International Centre for Radio Astronomy Research

Redundant Calibration

Breaking the constraints of Limited sky knowledge

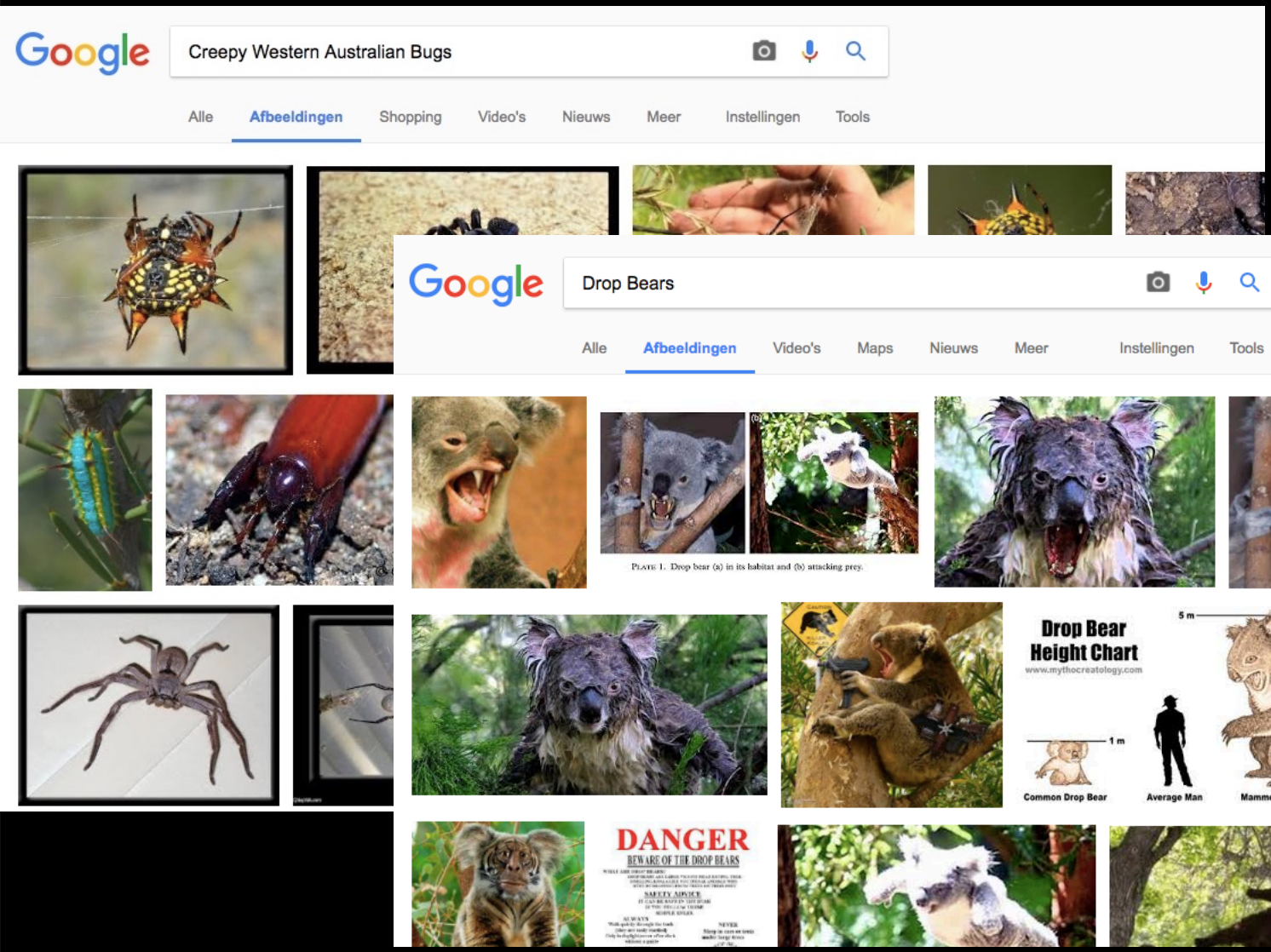
Ronniy Joseph @astronniy
ICRAR – Curtin University
Science at Low Frequencies IV

Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA

Government of Western Australia
Department of the Premier and Cabinet
Office of Science

1 year and … I am still alive!



