Energie noire et grille de calcul
Le projet ZEN

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Information Society and Media

Determination of cosmological parameters

- **Scientific Goal:**

Address open questions of fundamental cosmology:
dark matter/dark energy sector and primordial universe
Construct a public tool….

- **Main people involve:**

ANR program

CPPM

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CEA

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CPT

Christian. Marinoni, Pierre Taxil, Jean-Marc Virey, Stefan. Linden

LAL

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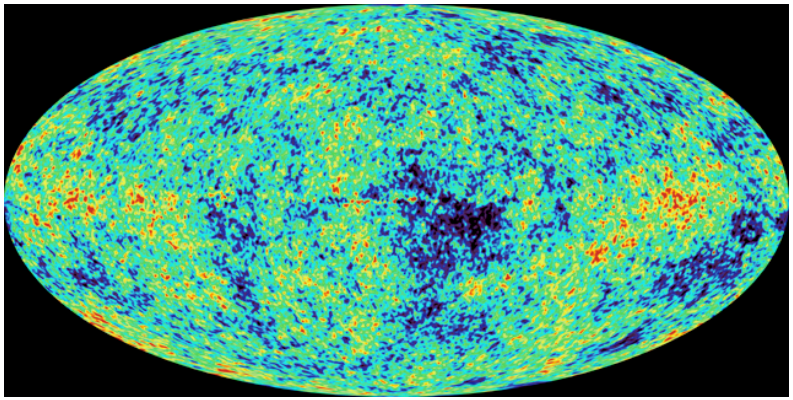
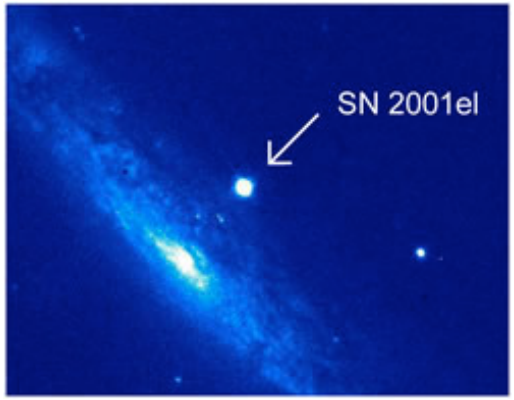
FCPPL: Franco-China-Particle-Physics-Laboratory program

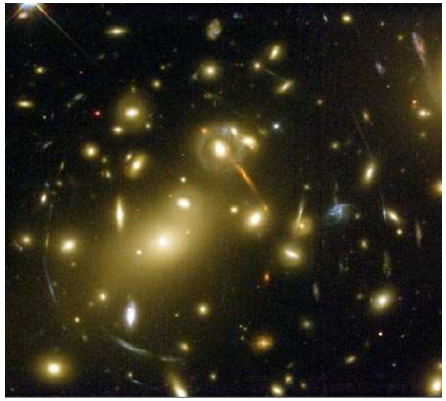
IHEP/PKU/NAOC/Tsinghua U/Beijing Normal U.

ZHANG XinMin, ZHAO Gongbo , QIAN Zuxuan , XIA Junqing, FAN Zuhui, LI Hong , Zhu Zhonghong, QIN Bo, DENG Jinsong , CHAO Wu , ZHOU Xu , WANG Xiaofeng

Plan



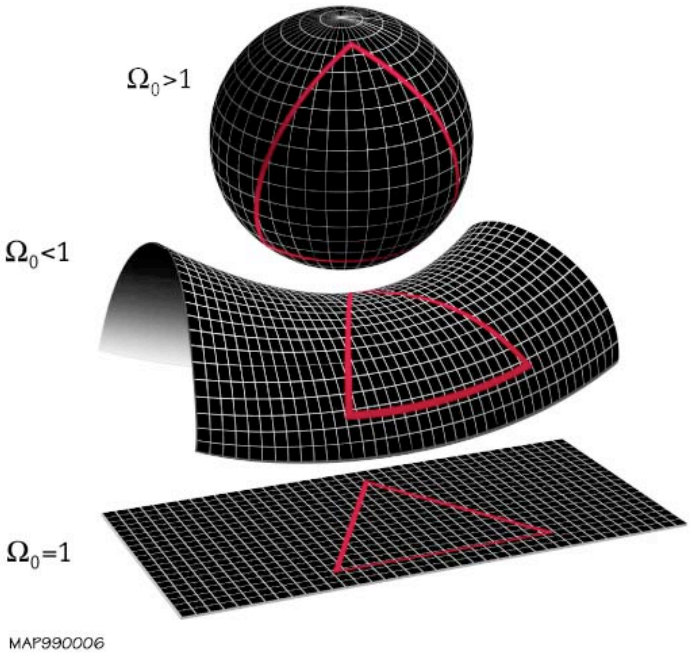




- Few words about cosmology and dark energy
- How to characterize dark energy
- Statistical method and datagrid
- Results already obtained by the Chinese and French groups (ESR and Euchina)
- Prospectives

Some words about cosmology

- Cosmology based on:
  - Homogenous and isotropic Universe
  - General relativity: $G_{\mu\nu} = 8\pi G T_{\mu\nu}$



Energy content: $\Omega = \rho/\rho_c$

Equation of state: $w(z)=p/\rho$

Matter (Ω_m) :	w =0
Radiation (Ω_r) :	w = 1/3
Cosmological cste (Ω_Λ):	w=-1
Dark energy (Ω_X) :	w(z)

$$\Omega_T = \Omega_m + \Omega_r + \Omega_X$$

($\rho_c = 10^{-29}\ g/cm^3$)

