Summary Talk

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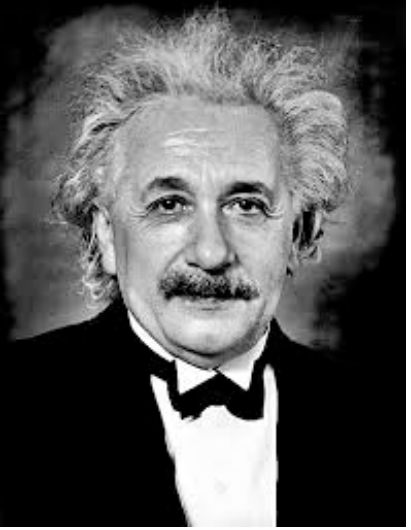
June 12 2015

Summary talk

Ceci n'est pas une pipe.

String Phenomenologists Working Hypothesis:

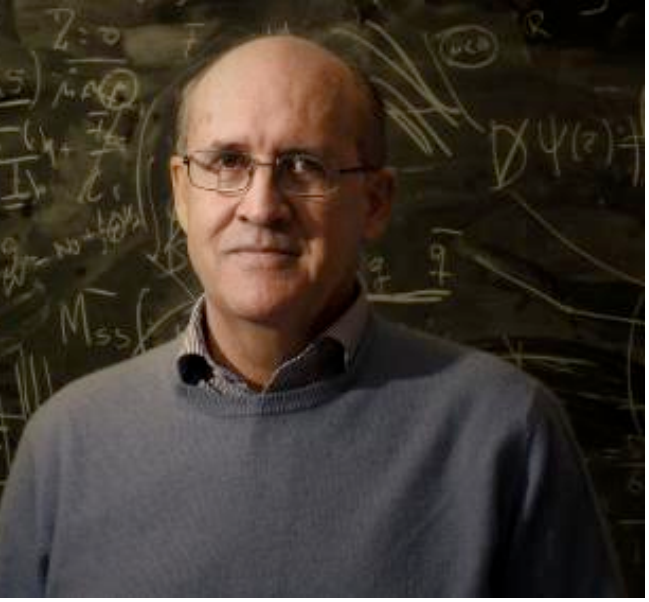
String theory scenario that satisfies all particle physics and cosmological observations and hopefully lead to measurable predictions



Einstein's "Credo"

"The most beautiful and deepest experience a man can have is the sense of the mysterious."

Albert Einstein, **"My Credo"**, 1932



Ibanez' "Credo"

"I only believe in two things: the Standard Model and String Theory"

Luis Ibanez, (a few years ago)

First Thoughts

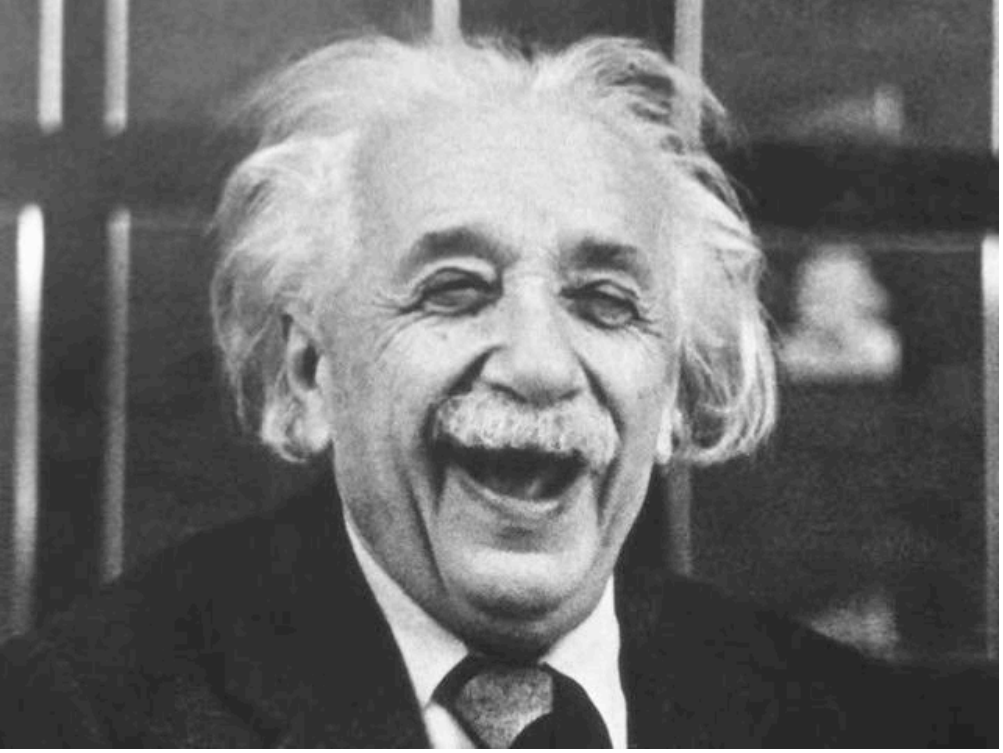
- **Standard Model of Particle physics: excellent shape!** Alcaraz, Zwirner's talks
- **Standard Model of Cosmology (ΛCDM): excellent shape!** Gratton, Ahmed talks
- **Post Higgs/Bicep depression!**

BSM: Role for String Phenomenologist?

