Synergies entre grands relevés pour les études Dark Energy

Prospectives in2p3 GT05

Cécile Roucelle - laboratoire APC

Survey synergies with Machine Learning - E. Aubourg et al.
Cosmological LSS analysis in the contexte of LSST - J. Neveu et al.
Réponse à l'appel de l'ESA Voyage 2050 Concept de mission GAUSS - C. Renault et al

Overview : the whole is greater than the sum of its parts

2020 - 2030 :

Next decade missions : focus on LSST & Euclid

ML based techniques as a framework for synergies (+ cf. prospectives GT09)

Next Developments of Deep Learning for DE analysis : BDL, Active learning

The LSS case : next developments and probe combination for DE studies

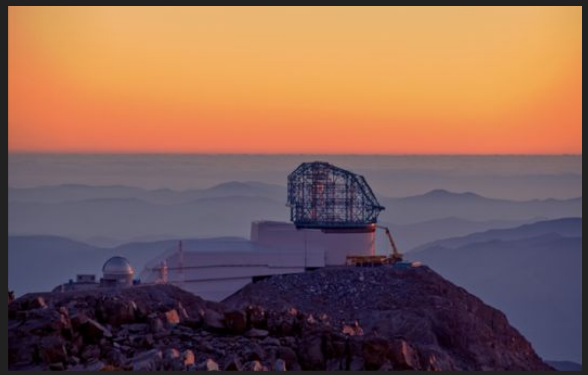
After 2030 : DE community

Preparation for GAUSS

LSST

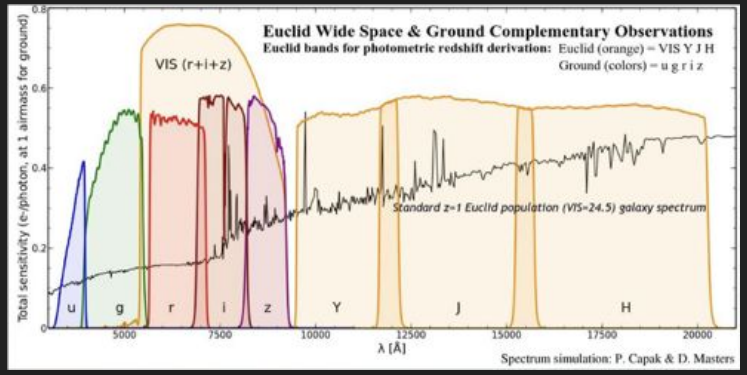
6 optical bands ugrizy
40 galaxies/ arcmin^2
10 years survey - 18 000 deg^2
depth (10 yrs) : 27.5 (r)
1st light (commissionning) 2021 - science 2022

30 TB images / night
DR11 : 60 PB of data - 20 billions galaxies ; 17 billions stars



Euclid

- Launching 2022
- 6 yrs mission - 15 000 deg^2
- 1,4 PB data
- 3 10^9 galaxies
- 2 instruments : VIS, NIR
- High resolution optical imaging
- Complementarity with LSST on + 7000 deg^2 of overlapping sky



Machine learning techniques for DE studies

- Addressing the volume of surveys
- Tackle the new challenges coming with the 2020-2030 surveys generation
- Exploit the complementarity of surveys at the deepest level [cf Schuhmann et al. 2019 for WL]

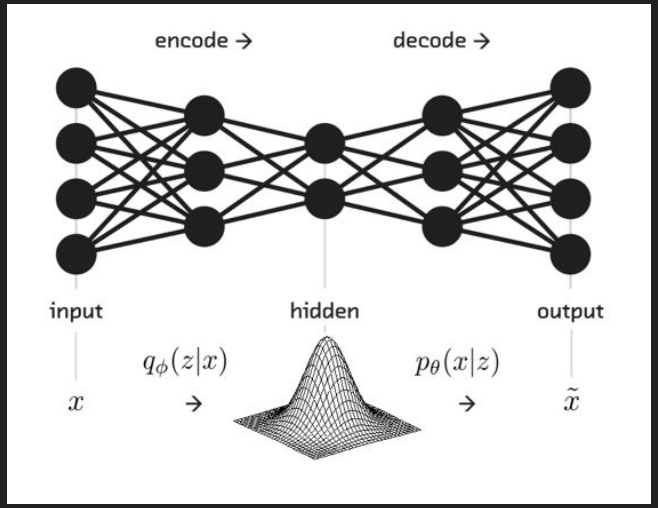
➔ Develop ground work (cf GT09 discussion) but also to allow and support synergies between surveys for this type of analysis with a workforce.