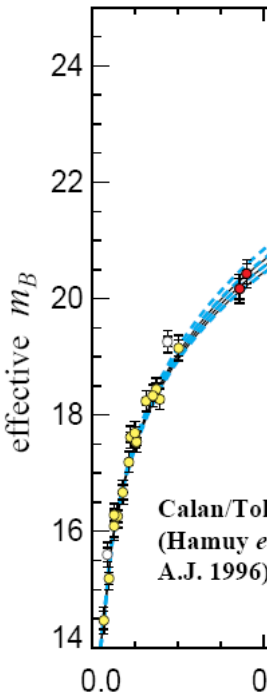
Some words about dark energy

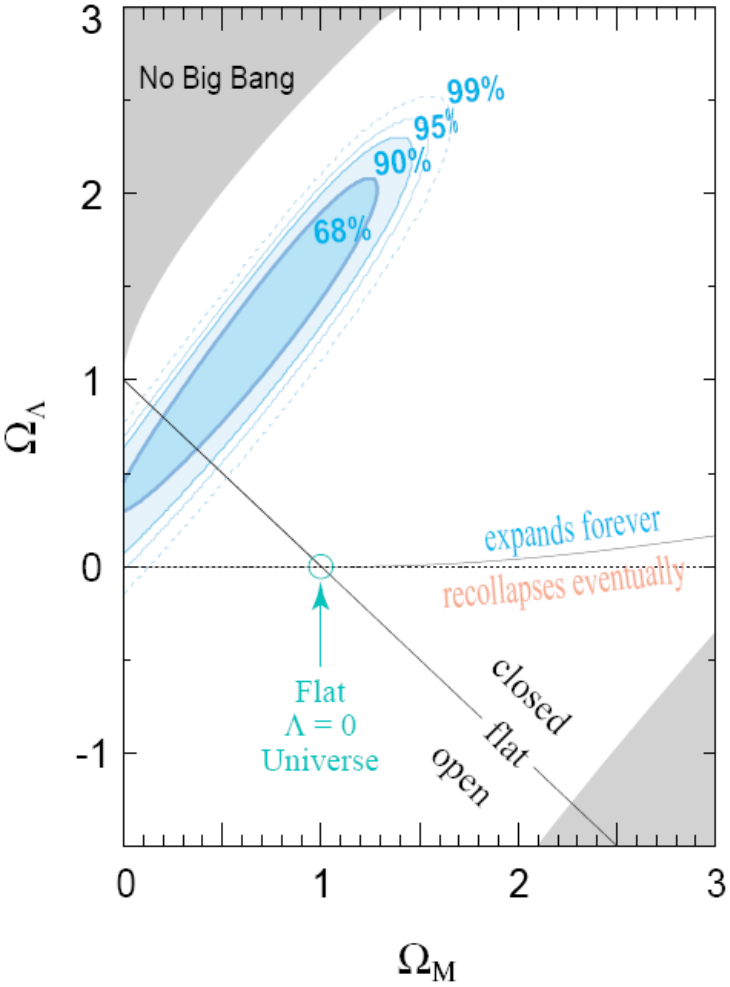
- In 1998, the Supernova Cosmology Project and High-z team shown that high red-shift supernovae are fainter than expected: a new energy component is needed.

Dark energy or cosmological constant caracterized by reduce density: $\Omega_\Lambda = \rho_\Lambda / \rho_c$

For a flat Universe:

$$\Omega_\Lambda = 0.72^{+0.09+0.05}_{-0.08-0.04}$$

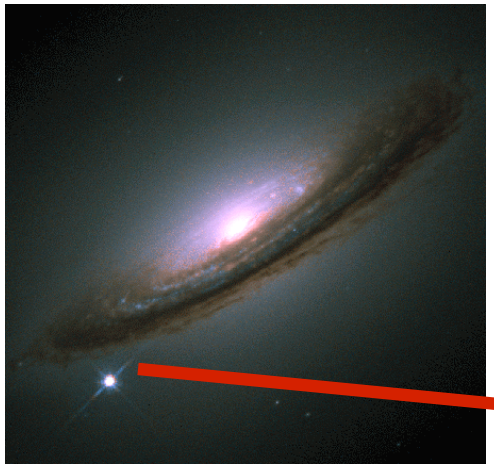


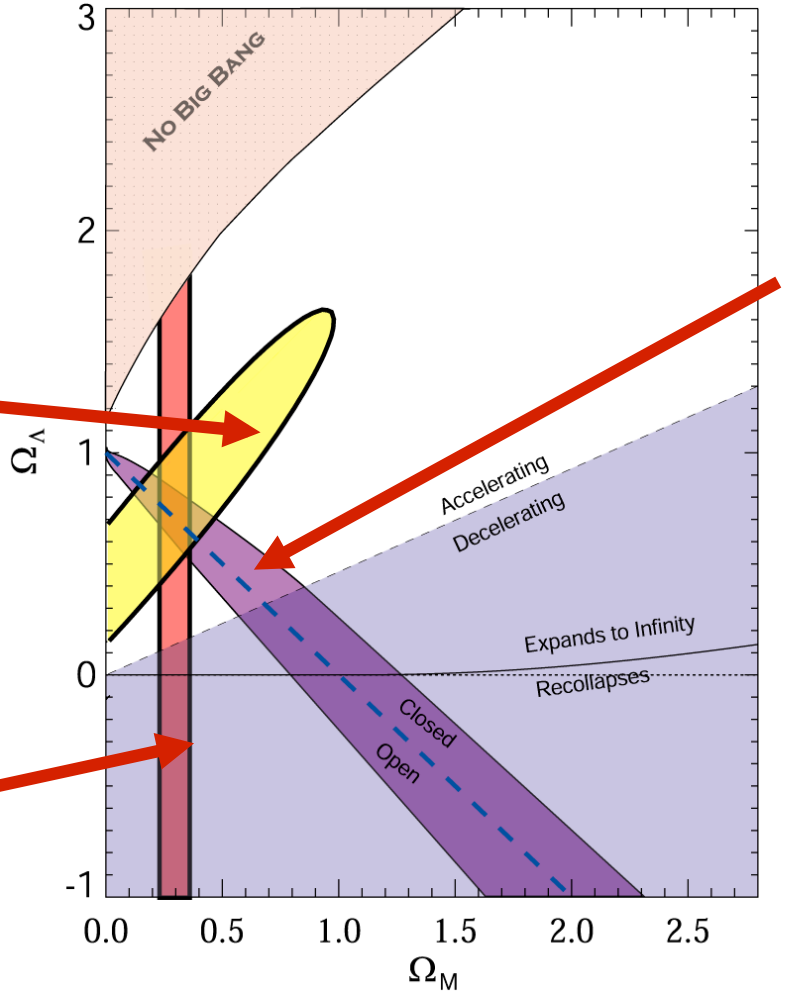


Definition: $\Omega = \rho / \rho_c$ ($\rho_c = 10^{-29}$ g/cm^3)

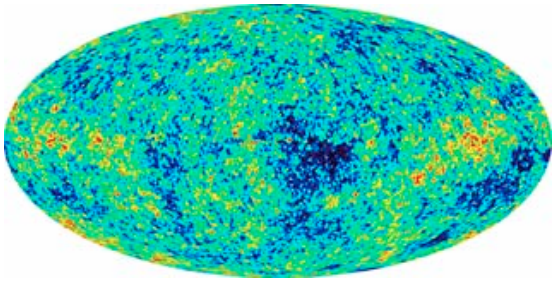
From observations to the Concordance Model

SNe Ia

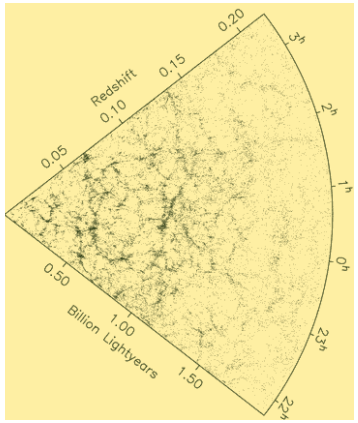




CMB(WMAP)



