

Classifying variable stars in TESS: a supervised and unsupervised approach

Accelerating Physics with ML @ MIT
Feb 1, 2023

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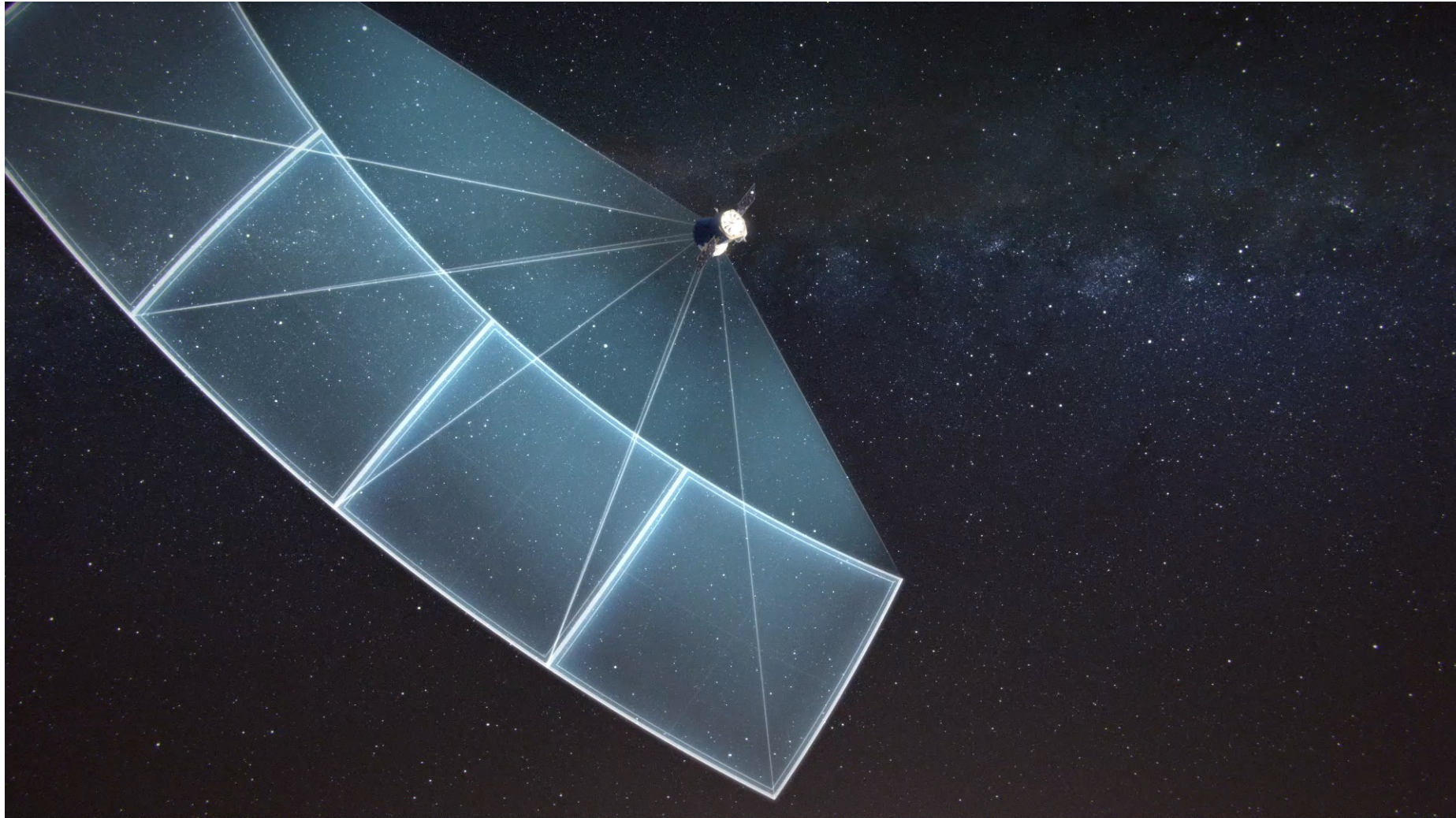
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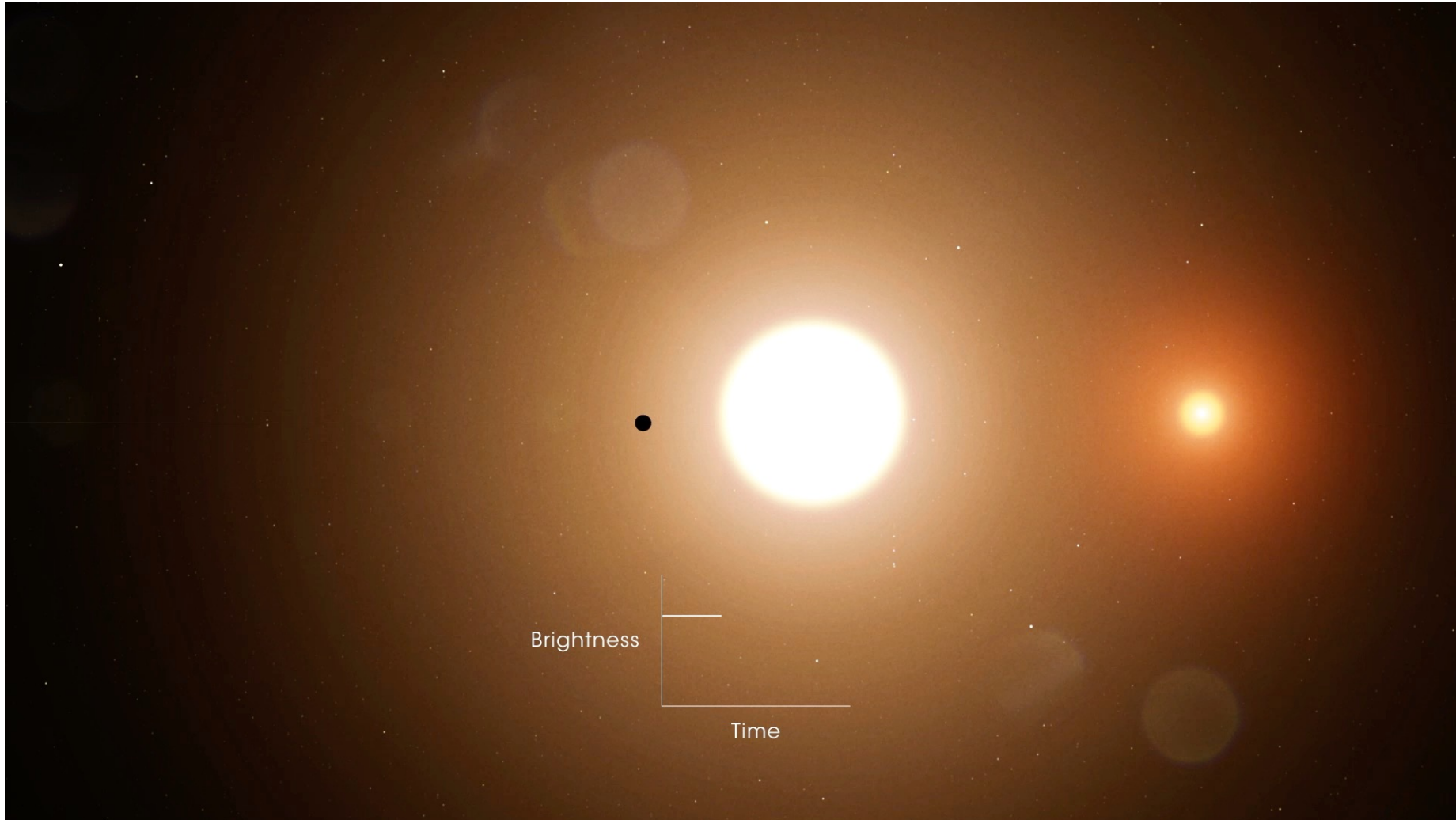


