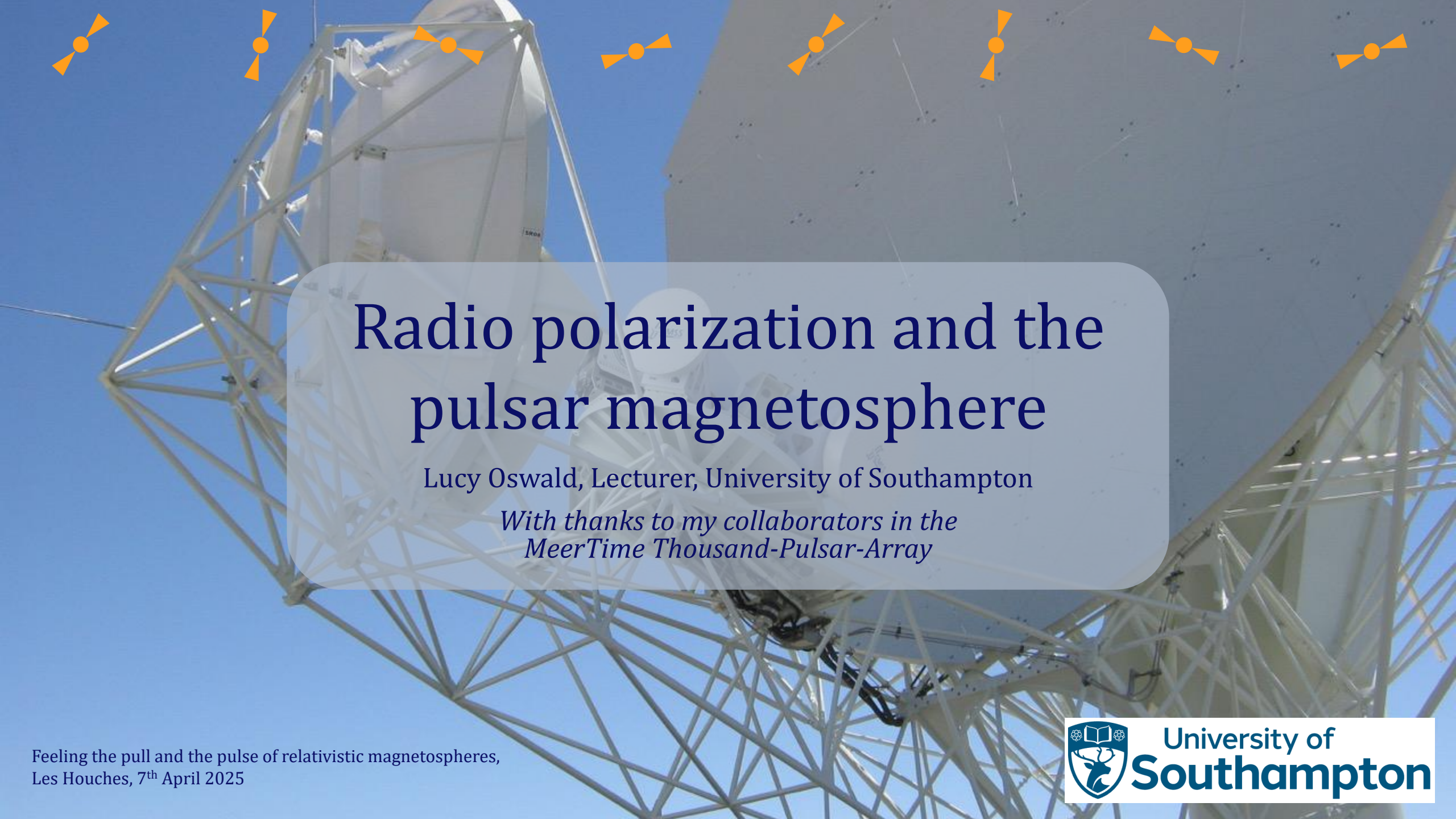


Radio polarization and the pulsar magnetosphere

Lucy Oswald, Lecturer, University of Southampton

With thanks to my collaborators in the MeerTime Thousand-Pulsar-Array

Feeling the pull and the pulse of relativistic magnetospheres,
Les Houches, 7th April 2025

University of Southampton

Goal

To understand pulsar magnetospheres through observations of their radio polarization.

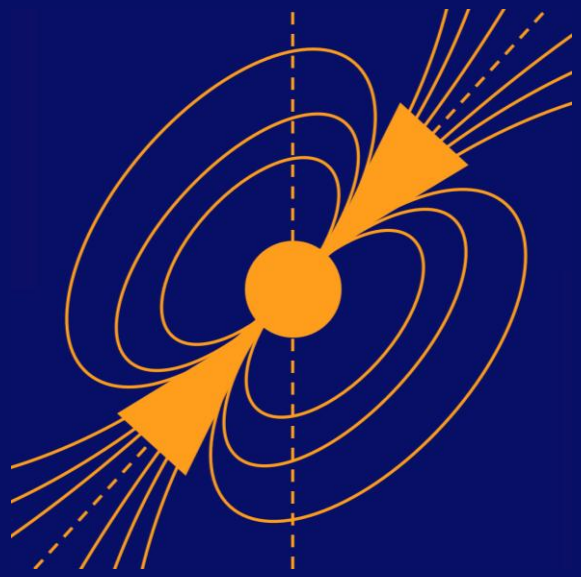
Premise

That different physical mechanisms lead to observably separable polarization effects.

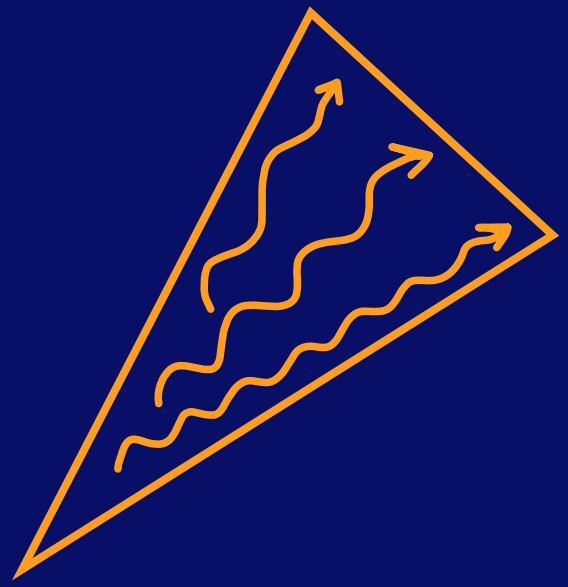
Proposal

A single-pulse population study of polarization decomposition with the *partial-coherence model.*