Essential stepping stones for several cosmology probes will gain from DL : galaxies deblending & photo-z

➔ Synergies can be achieved with and bring significant improvements

From Cosmos HSC - courtesy of P. Melchior

Deblending of galaxies with VAEs



Variational Auto Encoders (VAE)

INPUT VAE OUTPUT TARGET

B.Arcelin, E.Aubourg, A.Boucaud, C.Doux, C.Roucelle, F.Virieux, M. Le Jeune
ANR AstroDeep IA starting 2019

Deep Learning approach using 6 LSST bands + Vis YJH Euclid

- ➔ Follow a bayesian approach
- ➔ Multi-bands & multi survey analysis
- ➔ Develop further uncertainties treatment : noise propagation, model uncertainties

Maximizing the scientific return of our surveys with ML

Joint LSST & Euclid analysis for each filter at the pixel level

Gain of a factor 5 to 10 on the systematic error budget for the gravitational shear joint analysis when performed at the pixel level

Further developments :

Bayesian Deep Learning

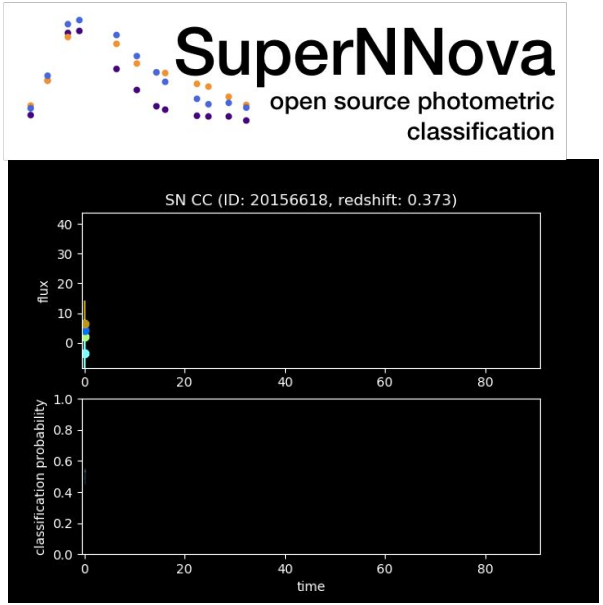
Propagation of uncertainties in NN pipelines (image noise, model uncertainties…)
Bayesian approach for active learning

Development of Bayesian NN for photo-zs

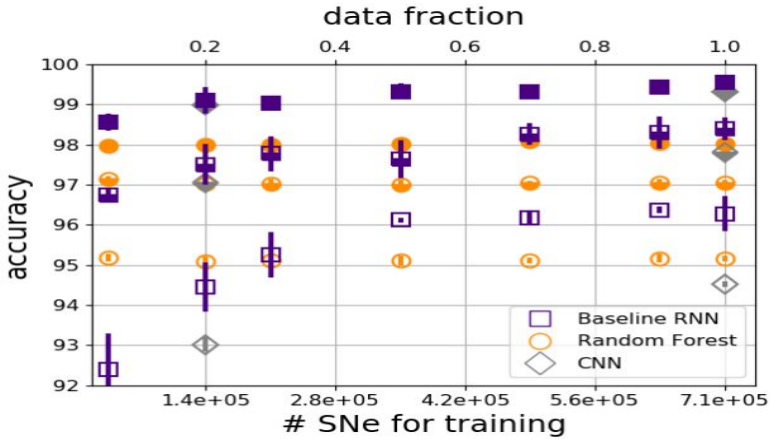
machine learning for photometric classification

* Impacting:
  - time-domain astronomy
  - supernova cosmology

* New deep learning networks: Bayesian, Convolutional, Recurrent
* Suitable for the big data era