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The Calibration Problem

$$c_{ij} = g_i^* g_j \times v_{ij}$$

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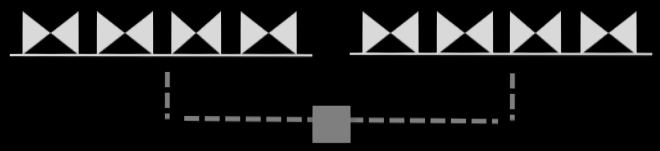

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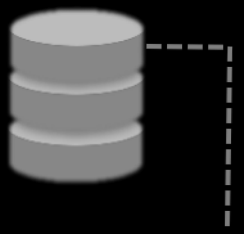


The Calibration Problem

$$c_{ij} = g_i^* g_j \times v_{ij}$$

The Calibration Schools

Image Based

$$c_{ij} = g_i^* g_j \times v_{ij}$$

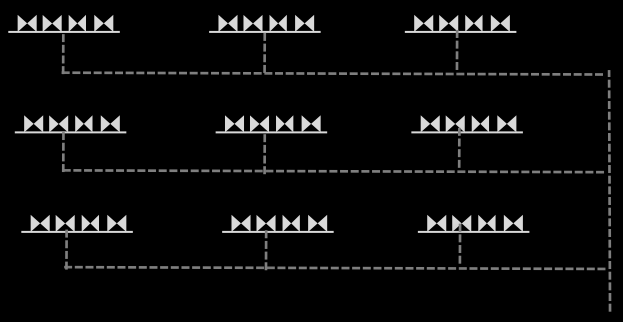
Redundancy Based

FHD (Sullivan+ 2012)

CLEAN -like

Omnical (Zheng+ 2014)

