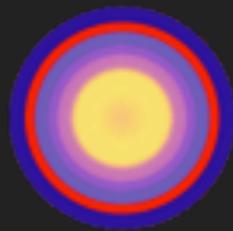


HOW TO LOOK INSIDE

**USING SUPERNOVA
TOMOGRAPHY**

EXPANDING EXPLODED OBJECT



100 AU

4 d days since Explosion

**EMITS
SMOOTH
CONTINUUM**

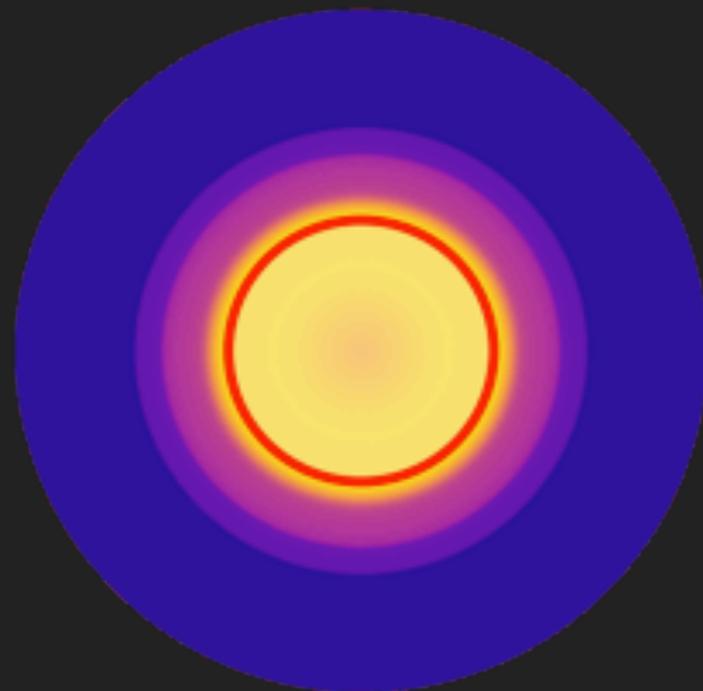
Flux

Wavelength

OBSERVED SPECTRA

**FEATURES IMPRINTED BY
ELEMENTS IN THE ENVELOPE**

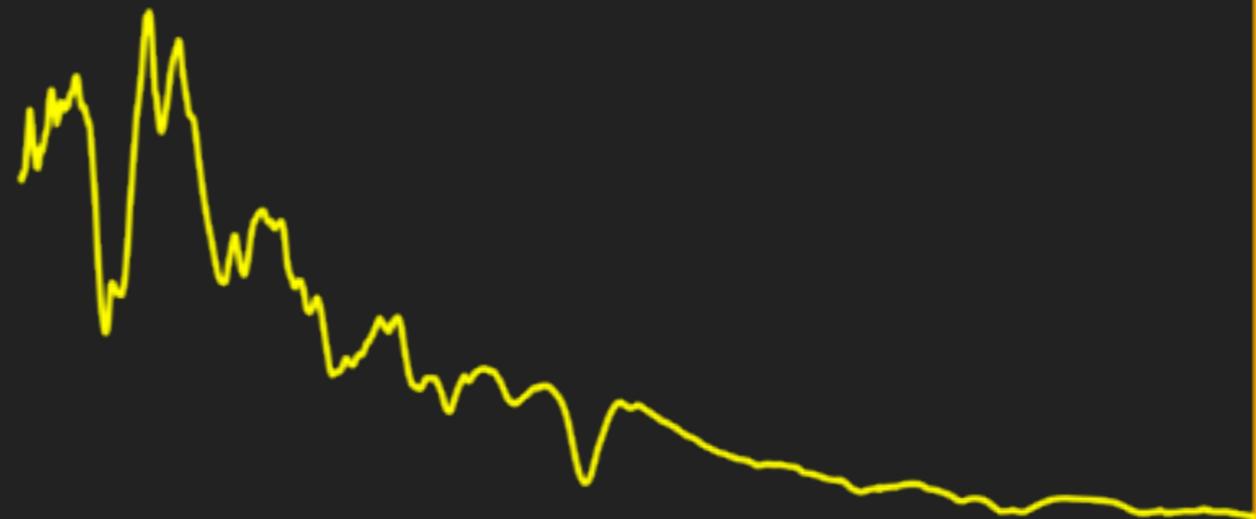
EXPANDING EXPLODED OBJECT



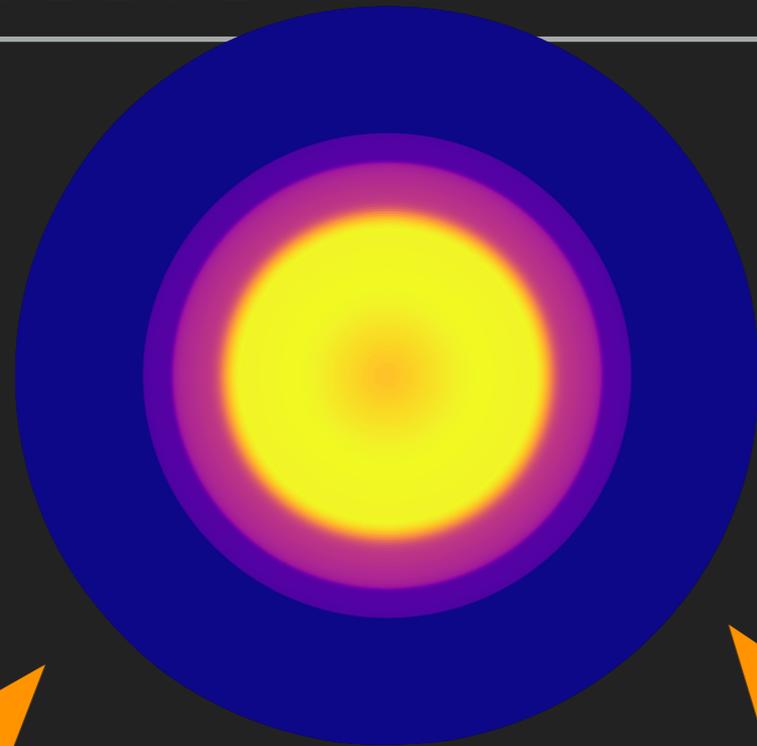
100 AU

12 d days since Explosion

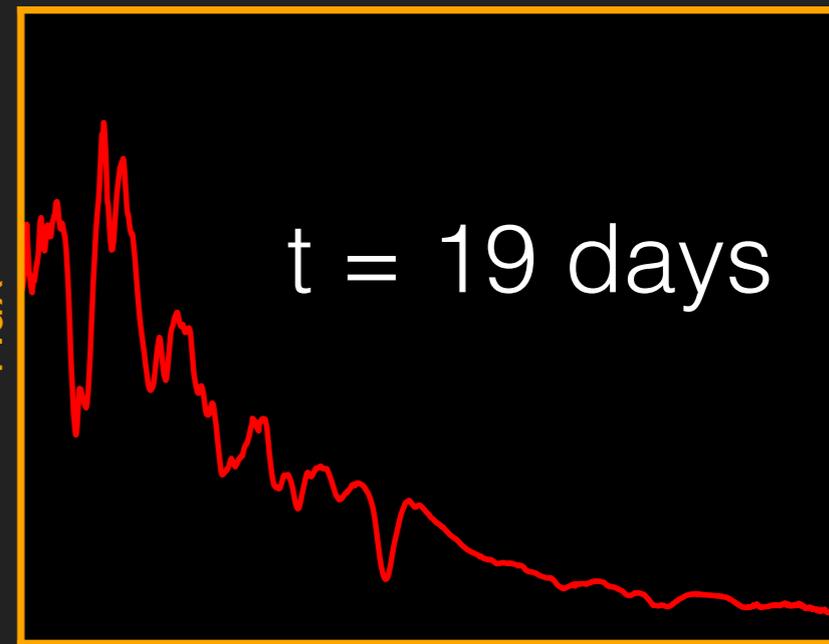
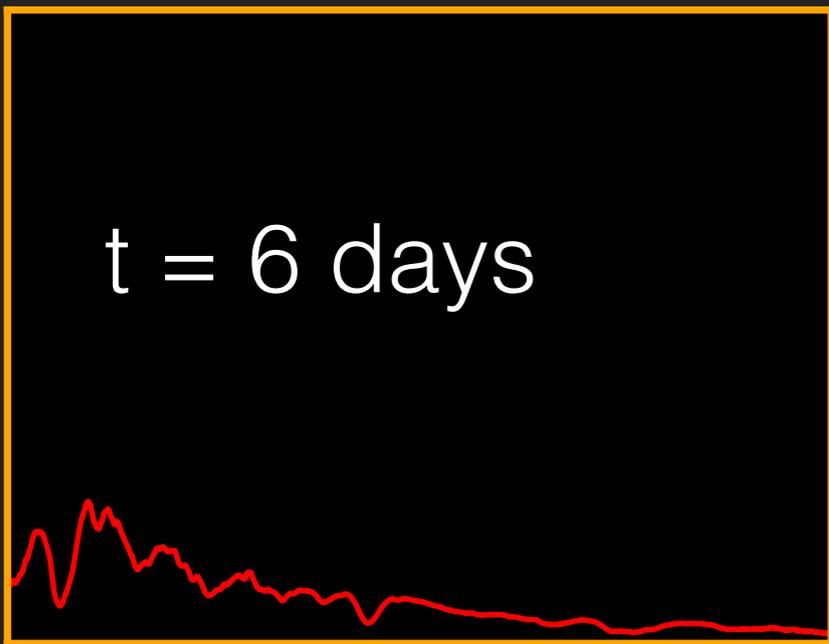
OBSERVED SPECTRA



REVERSE ENGINEERING THE EXPLOSION



$\text{Model}(\text{Fe, S, Co, O, C, \dots}) = \text{Model}(\vec{\theta})$



Flux

Flux

Flux

Wavelength

Wavelength

Wavelength

Data

t = 12 days

t = 6 days

t = 19 days

THE DREAM

EXPLORE THE POSTERIOR

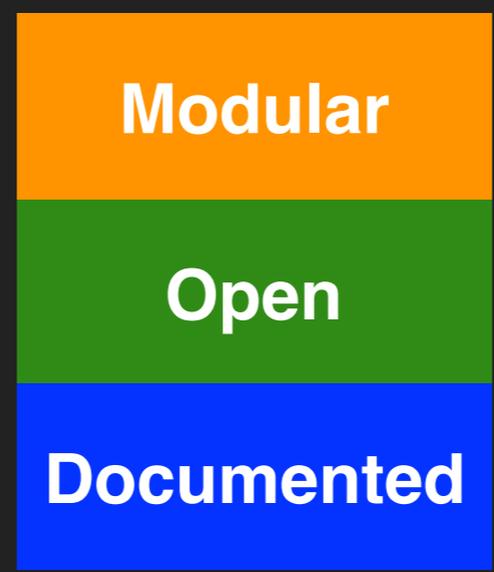
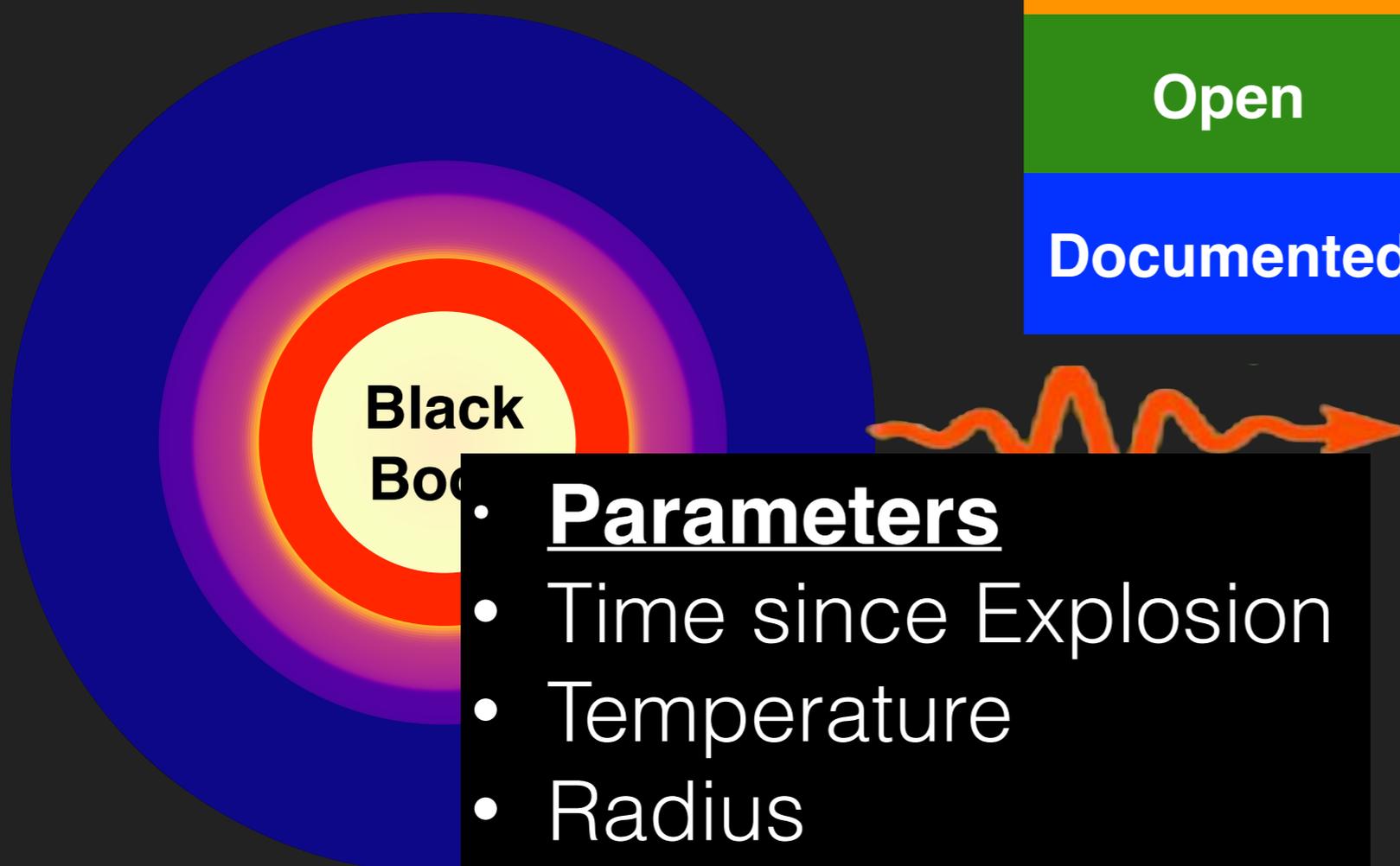
~~Likelihood - metric to compare model and data~~

