

# PSR B1937+21

## pulse-shape variability and timing residuals

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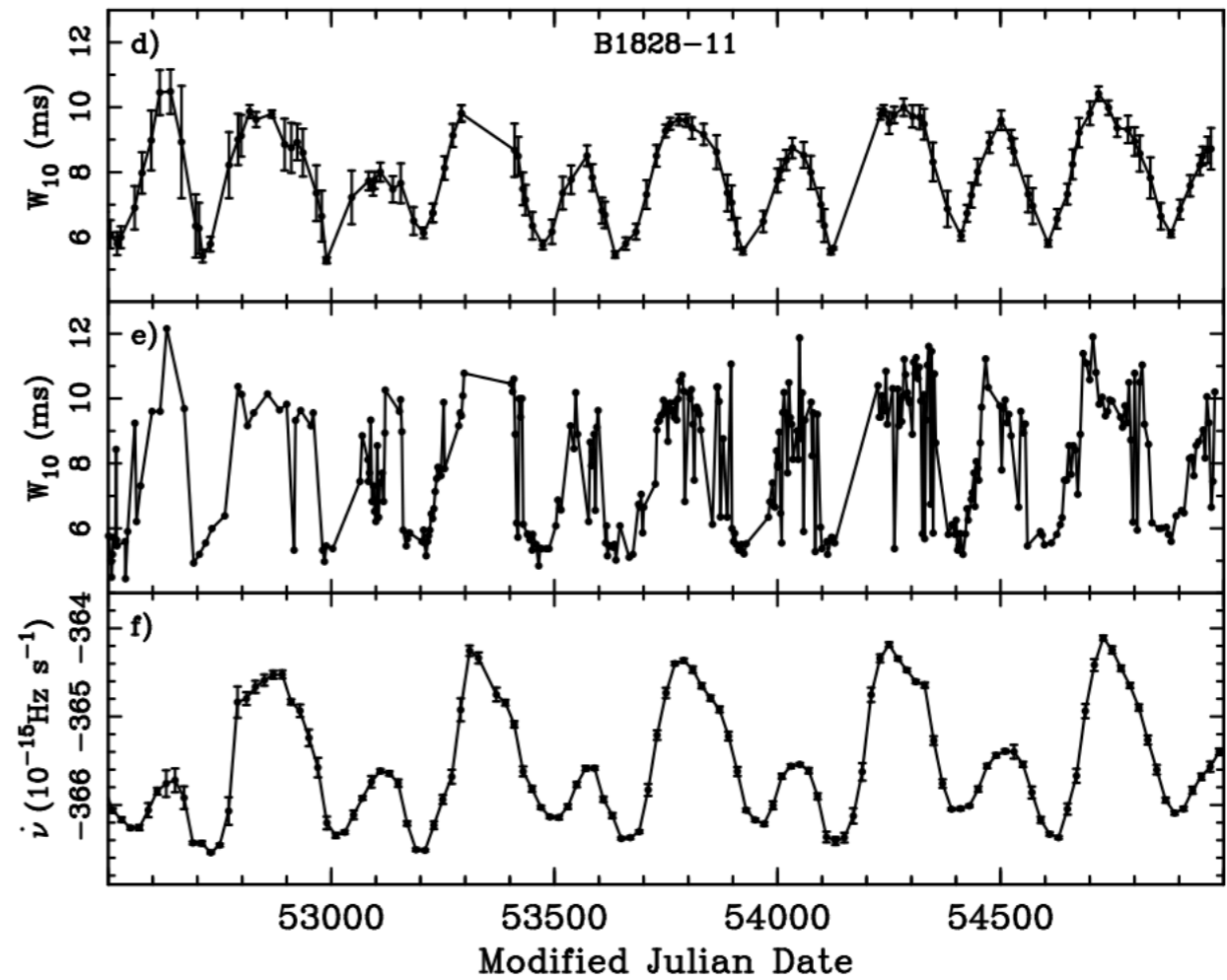
Xiaojin Liu, Mike Keith, Ben Stappers,  
Nancay, LEAP and EPTA Collaboration



北京師範大學  
BEIJING NORMAL UNIVERSITY

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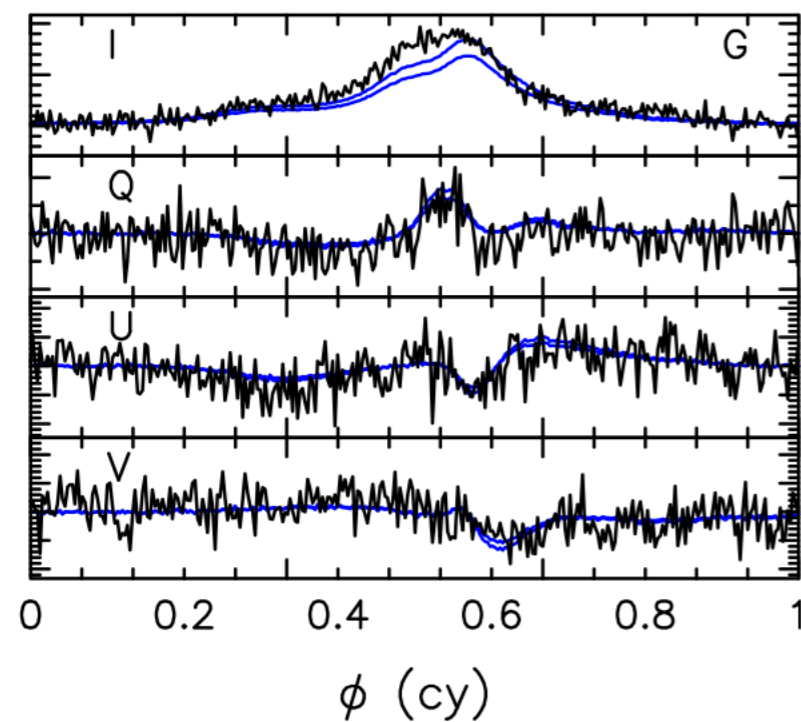
- Correlations between F-dot change and pulse-width change in normal pulsars



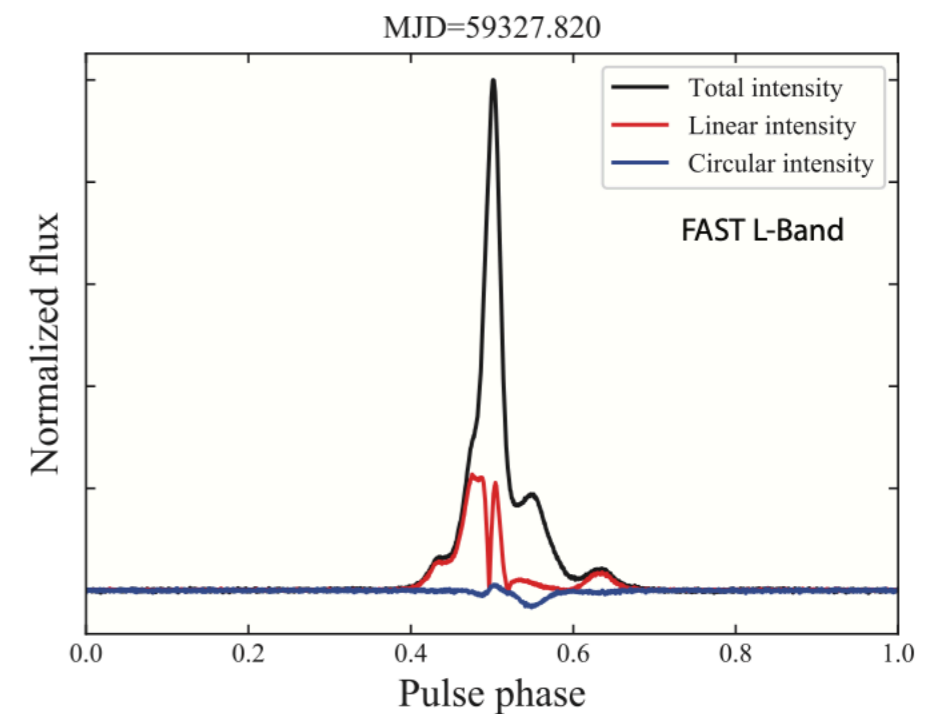
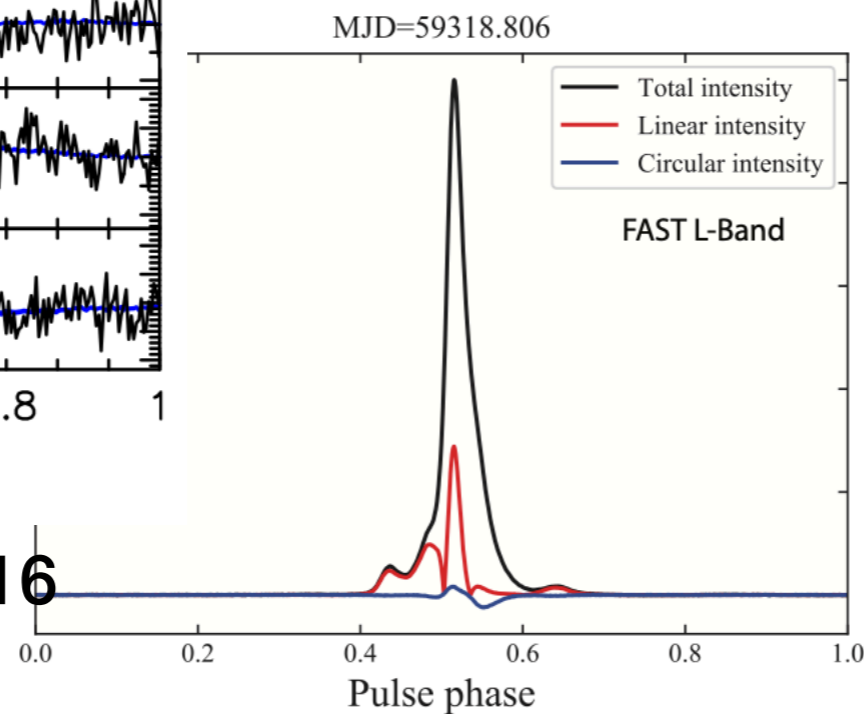
**Lyne+, 2010**

# PSR B1937+21

- Correlations between F-dot and pulse-width in normal pulsars
- Shape changes found in J1643-1224, J1713+0747



