

# Special Ofer! Biggest reductions ever!

Alan Heavens, ICIC, Imperial College

From Deep Learning to the Dark Universe  
Celebrating Ofer Lahav's 60th Birthday



# MOPED

Mon. Not. R. Astron. Soc. **317**, 965–972 (2000)

## Massive lossless data compression and multiple parameter estimation from galaxy spectra

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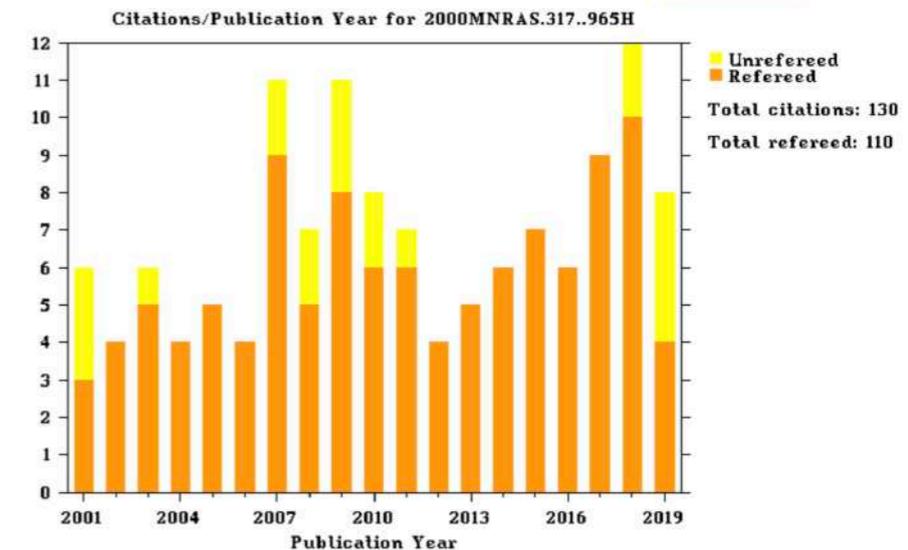
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### ABSTRACT

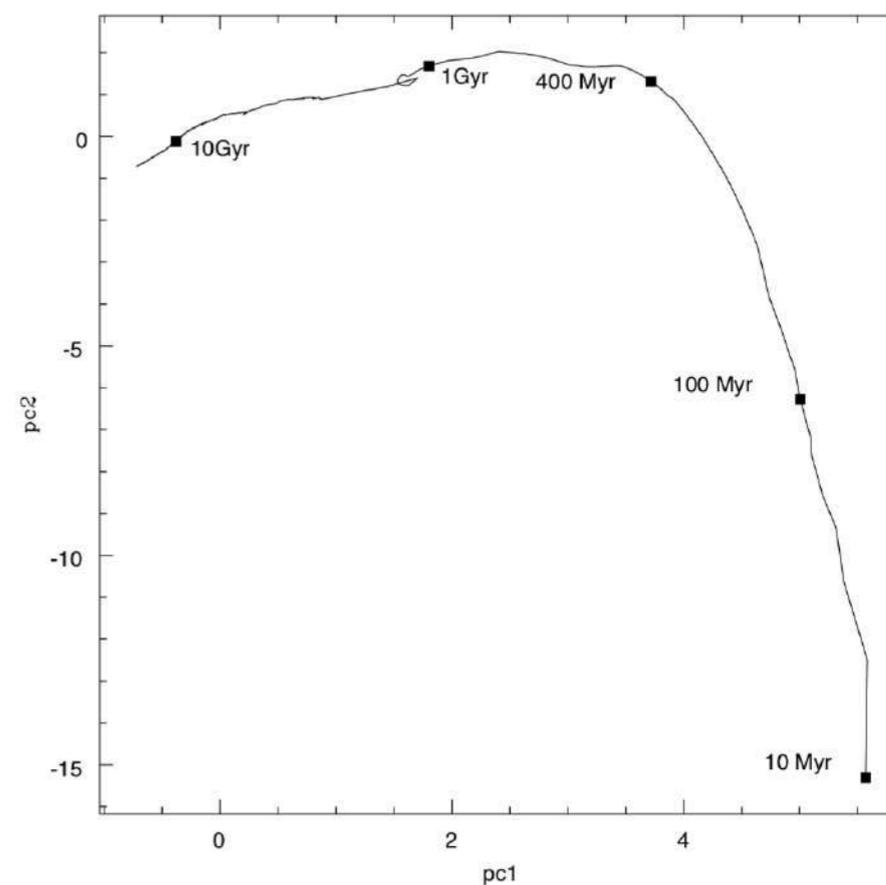
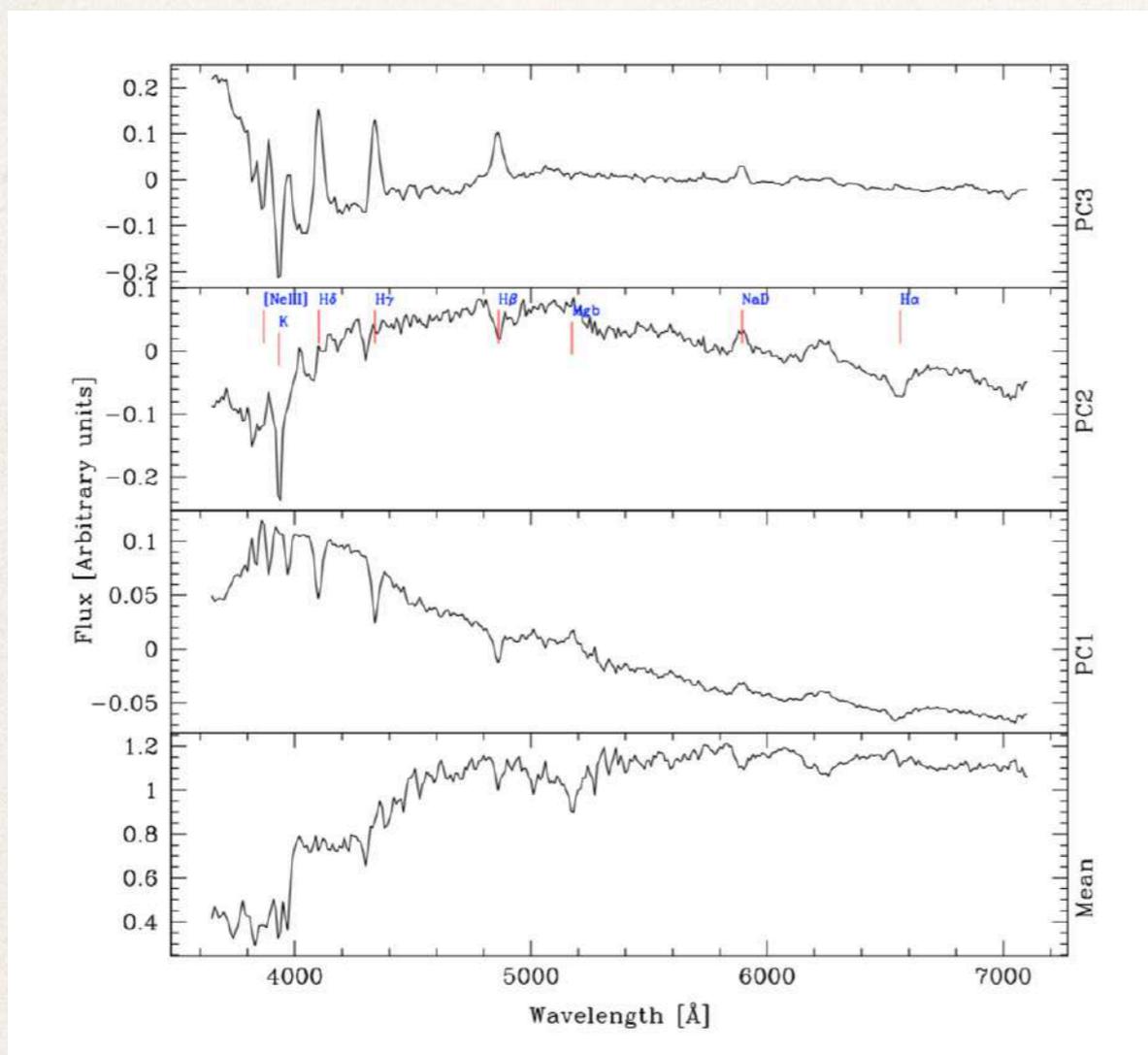
We present a method for radical linear compression of data sets where the data are dependent on some number  $M$  of parameters. We show that, if the noise in the data is independent of the parameters, we can form  $M$  linear combinations of the data which contain as much information about all the parameters as the entire data set, in the sense that the Fisher information matrices are identical; i.e. the method is lossless. We explore how these