~~Prior~~

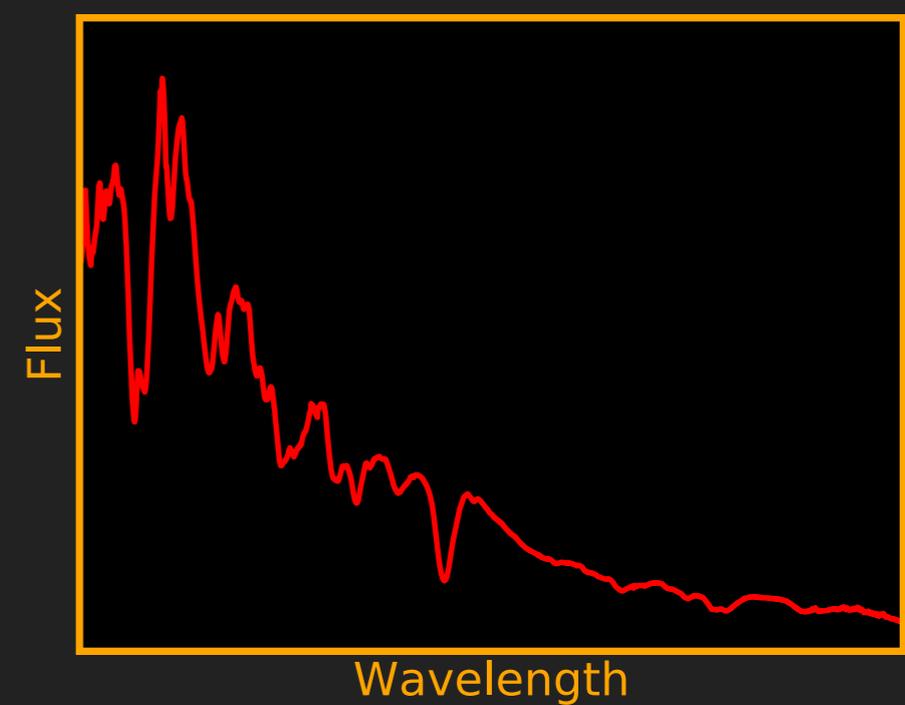
$$P(\text{Model}(\vec{\theta}) | \text{data}) \propto P(\text{data} | \text{Model}(\vec{\theta})) \times P(\vec{\theta})$$

Radiative Monte Carlo code

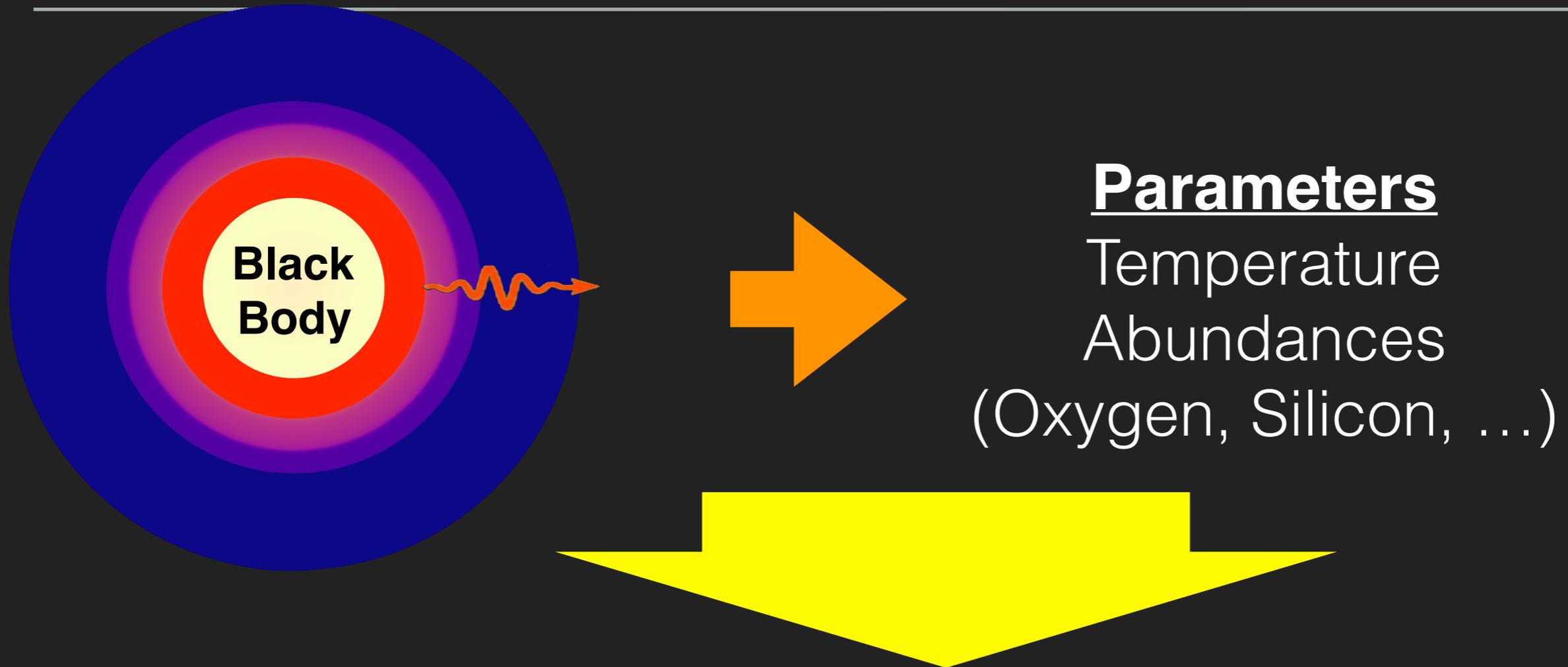
The Model



- **Parameters**
- Time since Explosion
- Temperature
- Radius
- Density Profile
- elemental abundance (O, Si, Ca, Fe, ...)



Kerzendorf & Sim 2014
Kerzendorf et al. 2018



Example Case for 1 Spectrum : 12 Parameters

1 Evaluation ~ > 1000 seconds single core

Building a simple grid (3 points in each dimension): 1×10^6 , 1×10^6 CPU hours



MICHIGAN STATE
UNIVERSITY

REVERSE ENGINEERING EXPLOSIONS

SPECTRAL EMULATORS

WOLFGANG KERZENDORF
RINGBERG ML 9TH DEC 2019

SN

For Tom ;-)

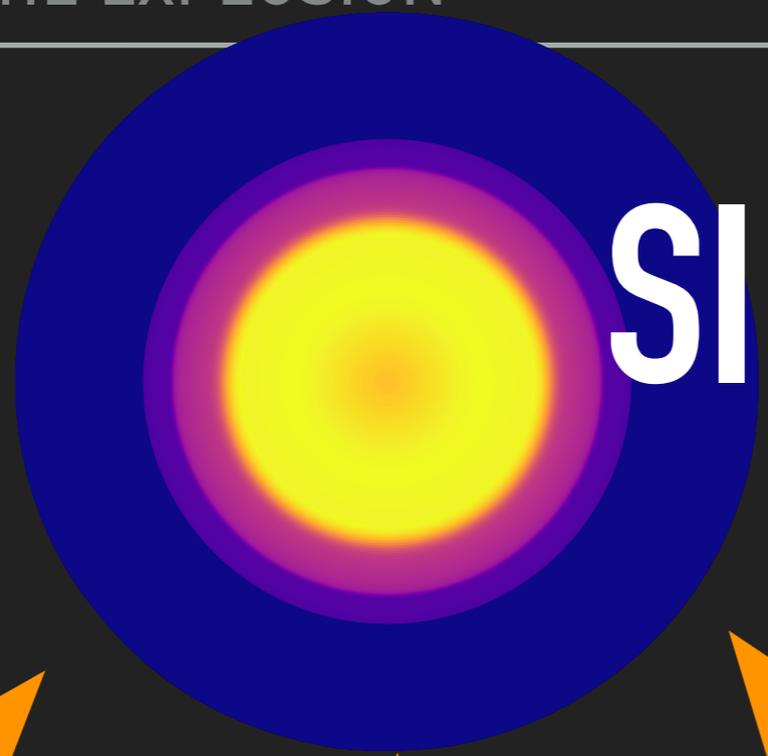


OR HOW I STOPPED
WORRYING

**AND TRUSTED THE
NEURAL NETWORK**

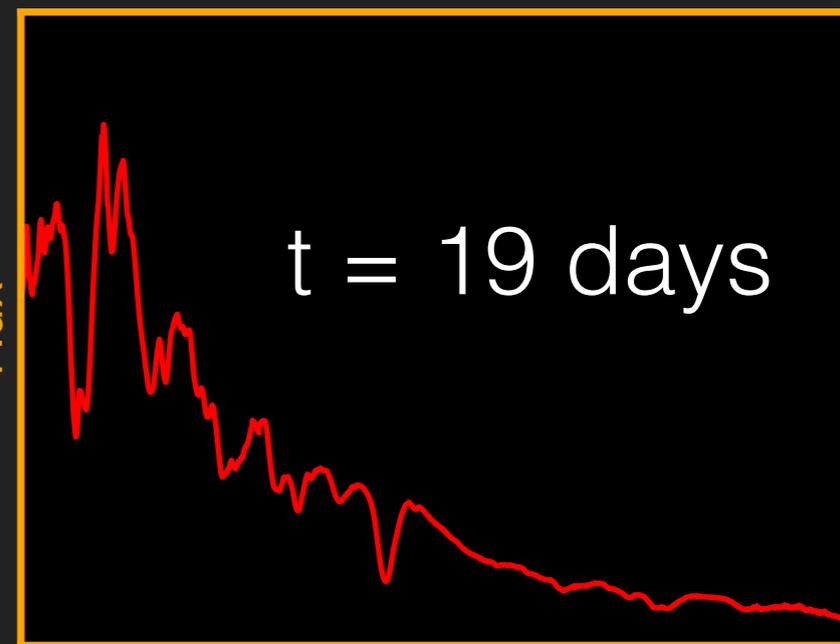
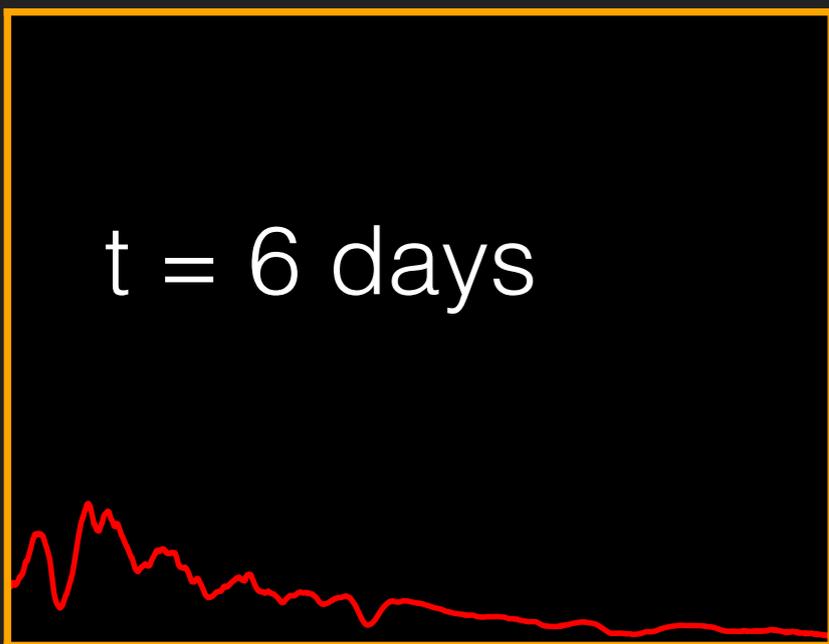
REVERSE ENGINEERING