LSS



Universe is mainly dark

~70% DE

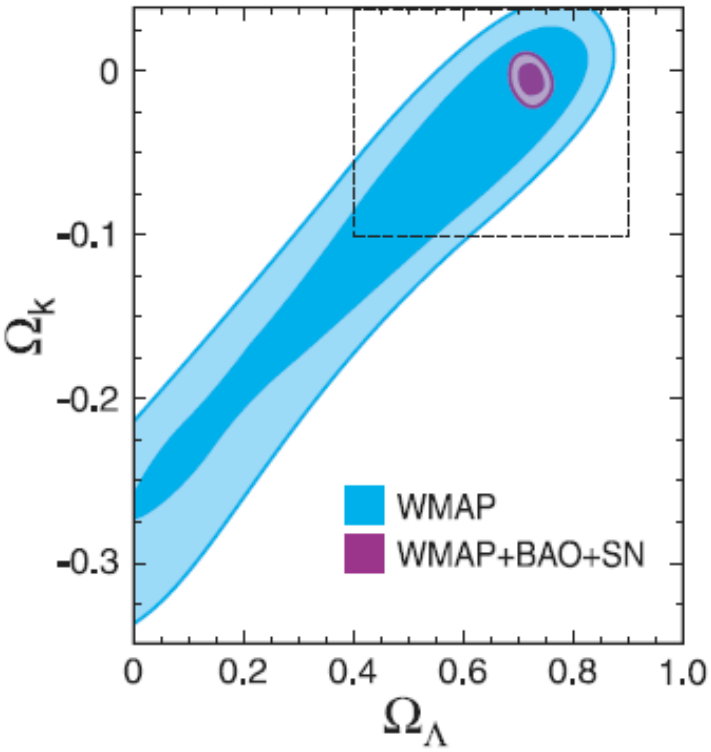
and

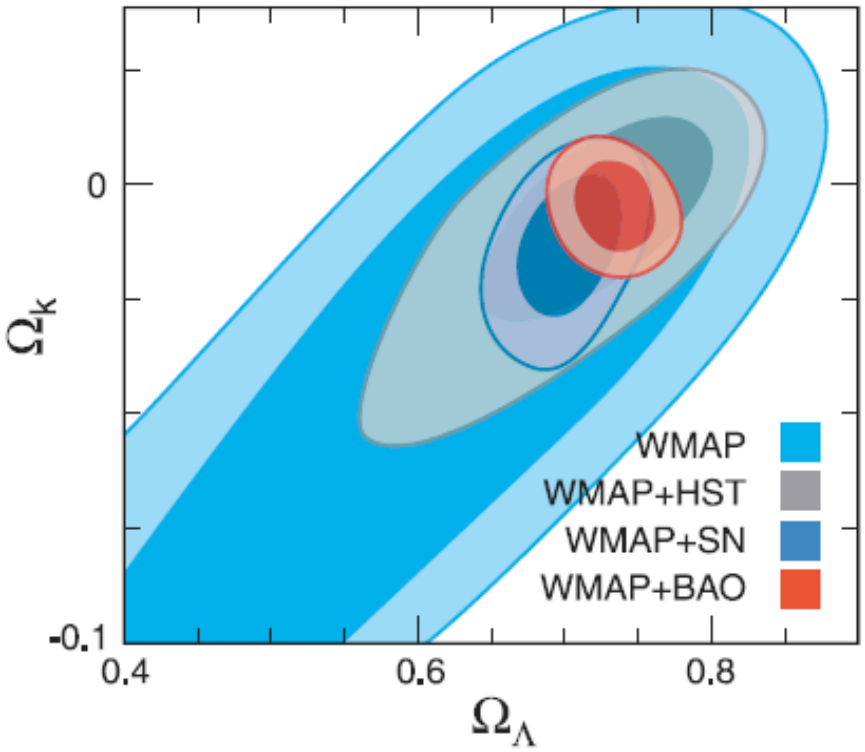
~25% DM.

Our Univers is accelerating

a 2006 status

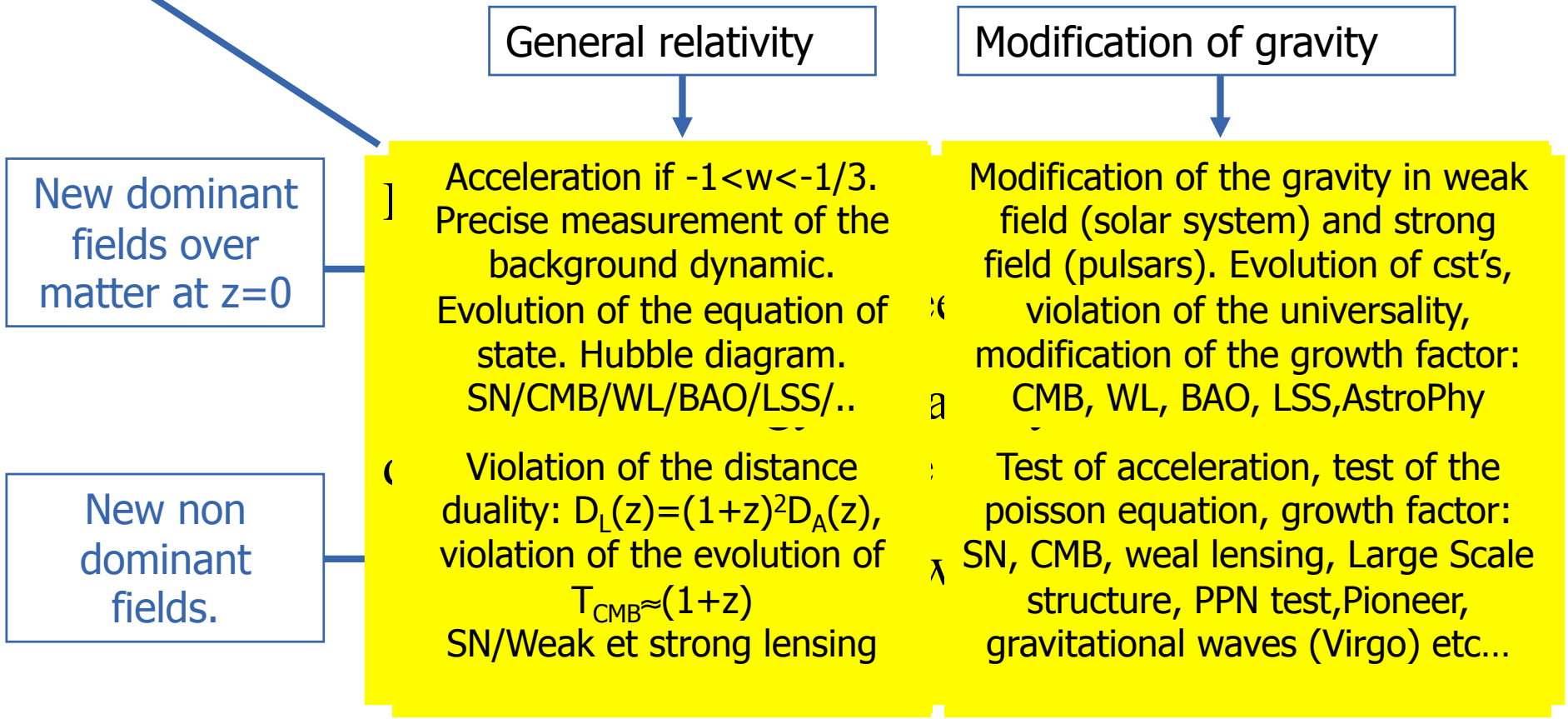
WMAP 5 years results





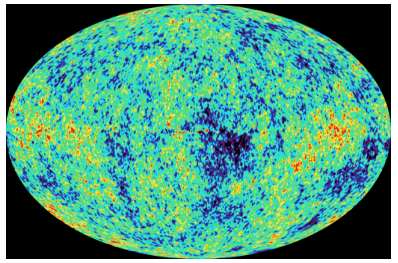
Phenomenological aspect

- From where this acceleration is coming from ?
- Two main classes of theory/model : Particle physics or Gravity ?