- **Not much: the standard scientific procedure is botton-up** (experts will interpret any new experimental discovery)

- **But: Simplicity vs top-down**

  (CMSSM, ϕ^2 inflation: RIP)

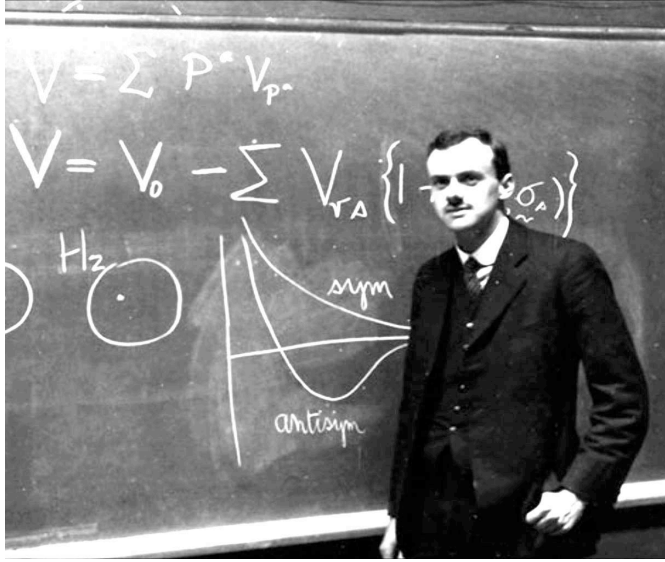


Einstein again !

“Everything should be as simple as it can be, but not simpler”

(assigned to Einstein by Louis Zukofsky 1950)

Dirac's statements



- **The discovery of the theory of relativity made it necessary to modify the principle of simplicity.**

- **We now see that we have to change the principle of simplicity into a principle of mathematical beauty.**

P.A.M Dirac: The Relation between Mathematics and Physics, 1939

Overview Plenary Talks

1. Inflation + antibranes
2. Phenomenology + WGC
3. F-theory models
4. G2/F/Heterotic models
5. “Exotics”

Inflation

Models of Inflation

- **Exponential potentials** (α-attractors,...)

  Kallosh + Linde's + Scalisi's talks

- **Axion potentials** (axion monodromy, alignement,...)

  Silverstein, Blumenhagen, Plauschin, Hebecker, Dudas, Shiu, McCallister

  +Rompinerve, Retolaza, Staessens, Ruelle, Otsuka,Kapl, Junghams... talks.

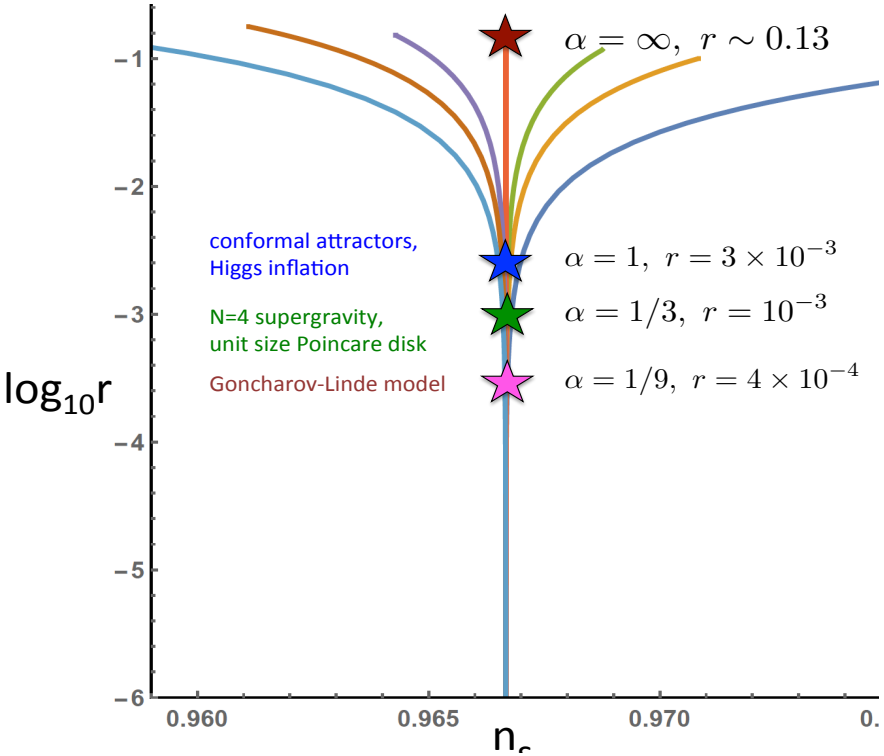
- **Higgs-otic** Pedro, Valenzuela's talks