SUPERNOVA EXPLOSIONS



SIMPLEST CASE

$$\text{Model}(\text{Fe, S, Co, O, C, } \dots) = \text{Model}(\vec{\theta})$$



Flux

Flux

Flux

Wavelength

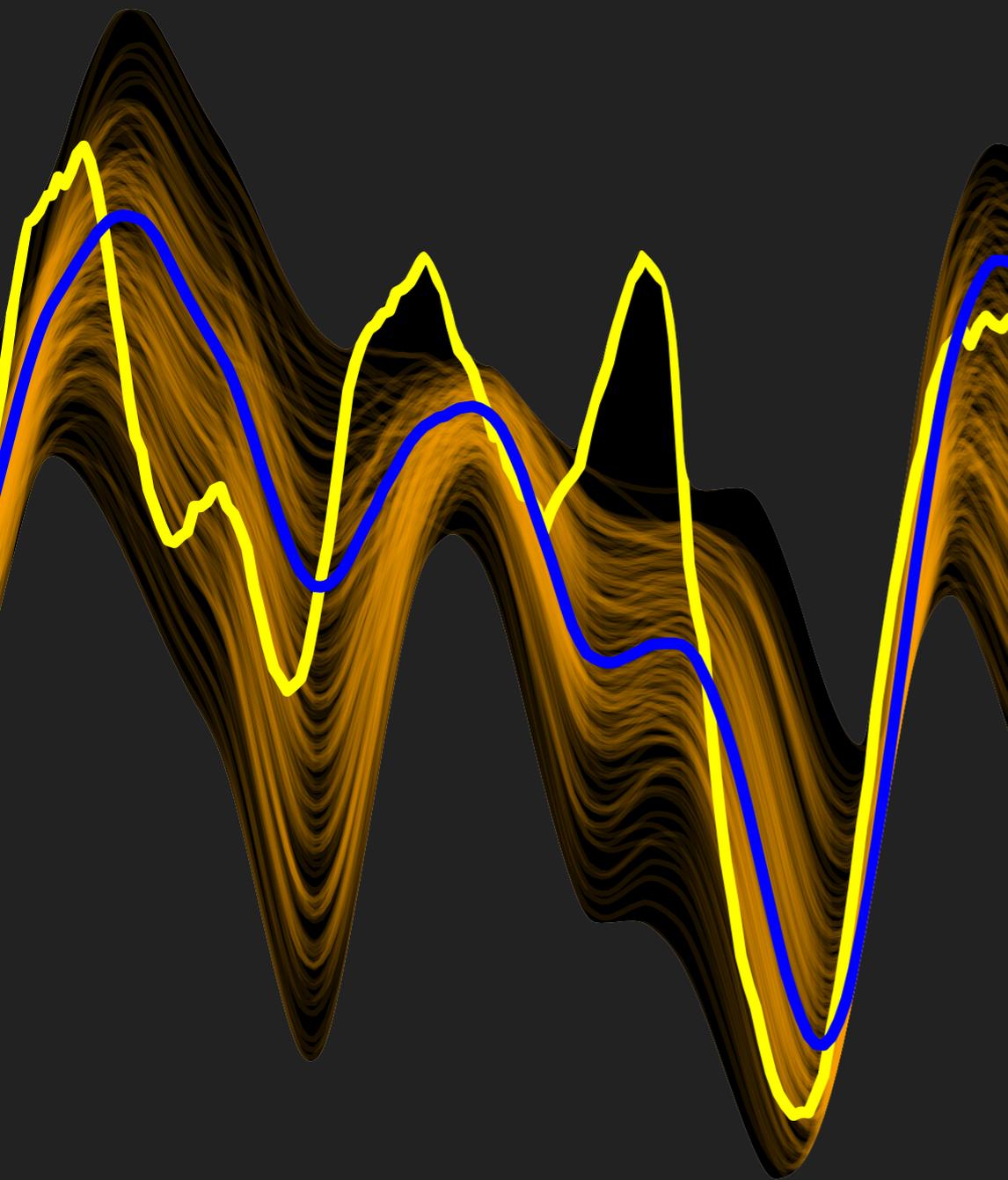
Wavelength

Wavelength



Data

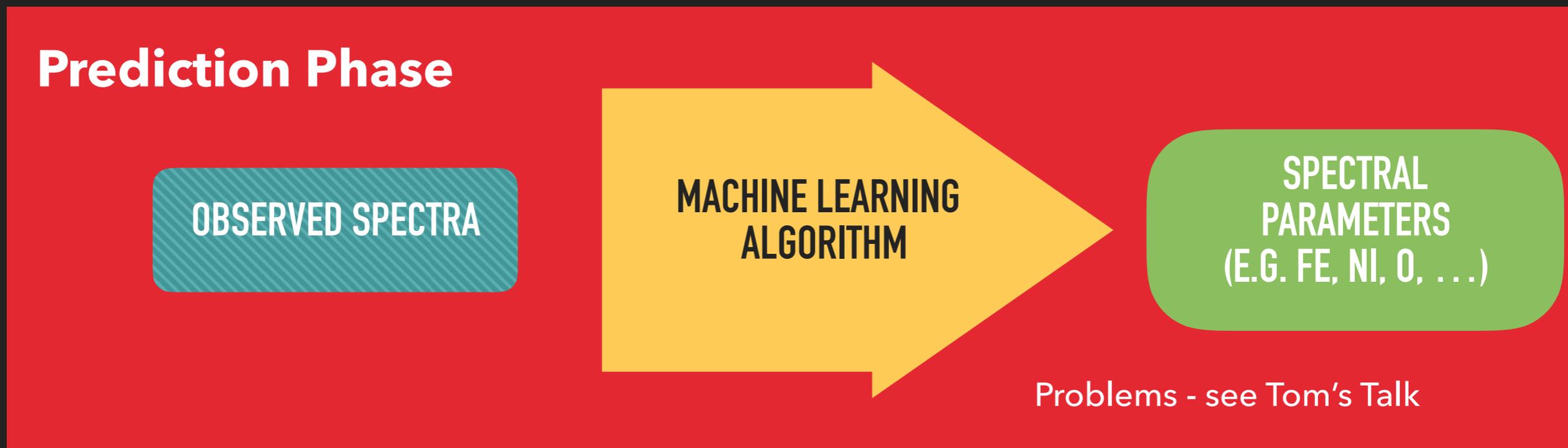
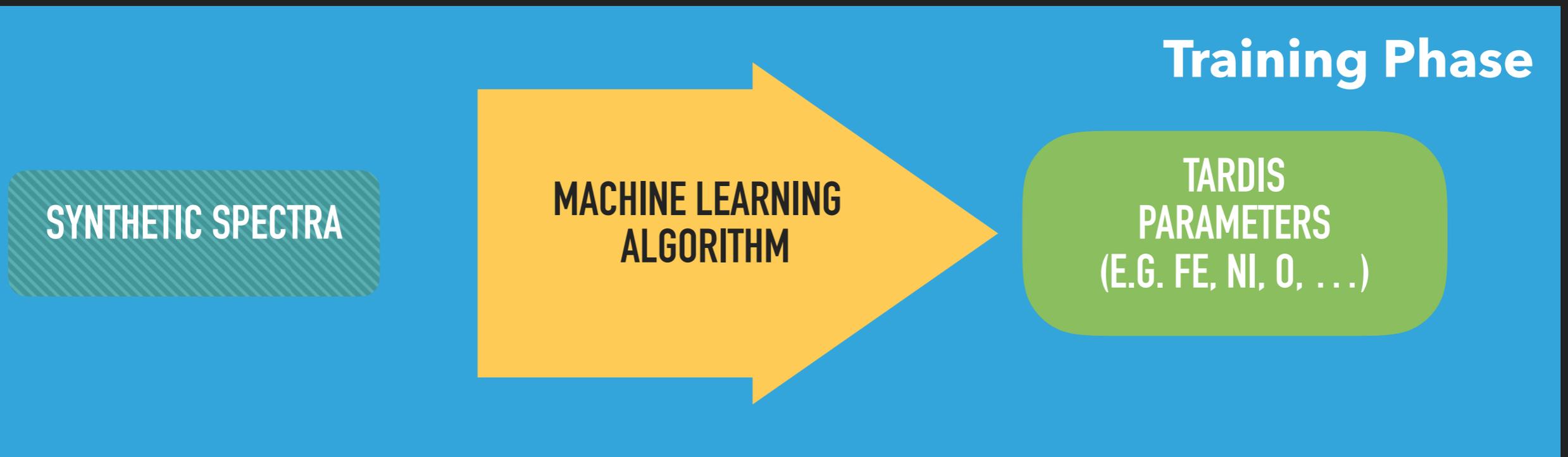
t = 12 days



- Christian Vogl (Max-Planck)
 - Patrick van der Smagt (VW Group - Fundamental AI Research)
 - Gabriella Contardo (Flatiron)
 - Marc Williamson (NYU)
-

EMULATORS

WHY NOT CLASSIC MACHINE LEARNING APPROACH?



REALITY

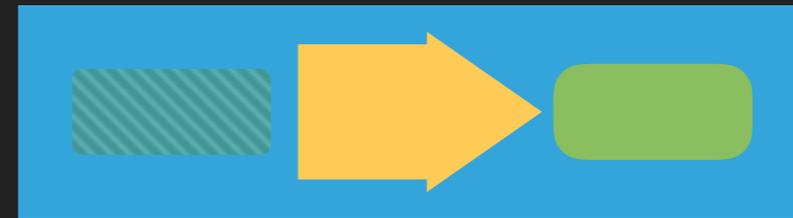
$$f_{\text{TARDIS}}(\vec{x}) \mapsto \vec{y}$$

TUNABLE PARAMETER

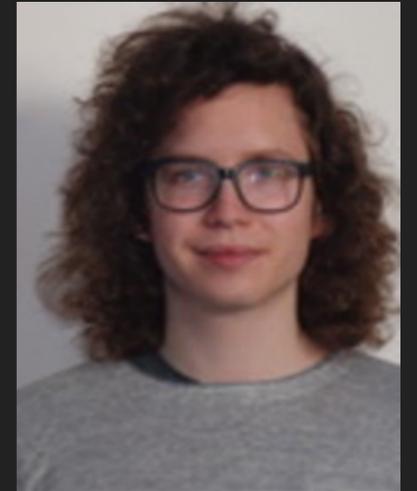
$$f_{\text{approx}}(\overbrace{\theta}^{\text{TUNABLE PARAMETER}}, \vec{x}) \mapsto \vec{y}$$

VERY GOOD APPROXIMATION

Emulator



$$P(\text{Model}(\vec{\theta}) \mid \vec{\text{data}}) = \frac{P(\vec{\text{data}} \mid \text{Model}(\vec{\theta})) \times P(\vec{\theta})}{P(\vec{\text{data}} \mid \text{Model}(\vec{\theta})) \times P(\vec{\theta})}$$



Christian Vogl @ MPA

MEASURING DISTANCES

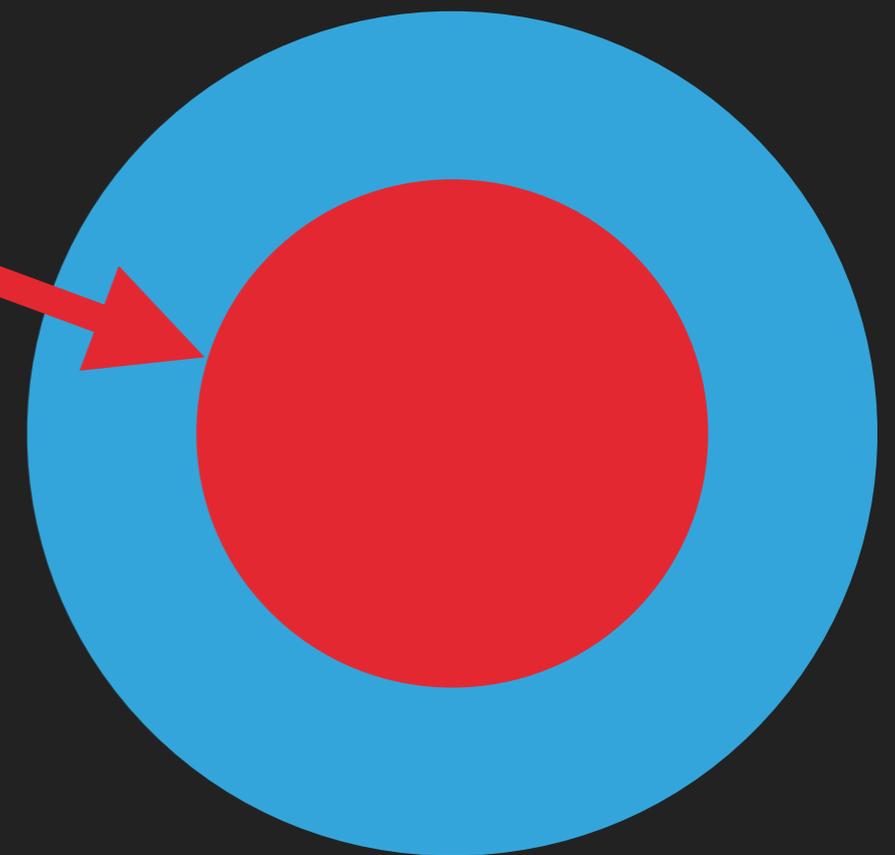
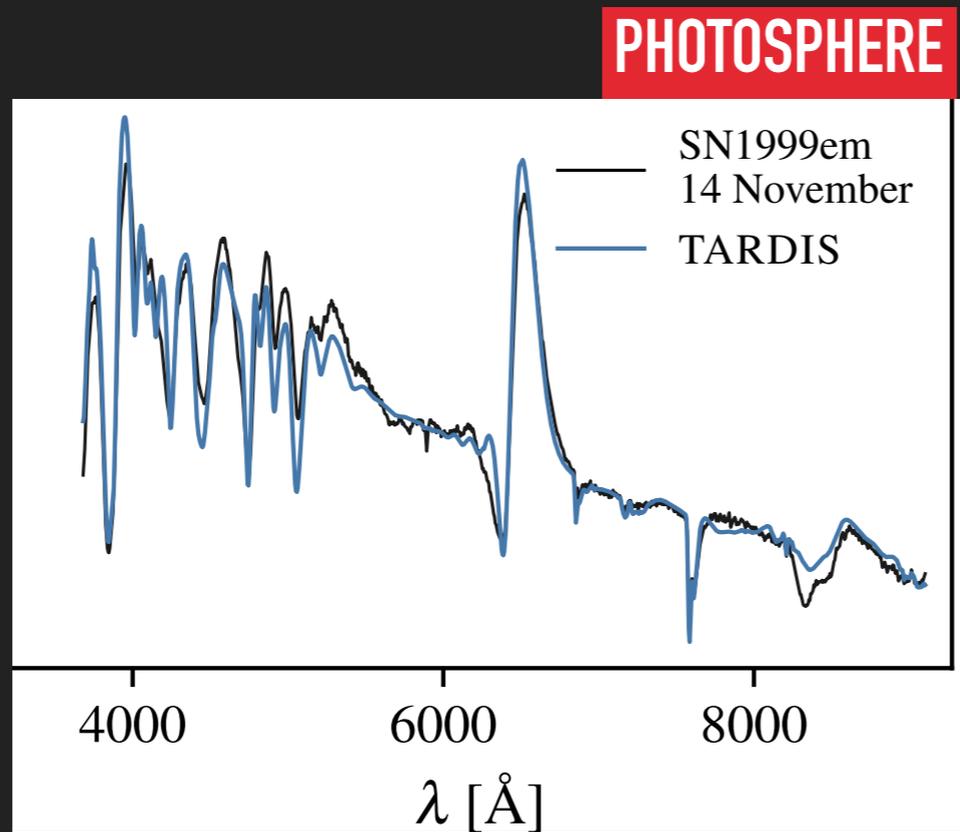
THE EXPANDING PHOTOSPHERE METHOD