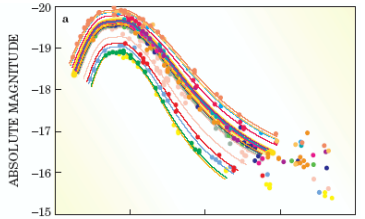
How to extract w_0, w_a?

Degeneracies between parameters imply multi-probes analysis sensitive to complementary quantities:



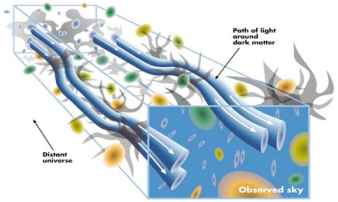
CMB

Snapshot at ~400,000 yr, viewed from z=0
Angular diameter distance to z~1000
Growth rate of structure (from ISW)



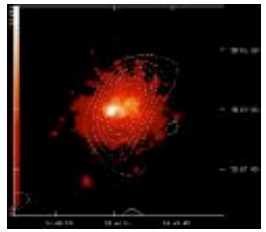
Supernovae

Standard candle
Luminosity distance



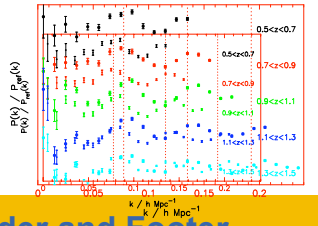
Cosmic Shear

Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure



Cluster counts

Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure

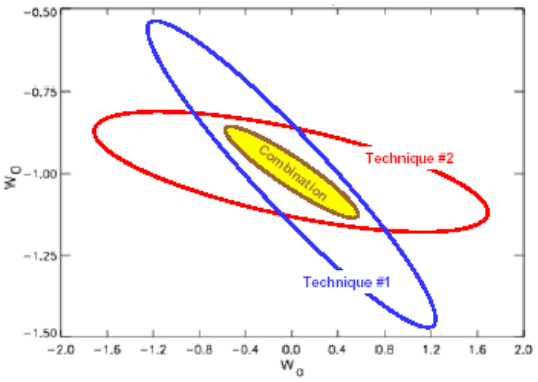


Baryon Wiggles

Angular diameter distance

Physical parameters

- **Important number of parameters, cosmological and astrophysical**
  - Ω_b/Ω_m density for baryon/matter
  - Ω_ν density for neutrino's
  - Ω_T curvature density
  - H Hubble constant,
  - n_s spectral index,
  - τ reionisation optical depth
  - σ_8 normalization for CMB, WL and BAO.
  - m_s normalization for SNIa.
  - yhe Helium fraction
  - w_0, w_a Equation of state….



- **Efficient statistical tools needed:**
  - Bayesian statistic and MCMC : Chinese and astrophysicist choice
  - Frequentist statistic and datagrid : French and particle physicist choice

Statisitcal method

- Statistic based on $\chi^2(\Omega_i, w_0, w_a, \ldots)$
- Minimum using the gradient method:

  $\partial\chi^2/\partial\Omega_i = 0$

$$\left(\Omega_i - \Omega_i^o\right) = -\left(\left.\frac{\partial^2\chi^2}{\partial\Omega_k\partial\Omega_i}\right|_{\Omega_k^o}\right)^{-1}\left.\frac{\partial\chi^2}{\partial\Omega_k}\right|_{\Omega_k^o}$$

- Numerical resolution and iterative:
- Error computation: $U_{kl}^{-1} = \frac{1}{2}\left[\frac{\partial^2\chi^2}{\partial\Omega_k\partial\Omega_l}\right]$
- Contour: Solving the equation $\chi^2 = \chi^2_{min} + s^2$

  Marginalization obtained by minimization:

  $\chi^2(w_0, w_a) = \chi^2_{min}(\Omega_i \mid w_0, w_a)$

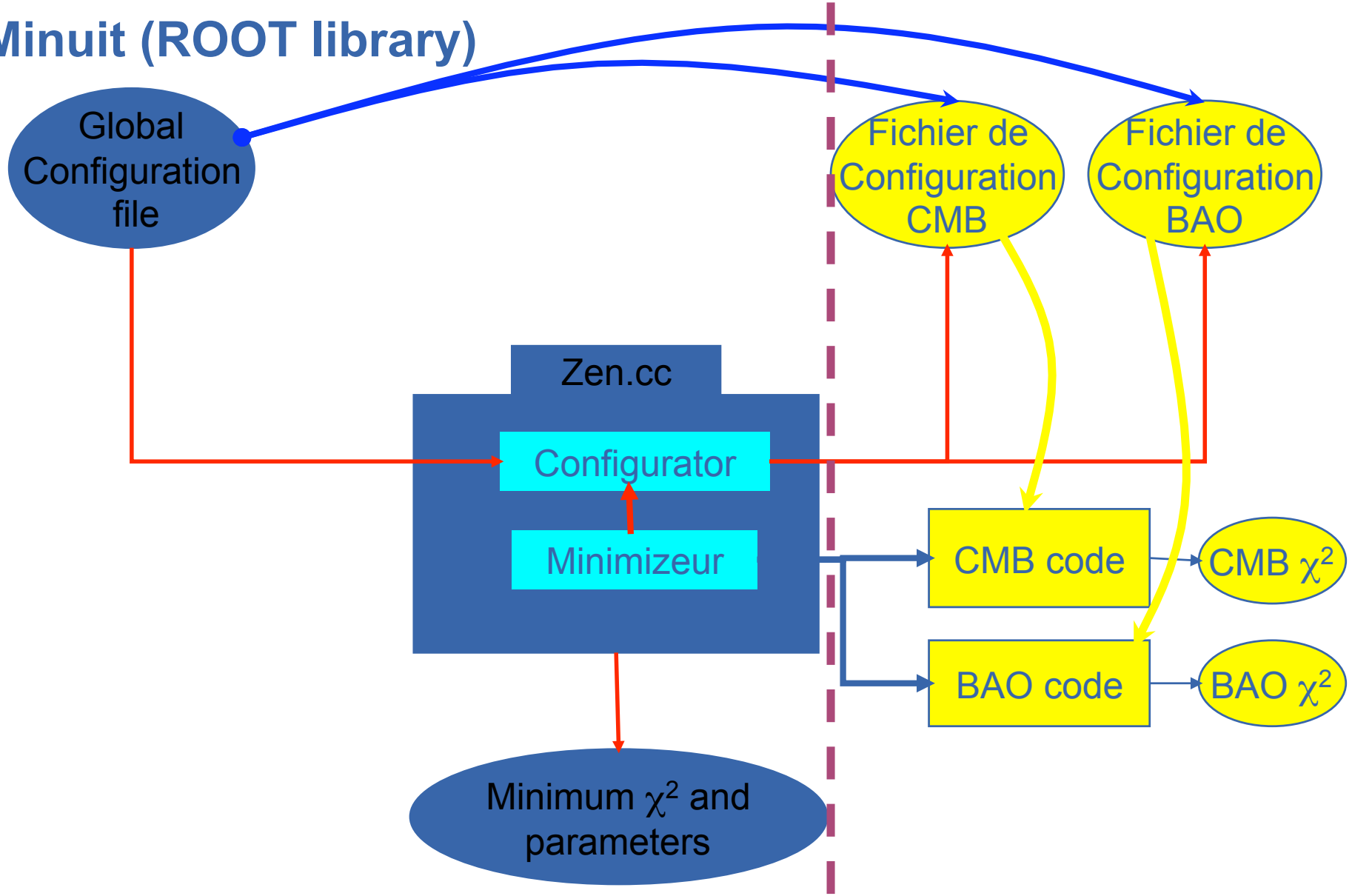
The contour is constructed by minimizing the χ^2 on a grid of points (minimum 20*20) and iso-χ^2 are constructed using interpolation. Each point (20 hours of computing) is calculated on a CE.