### Citations history for [2000MNRAS.317..965H](#) from the ADS Databases

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# Principal Component Analysis



**Figure 4. Single burst:** the projection of the spectra on the first and second PCs of figure 2. The ages are marked.

Ronen, Aragón-Salamanca, Lahav 1998

# MOPED: radical compression of gaussian data

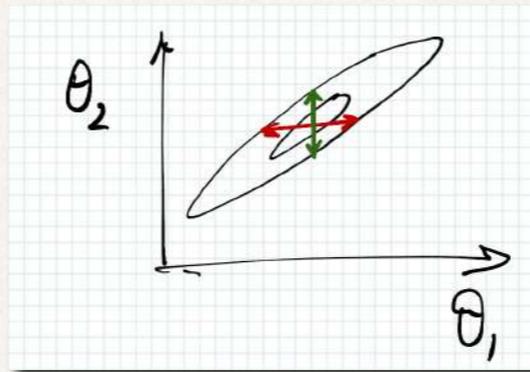
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Data  $\mathbf{x}$ ; mean  $\boldsymbol{\mu}(\boldsymbol{\theta})$ ; covariance matrix  $\mathbf{C}$ ; parameters  $\theta_\alpha, \alpha=1\dots M$

Find different projections of the data  $\mathbf{x}$ :  $y_\alpha = \mathbf{b}_\alpha \cdot \mathbf{x}$

Maximise Fisher Matrix element  $F_{11}$  subject to a constraint:  $b_1 \propto \mathbf{C}^{-1}\boldsymbol{\mu}_{,1}$

where  $\mu_{,\alpha} \equiv \frac{\partial \boldsymbol{\mu}}{\partial \theta_\alpha}$



Maximise  $F_{mm}$ :

$$b_m = \frac{\mathbf{C}^{-1}\boldsymbol{\mu}_{,m} - \sum_{q=1}^{m-1} (\boldsymbol{\mu}_{,m}^T \mathbf{b}_q) \mathbf{b}_q}{\sqrt{\boldsymbol{\mu}_{,m}^T \mathbf{C}^{-1} \boldsymbol{\mu}_{,m} - \sum_{q=1}^{m-1} (\boldsymbol{\mu}_{,m}^T \mathbf{b}_q)^2}}$$