How pulsar physics imprints on the radio polarization

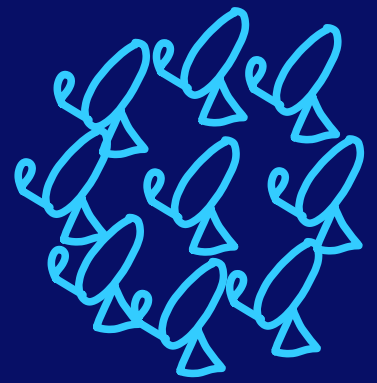


Radio beam produced in pulsar magnetosphere



Radio waves propagate to polarization limiting radius

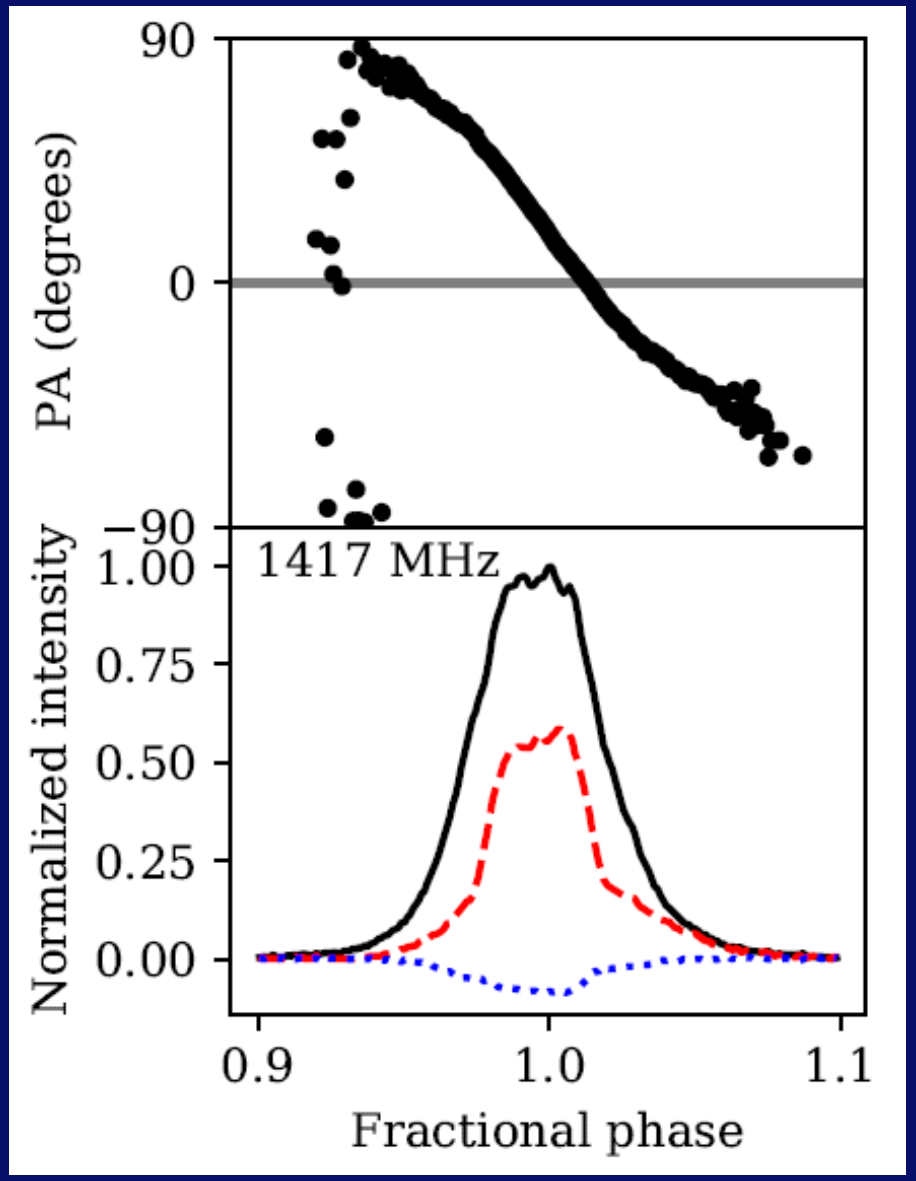
Radio waves travel through ISM

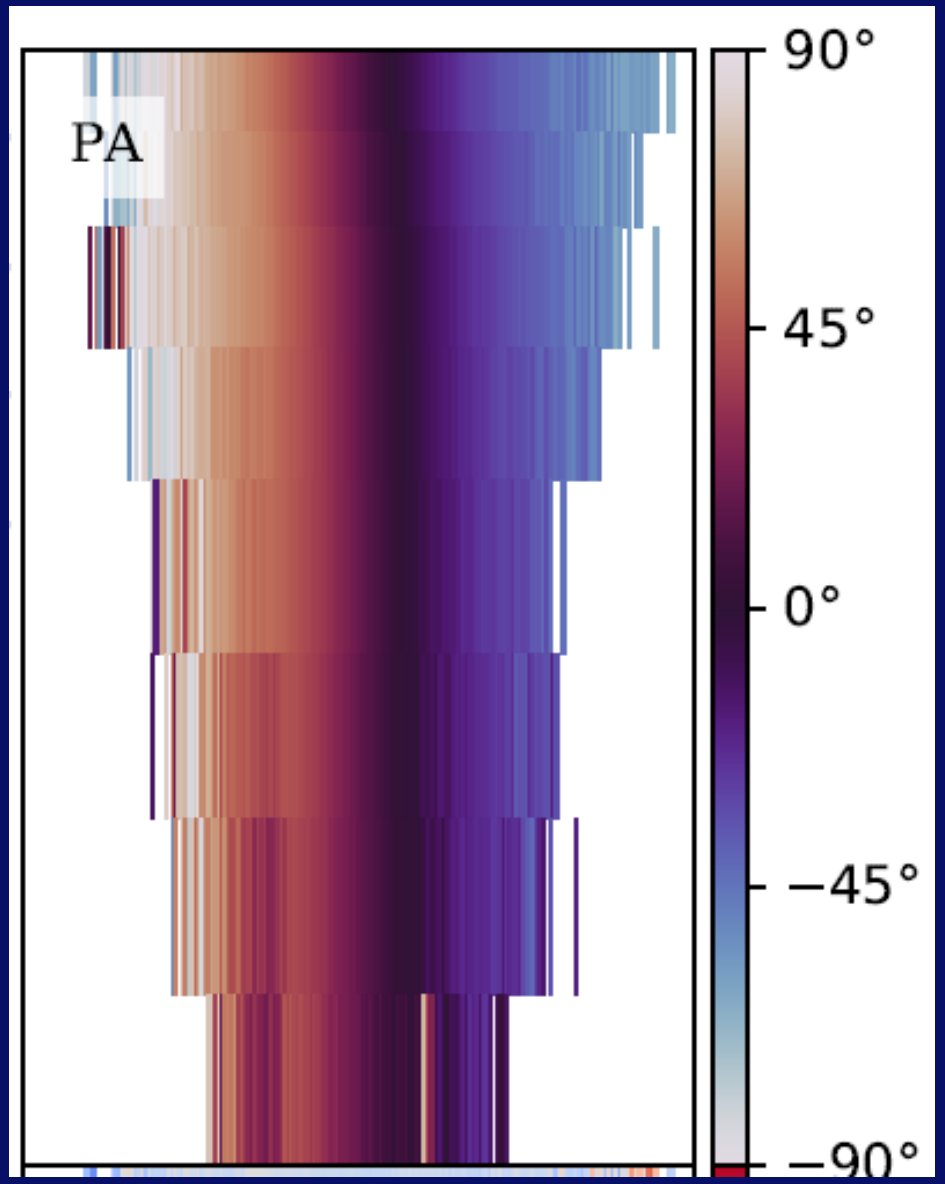


Pulses arrive at telescope

J0630-2834

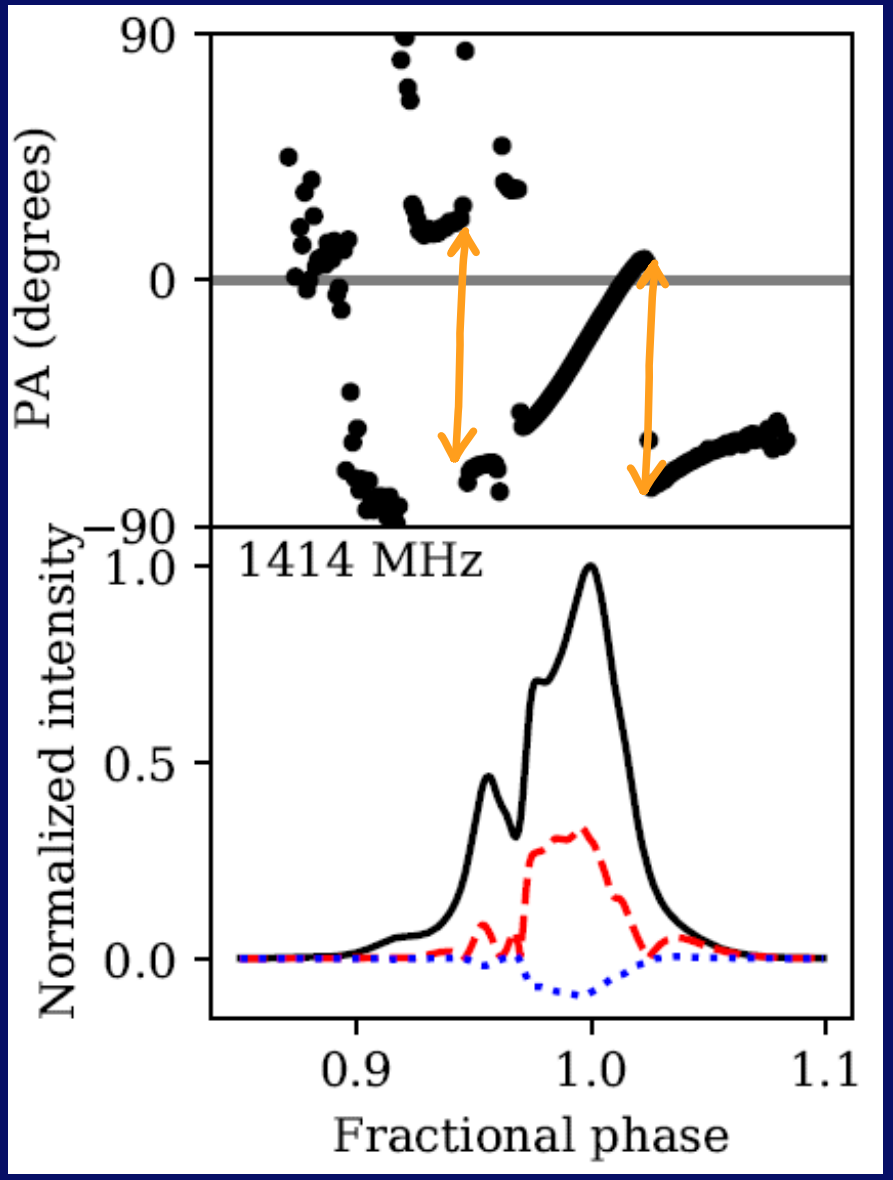