Transiting Exoplanet Survey Satellite (TESS)





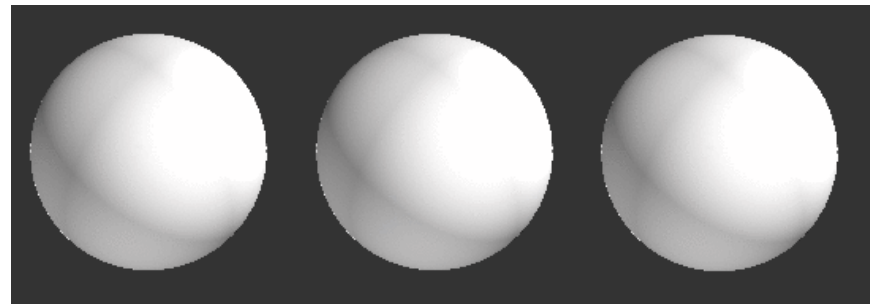
Transiting Exoplanet Survey Satellite (TESS)



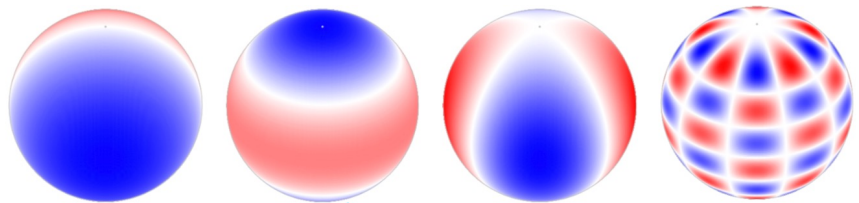


Stellar variability

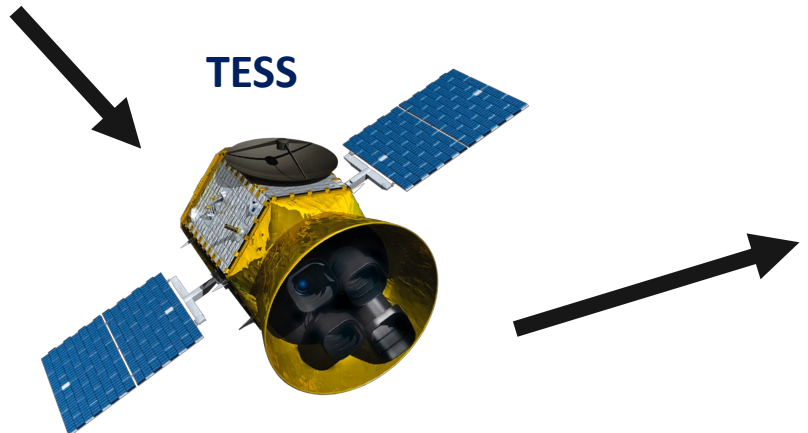
Credit: Joey Mombarg



Surface of a **pulsating** star:
red and blue are hotter
and cooler regions
alternating during the
pulsation cycle

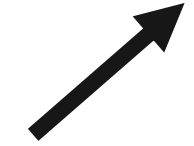


Credit: Aerts et al. (2010)