Comments on α-attractors

$$K = -3\alpha \ln(T + \bar{T}) \qquad \mathcal{R}_K = -\frac{2}{3\alpha}$$

Moduli space curvature

$$n_s = 1 - \frac{2}{N}\,, \qquad r = \alpha \frac{12}{N^2}\,, \qquad r \approx 3\,\alpha \times 10^{-3}$$



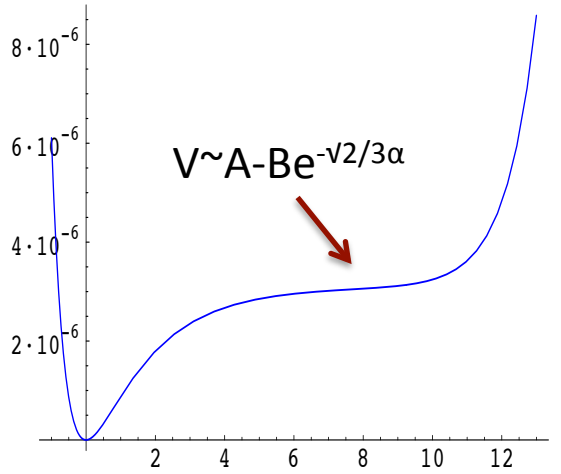
Questions:

Quantum corrections?

Stringy realisation?