Shannon+, 2016

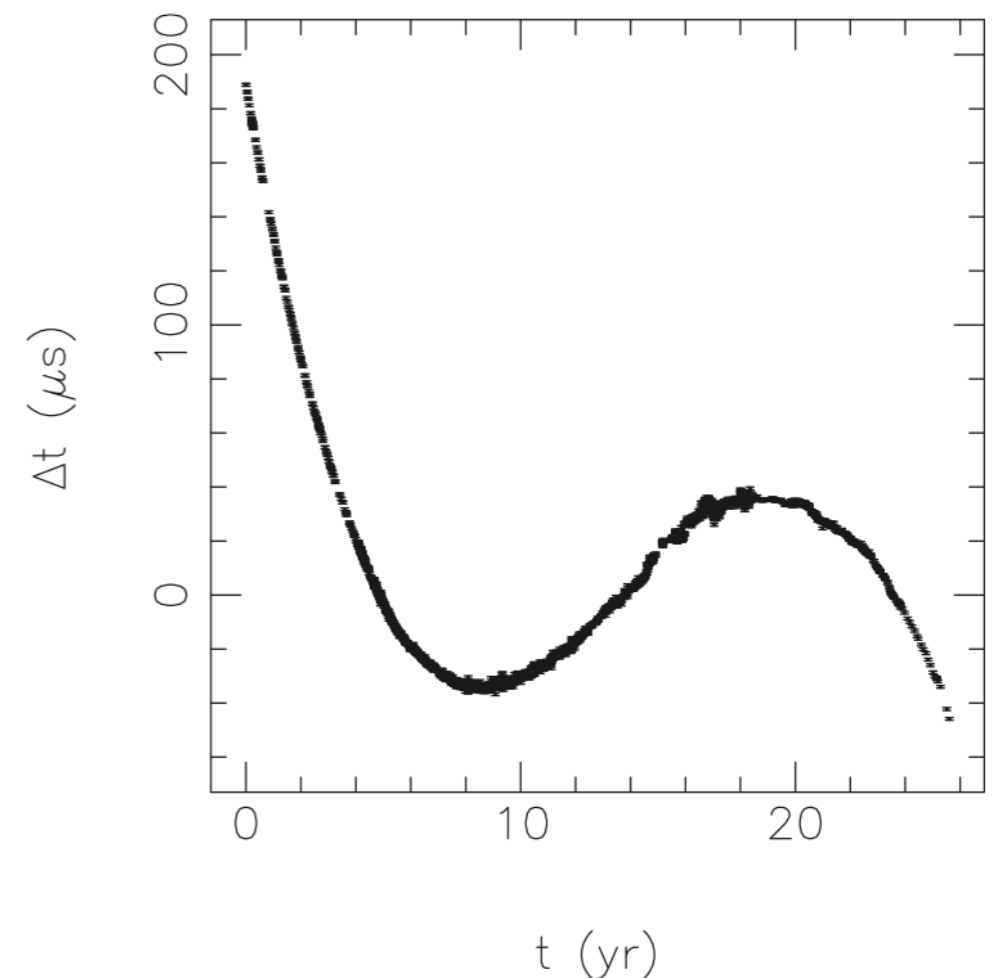


Lee+, 2021, ATel

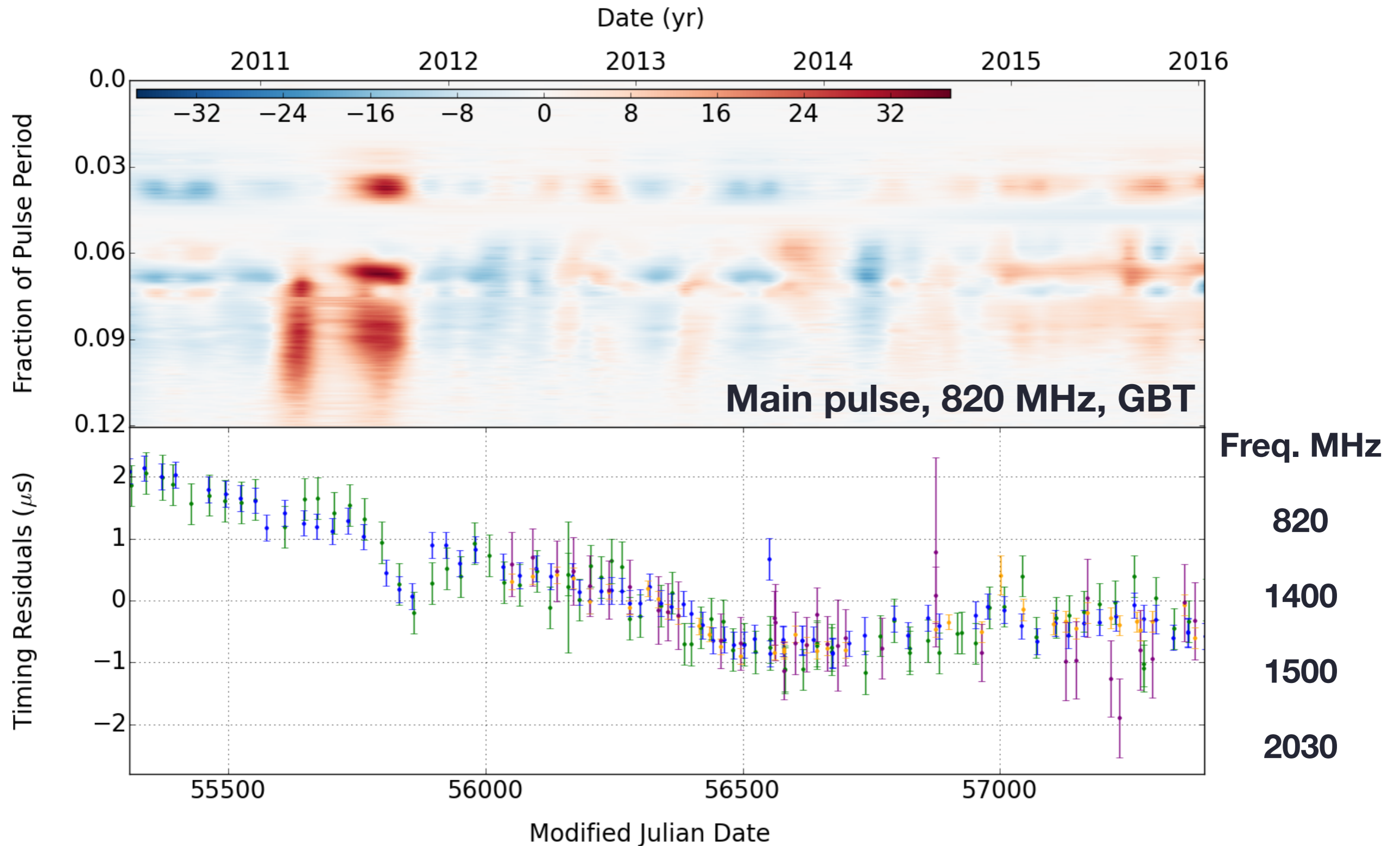
# PSR B1937+21

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- Correlations between  $\dot{F}$  and pulse-width in normal pulsars
- Shape and TOA changes found in J1643-1224, J1713+0747
- High-precision TOAs in short timescale, but unusual large timing residuals



# Pulse-shape changes of B1937: NANOGrav's result



Brook+ 2018

# Data used in this study

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Tel.	Backend	MJD	Obs.	Freq. (MHz)	Bandwidth (MHz)
42-ft <sup>a</sup>	Cobra2	55890-58557	2393	610	5/10 <sup>b</sup>
Lovell	Roach	55890-58557	587	1520	384
LEAP <sup>c</sup>	-	55967-58586	73	1400	128
Nançy 1	NUPPI	55898-58493	214	1400	512
Nançy 2	NUPPI	56020-57574	28	2000	512
Nançy 3	NUPPI	56707-58442	42	2500	512

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timing

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timing

1.4GHz



# Data reduction

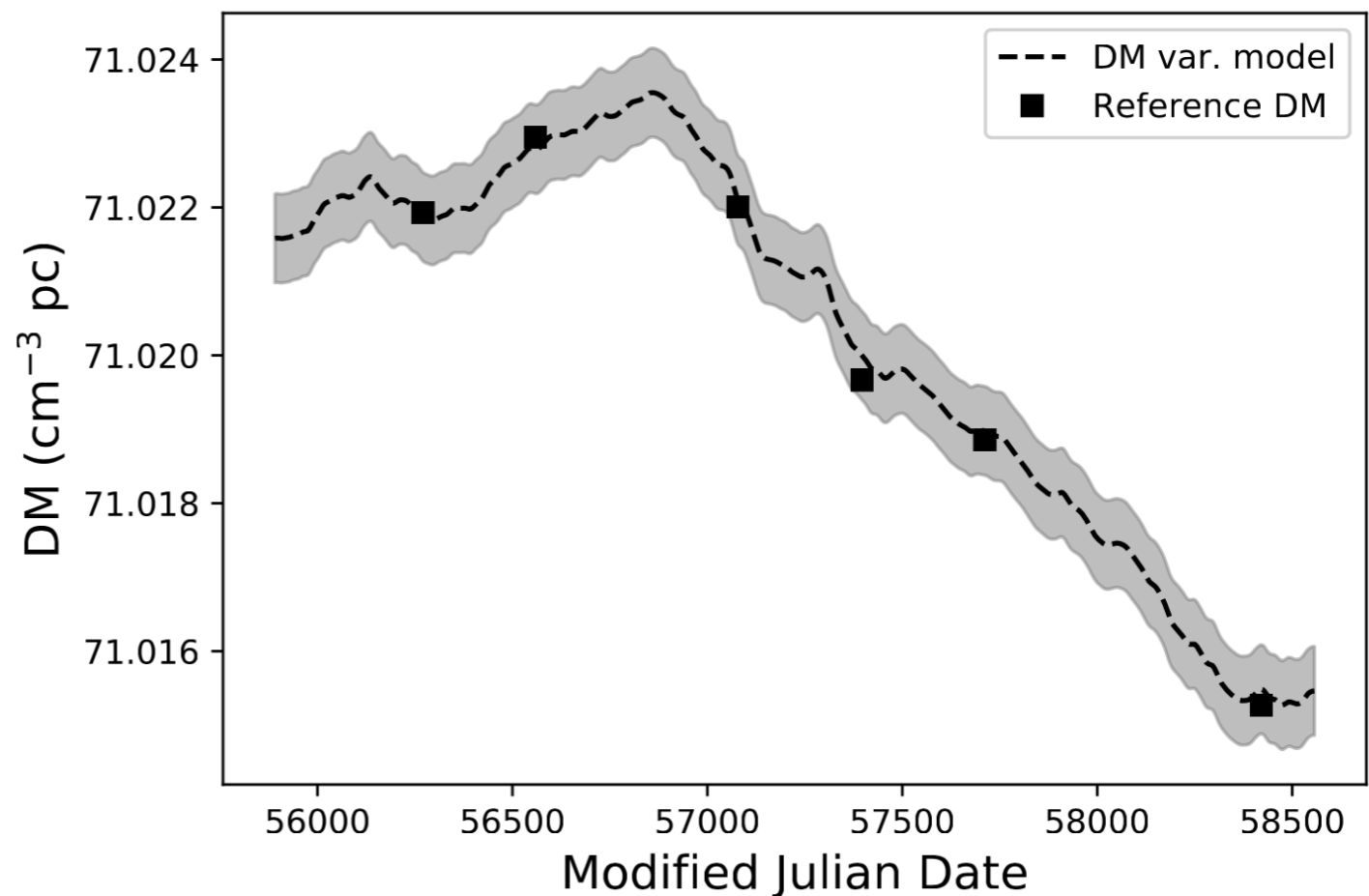
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- De-dispersed with DM variation model: a power-law

# Data reduction

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- De-dispersed with DM variation model: a power-law power-law spectrum  
Calibrating with DM value from individual observations



# Data reduction

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- De-dispersed with DM variation model: a power-law
- Scrunching over  $f$ ,  $t$ ,  $p$  to get pulse profiles
- Aligning the profiles by the peak
- Normalizing with area

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pulse shape of each obs

template: median of each bin

shape variation = individual shape - template

# Modeling the shape-variations

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- Shape data: time-series  $\mathbf{x} = \{x_1, x_2, \dots, x_n\}$   
 $\mathbf{y} = \{y_1, y_2, \dots, y_n\}$
- Modeling the shape of each bin a time
- Assuming Gaussian  $\rightarrow$  Gaussian process regression
- Using a Matern kernel (covariance function)

$$k_{3/2}(x_i, x_j) = \sigma_f^2 \left( 1 + \frac{\sqrt{3}d}{\lambda} \right) \exp \left( -\frac{\sqrt{3}d}{\lambda} \right) \quad \text{Brook+ 2018}$$

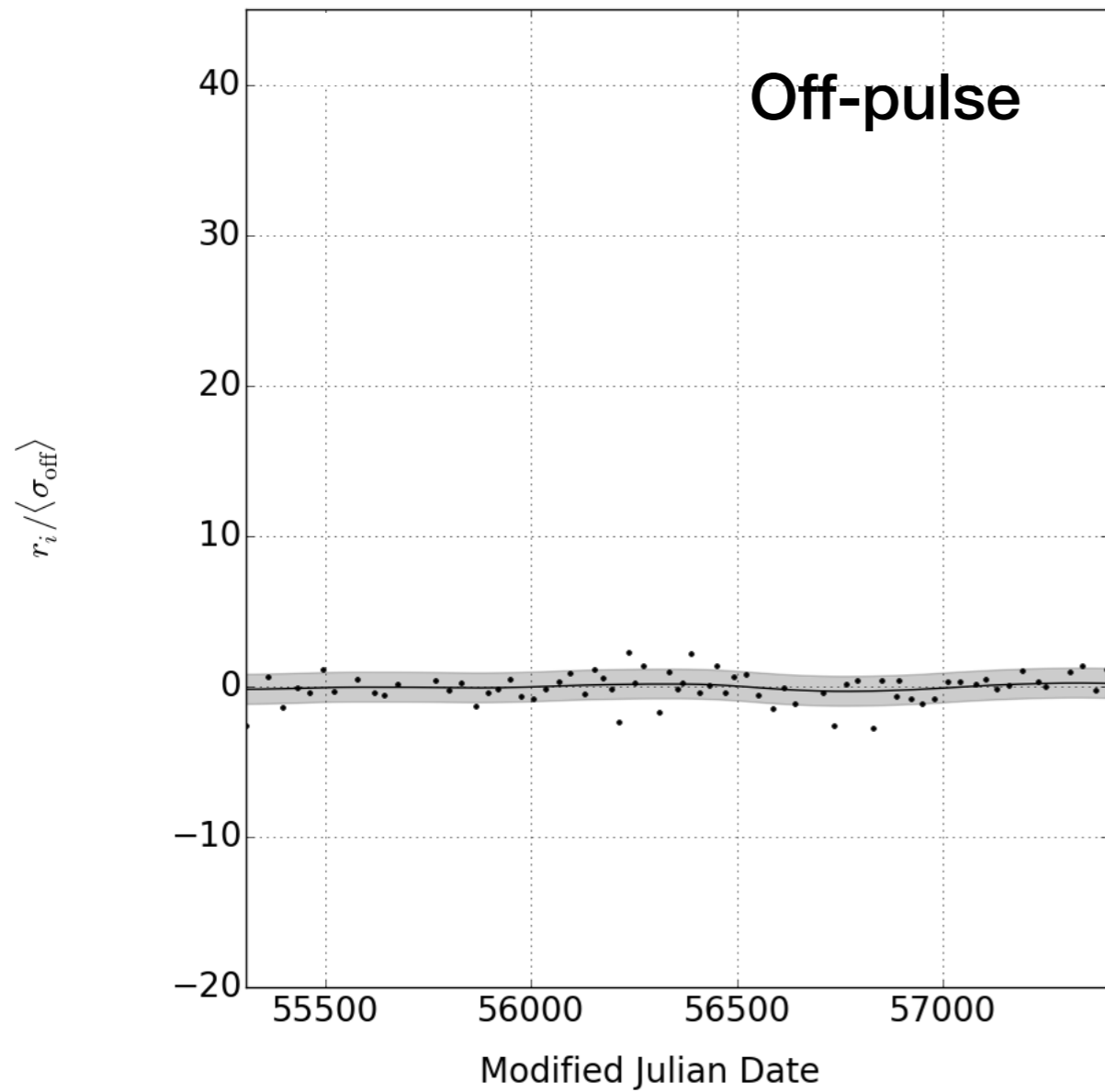
$$\mathbf{y}_* = \mathbf{K}_* \mathbf{K}_{ij}^{-1} \mathbf{y}$$

