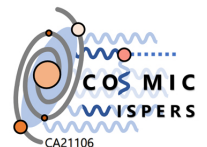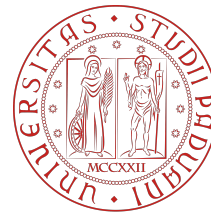# MC meeting

2nd General Meeting of COST Action COSMIC WISPers (CA21106), Istanbul, Turkey September 6, 2024

Edoardo Vitagliano
edoardo.vitagliano@unipd.it
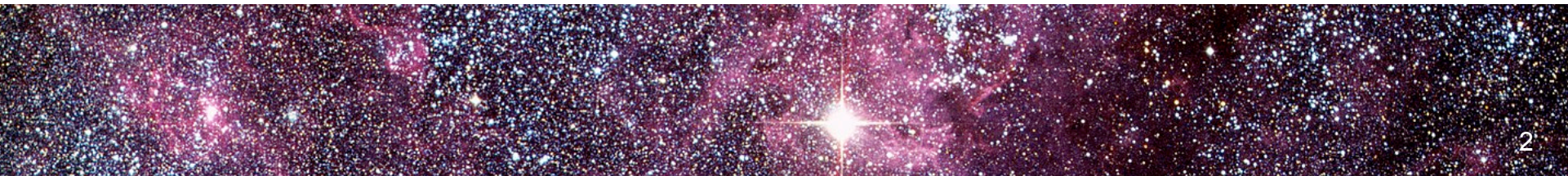University of Padua and INFN Padua

Credit: ESO (eso0708a), Buschmann et al. (2021)

Working group 2 in a glance

Many questions:
- WISPs are a great DM candidate—how many ways to produce them?
- Different non-thermal processes, misalignment mechanism, phase transitions, topological defects networks
- If QCD axion is *the* DM, can we reliably predict its mass and couplings?
- What is the abundance of miniclusters? Huge consequences for WG3 and WG4

Working group 2 in a glance

Different
production mechanisms

Hot DM component

WISPs
DM and cosmology

Phase transitions

Lattice QCD
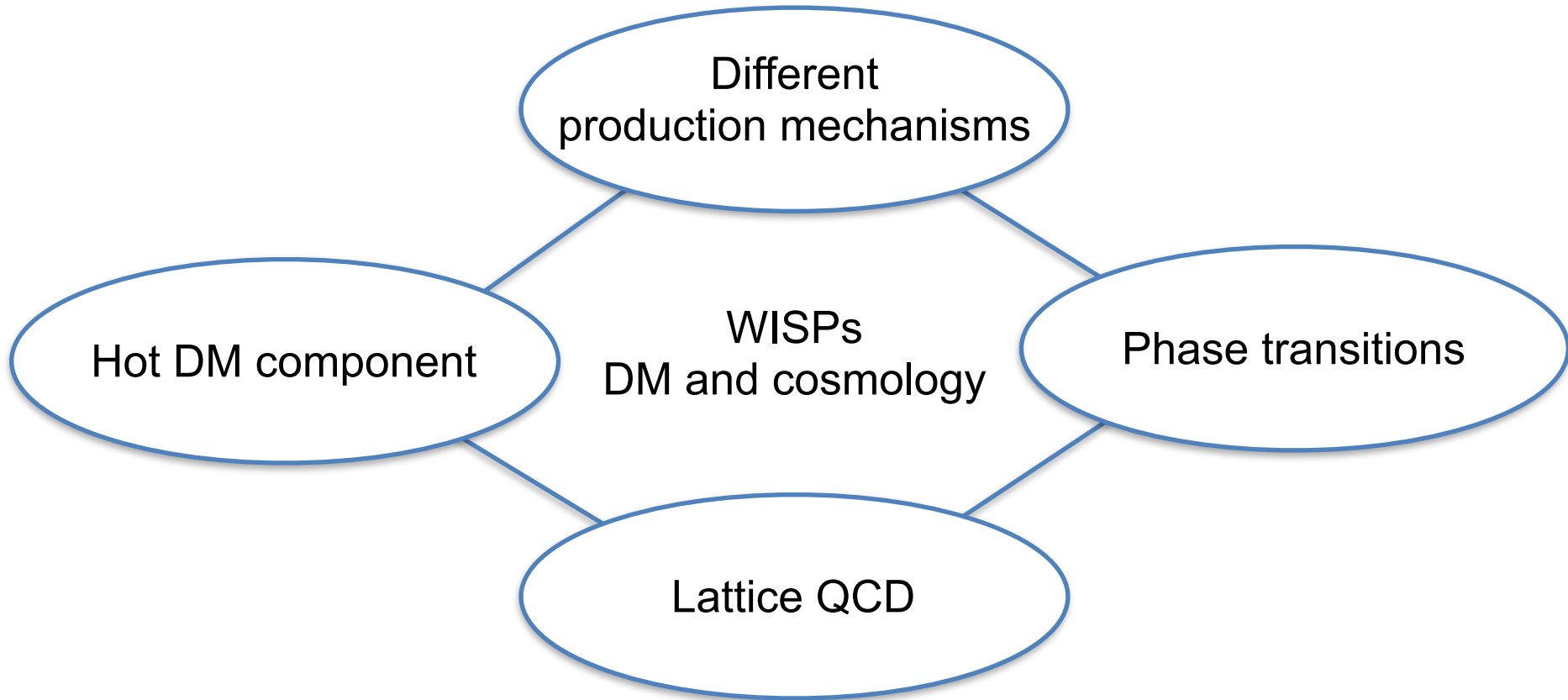
A large community with many different expertises

