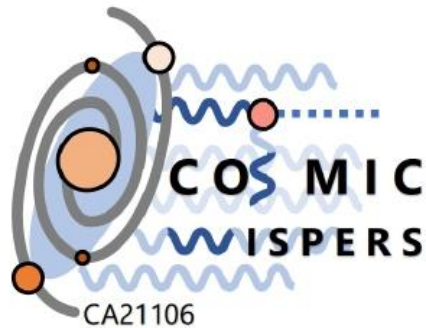


WG1: WISPs Model Building

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Bologna Univ. and INFN

2nd General Meeting COSMIC WISPers, 4 Sept 2024



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ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

WG1: Main goal

Tasks:

- Coordinate **theory advances** and promote **knowledge exchange**
- Give **theoretical guidance** to experiments
- Determine nature, number, masses and couplings of **WISPs** with applications to particle physics, cosmology and astrophysics via **2** complementary approaches:

1) **Bottom-up**: indication of **WISP** models promising for pheno

UV scenarios compatible with observations



phenomenology in low-energy effective field theory

2) **Top-down**: restrict **WISP** models from UV consistency (string theory)

UV complete model building



UV constraints on WISP properties


WG1: Organisation

- Leader: Michele Cicoli (Bologna) michele.cicoli@unibo.it
- Co-leader: Sophie Renner (Glasgow) sophie.renner@glasgow.ac.uk
- Google group “CosmicWISPers WG1”:
<https://groups.google.com/g/cosmicwispers-wg1/>
- 102 members so far
- Mailing list: cosmicwispers-wg1@googlegroups.com

WG1: Activities during year 2

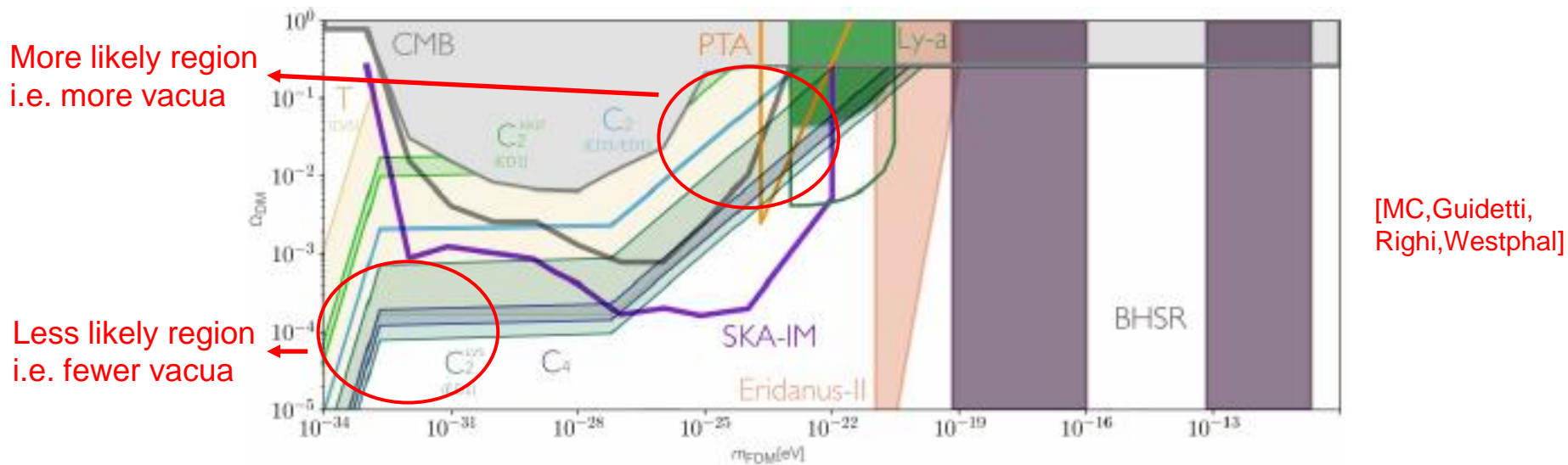
- Contributions to **organisation**:
 - i) Working group Meeting, 1-2 Feb 2024, Hamburg
 - ii) 2nd Training School, 11-14 Jun 2024, Ljubljana
 - “Axion theory”, Lecturer: G. Villadoro (ICTP, Trieste), Trainer: R. Petrossian-Byrne (ICTP)
 - iii) 2nd General Meeting, 3-6 Sep 2024, Istanbul
 - Plenary: A. Westphal, J. Leedom, M. Raidal, F. Pedro
 - Parallel: A.Sokolov, N.Righi, G.Villa, A.Racioppi, L.Brunelli, A.Schachner, C.Eroncel, A.Maharana, B.Pulice
- **Outreach talk**: “The infinity, the electron and the string”
Michele Cicoli, Occhialini Foundation, 5 April 2024, Pesaro (Italy)
- **Monthly WG1 meetings**:
 - i) Online via Zoom on Mondays at 2pm CET
 - iii) Duration: 1 hour: 30 minute talk by an invited speaker + 30 minute discussion
- **Joint meeting** with other WGs on “Non-axionic solutions of the strong CP problem”, 27 May 2024
 - i) Two invited speakers: Arsenii Titov, Carlos Tamarit
 - ii) Duration: 1 hours: 20 minute talks by each speaker + 30 minute discussion
- Contribution to writing up of **White Paper**
 - i) WG1 Editors: A. de Giorgi, N. Righi, M. Reig Lopez
 - ii) WG1 chapter: Low-energy WISP models from string theory, WISP model building in QFT, WISP EFT
- **STSM**: Gonzalo Villa from Cambridge to Bologna

