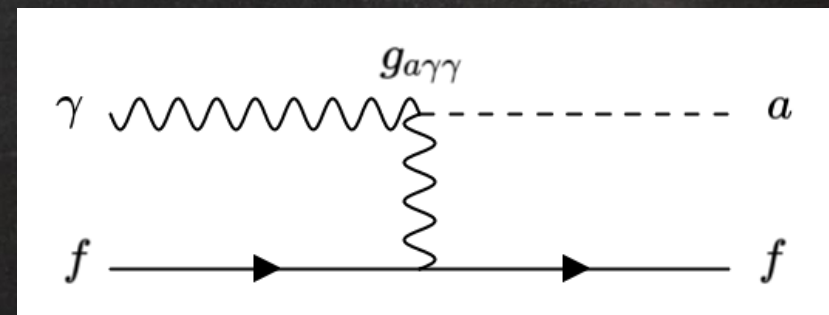
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→ Abundance given by  $Y_a = \frac{n_a}{s} \propto g_{a\gamma\gamma}^2 M_{\text{Pl}} (T_{\text{R}} - m_e)$

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→ ALP is subcomponent of DM

→ Agnostic about origin of  $n_a$

→ Model parameters:

$$\left\{ m_a, g_{a\gamma\gamma}, \xi = \frac{n_a m_a}{\rho_{\text{cdm}}} \right\}$$

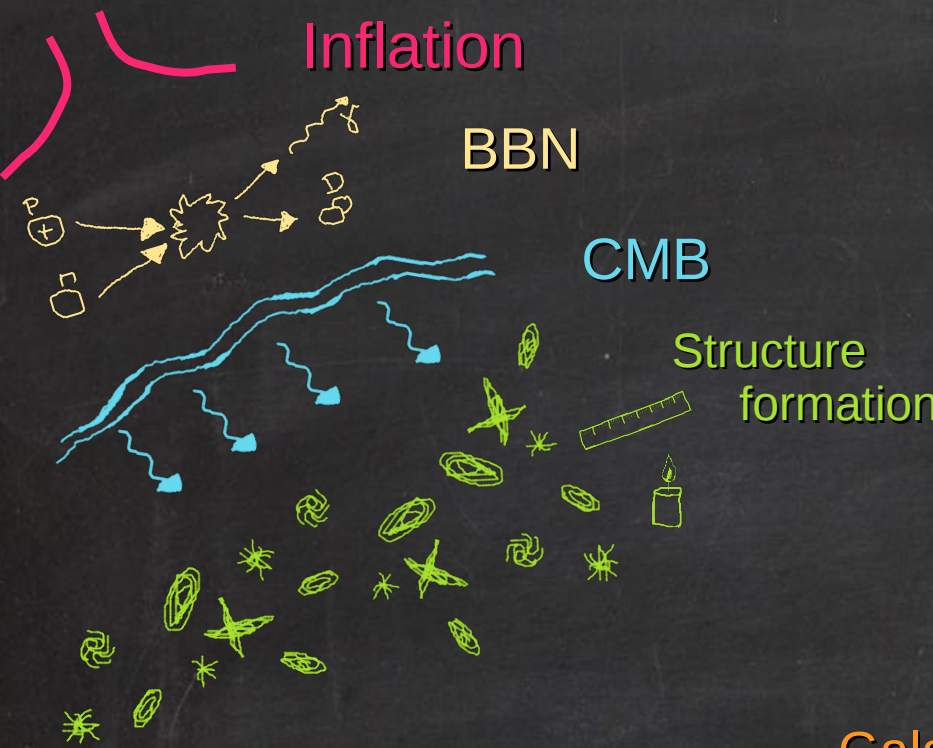
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BBN

