

Mathematica Evangelion

Savvas Nesseris

IFT/University of Madrid, Madrid, Spain



Instituto de
Física
Teórica
UAM-CSIC



Outline

- **Why use Mathematica?**
- **Contour Plots with ContourPlot**
- **Contour Plots for MCMC chains**

Advantages of Mathematica



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Advantages of Mathematica

- 1) You only need Mathematica, no need to compile for different environments, no need to worry for compilers/libraries etc.
- 2) License for Mathematica is already available in most Institutes.
- 3) Easy to add new models, change assumptions, by modifying a few lines of code. No need to recompile and install!
- 4) Makes nice plots quite easily, with zero effort.
- 5) Latest versions (9.0.1) are very fast, very small difference with native C/C++ code(*)
Really!!! If you disagree, you're doing something wrong :P
- 6) You don't have to spend enormous amounts of time debugging...
- 7) Parallelizing a code is trivial, eg `Do` → `ParallelDo`, `Dot` → `CUDADot`

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Education

In this part I will try to explain several key issues in data analysis and statistics with the use of explicit examples and numerical codes. Most of the following material is intended for master and fledgling PhD students who want to understand the basics of data analysis with a focus on cosmology and want to enter the world of research. However, some of the examples might be a bit more advanced...



Prerequisites:

- 1) Study Chapter 15 of Numerical Recipes regarding data-fitting, minimization, MCMC, statistics etc [1], see also [2].
- 2) Download the Mathematica codes found below and that illustrate several key issues, like minimization and basic statistical analysis, contours, MCMC, Fourier analysis, parallelization (CPU/GPU) etc.
- 3) Get CAMB from [here](#) and follow the instructions in the [Readme](#) to compile and install it. Gfortran 4.5+ is highly recommended.
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why.

Numerical codes: (right-click on "Download" and hit "Save as")

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Available at:

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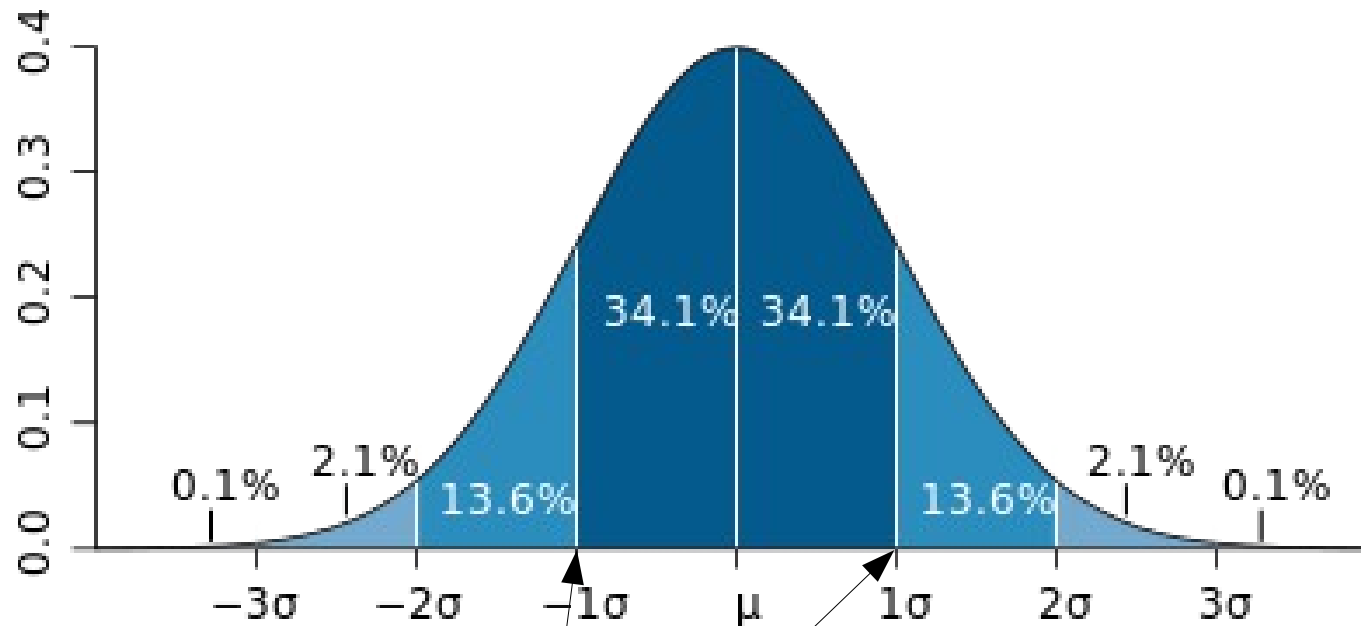
Solutions to Statistics Exercises with Mathematica