Oswald et al 2023a

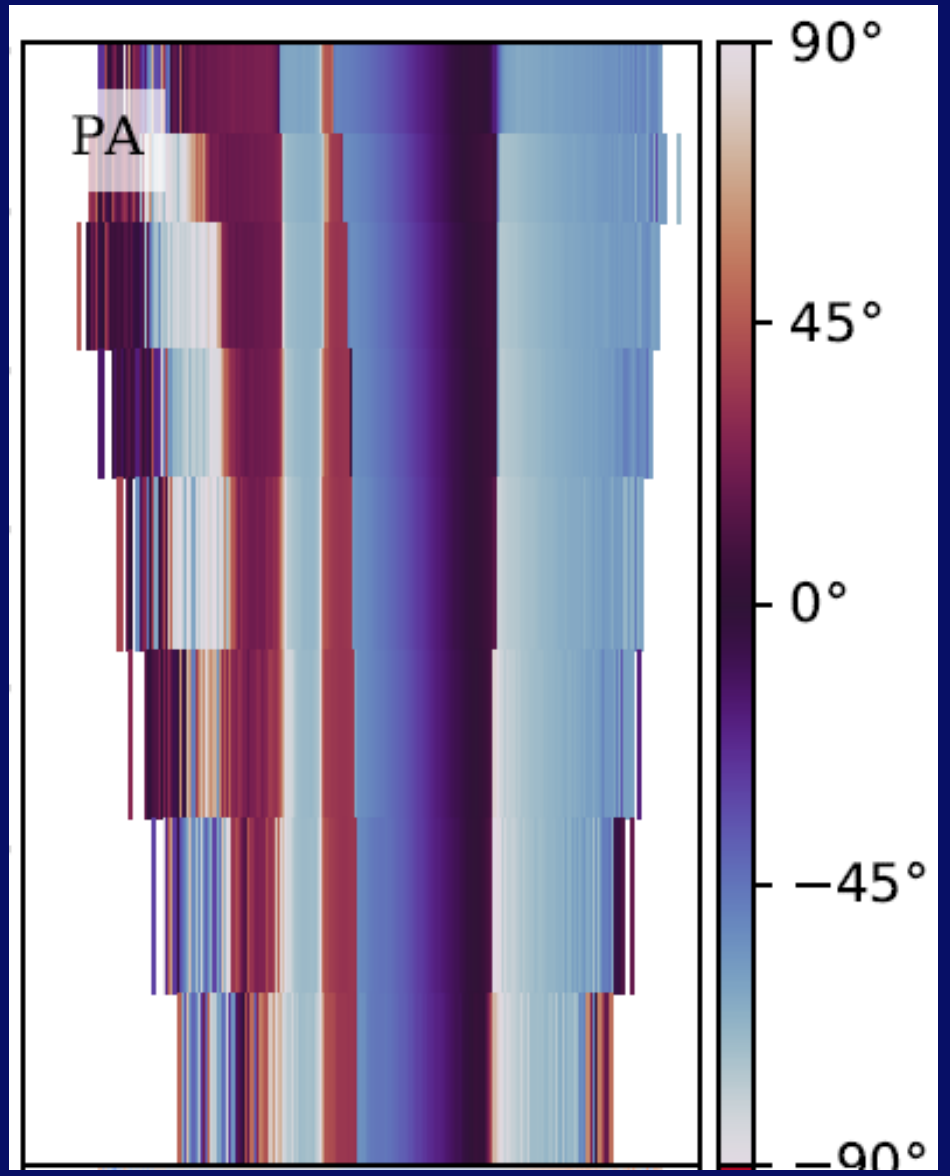




J0738-4042

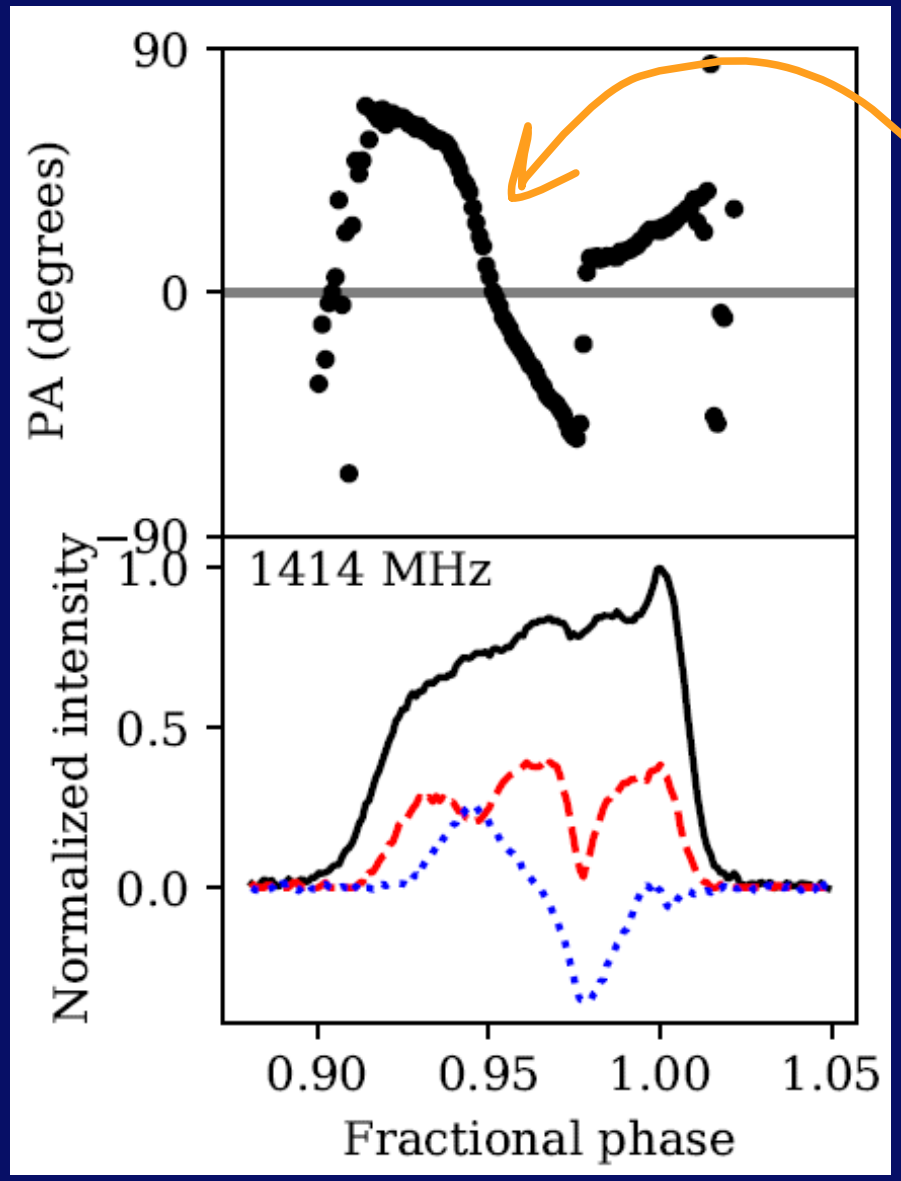
Oswald et al 2023a



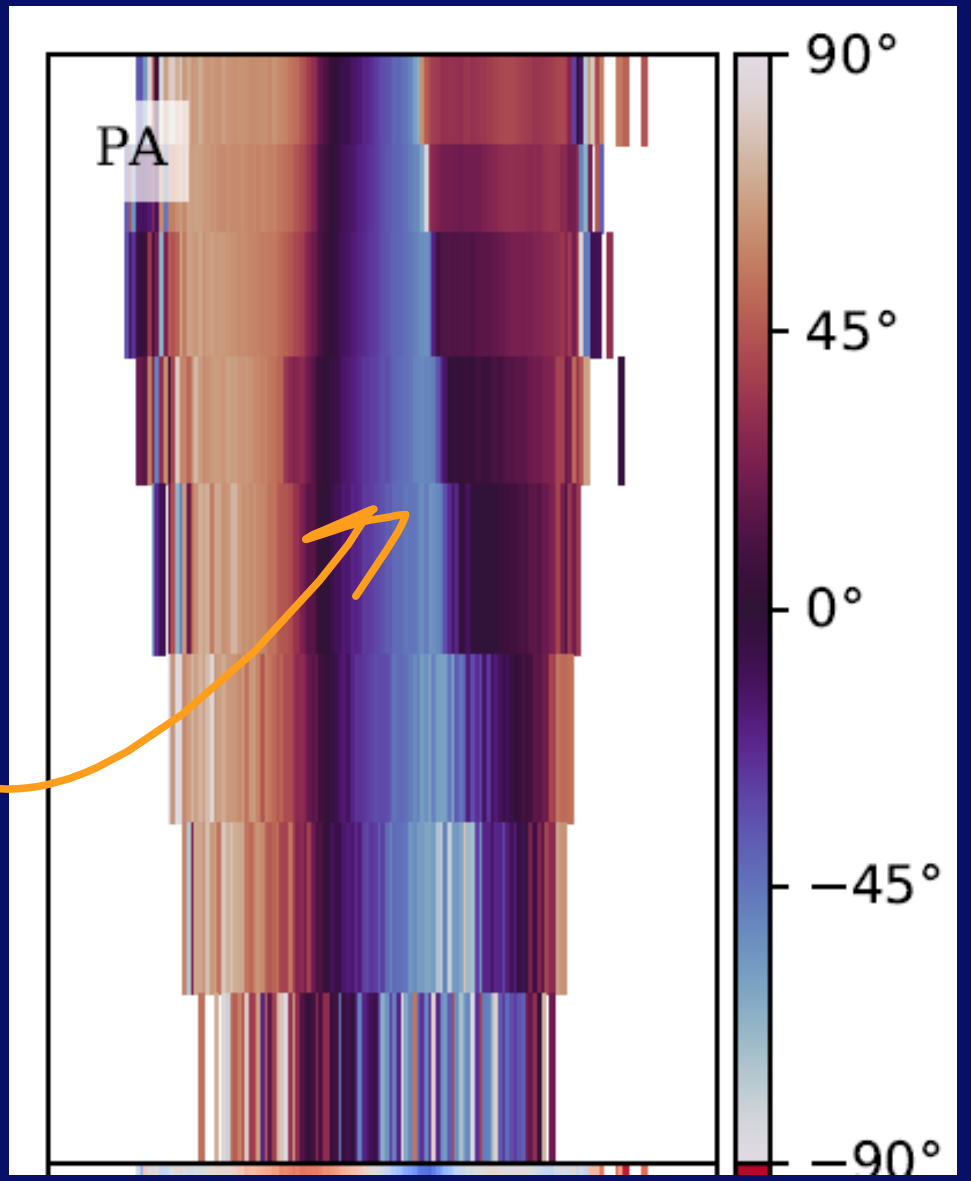


J1900-2600

Oswald et al 2023a

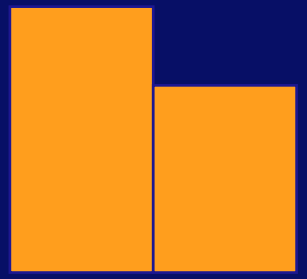


???



The partial-coherence model

Work inspired by
Radhakrishnan & Cooke 1969
Lyubarskii & Petrova 1998a,b
von Hoensbroech, Lesch & Kunzl 1998