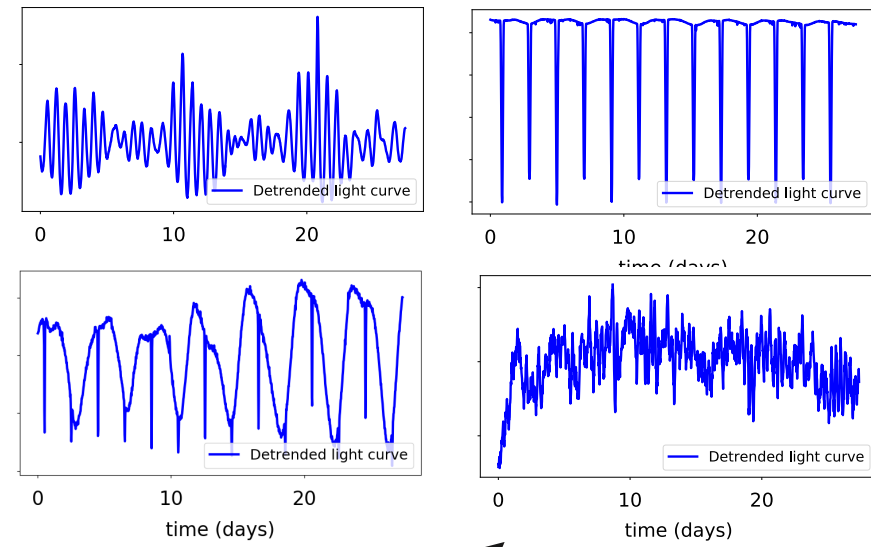


TESS

Credit: NASA Goddard Space Flight Center

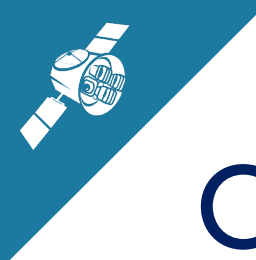


Light curves

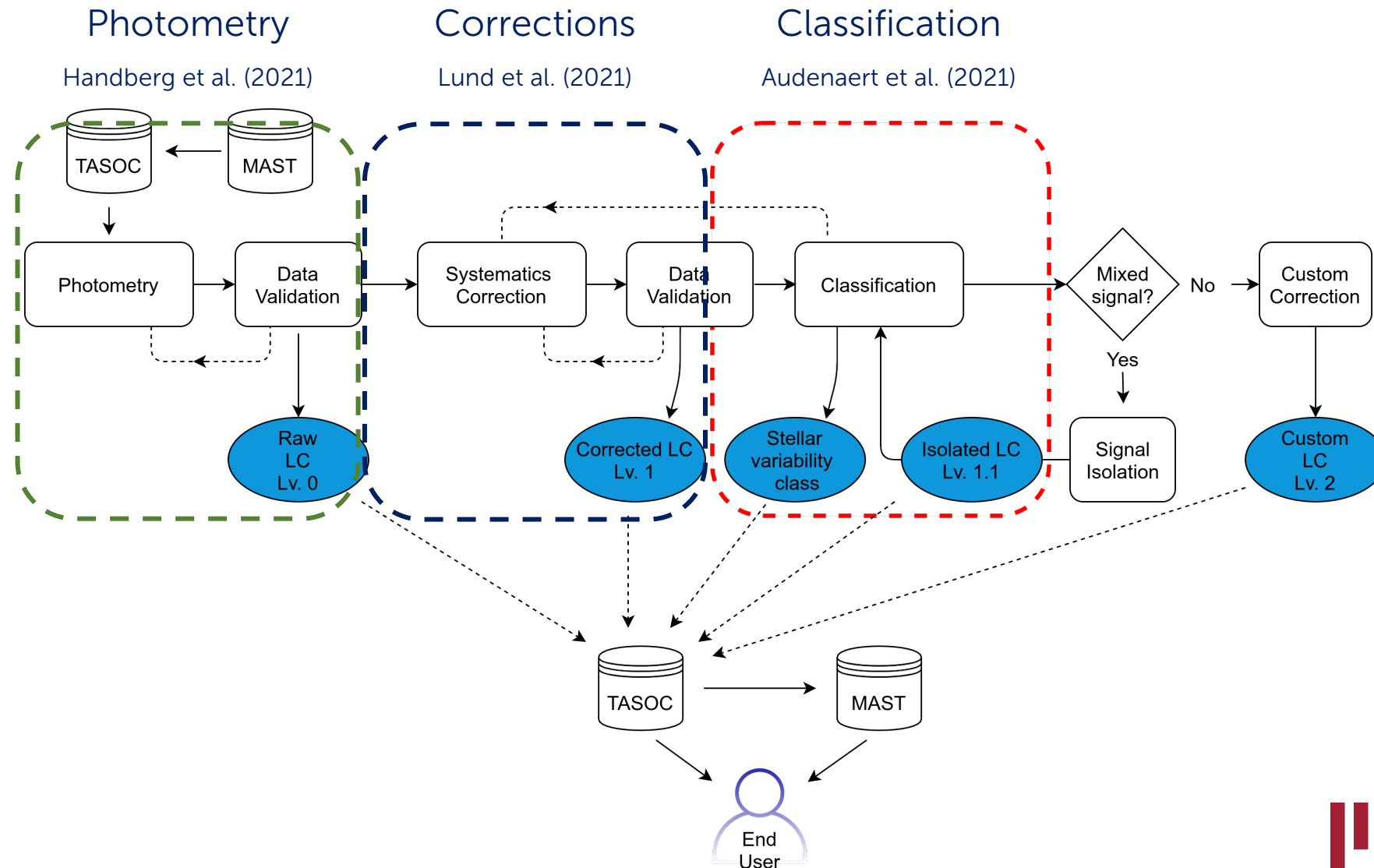




Light curve classification



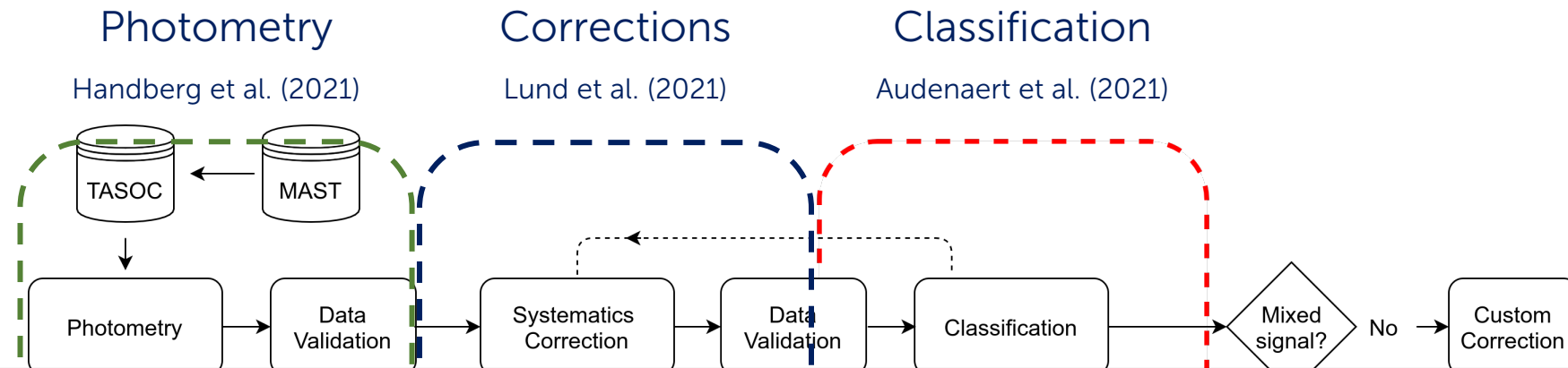
Current Variability Processing Pipeline



[arXiv:2106.08341](https://arxiv.org/abs/2106.08341)
[arxiv:2108.11780](https://arxiv.org/abs/2108.11780)
[arXiv:2107.06301](https://arxiv.org/abs/2107.06301)

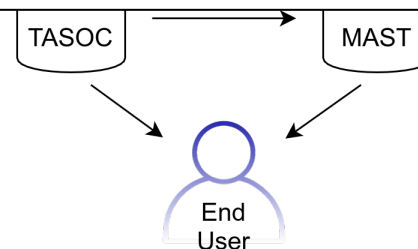


Current Variability Processing Pipeline



