

# PFNG-2010: summary of theoretical aspects

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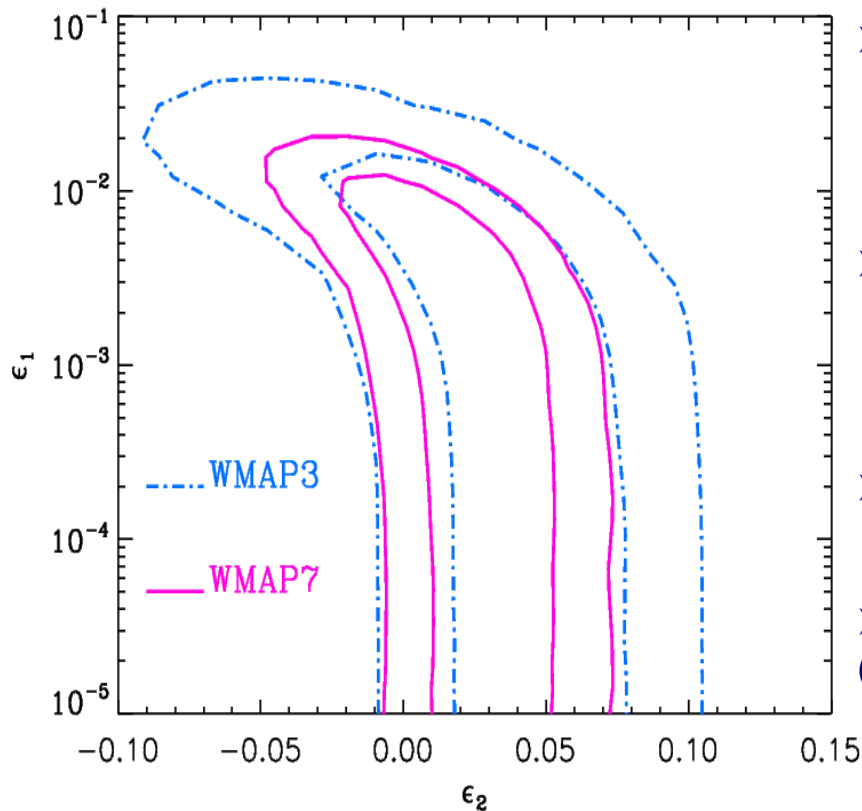
# PFNG-2010 in a few numbers

- 83 participants
- 5 days, 48 talks
- 1520 minutes ~ 25.33 hours
- 578 slides



## Vanilla model:

- 1 - single field inflation
- 2- canonical kinetic term
- 3- coupling with gravity described by GR
- 4- smooth potential such that slow-roll is always satisfied
- 5- perturbations of quantum-mechanical origin starting in the BD vacuum
- 6- Quantum mechanics interpreted in the « usual » way



- Slow-roll parameters:
  - $\epsilon_1 < 0.02$  (95%)
  - $-0.02 < \epsilon_2 < 0.06$
- No prior independent evidence for a running
- No entropy mode

- Energy scale:

$$\frac{H_{\text{inf}}}{m_{\text{Pl}}} < 1.3 \times 10^{-5}$$

$$< 10\%$$

- Gravity waves

$$r_{10} < 20\%$$

- Tendency for red tilt (3 sigmas)

$$n_s = 0.963 \pm 0.012$$

- No cosmic string
- No non-Gaussianities

$$f_{\text{NL}}^{\text{loc}} = 32 \pm 21$$

$$f_{\text{NL}}^{\text{eq}} = 26 \pm 140$$

$$f_{\text{NL}}^{\text{orth}} = -202 \pm 104$$

- No feature in the spectrum at a statistically significant level

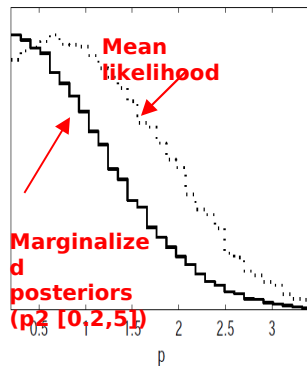
## So why should we go beyond?