CMB

Structure formation

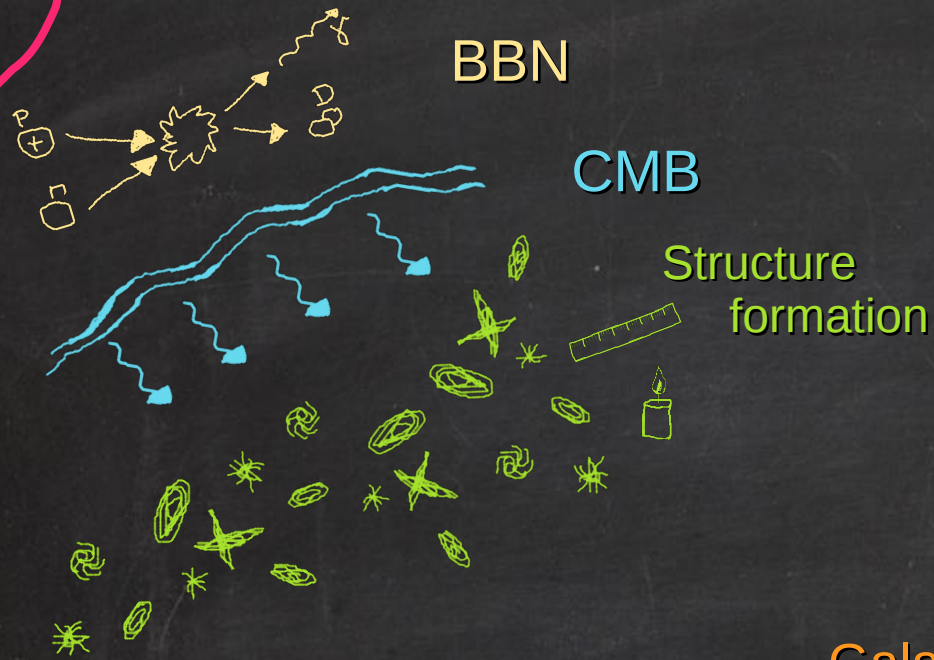
Galaxies & stars



Inflation

Observable signatures

ALP decay time

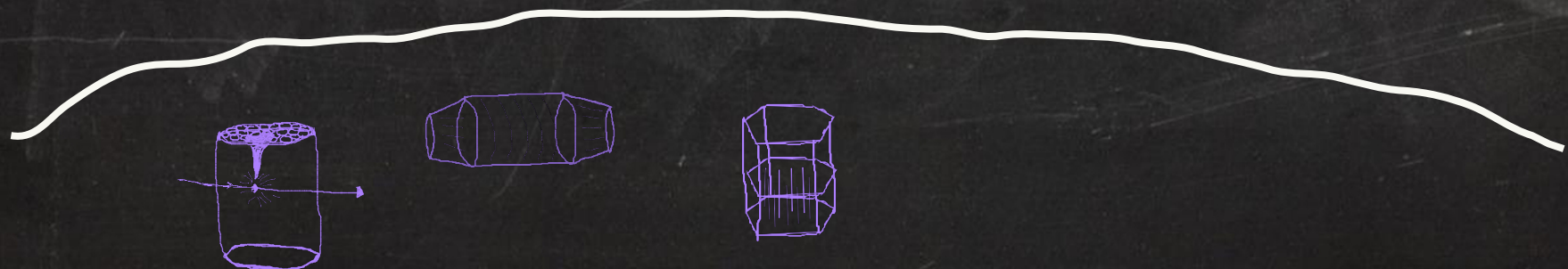


- Heat up  $\gamma$  w.r.t.  $\nu \rightarrow \Delta N_{\text{eff}}$
- Spectral distortions

$$t < t_{\text{rec}}$$



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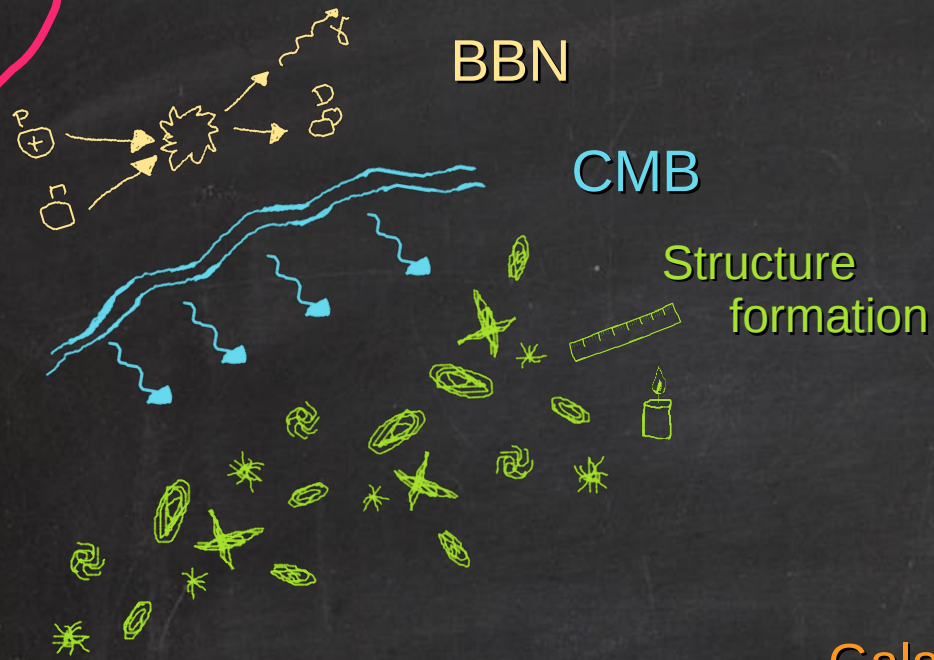