How should we to optimize this for future missions such as ESA's PLATO mission?

→ Low-latency onboard processing?



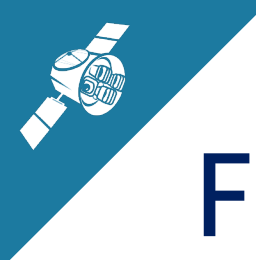
[arXiv:2106.08341](https://arxiv.org/abs/2106.08341)

[arxiv:2108.11780](https://arxiv.org/abs/2108.11780)

[arXiv:2107.06301](https://arxiv.org/abs/2107.06301)

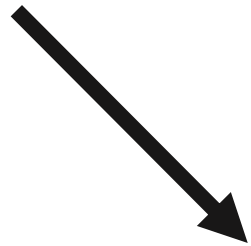
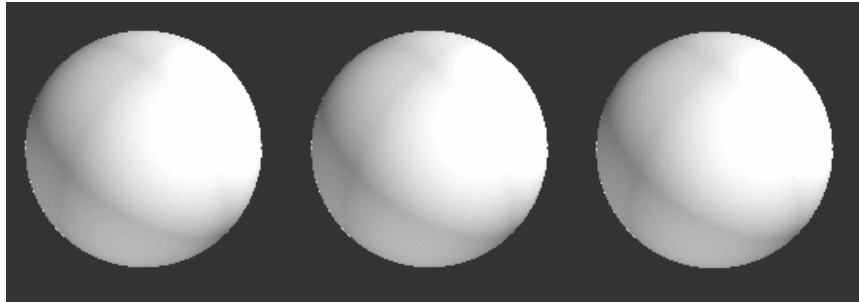


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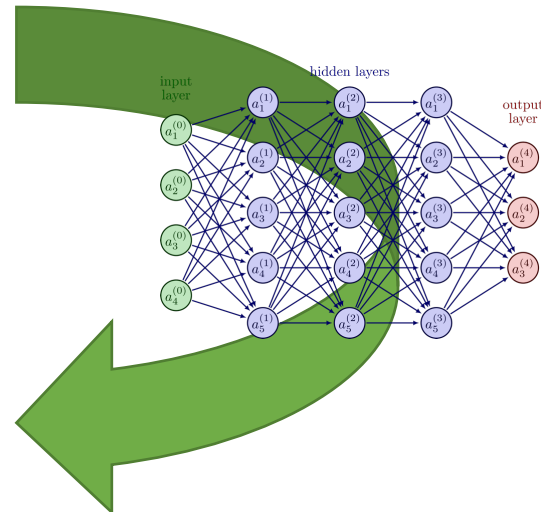
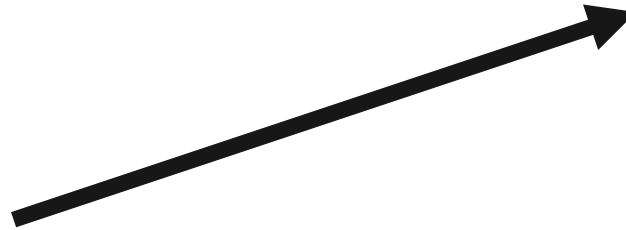