Commercial

Stringy realisation of α-attractors including moduli stabilisation for

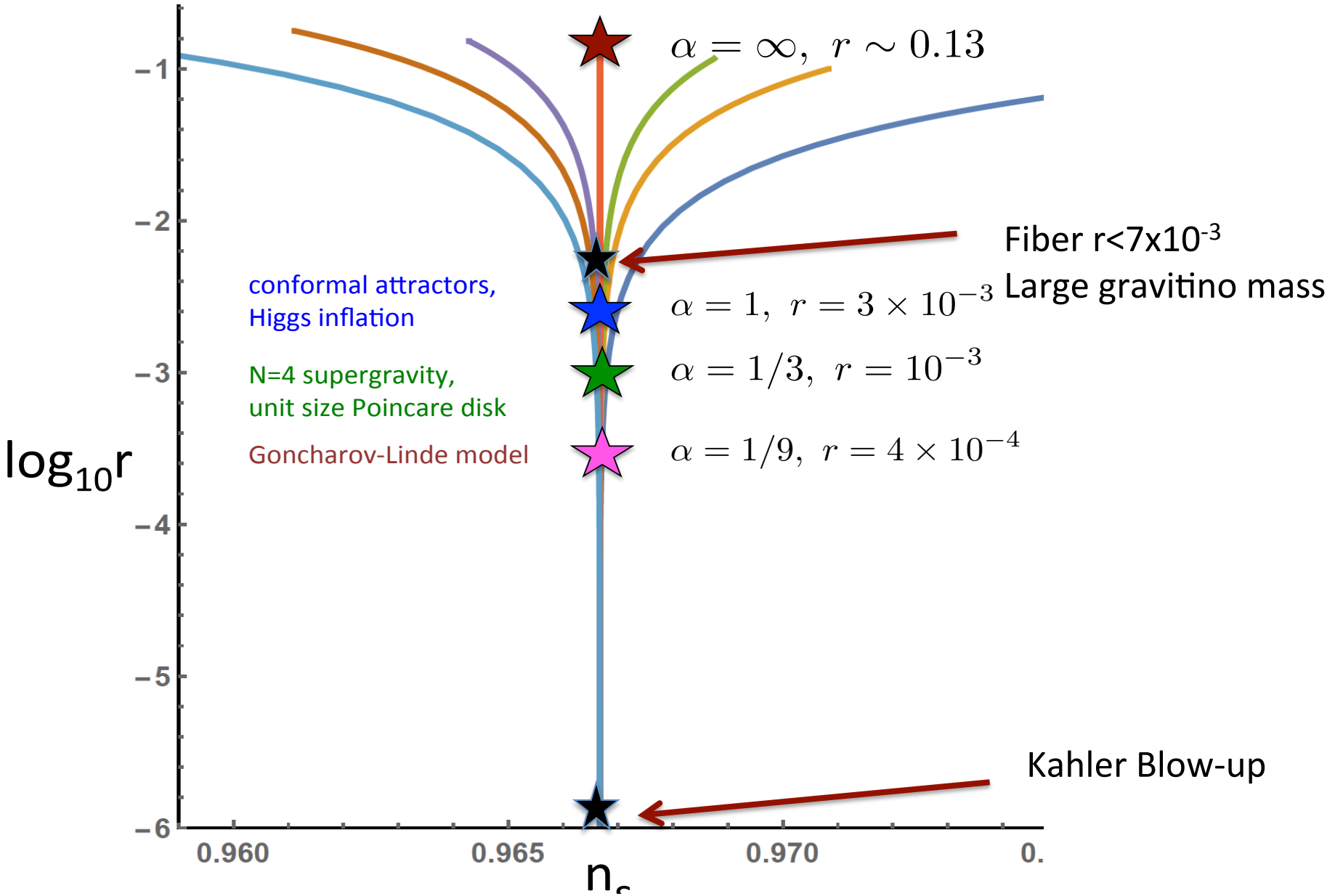


α=2 (fibre inflation) Burgess, Cicoli, FQ (2007)

$\alpha=(V\ln V)^{-1}$ (Kahler blow-up inflation)

Conlon, FQ (2006) + Sumitomo's talk

$\alpha=(\ln V)^{-1}$ (polyinstanton inflation) Cicoli, Pedro, Tasinato (2011)


$\alpha = \infty,\ r \sim 0.13$
Fiber r<7x10-3
Large gravitino mass
conformal attractors,
Higgs inflation
$\alpha = 1,\ r = 3 \times 10^{-3}$
N=4 supergravity,
unit size Poincare disk
$\alpha = 1/3,\ r = 10^{-3}$
Goncharov-Linde model
$\alpha = 1/9,\ r = 4 \times 10^{-4}$
Kahler Blow-up
log10r
−1
−2
−3
−4
−5
−6
0.960
0.965
0.970
0.
ns

Refined α-attractor

$$K = -3\,\alpha \log\left(T + \bar{T}\right) + S\bar{S}$$

$$S^2(x,\theta) = 0$$

S: Stabiliser

S appears naturally in (nonlinear) supersymmetric version of antibrane in KKLT

Consistent with small gravitino mass

Kallosh's talk

Moduli space and Escher's Angels and Devils

This is the simplest quadratic inflationary potential, with angels and devils concentrated near the boundary of the moduli space

Linde's talk

Axion inflation issues

- Weak gravity conjecture ? Shiu, McCallister, Hebecker, Soler, Witkowski, Montero's talks

- Controlled moduli stabilisation Hebecker, Blumenhagen's talk

(also issue for Higgs-otic inflation)

Antibranes

Anti-brane issues

- Singularity and its relevance Massai's talk
- Consistent effective field theory description
  Puhm's talk
- Non-linearly realised supersymmetry Kallosh's talk