WG1: Future activities

- Contributions to **organisation** of meetings and training schools
- **Dissemination** talks at major conferences and **outreach** activities
- Monthly WG1 **meetings**:
Same format for year **3**: topical discussions, invitation of external speakers, recent papers...
- More **STSM**: please apply!
- In year **3**: organise a **3-day WG1 workshop** in person (in Bologna?)
focused on a specific topic: axions? hidden photons? dark sector physics?
- Deliverables:
 - i) **talks** at major conferences and workshops
 - ii) **publications** on top refereed journals
 - iii) contribution to the writing up of **white paper** and **scientific reports**
 - iv) increase **interactions with other WGs**
 predictions from UV motivated classes of models superimposed on exclusion plots
- Suggestions!

Road to UV predictions

- Dream: UV-motivated predictions superimposed on exclusion plots for WG2, 3 and 4
- Is it doable with a **landscape** of 4D solutions from string theory?
 - Yes** but just for classes of motivated models with probability of each point in a band

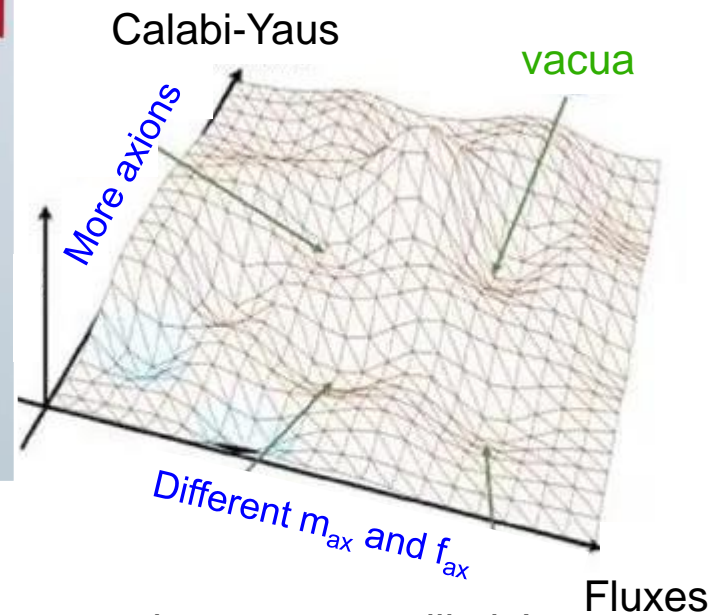
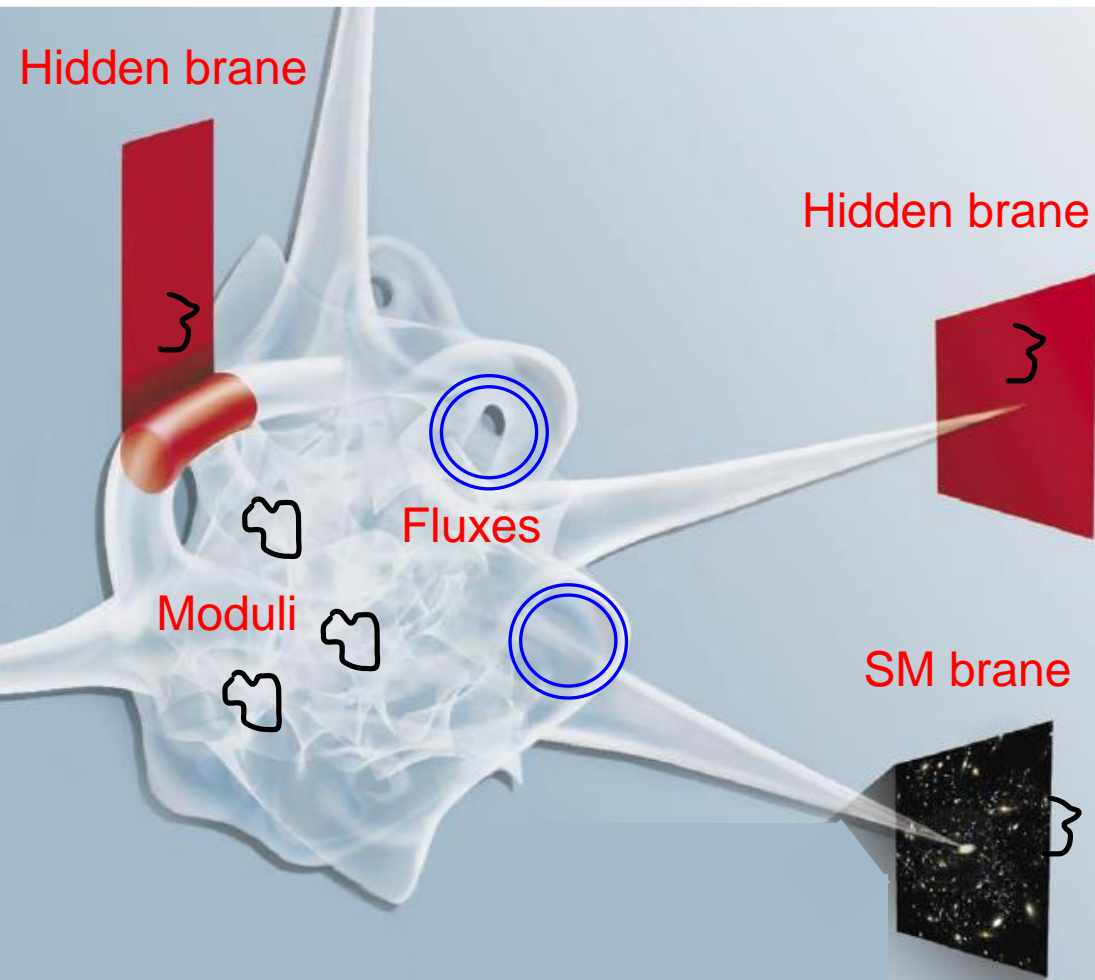


- Better to search for **scenarios** more than models
generic stringy signatures (especially if they are not motivated from **QFT** viewpoint):
 - O(100)** ultra-light **axions** with **gravitational** couplings
applications: fuzzy dark matter, dark radiation, stellar cooling, quintessence, early dark energy...
 - Non-standard cosmological histories with **early matter domination** or **kinetic domination**
applications: dilution effects on dark matter, baryogenesis, GWs, dark radiation, growth of pert...