Because, on theoretical grounds, there are reasons to. Three examples:

- 1- superimposed oscillations in the power spectrum.
- 2- multiple field inflation (simple single field are difficult to implement in HEP)
- 3- chaotic inflation is under pressure

$$p < 2.2$$

(95%CL)



Nicolas Regnier (1626)

NB: the box was actually a jar given to Pandora which contained all the evils of the world ...

## How to get features in the power spectrum?

- Change the initial conditions of the perturbations
- Put a feature in the inflaton potential (localized a la Starobinsky or resonant ie a small periodic modulation)
- Monodromy
- Multifield
- Bouncing Universe (this violates the belief that bounce+inflation cannot be distinguished from inflation)
- Collapse of the wave function of the perturbations

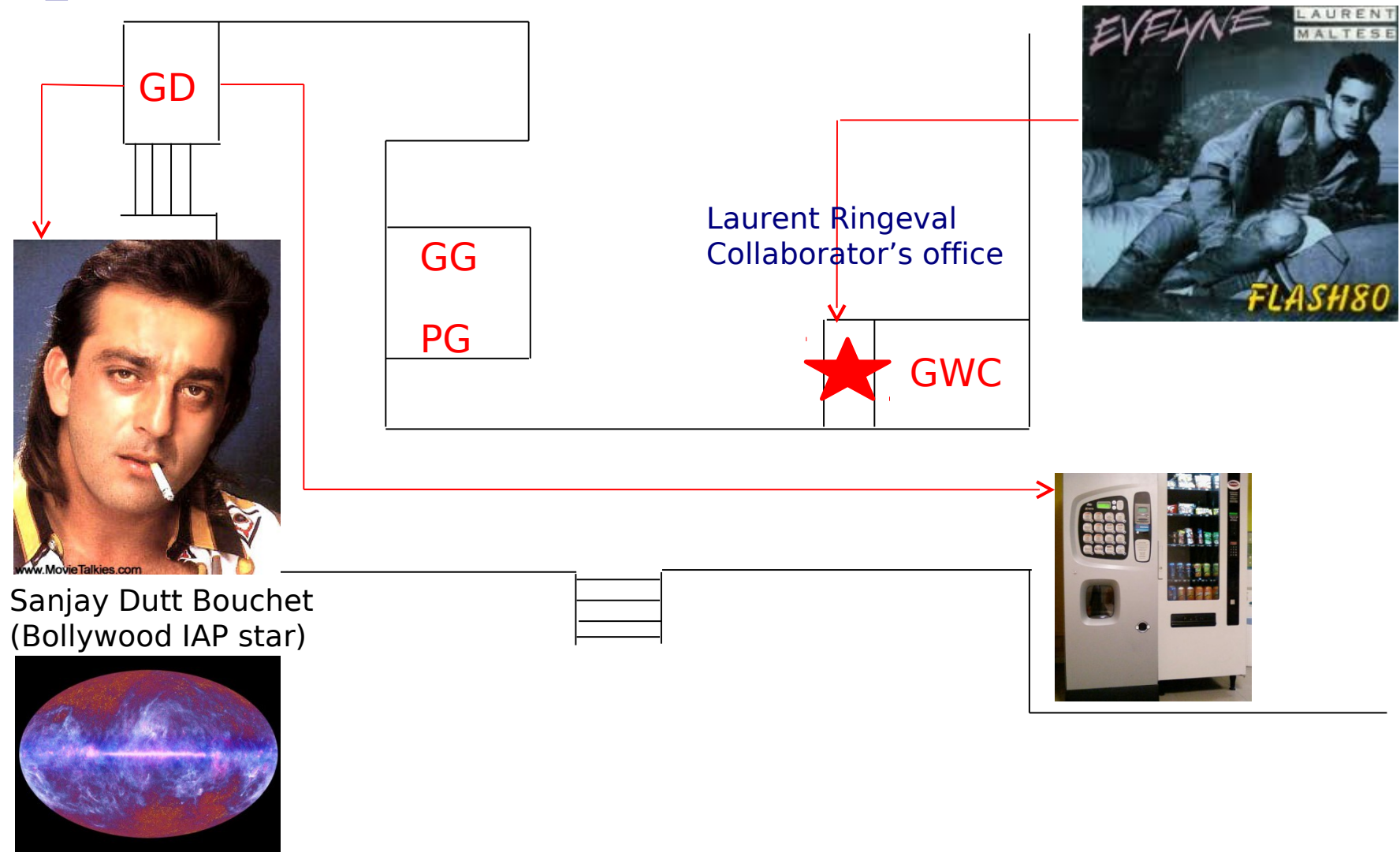
## How to produce non Gaussianity?