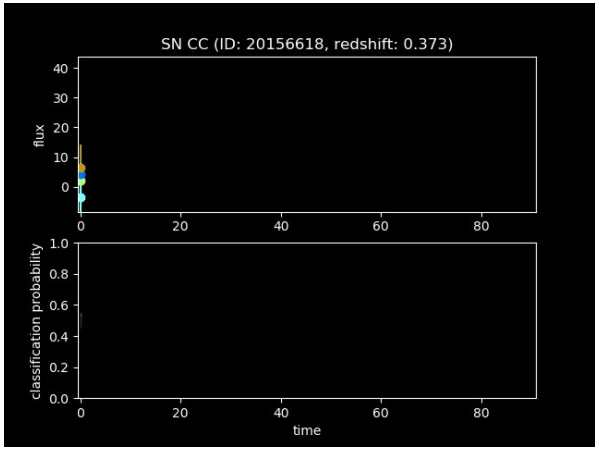
Möller + 2019

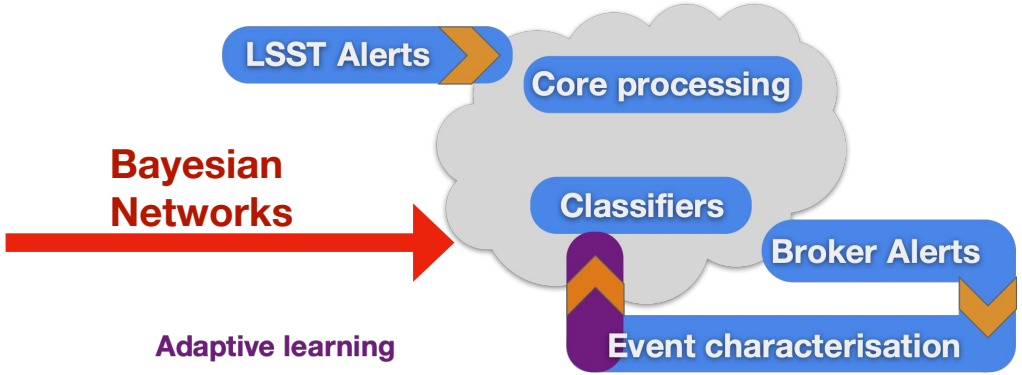


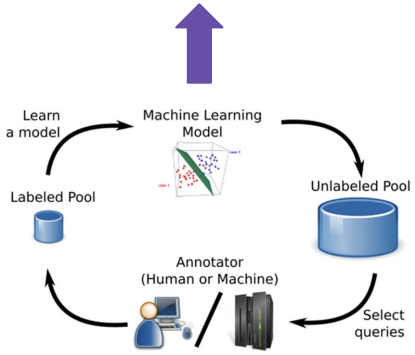
Slide by Anais Moller (LPC)

find, classify, improve

FINK an IN2P3 initiative







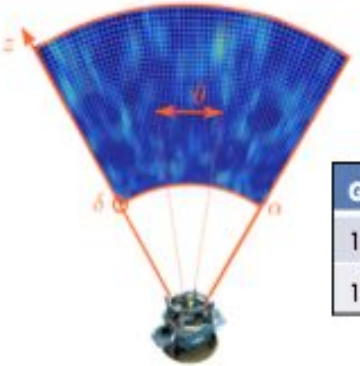
- 10 IN2P3/CNRS labs and centers
- Big data (15 TB/night)
- **ML on data stream**
- Automatized decision making
- Minimum duration of 10 years
- Connection across experiments

Julien Peloton (LAL)
Emille Ishida (LPC)
Anais Moller (LPC)

\+ 28 signatories

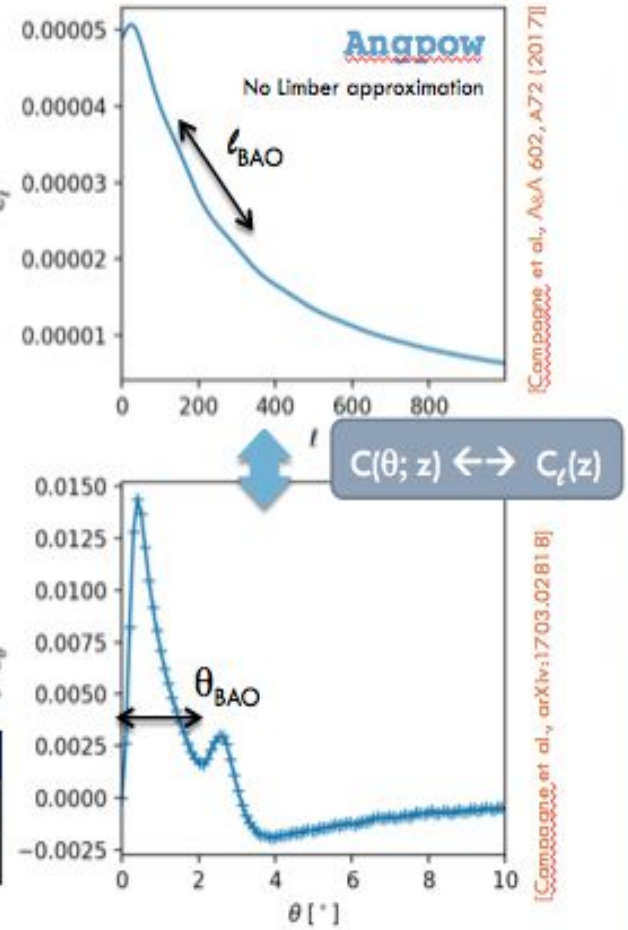
Large-scale structures with LSST - J.Neveu et al.