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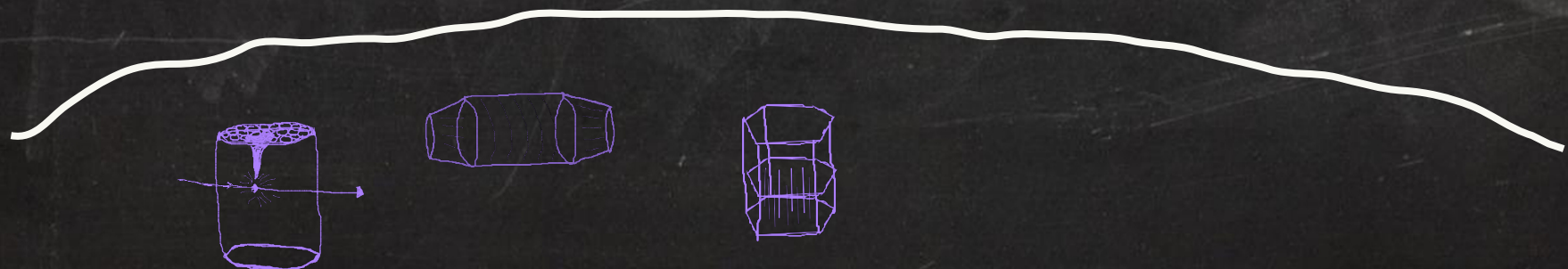
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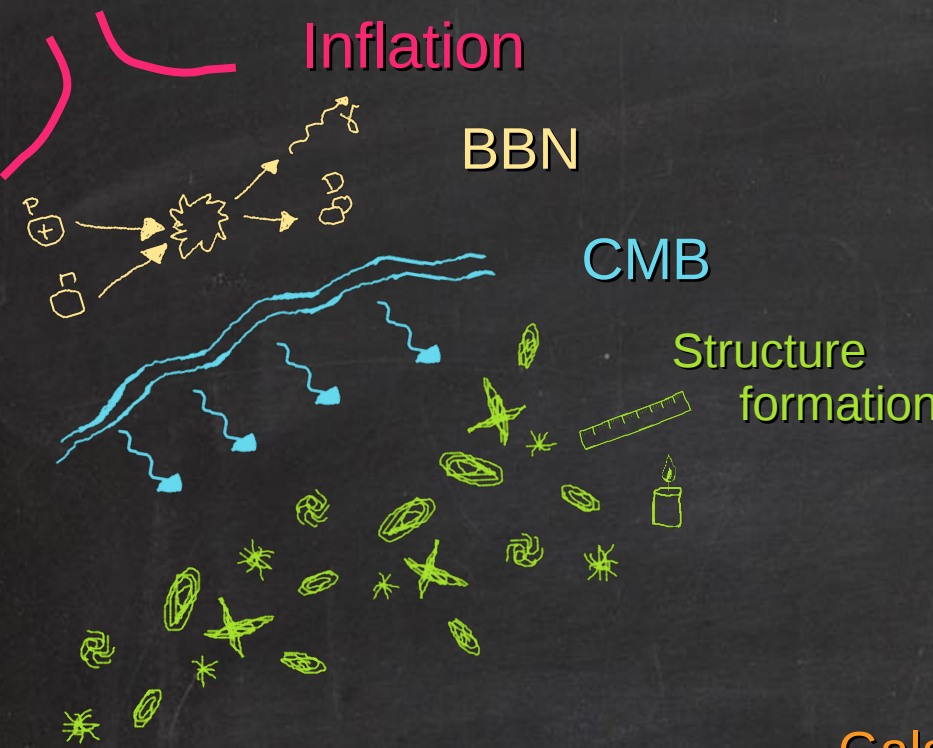
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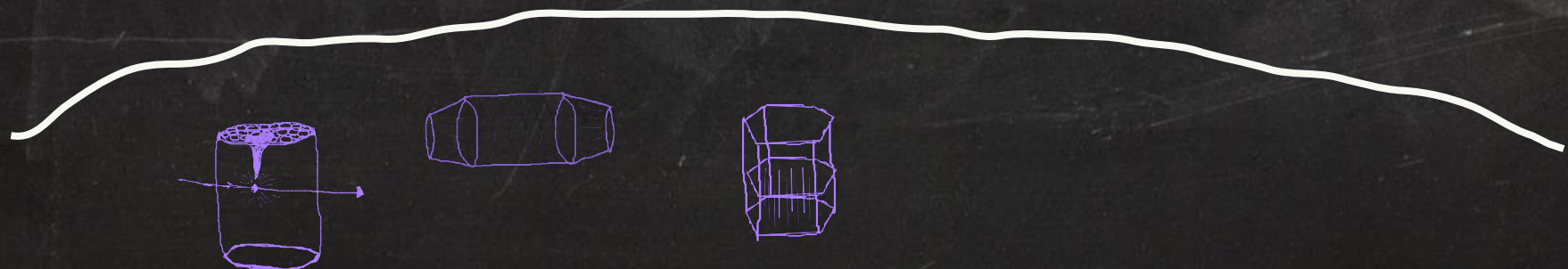
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## Galaxies & stars

- X- and  $\gamma$ -rays
- Stellar evolution  $\rightarrow$  horizontal branch
- ALP burst of type II SNe (SN1987A)