McKinnon & Stinebring 2000
Edwards & Stappers 2004
Karastergiou et al 2011
Ilie et al 2019
Dyks et al 2019, 2021
Primak et al 2022



Mode strength ratio

Mode phase offset

Coherence fraction

Oswald et al 2023b

The partial-coherence model

R

Mode strength ratio

η

Mode phase offset

C

Coherence fraction

Oswald et al 2023b

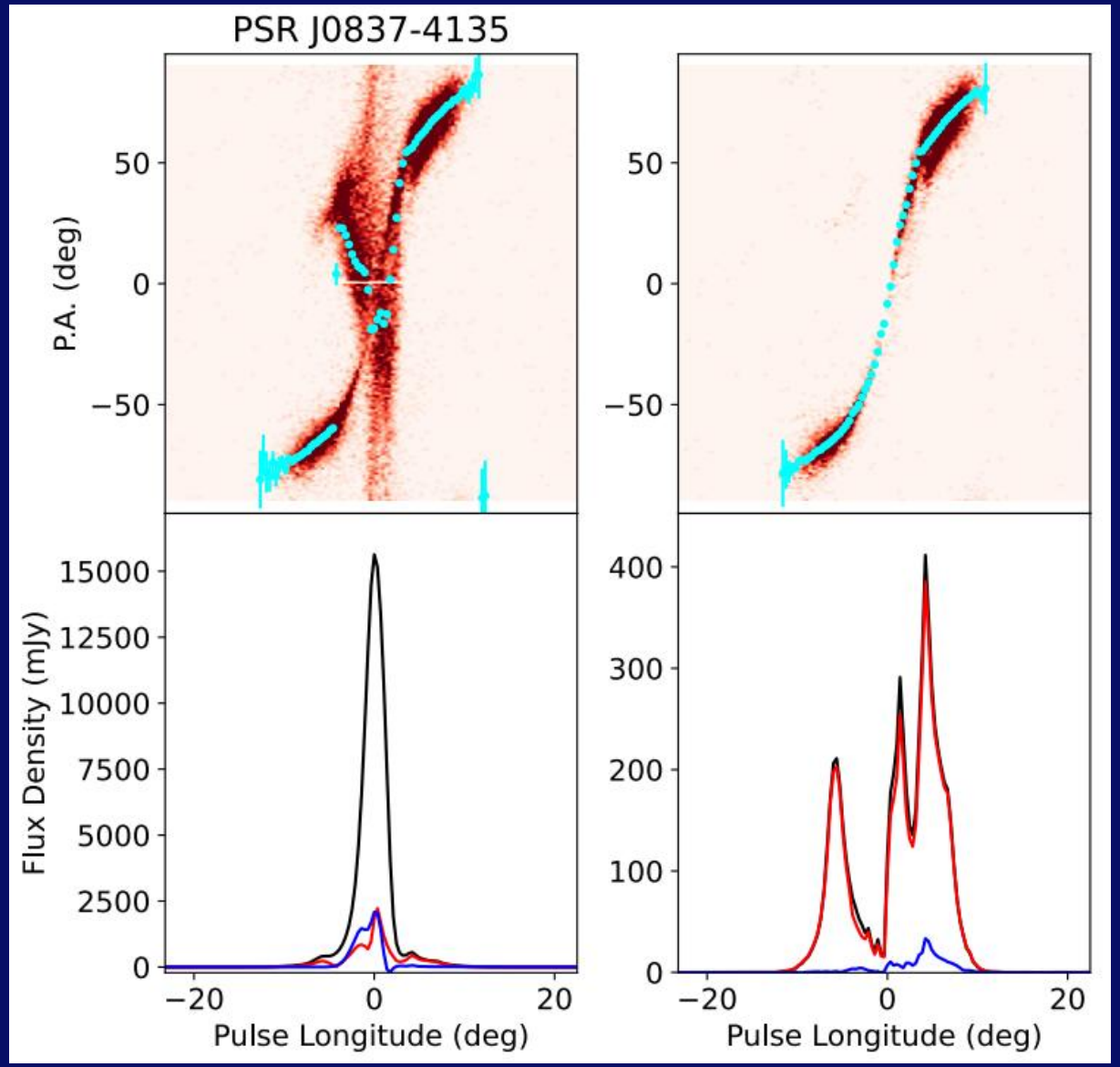
What about single pulses?