- **Pi estimate in 1 line!**
- **3D MC integration (volume) of Gaussian in 3 lines!**



Contour Plots in Mathematica

1) We need to find the region around the minimum that corresponds to the 68.3%, 95.5% or 99.7% of probability containing the true value, eg in 1D (pic from wiki)



2) Likelihood $\sim \text{Exp}[-\chi^2/2]$, so if close to Gaussian, we have to solve $\chi^2 = \chi^2_{\text{min}} + \Delta \chi^2$ (see Num. Recipes, chap 15).

Contour Plots in Mathematica

3) $\Delta\chi^2$ can be found by equating the CDF of the ChiSquare-Distribution with M dof to the probability inside n -sigmas of a Normal Distro, ie

$\text{GammaRegularized}[M/2,0,\Delta\chi^2/2]=\text{Erf}[n/\text{Sqrt}(2)]$ or

$\Delta\chi^2 = 2 \text{InverseGammaRegularized}[M/2,0,\text{Erf}[n/\text{Sqrt}(2)]]$

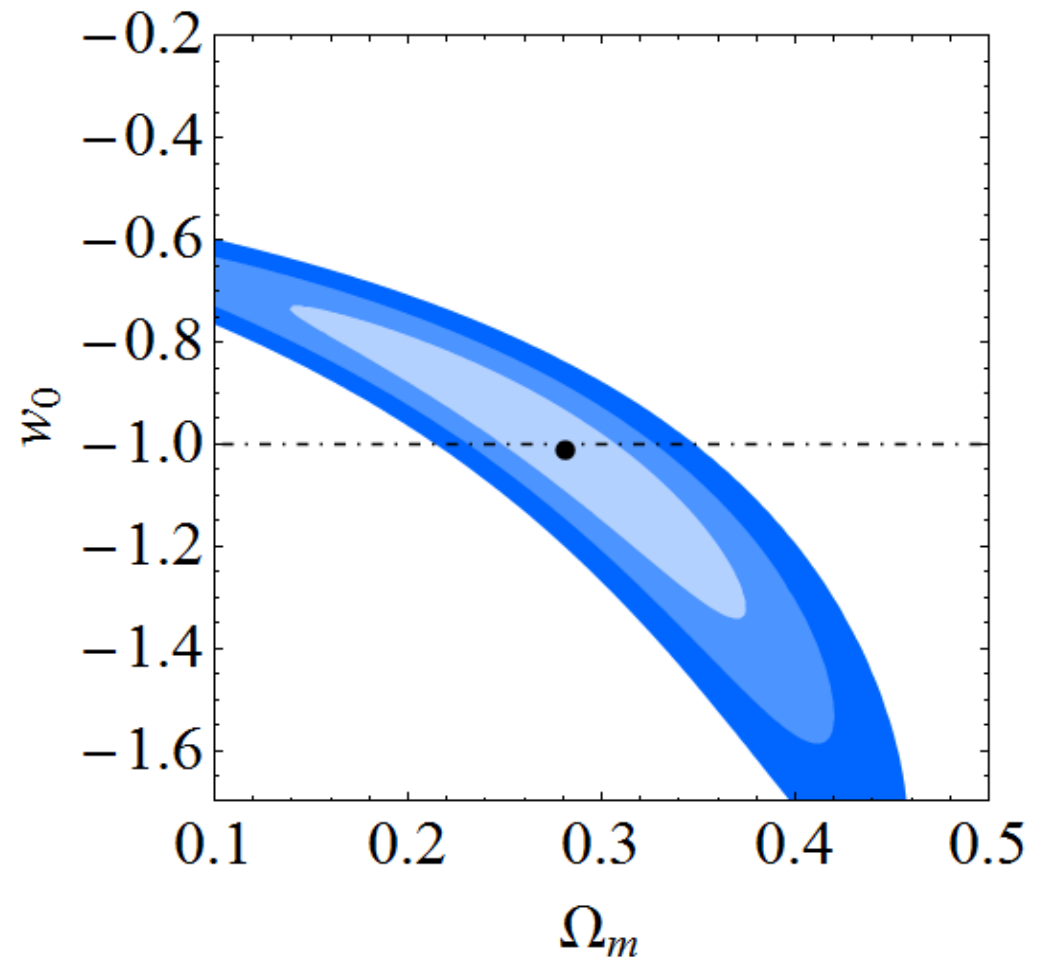
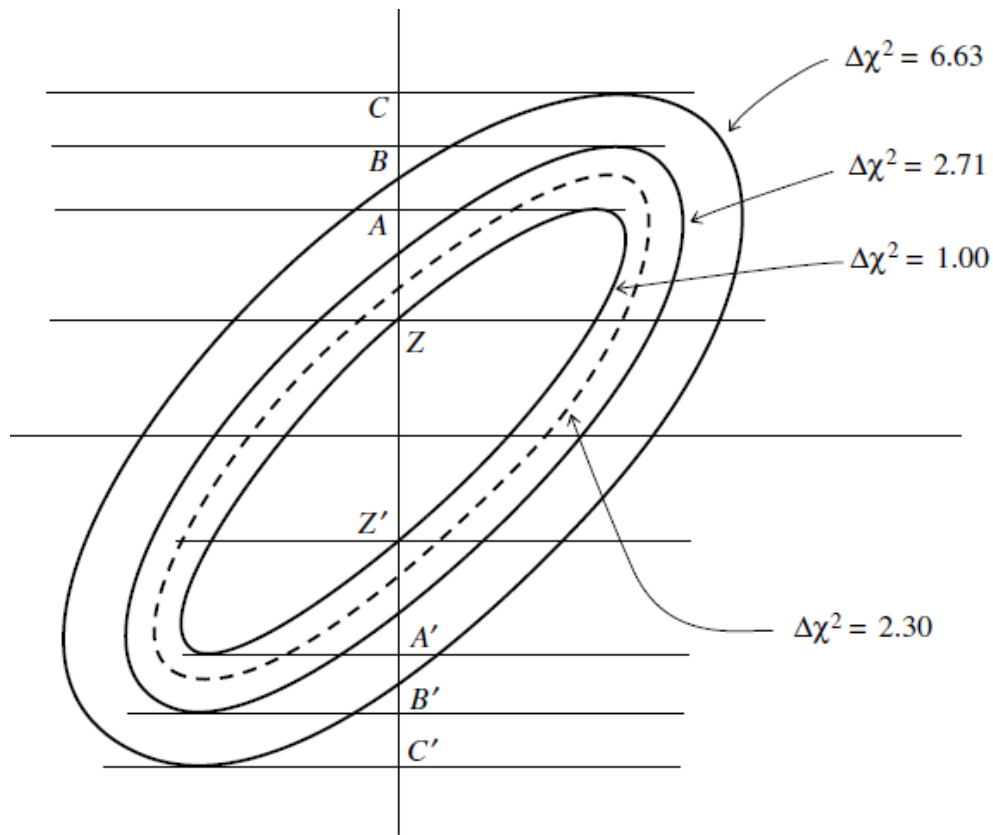
$\Delta\chi^2$ as a Function of Confidence Level p and Number of Parameters of Interest ν						
p	ν					
	1	2	3	4	5	6
68.27%	1.00	2.30	3.53	4.72	5.89	7.04
