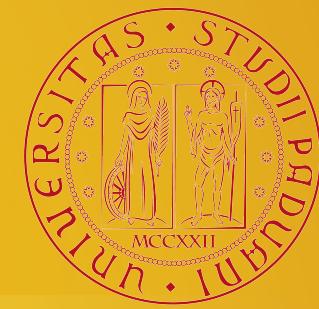




Dipartimento
di Fisica
e Astronomia
Galileo Galilei



LONG PERIOD VARIABLES IN THE LMC

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Peter Wood @ ANU
Josefina Montalbán @ UniPd
Paola Marigo @ UniPd
Giada Pastorelli @ UniPd
Léo Girardi @ INAF-OAPd

14.09.2017 – Stellar Populations and the Distance Scale
Kavli Institute for Astronomy and Astrophysics – Peking University

OUTLINE

- Observations of LPVs in the LMC
- Current interpretations

-
- Theoretical modelling →

population synthesis
+
pulsation models
 - Observations again: semi-empirical analysis

OUTLINE

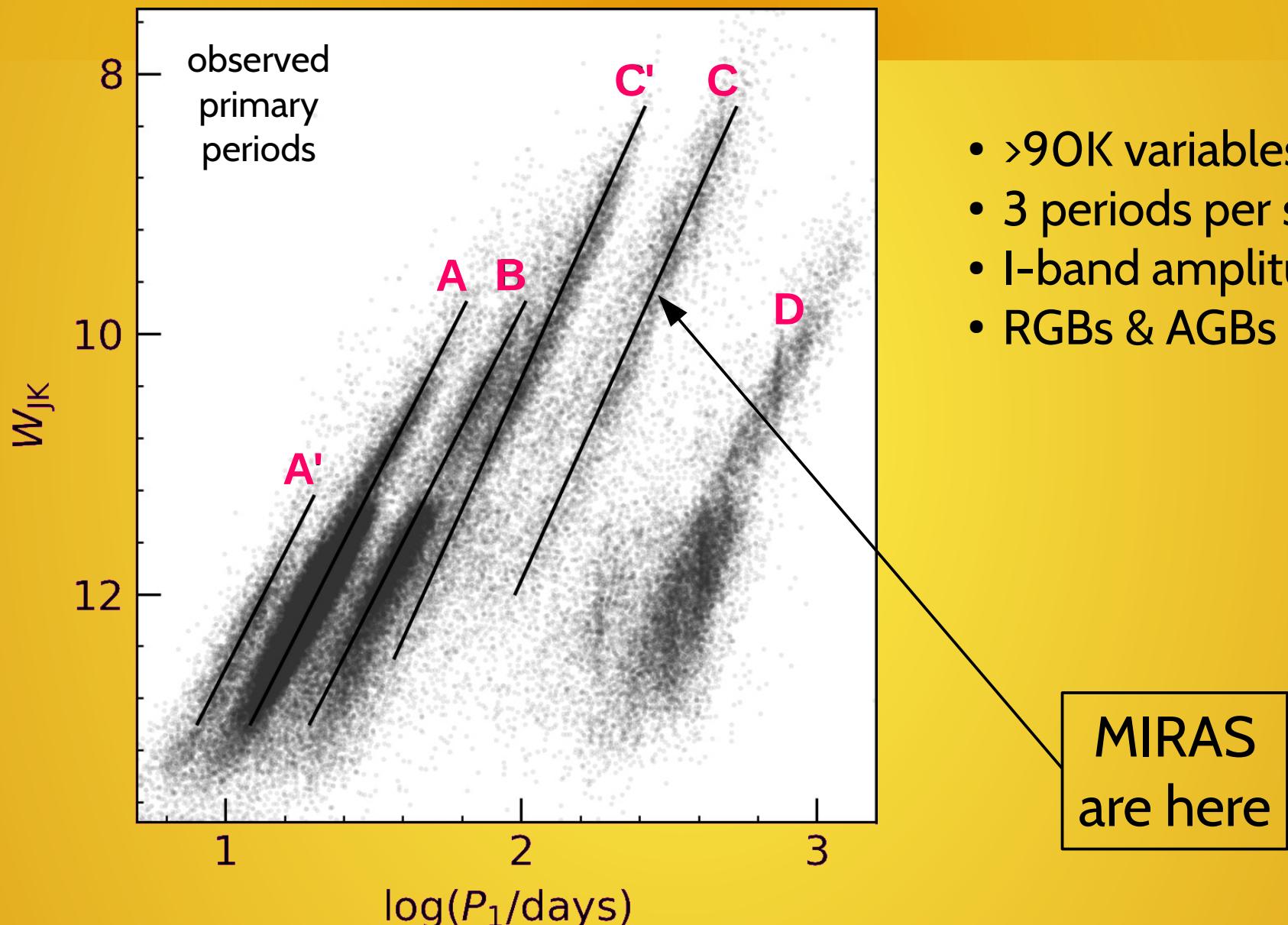
- Observations of LPVs in the LMC
- Current interpretations

Non-radial models of LPVs: Montalbán et al., 2017 (in prep.)

- Theoretical modelling
 - Observations again: semi-empirical analysis
-
- RADIAL
- population synthesis +
pulsation models

LPVs in the LMC from OGLE-3

(Soszyński, et al. 2009, Acta Astron., 59, 239)

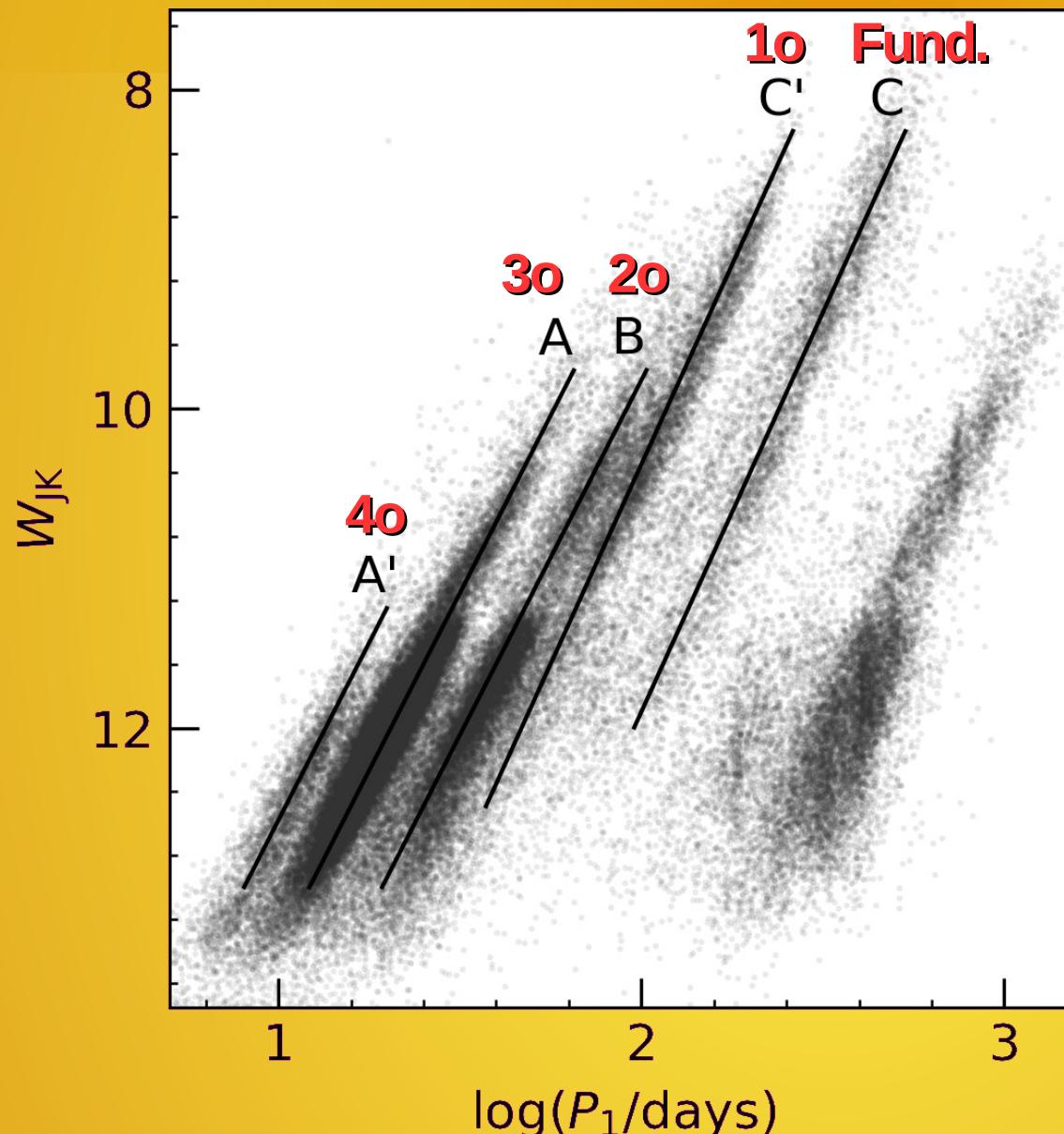


- >90K variables
- 3 periods per star
- I-band amplitudes
- RGBs & AGBs

MIRAS
are here

LPVs in the LMC from OGLE-3

(Soszyński, et al. 2009, Acta Astron., 59, 239)

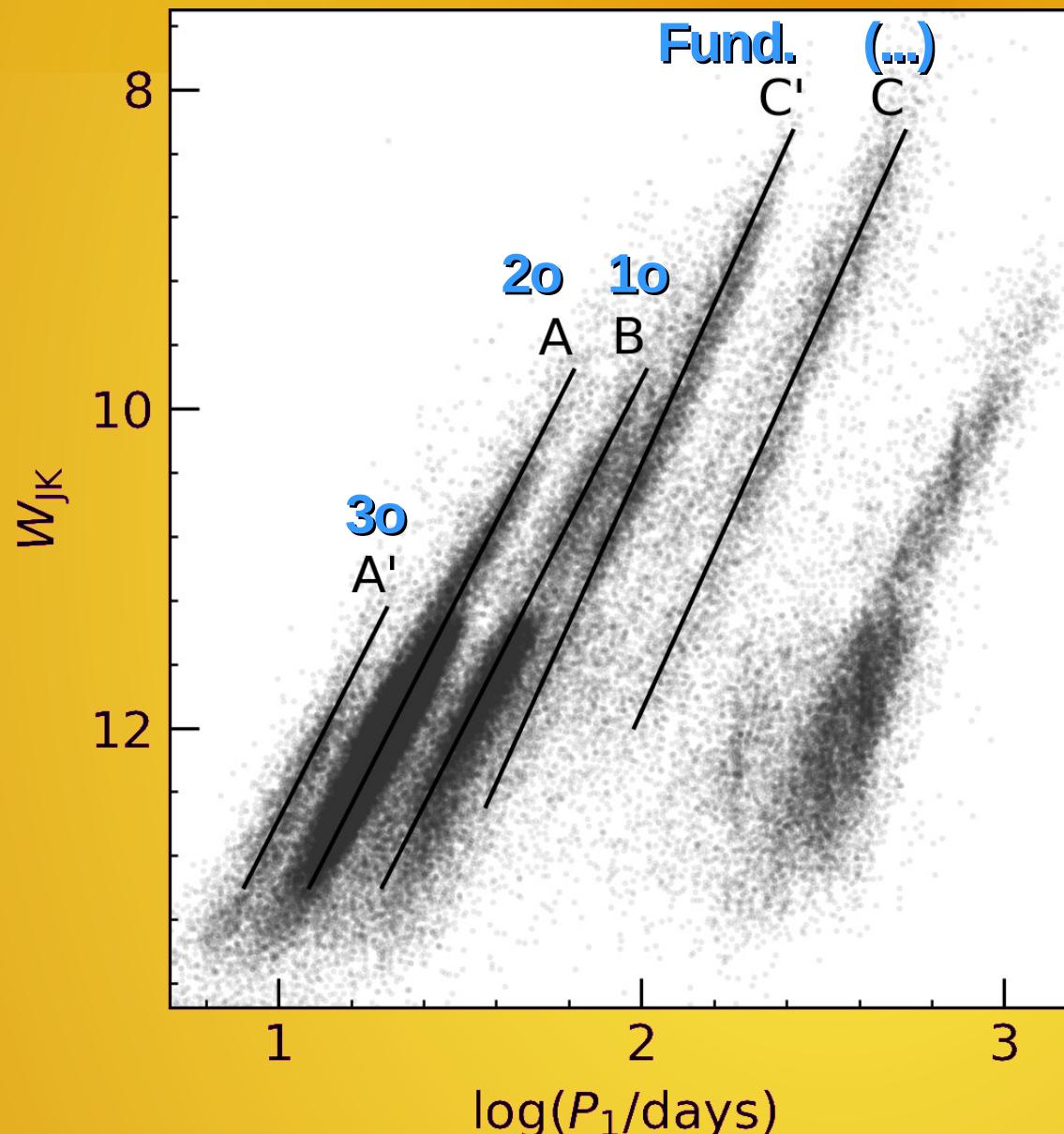


INTERPRETATIONS

Wood (2015)
MNRAS, 448, 3829

LPVs in the LMC from OGLE-3

(Soszyński, et al. 2009, Acta Astron., 59, 239)



INTERPRETATIONS

Mosser+ (2013)

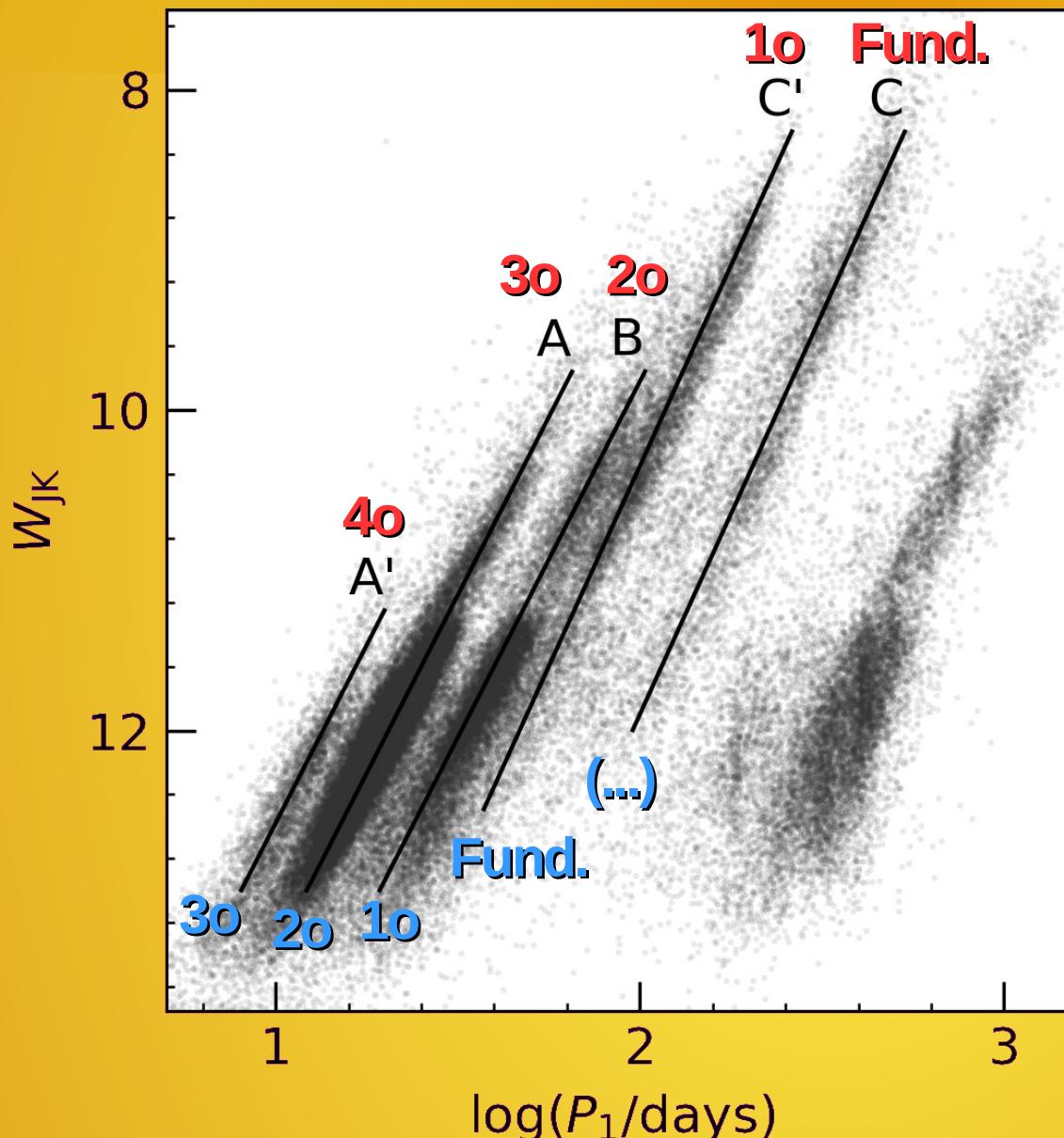
A&A, 559, A137

Soszyński+ (2007)