Vogl, **WEK** et al. 2019

EXPANDING PHOTOSPHERE METHOD

$$L \propto R^2 T^4 = \underbrace{v_{\text{phot}}^2 t_0^2}_{R^2} T^4$$

Large Hydrogen Envelope

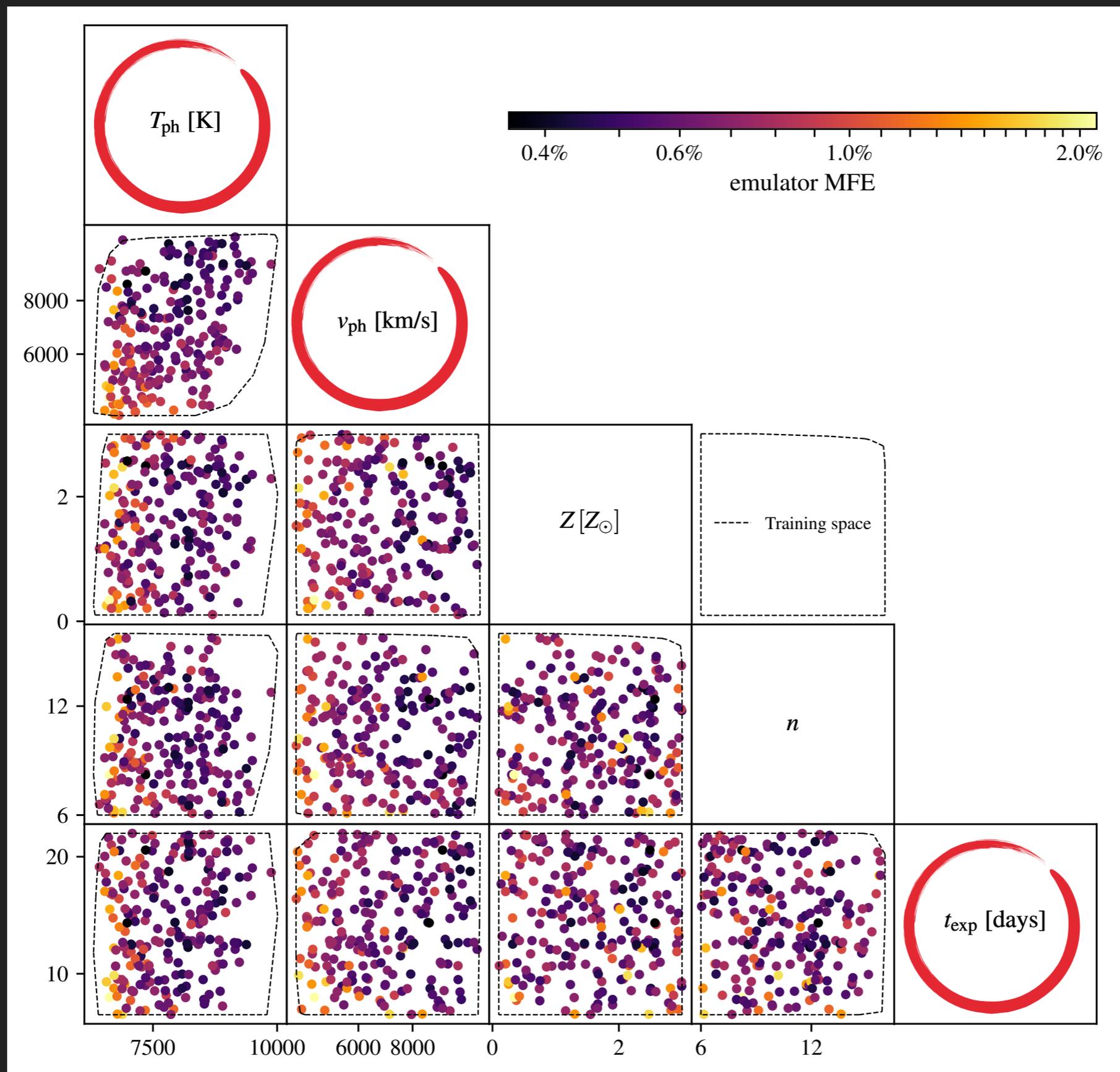


Luminosity Distance

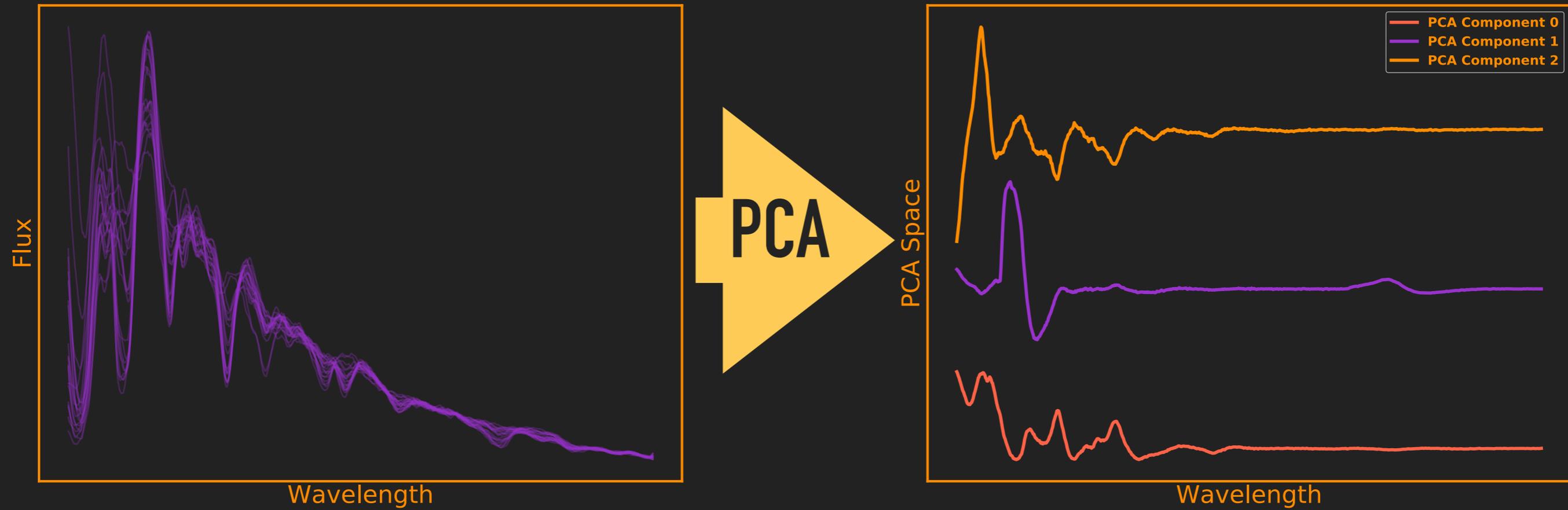
Type II-P Supernova

FITTING TYPE IIP SPECTRA

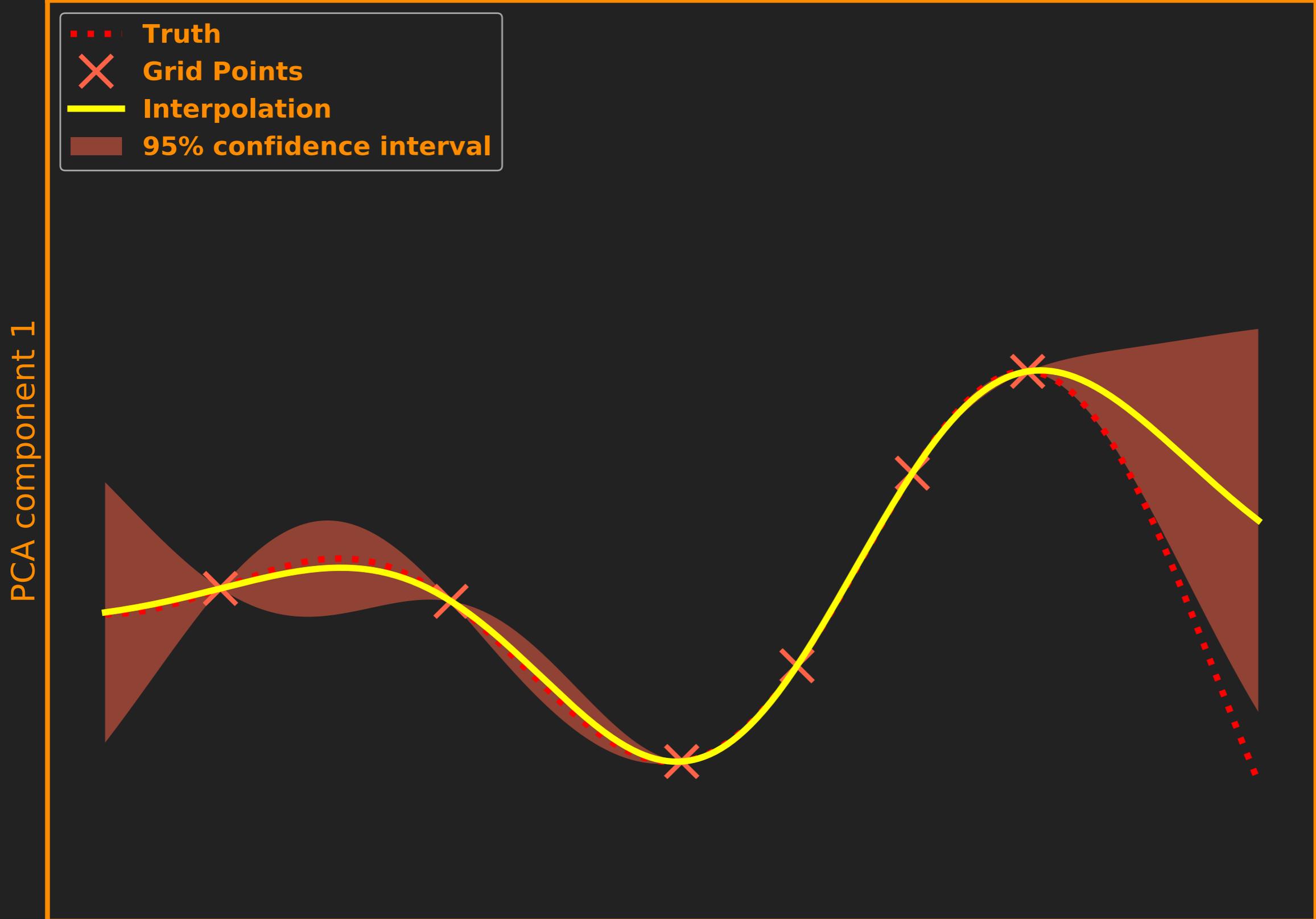
TRAINING SET



FEATURE EXTRACTION



GAUSSIAN PROCESSES



Fe Abundance

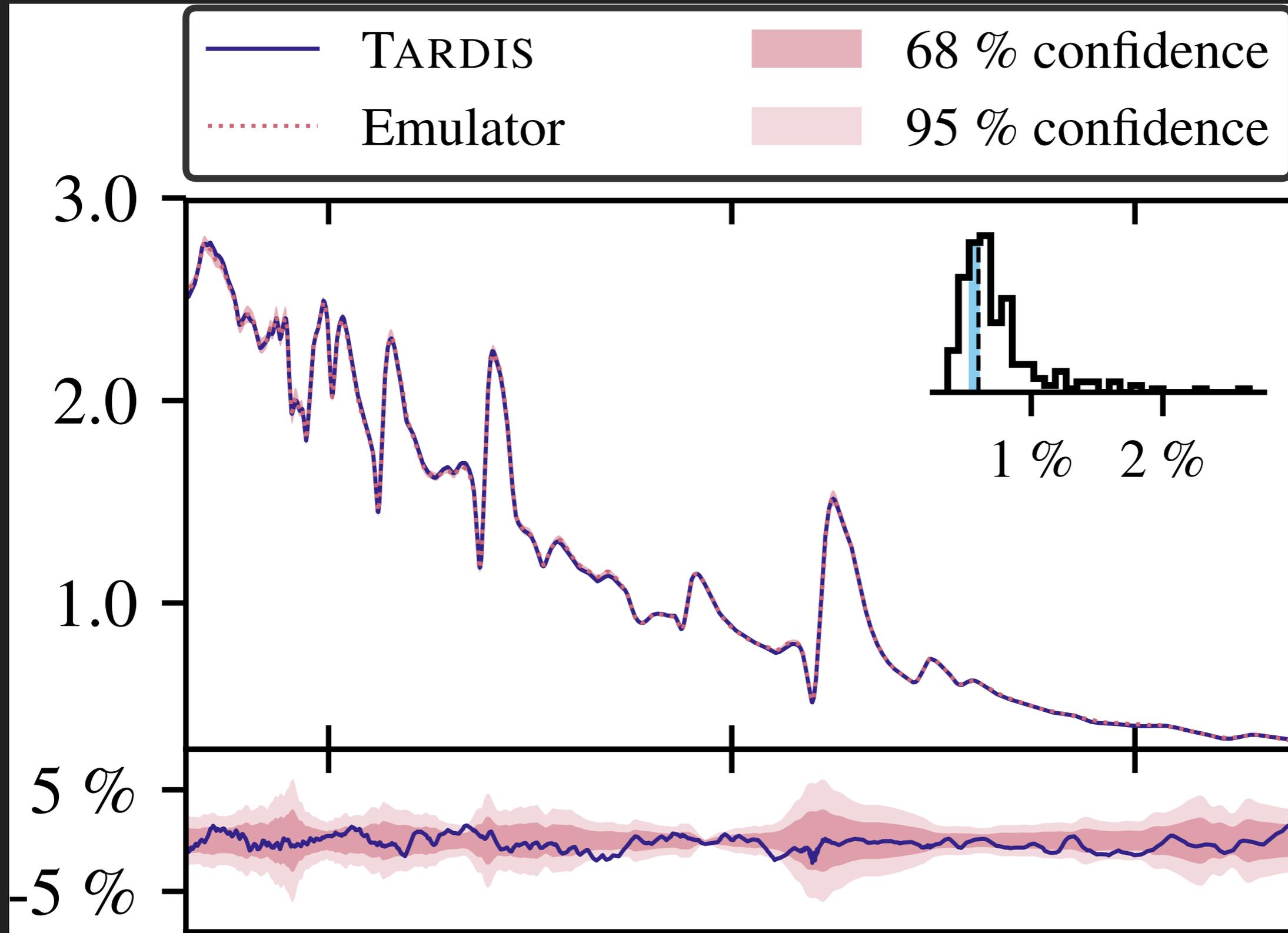
Vogl, **WEK** et al. 2019

TARDIS
PARAMETERS
(E.G. FE, NI, O, ...)