$$\text{var}(\mathbf{y}_*) = \mathbf{K}_{**} - \mathbf{K}_* \mathbf{K}_{ij}^{-1} \mathbf{K}_*^T$$

where  $\mathbf{K}_{ij}$  is a covariance matrix with components  $k(x_i, x_j)$

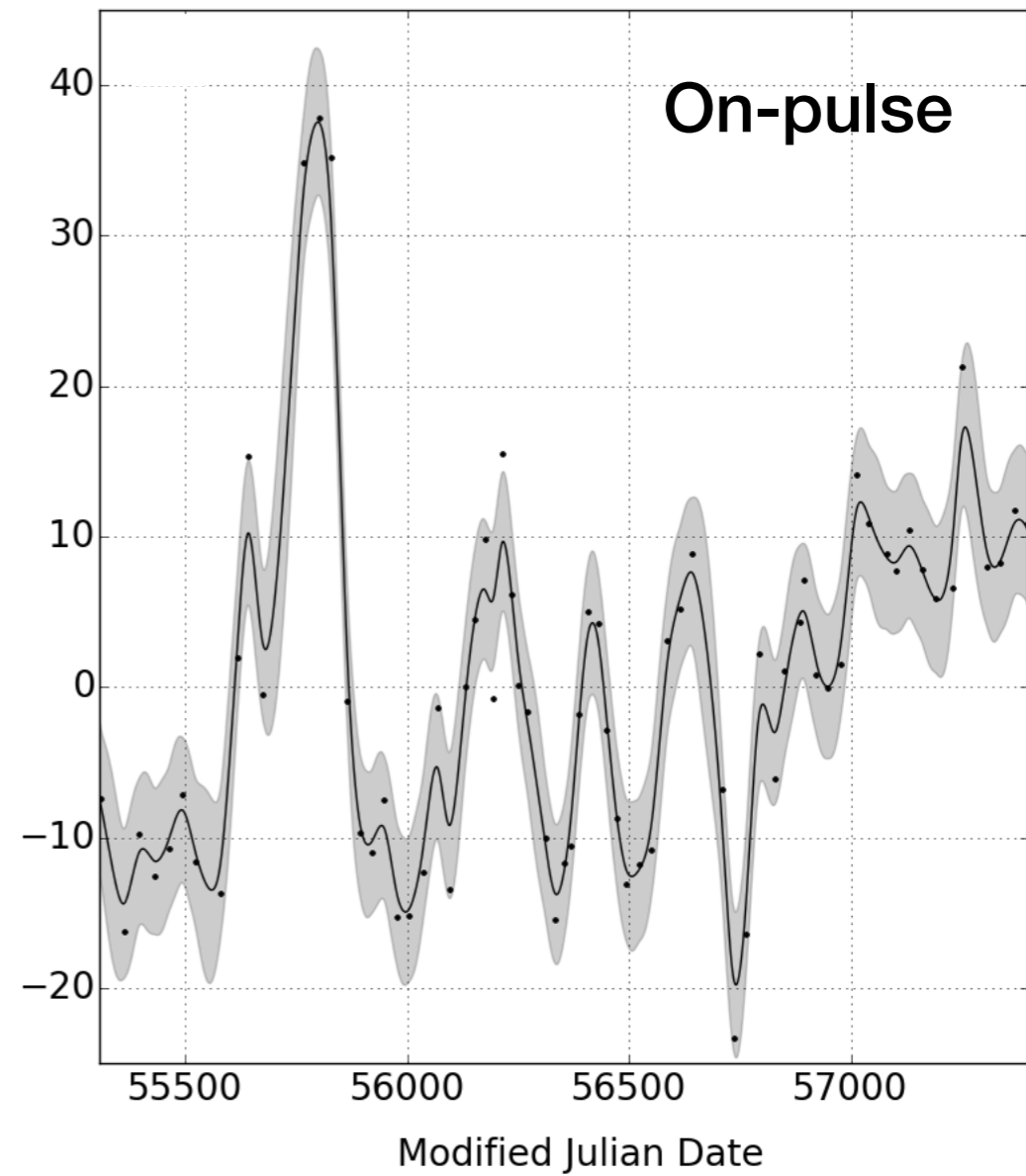
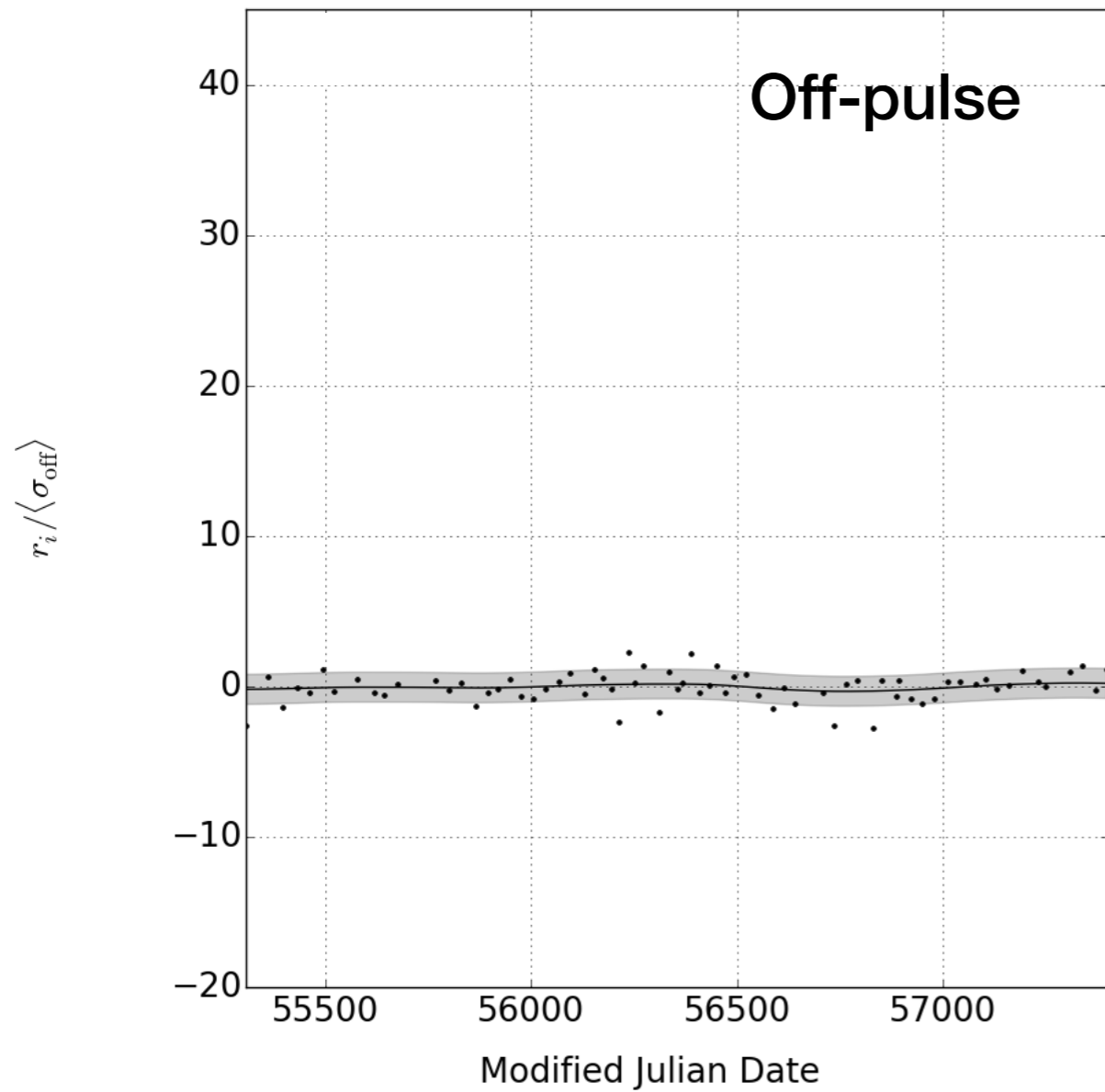
# Examples of Gaussian process regression

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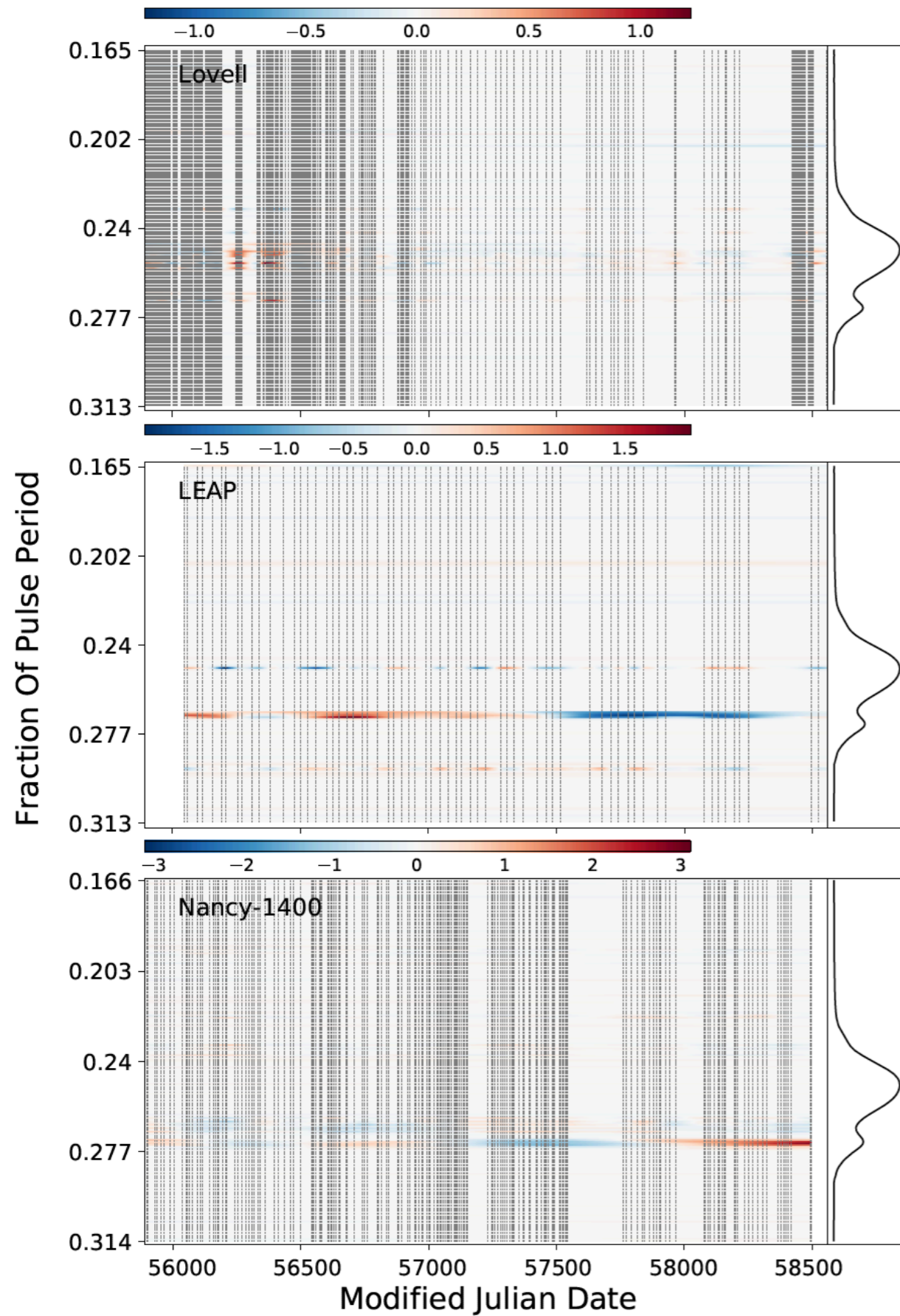
**Brook+ 2018**