# Something remarkable happens:

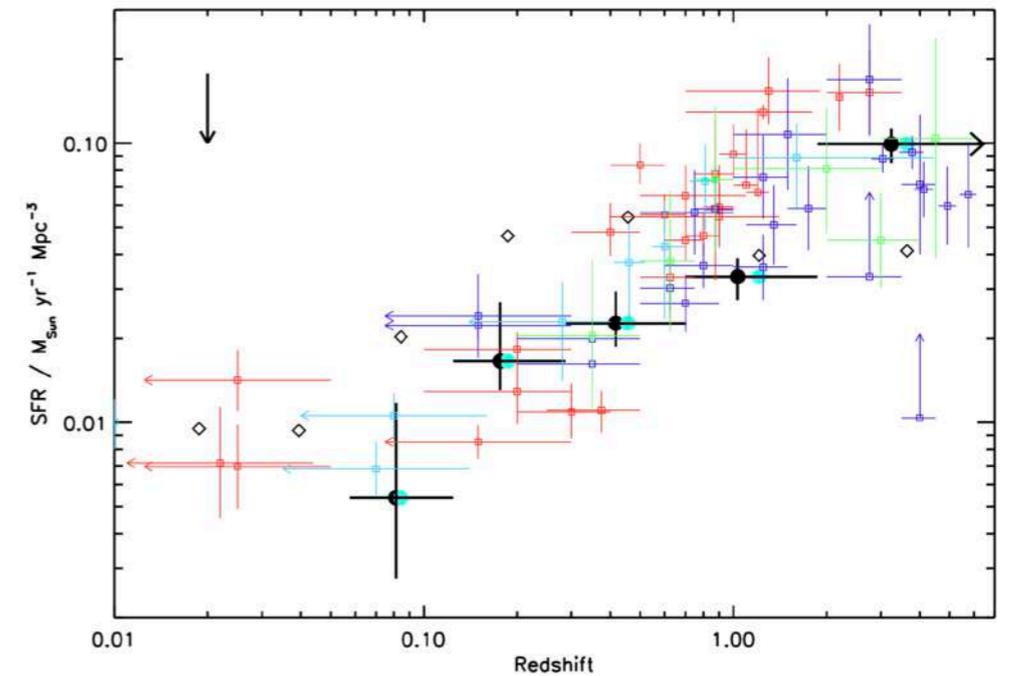
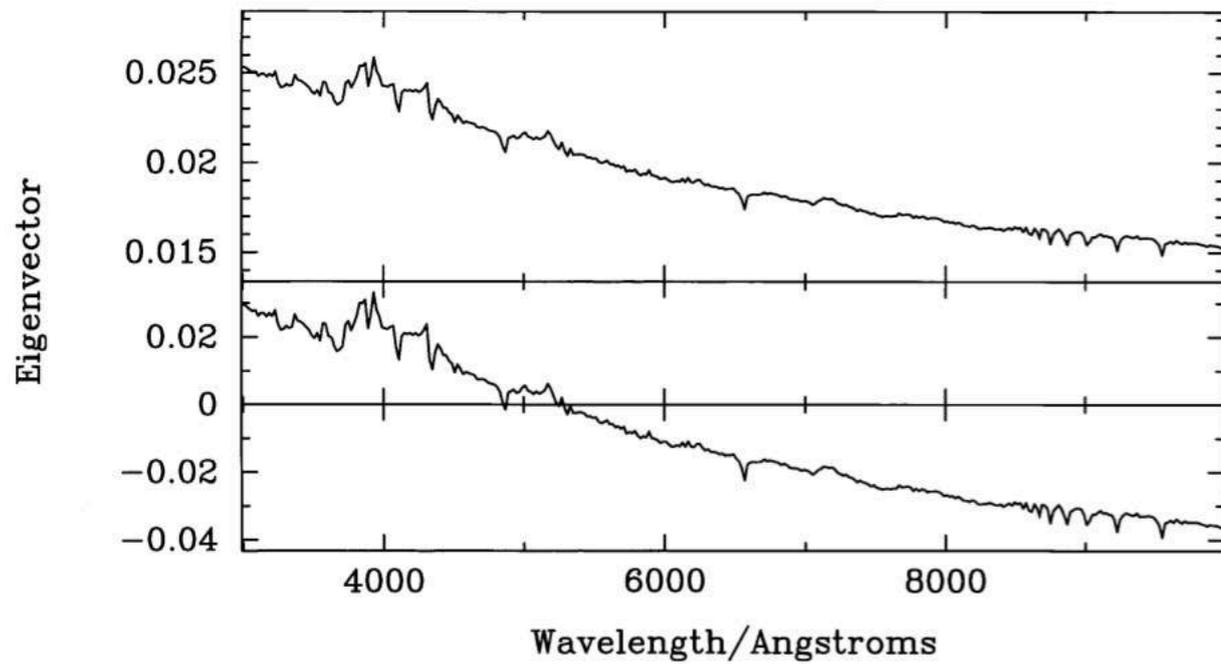
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There are only  $M$  MOPED vectors, however many original data points

Subject to some conditions, the whole Fisher matrix (for the compressed data  $y$ ) is identical to the Fisher matrix for the original dataset

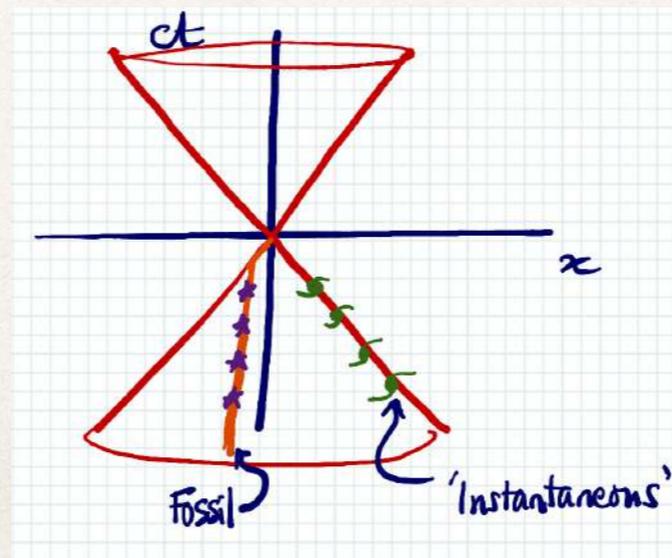
**MASSIVE DATA COMPRESSION  
WITHOUT INCREASING ERROR  
BARS**

# MOPED vectors



$b_1$  and  $b_2$  for galaxy spectra

Panter et al. 2007



# Generalising MOPED

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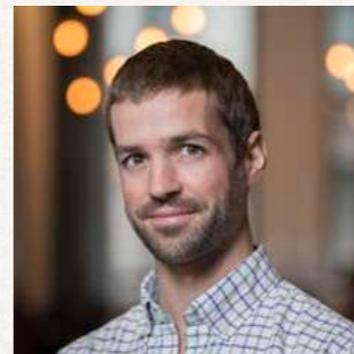
*Linear* compression (MOPED) is optimal if the mean  $\mu$  depends on the parameters  $\theta$ , but the covariance matrix does not.

