

LSST 3D Data Compression (3DDC) Taskforce

Jason McEwen

LSST:UK Informatics and Statistics Science Collaboration (ISSC) Point of Contact

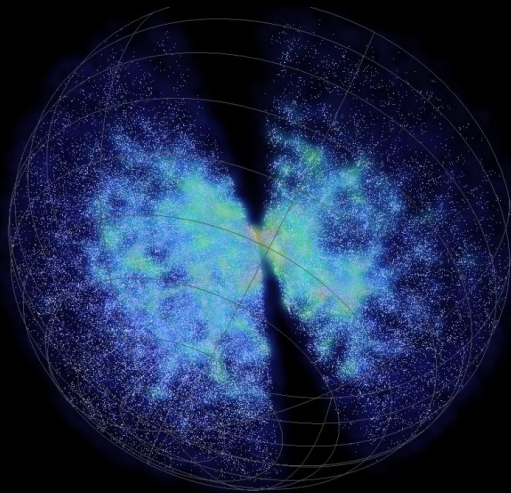
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@jasonmcewen

*Mullard Space Science Laboratory (MSSL)
University College London (UCL)*

LSST DESC collaboration meeting, University of Oxford, July 2016

3D LSS data



Credit: SDSS



Confluence wiki page

<https://confluence.slac.stanford.edu/pages/viewpage.action?pageId=195857648>



LSST Dark Energy Science Collaboration / Home / Taskforces 2015-16

3D Data Compression (3DDC)



Created by Boris Leistedt, last modified by Hiranya Peiris on Jun 20, 2016

Quick Start

Slack

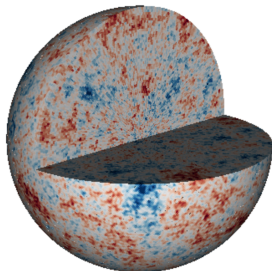
Register on the slack channel: <https://lsst3ddc.slack.com>. Some academic email addresses will be automatically accepted. If yours is not, feel free to email any of the coordinators (see list below).

Bluejeans

Bluejeans info / Participant code: <https://bluejeans.com/176885536>

Telephone call-in numbers: see <http://bluejeans.com/numbers>

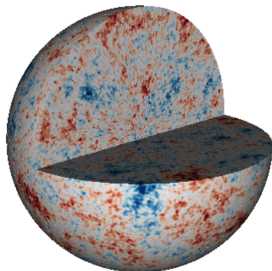
Contributors: Franz Elsner, Jean-Eric Campagne, Benjamin Joachimi, Thomas Kitching, Francois Lanusse, Boris Leistedt, Jason McEwen, Hiranya Peiris, Will Percival, Layne Price, Anze Slosar, Edo van Uitert, ...



3D visualization of the gravitational potential.
Copyright Franz Elsner.

We plan to develop a framework to easily create, manipulate and plot 3D data sets from galaxy clustering and cosmic shear observables. A strong emphasis will be put on developing user-friendly tools to facilitate the adoption by interested members. We will specifically aim to integrate existing tools and maintain compatibility with widely used formats, such as Healpix. We will study the scaling of the algorithms in detail. The goal is to provide a standard data compression tool to transform and store huge galaxy and shear catalogues into pixelised 3D signals that can be readily analysed with tools such as the Fourier-Bessel transform. Since grouping galaxy positions onto a grid is a lossy form of data compression, we will explore dedicated approaches to characterize and propagate errors on radial distances resulting from photometric redshift uncertainties in typical science analysis use cases. We will interface these maps with 3D power spectrum estimators and cosmological likelihoods that can deal with spatially-varying systematics via template marginalisation. The method can be applied to data from ongoing surveys as well as LSST simulations, and contributes to the development and testing of tools to optimally analyse LSST data when they arrive.