HERAcal



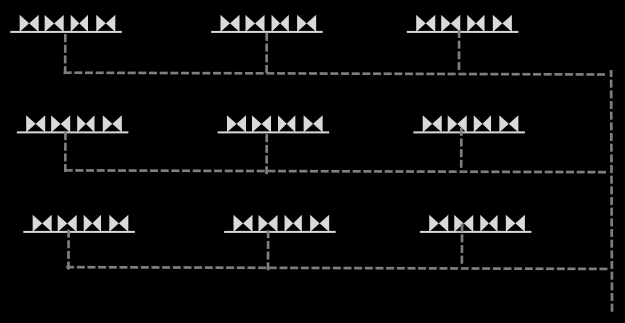
The Calibration Schools

+ Works on **all** arrays

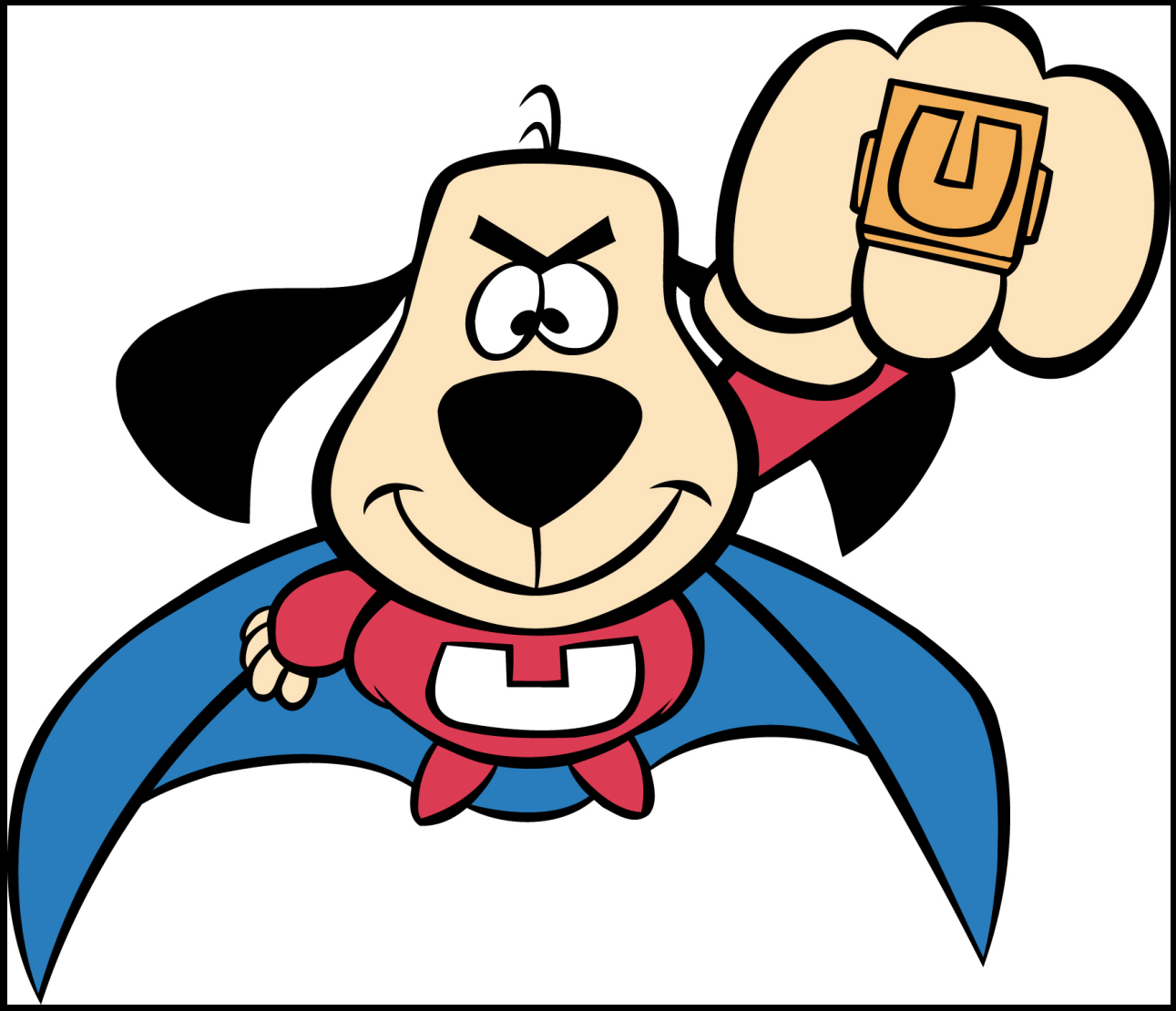
- Need a Sky Model

+ Sky Model Free

- Redundant Array



A Case for Redundant Calibration



The missing source problem

$$c_{ij} = g_i^* g_j \times v_{ij}$$

Incorrect Calibration Solutions

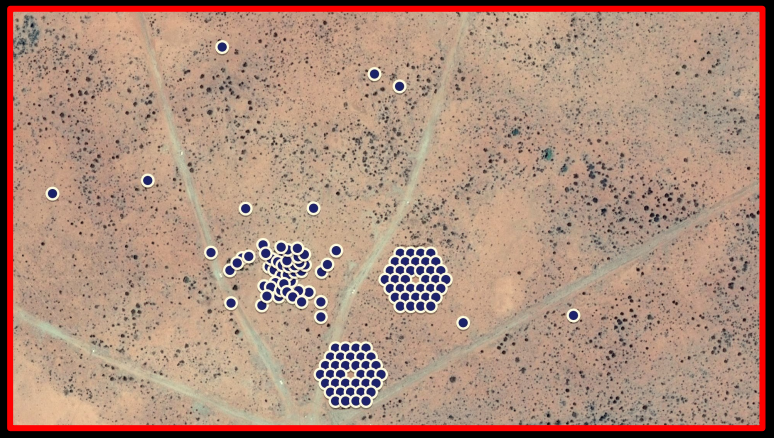
Image **Ghosts** [Grobler+2016, Wijnholds+ 2016]

Epoch of Reionization **Contamination**

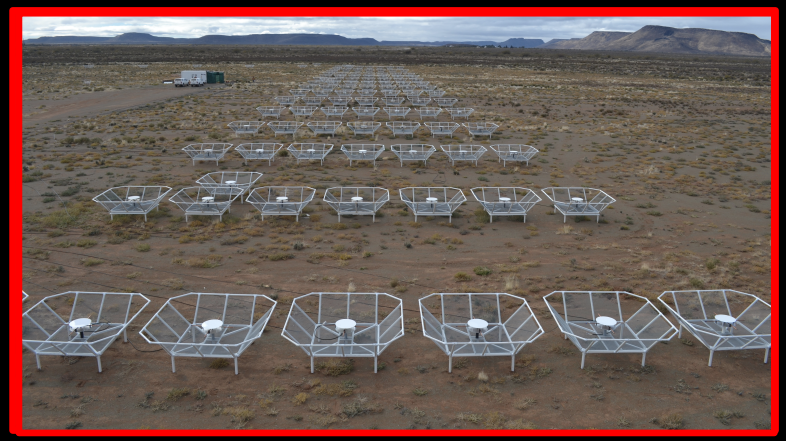
[Nichole Barry+ 2016]