Acta Astron., 57, 201

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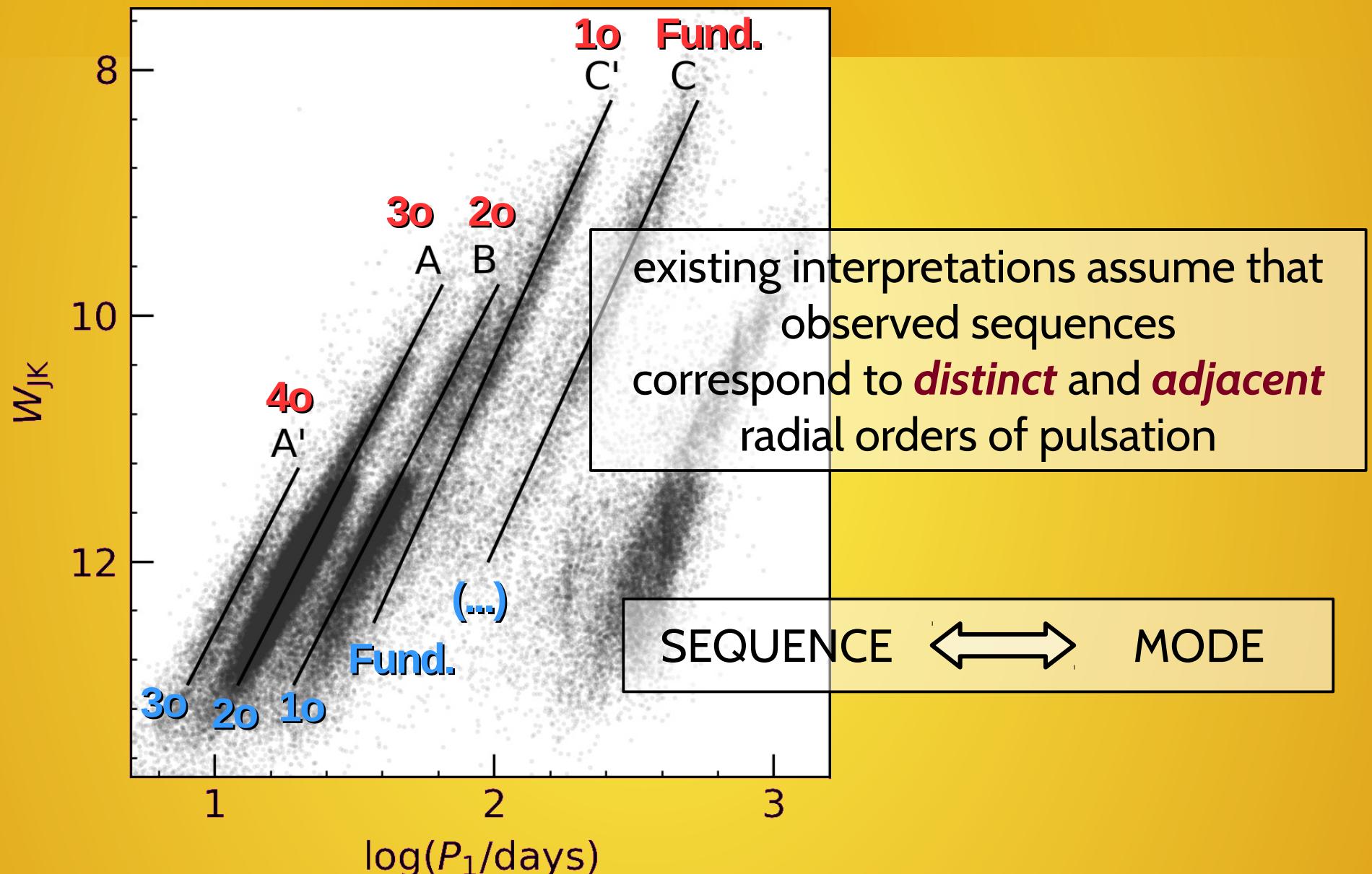
one sequence offset

Mosser+ (2013)
A&A, 559, A137

Soszyński+ (2007)
Acta Astron., 57, 201

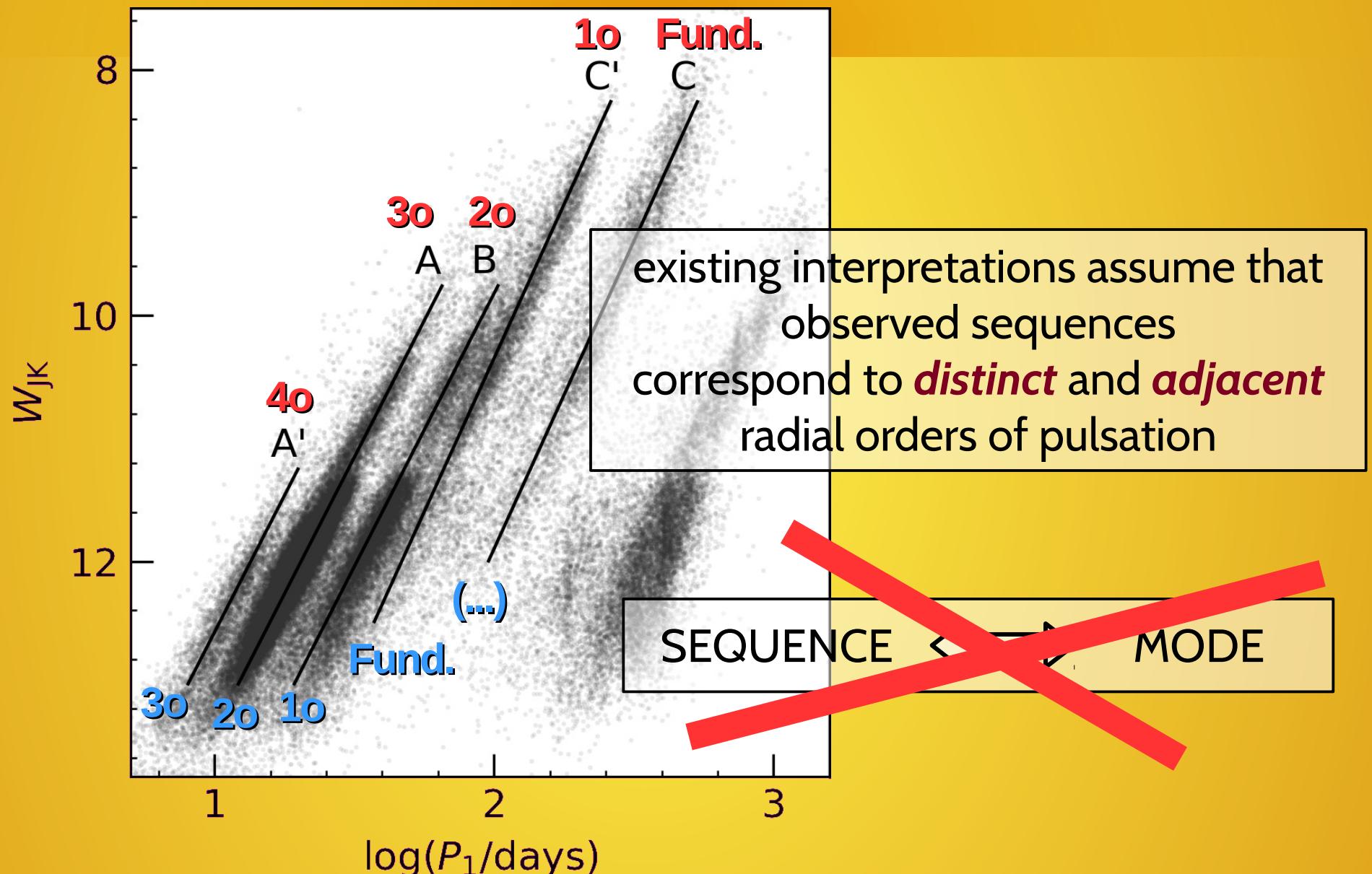
LPVs in the LMC from OGLE-3

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LPVs in the LMC from OGLE-3

(Soszyński, et al. 2009, Acta Astron., 59, 239)



THEORETICAL MODELLING

linear, radial, non-adiabatic

PULSATION MODELS

Wood & Olivier, 2014
MNRAS, 440, 2576

low-T atom.+mol. opacity

AESOPUS

Marigo & Aringer, 2009
A&A, 508, 1539

core mass,
sampling of parameters space

COLIBRI
AGB evolutionary tracks
Marigo et al., 2013
MNRAS, 434, 488

**GRID OF LPV
PULSATION MODELS**
Trabucchi et al., 2017 (in prep.)

THEORETICAL MODELLING

SYNTHETIC POPULATION
OF LONG-PERIOD VARIABLES

population synthesis
TRILEGAL
Girardi et al., 2005
A&A, 436, 895

GRID OF LPV
PULSATION MODELS
Trabucchi et al., 2017 (in prep.)

THEORETICAL MODELLING

SYNTHETIC POPULATION OF LONG-PERIOD VARIABLES

- 5 radial modes: from fundamental to 4th overtone
- periods and growth rates

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SYNTHETIC POPULATION OF LONG-PERIOD VARIABLES

- 5 radial modes: from fundamental to 4th overtone

- periods and growth rates

$GR < 0$
stable
(not observable)

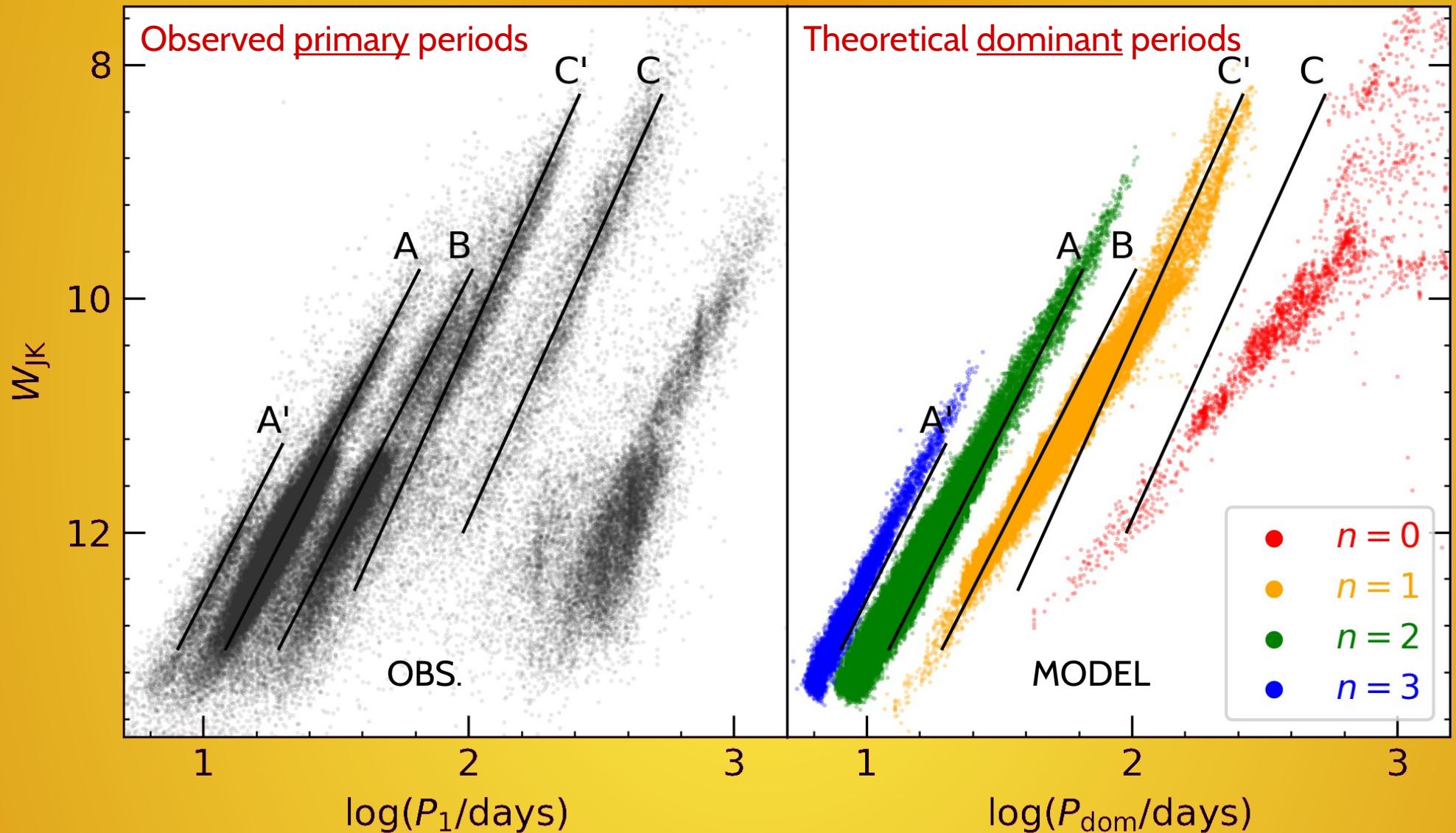
$GR > 0$
excited
(observable)

largest GR
(of the 5 modes)

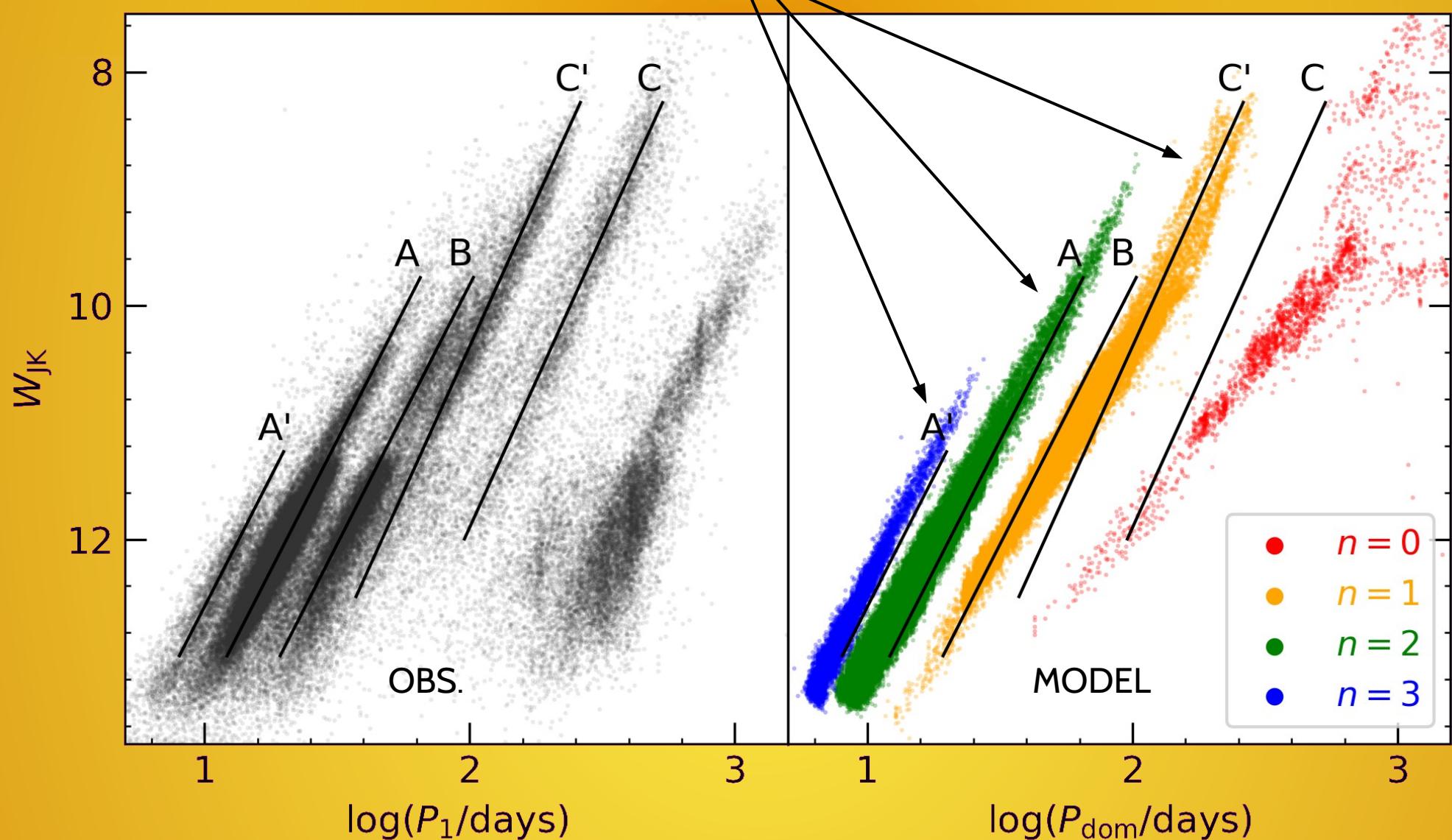
dominant
(most easily observed)