String compactifications

- String theory lives in **10D** and needs **SUSY** for consistency
- Compactification: $X_{10D} = M_{4D} \times Y_{6D}$
- **4D EFT** for $E \ll M_{\text{KK}} = \text{Vol}(Y_{6D})^{-1/6}$
- **Geometrical** and **topological** properties of Y_{6D} determine **4D** physics
- **N=1 SUSY** in **4D** if Y_{6D} is a Calabi-Yau manifold \longrightarrow **chiral** theory \longrightarrow realistic!
- Y_{6D} can be deformed in **size** and **shape**
 - maths**: deformations parametrised by **moduli**
 - 4D physics**: moduli ϕ are **new** scalar particles with gravitational couplings and **axionic** partners
- Only 1 **free** parameter: string length \longrightarrow all properties of EFT are ϕ -dependent
 $g_{\text{YM}}(\phi), Y_{ijk}(\phi), M_{\text{SUSY}}(\phi), m_{\text{ax}}(\phi), m_{\phi}(\phi), H_{\text{inf}}(\phi), \Lambda(\phi), \dots$
- Need to know ϕ to make predictions
 \longrightarrow **moduli stabilisation**: develop $V(\phi)$ to fix $\langle\phi\rangle$ at minimum
- $V(\phi)$ sourced by **background fluxes** = **non-zero VEVs** of **anti-symmetric forms**
- **2** choices:
 - Calabi-Yau topology gives number of moduli and axions
 - VEV of fluxes determines $\langle\phi\rangle$ \longrightarrow **landscape** of string vacua $\sim 10^{500}$

4D string models



Different fluxes can also yield same m_{ax} and f_{ax} \longrightarrow some values are more likely!

Different vacua but common features

- Questions with no answer without UV completion \longrightarrow need UV physics for consistency
- Vacuum-independent mechanisms:
 - 1: What is the origin of QCD axion shift symmetry? higher dimensional gauge symmetry
 - 2: What dynamics breaks $U(1)_{PQ}$ spontaneously and sets f_a ? non-linear realisation in EFT
 - 3: Is f_a related to some scale M_p , M_s , M_{kk} , M_{GUT} , M_{soft} ? M_{kk} for bulk and M_s for local cycles
 - 4: What breaks $U(1)_{PQ}$ explicitly and sets m_a ? stringy instantons/gaugino condensation
 - 5: Is m_a generated by QCD instantons or other effects? QCD instantons if EFT is under control
 - 6: What solves the axion quality problem? perturbative shift symm + control over EFT
- Vacuum-dependent issues:
 - 1: How is the axion produced in the early universe? Misalignment/moduli decay
 - 2: How many ALPs can arise? CY-dependent issue
 - 3: What is the parameter space of f_a and m_a for ALPs? determined by fluxes
 - 4: What can be the role of ALPs in phenomenology?
Inflation? Dark matter? Dark radiation? Quintessence? Astrophysical signals?
 - 5: How are ALP f_a and m_a statistically distributed in the string landscape?
 - 6: Are there UV correlations among ALP f_a and m_a and different physics?
like supersymmetry breaking, inflation, dark matter, dark radiation, etc...
 - 7: What are the properties of hidden photons with kinetic mixing with ordinary photons?
 - 8: Can we build from string theory fully consistent WISP models?
instead of just string-inspired scenarios
 - 9: Can we study WISPs in non-perturbative limits? Interesting for pheno?