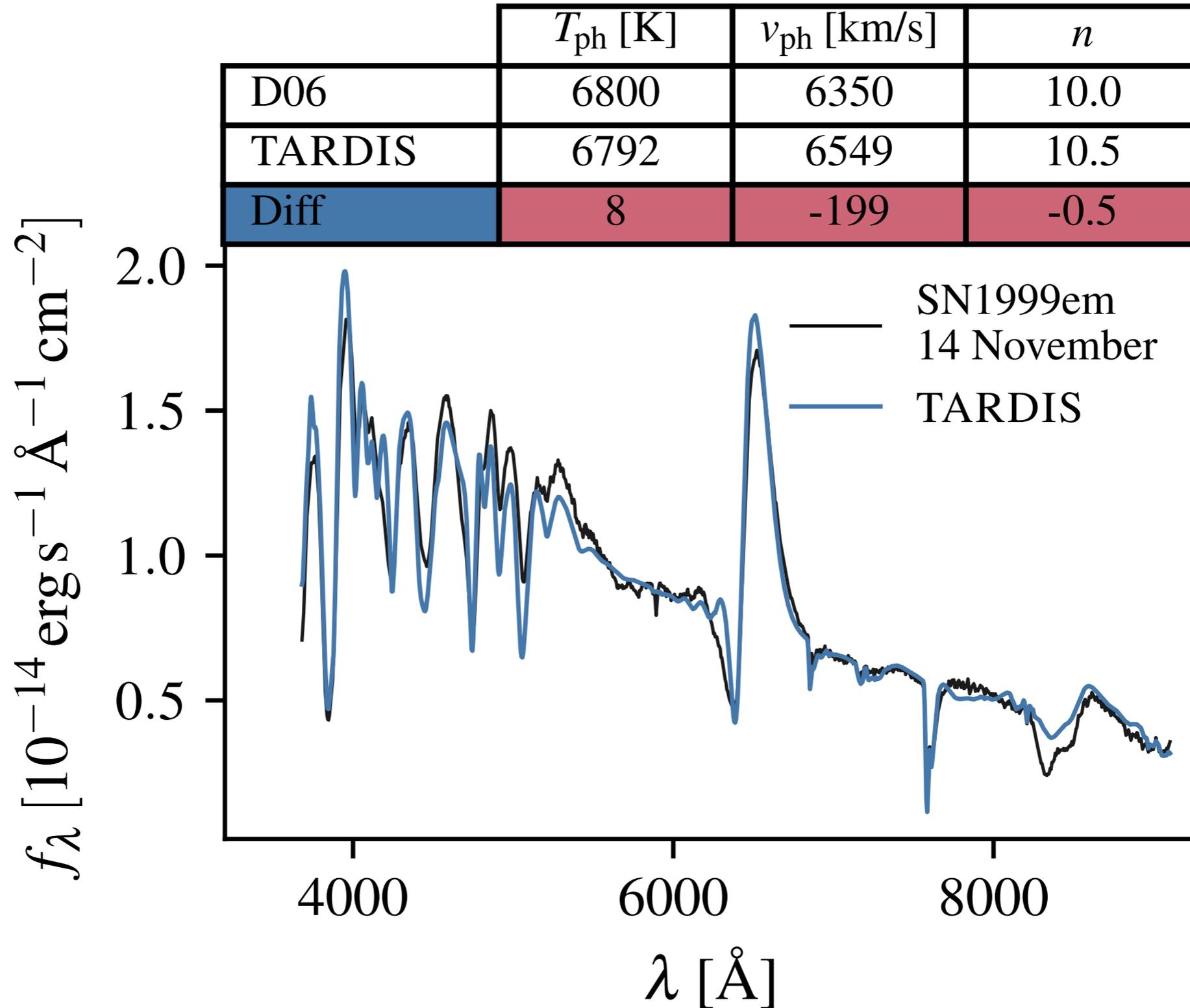
GAUSSIAN PROCESS

PCA SPACE OF SPECTRA

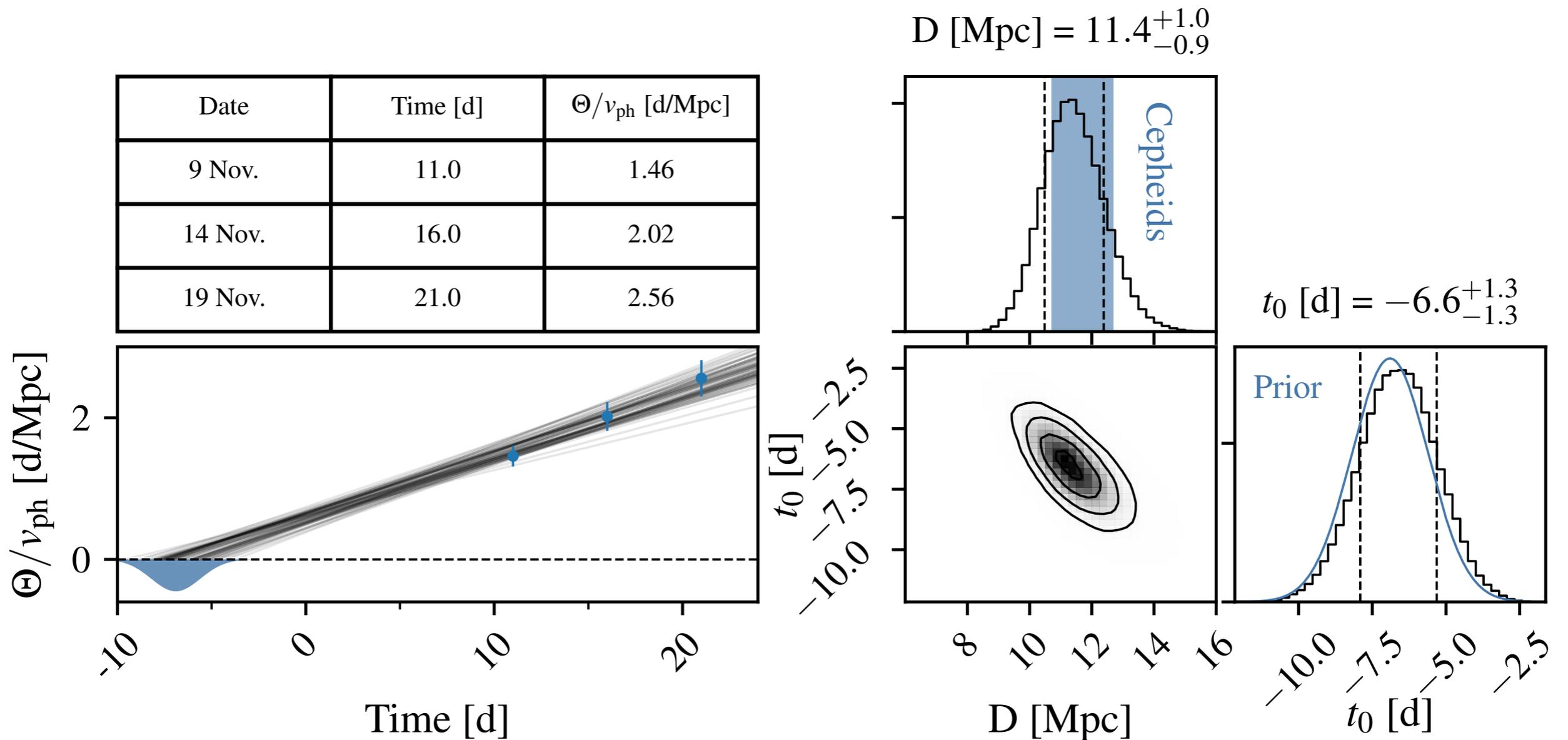
SYNTHETIC SPECTRA



FIT OF ACTUAL SPECTRUM



DISTANCE TO SN1999EM





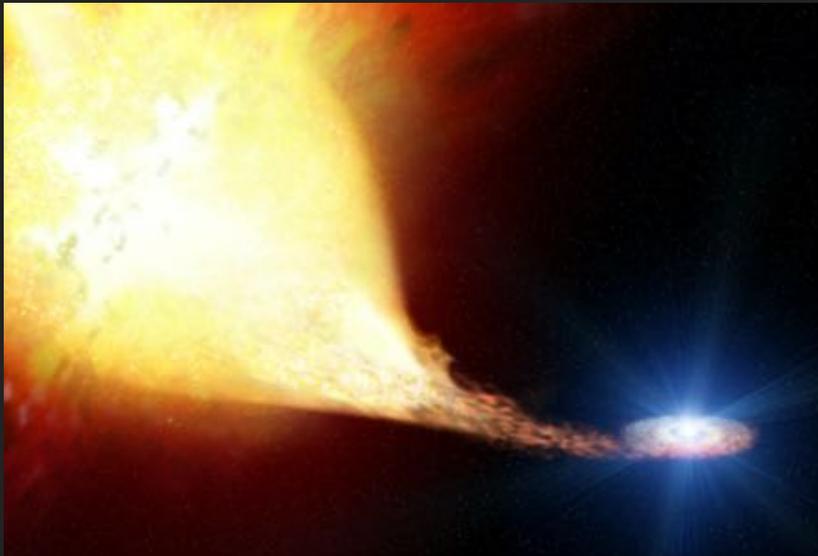
RECONSTRUCTING

EXPLODING

WHITE DWARVES

WHY DO WHITE DWARFS EXPLODE?

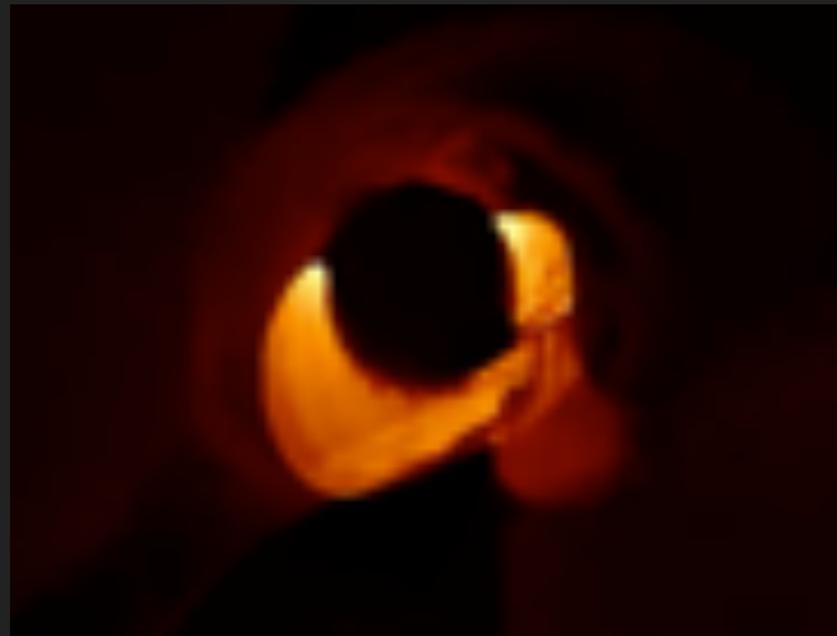
ACCRETORS



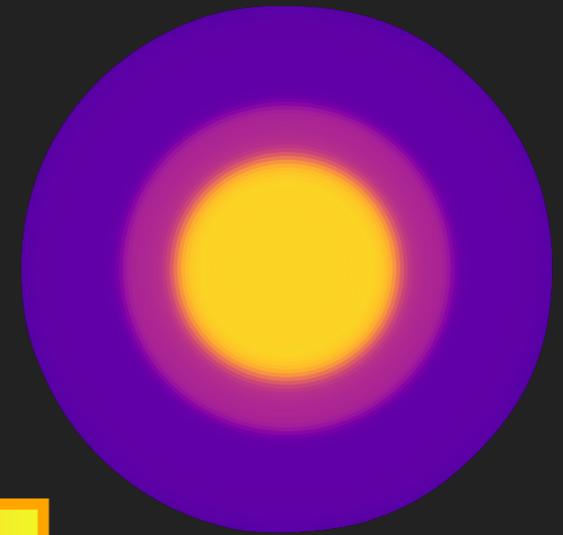
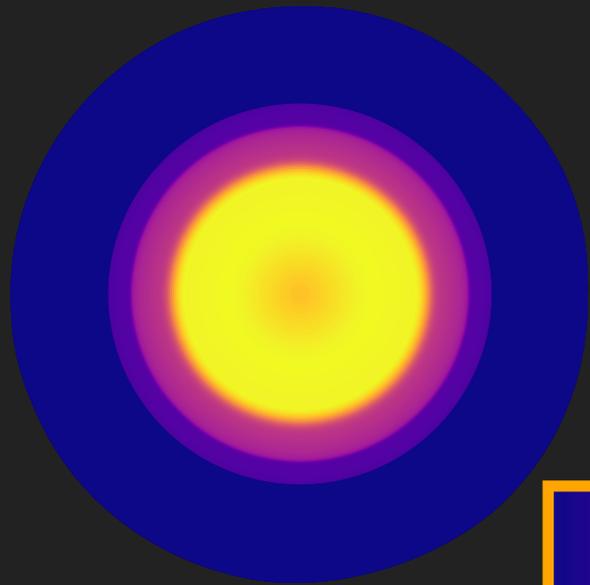
MERGERS



DOUBLE DETONATIONS



HOW TO DISCRIMINATE



High Dimensional Problem:

> 14 Parameters

> PCA - GP fails



O

Mg

Si

Ca

Fe

ACCRETORS

MERGERS

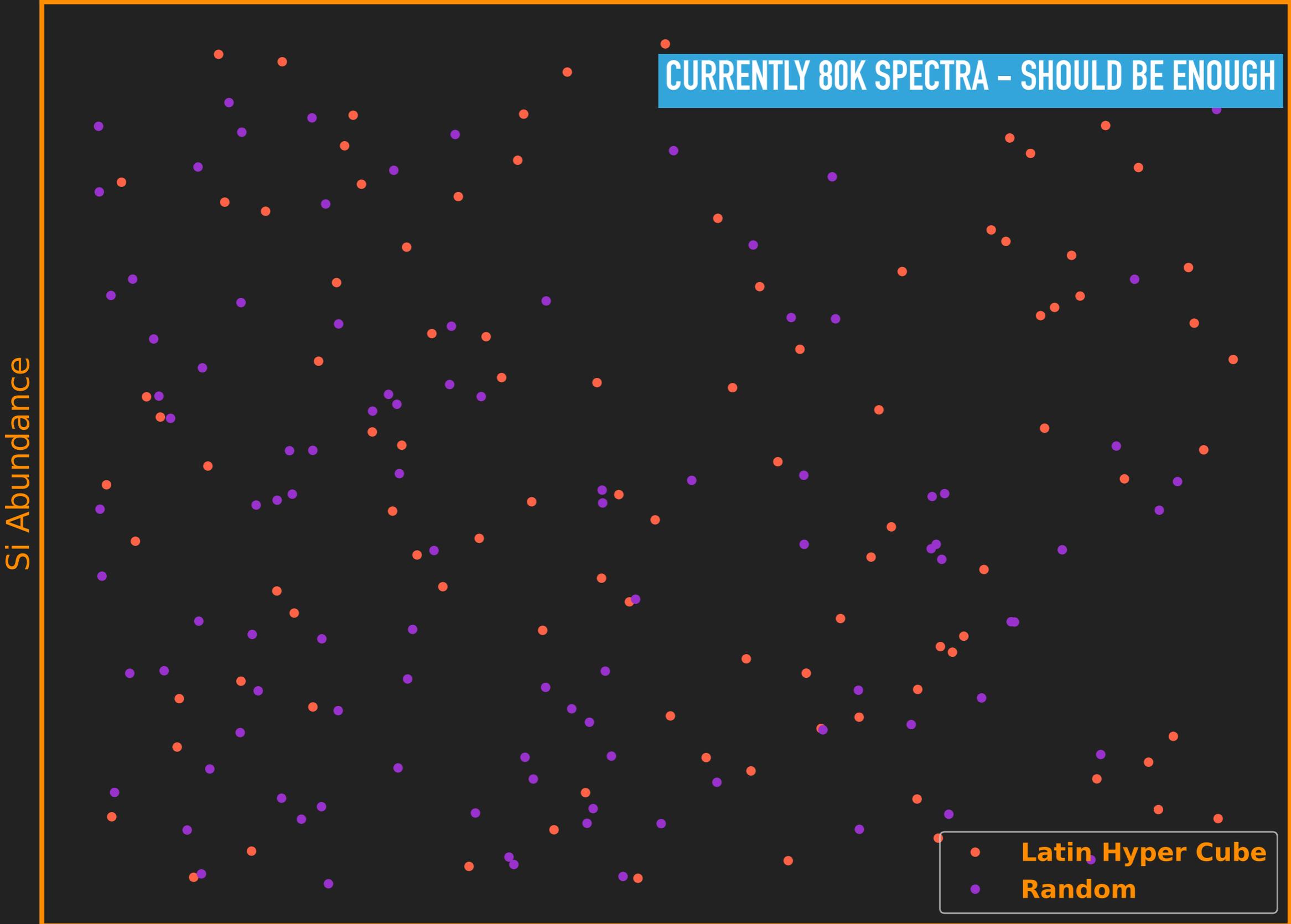




DEEP NEURAL
NETWORK

EMULATOR

GRID IN 14 DIMENSIONS



CURRENTLY 80K SPECTRA - SHOULD BE ENOUGH

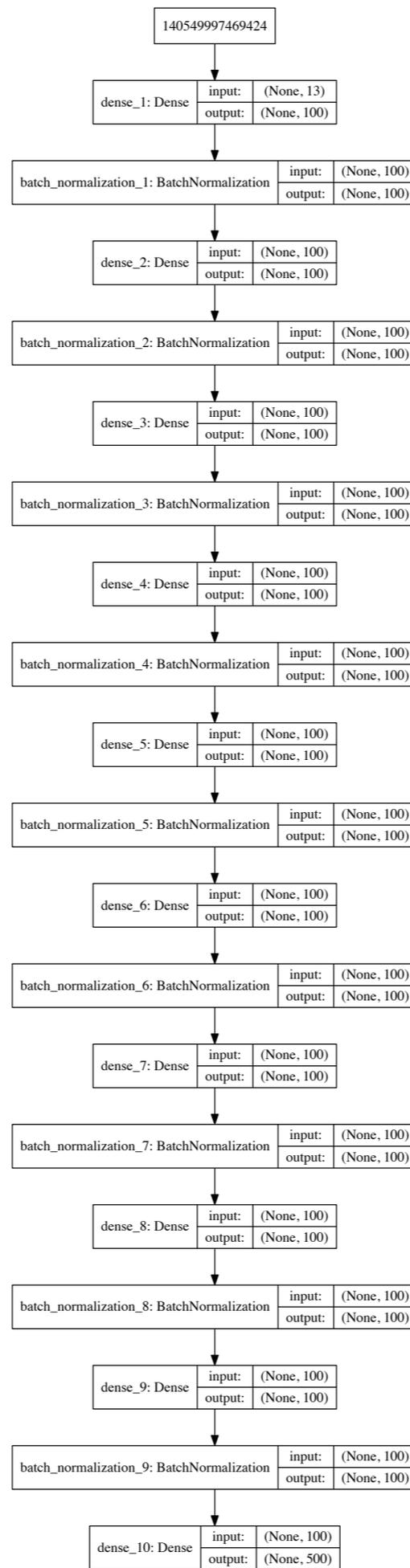
Si Abundance

Fe Abundance

- Latin Hyper Cube
- Random

NETWORK ARCHITECTURE

TARDIS
PARAMETERS
(E.G. FE, NI, O, ...)