- Tomographic analysis of the galaxy distribution on half a sphere
- LSS information directly from observable space:
  - In angular space or multipole space
  - Bins of redshifts: auto and cross correlations
- BAO scale difficult to measure because of photo-z uncertainties but power spectra estimated on large scales(no Limber approximation)
- Angpow code to produce the $C_\ell(z_1,z_2)$ observables
  https://gitlab.in2p3.fr/campagne/AngPow



Galaxy	z	α	δ
12345	1.01	-42.22°	-73.56°
12346	0.57	10.49°	-52.08°

...



The LSS observational landscape

	BOSS / eBOSS	DES Y1	DESI	LSST	Euclid
Years	2009 - 2019	2013 - 2018	2020 - 2025	2022 - 2032	2022 - 2028
Type of survey	Spectroscopic	Photometric	**Spectroscopic**	**Photometric**	**Photometric and spectroscopic**
Area [10^3 deg^2]	10	1	**14**	**18**	**15**
Depth [z]	3.5 / 2.2	0.9	3.5	3	2 & 6
# Galaxies	10^6 / 10^6	3x10^8	30x10^6	3x10^9	1.5x10^9 (photo) & 3e7 (spectro)
Colors	360-1000 nm	5 [grizy]	360-980 nm	6 [ugrizy]	4 [{riz}yjh] + 1-2um

Table 1. Main characteristics of previous and upcoming galaxy surveys: BOSS/eBOSS [Dawson K.S., et al., 2016], DES [Abbott T. et al., 2005], DESI [Levi et al., 2013, Aghamousa et al., 2016], LSST [Ivezic et al., 2008], Euclid [Laureijs et al., 2011].

LSS synergies over the next decade

LSST-DESI : small overlap of the sky footprints:

- share of spectroscopic redshift and galaxy photometry for a fraction of their galaxy catalogs

➔ better training of the LSST galaxy photometric redshifts

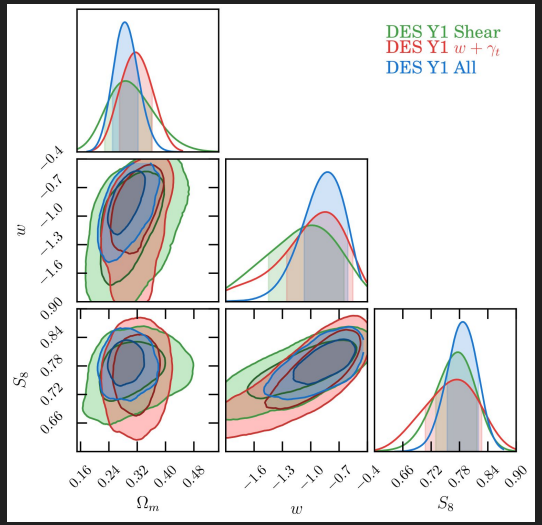
LSST-Euclid : large overlap of the sky footprints:

- share of the 6 visible LSST colors and the 3 IR Euclid colors for a large fraction of the galaxy
- better PSF for Euclid but each galaxy observed ~1000 times by LSST

➔ better photometric redshifts and deblending for both surveys

Combinations of probes

- LSS + weak lensing (aka 3x2pts analysis)
  - internal constraints of the systematics: galaxy bias, weak lensing bias
  - cross-correlation of the LSS and weak lensing shear maps to better constrain the **Dark Energy cosmological parameters** [DES Y1]
- LSS + CMB (+ CMB lensing + weak lensing)
  - constraints on gravity at cosmological scales
  - constraints on **sum of neutrino masses**
- LSS + Intensity Mapping (21 cm): cross-correlation of the LSS galaxy distribution and of the HI distribution to constrain dark energy parameters and **dark matter evolution of its distribution** [white paper GT05 21cm]
- LSS + GW: constraint on H_0 with BBH [Soares-Santos, et al., 2019]



+ see references in the LSS+LSST white paper GT05

Et après LSST/Euclid ?

C.Renault et al.