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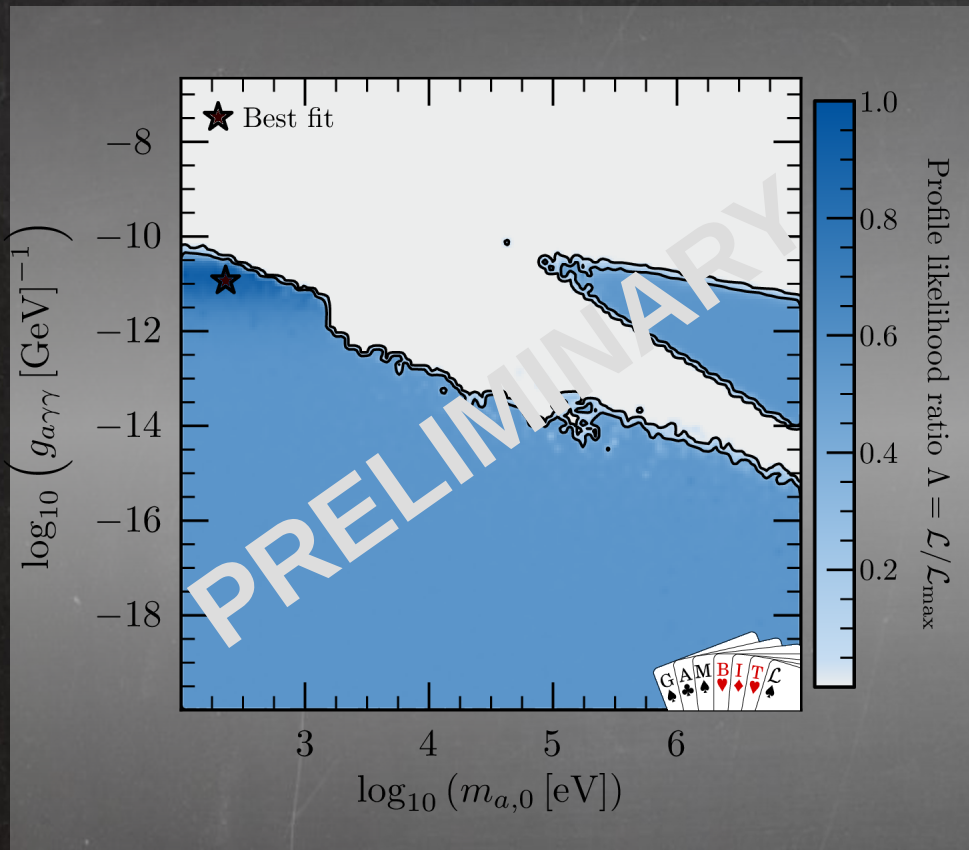
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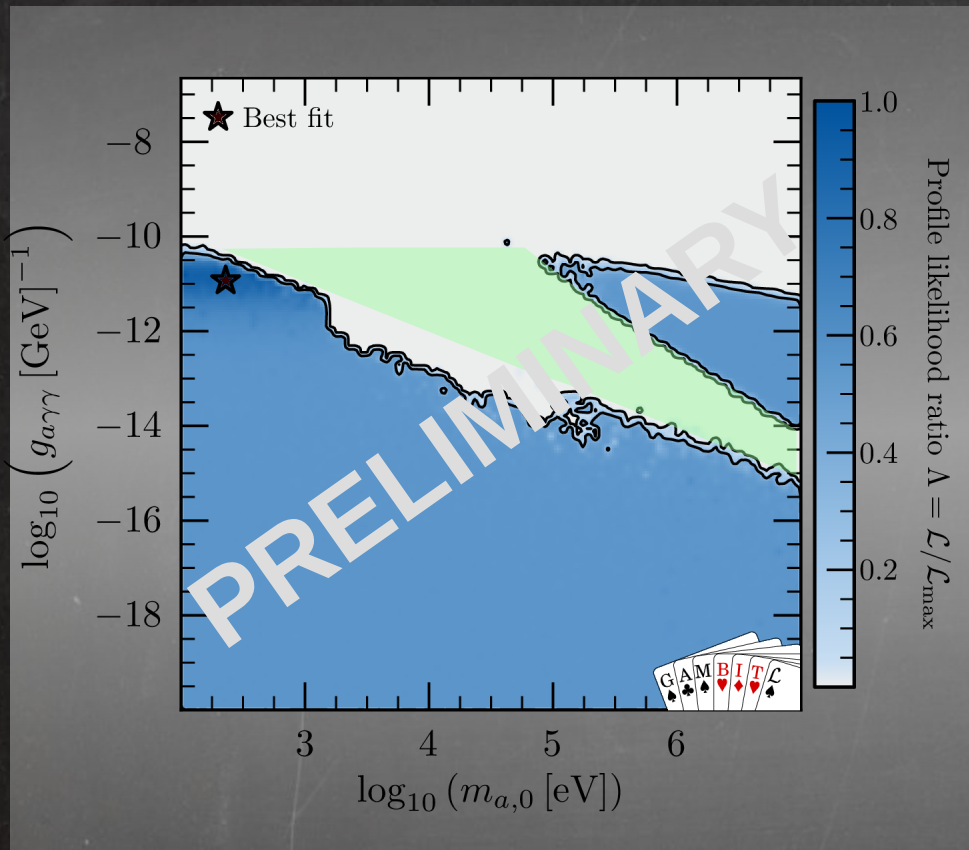
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