Deep CosmoStat Days

Rapport sur les contributions

https://indico.in2p3.fr/e/38088

ID de Contribution: **1** Type: **Non spécifié**

A plug-and-play approach with fast uncertainty quantification for weak lensing mass mapping

jeudi 12 février 2026 11:30 (20 minutes)

Stage-IV surveys such as Euclid will deliver vast amounts of high-precision data, opening new opportunities to constrain cosmological models with unprecedented accuracy. A key step in this process is the reconstruction of the dark matter distribution from noisy weak lensing shear measurements. Current deep learning-based mass mapping methods achieve high accuracy, but either require retraining a model for each new observed sky region (limiting practicality) or rely on slow MCMC sampling. Efficient exploitation of future survey data therefore calls for a new method that is accurate, flexible, and fast at inference. In addition, uncertainty quantification with coverage guarantees is essential for reliable cosmological parameter estimation. In this talk, we introduce PnPMass, a plug-and-play approach for weak lensing mass mapping. The algorithm produces point estimates by alternating between a gradient descent step with a carefully chosen data fidelity term, and a denoising step implemented with a single deep learning model trained on simulated data corrupted by Gaussian white noise. We also propose a fast, sampling-free uncertainty quantification scheme based on moment networks, with calibrated error bars obtained through conformal prediction to ensure coverage guarantees. Finally, we benchmark PnPMass against both model-driven and data-driven mass mapping techniques. PnPMass achieves performance close to that of state-of-the-art deep-learning methods while offering fast inference (converging in just a few iterations) and requiring only a single training phase, independently of the noise covariance of the observations. It therefore combines flexibility, efficiency, and accuracy, while delivering tighter error bars than existing approaches, making it well suited for upcoming stage-IV weak lensing surveys.

Orateur: LETERME, Hubert (CEA IRFU/DAp)

ID de Contribution: **2** Type: **Non spécifié**

Inferring 3D shapes and measuring intrinsic alignments of galaxies with UNIONS

jeudi 12 février 2026 15:25 (20 minutes)

Galaxies are subject to intrinsic alignments, which correspond to the correlations between their 3D shapes and orientations and the underlying tidal field of dark matter across the large-scale structure of the Universe. This intrinsic galaxy alignment is traditionally measured with the two-point galaxy-density correlation function projected in the sky plane. However, the projection of 3D shapes introduces an important loss of information about the alignment along the line of sight. In this talk, I will present a novel method that recovers this information by inferring the distribution of 3D galaxy shapes from the observed 2D images using likelihood-free simulation-based inference. I use the AbacusSummit N-body simulation to extract dark matter halos, in which galaxies are populated using a Halo Occupation Distribution (HOD) model. This simulation serves as model for imaging data from the Ultraviolet Near-Infrared Optical Northern Survey (UNIONS). UNIONS is a multi-band optical survey which is going to cover 6250 deg^2 in the Northern sky. I obtain constraints on the 3D galaxy-halo connection and on the distribution of 3D galaxy shapes from 4800 deg^2 of observed sky. The fitted model allows me to make a preliminary theoretical prediction of the intrinsic alignment, which is in good agreement with the data for Luminous Red Galaxies. Our simple model can hence provide powerful constraints of the physical properties about the 3D morphology of the galaxies that plays a crucial role to understand intrinsic galaxy alignment.

Orateur: CORINALDI, Antonin (CEA Paris-Saclay / AIM / CosmoStat)

Classification de Session: Weak lensing

ID de Contribution: **3** Type: **Non spécifié**

UNIONS cosmological results with 2D weak lensing

jeudi 12 février 2026 14:55 (30 minutes)

Orateur: KILBINGER, Martin (CEA Saclay/Irfu/DAp)

Classification de Session: Weak lensing

ID de Contribution: **4** Type: **Non spécifié**

Impact of Baryonic Physics on Weak Lensing Statistics

jeudi 12 février 2026 16:10 (20 minutes)

Weak gravitational lensing is a powerful probe of cosmology, but its small-scale information is affected by baryonic feedback from galaxy formation processes. Higher-order statistics offer access to non-Gaussian information beyond the angular power spectrum, yet their sensitivity to baryonic effects remains an open question. In this work, we study the impact of baryonic physics on cosmological inference from the power spectrum and wavelet-based higher-order statistics, including peak counts and the wavelet ℓ_1-norm. Using baryonified cosmoGRID V1 simulations and simulation-based inference with neural posterior estimation, we explore parameter biases and mitigation strategies based on scale cuts and alternative transformations. This analysis aims to clarify the role of higher-order statistics in maximizing the cosmological return of current and future weak-lensing surveys.