- Change the initial conditions of the perturbations
- Put a feature in the inflaton potential (localized a la Starobinsky or resonant ie a small periodic modulation)
- Monodromy
- Multifield (two methods to compute it:  $\delta N$  formalism or directly a Calculation of the action at third order)
- Bouncing Universe (this violates the belief that bounce+inflation cannot be distinguished from inflation) ????
- Collapse of the wave function of the perturbations ?????
- Modify the kinetic term of the scalar field(s)
- Cosmic strings
- Curvaton

## Interesting remarks

- **If one changes the primordial power spectrum, this can affect the non primordial cosmological parameters**
- **If we introduce a modification, it should show up in TT but also in TE, EE etc ...**
- **NG is usually scale dependent**
- **One should really compute everything until the curvature perturbation has become a constant**
- **One can search for features directly in the sky (discontinuity, breakdown of rotational invariance)**



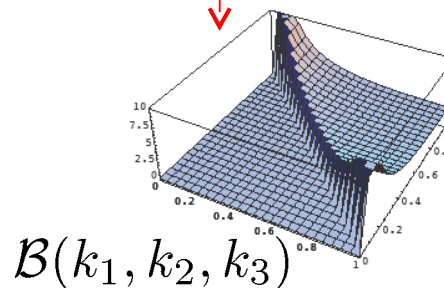
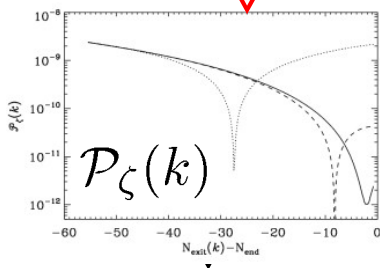


Given the plethora of models and mechanisms studied during the conference, what does it imply for our strategy to test Inflation (or something else)?



Model of inflation (or of the early Universe)

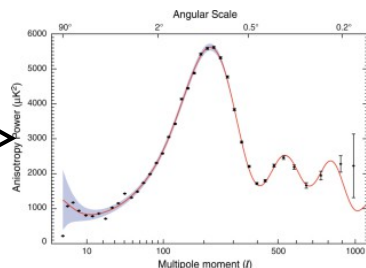
FieldInf



$\mathcal{T}(k_1, k_2, k_3, k_4)$

Hot Big Bang:

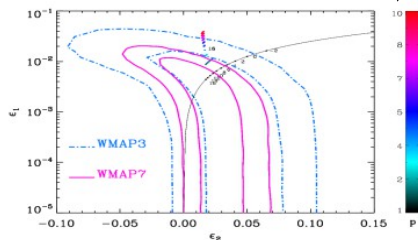
$H_0, \Omega_\Lambda, \Omega_b \dots$



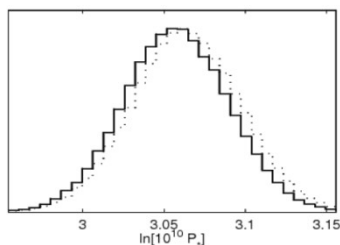
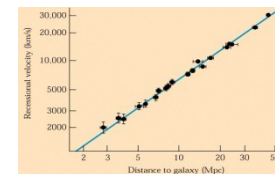
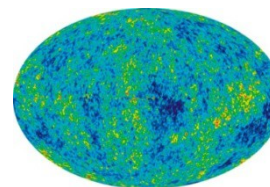
CAMB

NG on the celestial sphere

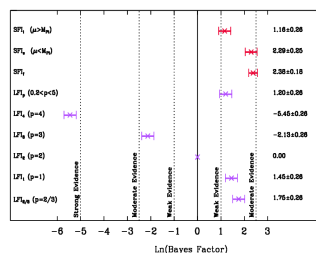
CosmoMC



Data:



Posterior distributions



MultiNest

What is the best model of Inflation?