EoR Machines

Reionization.org



Google Maps

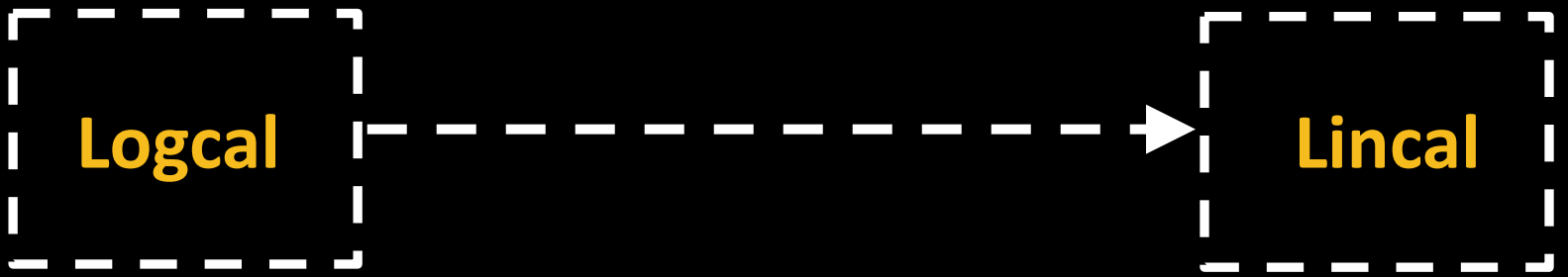


James Aguirre

ASTRON

Redundant Calibration Schemes

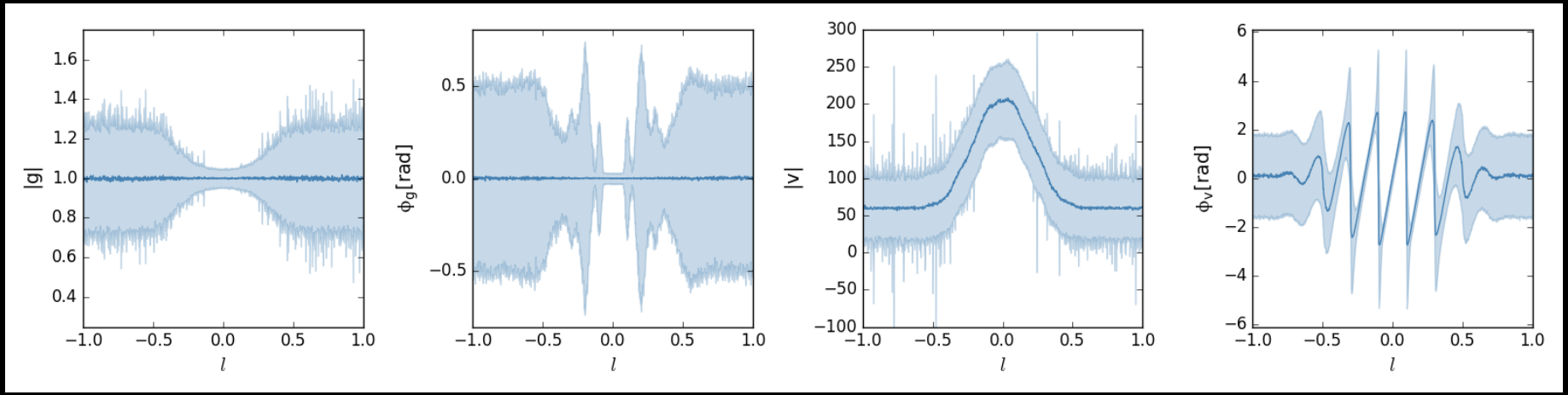
$$c_{ij} = g_i^* g_j \times v_{ij}$$



[Wieringa 1992]