Recovering the RVM

Keep just the highly linearly polarized bins of the single pulses and recover an S-shaped polarization curve

RVM fit failure rate reduced from 59% to 5% (for the 177 pulsars bright enough to be amenable to the method)

Theory and methodology proposed by Mitra et al 2023a and tested using the TPA data set by Johnston et al 2024



Source: Johnston et al 2024

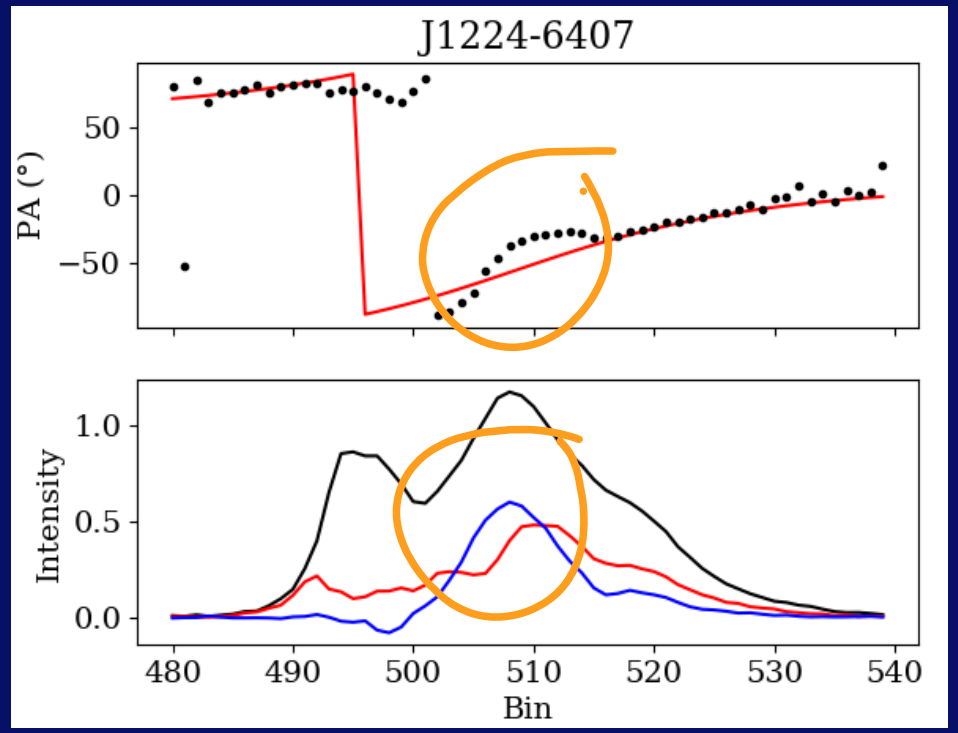
Proposal

A single-pulse population study of polarization decomposition with the *partial-coherence model.*

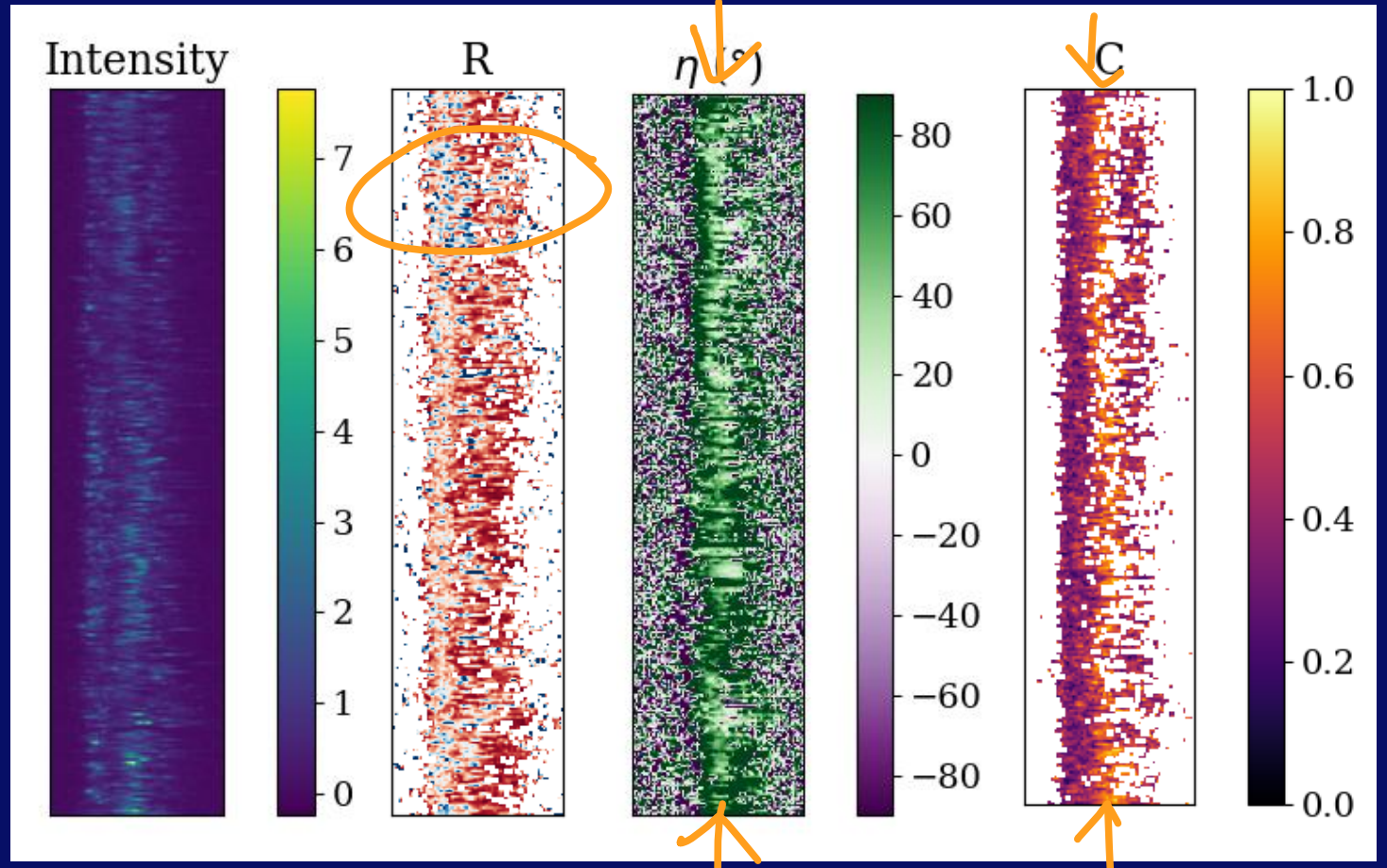
Methodology

1. Observe single pulses
2. Subtract “intrinsic” PA from “propagation” effects
3. Perform partial-coherent model transformation