compared with
observed **primary** modes

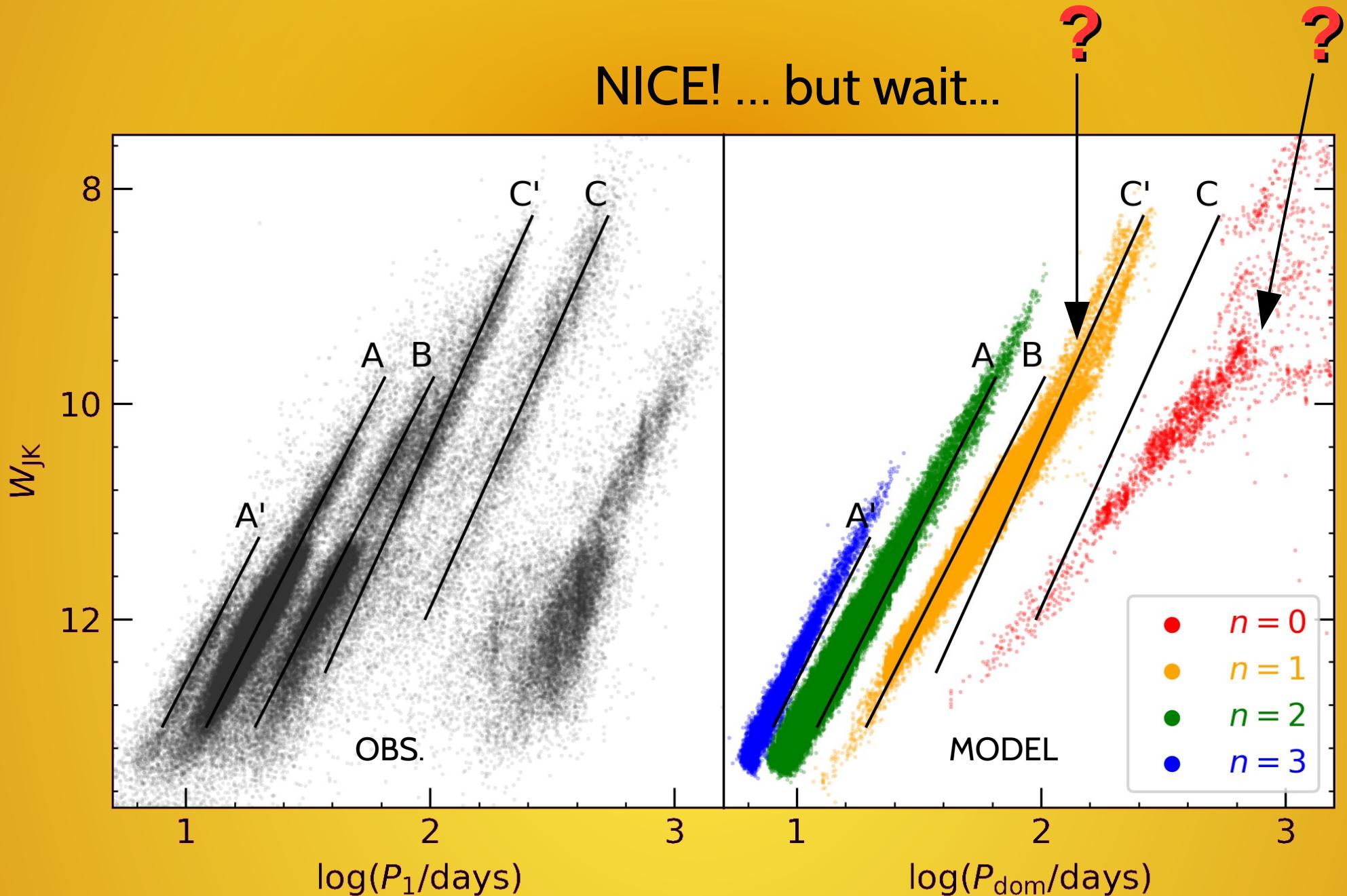
COMPARISON WITH OBSERVATIONS



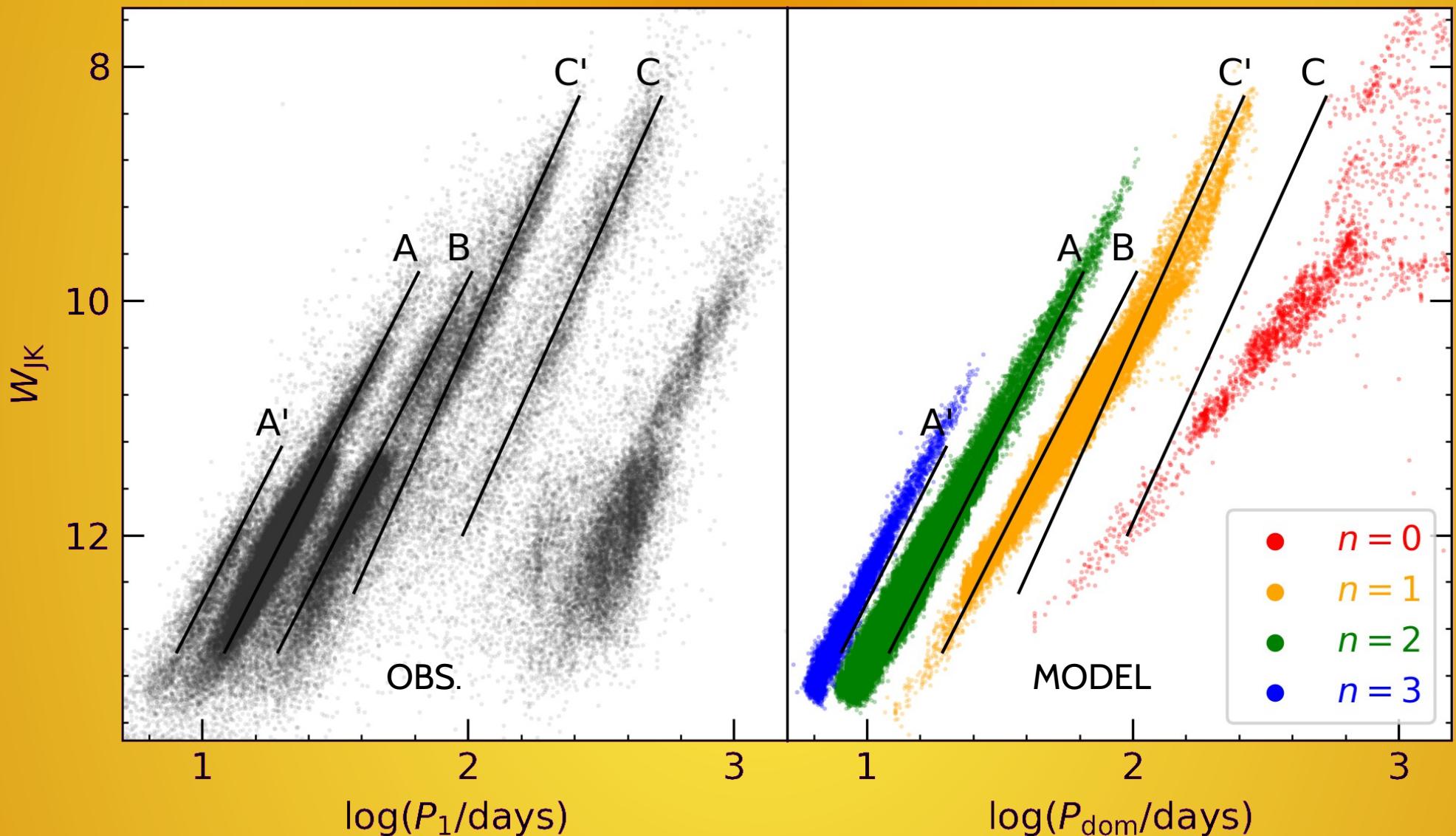
NICE!



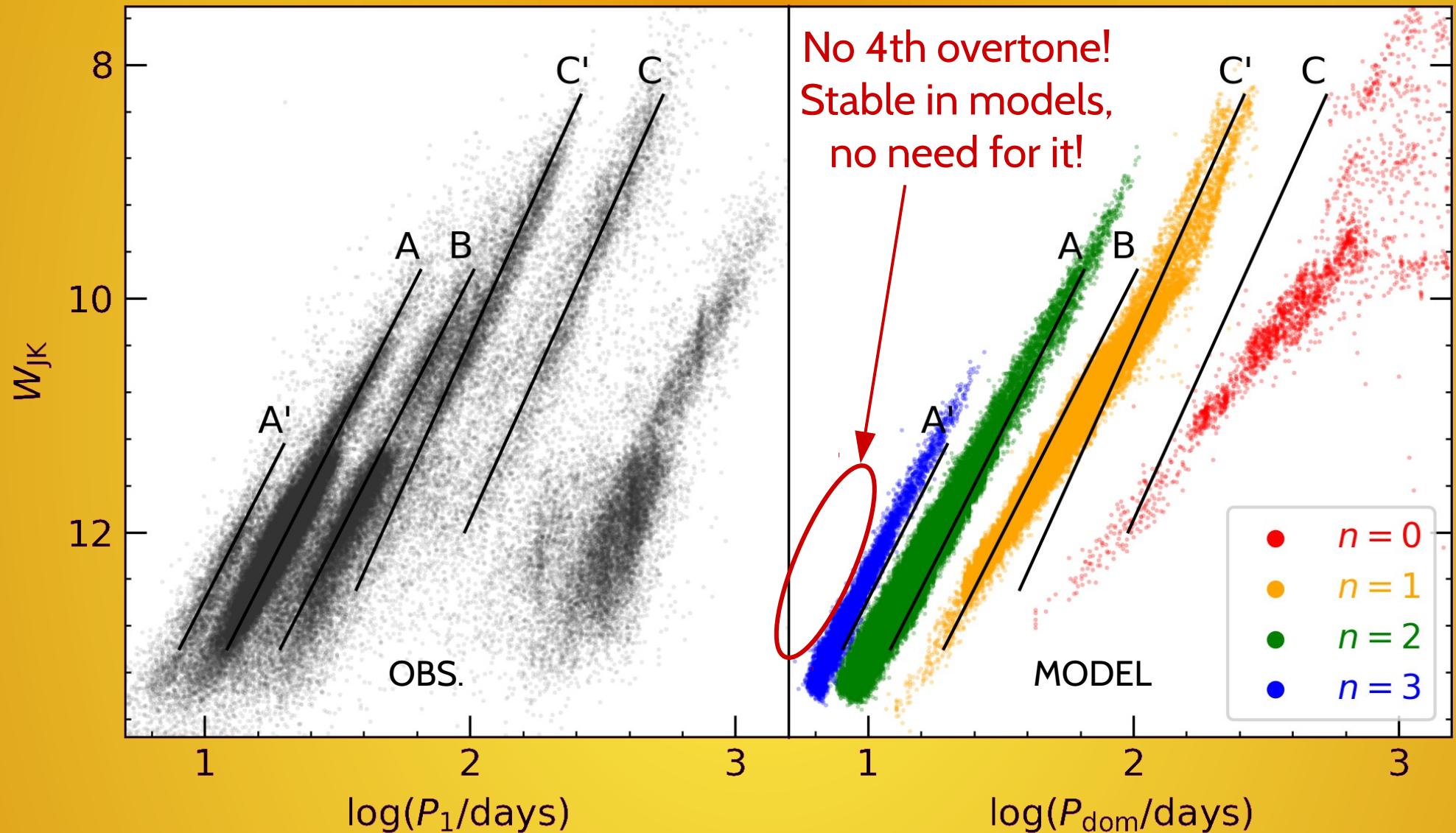
NICE! ... but wait...



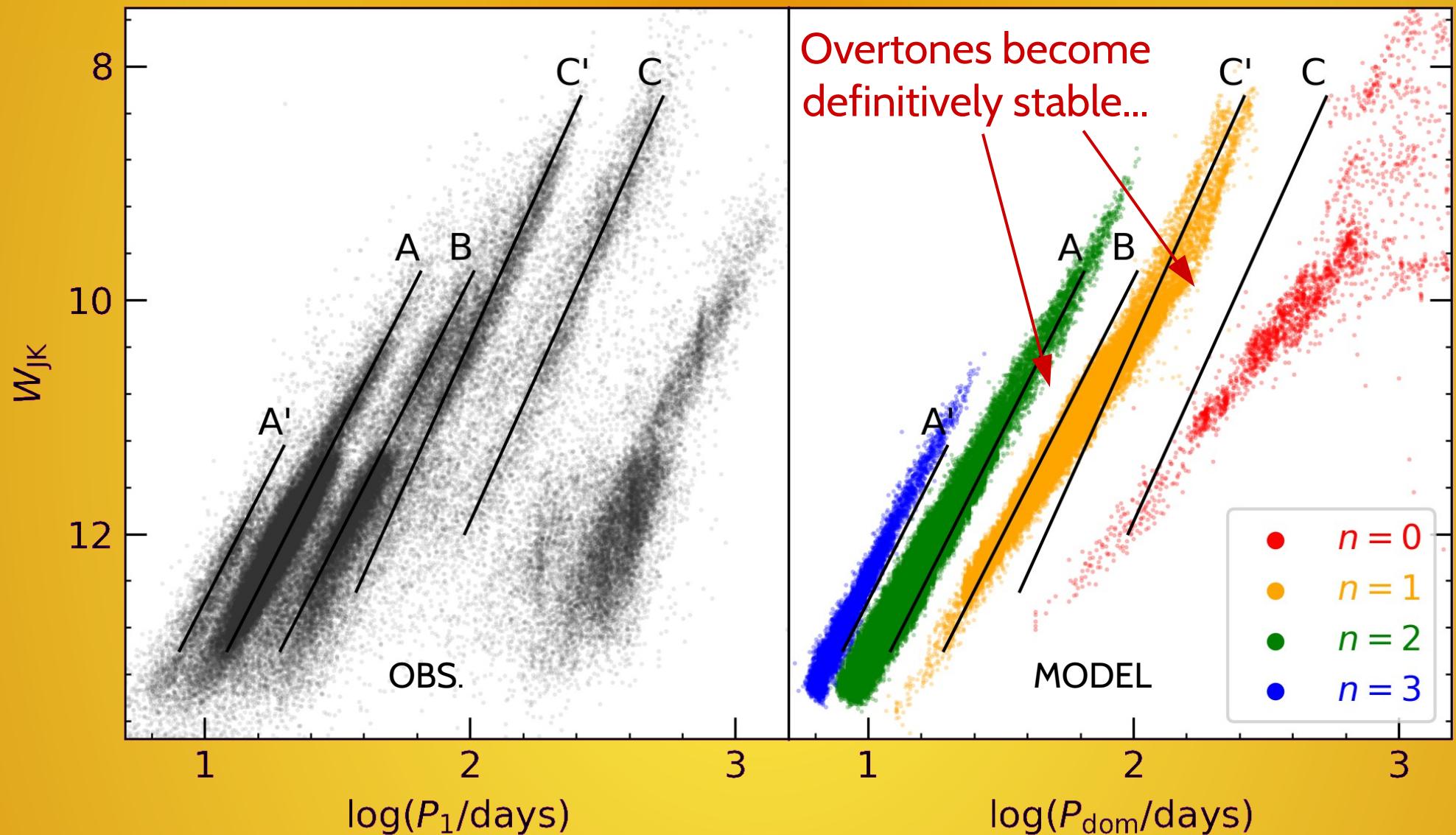
observed PL sequences are reproduced
with **EXACTLY 4** radial oscillation modes



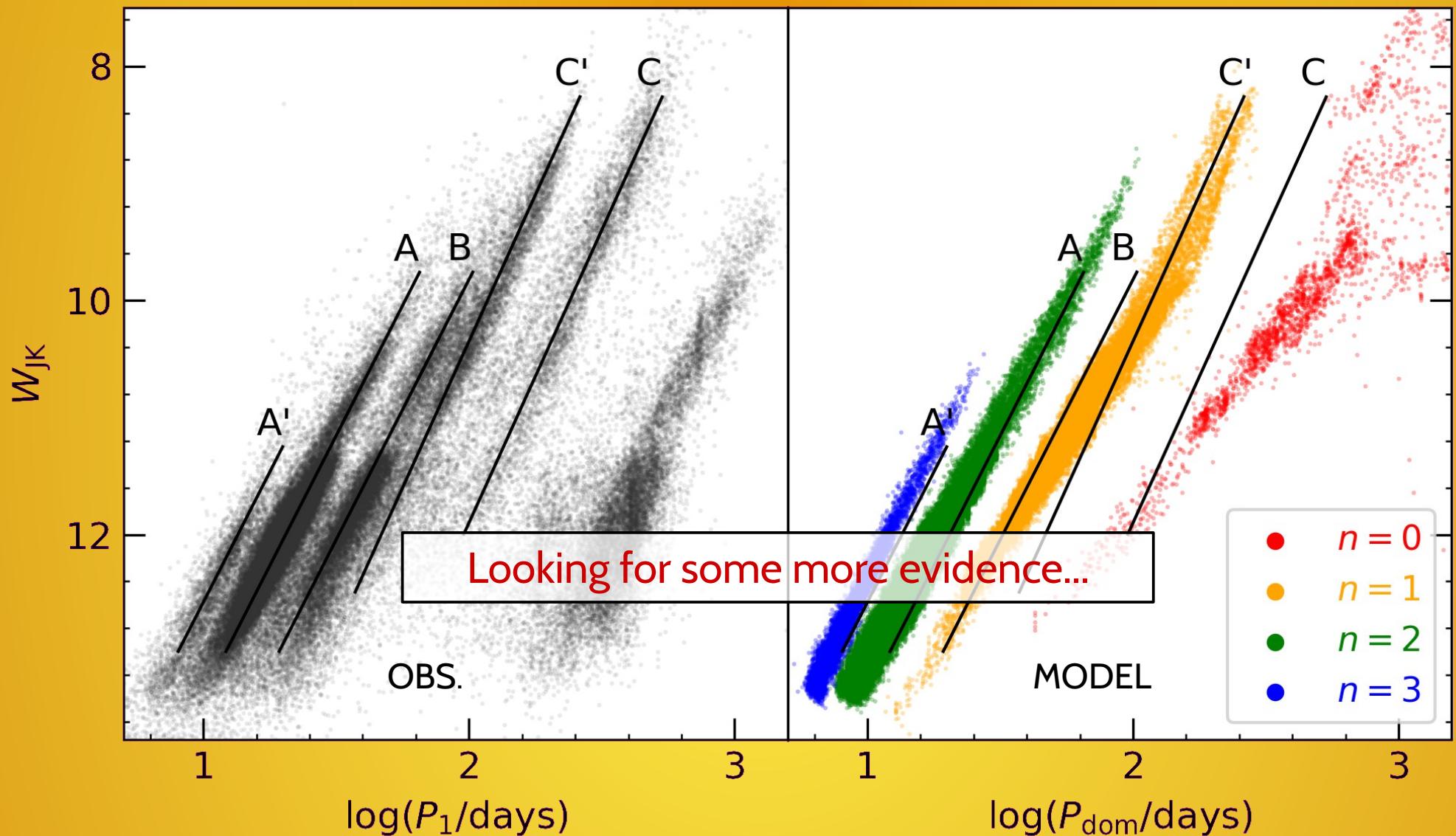
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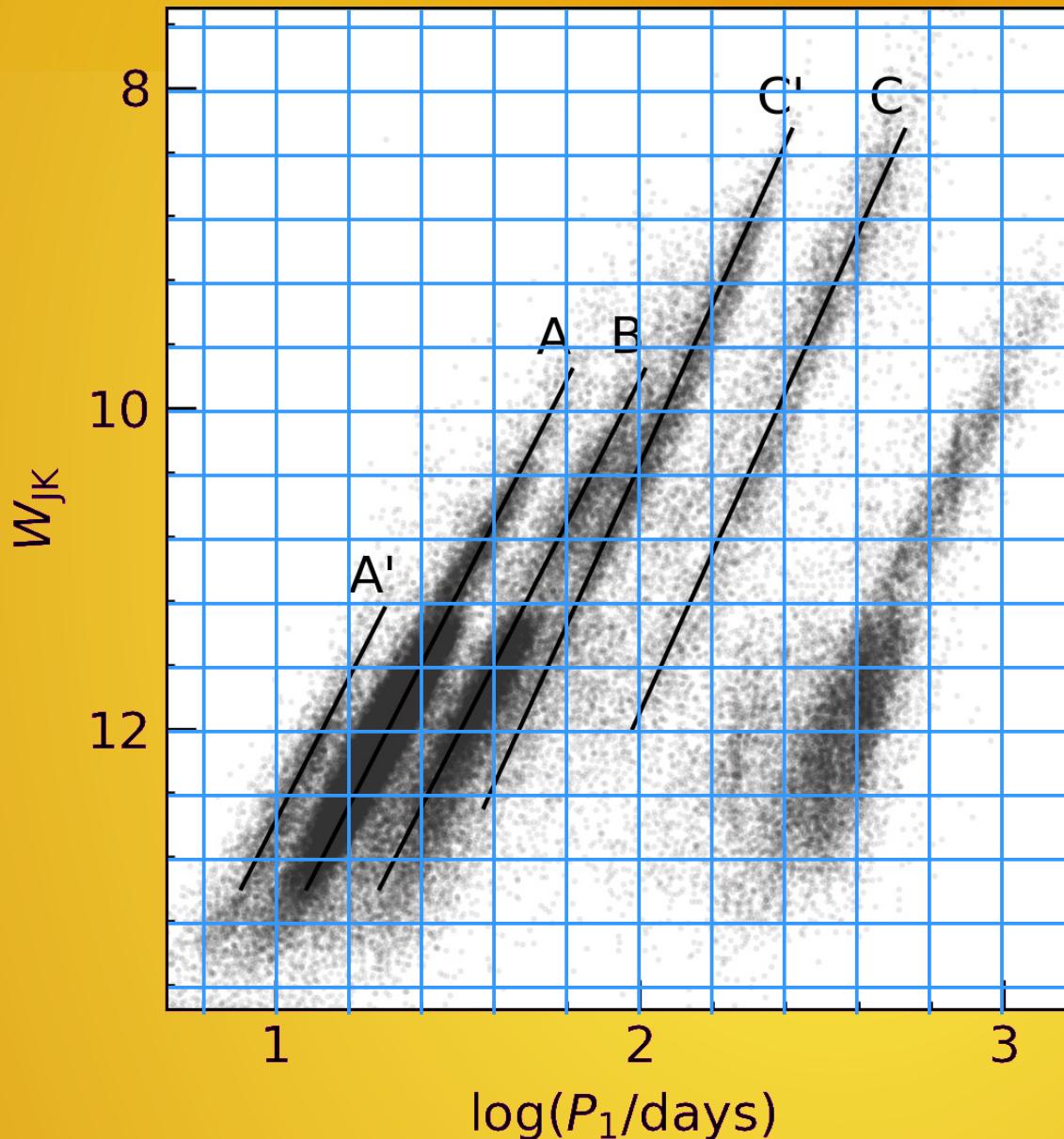
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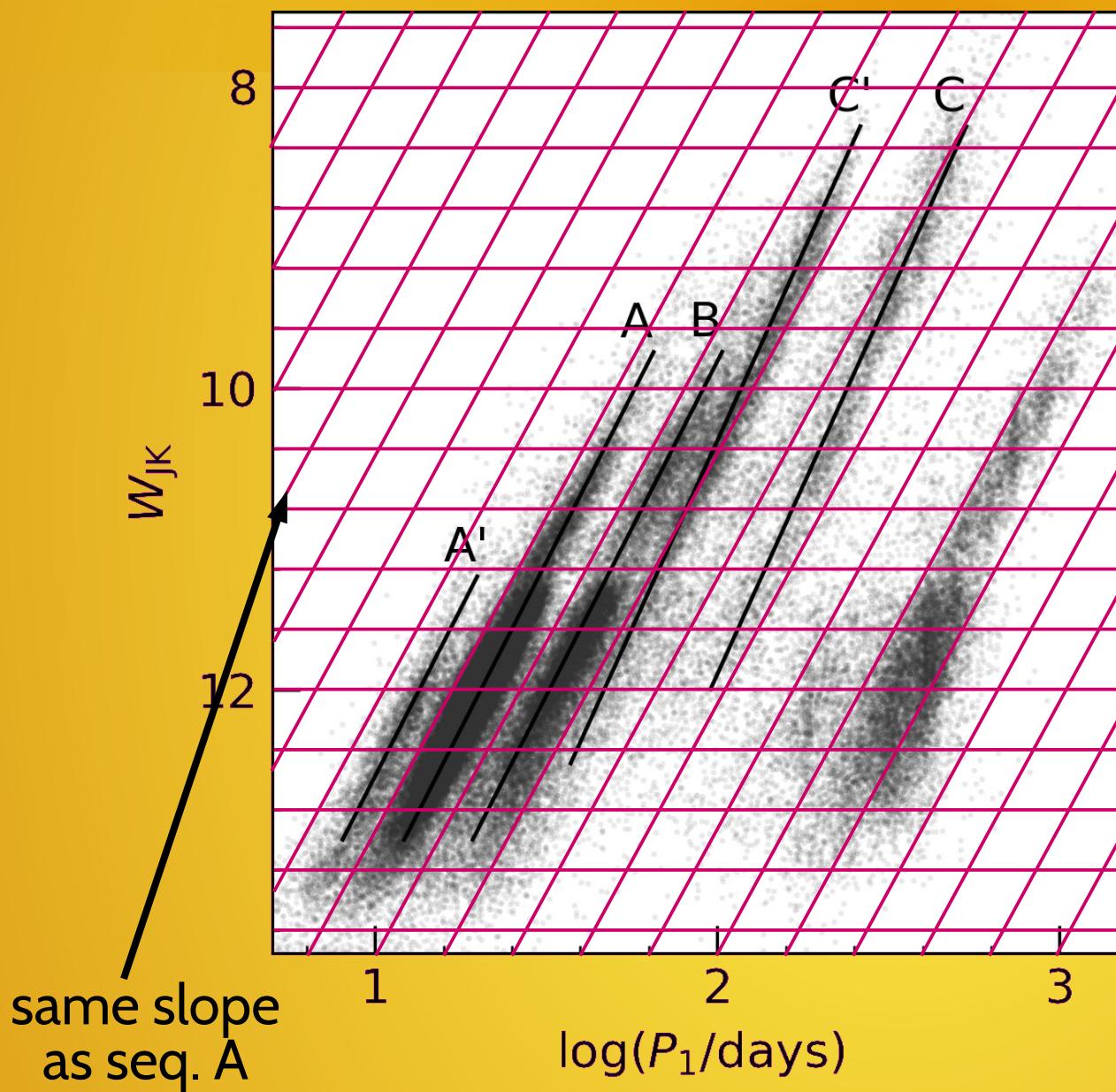
Definition of a useful quantity