*Nonlinear* compression optimises if  $C$  depends on  $\theta$  as well:

$$\mathbf{t} = \nabla \mu_*^T \mathbf{C}_*^{-1} (\mathbf{d} - \mu_*) + \frac{1}{2} (\mathbf{d} - \mu_*)^T \mathbf{C}_*^{-1} \nabla \mathbf{C}_* \mathbf{C}_*^{-1} (\mathbf{d} - \mu_*),$$

Data  $d$

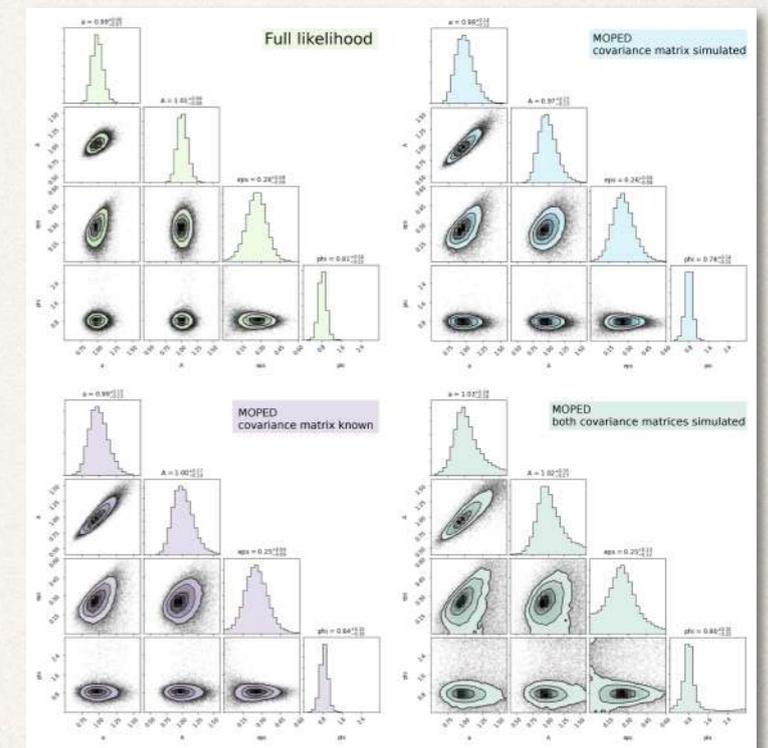
Alsing and Wandelt 2018



Justin Alsing

# Solving the covariance matrix problem

- ❖ Euclid and LSST could easily have  $s=10,000$  summary statistics
- ❖ If you get the covariance matrix from simulations, you need at least  $s+2$  simulations
- ❖ If the covariance matrix varies with parameters, you might need  $10^9$  simulations
- ❖ Can reduce this to  $10^3$  simulations with MOPED data compression
- ❖ Marginalise over true covariance matrix: use Sellentin & Heavens (2016) likelihood



Heavens et al. (2017)