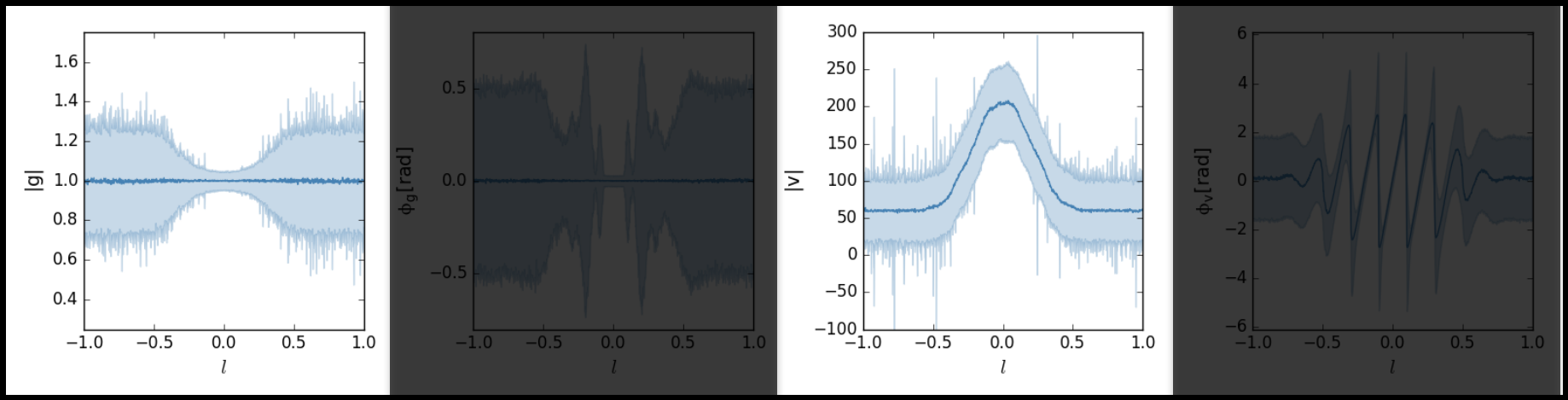
[Liu+ 2010]

Sky Dependency



[R. Joseph+ in prep.]

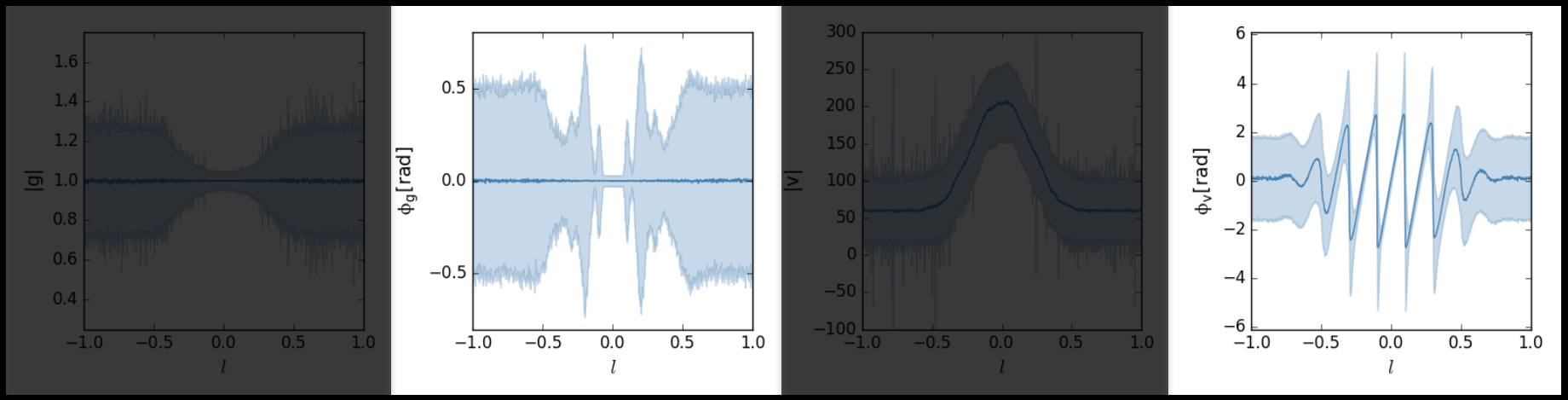
Sky Dependency - Logcal



Source Location

[R. Joseph+ in prep.]