Use the Thousand-Pulsar-Array on MeerKAT



Preliminary

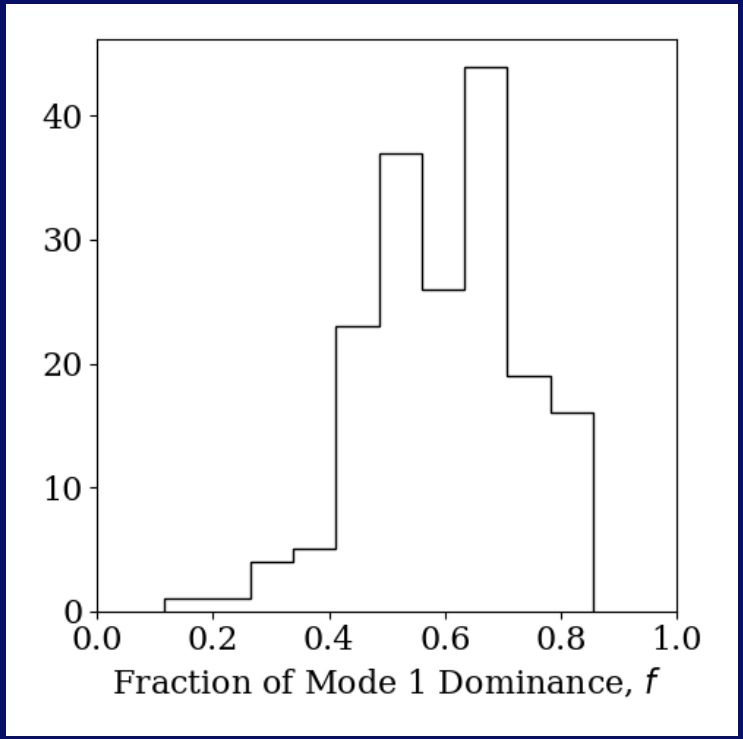


Preliminary Results…

Parameters averaged
across *on-pulse phase*,
time, and *epoch*

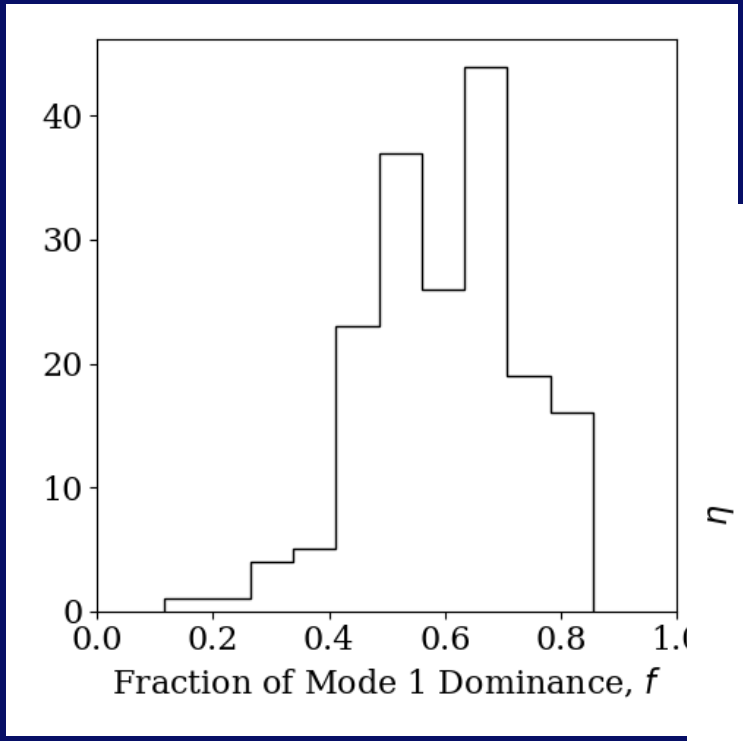
Average parameter distributions

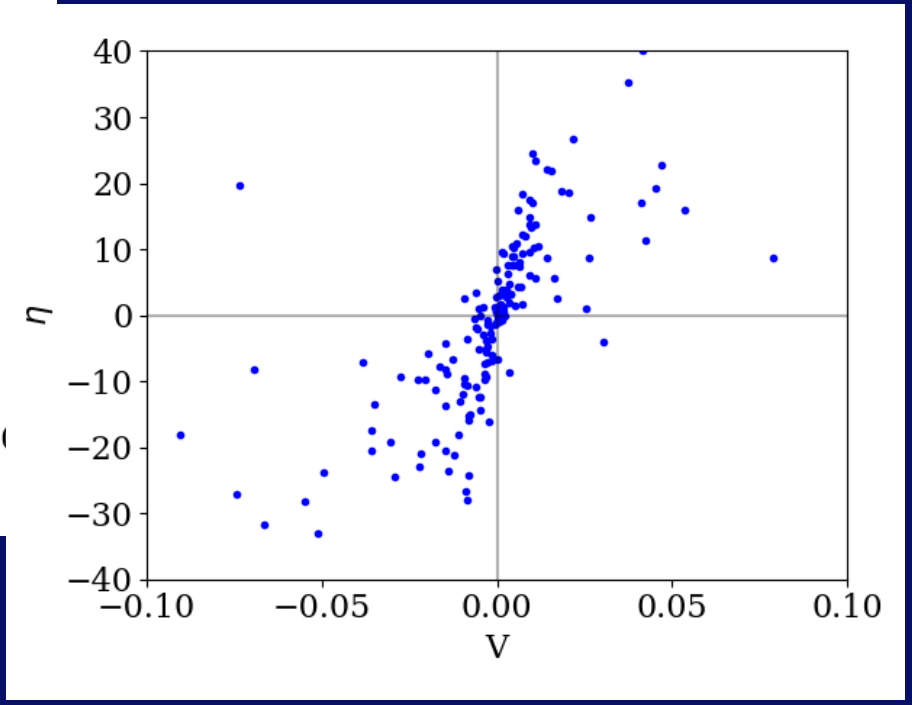
Preliminary



Average parameter distributions

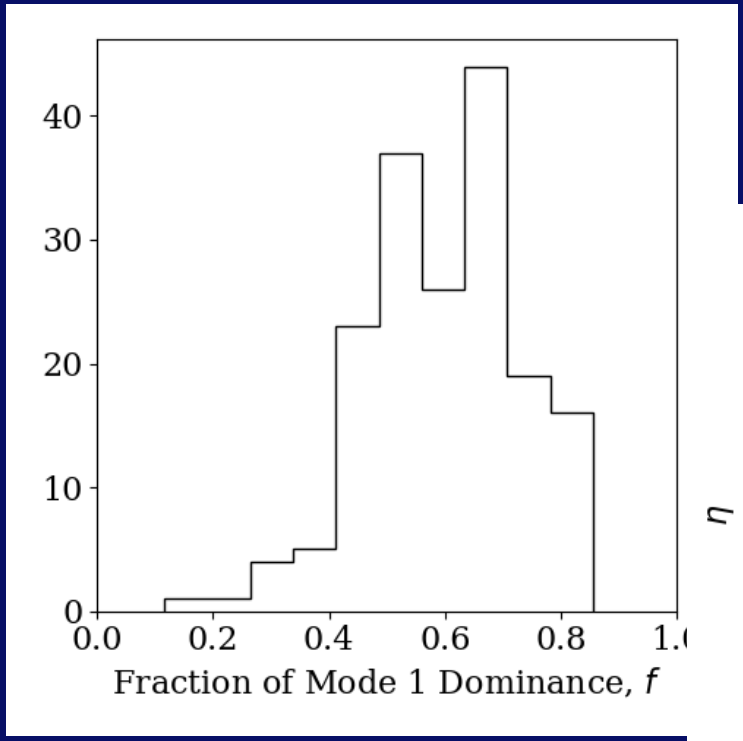