Orateur: TERSENOV, Andreas

Classification de Session: Weak lensing

ID de Contribution: **5** Type: **Non spécifié**

Modelling Uncertainty in Multi-Source Data Fusion

jeudi 12 février 2026 09:50 (30 minutes)

Orateur: TSAGKATAKIS, Grigorios (FORTH)

ID de Contribution: **6** Type: **Non spécifié**

Foreground removal in HI 21 cm intensity mapping under frequency-dependent beam distortions

vendredi 13 février 2026 11:30 (20 minutes)

Neutral hydrogen (HI) intensity mapping with single-dish telescopes is a powerful probe of post-reionization cosmology, but extracting the signal is challenging due to bright foregrounds and realistic, frequency-dependent beam effects that degrade most standard methods. I present an evaluation of SDecGMCA, a spherical extension of GMCA that combines sparse component separation with explicit beam deconvolution, using simulations tailored to MeerKAT and SKA-Mid. Compared with model-fitting and other blind source separation techniques, SDecGMCA remains robust under complex beam distortions, suppresses spurious spectral features, and recovers the HI power spectrum to better than 5% accuracy on intermediate angular scales ($10<\ell<200$). I will show that an improved version of SDecGMCA, which uses learnlets instead of starlets performs even better removing previous limitations of the method.

Orateur: GKOGKOU, Athanasia (IA/ICS-FORTH)

Classification de Session: Radio Astronomy

ID de Contribution: **7** Type: **Non spécifié**

Learnlets on the sphere

jeudi 12 février 2026 11:10 (20 minutes)

Orateur: BONJEAN, Victor (FORTH)

ID de Contribution: **8** Type: **Non spécifié**

Starlet l1-norm for neutral hydrogen intensity mapping

vendredi 13 février 2026 12:10 (20 minutes)

Neutral hydrogen intensity mapping encodes valuable non-Gaussian cosmological information, particularly at late times in the Universe's evolution. Traditional two-point statistics, such as the angular power spectrum, are not sensitive to this information. In this work, we employ the starlet l1-norm, a multi-scale, higher-order statistic robust to instrumental effects to capture non-Gaussian features in HI maps. Using a simulation-based inference (SBI) framework, we assess the improvement in cosmological parameter constraints obtained with the starlet l1-norm compared to those derived from the angular power spectrum.

Orateur: GORBATCHEV, Pauline (FORTH)

Classification de Session: Radio Astronomy

ID de Contribution: **9** Type: **Non spécifié**

Inferring Physical Properties of High-z Galaxies from IFU Spectral Data cubes: Signal Enhancement and Data-Driven Mapping Beyond Power-Law Relations

vendredi 13 février 2026 10:30 (20 minutes)

Studies of galaxy evolution at z⊠3 are limited by low signal-to-noise ratios and the difficulty of extracting faint, spatially resolved signals. I briefly summarise my first PhD project on denoising and signal restoration of high-redshift IFU datacubes, including the development of a dedicated software framework for generating and analysing controlled toy-model simulations. Wavelet-based iterative methods and U-Net architectures were applied to toy data, mock IFU cubes from cosmological simulations, and ALMA observations, demonstrating substantial SNR improvements while preserving spatial and spectral morphology. The main focus of the talk will be my ongoing work on inferring physical properties from IFU spectral data cubes. Using a limited but physically motivated set of mock IFU cubes from cosmological simulations, which comprise multiple emission lines, observed inclinations, and corresponding resolved maps of galaxy properties (e.g., star formation rate surface density), I develop novel deep learning approaches to learn non-linear mappings between observables and physical quantities. This framework aims to move beyond traditional power-law scaling relations by exploiting spatially/spectrally resolved, multi-line information. A key aspect of this study is assessing the information content of the full spectrum at each spaxel, and determining whether incorporating the spectral axis improves the inference of galaxy properties. These results will have direct implications for the optimal use of current and upcoming IFU observations in the high-redshift regime.