## Step 1: single field slow-roll

### 1- Using the slow-roll approximation for the power spectrum

#### Pros

- Simple and model independent
- Usually quite accurate
- Important to understand the model

#### Cons

- Not exact
- Prior choices not very appropriate
- Not well-suited for reheating
- breaks down if we go beyond slow-roll

### 2- Model by model exactly (ie numerically)

#### Pros

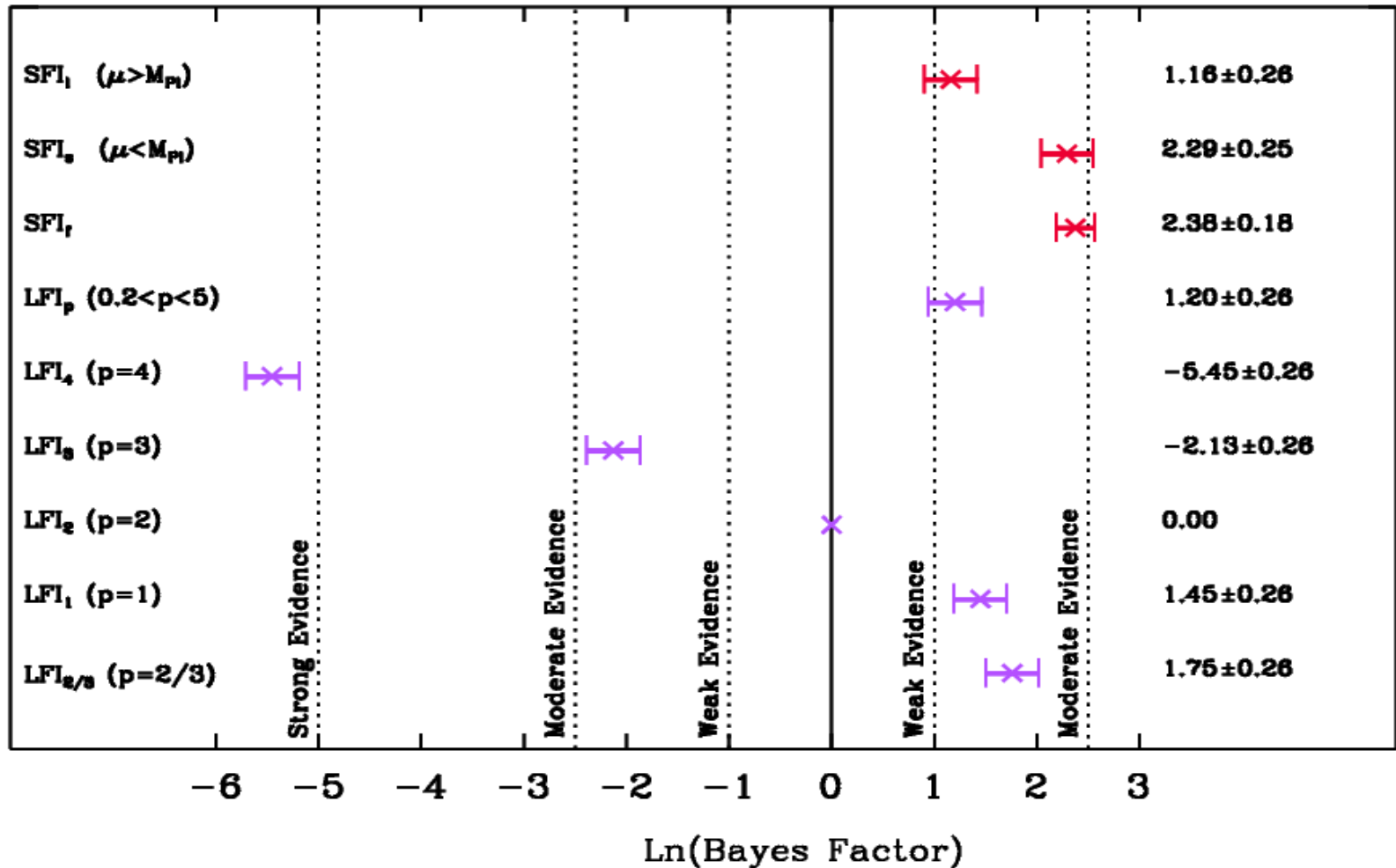
- All the sr Cons!
- Perfect to compute the Bayesian evidence