9 LAYERS - 100 NODES EACH

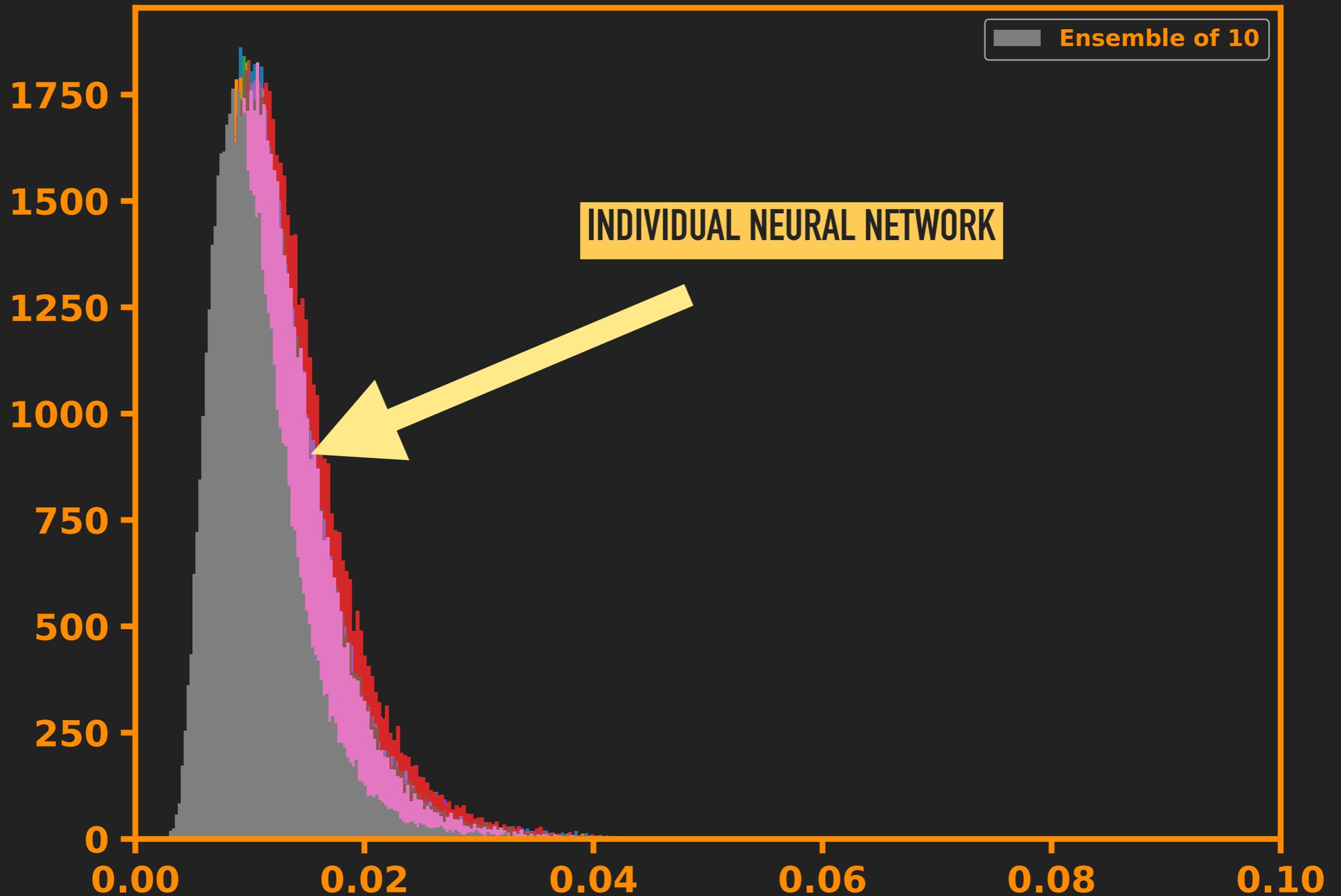
SYNTHETIC SPECTRA



CROWD SOURCING

**ENSEMBLE
MODELING**

MANY EYES ARE BETTER THAN ONE

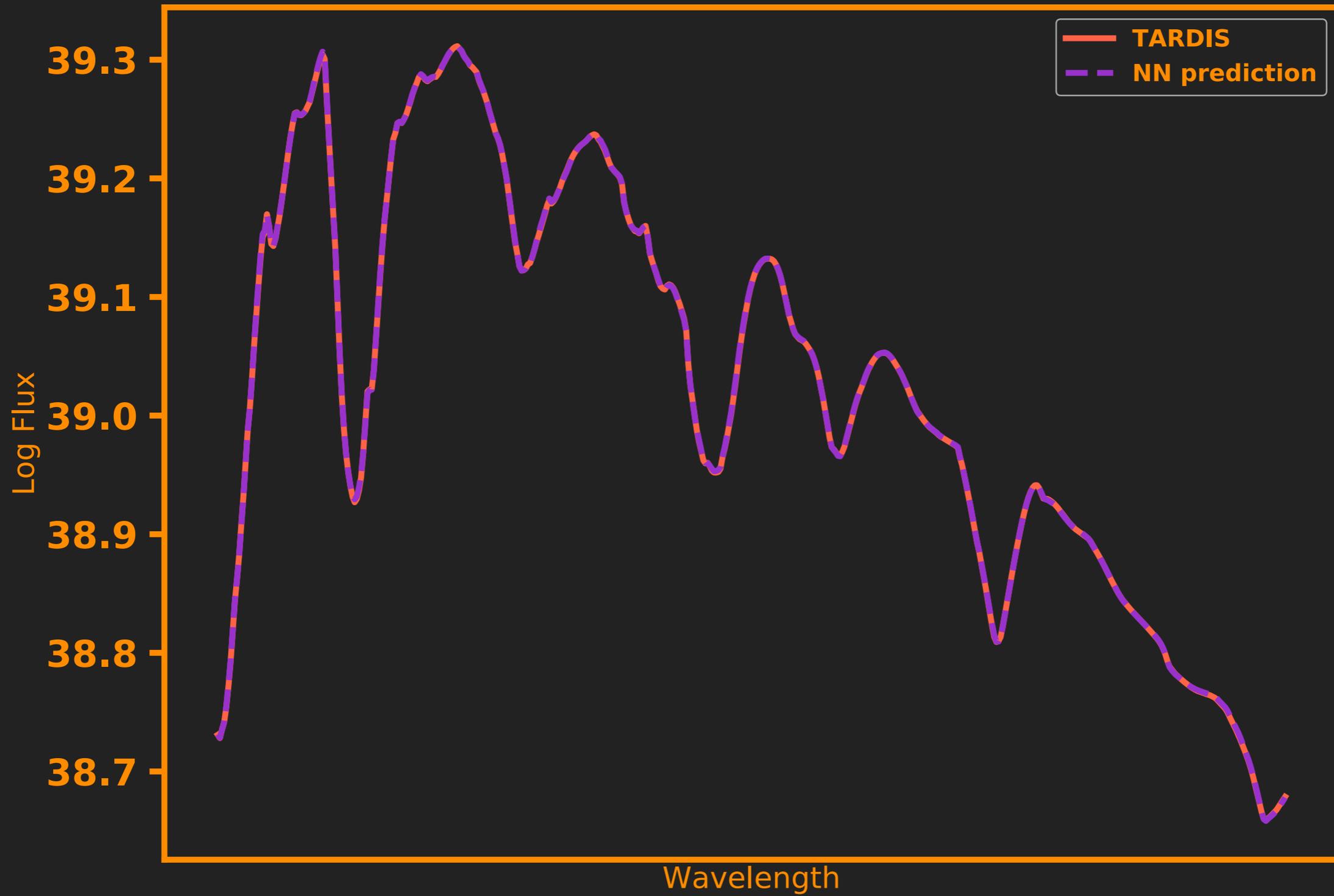


RESULTS

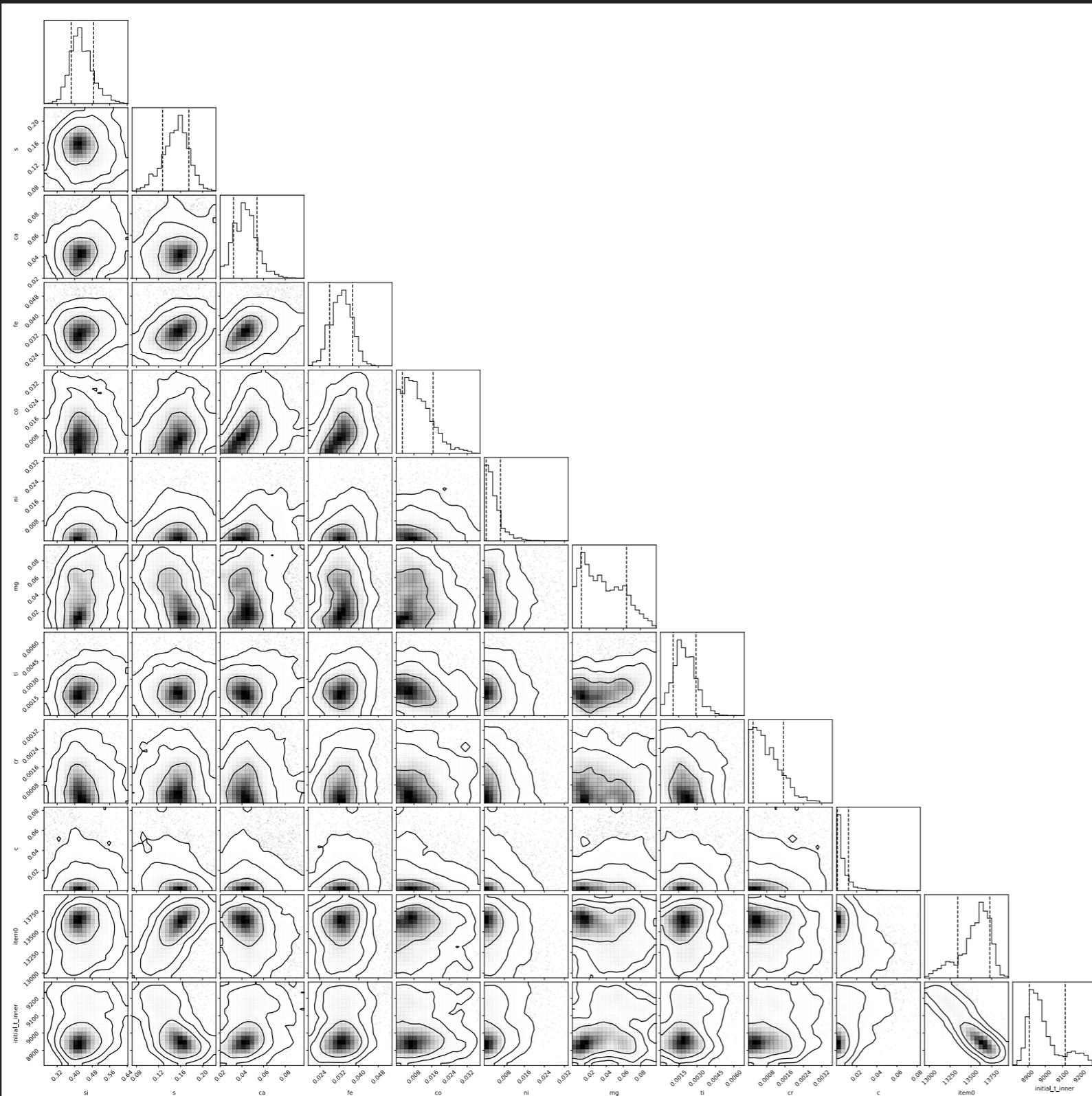
NEURAL NETWORK (WORST)



NEURAL NETWORK (BEST)



SAMPLING THE POSTERIOR



SUMMARY

- ▶ Emulators
 - ▶ Comparing of observations and complex models
 - ▶ Quickly Exploring parameter space within models
- ▶ Several ongoing projects in the TARDIS collaboration
 - ▶ White dwarf explosions, Expanding Photosphere methods (Vogl, MPA), Stripped core collapse (Williamson, NYU)
- ▶ Potentially learn from faster codes and transfer to more costly one