Orateur: LAHIRY, Arnab (FORTH)

Classification de Session: IA

ID de Contribution: **10** Type: **Non spécifié**

Uncertainty Quantification for Generative Models in Astrophysics

vendredi 13 février 2026 10:50 (20 minutes)

As astronomy enters a new era of big data, machine learning, and novel generative models enable inference in high-dimensional spaces and help tackle previously intractable problems. In this context, defining and measuring the accuracy of inferred posteriors, especially in high-dimensional parameter spaces such as images, has become increasingly pressing. Specifically, two questions need to be answered: For a given inference pipeline that provides a posterior estimator for potentially high-dimensional variables, how can we assess the accuracy of this pipeline? And if generative models are used as components of such an inference pipeline, how do we quantify the accuracy with which these models represent their underlying training distribution? I will introduce PQMass and MIRA, two likelihood-free, sample-based statistical approaches designed to tackle these challenges directly. PQMass evaluates the quality of generative models and their ability to learn the underlying data distribution without assuming the data distribution or performing dimensionality reduction, making it highly effective for detecting subtle distributional shifts and validating generative models in cosmological data analyses. MIRA, on the other hand, compares posterior distributions from Bayesian models solely through simulated joint samples, enabling direct model comparisons without evidence computation and quantitative calibration validation. PQMass and MIRA provide new avenues for scalable accuracy assessment and for improving the reliability of data-driven astronomical analysis.

Orateur: SHARIEF, Sammy (CEA)

Classification de Session: IA

ID de Contribution: **11** Type: **Non spécifié**

Probing large-scale structures through cross-correlations of the tSZ effect

jeudi 12 février 2026 16:30 (20 minutes)

Cross-correlations between the thermal Sunyaev–Zel'dovich (tSZ) effect and tracers of large-scale structure provide a powerful probe of both astrophysics and cosmology. In this talk, I will present results on the cross-correlation of the tSZ signal with weak gravitational lensing and galaxy clustering in the context of the Euclid mission. These measurements allow us to study the distribution of hot gas within cosmic structures and to constrain models of baryonic physics as well as cosmological parameters.

Orateur: AYCOBERRY, Emma (CosmoStat, CEA Paris-Saclay)

Classification de Session: Weak lensing

ID de Contribution: **12** Type: **Non spécifié**

Generative model for shear inference in the context of radio weak gravitational lensing

vendredi 13 février 2026 11:50 (20 minutes)

Next-generation radio interferometers, such as the SKA, will observe the radio sky with unprecedented sensitivity and resolution. Their wide sky coverage will also enable weak lensing studies using radio data. Radio weak lensing not only complements optical observations, but also allows access to higher redshifts. However, traditional shear estimation methods—based on measuring the ellipticity of observed galaxies—are not directly applicable to radio data. Interferometric observations are acquired in the Fourier domain, where galaxy images are delocalised, making shape measurements non-trivial. Moreover, even in the image domain, radio galaxy morphologies differ significantly from their optical counterparts, making parametric shape fitting unreliable and prone to model bias. To address these challenges, we propose a cosmic shear inference method based on deep generative models, which avoids parametric fitting and explicit shape measurements. In this presentation, I will outline the main challenges involved in building this inference pipeline and share preliminary results.

Orateur: CENTOFANTI, Ezequiel (CosmoStat, CEA Paris-Saclay)

Classification de Session: Radio Astronomy

ID de Contribution: **13** Type: **Non spécifié**

Learning Domain-Invariant Representations via Optimal Transport and Spectral Embeddings

vendredi 13 février 2026 10:00 (30 minutes)

In many learning problems, labeled data are available only in a source domain, while the target domain remains unlabeled and distributionally different. This talk introduces a principled approach to unsupervised domain adaptation based on optimal transport. By interpreting transport plans between source and target distributions as weighted graphs and embedding them spectrally, the method constructs domain-invariant representations without requiring target labels. This framework offers a generic, theoretically grounded alternative to direct sample alignment, applicable to a wide range of learning problems involving heterogeneous and partially labeled datasets.