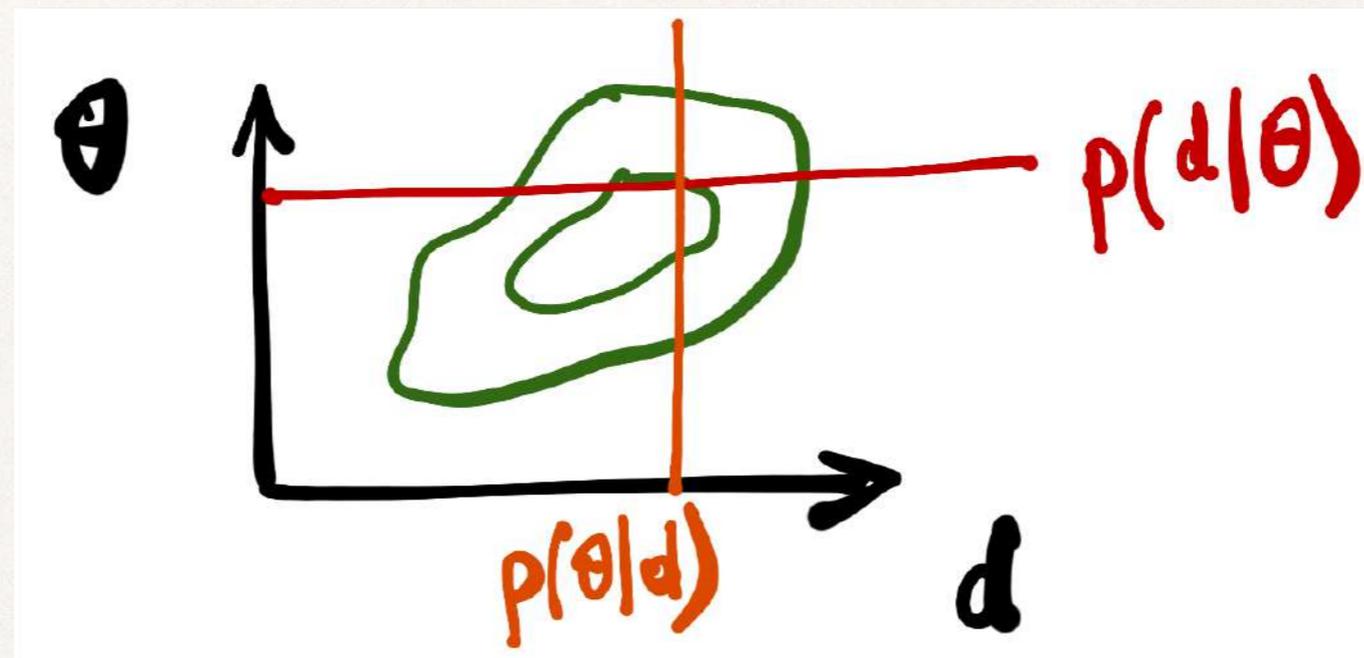


Elena Sellentin

# ABC and Likelihood-free inference

Simulate, and populate *Data-Parameter* space

$N$  data,  $M$  parameters



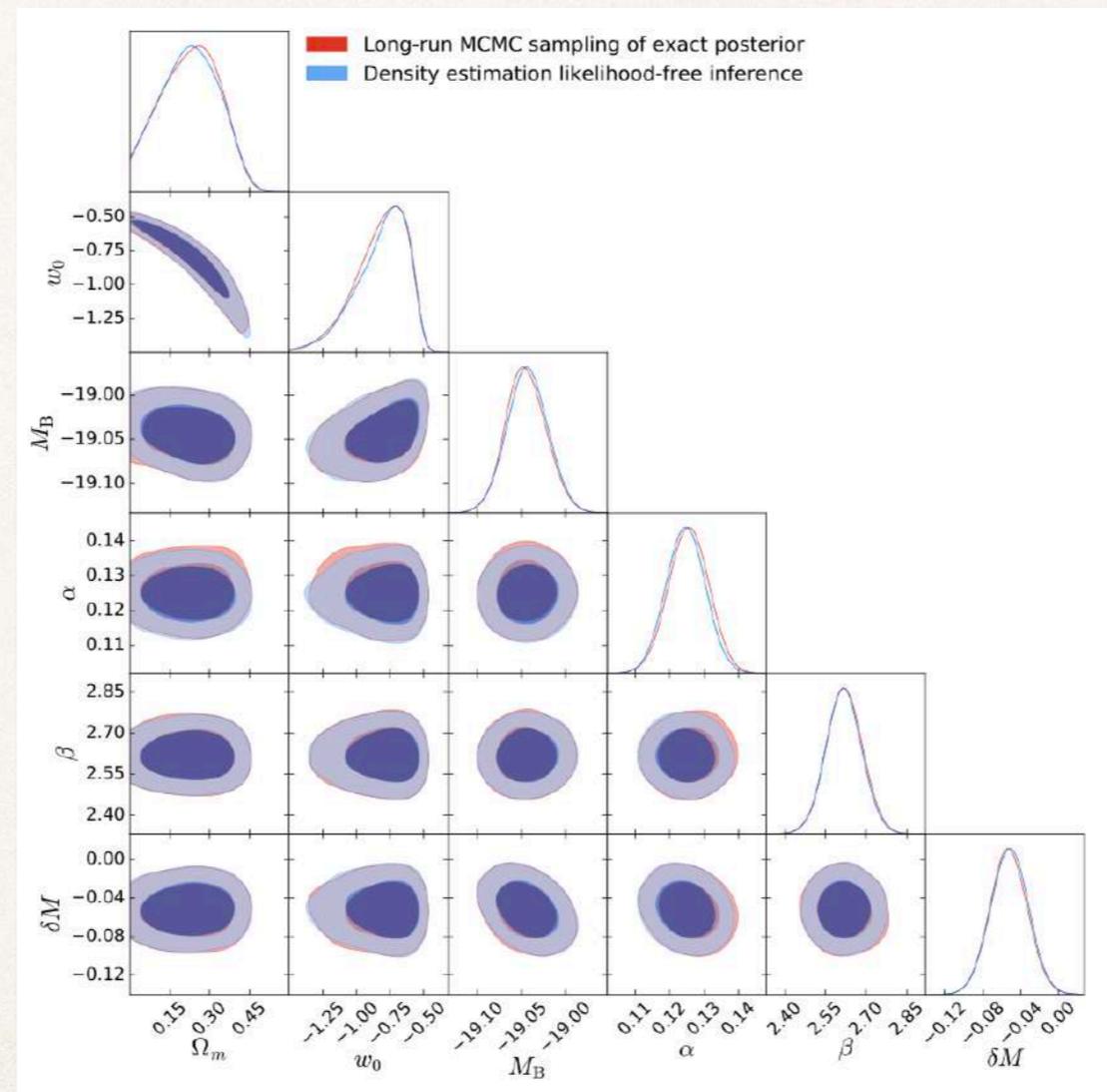
Posterior

$M \sim 10$ ;  $N \sim$  very large. This is an  $M+N$  dimensional problem.

Impossible to do without radical data compression

MOPED:  $2M$ -dimensional space

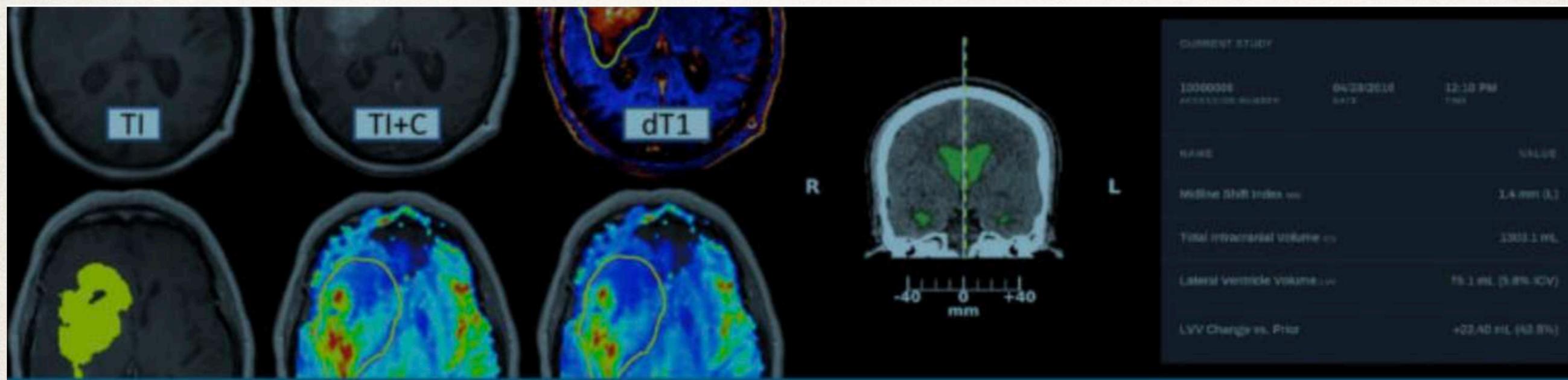
# Likelihood-free inference with data compression