- More than 200 people in the WG (September 2024)

- Great overlap with all the other WGs (unsurprisingly!)

- Several activities organized together with WG3 in the past years

Coordinators

Marco Gorghetto (DESY)   Edoardo Vitagliano (U. of Padua)

WG2 activities during year 2

- Organization of general events:

  - Working group meeting 1-2 Feb 2024, Hamburg

  - 2nd Training School, 11-14 Jun 2024, Ljubljana
    "Axions in early universe and cosmo bounds". Lecturer: Benjamin Safdi (UC Berkley). Trainer: Toby Opferkuch (SISSA)

- 2nd General Meeting, 3-6 Sep 2024, Istanbul

  - Plenary: C. Garcia Cely, L. Visinelli, F. D'Eramo, E. Pinetti, E. Hardy, M. Boskovic, E. Todarello, A. Davis

  - Parallel: K. Muursepp, F. Giacchino, C. Smarra, S. Gasparotto, M. Kaltschmidt, G. Pierobon, T. O'Shea, M. Crnogorcevic, M. Vanvlasselaer, A. Lenoci, O. Ghosh, L. Hamolli

Many Short Term Scientific Missions

- C. Käding
- J. Eby
- M. Benito Castaño
- M. Caruana
- P. De la Torre Luque
- D. Gavilán Martín
- G. Lukasiewicz
- J. Leedom
- S. Balaji
- N. Barbieri
- A. Lella
- M. Kaltschmidt
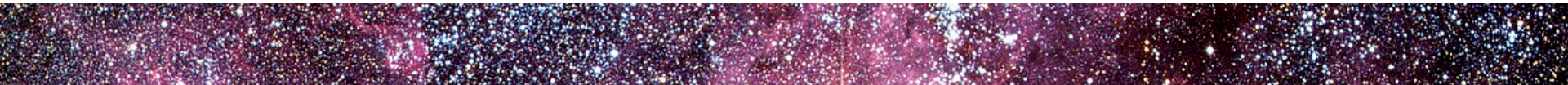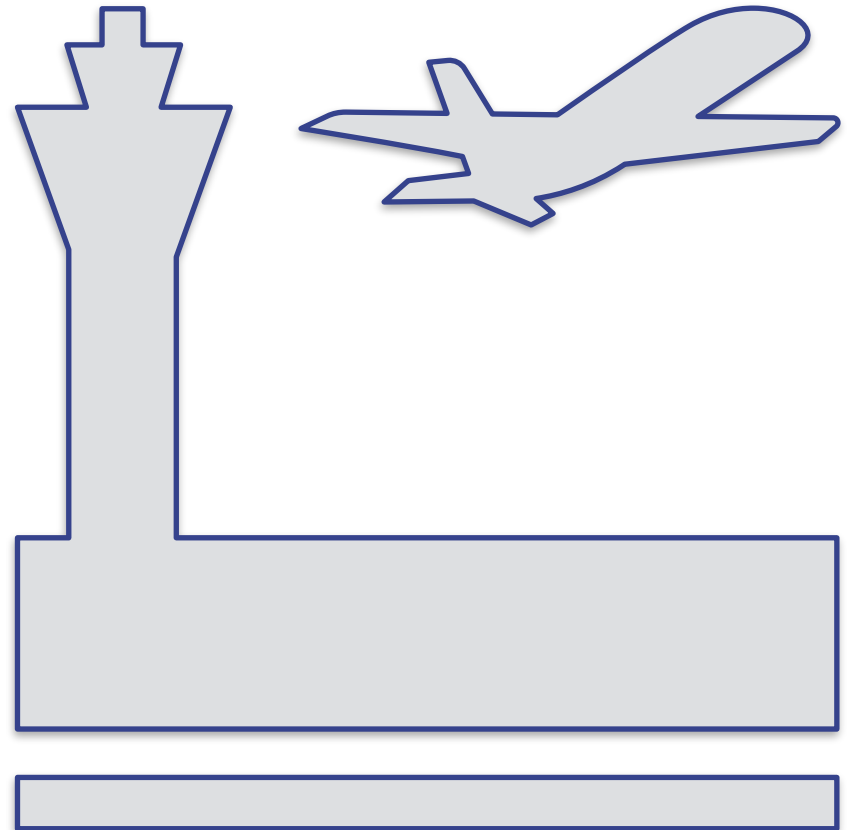
Ongoing White Paper