REGULAR PERIOD

$\log(P/\text{days})$

Definition of a useful quantity

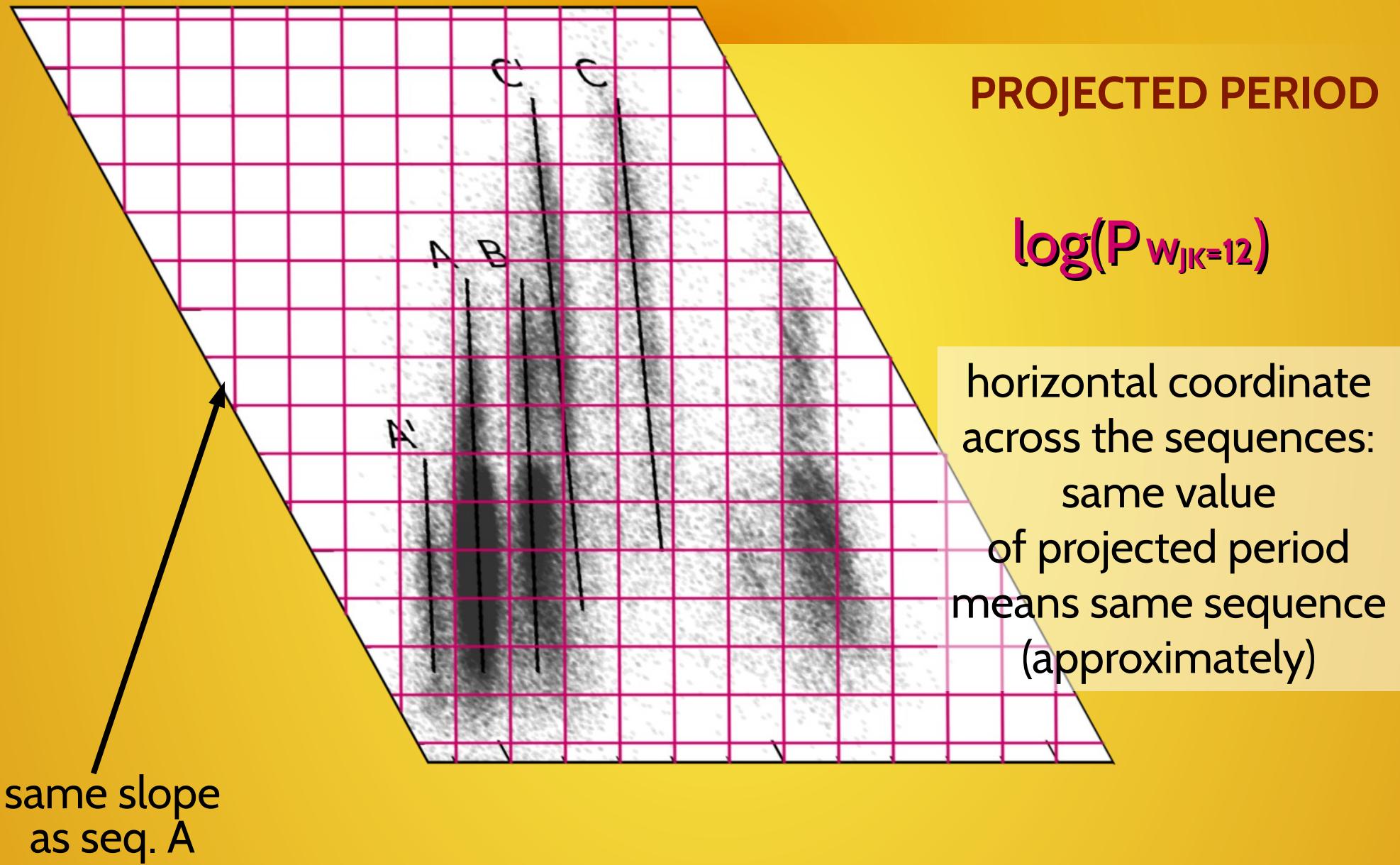


PROJECTED PERIOD

$$\log(P_{W_{JK}=12})$$

horizontal coordinate
across the sequences:
same value
of projected period
means same sequence
(approximately)

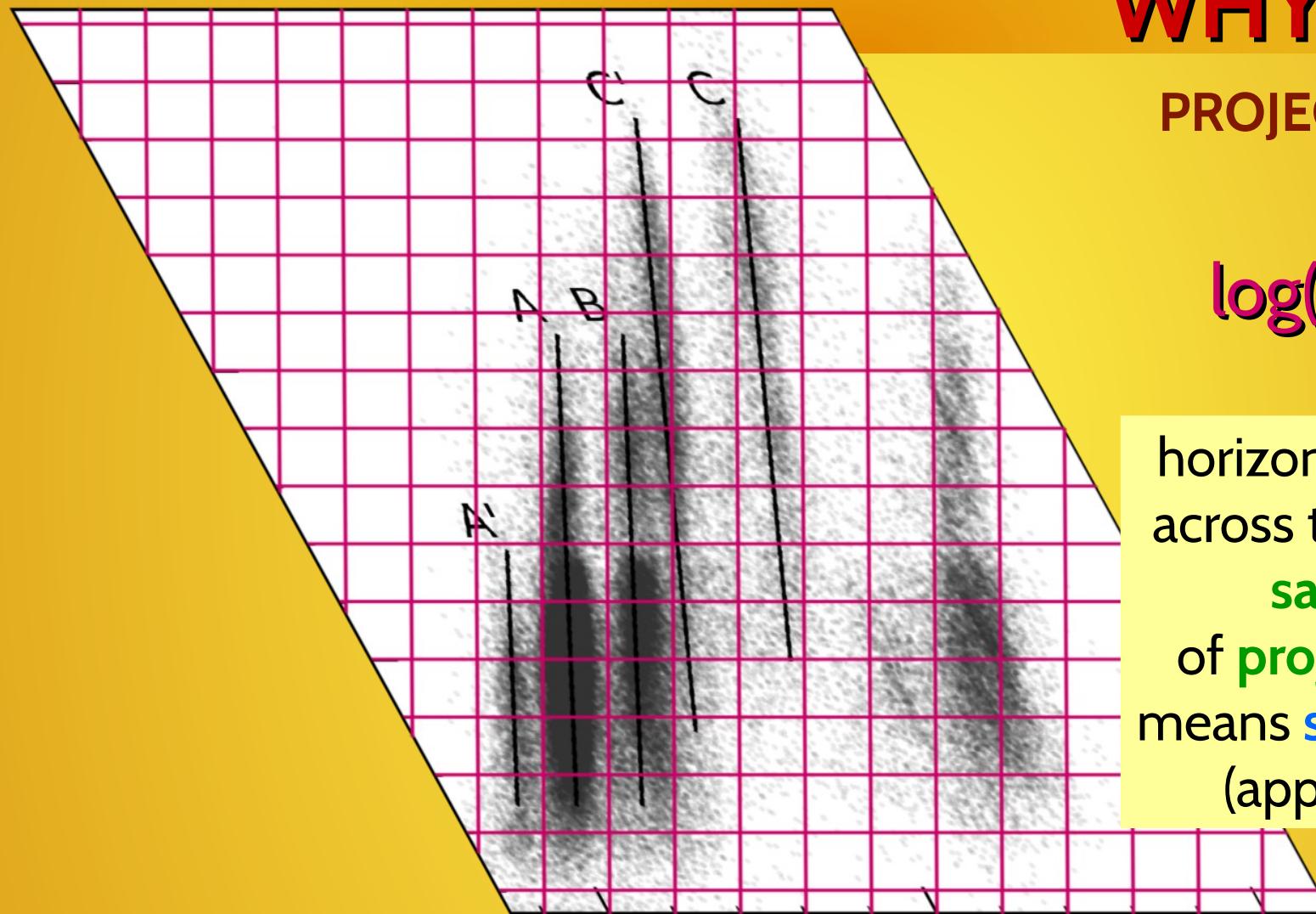
Definition of a useful quantity



Definition of a useful quantity

WHY?