See  
Davide Gualdi  
Niall Jeffrey  
talks

Alsing, Wandelt & Feeney 2019:  
DELFI (see also BOLFI - Florent Leclercq)

# Medical imaging scans



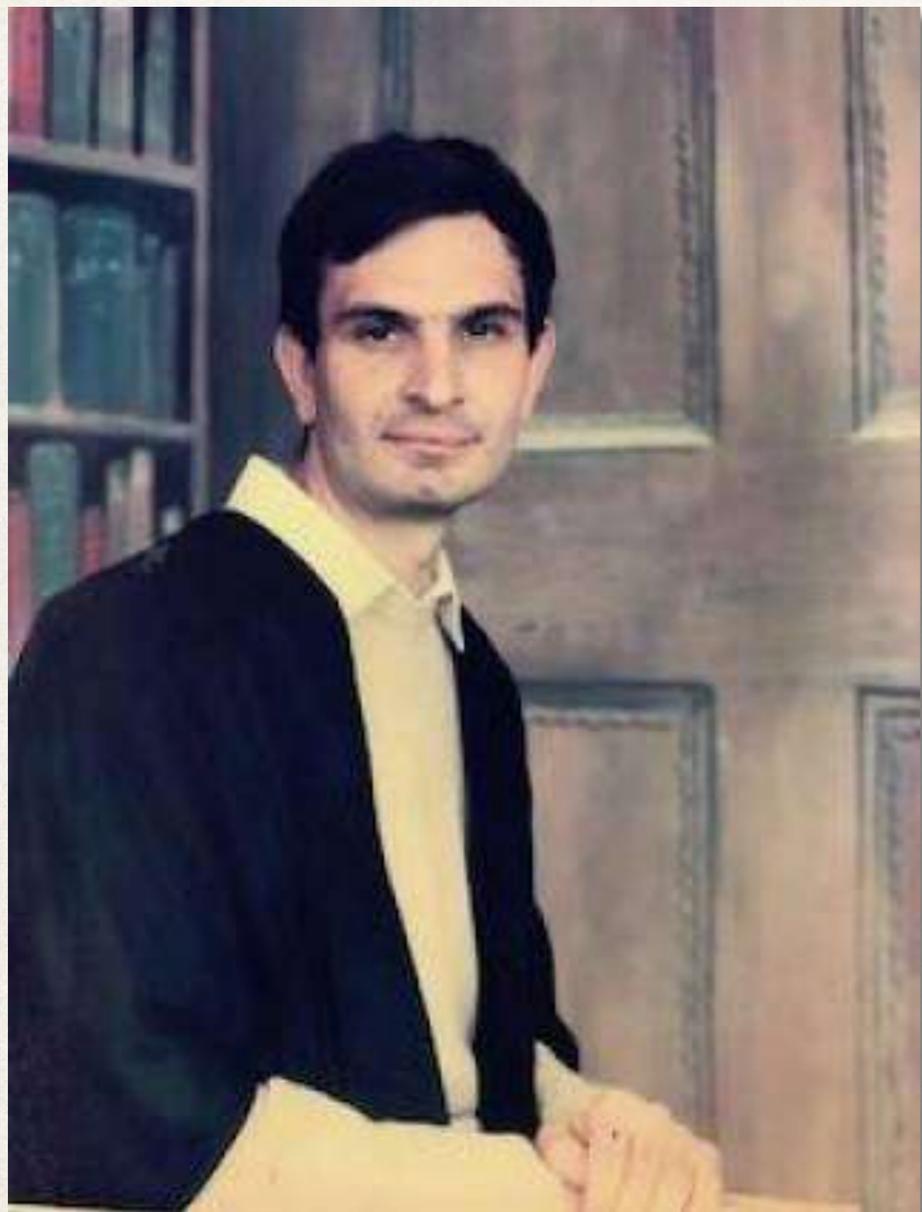
Ben Panter

Approaching 1 million medical scans per year

**Blackford**

# Descent into chaos

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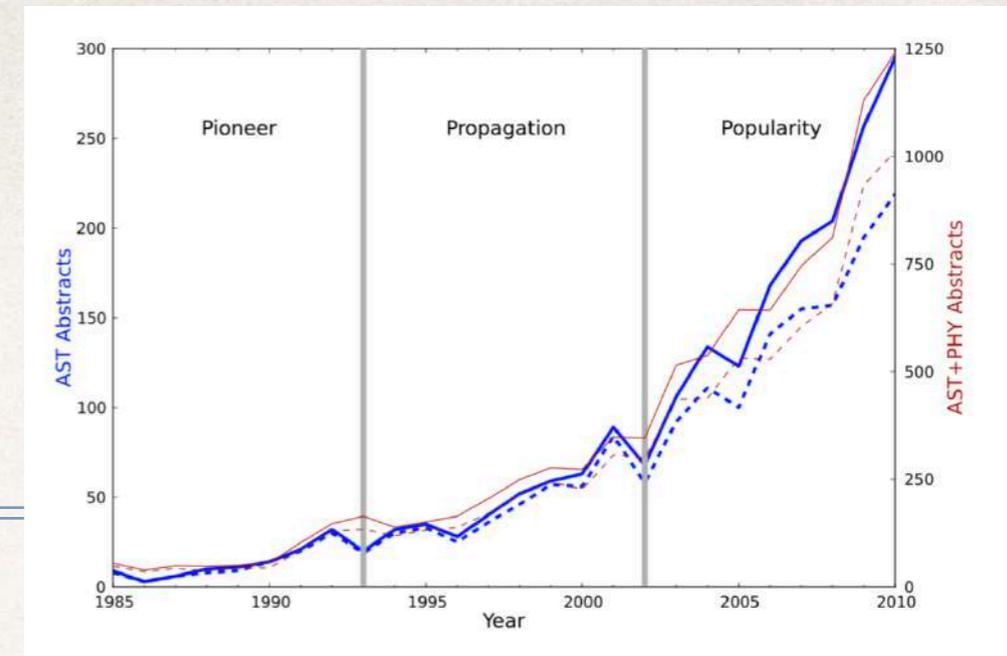
# Builder of UCL Cosmology