# Examples of Gaussian process regression



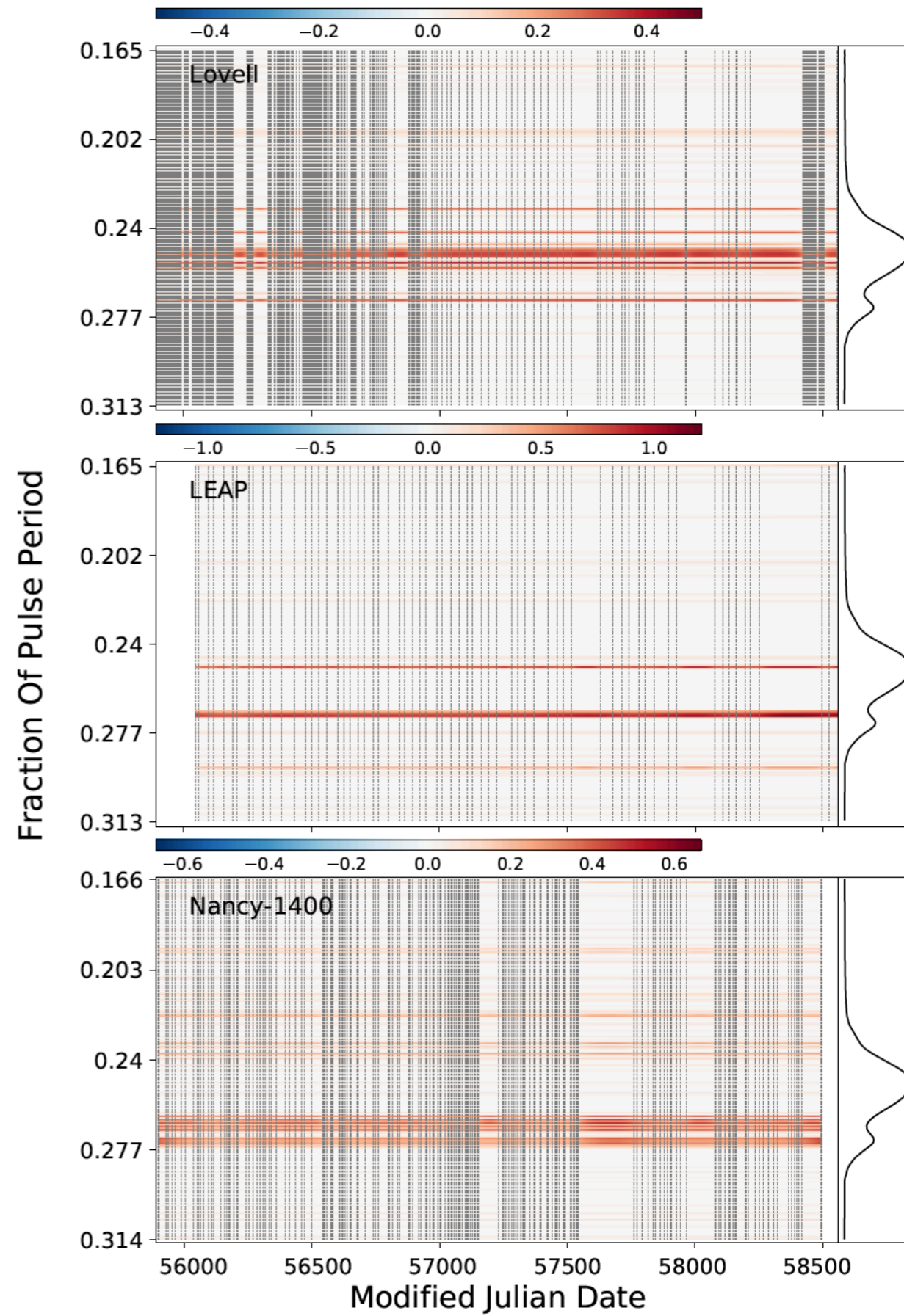
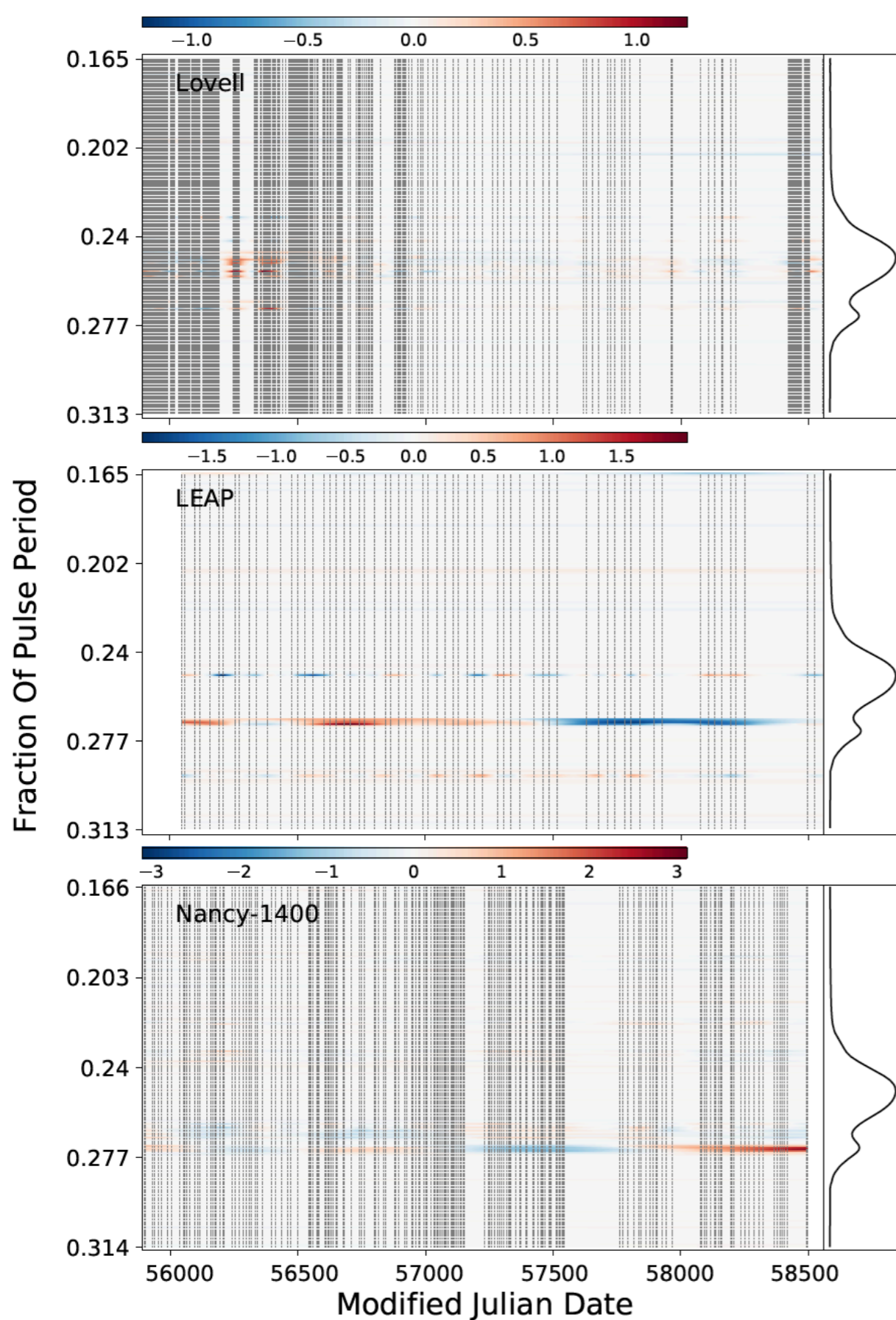
**Brook+ 2018**

# Results: 1400MHz main-pulse

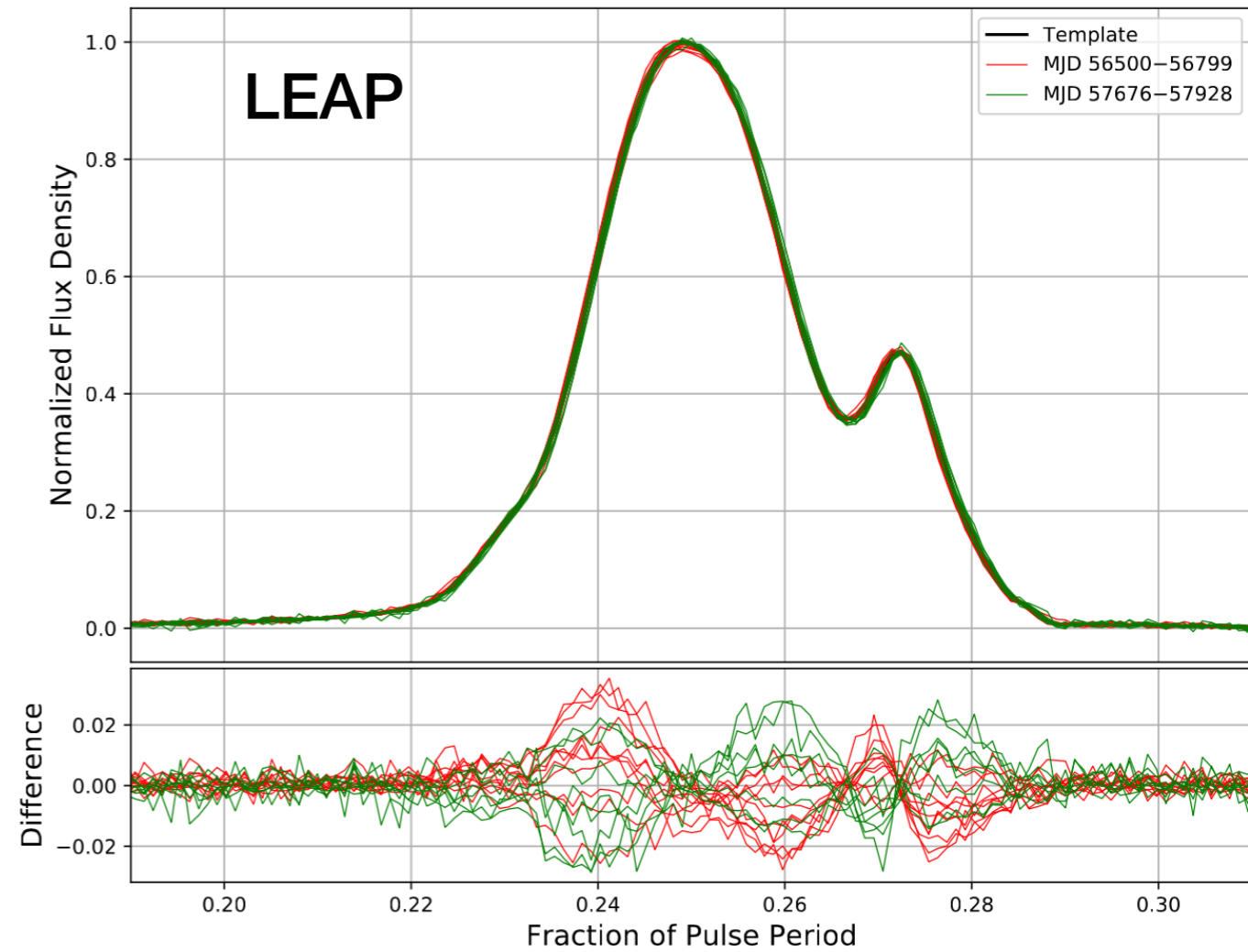
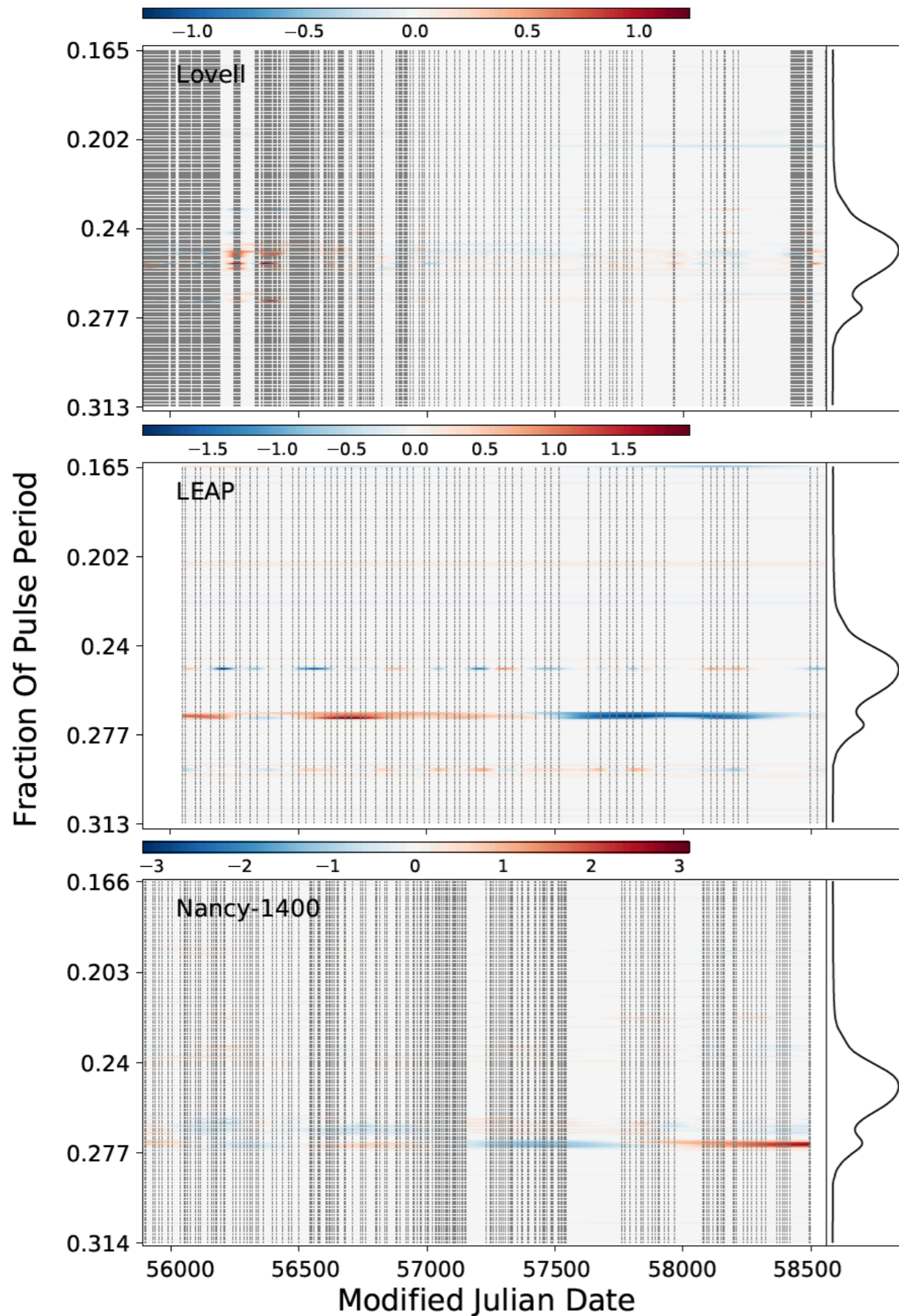