90%	2.71	4.61	6.25	7.78	9.24	10.6
95.45%	4.00	6.18	8.02	9.72	11.3	12.8
99%	6.63	9.21	11.3	13.3	15.1	16.8
99.73%	9.00	11.8	14.2	16.3	18.2	20.1
99.99%	15.1	18.4	21.1	23.5	25.7	27.9

(Table from Num. Rec., chap 15)

See uam.es/savvas.nesseris/codes
for more details + Mathematica
code

Contour Plots in Mathematica

4) In 2D for a Gaussian, the contour will be an Ellipse. If not a Gaussian, but close enough, then the contour will be banana-like ^_^



Contour Plots in Mathematica

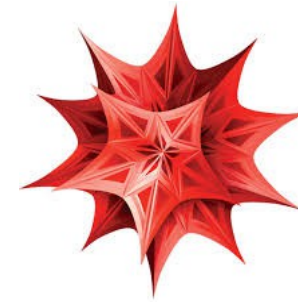
Two ways to make contours in Mathematica

1) If you know the $\chi^2(a,b)$, solve $\chi^2 = \chi^2_{\min} + \Delta \chi^2$,
example (found at uam.es/savvas.nesseris)

Example



ContourPlot



Contour Plots in Mathematica

Two ways to make contours in Mathematica

2) If you have a chain from an MCMC run

a) Find all the points that correspond to the 1, 2, 3 sigmas

b) Do some smoothing (ConvexHull+Interpolation) to get nice plots...

Mathematica Interface for CosmoMC



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