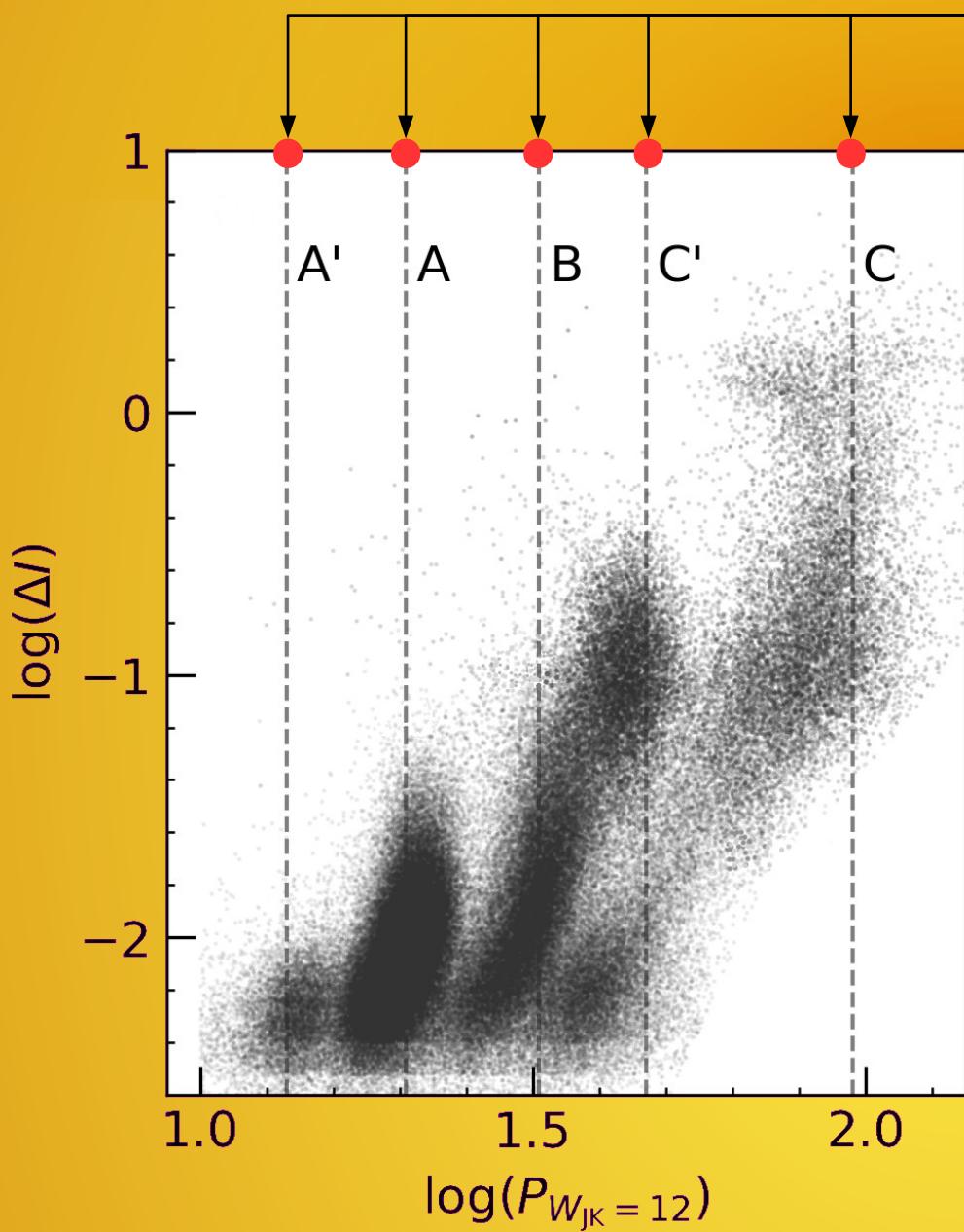
PROJECTED PERIOD



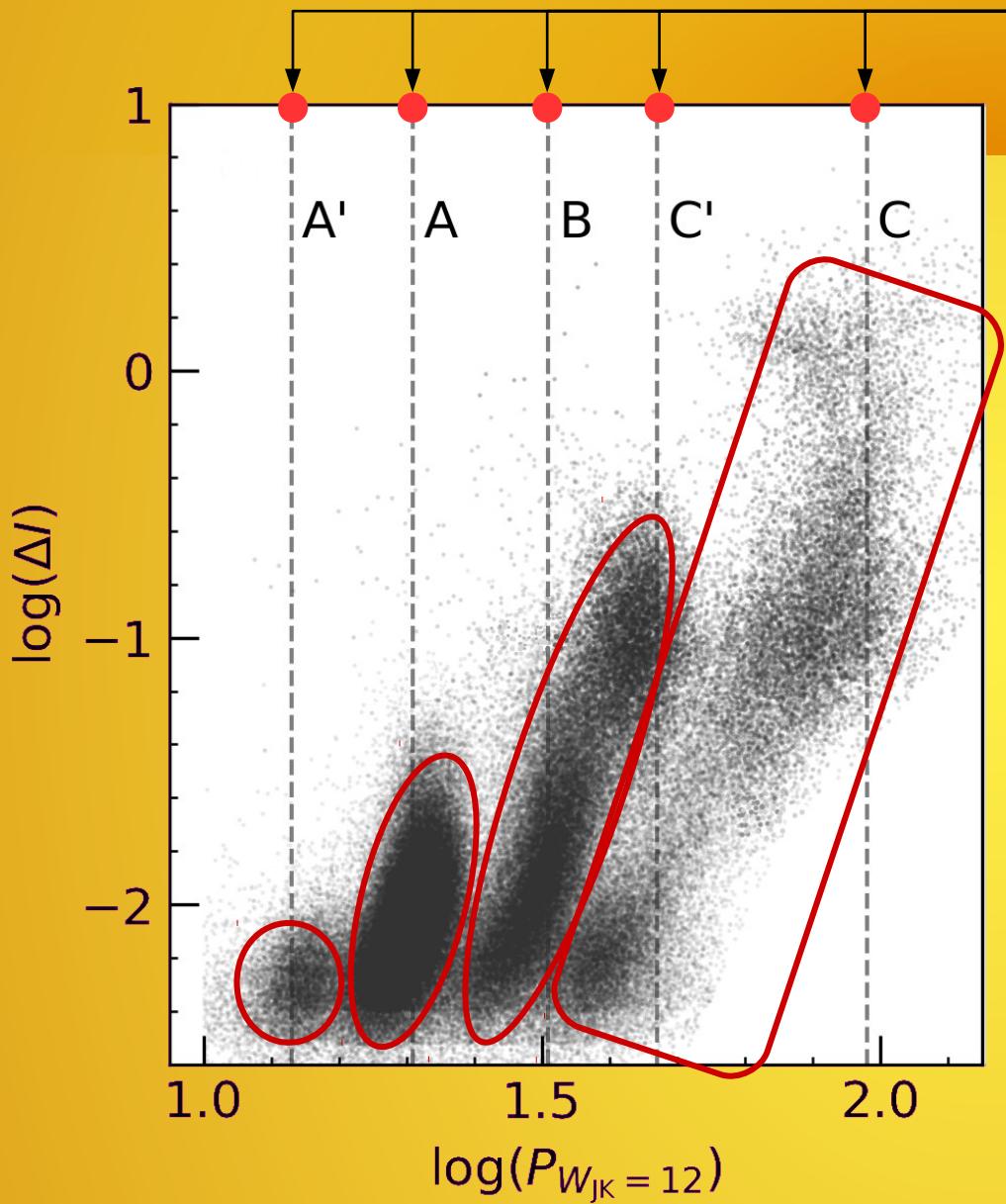
$$\log(P_{W_{JK}=12})$$

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PL SEQUENCES

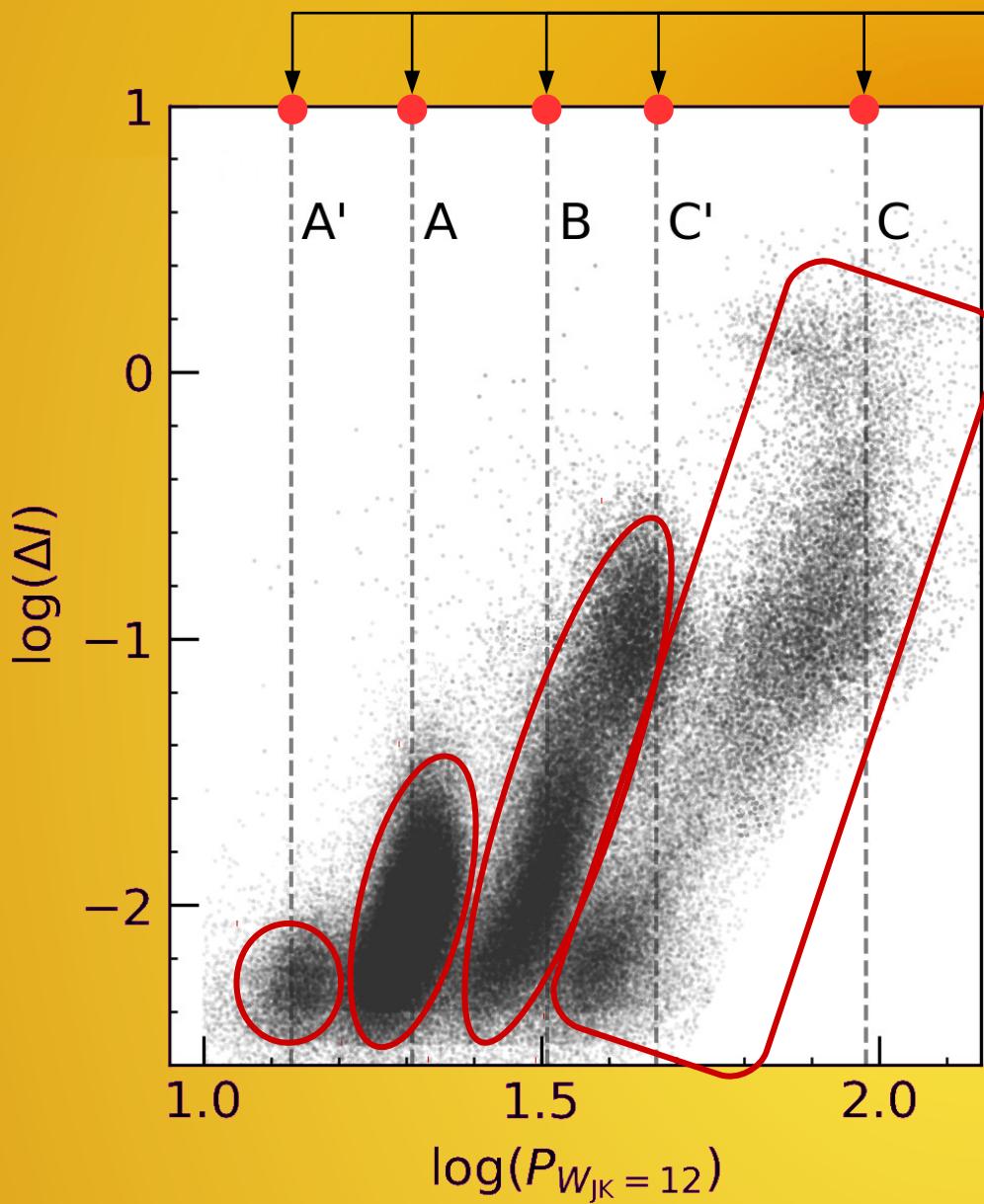


PL SEQUENCES



4 PAL Relations
(Period-Amplitude-Luminosity)

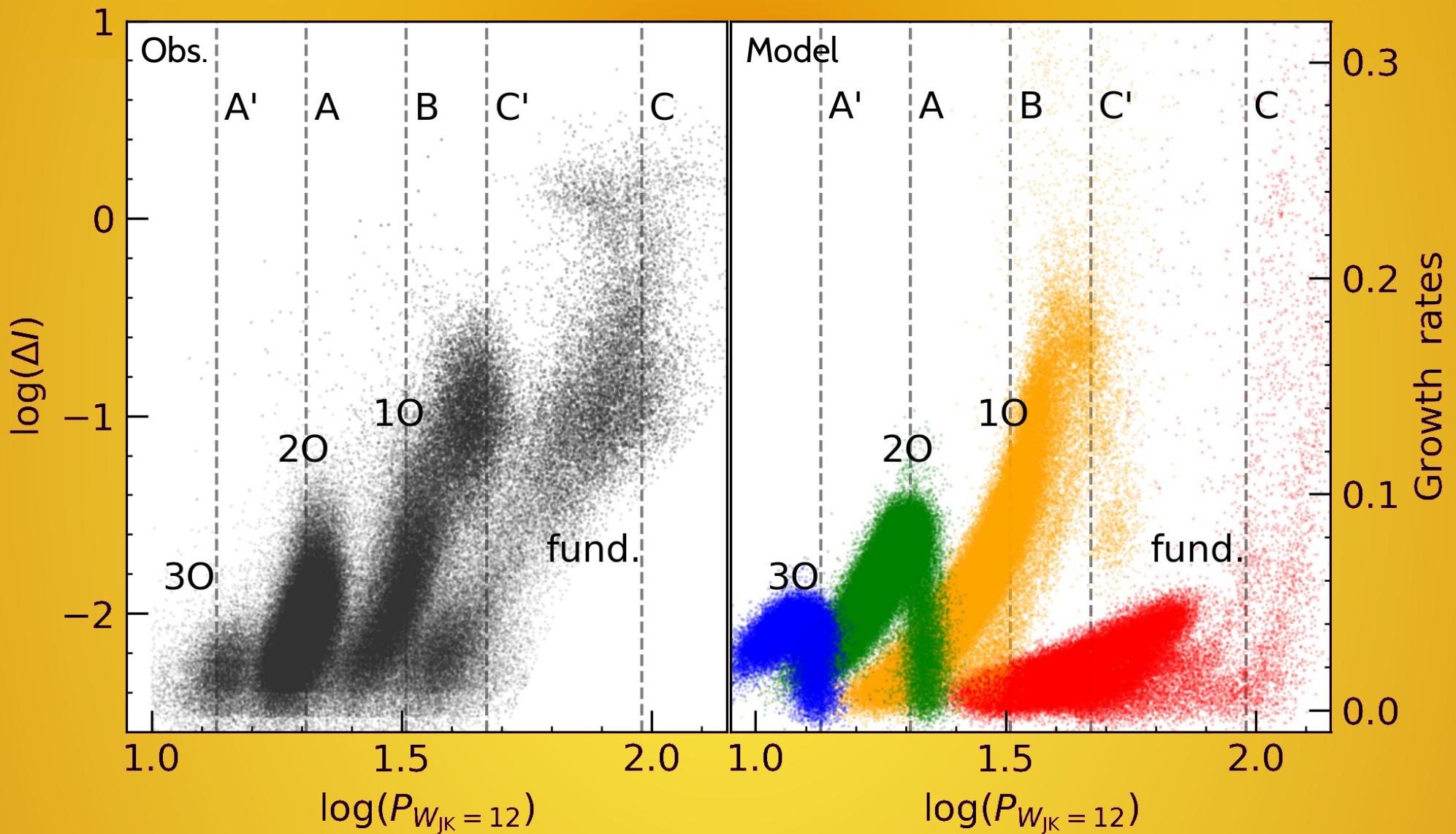
PL SEQUENCES

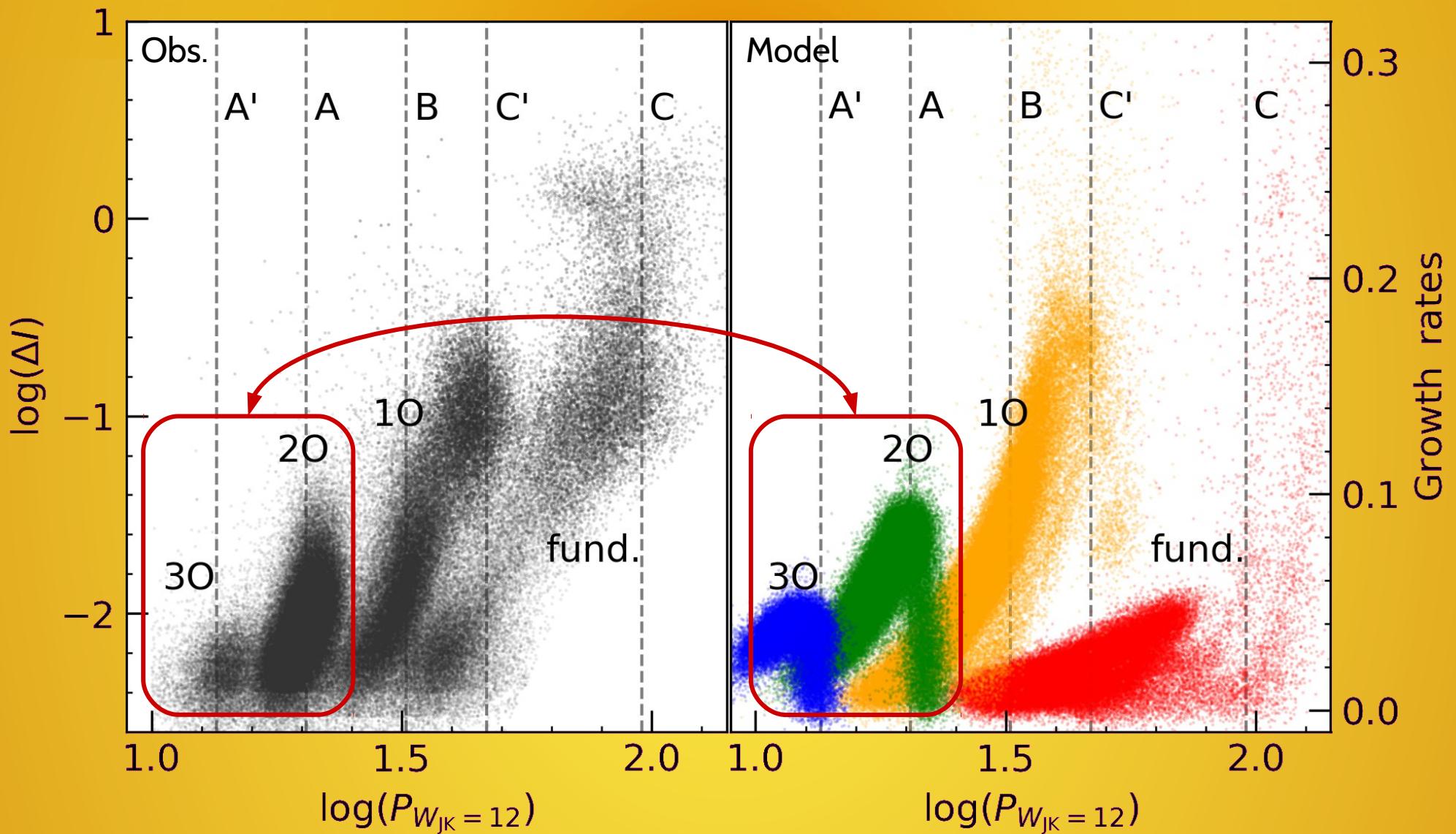


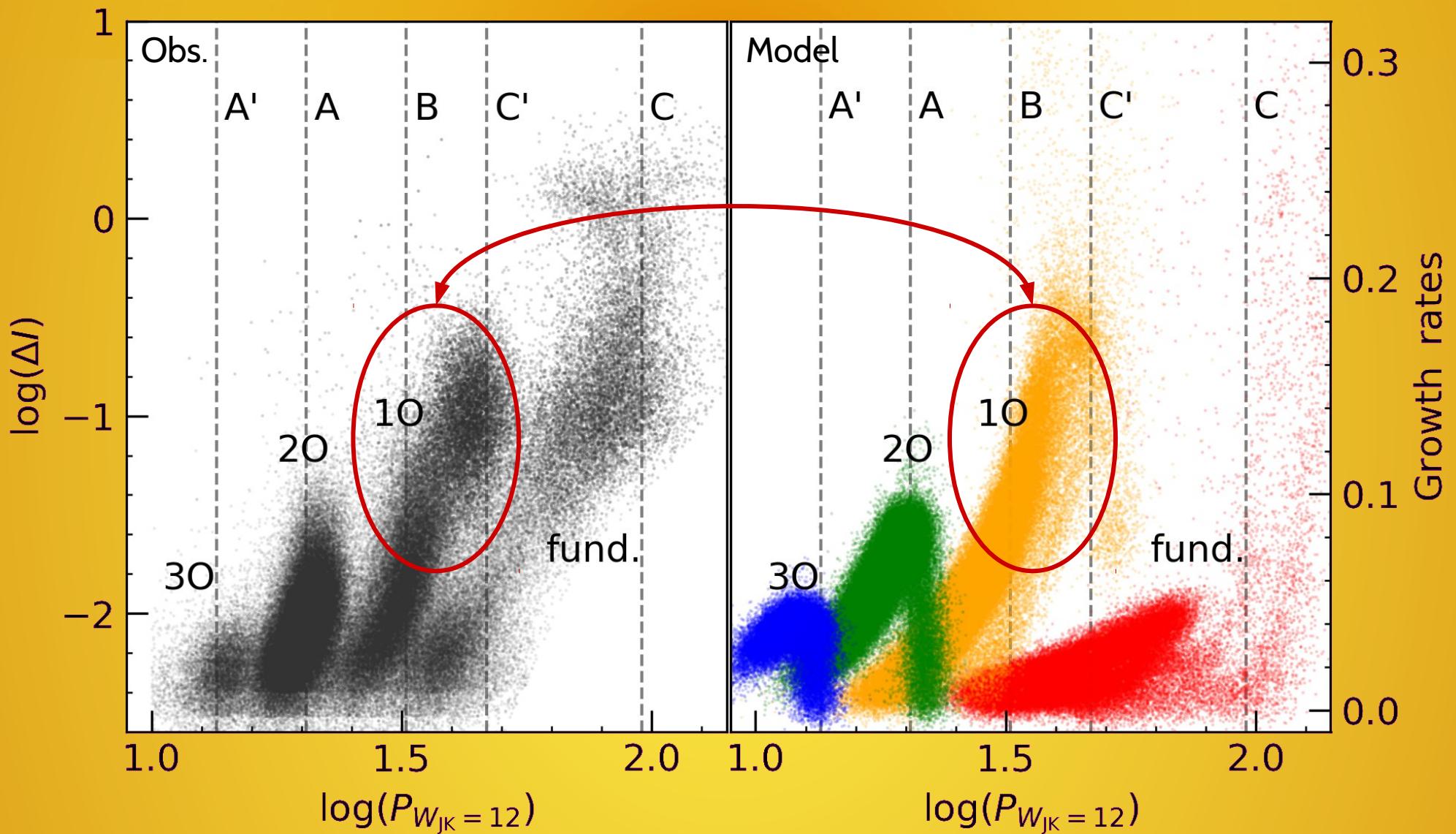
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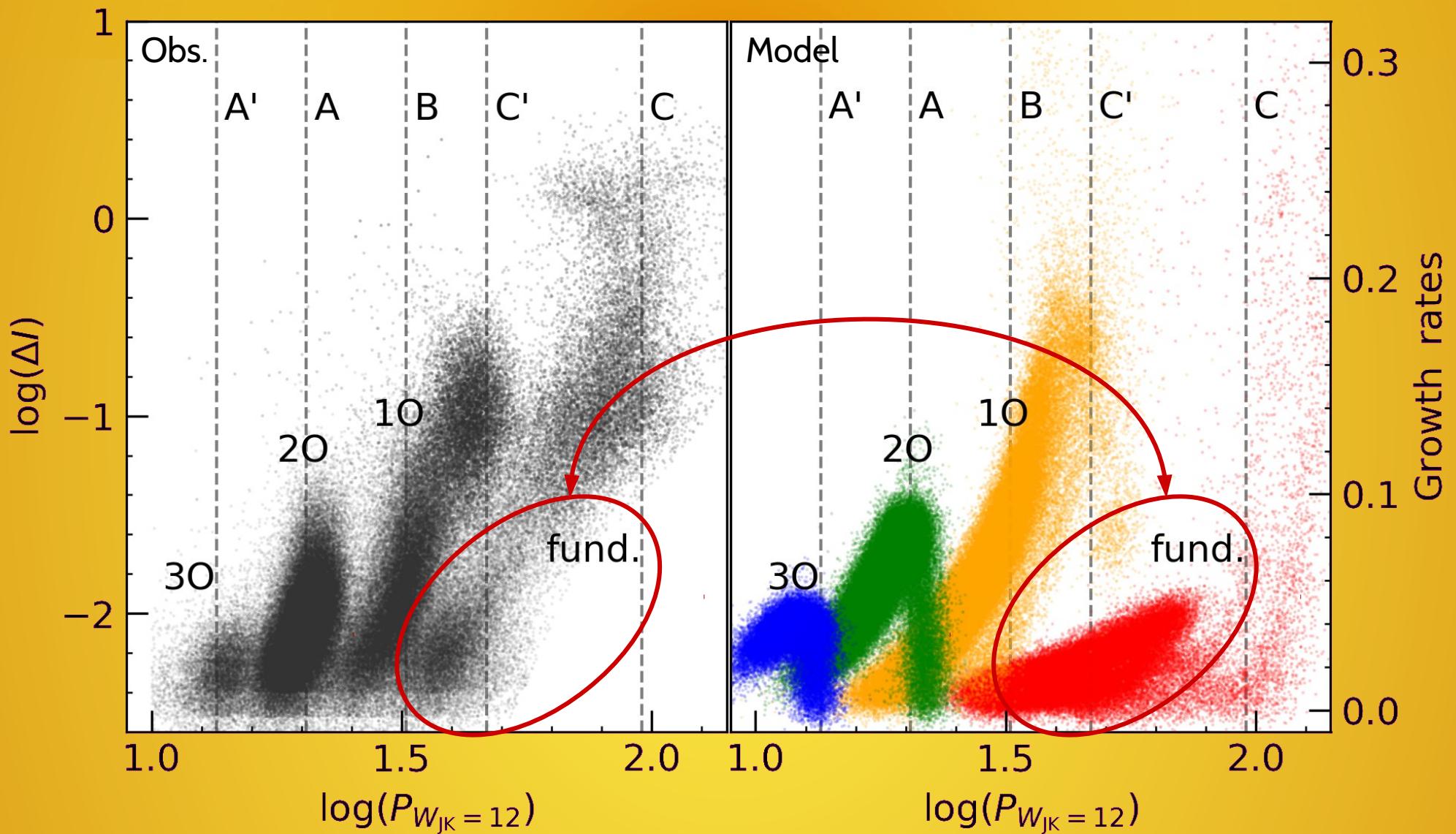
correspond to 4
oscillation modes?