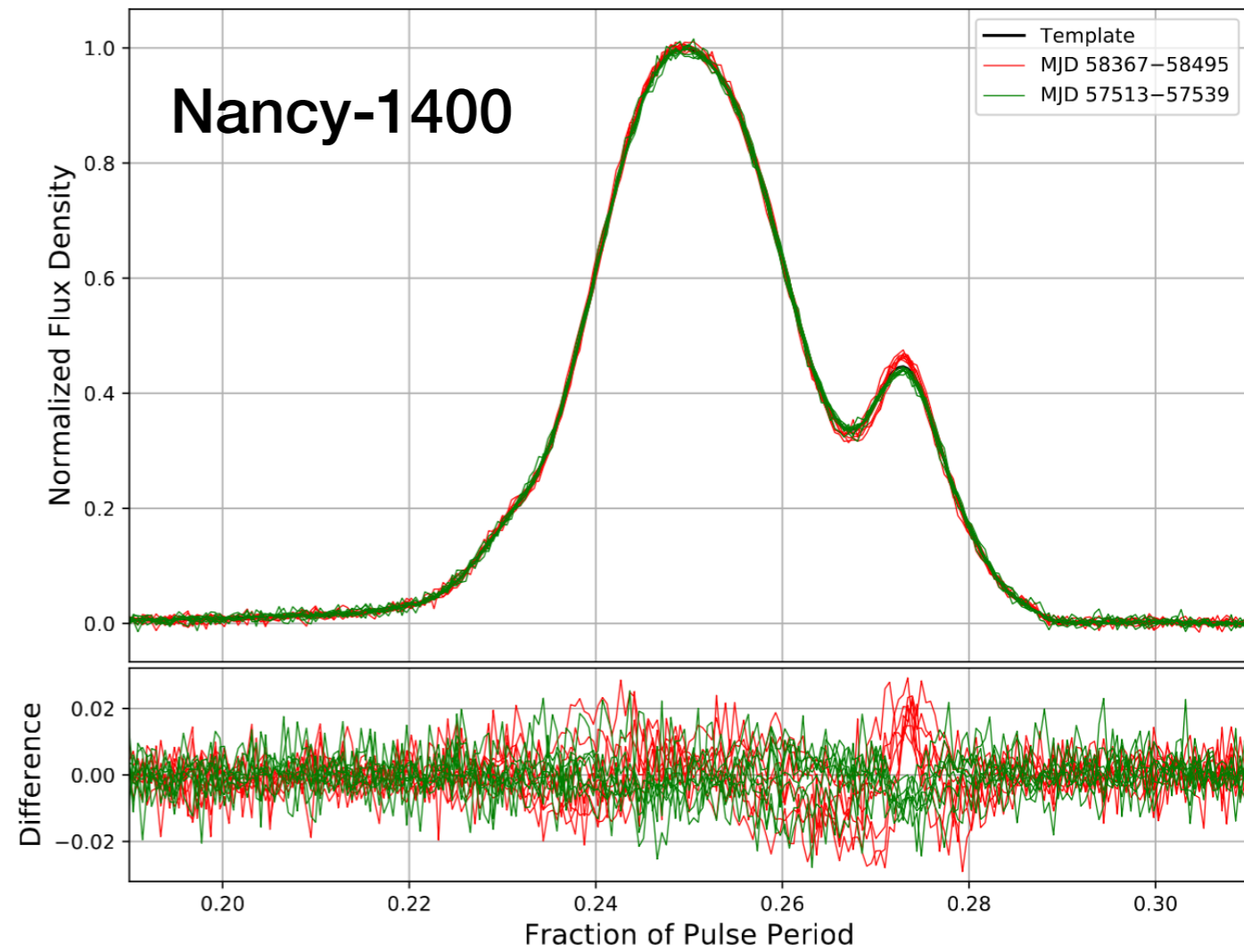
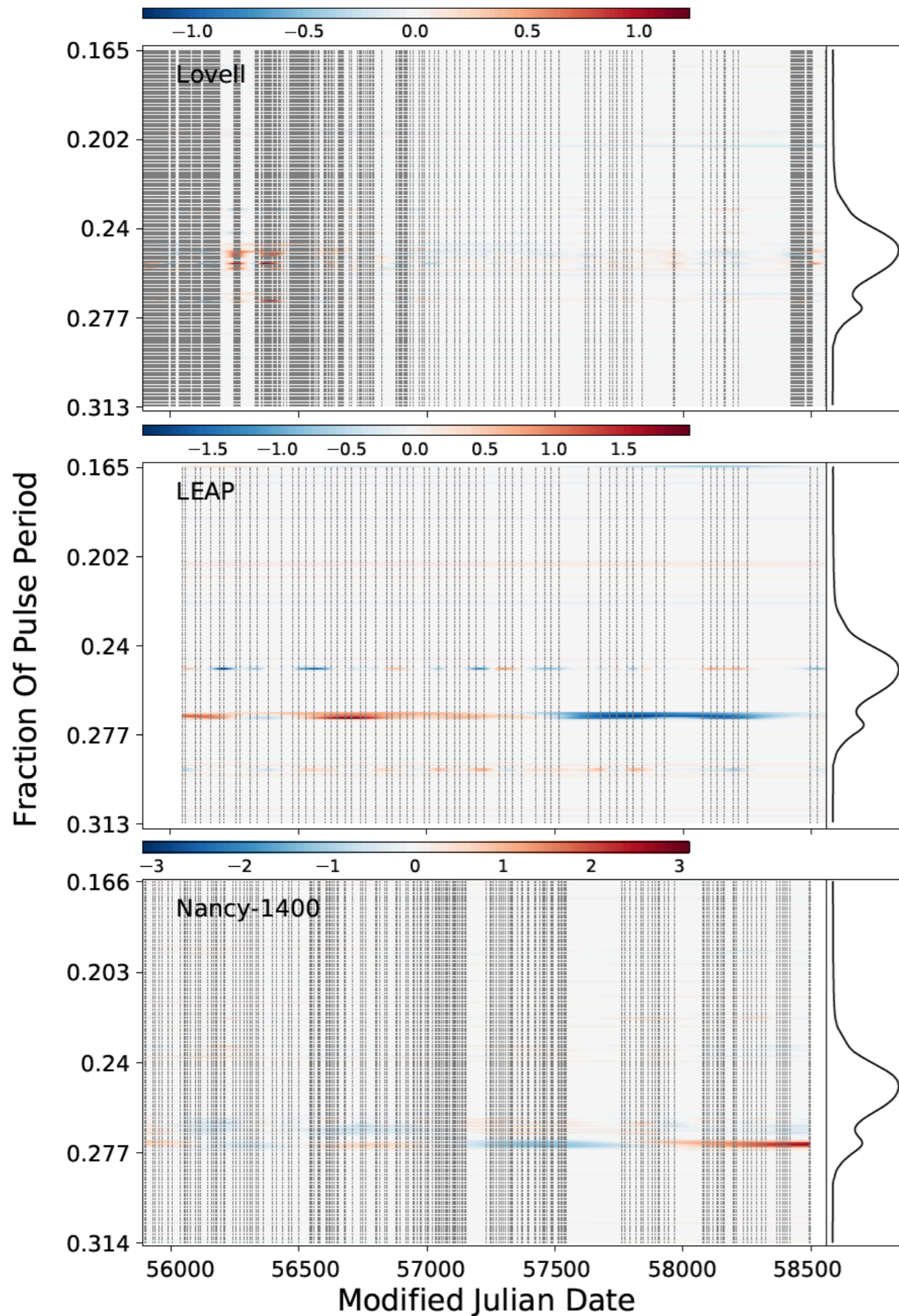
# Results: 1400MHz main-pulse