DESC SRM task LSS4.1: Robust 3D pixelizations and transforms



3D visualization of the gravitational potential.
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Goals, challenges and uses

- Why 3D?
 - Extract more information
 - Fewer approximations
 - Filtering (*e.g.* non-linear scales)
 - Build spatial-spectral representations (*e.g.* wavelets)
- Challenges
 - Fast transforms for data and theory
 - 3D pixelisations
 - Masks, selection effects, covariances, systematics
- Uses
 - Cosmic shear
 - Galaxy clustering
 - Joint probes
 - ...

What is 3D?

Everything that is not redshift tomography!

- Fourier-Bessel basis:

$$j_\ell(kr) Y_{\ell m}(\theta, \varphi)$$

- Fourier-Laguerre basis:
(introduced by Leistedt & McEwen 2012; [arXiv:1205.0792](https://arxiv.org/abs/1205.0792))

$$K_n(r) Y_{\ell m}(\theta, \varphi)$$

Connecting Fourier-Bessel and Fourier-Laguerre

- Connect Fourier-Bessel and Fourier-Laguerre via

$$J_{\ell np} \propto \int_0^\infty dr r^2 j_\ell(k_{\ell p} r) K_n(r)$$

- Difficult numerical problem (require accurate computation up to high orders)
- Analytic expression in terms of hypergeometric functions (Leistedt & McEwen 2012)
- Studied extensively by Jean-Eric Campagne (LagSHT)
 - Limber expansion
 - Discrete Fourier Bessel transforms
 - Clenshaw-Curtis quadrature
 - Chebyshev transform with use of Discrete Cosine Fourier Transform

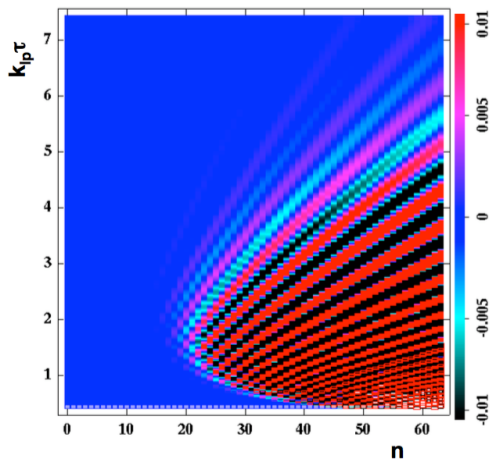
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Connecting Fourier-Bessel and Fourier-Laguerre



Credit: Jean-Eric Campagne

Identified existing codes for 2D/3D transforms

Add yours!

CosmicPy	C++, Py	Theory Fourier-Bessel
MRS3D	C++	Fourier-Bessel + wavelets
3DEX	F90 (!)	Fourier-Bessel transform
HEALPIX	C, F90, Py, IDL	2D Spherical harmonics
SSHT	C, Matlab	2D Spherical harmonics
FLAG(LET)	C, Py, Matlab	3D Fourier-Laguerre + wavelets
LagSHT	C++	3D Fourier-Laguerre + Bessel
3DFast	C	Flat-sky Fourier-Bessel

Plan to start **Uber 3D code**™

Get in touch if you'd like to contribute!





Uber 3D code™

<https://github.com/astro-informatics/uber3d>



- **Data:** survey => 3D clustering+shear power spectra
 - **Theory:** interfaced with cosmology library
- Supports all existing transforms and pixelizations
- **Extras:** likelihoods, systematics mitigation, etc