comparison of
amplitude with growth rates

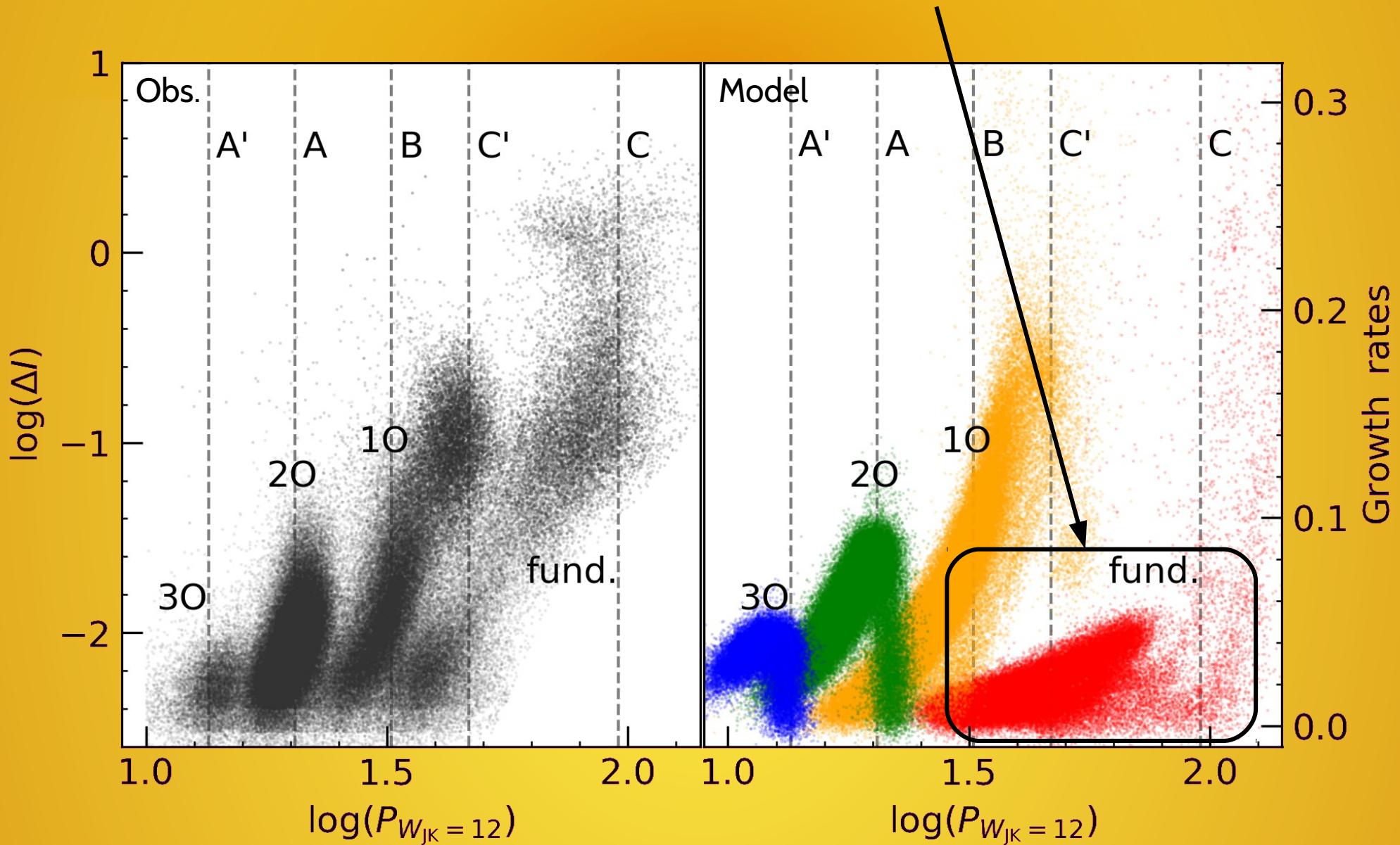






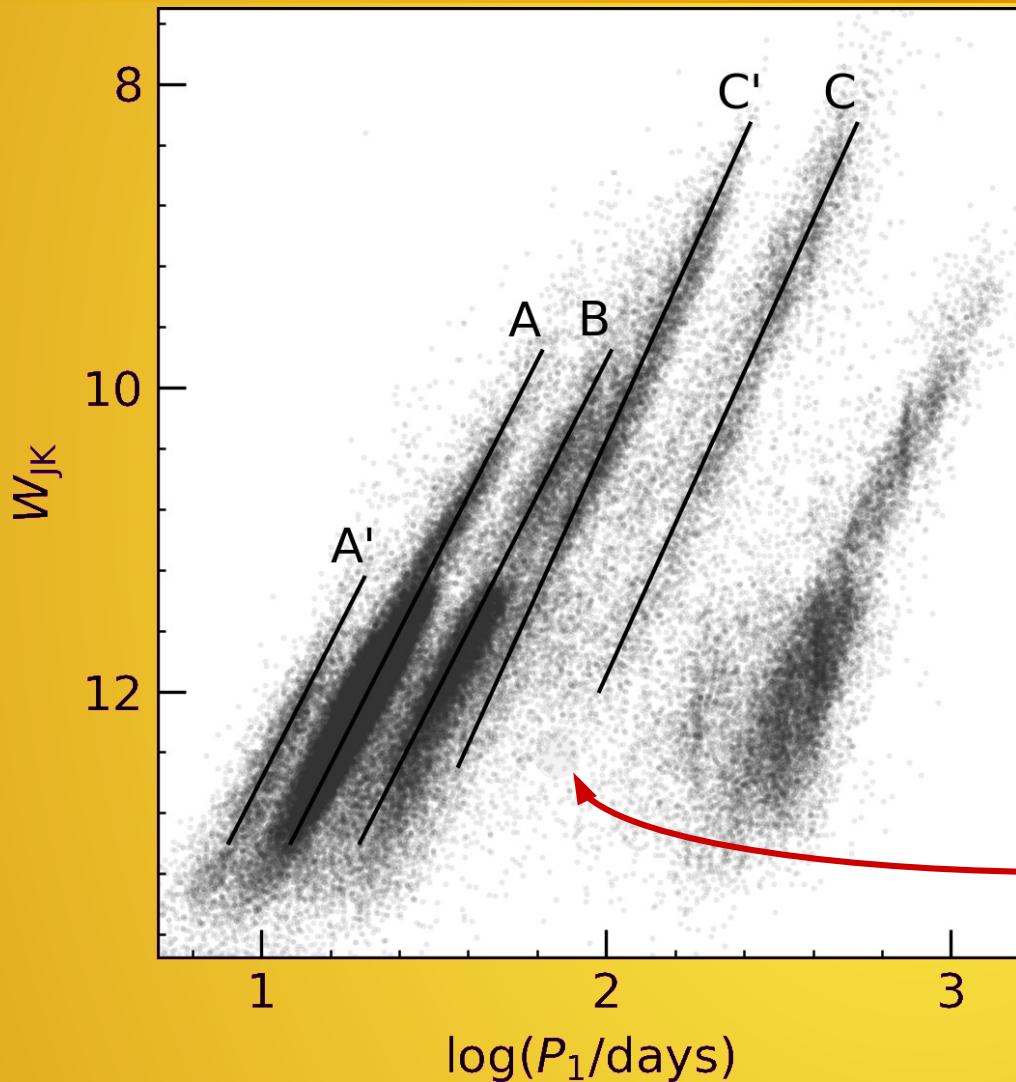


problems with fundamental mode growth rates?

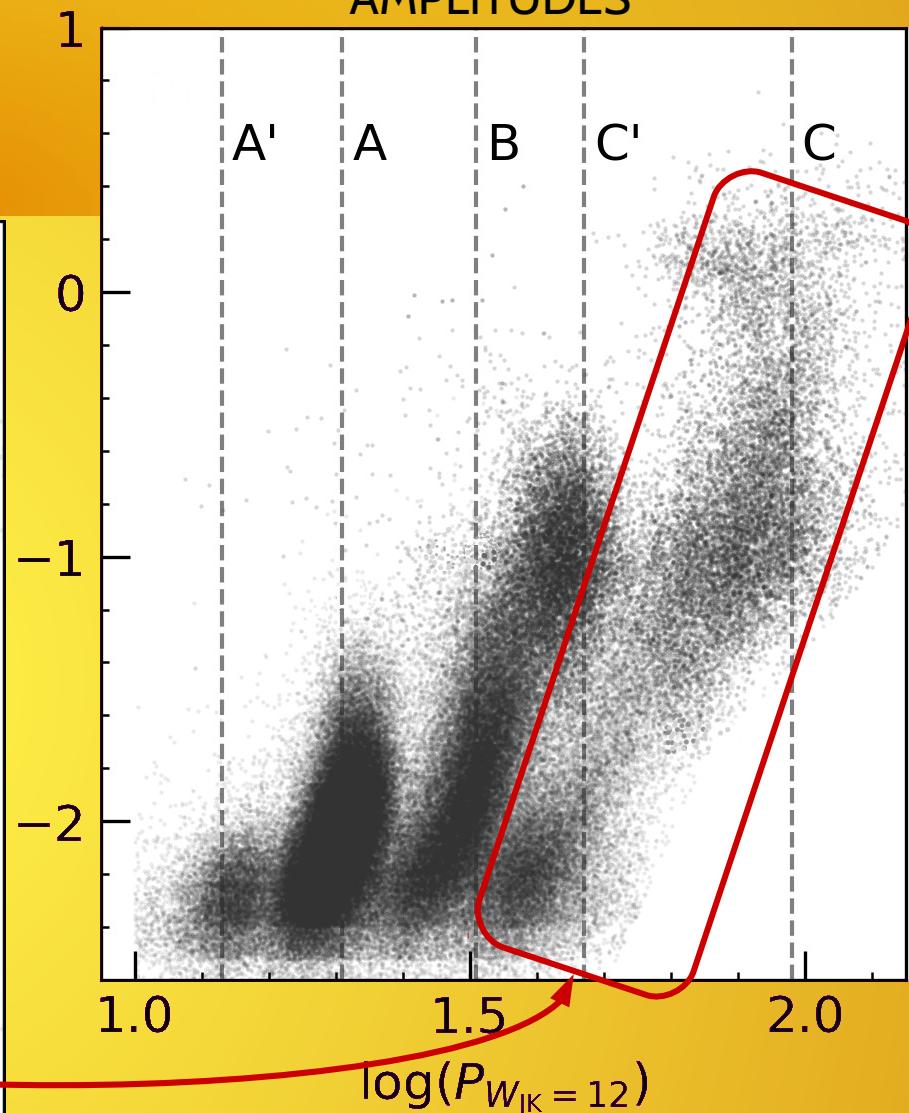


OBSERVATIONS ONLY (OGLE3)

PL SEQUENCES

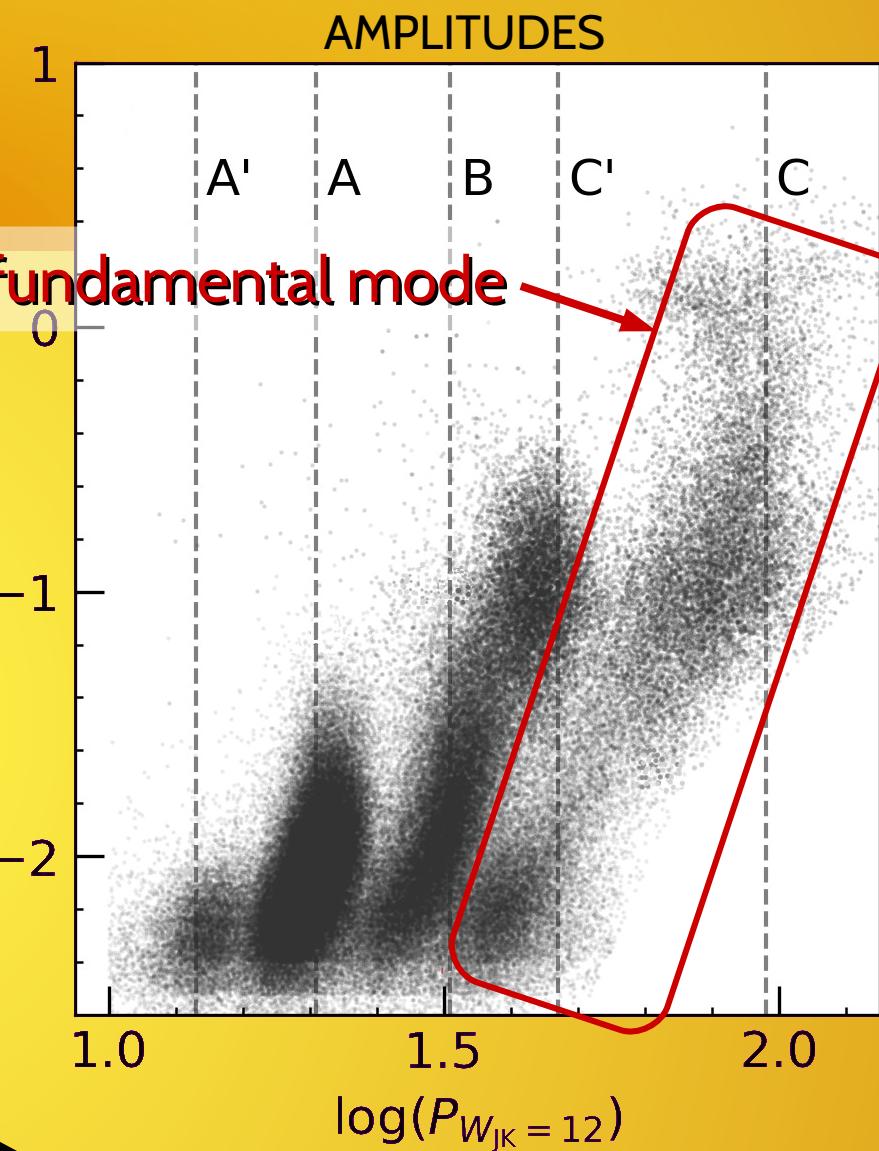
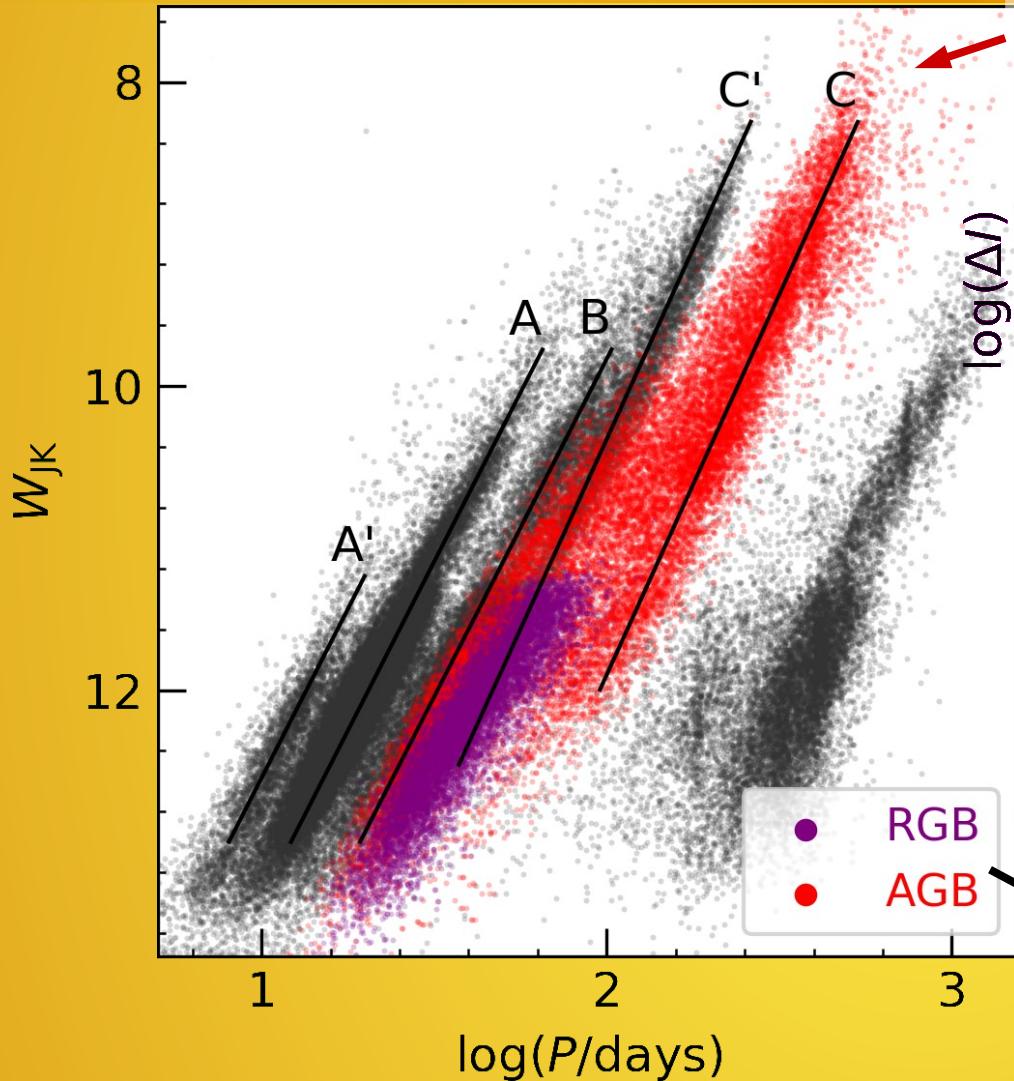


AMPLITUDES



OBSERVATIONS ONLY (OGLE3)