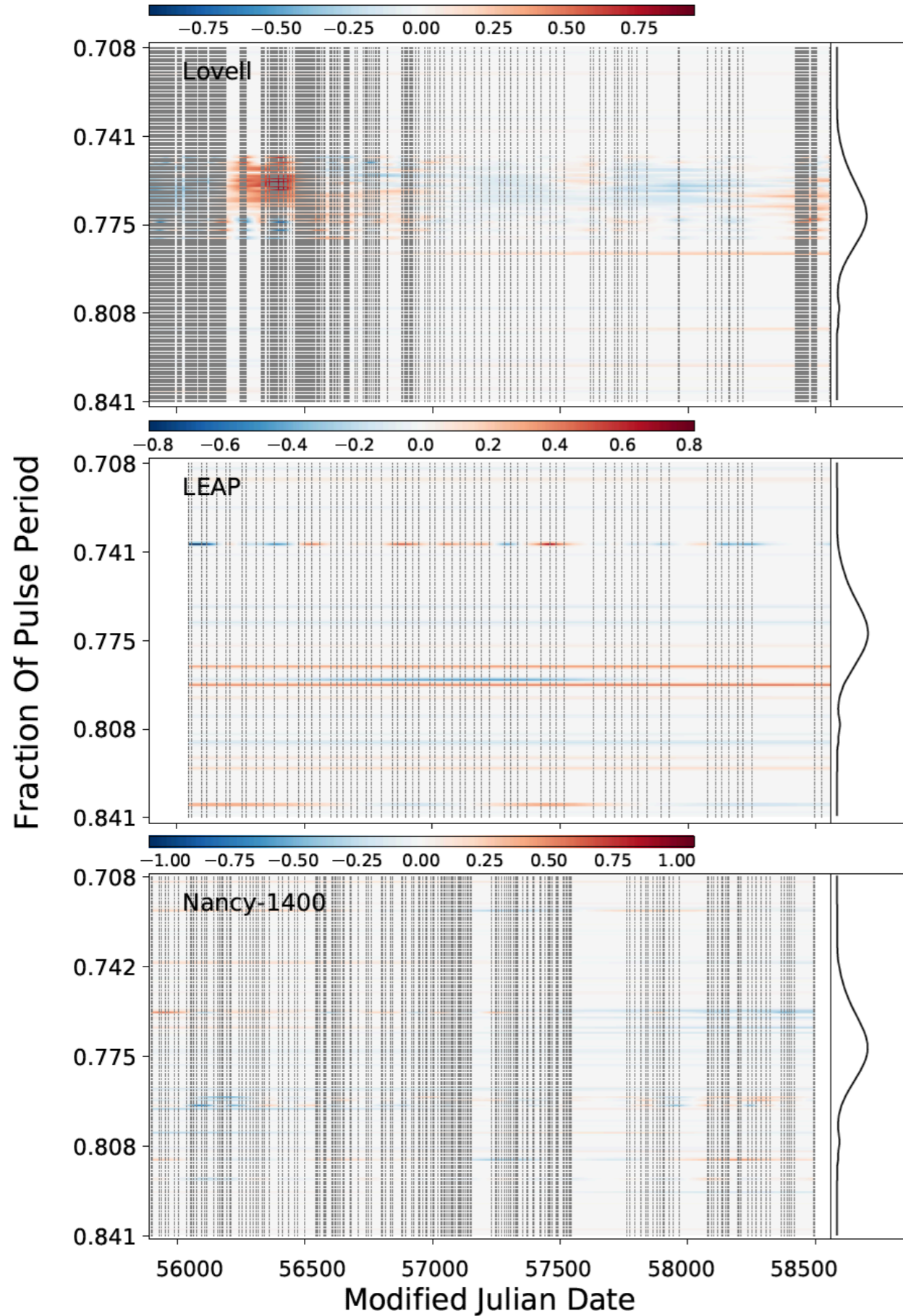
# Results: 1400MHz main-pulse



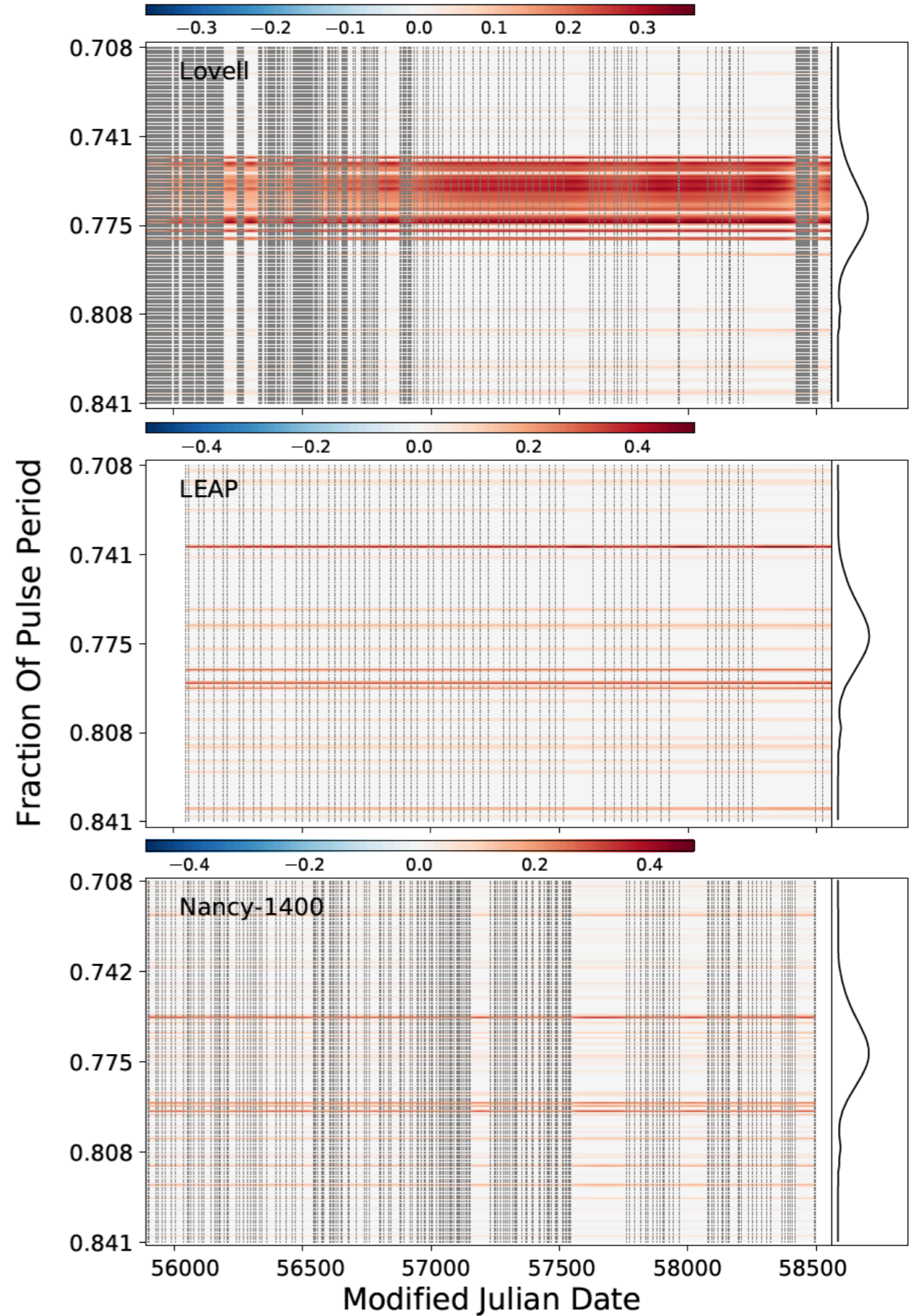
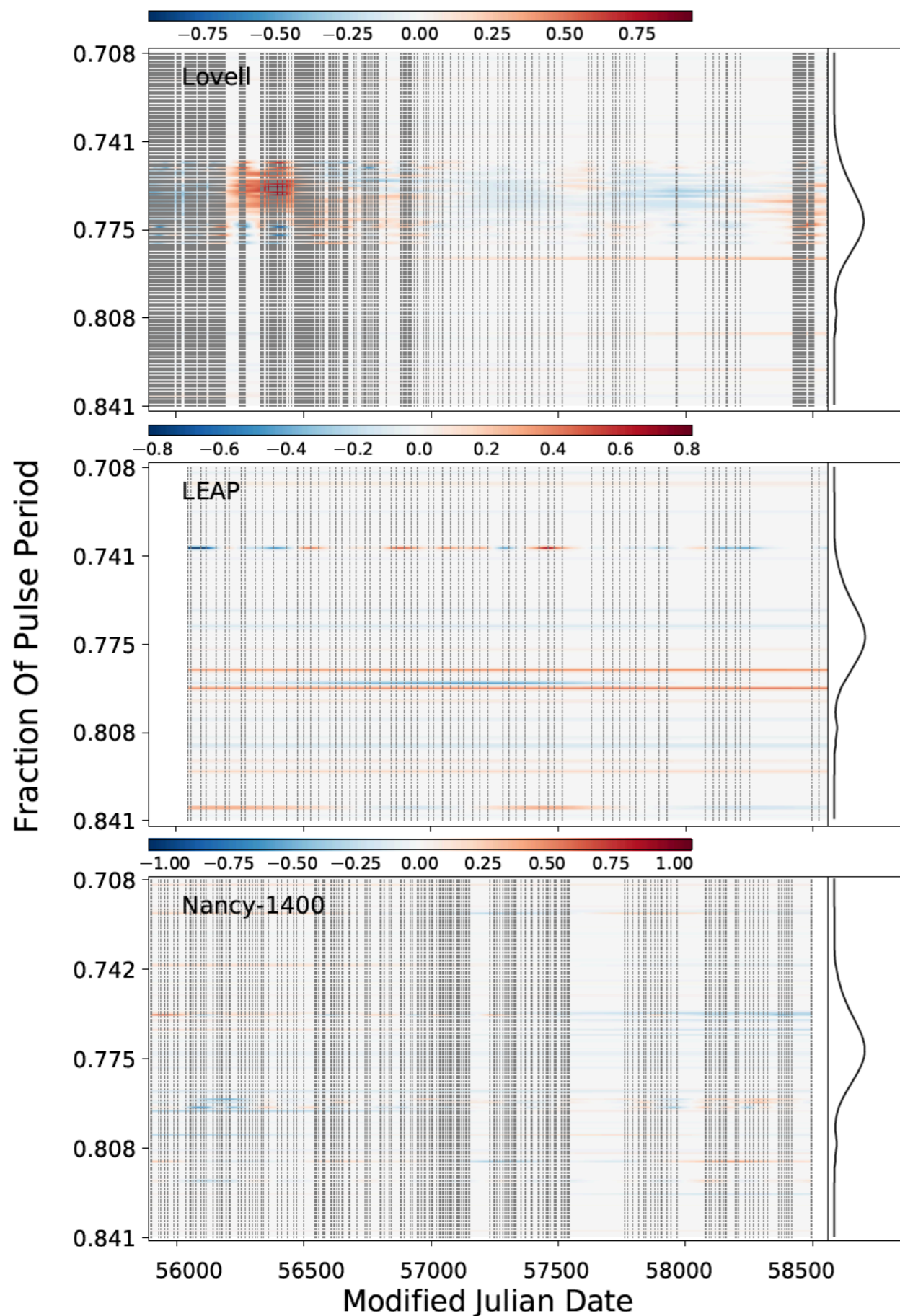
# Results: 1400MHz main-pulse



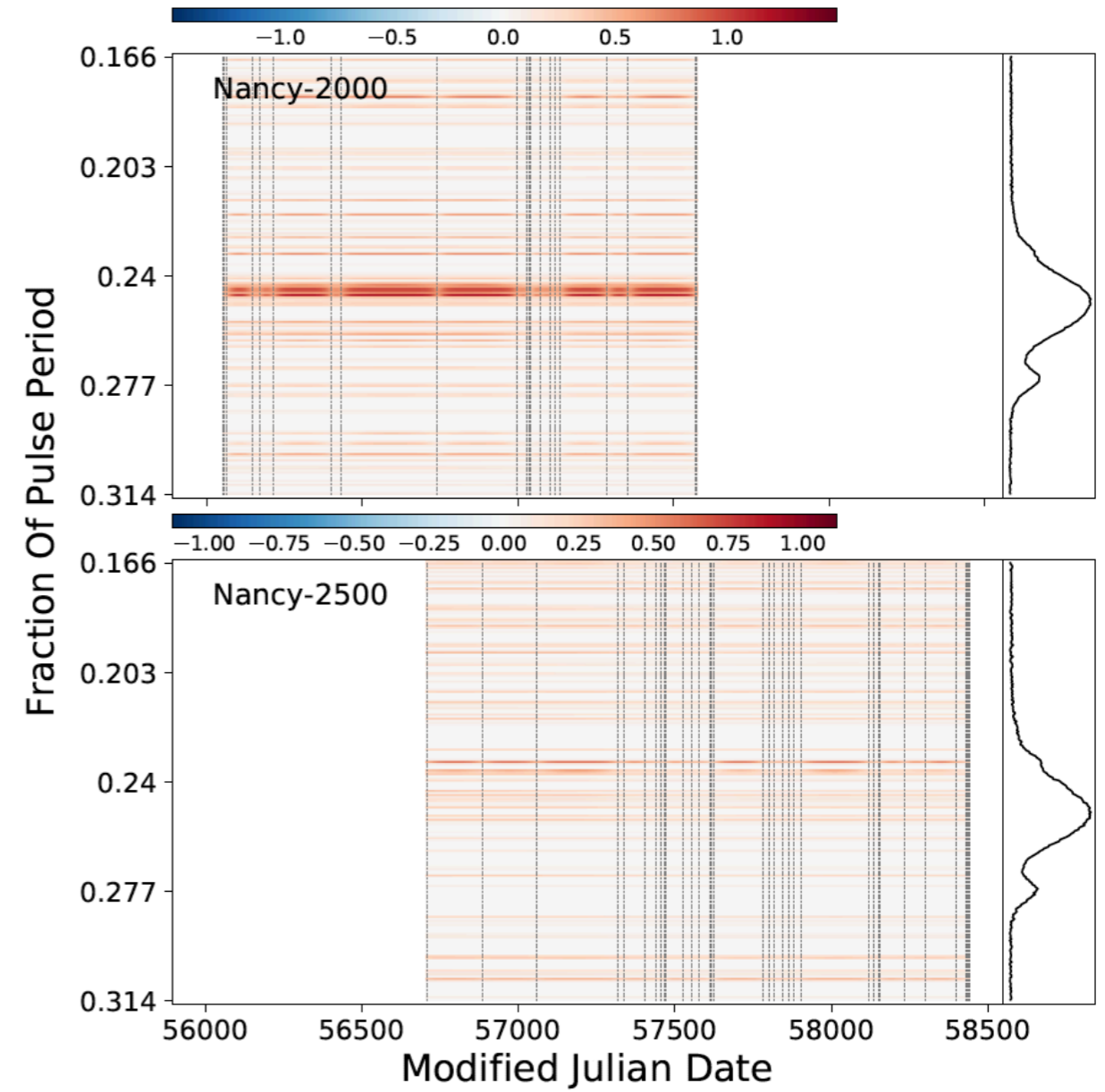
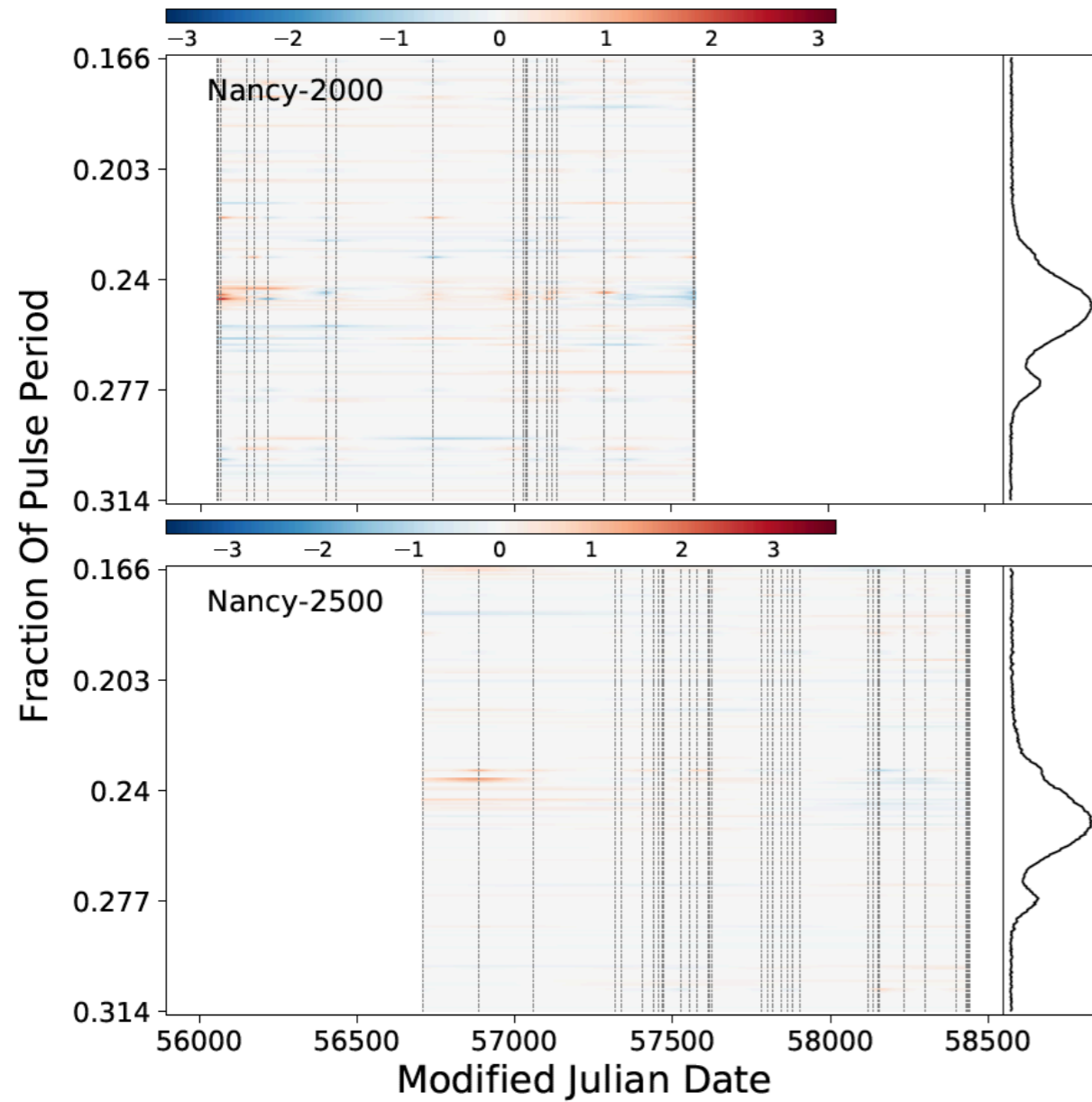
# Results: 1400MHz inter-pulse