LHC String Phenomenology

LHC String Phenomenology

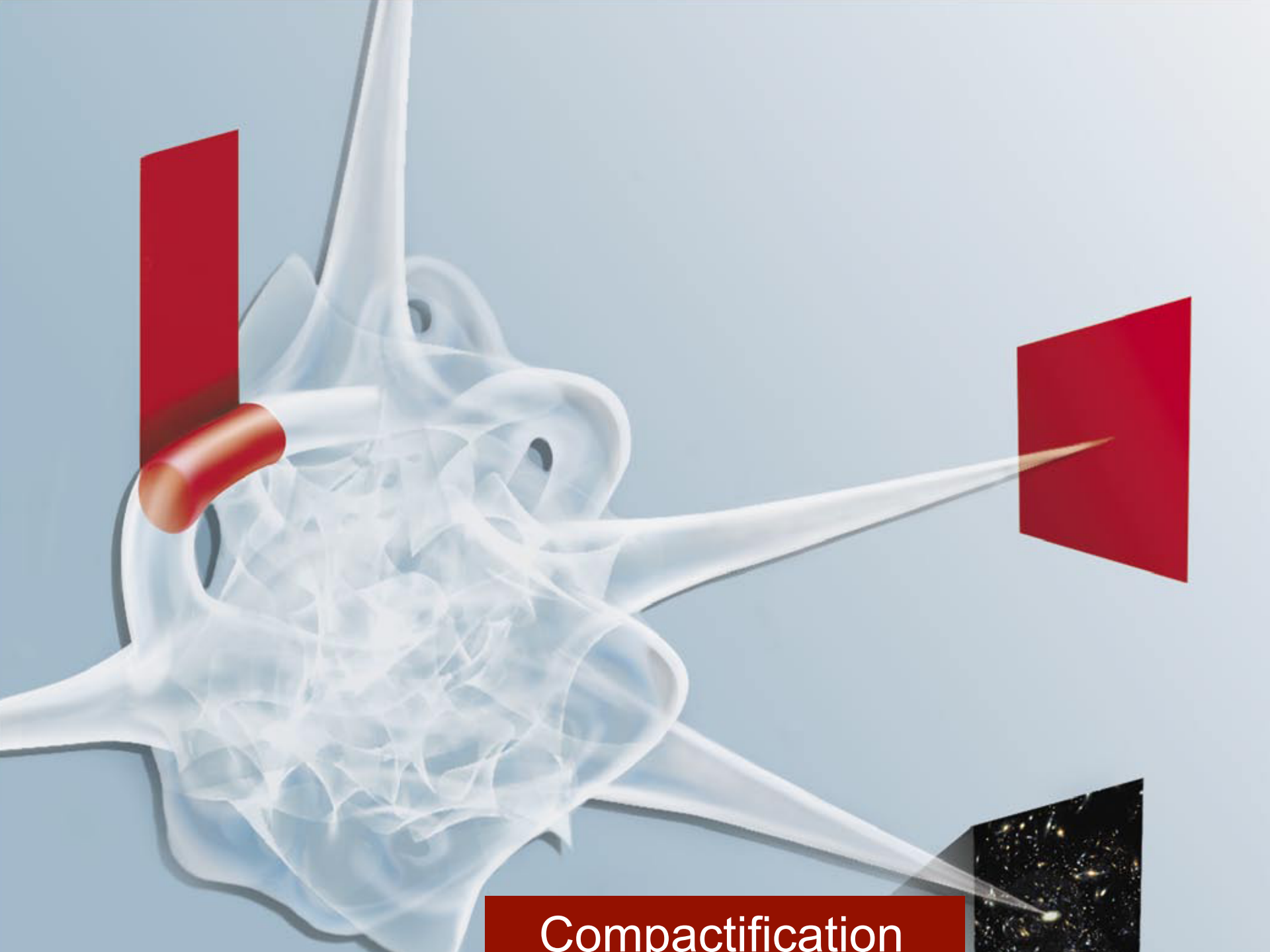
- General remarks Zwirner's talk

- Concrete soft terms calculations Cicoli + Aparicio's talks

Different SUSY Scenarios

Scenario	String Scale	W_0	$m_{3/2}$	Soft masses	CMP
Intermediate Scale	10^{11} GeV	$\mathcal{O}(1)$	1 TeV	$M_{soft} \sim 1$ TeV	Yes
Tuned GUT Scale	10^{15} GeV	10^{-10}	1 TeV	$M_{soft} \sim 1$ TeV	Yes
Generic GUT Scale	10^{15} GeV	$\mathcal{O}(1)$	10^{10} GeV	$M_{soft} \sim 10^{10}$ GeV	No
Sequestered Unsplit	10^{15} GeV	$\mathcal{O}(1)$	10^{10} GeV	$M_{soft} \sim \frac{m_{3/2}}{\mathcal{V}} \sim 1$ TeV	No
Sequestered Split	10^{15} GeV	$\mathcal{O}(1)$	10^{10} GeV	$M_{1/2} \sim \frac{m_0}{\mathcal{V}^{1/2}} \sim \frac{m_{3/2}}{\mathcal{V}} \sim 1$ TeV	No

- First two not yet obtained from dS uplifting
- 3rd: high scale SUSY breaking (e.g. Ibanez et al.)
- 4th +5th SUSY 'solve' hierarchy small 'tuning' by flux dependence of GUT soft terms.


Compactification

Soft terms for Sequestered Scenarios

Soft term	Local Models	Ultra Local dS_1	Ultra Local dS_2
$M_{1/2}$	$c_{1/2}\, m_{3/2}\, \frac{m_{3/2}}{M_P} \left[\ln\left(\frac{M_P}{m_{3/2}}\right)\right]^{3/2}$		
m_α^2	$c_0\, m_{3/2} M_{1/2}$	$c_0\, \frac{m_{3/2} M_{1/2}}{\ln(M_P/m_{3/2})}$	$(c_0)_\alpha\, M_{1/2}^2$
$A_{\alpha\beta\gamma}$	$(c_A)_{\alpha\beta\gamma}\, M_{1/2}$		
$\hat{\mu}$	$c_\mu\, M_{1/2}$ (contribution from K) $c_\mu M_P \left[\frac{m_{3/2}}{M_P}\right]^{n+1/3}$ (contribution from W)		
$B\hat{\mu}$	$c_B\, m_0^2$ (contribution from K) $c_B m_{3/2} \left[\frac{m_{3/2}}{M_P}\right]^{n+1/3}$ (contribution from W)		

The coefficients c are flux-dependent! (explicit stringy tuning at UV!)

i) Local and ultra-local dS_1: split SUSY scenario

ii) Ultra-local dS_2: standard MSSM with possible small non-universalities

Need to perform RG running down to LHC scale, study SUSY phenomenology combined with cosmological constrains from dark matter and dark radiation

Nonthermal CMSSM*

$T_{rh}<T_f=m/20$

- Assume: CMSSM parameters (M,m,A,tanβ, signμ plus T_{rh})
- REWSB with 125 GeV Higgs
- Constraints:

  Colliders (LEP, LHC)