PL SEQUENCES

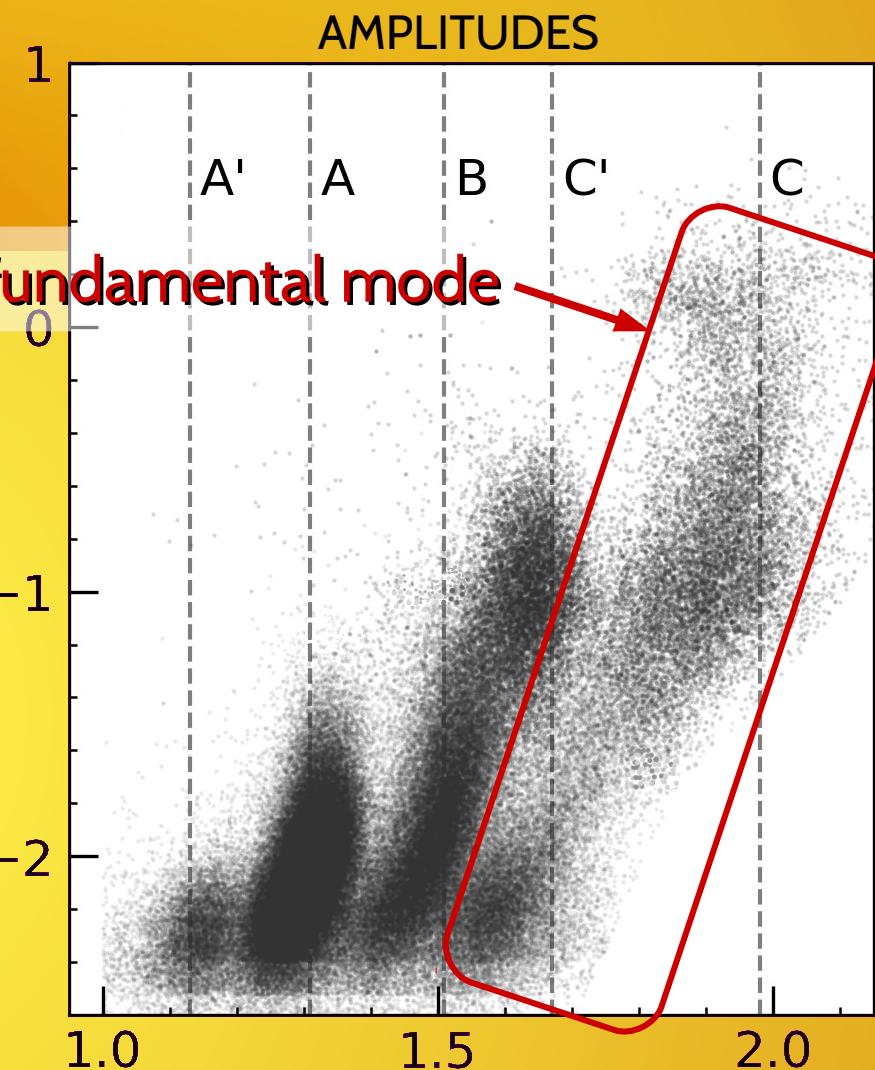
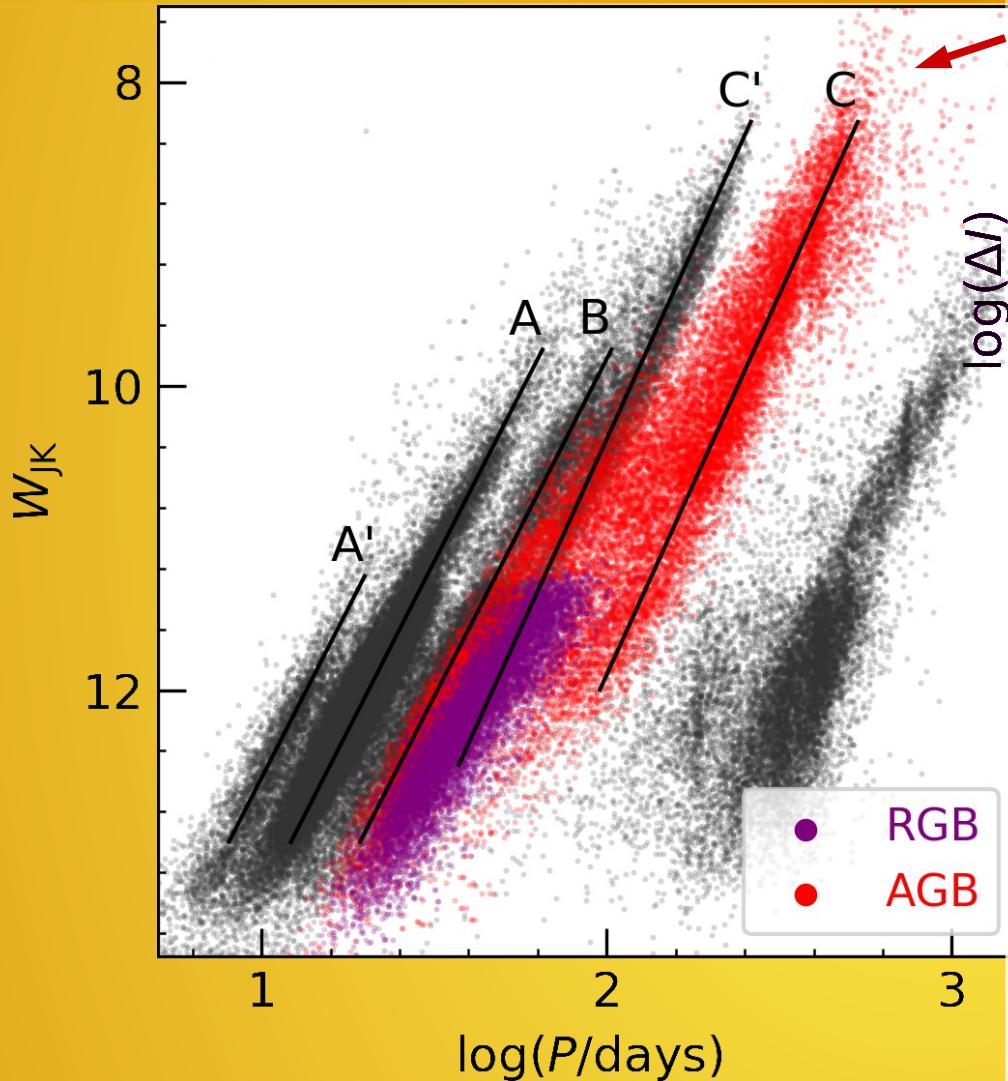


OGLE evolutionary
classification

(Soszyński et al., 2004, Acta Astron., 54, 129)

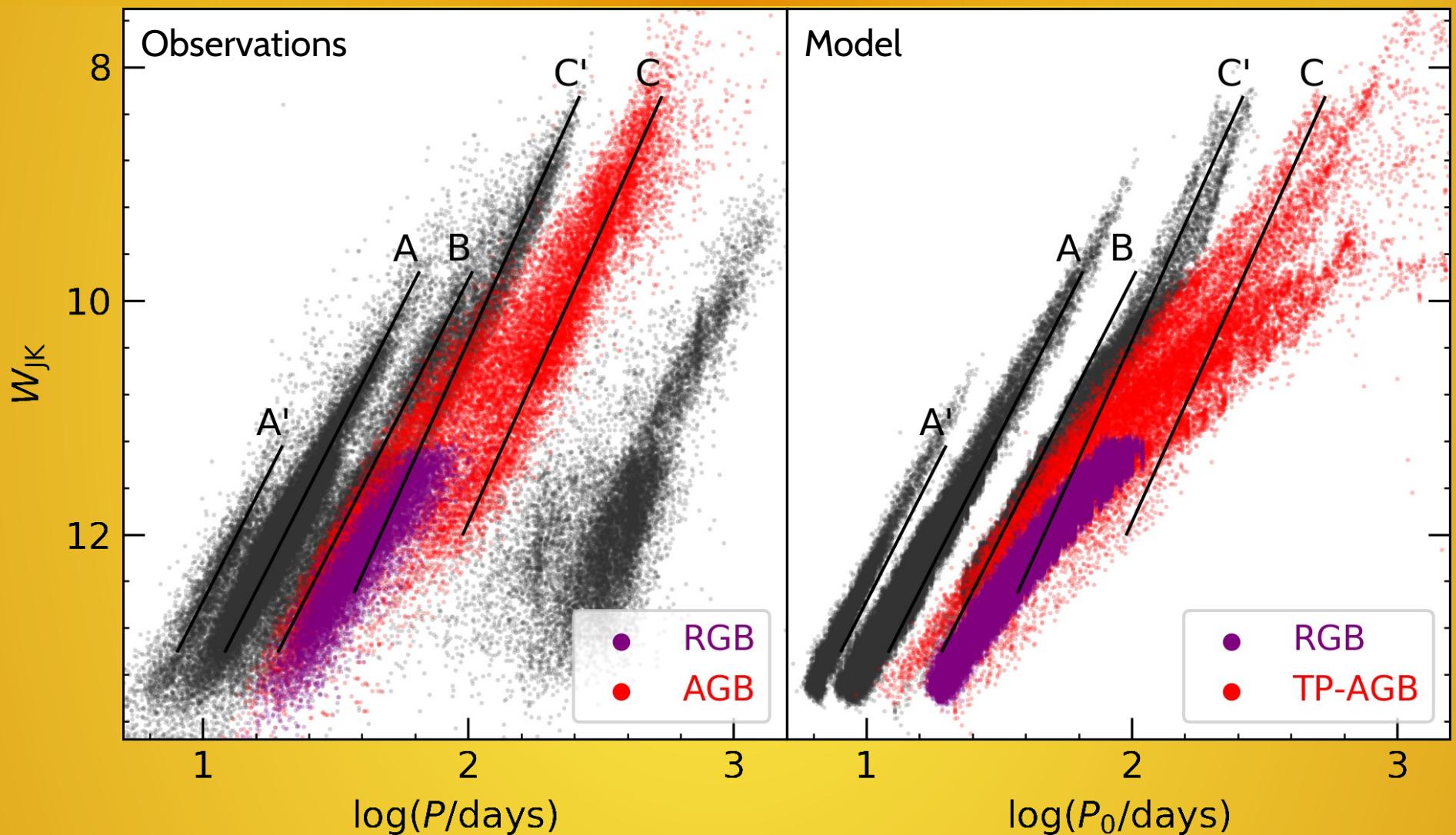
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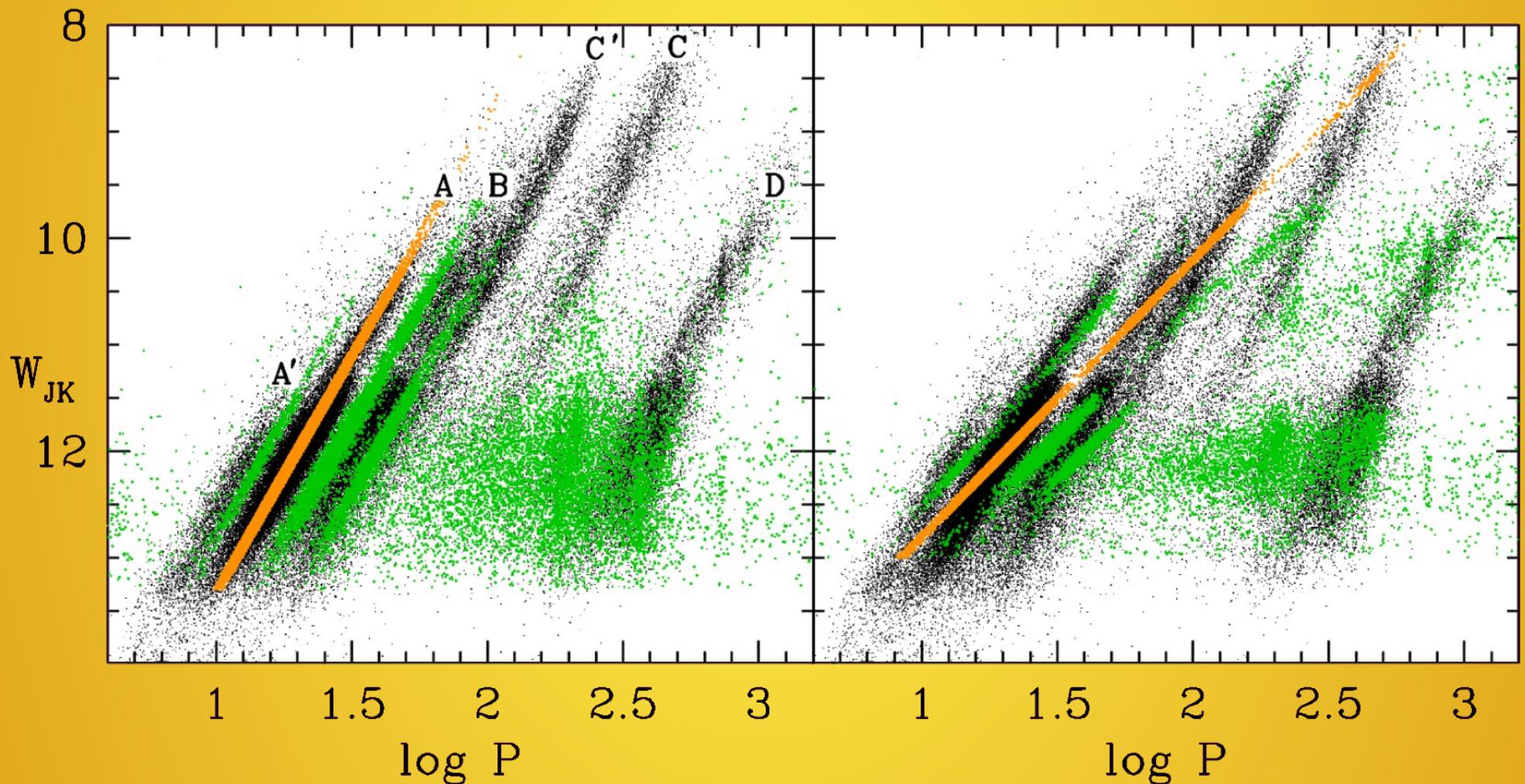


Note that fundamental mode periods selected this way extend as far as into sequences C' and B!
(more massive than 1O-dominated at same L)

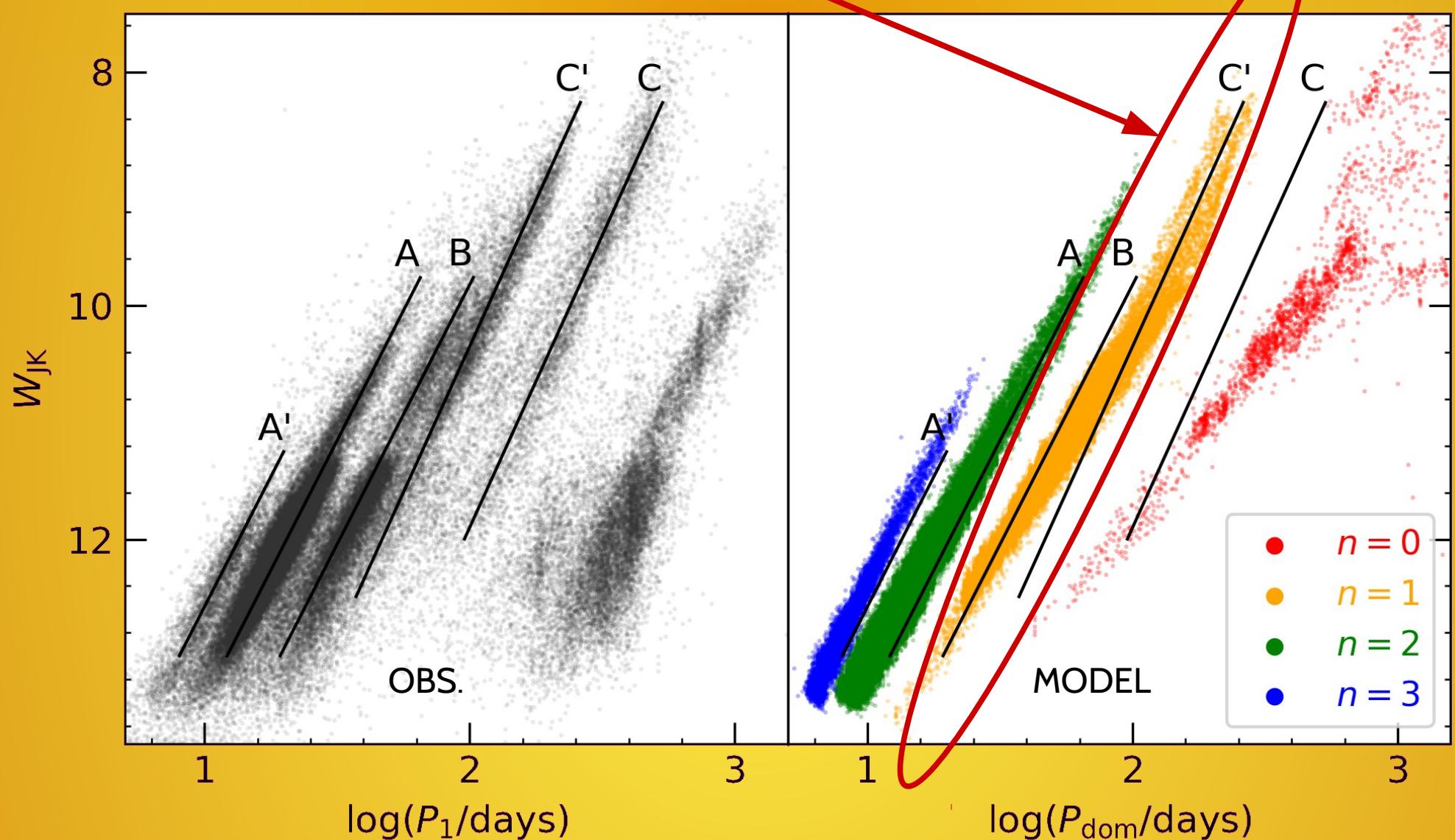
Distribution of theoretical
fundamental mode periods
regardless of their GR