#### Cons

- Obviously, it requires to specify models so maybe it is not generic enough?

We should do both (important: there is also the reconstruction program!). The two approaches are complementary!

Step 1 has already been completed. Ex first calculation of the Bayesian evidences for prototypical inflationary models

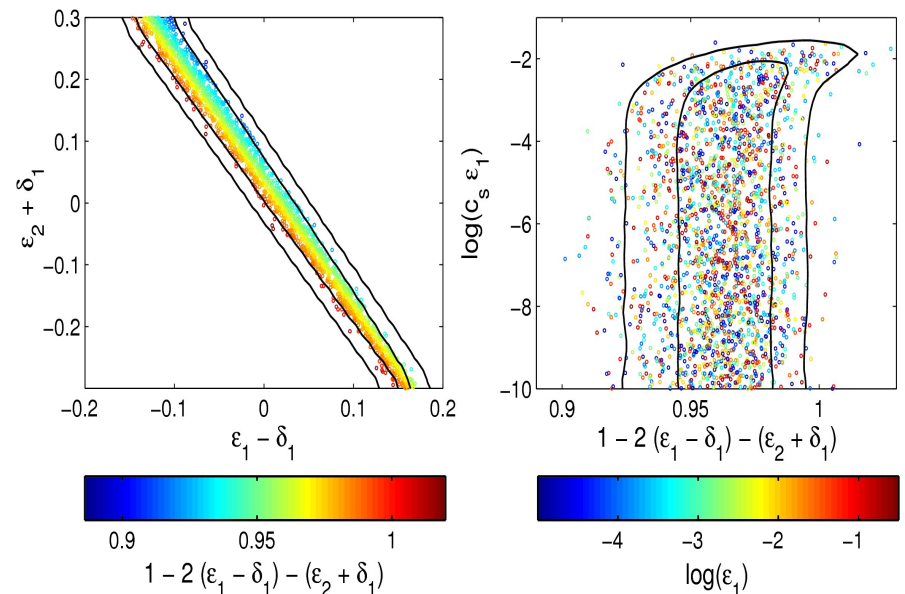


## Step 2: single field but more complicated

- This mainly includes models with non minimal kinetic terms, models with features in the potential and models with non-standard initial conditions
- Generic results (ie analytical) are still available, for instance for k-inflation (although the standard calculation breaks down) or Starobinsky's model. Otherwise, numerical methods are compulsory
- The new observables, for instance, NG are going to play a crucial role. The classic example is DBI inflation

$$P_{\text{DBI}}(X, \phi) = -T(\phi) \sqrt{1 - \frac{2X}{T(\phi)}} + T(\phi) - V(\phi)$$

$$f_{\text{NL}} = \frac{35}{108} \left( 1 - \frac{1}{c_s^2} \right)$$



### Step 3: Multiple field inflation

- Even more challenging ... as long as the slow-roll is satisfied there is still a general description but if not this becomes model dependent ... maybe a minimal set would be: double inflation, double inflation with interaction and hybrid inflation?

### Step 4: Alternatives eg a bounce

- What is the NG produced by a bounce? Does its spectral shape depends on the bounce?

## Some stupid questions ...

- NG and cosmic strings
- NG and post inflationary dynamics
- NG and modified gravity
- Does a feature imply a recoherence?
- NG and bouncing cosmology



Thank you very much!