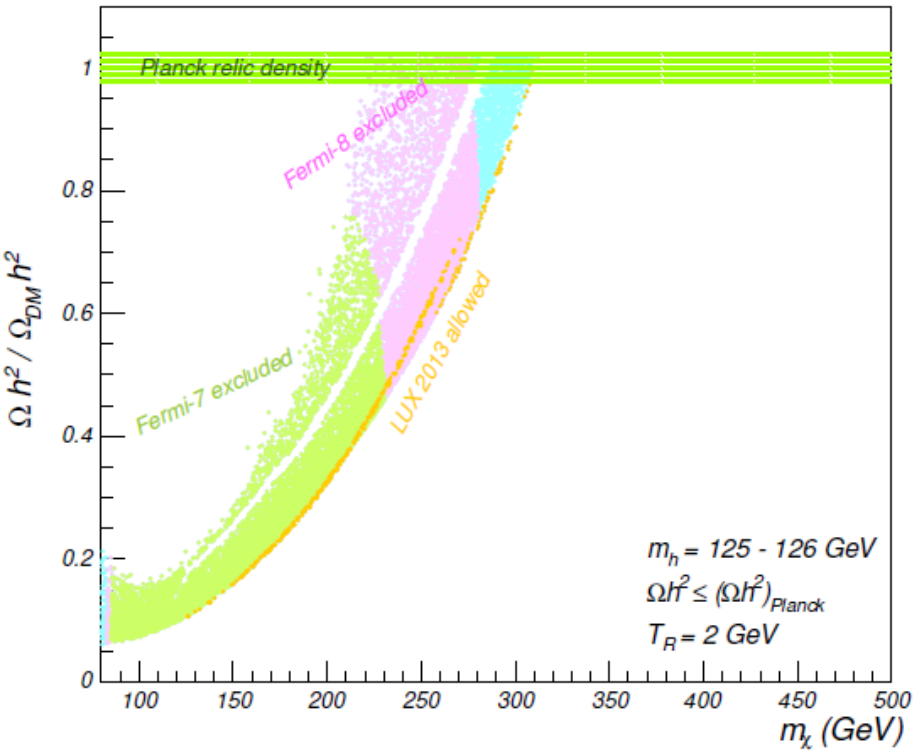
  CMB (Planck)

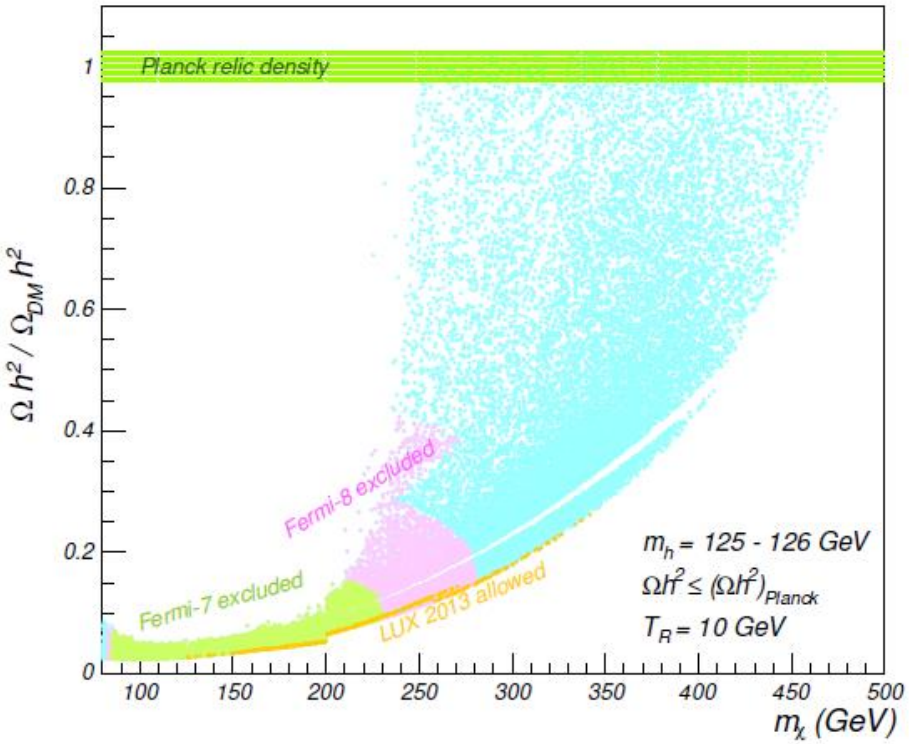
  Direct (LUX, XENON100, CDMS, IceCube)

  Indirect (Fermi)

* Warning: at this stage is purely phenomenological not stringy!