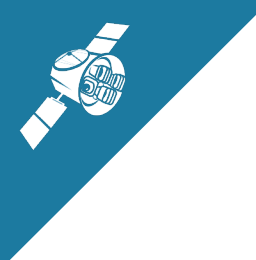
Future

Credit: Joey Mombarg

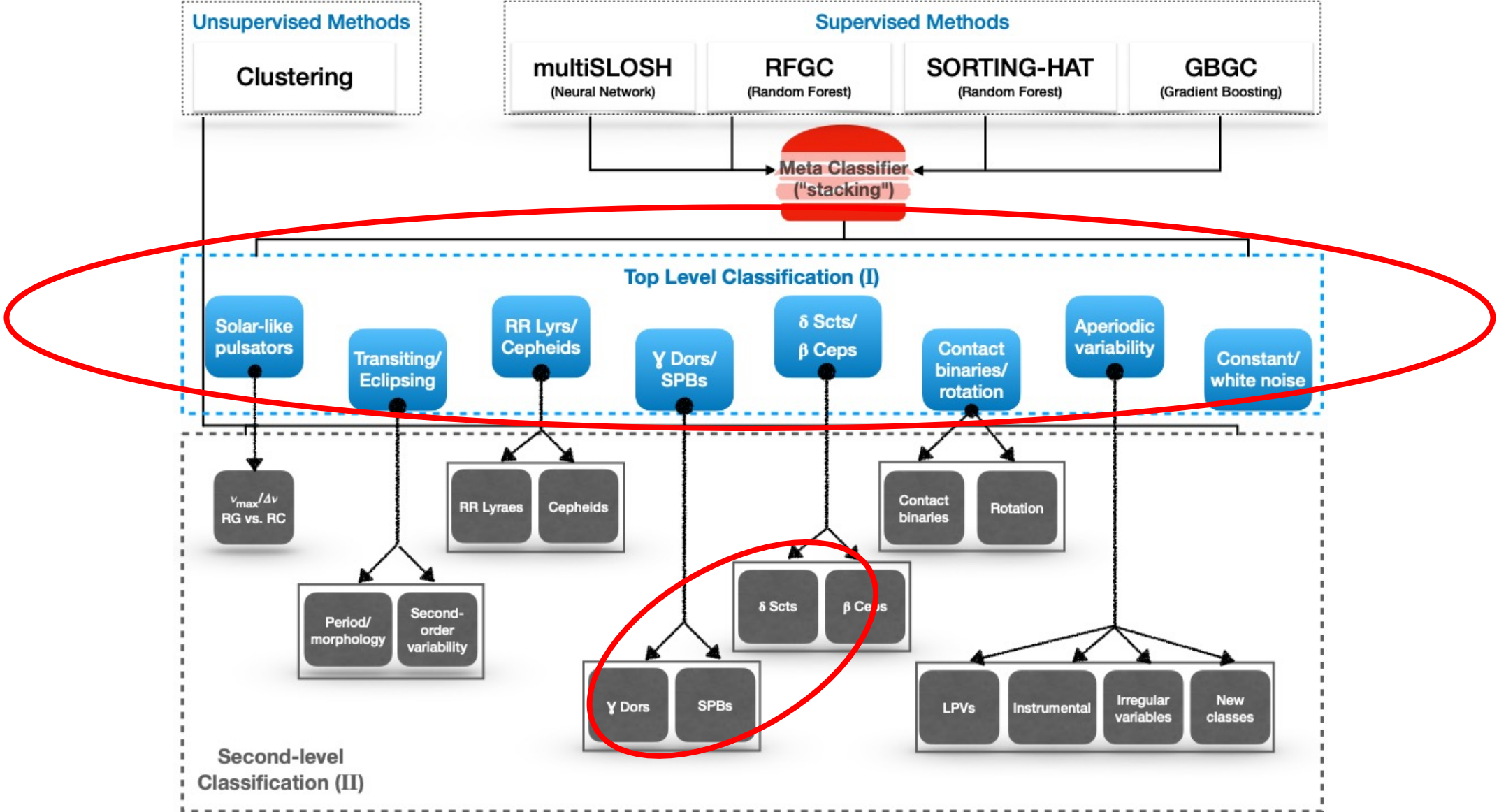


Future missions
e.g. ESA PLATO





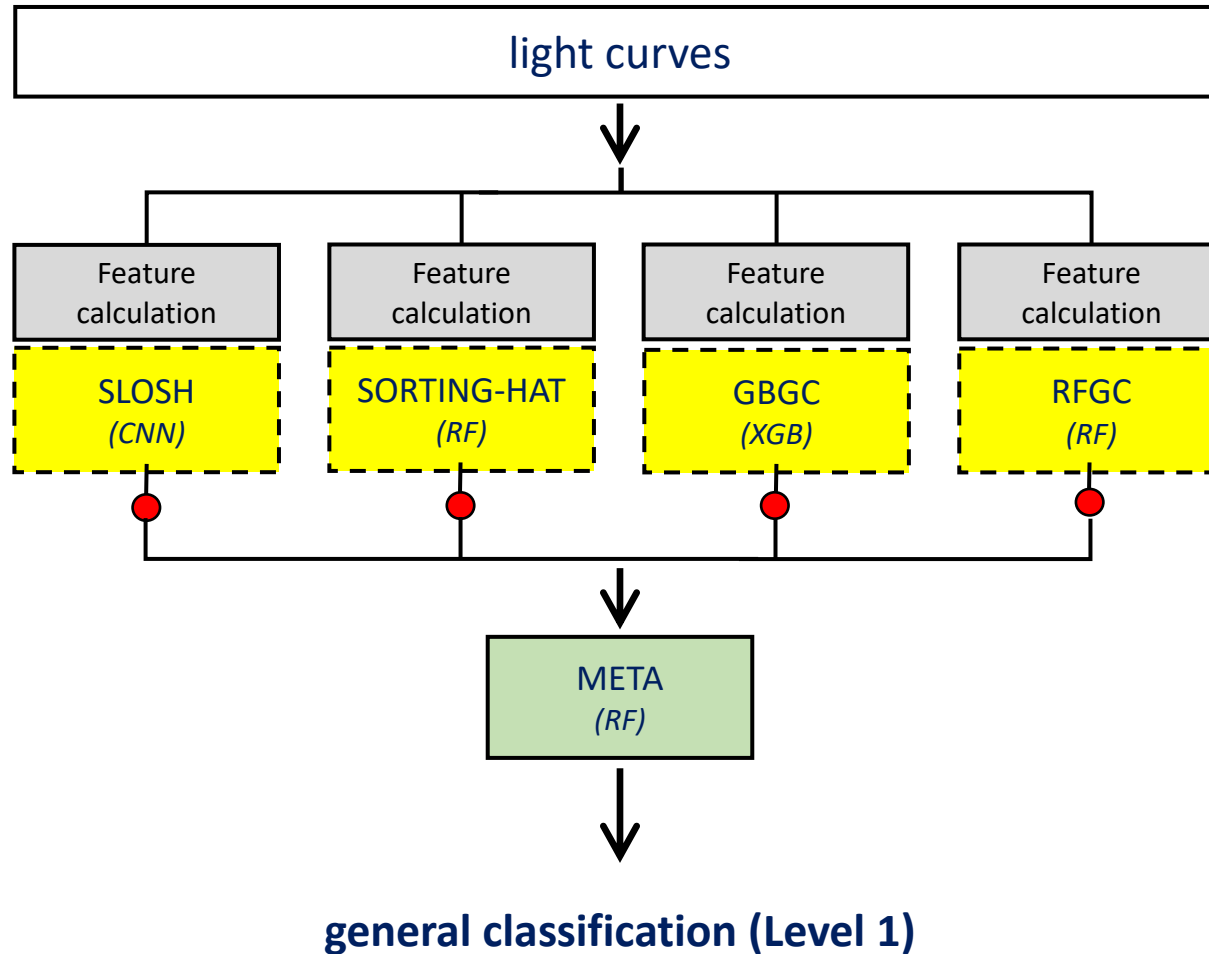
Stellar Variability Classification





Classification scheme