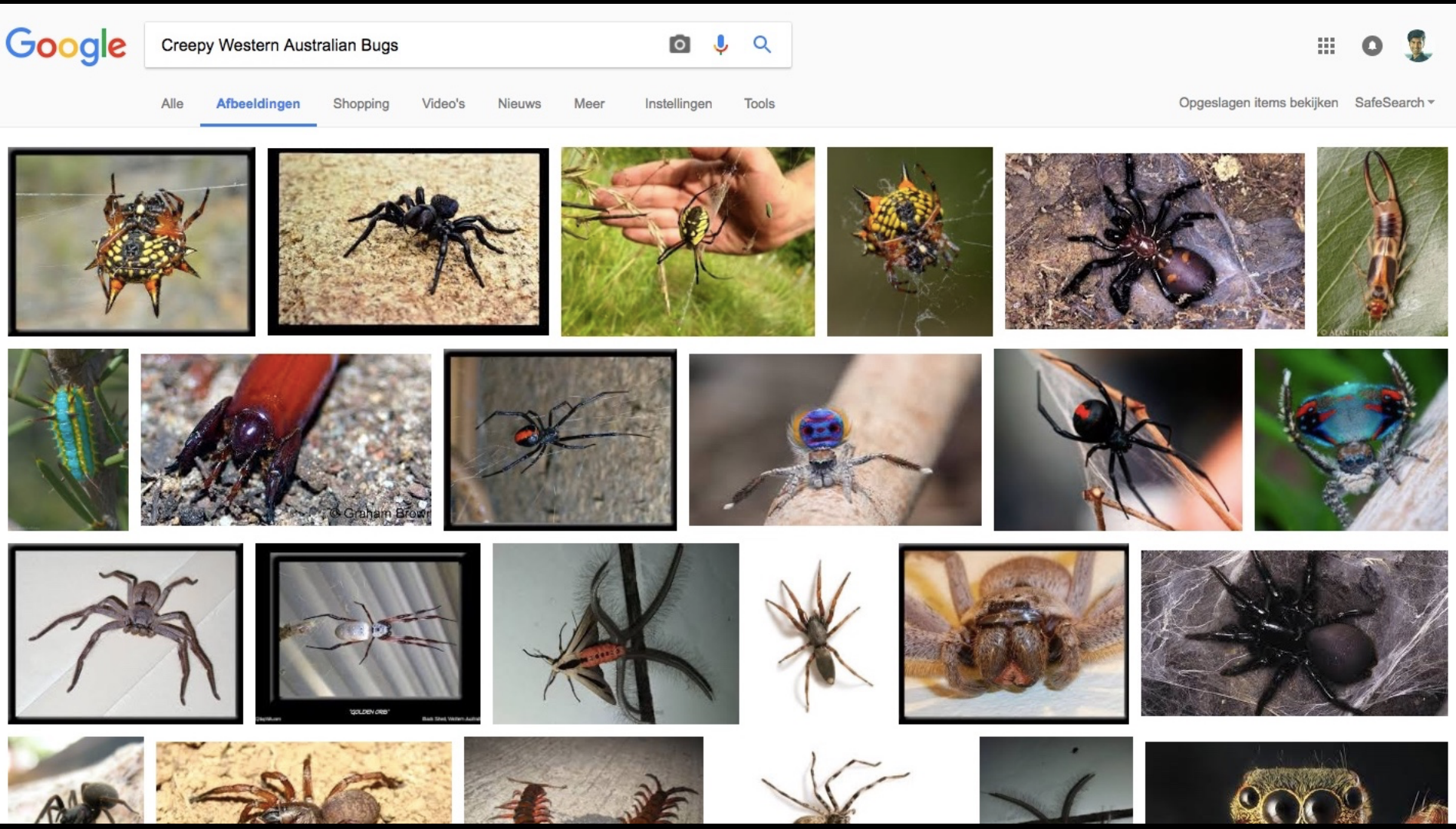
Sky Dependency - Logcal



Source Location

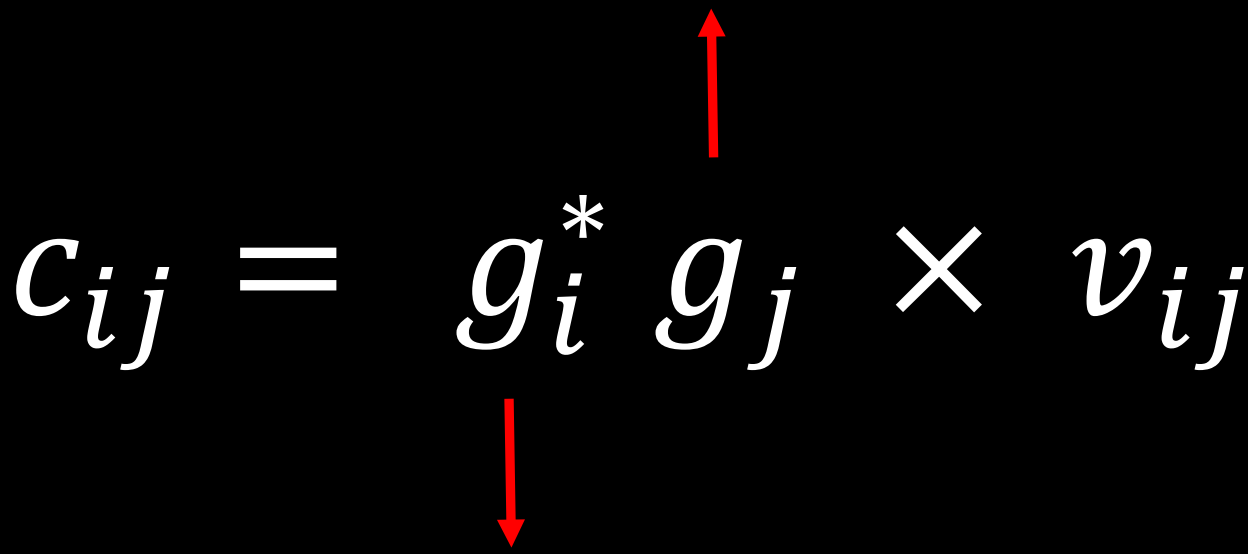
[R. Joseph+ in prep.]

Sky Dependency - Lincal



Redundant Degeneracies

Fitting **internal** consistency.



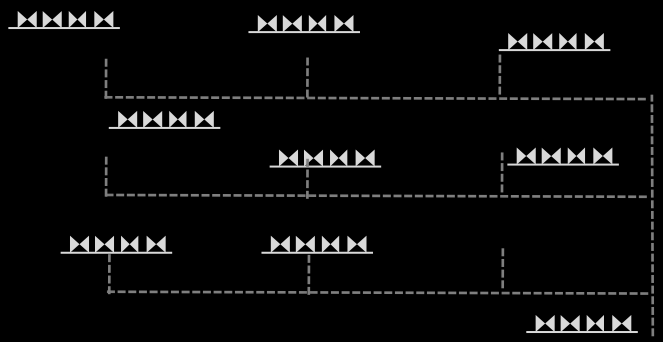
$$c_{ij} = g_i^* g_j \times v_{ij}$$

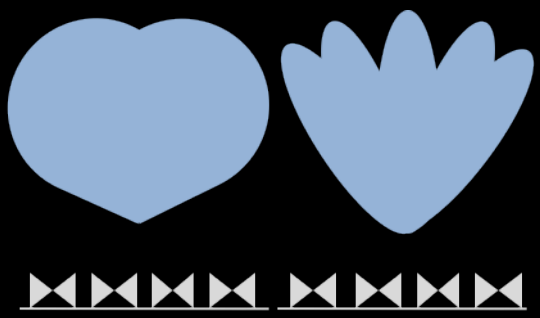