A simple contour requires about 1 year of CPU on a single CPU.

Thanks to datagrid (result in few days)

The Zen program

Minuit (ROOT library)



Global configuration file

```
action = compute_chi2/find_minimum
simulation = no
#-----------------------------------------
scan   = wa
from   = 0.
upto   = 0.1
nbscan = 100
# contour ?
scan2d   = none
from2d   = -1.0
upto2d   = 0.0
nbscan2d = 2
#-----------------------------------------
use_sn  = yes
use_bao = yes
use_wl = no
use_cmb = yes
use_hst = no
cmb_code = cmbeasy
flatness =yes
#-----------------------------------------
```

```
#-----------------------------------------
fit_omega_b = yes
fit_omega_cdm = yes
fit_omega_nu = no
fit_ns = yes
fit_w0 = yes
fit_wa = yes
.....
#-----------------------------------------
perturb_type = noperturbsup
gauge = quintsynchronous
……
#  Equation of state
w0       = -1.095936698
min_w0   = -3.
max_w0   = -0.3
error_w0 = 0.2
#  Equation of state variation.
wa       = -0.2295558424
min_wa   = -2.5
max_wa   = 2.5
error_wa = 0.8
```

User configuration file

- **Format totalement libre (fichier texte)**
- **Héritage des paramètres globaux**

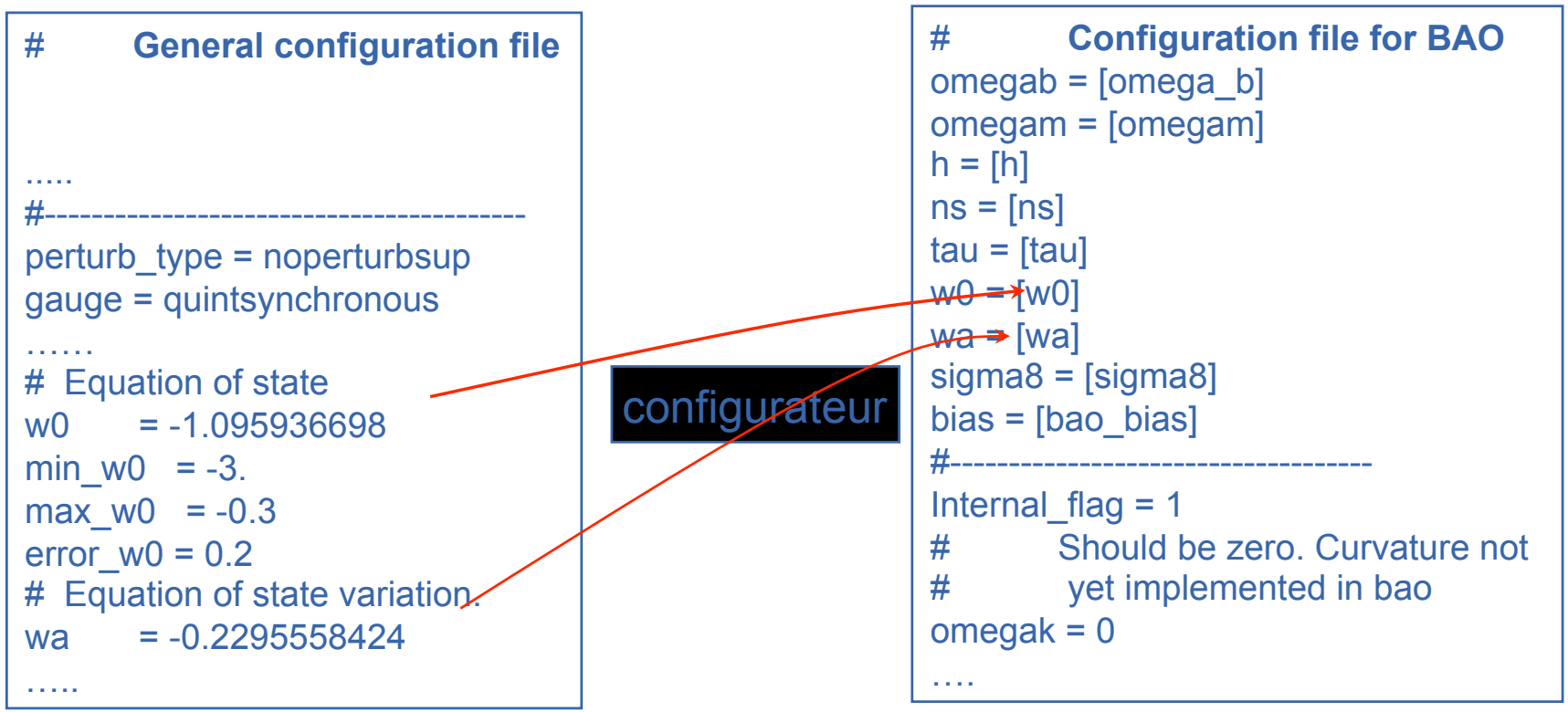
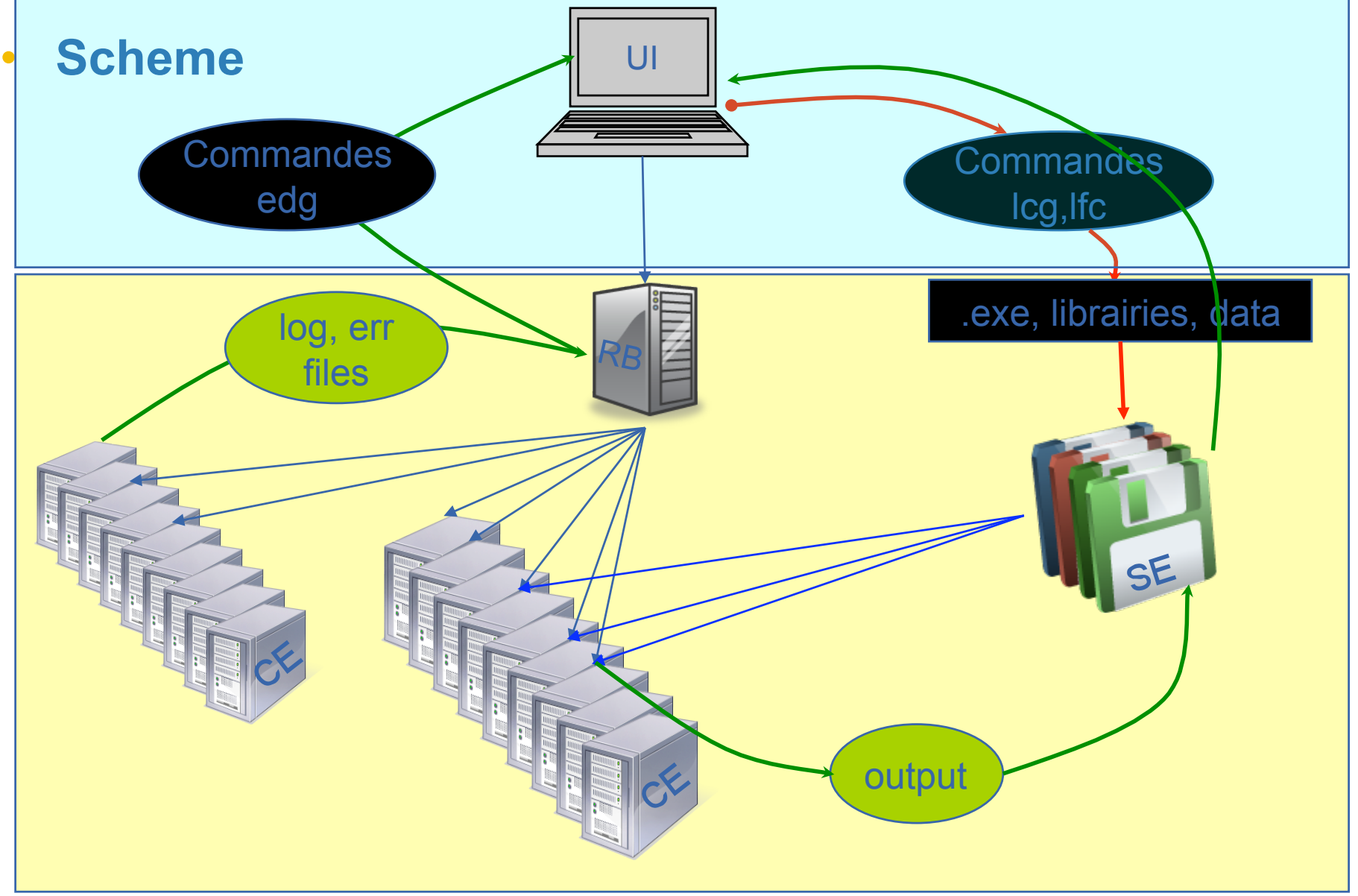