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Started cosmology from scratch, with Jochen Weller and Sarah Bridle

~10 Academic Staff, ~40 total

# Early Bayesian



above. We appreciate that there are widely differing views on how to use statistics, particularly for problems like this. We hope that the combination of statistics used here will have some appeal to both ‘frequentists’ and ‘Bayesians’.

According to the ‘Bayesian’ school of statistical inference, one should calculate the likelihood function for the parameter of interest. For example, the angular dipoles of the galaxy counts constrain the parameter  $\sigma_{\text{gal}} \equiv b\sigma_{\rho}$ , so for these data we can form the likelihood function

$$L(\sigma_{\text{gal}}) = P(\text{data} | \sigma_{\text{gal}} \dots), \quad (1)$$

where ... is shorthand for all the other assumptions in the theory like  $P(k)$ ,  $H_0$ , etc.. In the Bayesian approach one assigns probabilities to the various hypotheses – these probabilities describe one’s state of knowledge about  $\sigma_{\text{gal}}$ , or indeed about the world in general – and one updates these according to Bayes theorem

$$P(\sigma_{\text{gal}} | \text{data}) d\sigma_{\text{gal}} = \frac{P(\text{data} | \sigma_{\text{gal}})}{\int d\sigma'_{\text{gal}} P(\text{data} | \sigma'_{\text{gal}}) P(\sigma'_{\text{gal}})_{\text{prior}}} P(\sigma_{\text{gal}})_{\text{prior}} d\sigma_{\text{gal}}. \quad (2)$$

Tom Loredo

# Modesty: (semi-)popular articles:

## Selected Reviews & Semi-popular Articles

"[The Dark Energy Survey: more than Dark Energy - an overview](#)" DES collaboration, MNRAS, 460, 1270, 2016

"[The Cosmological Parameters 2016](#)" Lahav, O. & Liddle, A.R., 2016 - Invited review, in "The Review of Particle Physics" (Particle Data Group)

"[Dark Energy: back to Newton?](#)" Calder, L. & Lahav, O., RAS A&G, Feb 2008 issue (revised version)

"[Dark Energy: how the paradigm shifted](#)" Calder, L. & Lahav, O., Physics World, Jan 2010 issue

"[Dark Energy, paradigm shifts and the role of evidence](#)" Lahav, O. & Massimi, M., RAS A&G June 2014 issue

"[Let there be darkness, let there be light](#)" Lahav, O., Odyssey magazine (in Hebrew), Jan 2010 issue, pg. 38

# Un-popular articles:

357	<input type="checkbox"/> <a href="#">2018MNRAS.tmpL.242T</a>	0.000	06/2018	<a href="#">E</a>	<a href="#">U</a>
	Troxel, M. A.; Krause, E.; Chang, C.; Eifler, T. F.; Friedrich, O.; Gruen, D.; MacCrann, N.; Chen, A.; Davis, C.; DeRose, J.; <b>and 71 coauthors</b>		Withdrawn as Duplicate: Survey geometry and the internal consistency of recent cosmic shear measurements		
358	<input type="checkbox"/> <a href="#">2015AJ....150..165G</a>	0.000	11/2015	<a href="#">E</a> <a href="#">F</a>	<a href="#">O</a> <a href="#">U</a>
	Goldstein, D. A.; D'Andrea, C. B.; Fischer, J. A.; Foley, R. J.; Gupta, R. R.; Kessler, R.; Kim, A. G.; Nichol, R. C.; Nugent, P. E.; Papadopoulos, A.; <b>and 57 coauthors</b>	<b>Erratum:</b>	"Automated Transient Identification in the Dark Energy Survey" ( <a href="#">2015, AJ, 150, 82</a> )		
359	<input type="checkbox"/> <a href="#">2015APh....65..112N</a>	0.000	05/2015	<a href="#">A</a> <a href="#">E</a>	<a href="#">O</a> <a href="#">U</a>
	Newman, Jeffrey A.; Abate, Alexandra;	<b>Corrigendum to</b>	"Spectroscopic needs for imaging dark energy experiments" [Astropart. Phys. 63 (2015) 81-100]		

# Prolific Author

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## Research [\[ edit \]](#)

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Lahav's research is focused on cosmological probes of Dark Matter and Dark Energy, in particular large galaxy surveys.<sup>[4] [5]</sup> As of 2016 Lahav has co-authored over 200<sup>[citation needed]</sup> research articles in [peer reviewed](#) scientific journals and he is a [Thomson ISI](#) highly cited author.<sup>[6]</sup> His doctoral students include [Chris Lintott](#).<sup>[1]</sup>

Ofer has written over 200 papers  
that *have never been cited*

# DES Leader

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Lahav is one of the founders of the Dark Energy Survey (DES), and he co-chaired the international DES Science Committee from inception until 2016.