Different feature sets per classifier

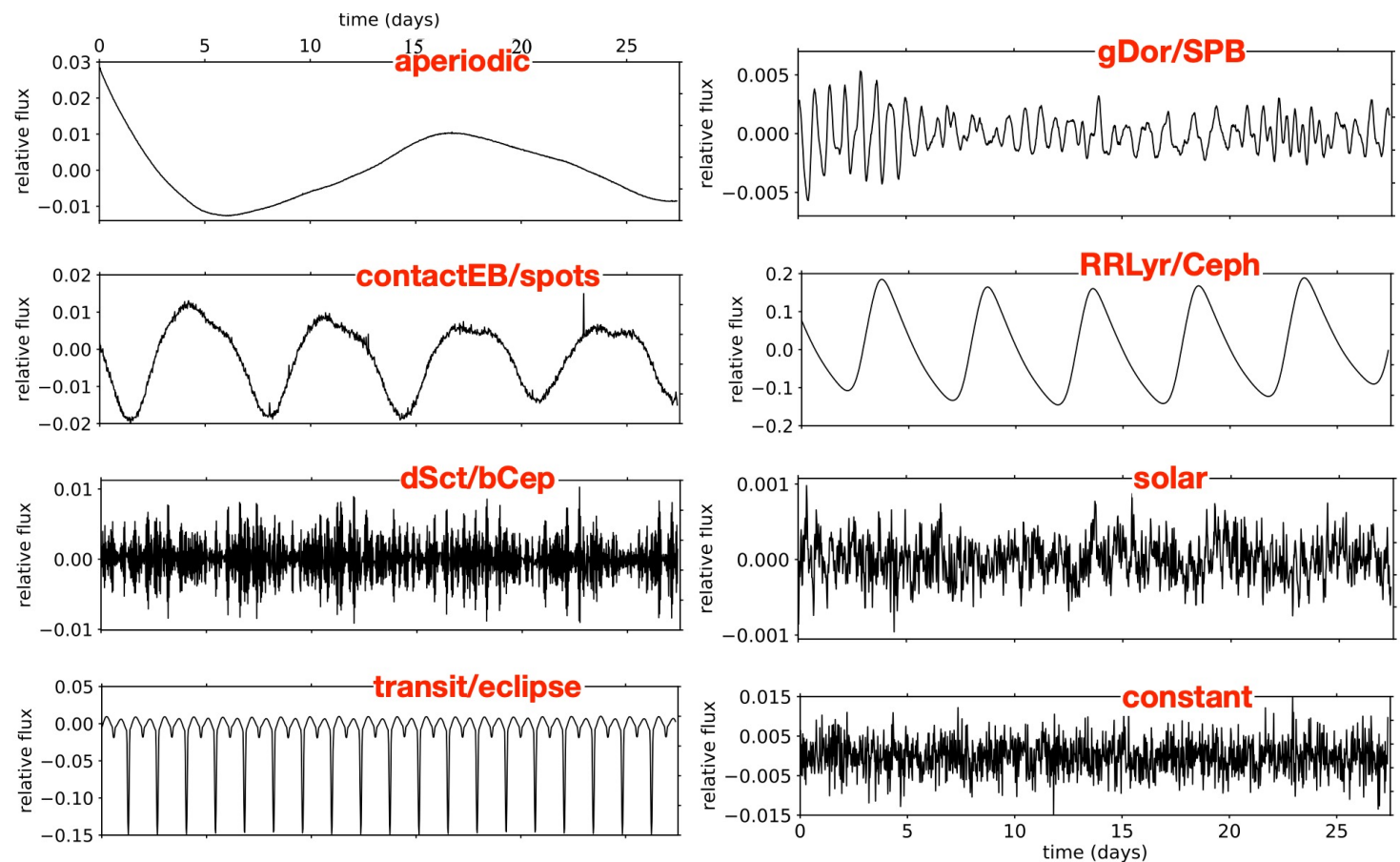


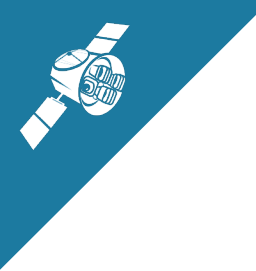


Results (metaclassifier)

Confusion matrix showing True Class vs Predicted Class. A large red diagonal watermark reads "~95% accuracy".