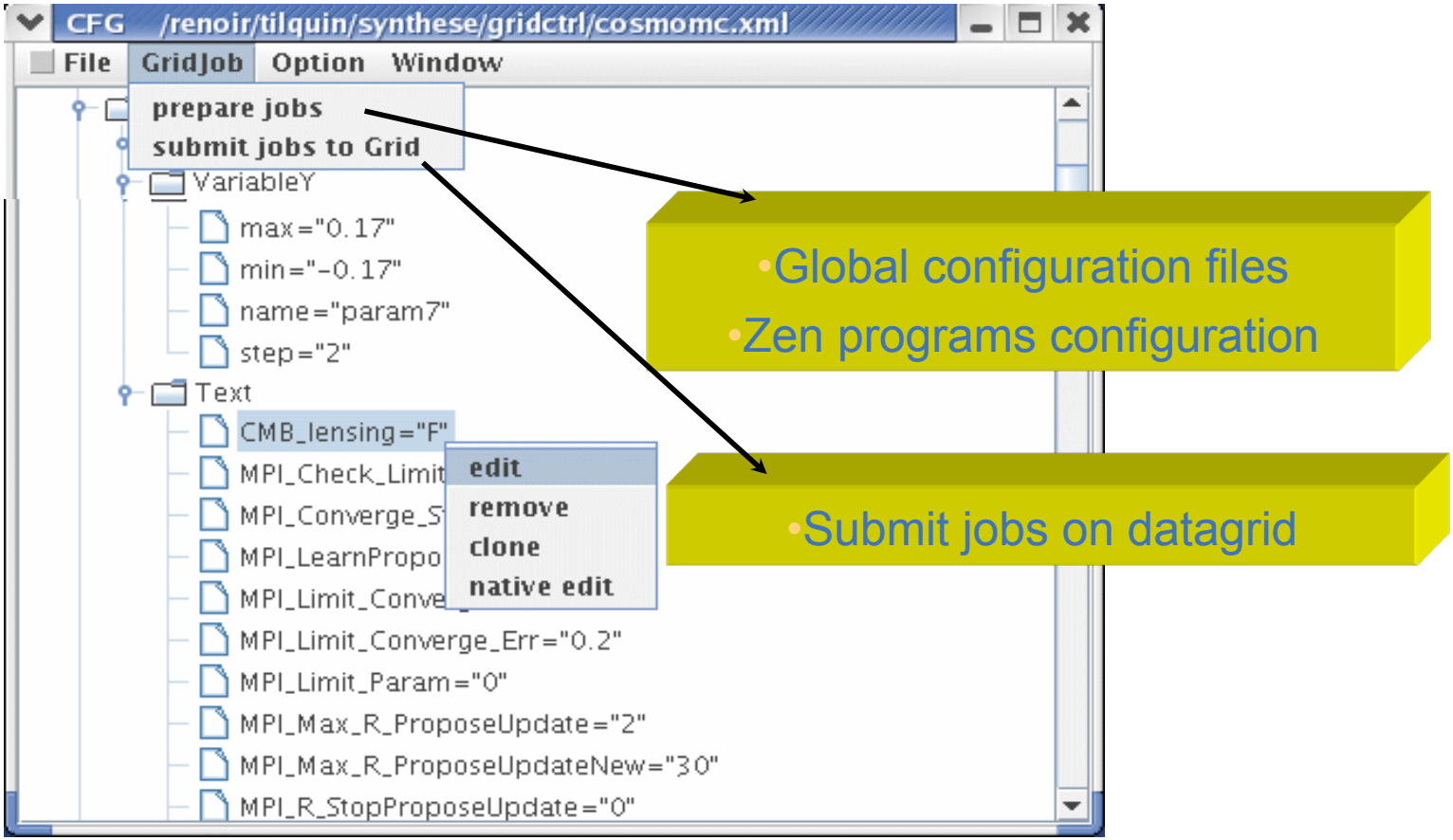
Schéma de la grille

- Scheme



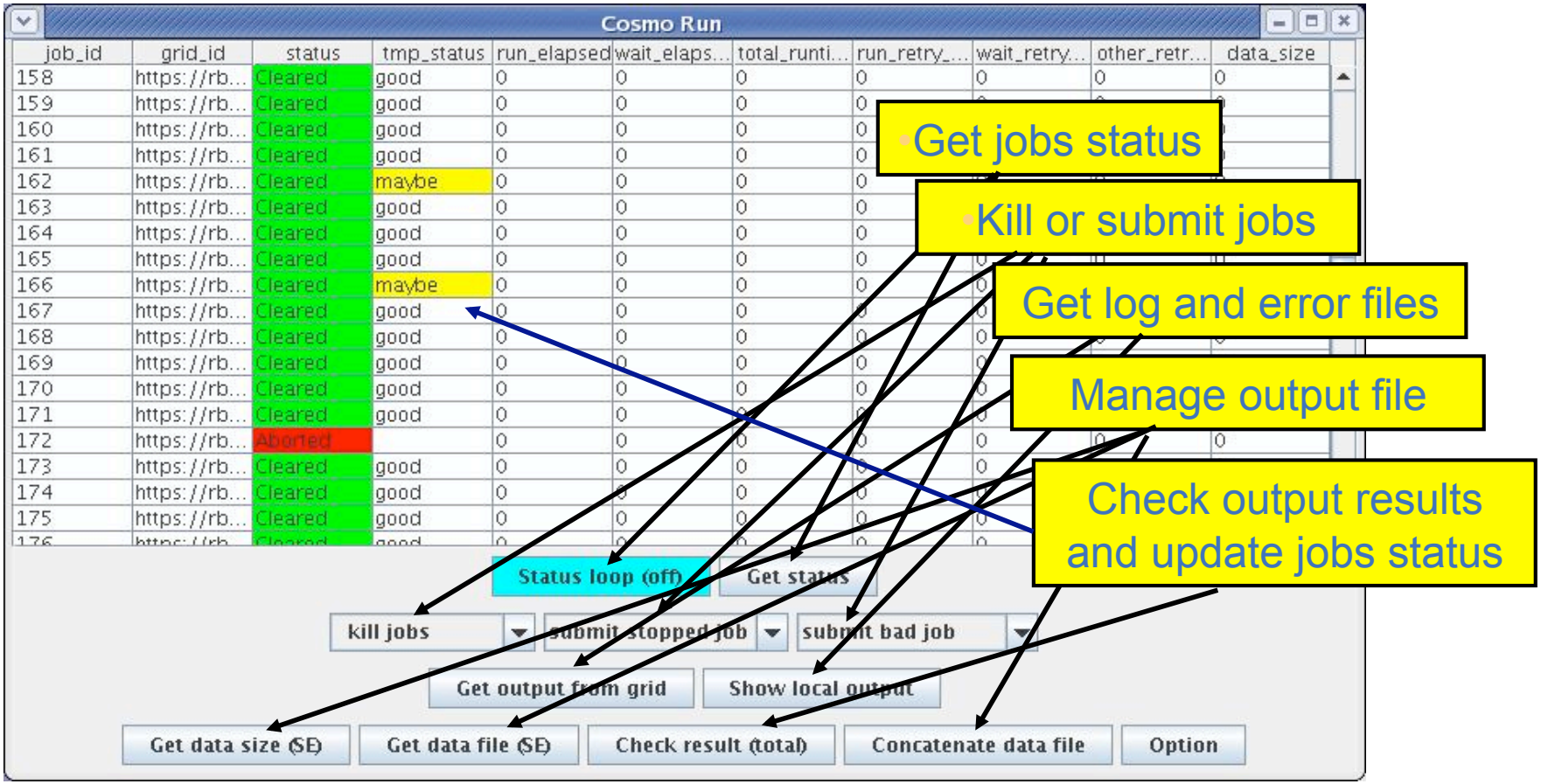
Submission graphical interface

- A run is a set of n*n jobs (400) send in parallel. A graphical interface has been developed (thanks to Zuxuan Qian) to construct and submit them.