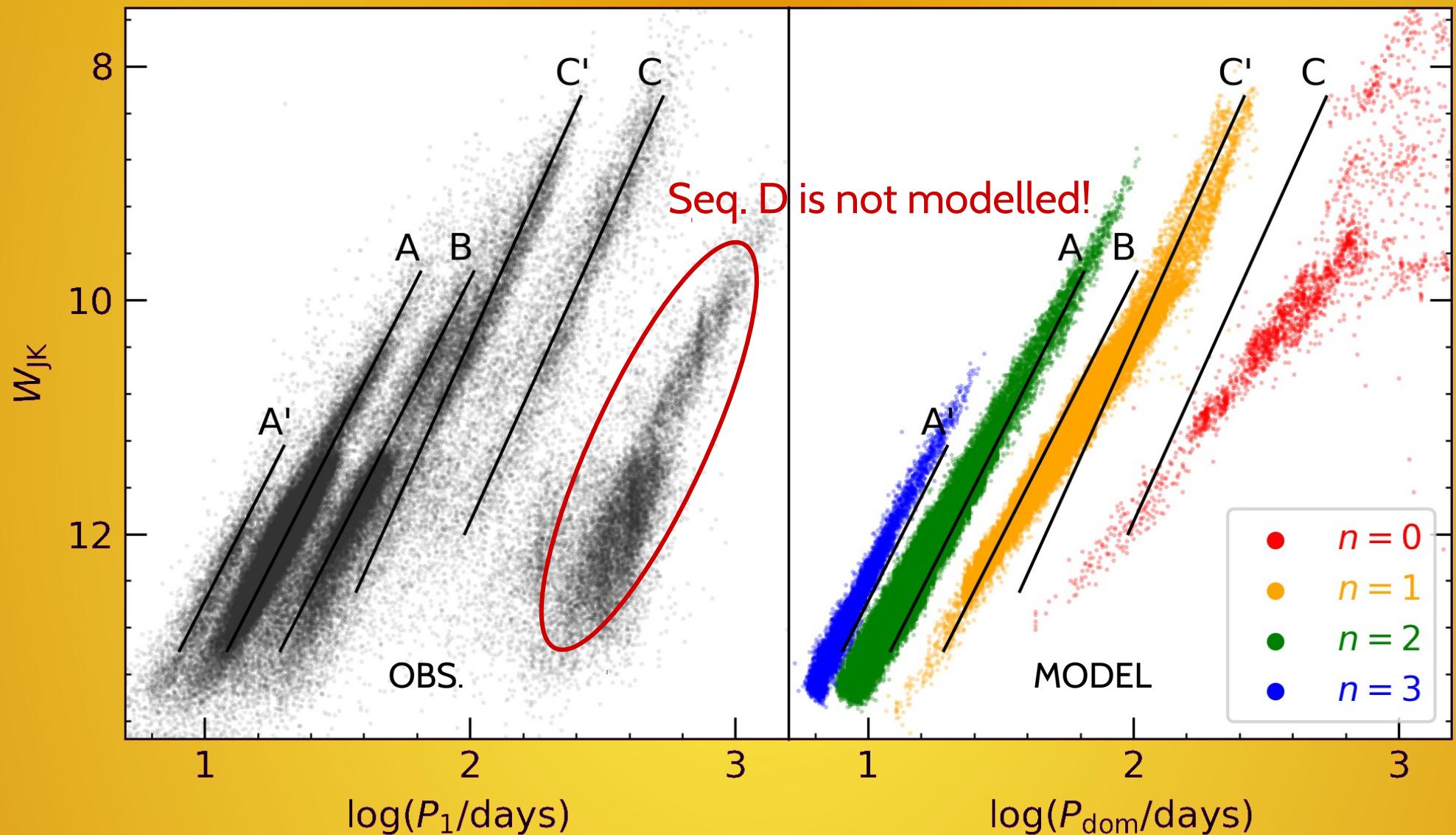
Interpretation consistent
with observed periods
of multi-mode pulsators!

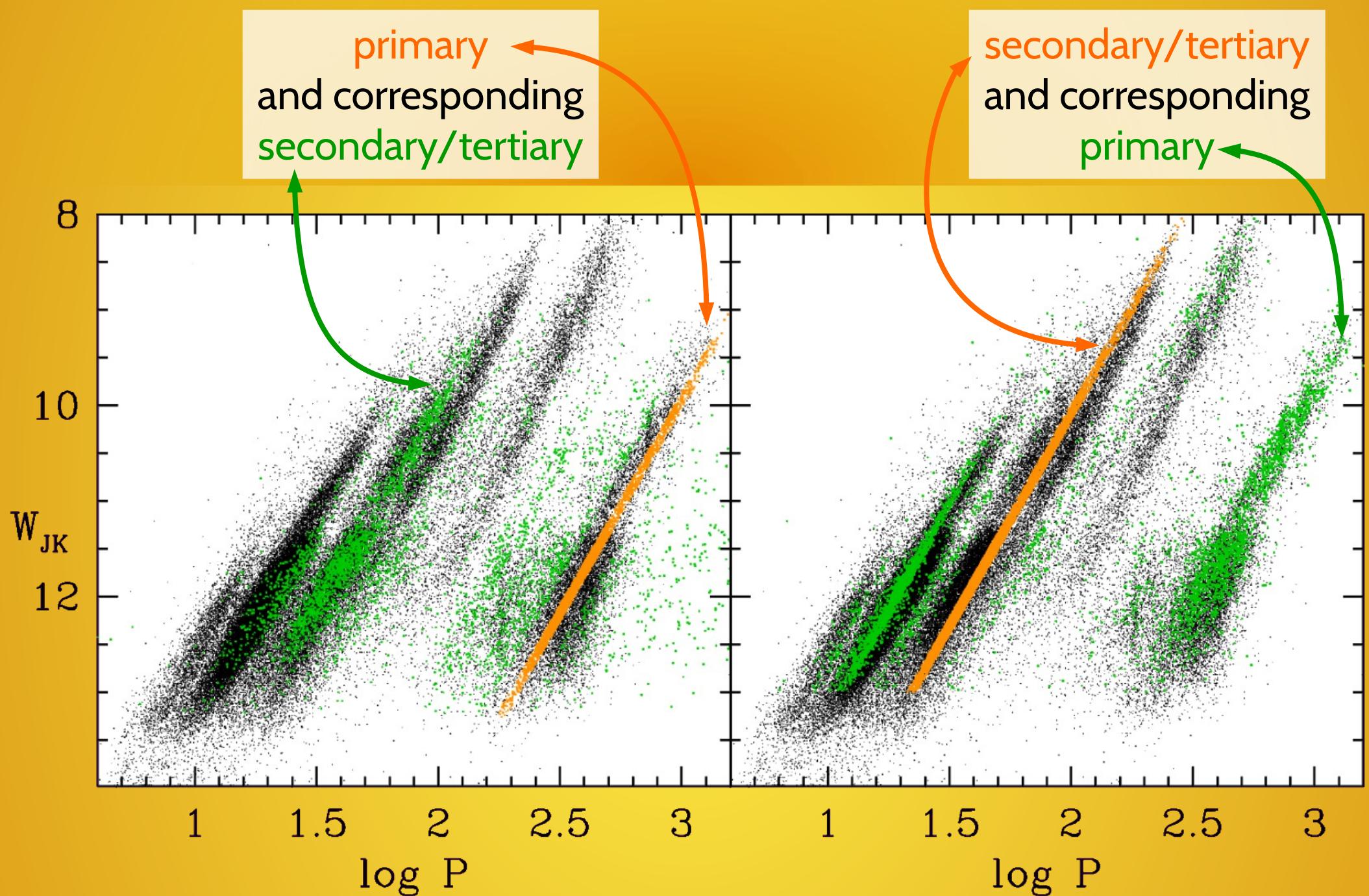


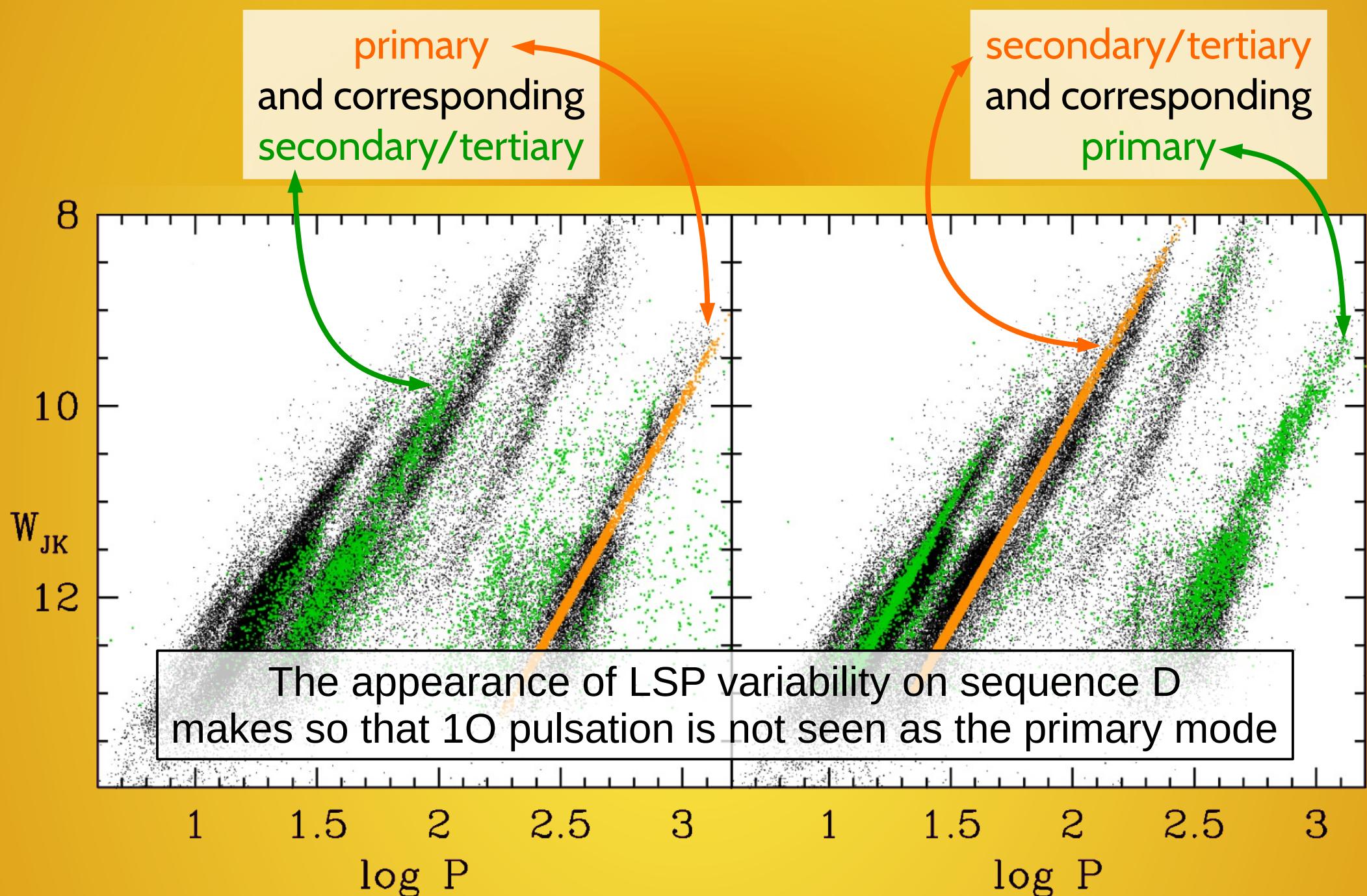
What about sequences B and C'?

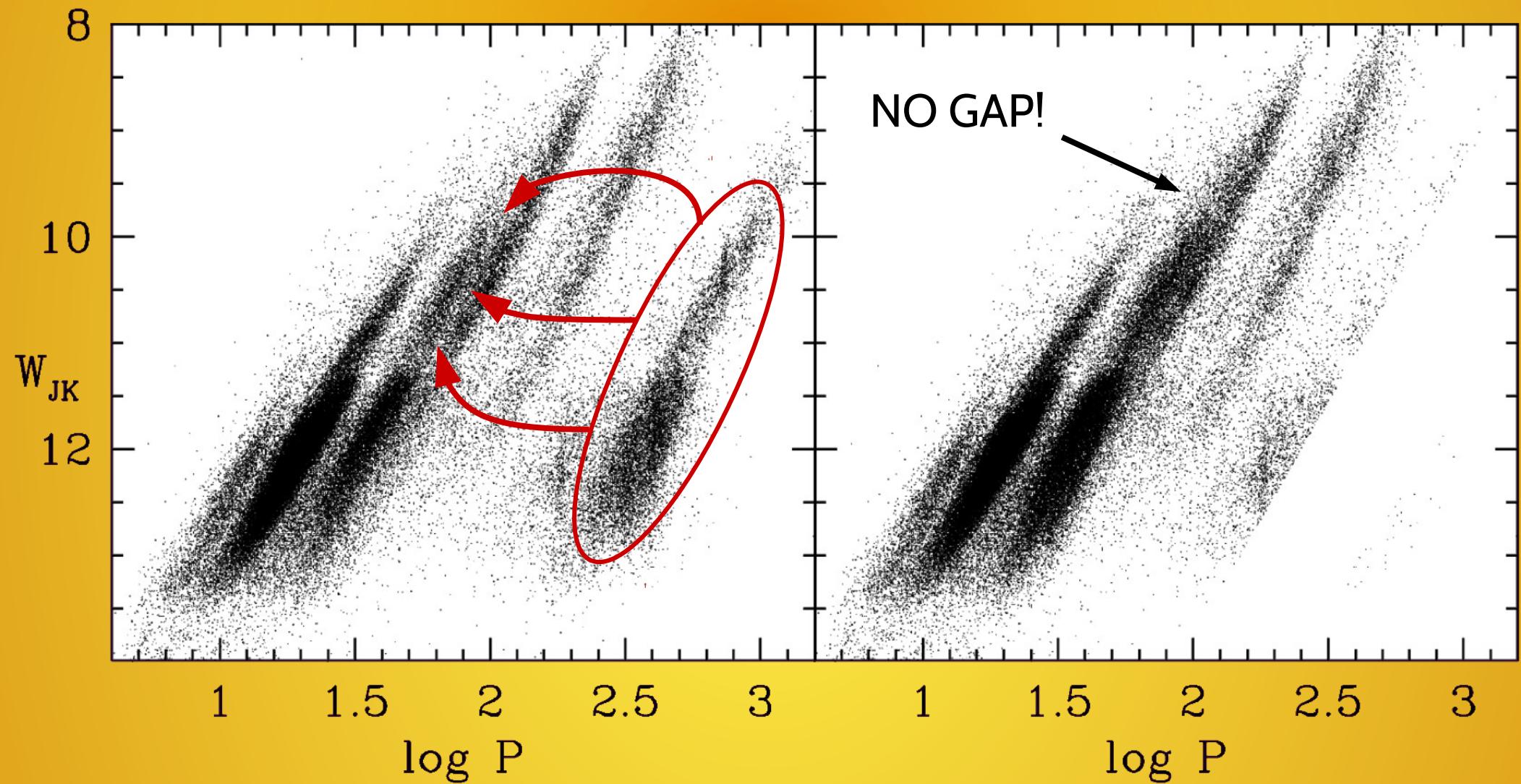


What about sequences B and C'?

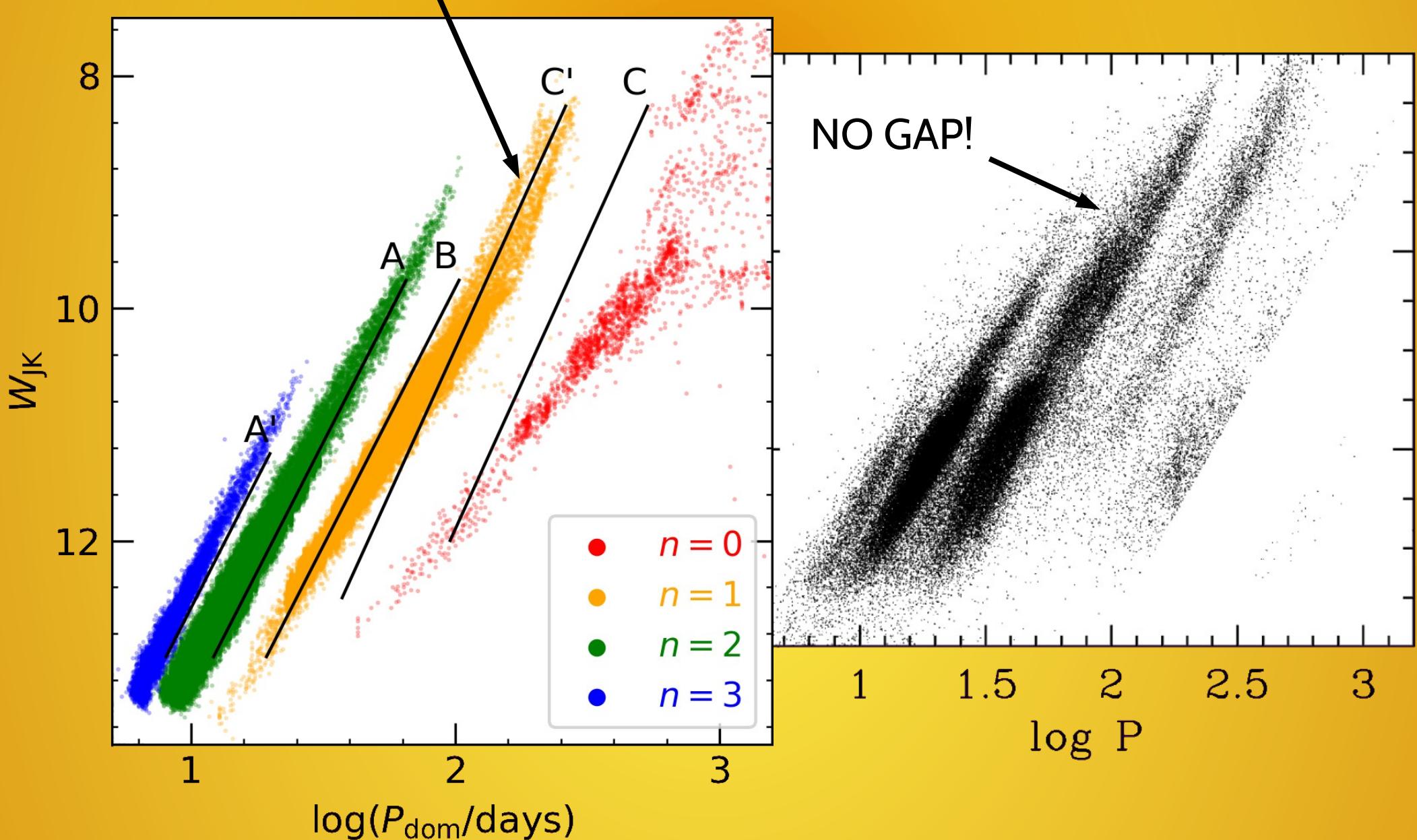








Long Secondary Periods are not modelled!
Model cannot reproduce B-C' splitting



CONCLUSIONS

- Synthetic population + pulsation model of red giants in the LMC

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- Fundamental mode in agreement if GR are ignored
- Sequences B and C' are both 1O mode: gap due to LSPs on seq. D
- Studies by Wood(2015) and by Mosser+(2013), Soszynski+(2007) can be brought into alignment with the modal assignment:

| Sequence: | A' | A | B | C' | C |
|-----------|---------|---------|--------------------------|--------------------------|---------------------|
| Mode(s) | 3O mode | 2O mode | 1O mode (faint Fund.) | 1O mode (faint Fund.) | Fundamental mode |

THANKS!