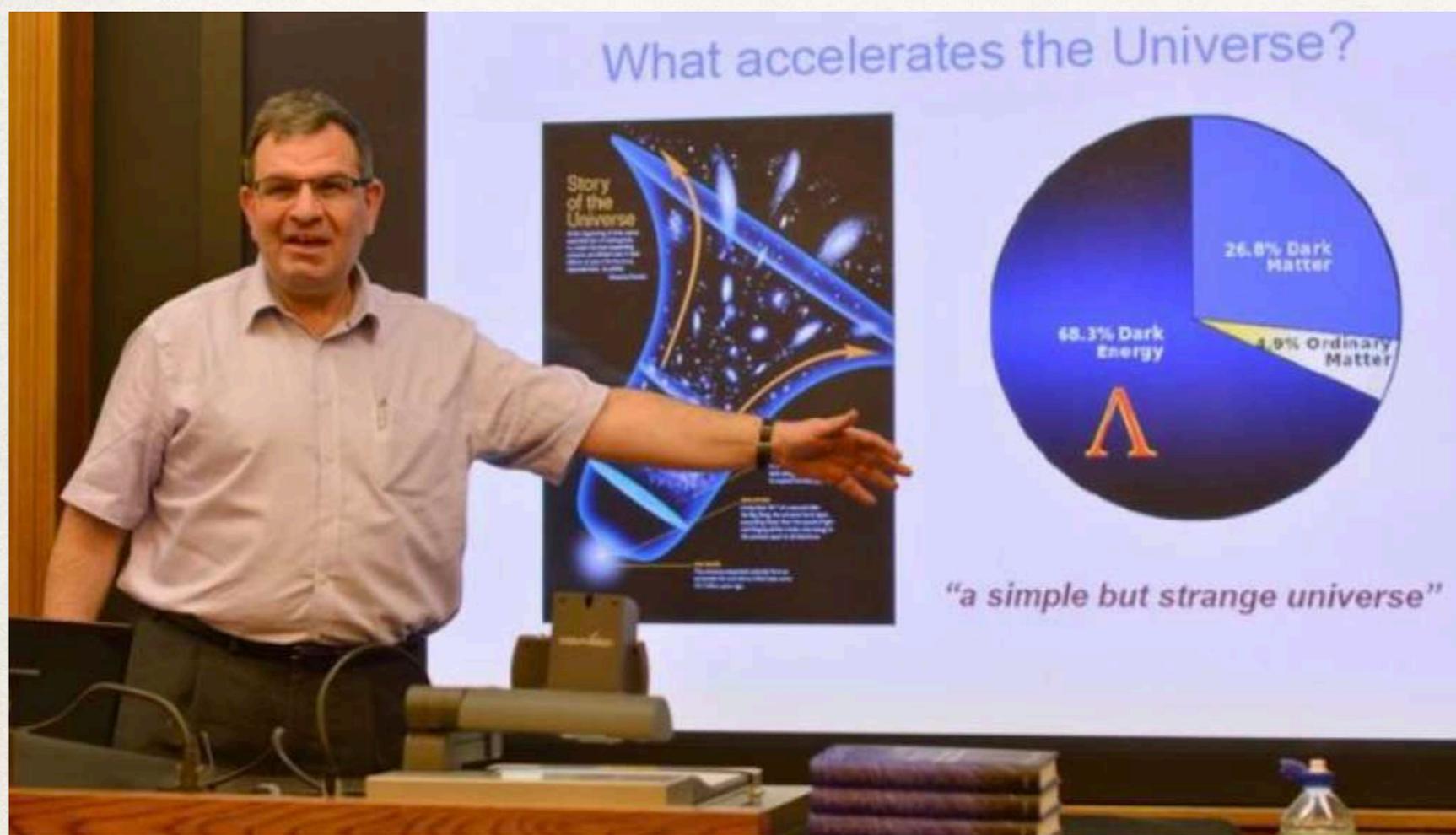


Ofer has led DES *since he was a baby*



# A great and willing populariser

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“Outreach”

Ofer at a Public Outreach lecture (2015)

# Reaching out to the skeptics:

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**harderwijk** Feb 23

This brilliant man

appears to be having trouble expressing himself clearly.

I must say, I'm not surprised.

**(followed by a letter that would normally be written in green ink)**

# Great educator



**Ofer Lahav** @Ofer\_Lahav · 19 Oct 2018

This is the last day of a DESI collaboration meeting near Barcelona, **by the sea.** It is exciting that observations will start next year, leading to a huge spectroscopic survey of galaxies.



# Cosmologist? Astrophysicist?

**Ofer Lahav** is a famous people who is best known as a **Celebrity**. Ofer was born on **April 5, 1959** in Tiberias, Israel. Ofer Lahav is a member of famous **Celebrity** list.

On CELEBS TREND NOW, Ofer's is ranked in the list of most popular celebrities. Also, ranked on the list with those people who were **born on April 5**. Have Position Among the list of Most popular Celebrity. Ofer Lahav is 1 of the celebs with the **age 58 years** old.

Short Profile	
First Name	Ofer
Last Name	Lahav
Profession	Celebrity
Age	58 years <small>✖</small>
Birth Sign	Aries
Birth Date	April 5, 1
Birth Place	Tiberias,
City	Tiberias
Country	British

From  
celebstrendnow.com

“Shoe size will be added later”



# OFFER

Into Darkness

MOVIEPOSTERMAKER PRESENTS A MMP FILM BY WWW.MOVIEPOSTERMAKER.COM COSTUME DESIGNER POSTER MAKER 'GENERATOR' WRITTEN BY SOMEONE OKIDO  
MUSIC BY THE MUSICIAN COSTUME DESIGNER NAME EDITED BY EDITORS NAME PRODUCTION DESIGNER DESIGNERSNAME DIRECTOR OF PHOTOGRAPHY CINEMATOGRAPHER WUT LOL  
EXECUTIVE PRODUCER EX PRODUCER 1 EX PRODUCER 2 PRODUCED BY PRODUCER ONE PRODUCER 2 STORY BY STORY WRITER TROLOLO DIRECTED BY DONTKNOW

[www.MoviePosterMaker.com](http://www.MoviePosterMaker.com)

# Who should play Ofer?

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David Suchet



Ofer Lahav



Happy Birthday, Ofer!