Complex numbers are a pain. : (

Hybrid Calibration

Redundant ---------- **Sky Model**

No True Redundancy





Positions offsets

Beam variations

No Perfect Sky Model

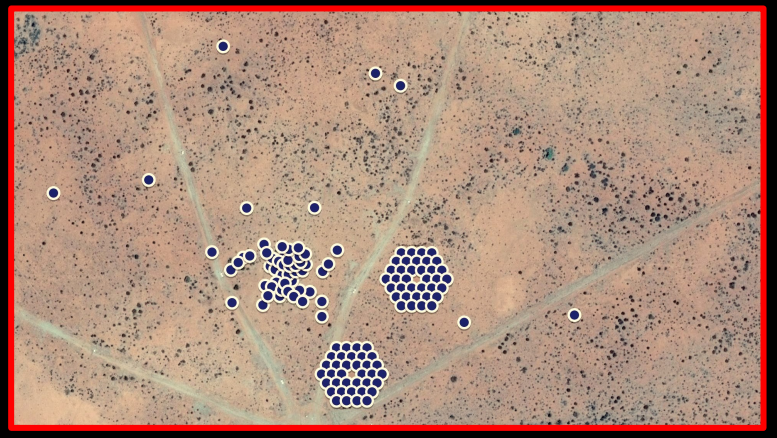
[Sievers 2017]

Generalized Calibration

SKA **Partial** Coherence

http://skatelescope.org

Hybrid MWA



Google Maps

Optimally combine all the information we have?