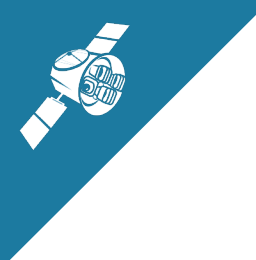
True Class \ Predicted Class	solar	transit/eclipse	RRLyr/Ceph	dSct/bCep	gDor/spB	contactEB/spots	aperiodic	constant
constant								100
aperiodic	1					1	98	
contactEB/spots	<1			<1	5	92	<1	<1
gDor/spB				5	90	5		
dSct/bCep			<1	97		<1		
RRLyr/Ceph			92				8	
transit/eclipse		96				4		
solar	94				<1	<1	5	



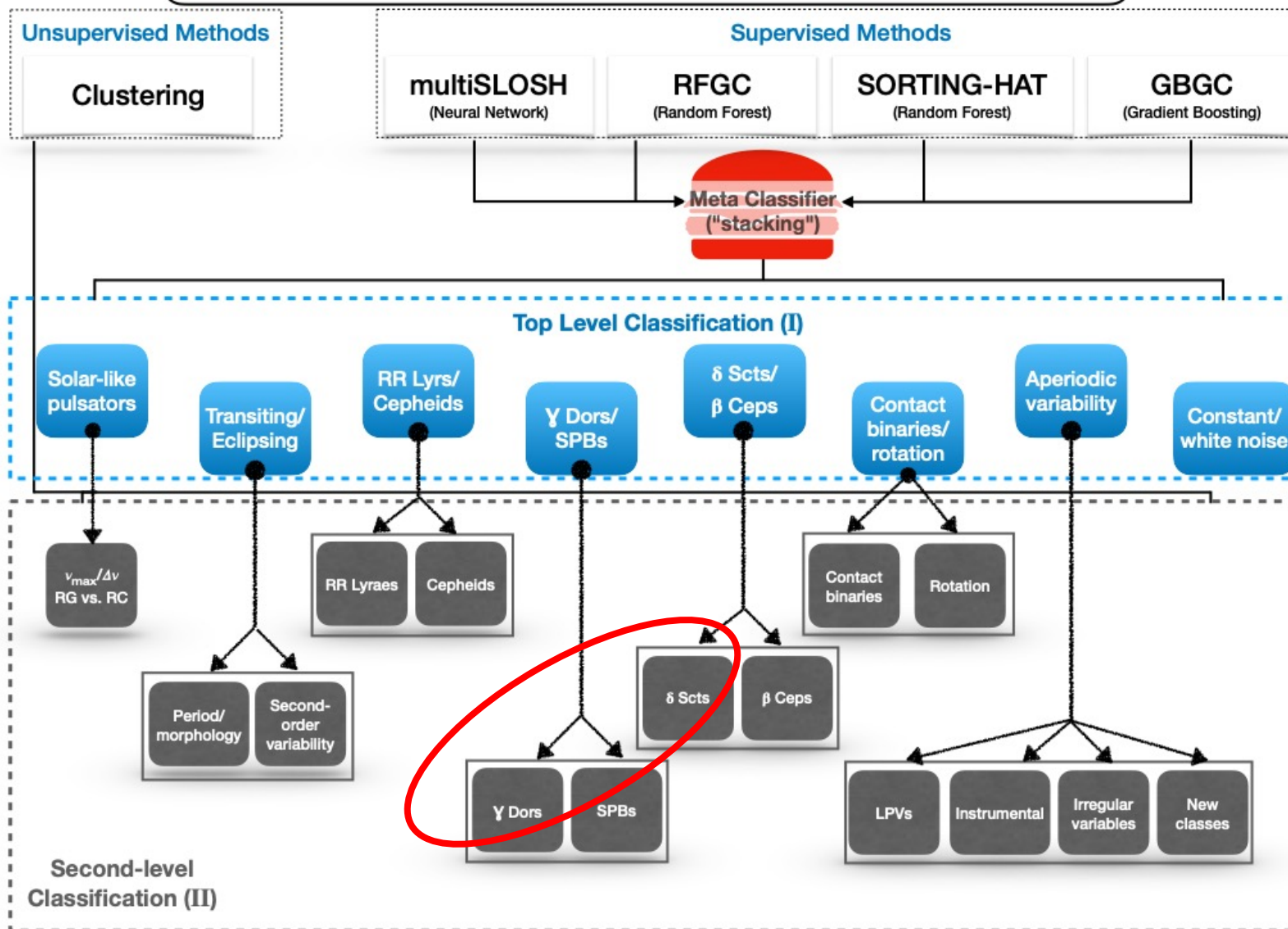


Discovering subclusters with unsupervised learning