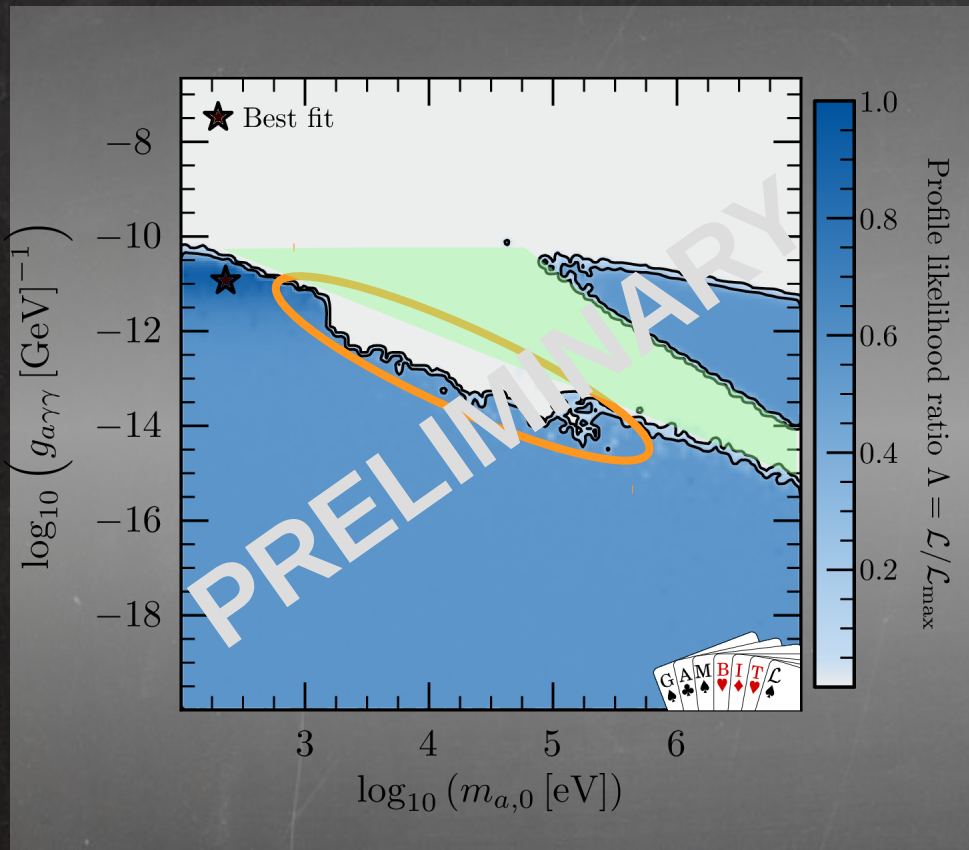
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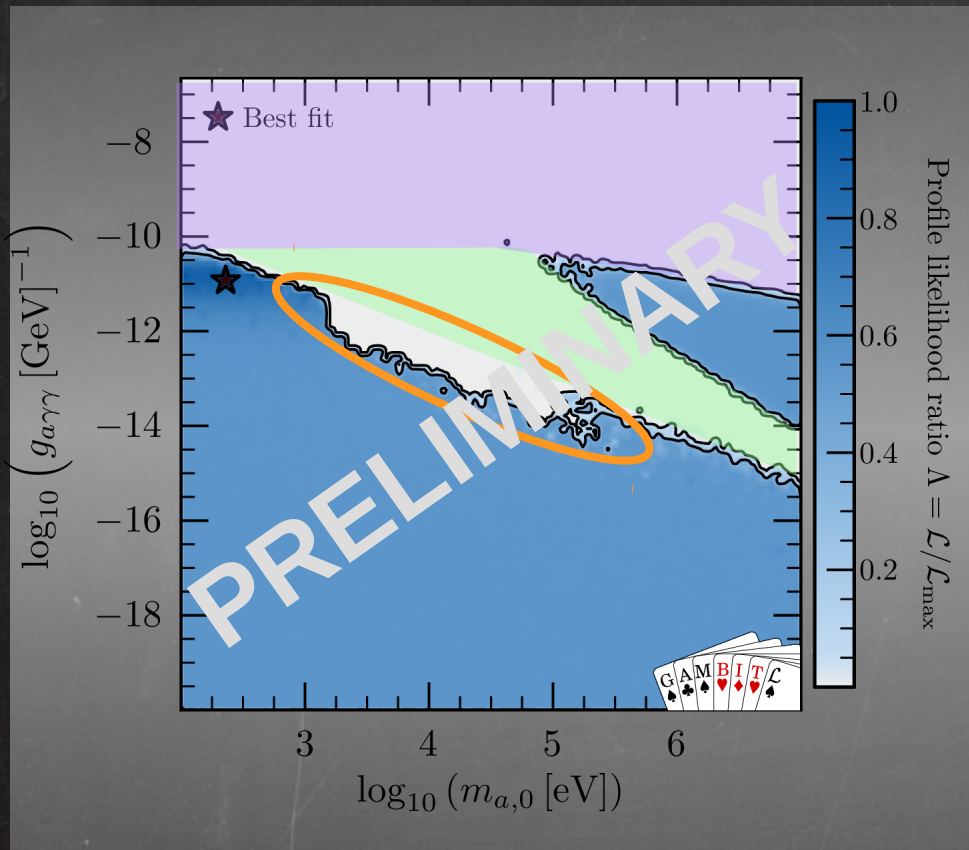
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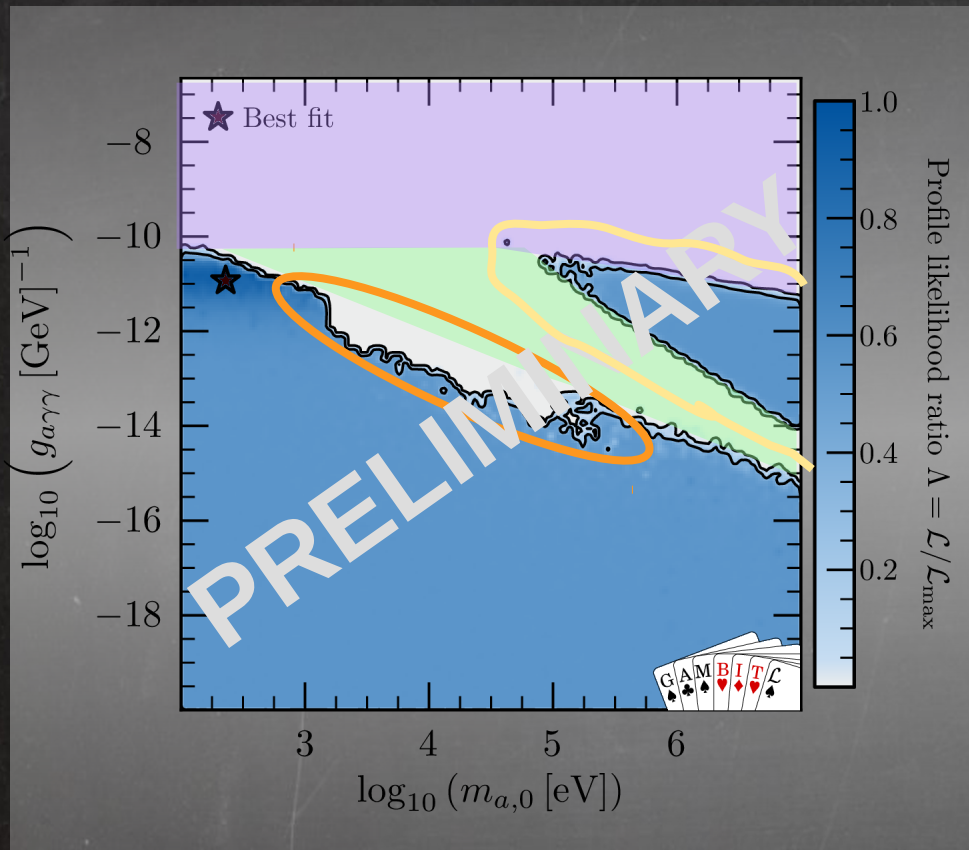