DOWNLOAD THE DATASET



<https://zenodo.org/record/3235017>

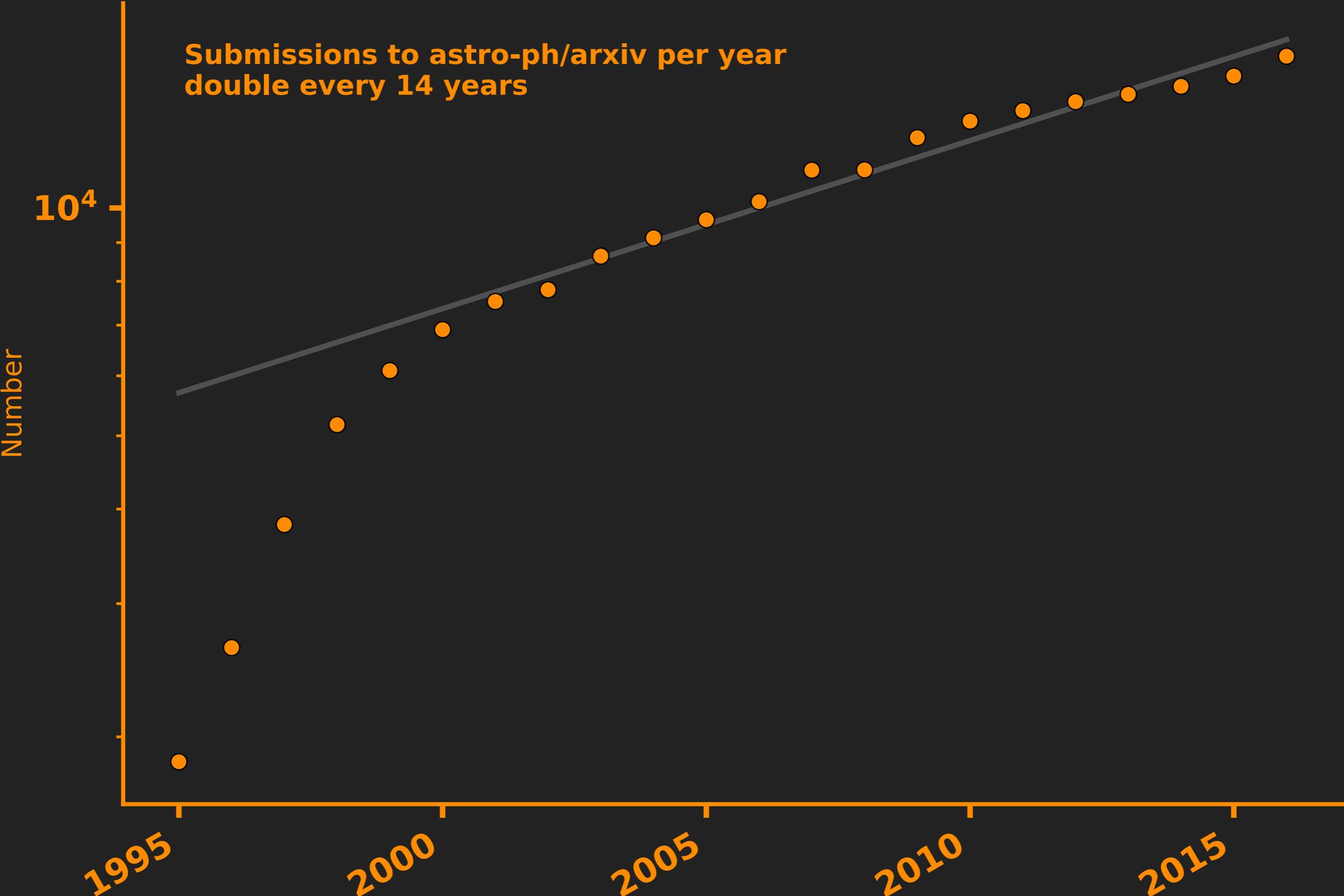
THANK YOU



**MACHINE LEARNING TO
ACCESS LITERATURE**

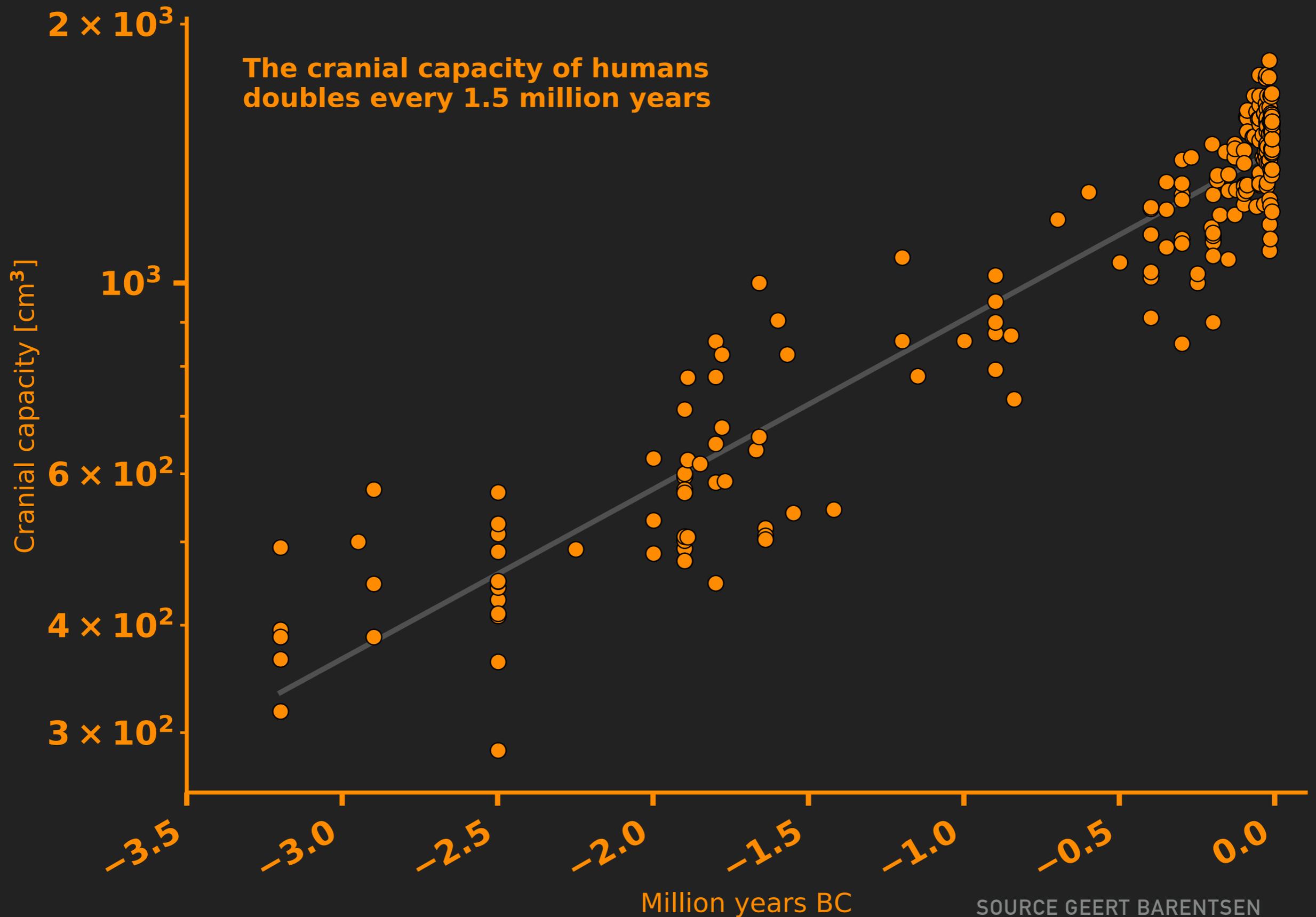
**DEEPTHOUGHT
PROJECT**

ASTRO-PH SUBMISSIONS



SOURCE: KERZENDORF 2017
DEEPTHOUGHT PROJECT

HUMANS WON'T GET SMARTER ... FAST ENOUGH



The dream you can't
escape **ALIVE!**

NIGHTMARE

IF YOU WERE TERRIFIED BY
"DAWN OF THE DEAD"
& "FRIDAY THE 13th"
YOU MUST SEE NIGHTMARE



Several problems:

- We do not know what we know
- Credit is given to the loudest
- Someone has to referee all of that

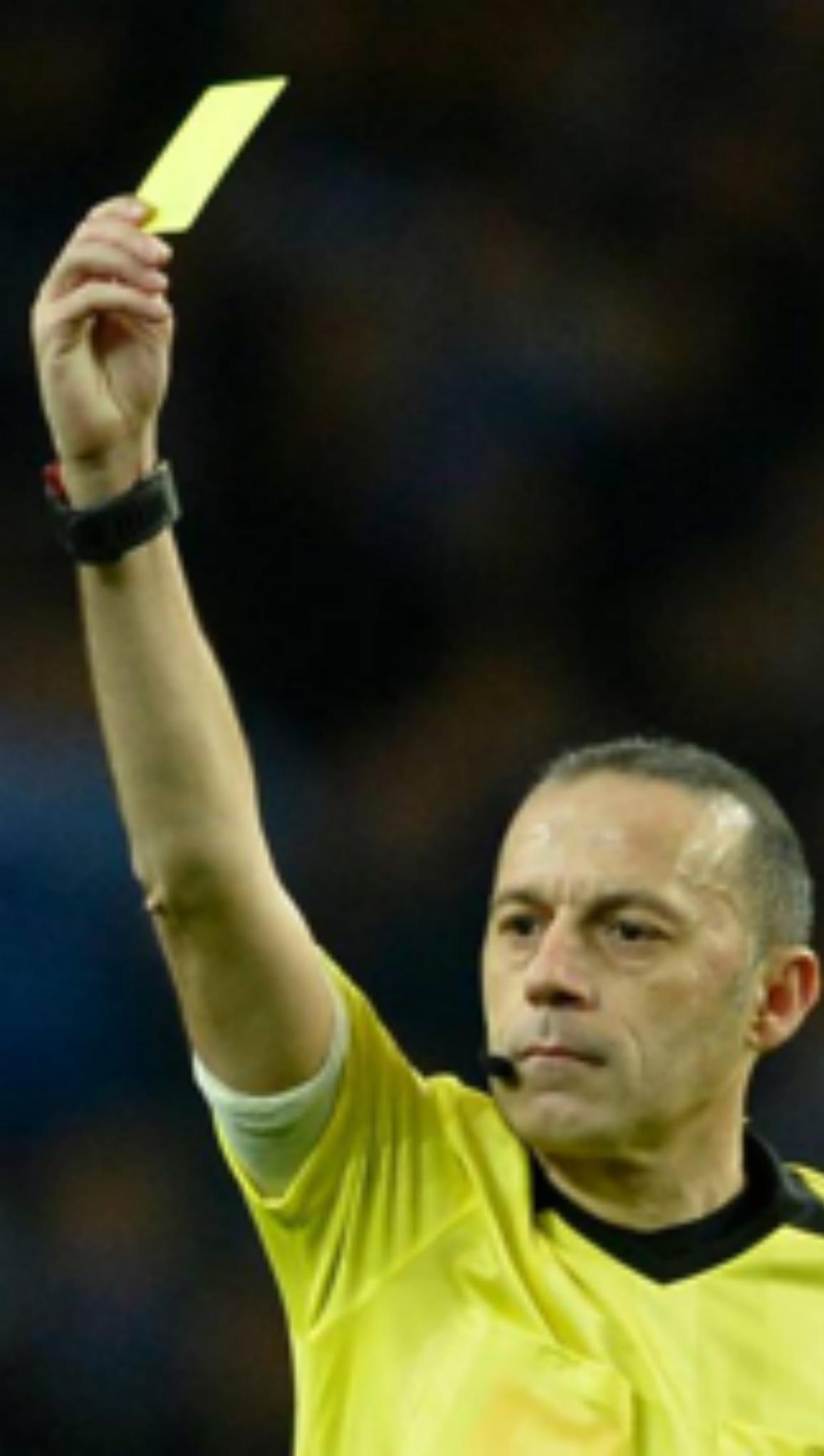
DAVID JONES Presents A GOLDMINE PRODUCTION

Starring **SHARON SMITH** • **BAIRD STAFFORD** and introducing **C.J. COOKE**
Also Starring **MIK CRIBBEN** • **KATHLEEN FERGUSON** • Produced by **JOHN L. WATKINS**
Written & Directed by **ROMANO SCAVOLINI** • Music by **JACK ERIC WILLIAMS**
Executive Producer **DAVID JONES**

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NO ONE UNDER THE AGE OF 17 WILL BE ADMITTED
DUE TO THE VIOLENT NATURE OF THIS FILM