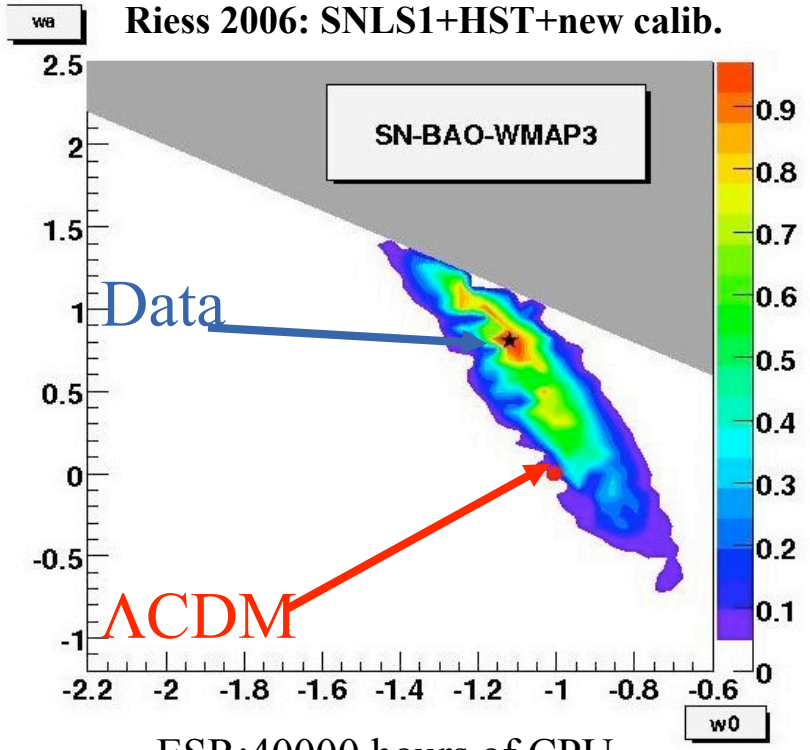
Job control graphical interface

- **Jobs monitoring and output data manager**

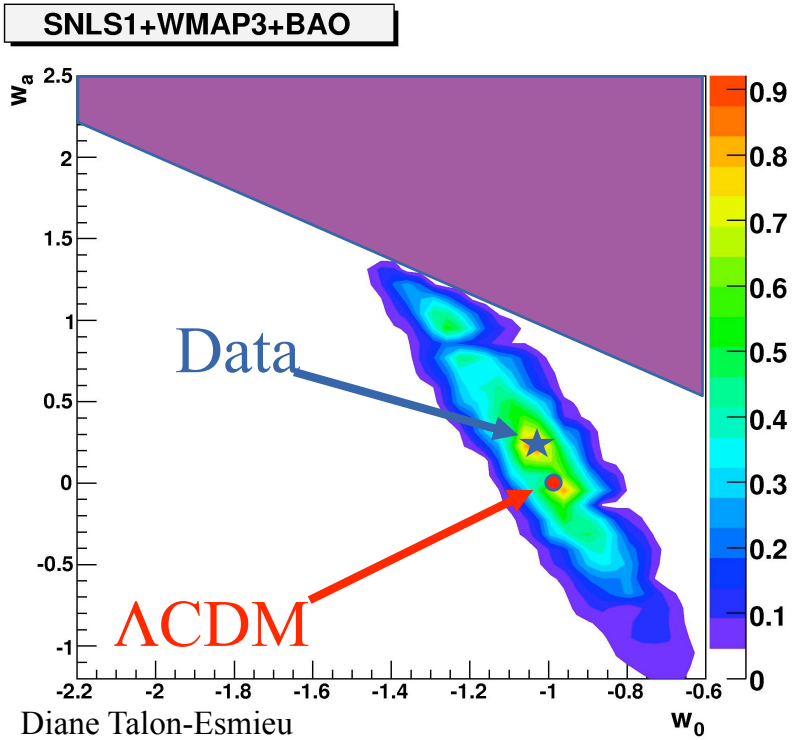


Cosmological constraint using BAO

- **First results using datagrid within:**
  - ESR (Earth Science Research) VO (thanks to M. Petit-Didier) and Euchina Virtual organization
  - Using SN+CMB+BAO with frequentist statistic and (BAOfit from Sun Lei, PKU-CPPM Join PhD)



ESR:40000 hours of CPU



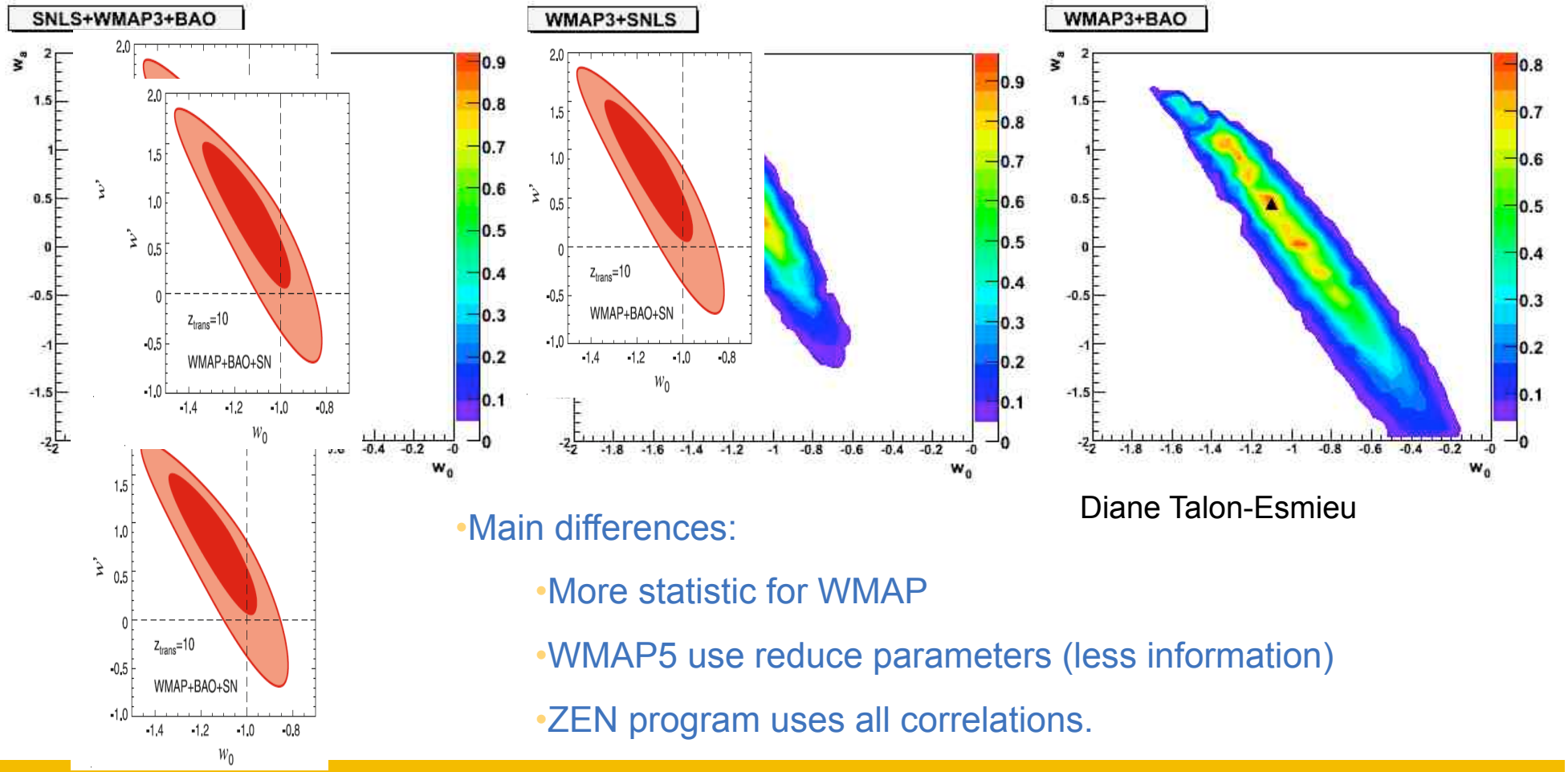
Diane Talon-Esmieu

ESR+Euchina: 10000 hours of CPU

More studies

- **News results on WMAP3-SNLS-BAO comparison**

Comparison with WMAP5+SNLS+BAO last publication



Diane Talon-Esmieu

- Main differences:
  - More statistic for WMAP
  - WMAP5 use reduce parameters (less information)
  - ZEN program uses all correlations.

Summary and perspectives

- **The ZEN program is now running on datagrid**
  Thanks to ESR virtual organization
- **The two graphical interfaces are very powerfull tools to submit jobs and to debug.**
- **Major problem was the linux version (SL3,SL4)**
- **Our first results on multi-probes analysis are compatible with competitive analysis (Bayesian) and WMAP5**
- **Perspectives:**
  - Add new probes (WL, etc…) and add new data (WMAP5,SNLS3…)
  - Investigate new theoretical models and implement them in ZEN
  - Add new statistics (MCMC, Bayesian…)
  - Start systematic analysis !
  - Write a documentation : IT IS A PUBLIC TOOL
    - If you want to use it you are welcome (possible training).