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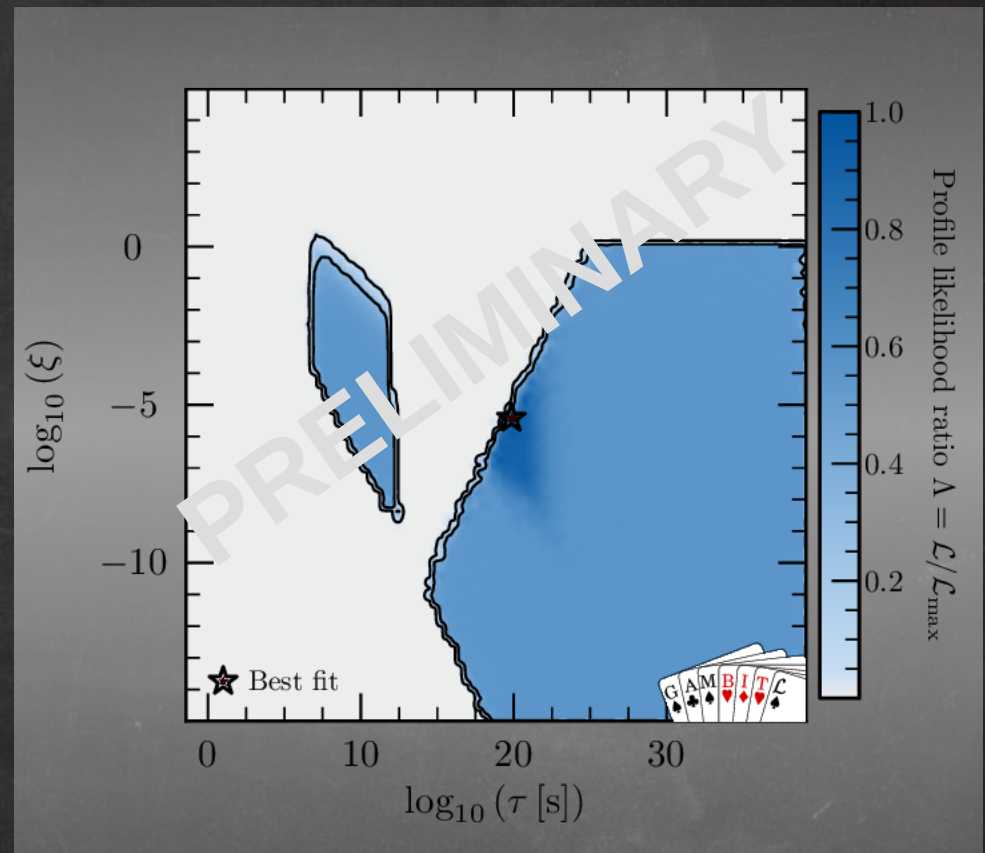
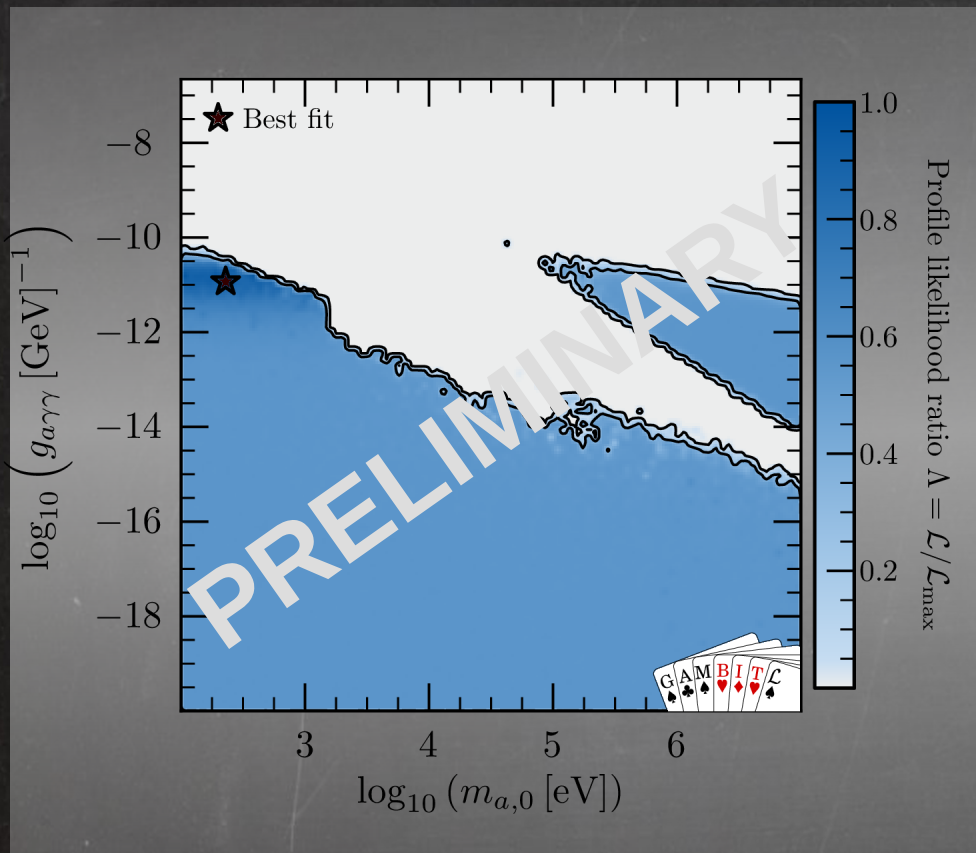
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# More about GAMBiT ..