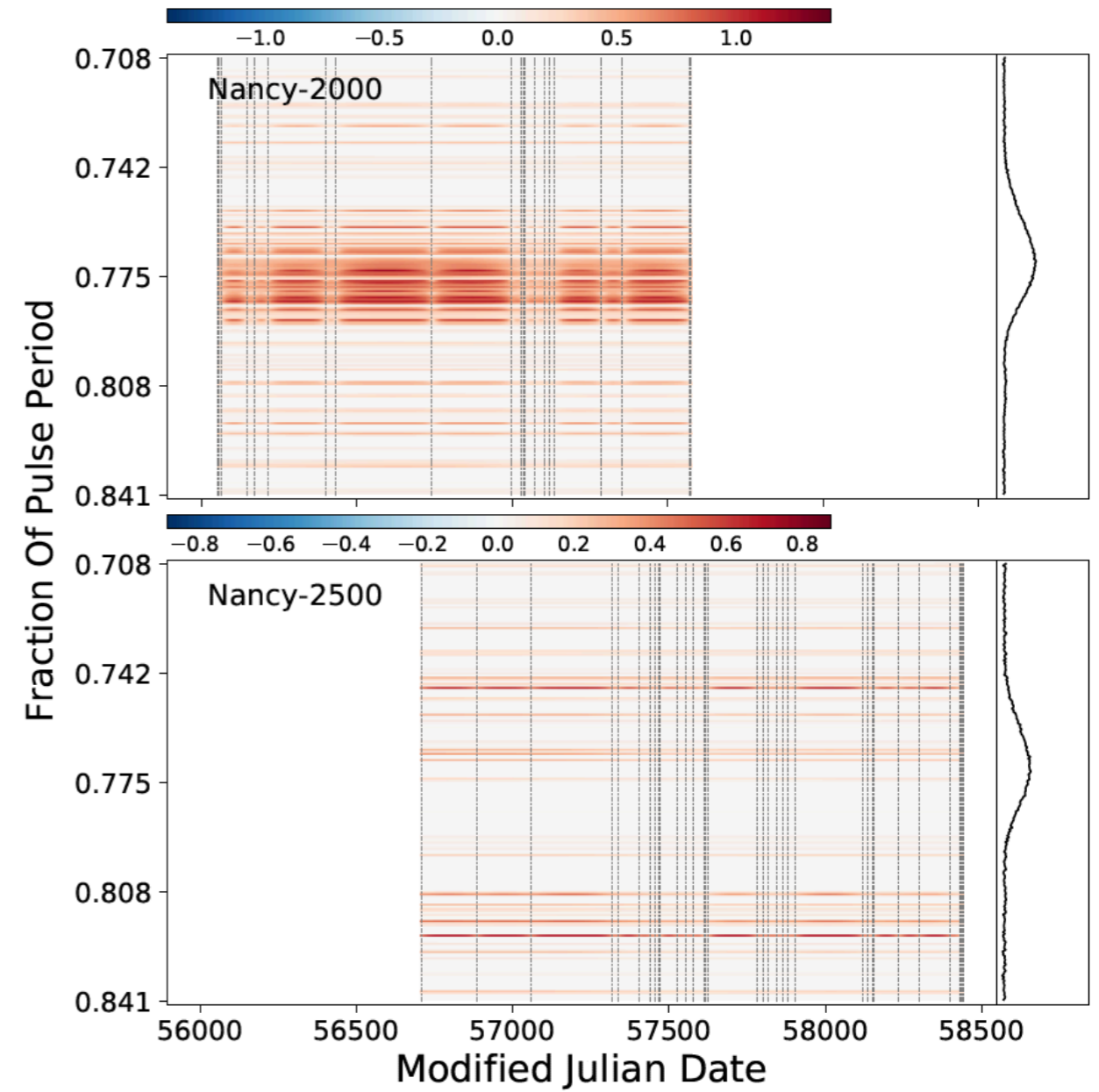
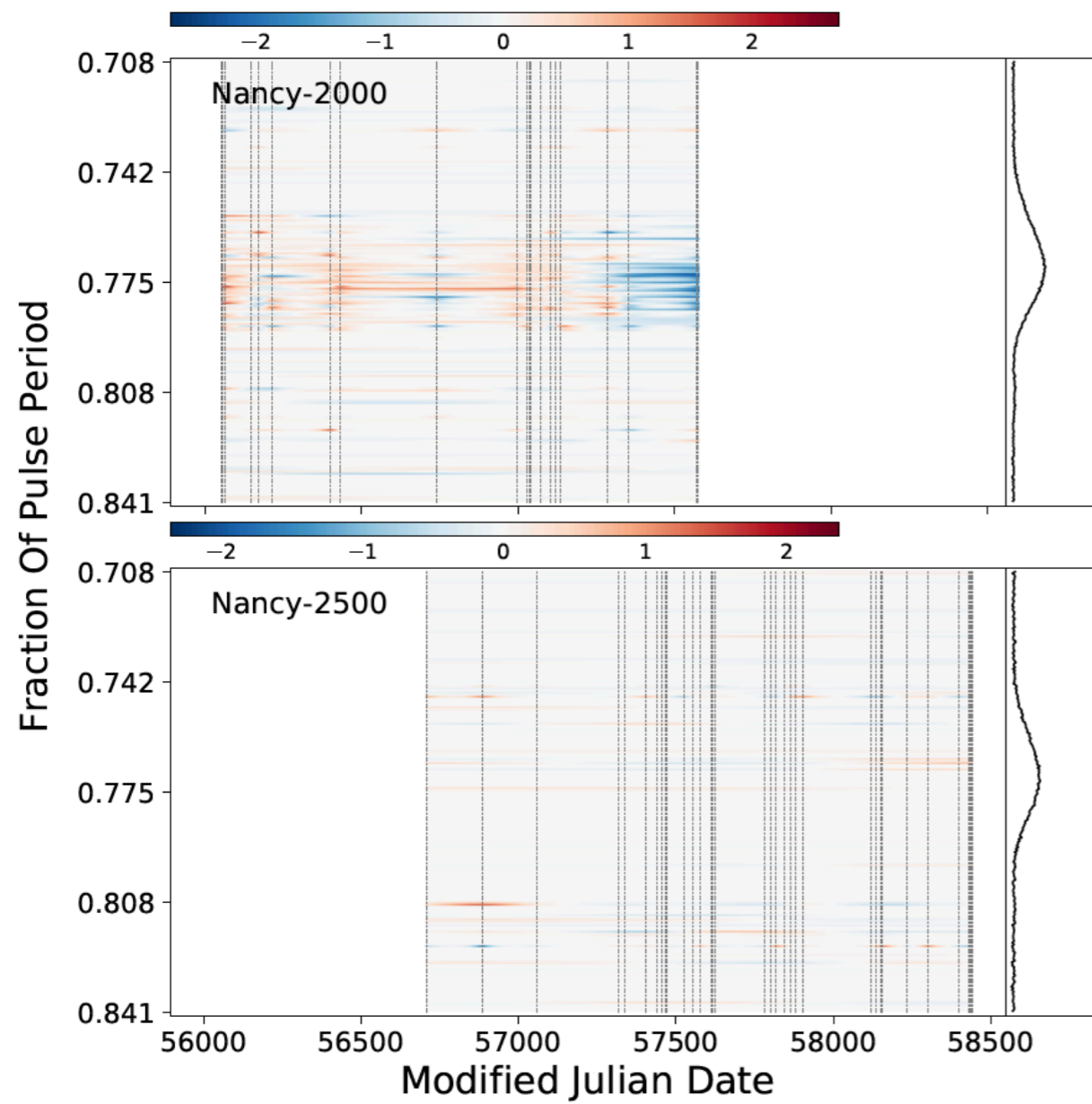
# Results: 1400MHz inter-pulse



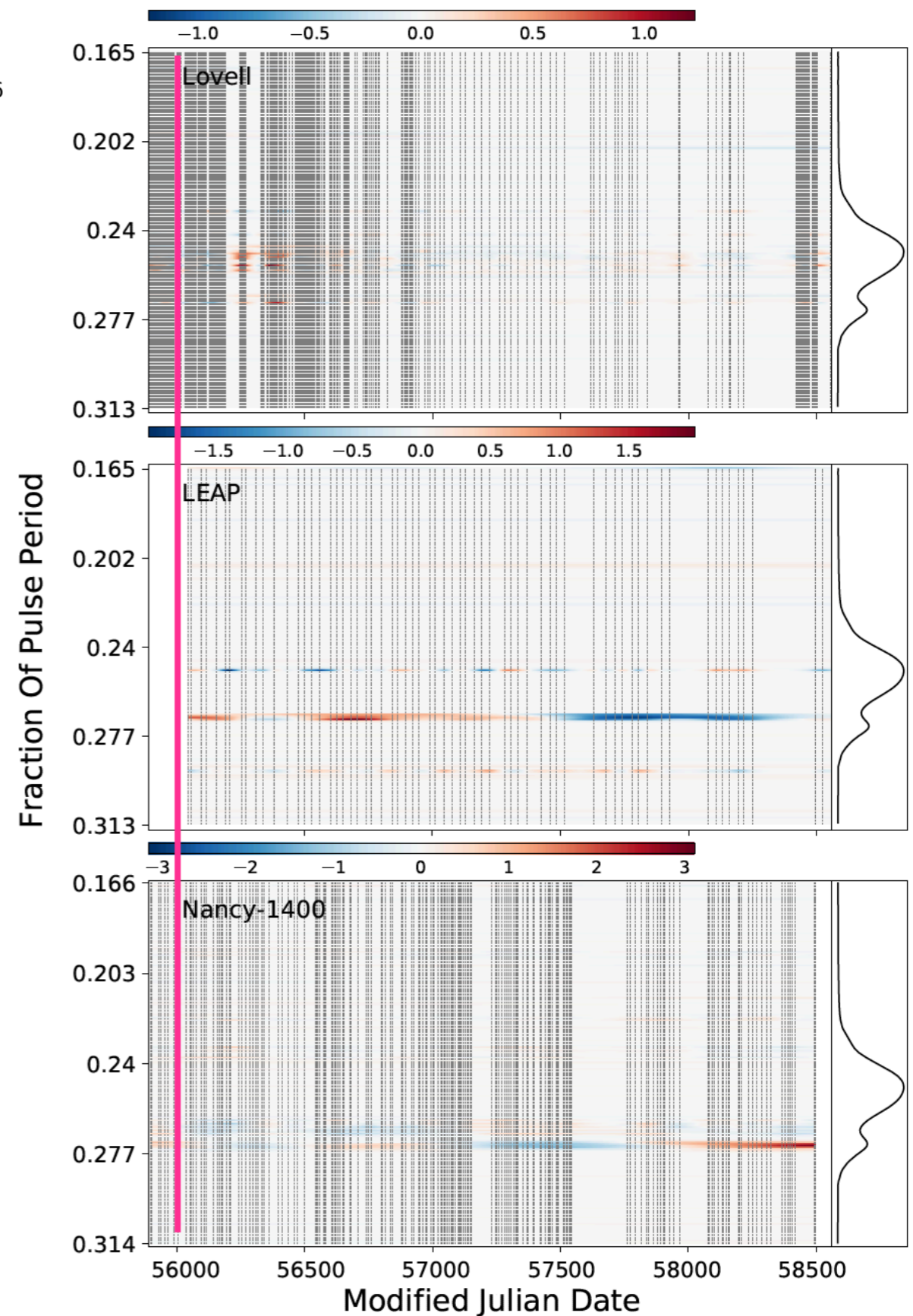
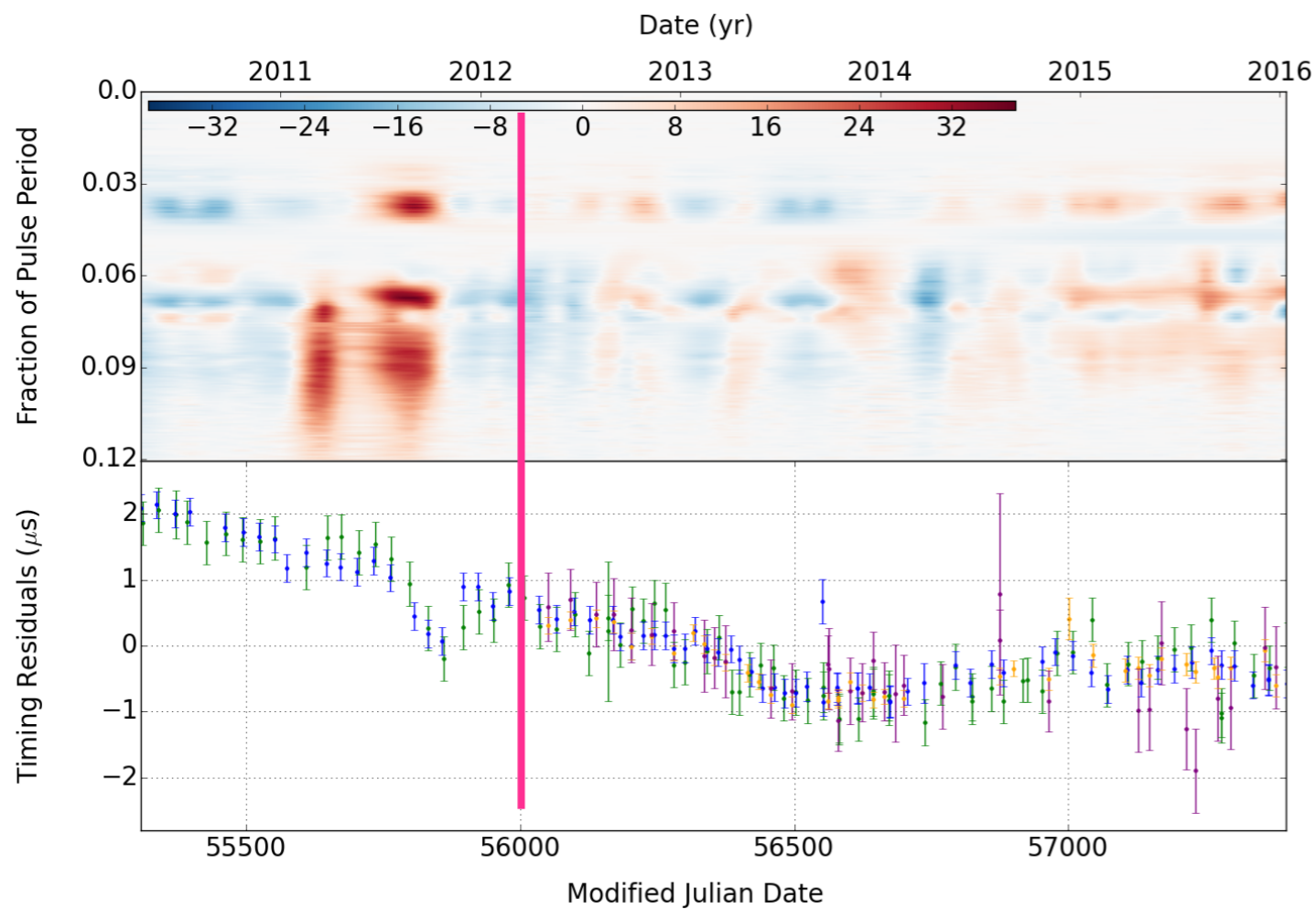
# Results: 2000 & 2500 MHz main-pulse