Preliminary

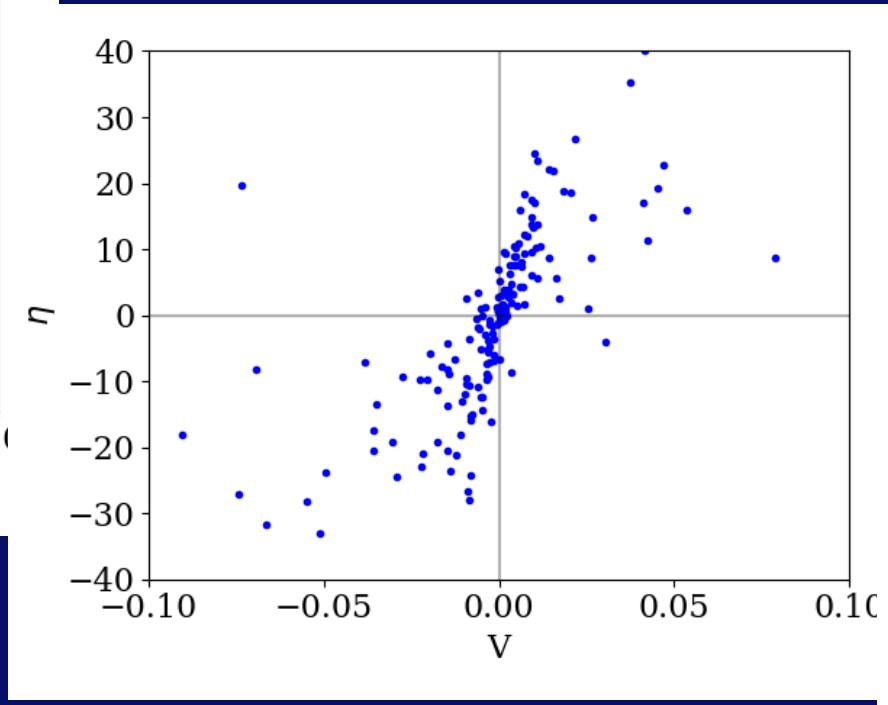


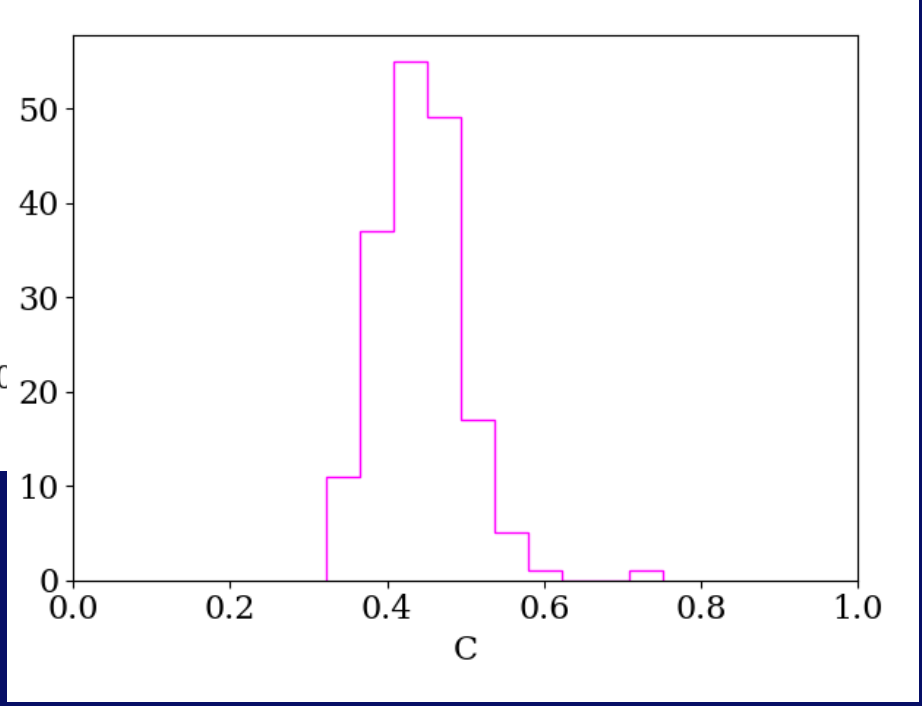


Average parameter distributions

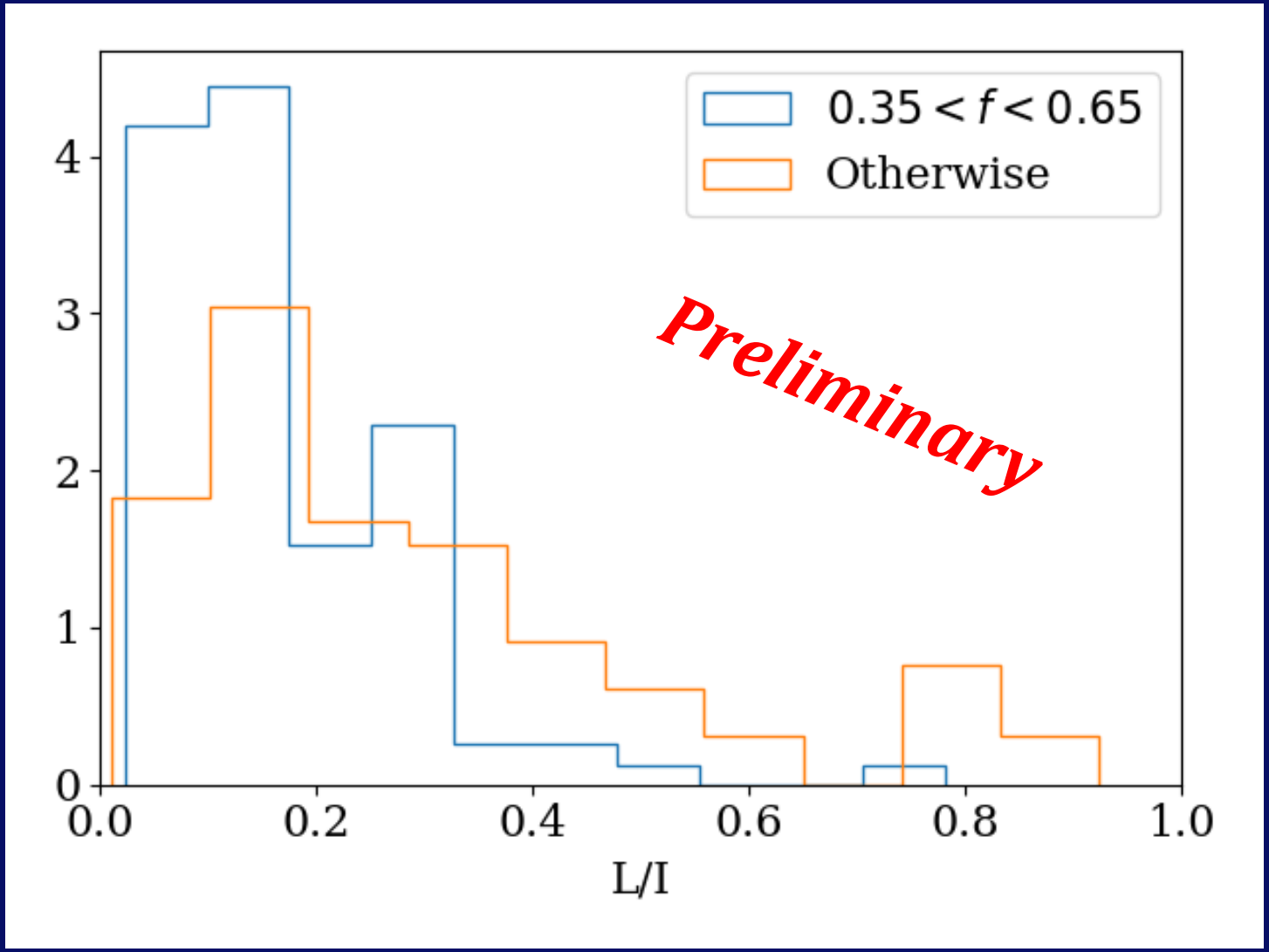
Preliminary



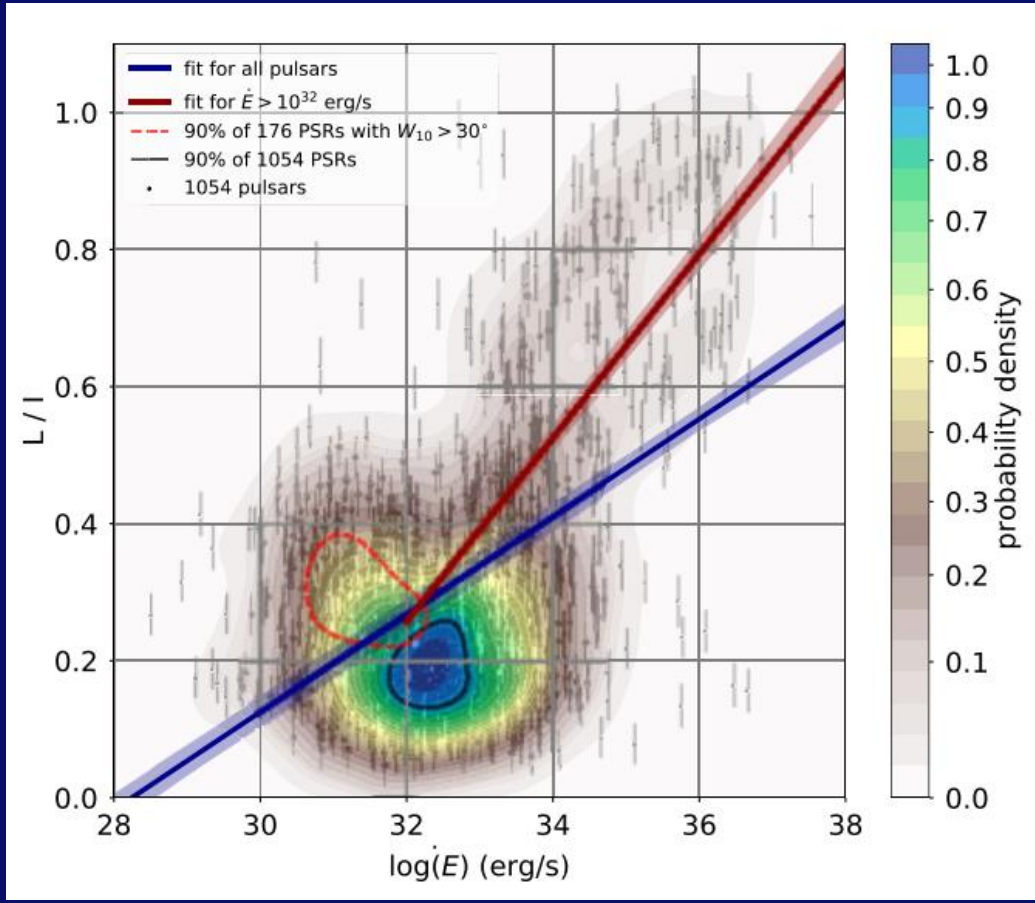




Mode dominance and linear polarization fraction

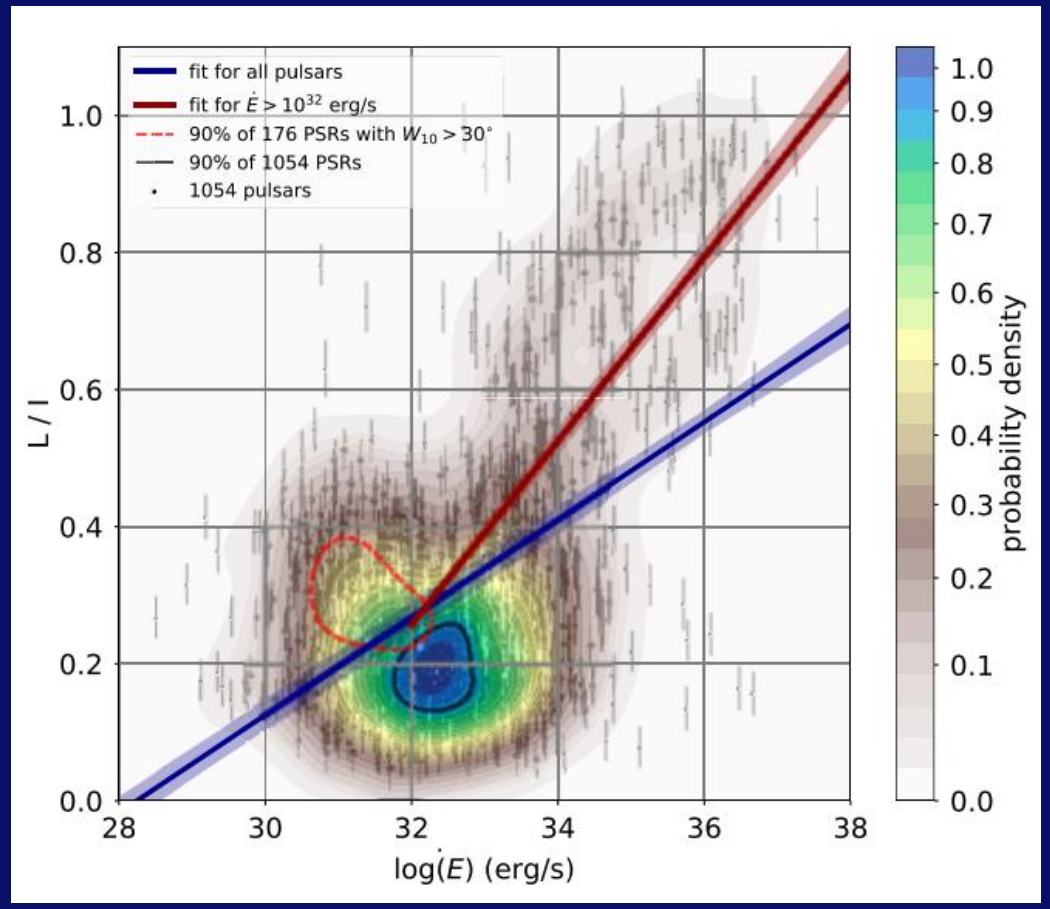


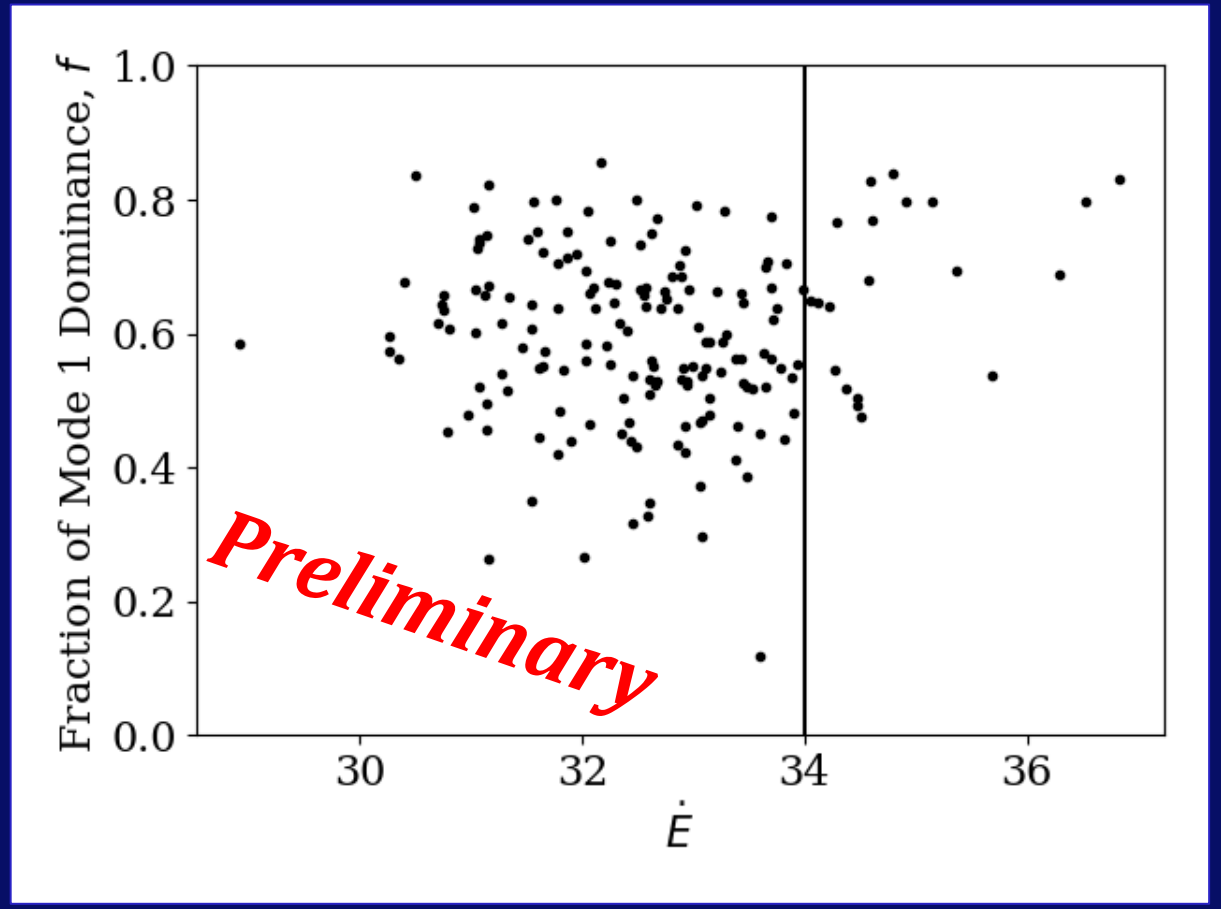
Dependence on spin-down energy



Posselt et al 2023

Dependence on spin-down energy





Posselt et al 2023

In summary

Is it possible to separate “intrinsic” and “propagation” effects in pulsar polarization?

YES

Does the partial-coherence formalism reveal interesting mode properties on the population scale?

YES

Is there more to do?

YES

Thank you for listening!