Survivors



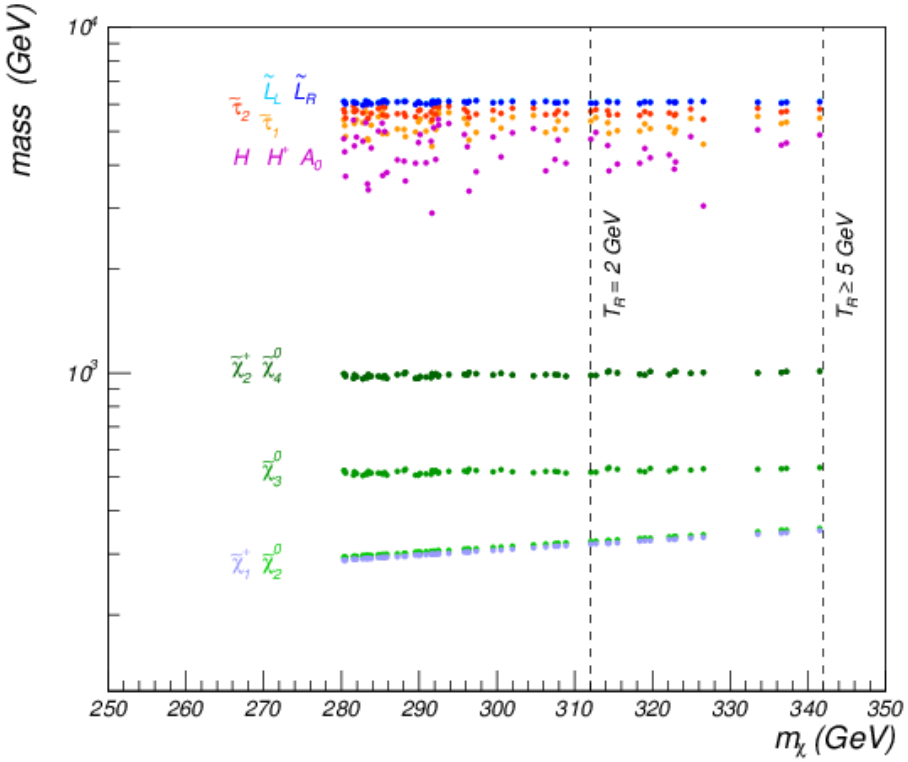


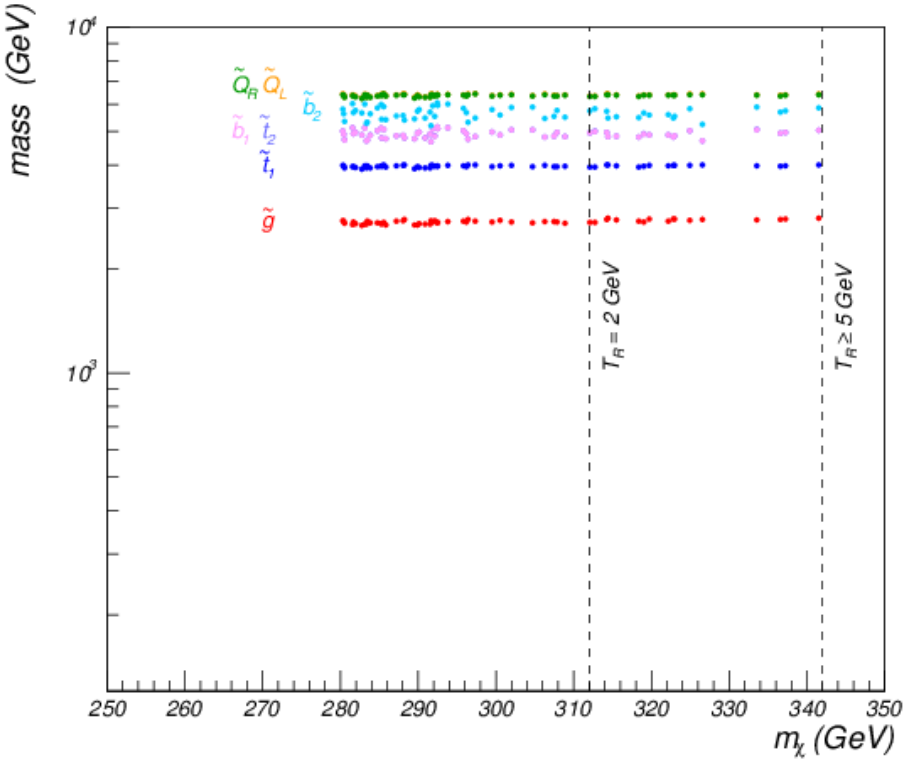
Neutralino Higgsino-like saturates Planck's density for m=300 GeV, T_{rh}=2 GeV