-> Recent results:

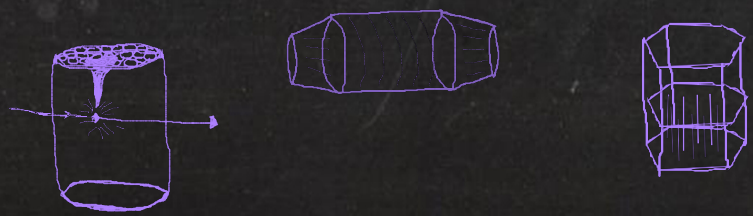
- right-handed neutrinos ([1908.02302](#)) → Tomas Gonzalo's talk
- Axions & ALPs ([1810.07192](#))
- EW-MSSM ([1809.02097](#)) → Pat Scott's talk
- Higgs portal DM ([1808.10465](#)) → Ankit Beniwal's talk

-> Code publicly available: [gambit.hepforge.org](https://gambit.hepforge.org)

-> Talk to one of us @TeVPA (Peter Athron, Csaba Balazs, Ankit Beniwal, Sanjay Bloor, Torsten Bringmann, Tomas Gonzalo, Andre Scaffidi, Pat Scott, Wei Su, Aaron Vincent, Martin White or me)

# CONCLUSION

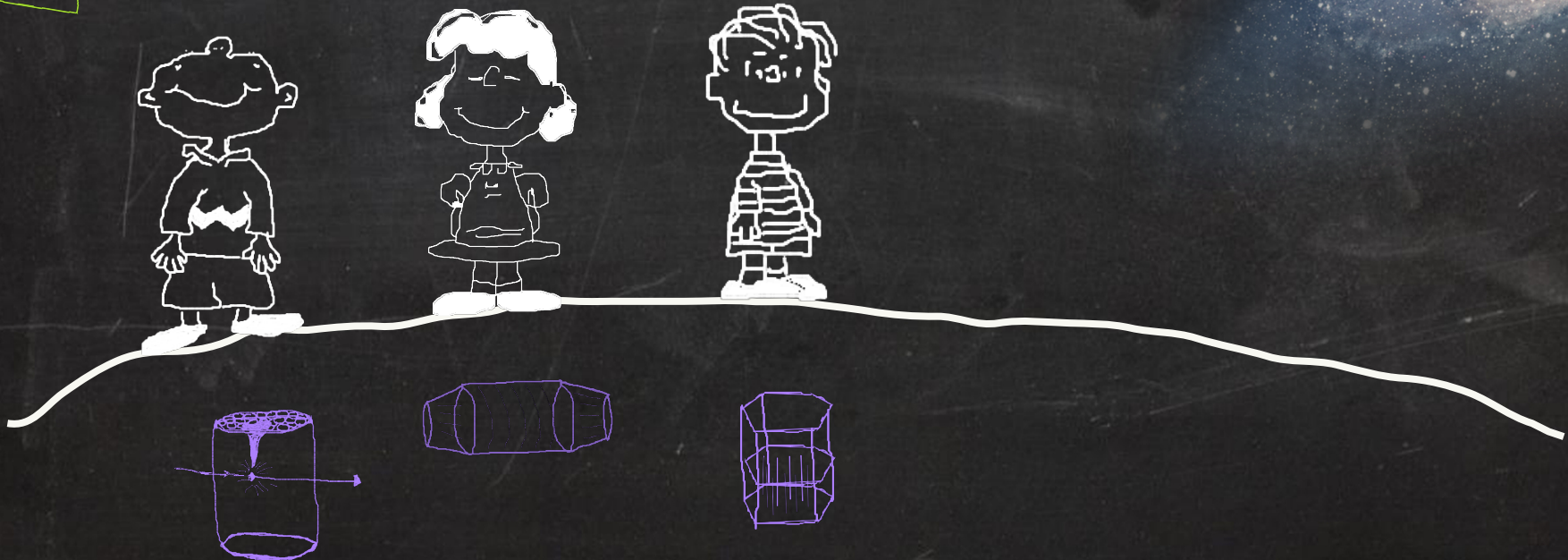
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# CONCLUSION