SLAC DESC hack in March

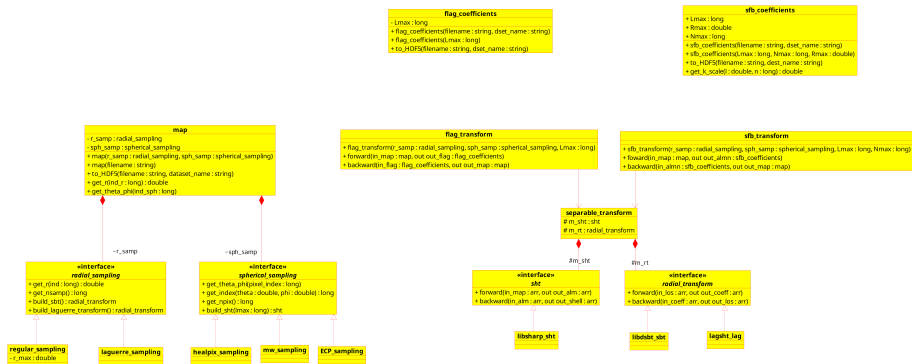
```
77%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/moc_query.cc.o
79%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/alm_fitsio.cc.o
81%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/powspec_fitsio.cc.o
83%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/healpix_data_io.cc.o
84%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/healpix_map_fitsio.cc.o
86%] Building CXX object src/Healpix_cxx/CMakeFiles/healpix.dir/moc_fitsio.cc.o
88%] Linking CXX shared library libhealpix.so
88%] Built target healpix
90%] Building CXX object src/uber3d/CMakeFiles/uber3d.dir/almn_cln_tools.cpp.o
92%] Building CXX object src/uber3d/CMakeFiles/uber3d.dir/almn_fitsio.cpp.o
94%] Building CXX object src/uber3d/CMakeFiles/uber3d.dir/cln_fitsio.cpp.o
96%] Linking CXX shared library libuber3d.so
96%] Built target uber3d
98%] Building CXX object src/dsbt/CMakeFiles/dsbt.dir/fastDSBT.cpp.o
100%] Linking CXX shared library libdsbt.so
100%] Built target dsbt
francois@Procyon build]$
```

Uber3D Trello Board after hack day,
March DESC Collaboration Meeting @SLAC

The image shows a Trello board for 'Uber 3D' with four columns: To Do, Queued, Doing, and Done. The 'To Do' column contains tasks like 'Review Fourier-Bessel equations' and 'Set up data structures'. The 'Queued' column has 'Set up test framework for code'. The 'Doing' column includes 'Class for Radial Sampling' and 'Class for Angular Sampling + SHT and Healpix children'. The 'Done' column lists completed tasks such as 'Add text surrounding equations' and 'Inverse spherical Bessel transform'. An activity log on the right shows recent updates by Jason McEwen and Francois Lanusse.

Column	Task
To Do	Review Fourier-Bessel equations
To Do	Add discussion of sampling and quadrature to doc
To Do	Set up data structures
To Do	Read/write data structures to fits files
To Do	Forward Fourier-Bessel transform on separable sampling
To Do	Inverse Fourier-Bessel transform on separable sampling
To Do	Create a template documented function
To Do	Radial construction (linear, log, quadrature)
Queued	Set up test framework for code
Doing	Class for Radial Sampling
Doing	Class for Angular Sampling + SHT and Healpix children
Done	Add text surrounding equations
Done	Inverse spherical Bessel transform
Done	Compute zeros of spherical Bessel functions
Done	Forward spherical Bessel transforms
Done	Enter overview equations of interest into doc
Done	All get code framework running locally
Done	Brainstorm expressions for transforms on whiteboard

Oxford DESC hack



Credit: Francois Lanusse

BASP workshop 2017

Dedicated LSST informatics and statistics session organised by **Tim Eifler**.

<http://www.baspprogress.org/>



International BASP Frontiers workshop 2017
January 29 - February 3, 2017 - Villars-sur-Ollon, Switzerland

General Programme Venue and resort Contributions Registration



IMPORTANT DATES

01.06.2016 Session proposal deadline

01.09.2016 Abstract submission opening

About the workshop

The **International Biomedical and Astronomical Signal Processing (BASP) Frontiers workshop** was created to promote synergies between selected topics in astronomy and biomedical sciences, around common challenges for signal processing.

Building on the success of the first workshops (2011, 2013 and 2015), BASP Frontiers 2017 will gather around 100 participants and open its floor to many interesting hot topics in theoretical, astrophysical, and biomedical signal processing, with a particular focus on imaging.