Adding nonuniversalities increase allowed parameter space

Aparicio's talk

Spectrum


mass (GeV)
10^4
10^3
$\tilde{L}_L$ $\tilde{L}_R$
$\tilde{\tau}_2$ $\tilde{\tau}_1$
H H^+ A_0
$\tilde{\chi}_2^+$ $\tilde{\chi}_4^0$
$\tilde{\chi}_3^0$
$\tilde{\chi}_1^+$ $\tilde{\chi}_2^0$
$T_R = 2$ GeV
$T_R \geq 5$ GeV
250 260 270 280 290 300 310 320 330 340 350
m_χ (GeV)


mass (GeV)
10^4
10^3
$\tilde{Q}_R$ $\tilde{Q}_L$ $\tilde{b}_2$
$\tilde{b}_1$ $\tilde{t}_2$
$\tilde{t}_1$
$\tilde{g}$
$T_R = 2$ GeV
$T_R \geq 5$ GeV
250 260 270 280 290 300 310 320 330 340 350
m_χ (GeV)

Non Standard SUSY Physics

- **Soft terms much lighter than gravitino**
- **Lightest modulus much lighter than gravitino**
- **Light reheating temperature**
- **Nonthermal dark matter**
- **Gravitino mass and inflation scale** see Kallosh talk
- **Dark radiation issue** see Muia's talk

Model Building

Model Building

- **F-theory** (talks by: Palti, Weigand, Klevers, Schaeffer-Nameki, Krippendorf, Leontaris, Lin, Taylor, Grimm, Watari, Garcia-Etxeberria, Mayorga, Colinucci, Gray, Anderson, Baume, Oehlman, Till, ..)

- **Heterotic** (supersymmetric and non supersymmetric)
  (talks by Anderson, Vaudrevange, Lukas, Groot-NIbbelink, Mavroudi, Kuwakino, Athanasopoulos, Ashfaque...)

- **G2 manifolds** (talk by Halverson)

- **D-branes** (Berasaluce-Gonzalez,...)

F-Theory

- U(1)'s and discrete symmetries under much better control
- Improved model building
- Statistics and classifications (Taylor, Watari, Gao, Gray, see also Marsh, Nelson)
- Effective field theory open...?

Moduli Stabilisation

Moduli Stabilisation

- Non geometric fluxes (Blumenhagen, Plauschin, Shukla,...)
- General constraints for inflation(Dudas, Hebecker)
- de Sitter (Rummel, Soussa, ...)
- D-brane moduli (Regalado)
- Others (Angus, Ciupke)....

Effective Field Theory

Effective Field Theory

- Warped Kahler potential (Martucci's talk)

- Yukawa's in heterotic (Lukas' talk)

“Exotics”

Post Inflation Cosmology

- **ALP's and dark matter** (Conlon, Takahashi and Martin Lozano's talks)
- **Dark radiation** (Muia's talk)
- **Nonthermal history** (Aparicio's talk)
- **Anthropics** (Talk Schellekens, after dinner speech Linde!)

Also: Neutron-antineutron oscillations (Bianchi, Addazzi)

Conclusions

- Interesting recent developments
- Continuously progressing field
- Concrete achievements
- Some open debates
- Long term goals
- Well defined open questions (remember bow)
- The field is well and alive!
- Hopefully experimental results will change it radically soon....

F. Quevedo Statements

Es cosa averiguada, así lo siente Metrodoro Chío y otros muchos, que no se sabe nada, y que todos son ignorantes, y aun esto no se sabe de cierto, que a saberse ya se supiera algo; sospéchase. Dícelo así el doctísimo Francisco Sánchez, médico y filósofo, en su libro cuyo título es *Nihil Scitur,* no se sabe nada. En el mundo hay algunos que no saben nada y estudian para saber, y estos tienen buenos deseos y vano ejercicio, porque al cabo solo les sirve el estudio de conocer cómo toda la verdad la quedan ignorando. Otros hay que no saben nada y no estudian porque piensan que lo saben todo; son destos muchos irremediables; a estos se les ha de invidiar el ocio y la satisfactión y llorarles el seso. Otros hay que no saben nada y dicen que no saben nada porque piensan que saben algo de verdad, pues lo es que no saben nada, y a estos se les había de castigar la hipocresía con creerles la confesión. Otros hay, y en estos, que son los peores, entro yo, que no saben nada, ni quieren saber nada, ni creen que se sepa nada y dicen de todos que no saben nada y todos dicen dellos lo mismo y nadie miente. Y como gente que en cosas de letras y sciencias no tiene que perder tampoco, se atreven a imprimir y sacar a luz todo cuanto sueñan.

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Francisco de Quevedo y Villegas
Great Spanish writer XVII century

Rough Translation

It is understood that nothing is known and that we are all ignorants and even this is not known since if it were known we would already know something...In the world there are some that know nothing and study in vain to learn. Others that know nothing and claim that they know nothing because they think they know something...Others, including myself, are the worst since they know nothing and don't want to know anything since they think nothing is known and claim nobody knows anything and the others say the same about them and nobody lies...

Thank you Luis, Angel and Fernando (La Casta)!

and

All others who helped to make this a great conference!