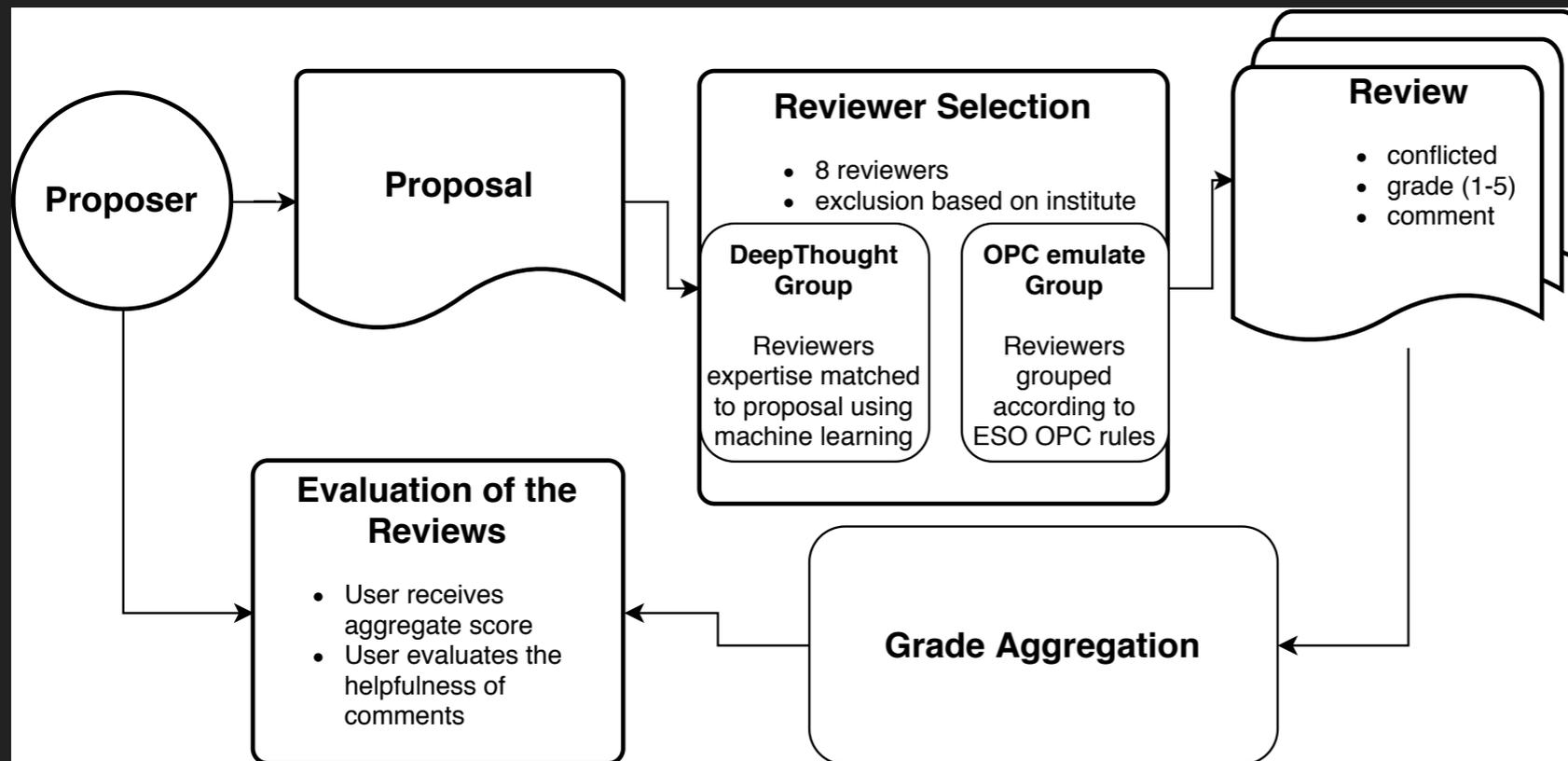
SMART

REFEREEING

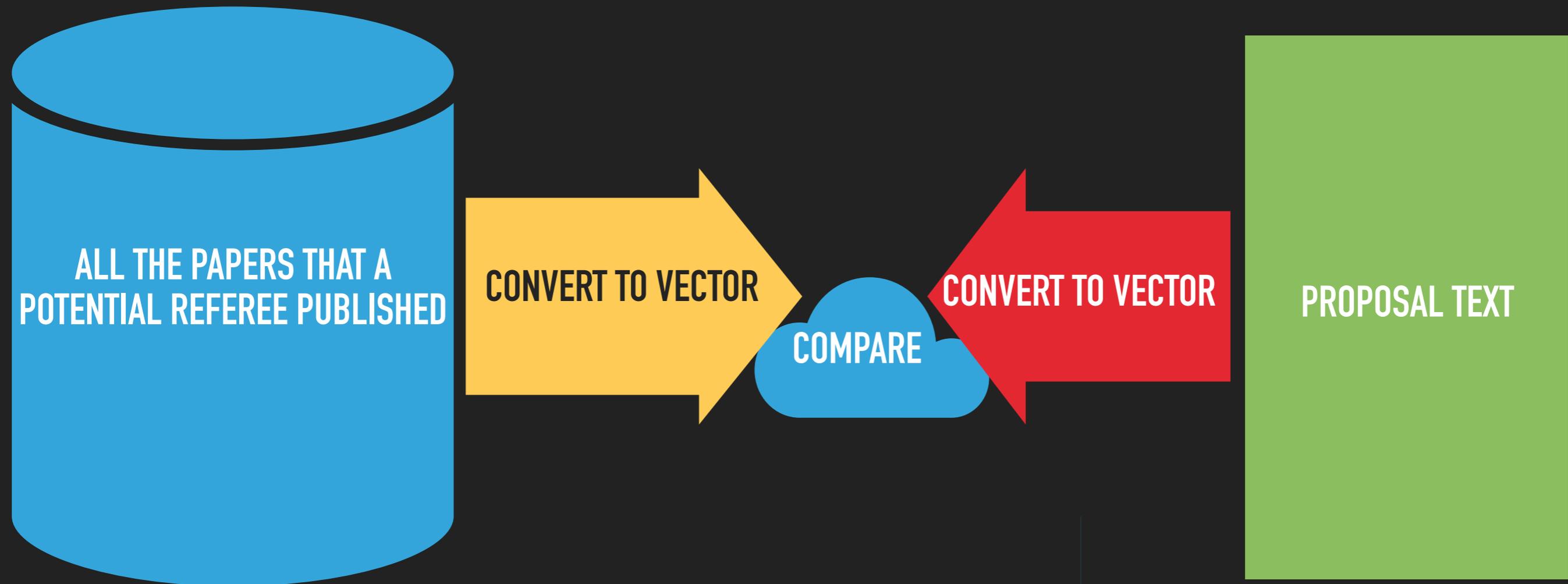
Kerzendorf+ 2020 in review

DEEPTHOUGHT DISTRIBUTED PEER REVIEW AT ESO

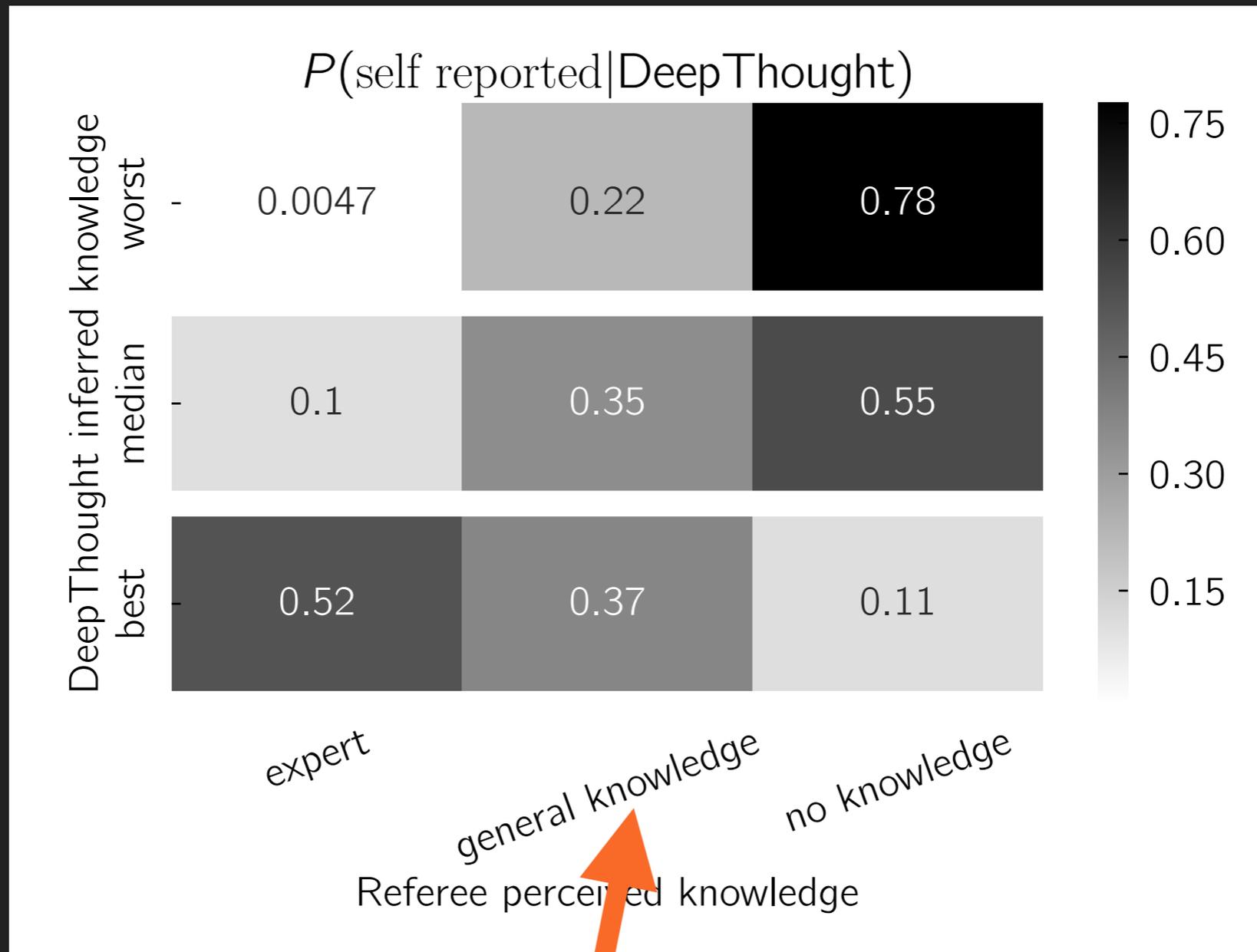
- ▶ 1 - If we use the proposers to review - is that different from experts
- ▶ 2 - Can we match proposers and proposals automatically



REFEREE MATCHING



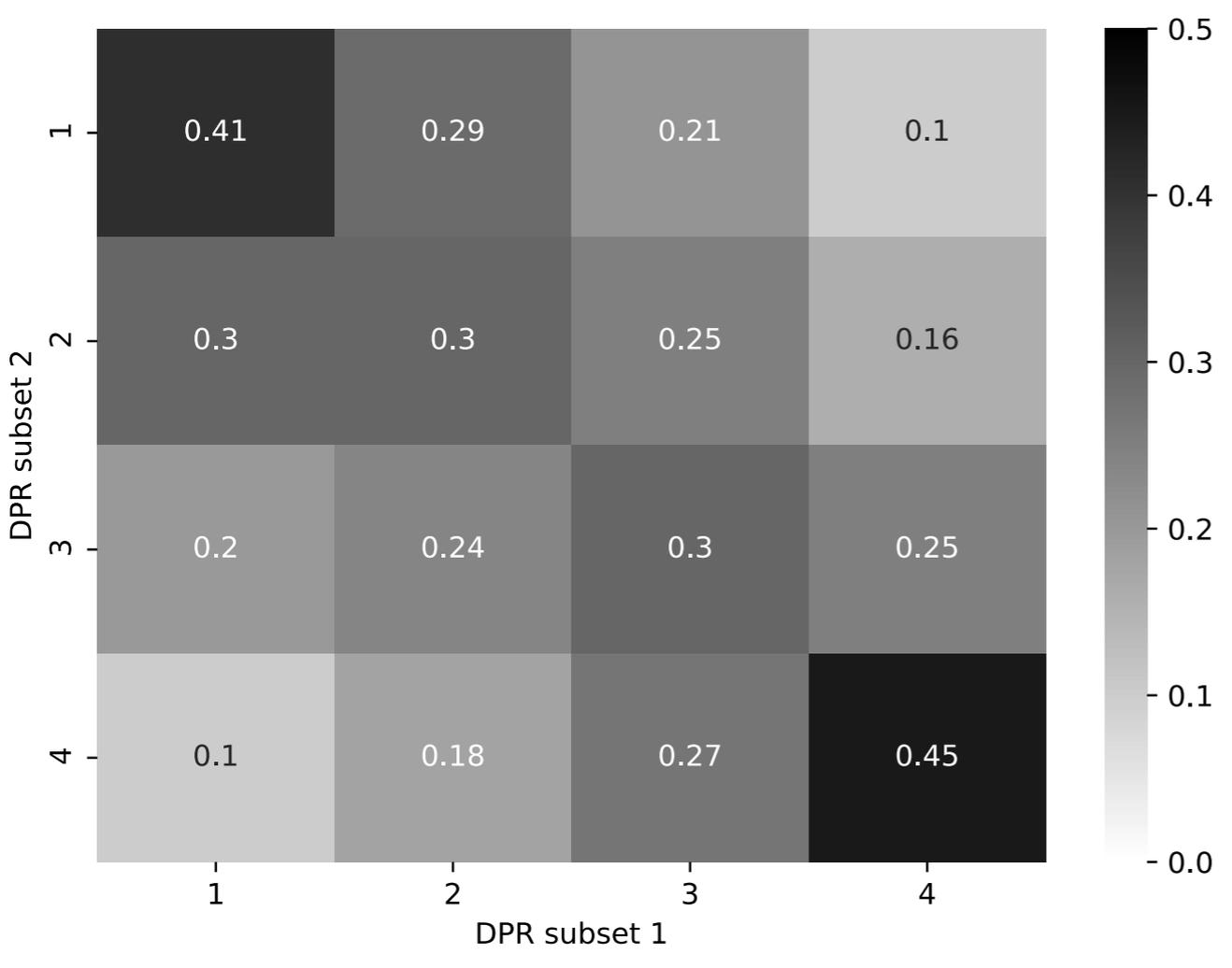
RESULT



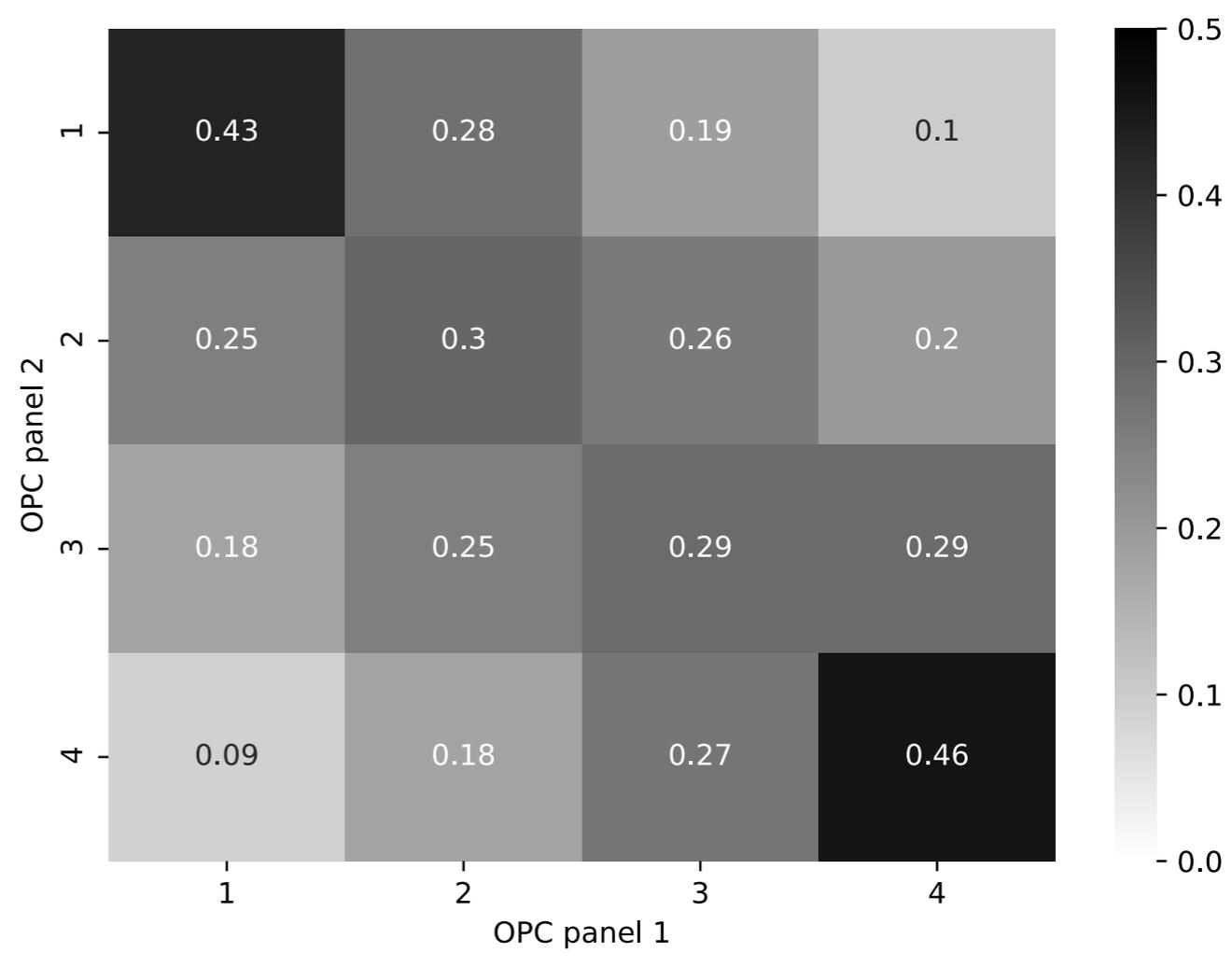
We asked them

COMPARISON BETWEEN DISTRIBUTED PEER REVIEW AND NORMAL REVIEW

DISTRIBUTED PEER REVIEW



TRADITIONAL PANEL



THANK YOU