# Results: 2000 & 2500 MHz inter-pulse

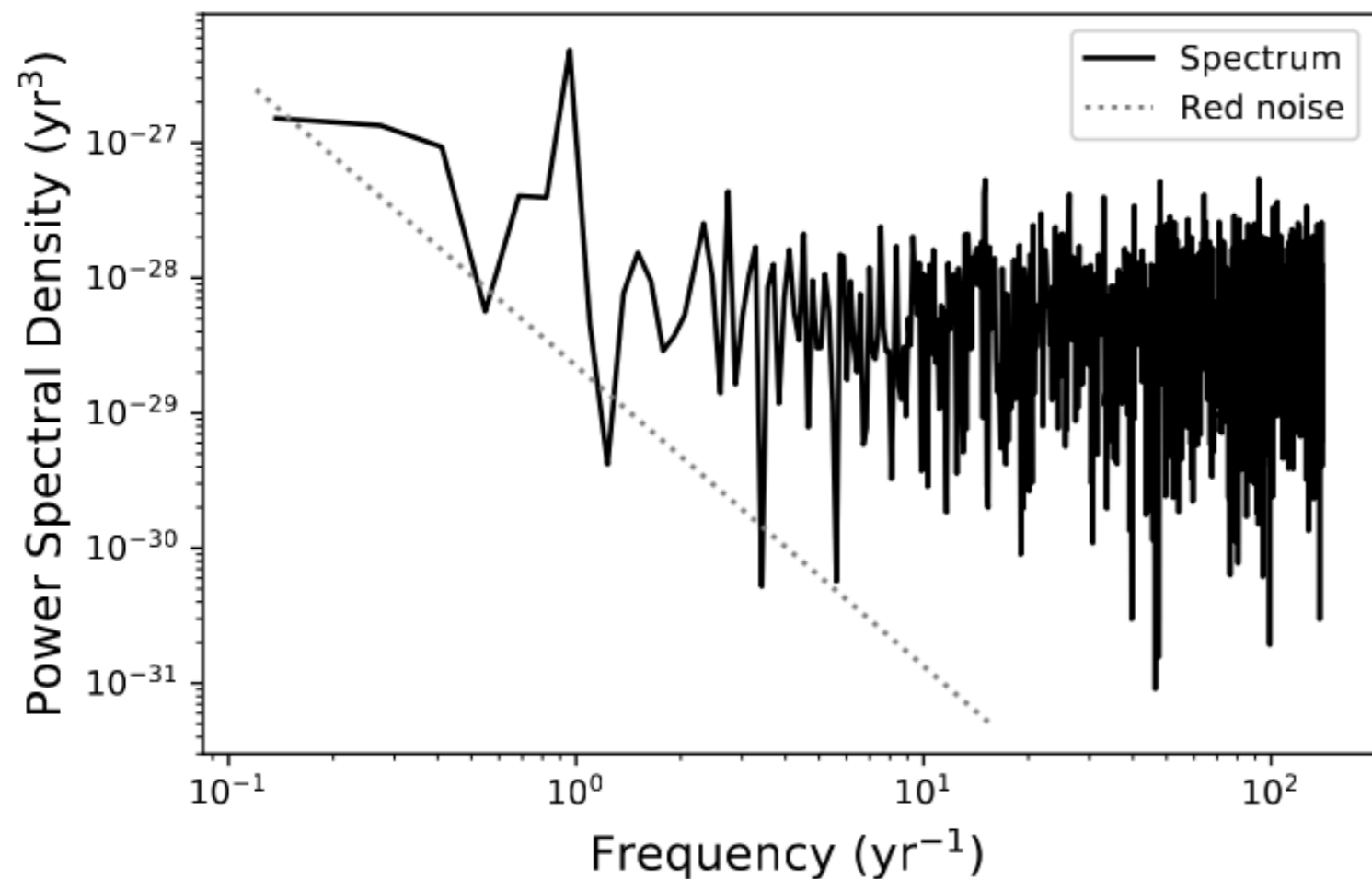
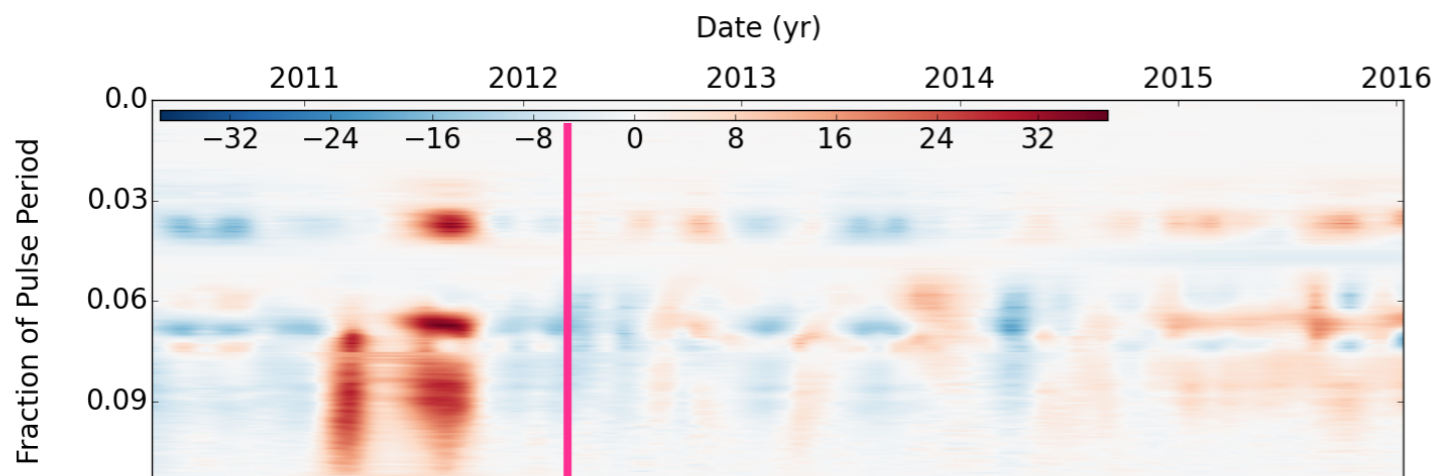


# Relation with timing residuals

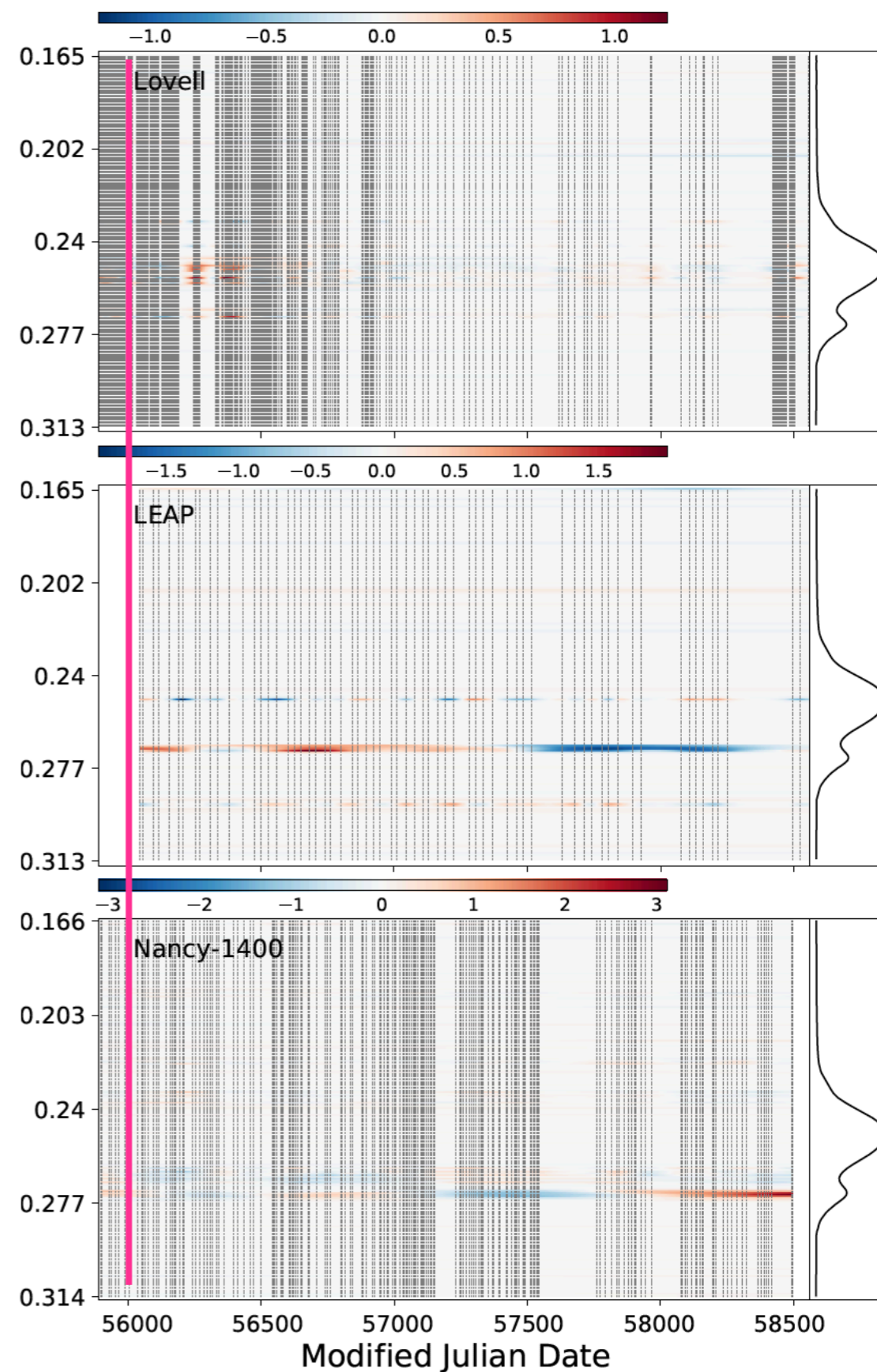




# Relation with timing residuals



unusual peak at  $f = 0.96 \text{ yr}^{-1}$ ,  
close to  $1 \text{ yr}^{-1}$



# Conclusion

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- We used the Lovell, LEAP, Nancy data to search for shape changes in B1937+21
- Gaussian process regression was applied in modeling the shape variations
- No shape-change was found up to our data precision