Editors: A. Drew, S. Gasparotto, Marco Gorghetto, M. Kaltschmidt, E. Vitagliano

WISPs in Cosmology

(A) Axion cosmology

1 Predictions of Axion Mass from Misalignment: Status of Lattice Simulations on Topological Susceptibility and Axion Potential

Claudio Bonati, Maria Paola Lombardo

2 Comparison of String Network and Domain Wall Simulations: Range of Axion Mass

Kenichi Saikawa, Malte Buschmann, Amelia, Mathieu

3 Axion Dark Matter small-scale structure (miniclusters, axion stars)

Ciaran O'Hare, Joshua Eby, Giovanni Pierobon

4 Axions as hot/warm dark matter: Status of Calculation of Axion Thermalization rate, Bounds for Planck

Francesco D'Eramo

(B) WISP cosmology

5 Axion-like particles and ultralight dark matter

1. Jeans scale, suppression of perturbations, effect on structure formation, and cosmological bounds

   Keir Rogers, Diego Blas

2. ALPs as dark energy and as the inflaton (theory/models; observables/bounds)

   S. Gasparotto, Ippei Obata , Elisa Ferreira

3. Gravitational/gravity wave signatures

6 Dark Photons

1. Production mechanisms (from inflation, parametric resonance...)

   Wolfram Ratzinger, Lorenzo Ubaldi, Marco Gorghetto

Past activities

Together with WG3, we have organized a timely online mini workshop on NANOGrav results in 2023

Wednesday, 5th of July

- 3pm Prof. Alberto Sesana, **Nano-Hz gravitational waves: first evidence and implications**

From 4pm on the same day

- Fabrizio Rompineve (CERN), **Footprints of the QCD Crossover on Cosmological Gravitational Waves at Pulsar Timing Arrays**
- Yann Gouttenoire (Tel Aviv University), **TBC**
- Marek Lewicki (University of Warsaw), **Cosmic Superstrings Revisited in Light of NANOGrav 15-Year Data**
- Antonio Iovino (La Sapienza University of Rome), **The recent gravitational wave observation by pulsar timing arrays and primordial black holes: the importance of non-gaussianities**
- Anish Goshal (University of Warsaw), **Probing the Dark Matter density with gravitational waves from super-massive binary black holes**

Planning ahead

T2.1: Perform accurate numerical simulations to obtain precise predictions of axion and WISP DM relic abundance.

- Subtask 2.1.1: Perform additional simulations of the evolution of the string network to obtain the number density of QCD axions that contributes to DM.
- Subtask 2.1.2: Perform QCD lattice simulations at the QCD phase transition to improve the knowledge of the temperature dependence of the axion mass, which affects the relic abundance.
- Subtask 2.1.3: Perform lattice QCD simulation to determine the axion-pion thermalization rate and determine a reliable hot-dark matter axion bound.
- Subtask 2.1.4: Compile a list of WISP DM candidates and their production mechanisms, in order to identify calculations required to improve relic abundance predictions, and also to clarify whether the WISP-DM parameter space is fully explored.

T2.2: Study the formation of Large Scale Structures (LSSs) in various WISP scenarios.

- Subtask 2.2.1: Perform numerical studies of the growth of inhomogeneities in QCD axion DM, from the QCD phase transition onwards.
- Subtask 2.2.2: Study the formation of Large Scale Structures (LSSs) in various WISP scenarios and work to obtain a public code that could describe ALPs and QCD axions impact on LSS.

Planning ahead

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NEXT SLIDE STMT EXAMPLE

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T2.2: Study the formation of Large Scale Structures (LSS

PART OF THE WHITE PAPER

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Fostering collaboration: axion mass

- One of the issues that could contribute to the discrepancies in the literature (interpretation of the emission spectrum and especially the associated spectral index q and its direct relation to the prediction of the axion DM mass) is that everybody is using their own code(s) to run the simulations

- Mathieu Kaltschmidt visited Amelia Drew at the DAMTP in Cambridge thanks to the COST action

- Different initial conditions can play a role

- Comparison for some benchmark between different codes (jaxions, GRChombo, axioNyx, sledgehamr)

- Ongoing work by Mathieu on it (thanks for the update!)

This workshop

WG1: Which particle models are interesting?

WG2: Computing the abundance, large overlaps with numerical simulation communities

WG3: Effects on astrophysical bounds!

WG4: Effects on laboratory searches!

WG5: Nice plots and visualizations, good help for outreach