Voyage 2050 - long-term planning of the ESA science program

Appel 4 mars 2019, white papers pour le 5 août 2019

Mail et organisation d'un brainstorming le 17 mai 2019 coordonné par l'action Dark Energy → pour un super-Euclid (pas d'alternative plus "originale" identifiée)

Rédaction de la proposition GAUSS soumise le 1er août (détails après) - porteur A. Blanchard, signataires IN2P3, INSU, INP, IRFU + qq étrangers

Présentation lors du colloque à Madrid du 29-31 octobre par le chair E. Komatsu

GAUSS: Gravitation And the Universe from large-Scale-Structures

Science : couvrir avec une seule expérience toutes les phases de l'évolution cosmique post âges sombres

- non-gaussianité : f_NL = 1 à 5 sigmas
- somme masse des neutrinos = 0.06 eV à 5 sigmas
- capacité à briser les dégénérescences entre croissance des structures / gravité modifiée / propriétés de l'énergie noire

Observations : relevé de tout le ciel en visible/infrarouge jusqu' à 5 microns pour tracer la distribution des galaxies de z=0.5 à 5
→ volume maximal

miroir : 3 à 4 m, centre PF : photométrie (160x(8kx8k)),
couronne : slit-spectrométrie (16x(4kx4k))

Aujourd'hui et en 2020 - 2030

Soutien à l'Action DARK Energy (quelle que soit la forme)

C'est LE lieu pour préparer une future demande de mission spatiale avec tous les acteurs potentiellement intéressés > regroupe les acteurs LSST et Euclid

Possibilité d'avoir un thème cosmo au sens large pour une prochaine mission L, ou le CMB

- réflexion à avoir avec le CMB : voir ce qu'on pourrait faire en cas de sélection de ce sujet (lensing, SZ …)
- si cosmo, réfléchir aussi avec le CMB pour peut-être ne pas se concurrencer à un même niveau de mission ?
- se préparer en amont (simus, R&T) pour avoir une demande réaliste

Conclusions :

Powerful analysis will be developed combining probes & information “at the pixel level”.

We are entering the big data era : discovery will be ML driven

Deep Learning based development offers a promising interdisciplinary framework between statistics, cosmology and computer science

Analysis will change for deblending of galaxies (WL shear), photo-z, supernovae : best results will come from synergies between surveys

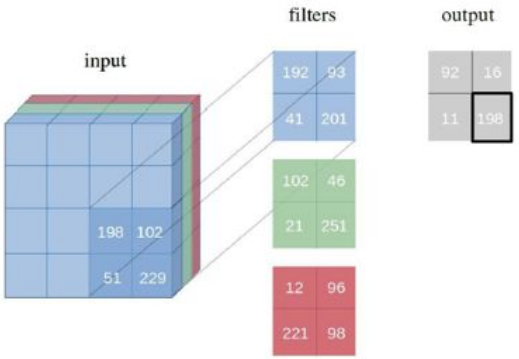
Combining LSS with other probes at the map level will lead to better results

Staff & organisation are essential to support these synergies to maximize scientific return

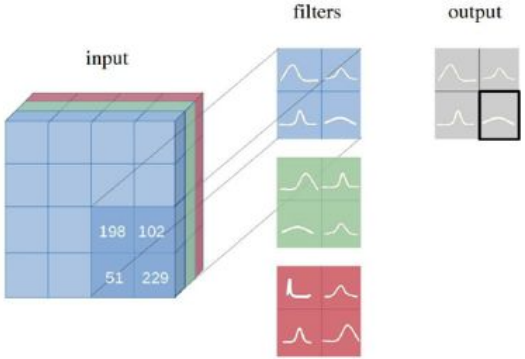
The scientific community (action dark energy) will also be essential to the preparation of the further projects especially if space based.

En +

BNNs



Réseau classique avec les poids fixés



Réseau bayésien avec les poids suivant des distributions

Courtesy of F. Pennerath - AstroDeep kickoff meeting

La suite

Printemps 2020: l'ESA doit annoncer les 3 thèmes scientifiques des 3 missions L (2035-2050), après l'annonce du Decadal US

→ l'ESA a demandé presque choix des missions, refus du senior committee : thèmes scientifiques. Mais ca ne devrait pas être comme pour Cosmic Vision où tout rentrait ...

→ première évaluation chiffrées des propositions (beaucoup plutot à 10 qu'à 1 milliard. Mais on nous demandait de rêver, alors …) Chiffrage de GAUSS ????

→ demande via le CNES de choisir le 1er thème seulement et une liste plus longue que deux pour la suite (ridicule de se bloquer pour les 30 prochaines années)