

Emmanuel Schaan

# **Rubin Observatory & the CMB**

## **Steve Kahn symposium**

# A legacy: Rubin Camera & Observatory



#### 27 June 2006 The LSST camera system overview

Kirk Gilmore, Steven Kahn, Martin Nordby, David Burke, Paul O'Connor, John Oliver, Veljko Radeka, Terry Schalk, Rafe Schindler





Berni Ried-Guachalla

LSST Camera teamSLAC/Rubin

# Rubin is not alone: CMB

#### Summary





• Joint reduction of the LSST and CMB S-4 datasets will address a host of important problems in fundamental cosmology.



# Full overlap with Rubin LSST

# Simons Observatory large aperture survey



RA=0

## AdvACT now Simons Observatory from 2024 CMB S4 from 2028

Emmanuel Schaan

# Why combine LSST & CMB?



## **1. Compare initial & final conditions** Neutrino masses & S<sub>8</sub> tension



### **2. CMB helps LSST** Baryonic uncertainty Shear validation



### **3. LSST helps CMB** Foreground cleaning Detect new CMB secondaries

### Massless v

Massive v

### Cosmology can weigh the neutrinos

Neutrinos = 0.5% of all matter, but their gravity suppresses LSS 8-fold = 4%



~1Mpc

# Neutrino masses require Rubin x CMB



Mishra-Sharma+18

Look for a 4% power reduction between CMB & LSST...

# ... but we already see a 10% suppression!

### CMB

#### Cosmic shear

### Galaxy clustering

#### **Optical clusters**

tSZ clusters

Redshift-space distortions

#### Abdalla+22

• CMB Planck TT,TE,EE+lowE • CMB Planck TT,TE,EE+lowE+lensing • CMB ACT+WMAP

• WL KiDS-1000

• WL KiDS-450

• WL KiDS-450

• WL DES-Y3

• WL DES-Y1

• WL HSC-TPCF

• WL CFHTLenS

• WL HSC-pseudo-C<sub>l</sub>

• WL+GC HSC+BOSS

WL+GC KiDS-1000 3×2pt

• WL+GC KiDS-450 3×2pt

• WL+GC DES-Y3 3×2pt

• WL+GC DES-Y1 3×2pt

• WL+GC KiDS+GAMA 3x2pt

• GC BOSS DR12 bispectrum

• GC BOSS galaxy power spectrum • GC+CMBL DELS+Planck

• GC+CMBL unWISE+Planck

• GC BOSS power spectra

CC AMICO KiDS–DR3

• GC BOSS+eBOSS

GC BOSS DR12

• CC DES-Y1

• CC SPT tSZ

• RSD

• RSD

• CC Planck tSZ

• CC Planck tSZ

0.2

0.4

0.6

0.8

 $S_8 \equiv \sigma_8 \sqrt{\Omega_m / 0.3}$ 

• CC SDSS-DR8

• CC XMM-XXL

• CC ROSAT (WtG)

• WL+GC KiDS+VIKING-450+BOSS

• WL+GC+CMBL KiDS+DES+eBOSS+Planck

• WL KiDS+VIKING+DES-Y1

• WL KiDS+VIKING+DES-Y1

• WL KiDS+VIKING-450

• WL KiDS+VIKING-450



Aghanim et al. (2020d)
 Aghanim et al. (2020d)
 Aiola et al. (2020)

#### Early Universe

#### Late Universe

Asgari et al. (2021)
Asgari et al. (2020)
Joudaki et al. (2020)
Wright et al. (2020)
Hildebrandt et al. (2020)
Kohlinger et al. (2017)
Hildebrandt et al. (2017)
Amon et al. and Secco et al. (2021)
Troxel et al. (2018)
Hamana et al. (2020)
Hikage et al. (2019)
Joudaki et al. (2017)

Miyatake et al. (2022)
García-García et al. (2021)
Heymans et al. (2021)
Joudaki et al. (2018)
Abbott et al. (2021)
Abbott et al. (2018d)
Tröster et al. (2020)
van Uitert et al. (2018)

Philcox et al. (2021)
Ivanov et al. (2021)
Chen et al. (2021)
Tröster et al. (2020)
Ivanov et al. (2020)
White et al. (2022)
Krolewski et al. (2021)

Lesci et al. (2021)
Abbott et al. (2020d)
Costanzi et al. (2019)
Pacaud et al. (2018)
Mantz et al. (2015)

· Bocquet et al. (2019) · Salvati et al. (2018) · Ade et al. (2016d)

1.0

Benisty (2021)
 Kazantzidis and Perivolaropoulos (2018)

1.2



#### Federico Bianchini



#### Alex Friedland



Kimmy Wu

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### Why care? Cosmology & Galaxy formation



Illustris

Supernovae and supermassive black holes regulate galaxy formation Unknown "feedback" amplitude

→ Missing baryon problem

How to analyze 1% precision LSS data when baryons (15% of matter) are missing?

## Consequence: much of the statistical power is lost



DES Y3 Amon+22

Localizing the baryons would unleash the constraining power of LSST

## How? CMB is an LSS probe



## Gas profiles around galaxies: stacking

noving radius [Mpc/h] at z = 0.31-1.240.01.24





## Directly subtract the baryonic contribution!



## How? CMB is an LSS probe



# LSST shear calibration with CMB lensing





Intrinsic galaxy (shape unknown)

Gravitational lensing causes a **shear (g)** 



Atmosphere and telescope cause a convolution



Detectors measure a pixelated image

sure Image also age contains noise Heymans, Euclid Science Book 2010





Schaan Krause Eifler+16



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# CMB Extragalactic Foregrounds

Berni Ried-Guachalla



adapted from Sehgal+09



Most extragalactic foregrounds come from Rubin galaxies & their friends → Subtract!

Mishra Schaan 19

## New CMB secondaries: Patchy screening



Will Coulton

Probe gas density directly Combined with kSZ, extract LOS velocity → Primordial non-Gaussianity, tests of GR

# New CMB secondaries: Moving lens effect



Unique probe of galaxy velocities across the LOS Combined with kSZ, infer 3d galaxy velocities → Primordial non-Gaussianity, tests of GR

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