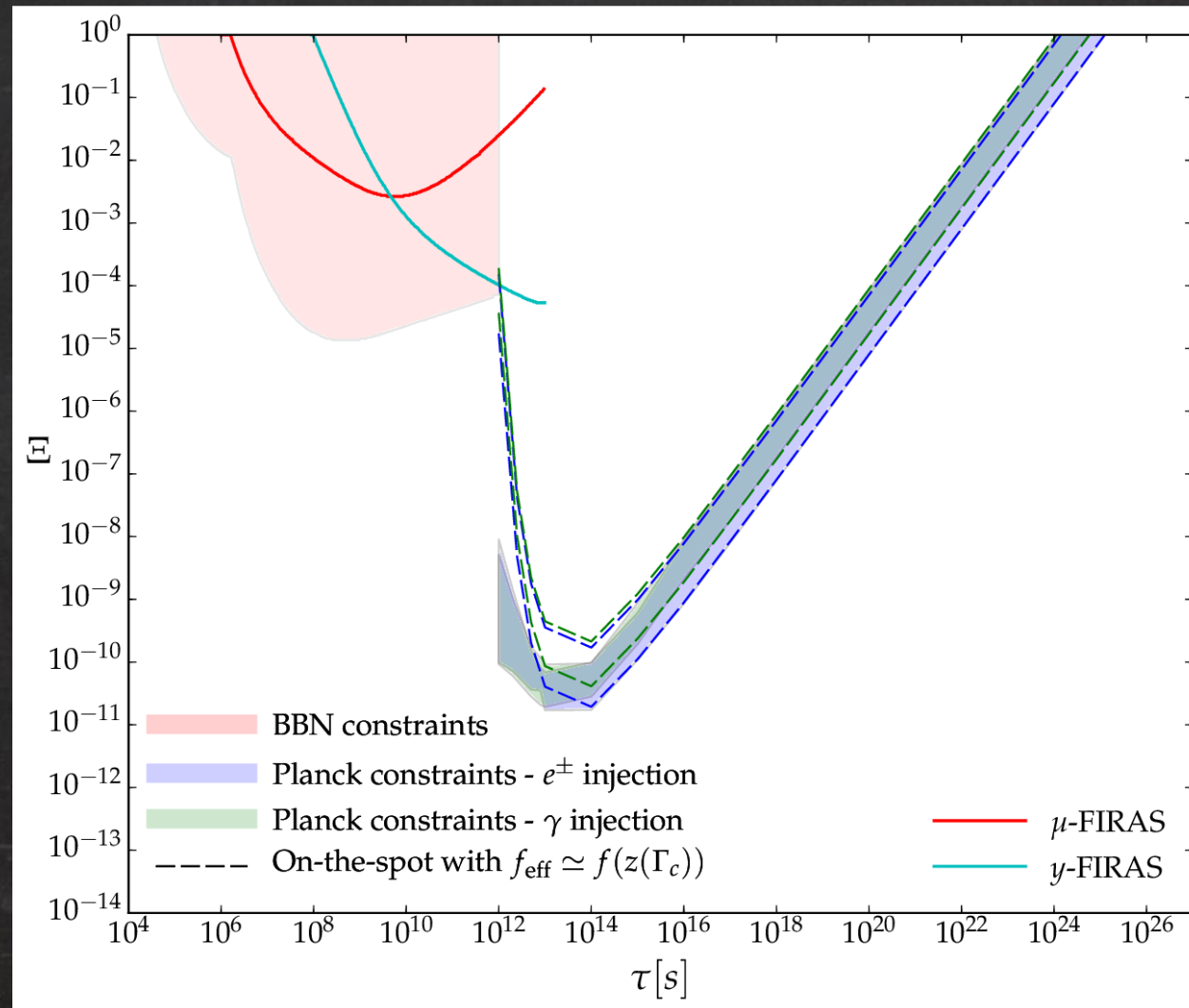
Simultaneous Global Fits  
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Cosmology!

=> GAMBIT can help!



# Backup Slides

# Electromagnetic constraints on ALPs



# When will CosmoBit be released?

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