Calibration Symbiosis

Wenyang Li (Brown University)

[in the ApJ sausage machine]

FHD + Omnical and Omnical + FHD

COMPARING REDUNDANT AND SKY MODEL BASED INTERFEROMETRIC CALIBRATION: A FIRST LOOK WITH PHASE II OF THE MWA

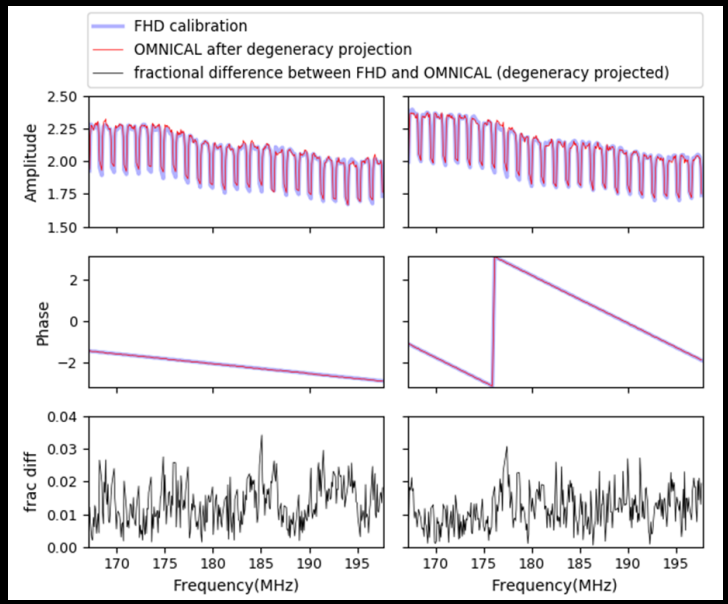
W. Li[1], J. C. Pober[1], B. J. Hazelton[2], N. Barry[2], M. F. Morales[2], I. Sullivan[2], A. R. Parsons[3], Z. Ali[3], J. S. Dillon[3], A. Beardsley[2], J. D. Bowman[4], F. Briggs[5], R. Byrne[2], P. Carroll[2], B. Crosse[6], D. Emrich[6], A. Ewall-Wice[7], L. Feng[7], T. M. O. Franzen[6], B. M. Gaensler[8,9,10], J. N. Hewitt[7], L. Horsley[6], D. C. Jacobs[4], M. Johnston-Hollitt[11], C. Jordan[6], D. L. Kaplan[12], D. Kenney[6], H. Kim[13], P. Kittiwisit[4], A. Lanman[1], E. Lenc[8,9], J. Line[13], B. McKinley[13], D. A. Mitchell[14,9], S. Murray[6], A. Neben[7], A. R. Offringa[15], D. Pallot[16], S. Paul[17], B. Pindor[13], P. Procopio[13], M. Ramini[13], J. Riding[13], S. K. Sethi[17], N. Udaya Shankar[17], K. Steele[6], R. Subrahmanian[17], M. E. Tegmark[7], N. Thyagarajan[4], S. J. Tingay[6,9,18], C. Trott[6,9], M. Walker[6], R. B. Wayth[6,9], R. L. Webster[13,9], A. Williams[6], C. Wu[16] and S. Wyithe[13]

Draft version October 27, 2017

ABSTRACT

We present the first results of redundant calibration on MWA Phase II observations, as well as sky model based calibration. In Phase II, the MWA installed 71 antenna tiles in two highly redundant hexagonal layouts. In this paper, we apply the publicly available package `OMNICAL`, developed for instrument calibration using redundant baselines, on data from the two hexagons. We also produce sky-based calibration solutions with the publicly available analysis package Fast Holographic Deconvolution (FHD). The principal results consist of three sections. (1) We report the success of `OMNICAL` on observations of ORBCOMM satellites, showing substantial agreement between redundant visibility measurements after calibration. (2) We further compare `OMNICAL` results with FHD sky model calibration on observations of the EoR0 field, and we find the evidence that these two different calibration schemes give consistent results. (3) We explore improved calibration by combining `OMNICAL` and FHD. We evaluate the different calibration solutions by looking at visibility redundancy and power spectra, and suggest future directions for combining these two calibration schemes.

Keywords: dark ages, reionization, first stars; instrumentation: interferometers; methods: data analysis; techniques: interferometric



2018 Resolutions

Sky Dependency Redundant Calibration

Position offset impact on Redundant Calibration

Expand **Hybrid Calibration** [Sievers 2017]

Less Bugs…….

More fresh air

Eat healthy

Exercise more

Be more mindful.