Orateur: Dr NGOLE, Fred (CEA/DRT)

Classification de Session: IA

ID de Contribution: **14** Type: **Non spécifié**

On Diffusion Models for Inverse Problems

jeudi 12 février 2026 10:20 (30 minutes)

Diffusion models are emerging as powerful tools for probabilistic prediction and inference in the physical sciences, but their application faces key challenges: high-dimensional state spaces, partial observability, and expensive simulations. In this talk, I present a unified diffusion-based framework addressing these issues across three complementary directions. First, latent-space diffusion models enable fast, high-fidelity emulation of complex dynamical systems at a fraction of the computational cost. Second, we introduce an expectation-maximization approach that learns diffusion priors directly from incomplete and noisy observations, enabling principled Bayesian inference without fully observed training data. Third, we embed diffusion models into a multiscale temporal inference scheme that improves stability and accuracy in partially observable systems. Together, these methods demonstrate how diffusion models can serve as scalable, uncertainty-aware engines for physical prediction and inference. https://arxiv.org/abs/2507.02608 https://arxiv.org/abs/2511.19390 https://arxiv.org/abs/2405.13712

Orateur: LANUSSE, François (AIM, CNRS/CEA Paris-Saclay)

ID de Contribution: **16** Type: **Non spécifié**

The Hubble Tension in Light of the Symmetry of Scale Invariance

jeudi 12 février 2026 14:25 (30 minutes)

When the expansion rate of the Universe at recombination is used to infer the present expansion rate 0, the value derived in the ΛCDM model, 0 =67.4 km s−1 Mpc−1, is about in 6 tension with the value measured locally, 0 =74 km s−1 Mpc−1. In this work, we consider instead the expansion history in the context of the symmetry of scale-invariant vacuum (SIV model). We first perform two major cosmological tests: the Hubble diagram for type-Ia supernovae and the fundamental relation between 0, the age of the Universe, and the total density of matter, Ωm. This allows us to constrain Ωm in SIV, with both tests giving the best agreement for Ωm = 0.20. We then study the physical connections of the dynamical and thermal states of the Universe at recombination with the present Hubble constant, 0, and the present temperature, T, in the ΛCDM and SIV contexts. We find that, in SIV, the properties at recombination may be conveyed to the present ones (=2.726 and 0 at =0) without any tension, indicating 0 =74 km s−1 Mpc−1 in spite of the anchoring on the CMB. This is due to the slightly different expansion and temperature histories of the two cosmological models. Importantly, this happens to occur for Ωm = 0.20, as constrained in SIV with supernovae and cosmic age. This suggests that the Hubble tension currently found between 0 values in the early and late Universe may simply be the result of Λ ignoring the small but still measurable effects of scale invariance.

Orateur: Prof. COURBIN, Frederic (ICCUB - IEEC - ICREA)

ID de Contribution: **17** Type: **Non spécifié**

CHEM- Estimating and Understanding Hallucinations in Deep Learning for Image Processing

jeudi 12 février 2026 10:50 (20 minutes)

U-Net and other U-shaped architectures have become standard tools for image deconvolution in astronomy and related imaging tasks. Despite their success, these models might produce unrealistic artifacts, or hallucinations, which can compromise analysis in safety-critical settings. In this talk, I will present CHEM (Conformal Hallucination Estimation Metric), a general framework for identifying and quantifying hallucination artifacts in deep learning–based image reconstruction models. CHEM is model-agnostic and combines multiscale wavelet and shearlet representations with conformalized quantile regression to assess hallucination levels in a distribution-free manner. I will focus in particular on experimental results obtained on the CANDELS dataset, comparing different architectures such as U-Net, Swin-UNet, and Learnlets. These results provide new insights into how hallucinations manifest across models and scales, and how they can be systematically detected and analyzed in practice.

Orateur: ROSELLON INCLAN, Ines (LMU)

ID de Contribution: **18** Type: **Non spécifié**

Introduction

jeudi 12 février 2026 09:40 (10 minutes)

Orateur: STARCK, Jean-Luc (CosmoStat, CEA Paris-Saclay)

ID de Contribution: **19** Type: **Non spécifié**

Convergence map emulator & validation

jeudi 12 février 2026 16:50 (20 minutes)

Orateur: TINNANERI SREEKANTH, Vilasini

Classification de Session: Weak lensing

ID de Contribution: **20** Type: **Non spécifié**

AI Vision for the battlefield: IMINT and Embedded Video Processing

jeudi 12 février 2026 17:10 (30 minutes)

Orateur: Dr WOISELLE, Arnaud (Safran)