Stellar Variability Classification



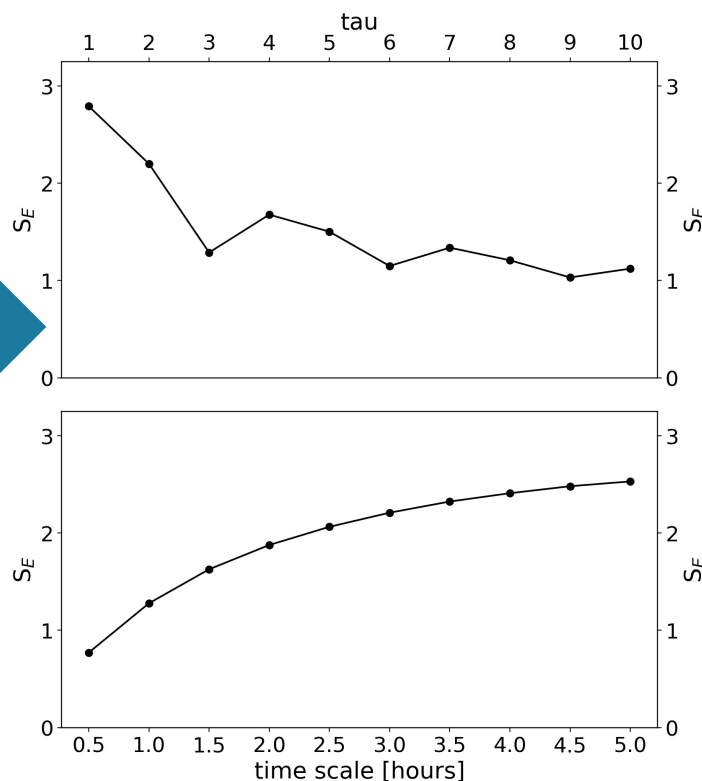
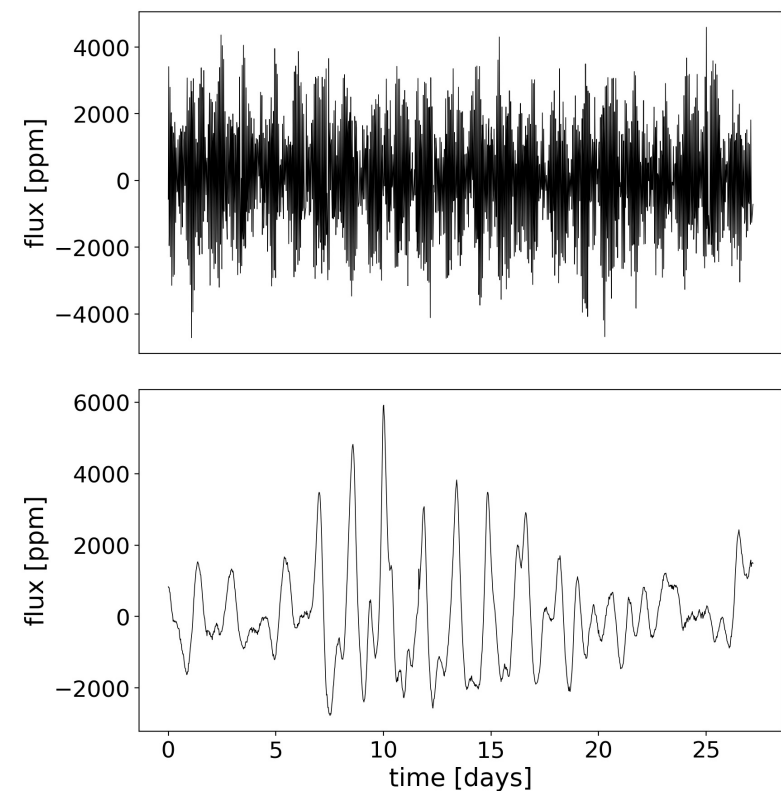


Discovering subclusters of pulsating stars with the multiscale entropy

Light curves

Multiscale Entropy
("complexity")

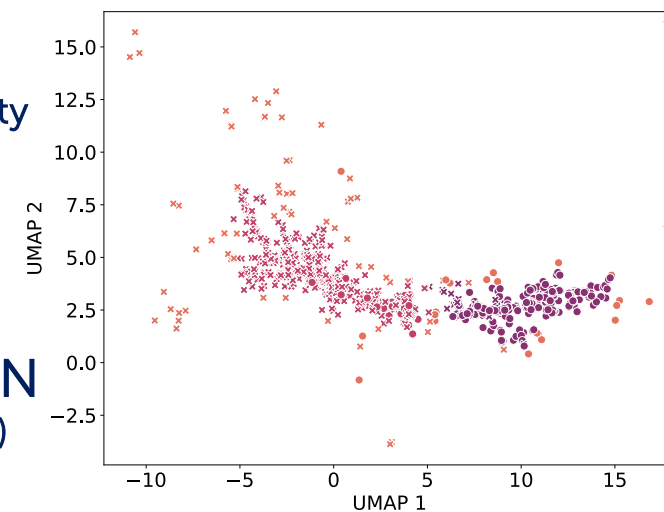
Clusters



UMAP
(dimensionality reduction)



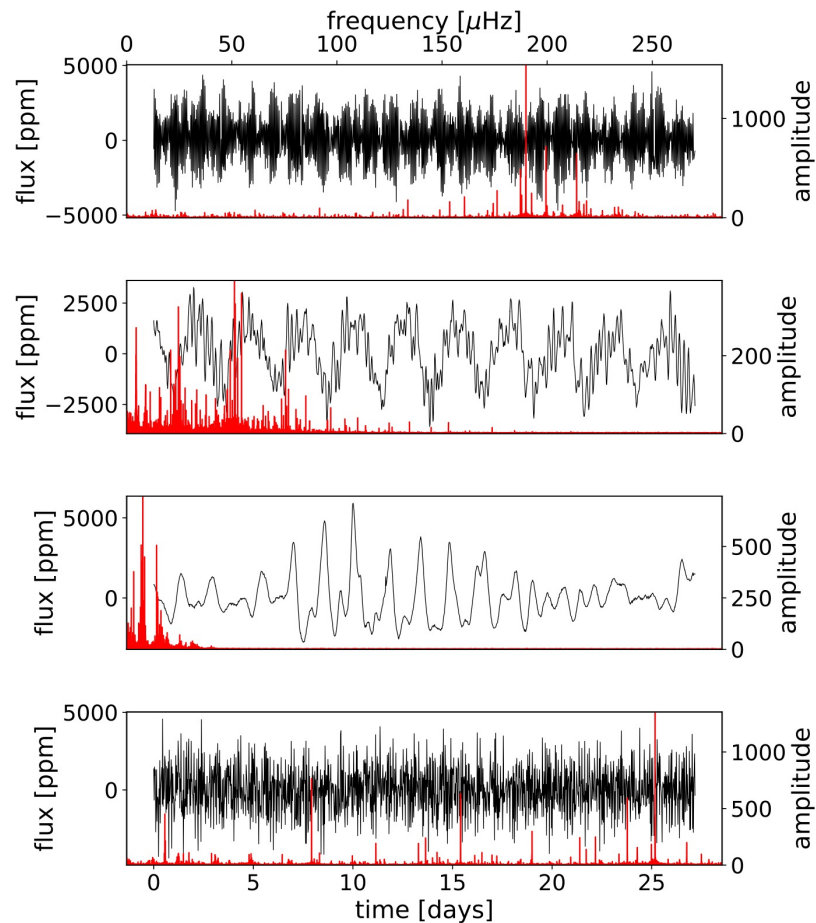
HDBSCAN
(clustering)



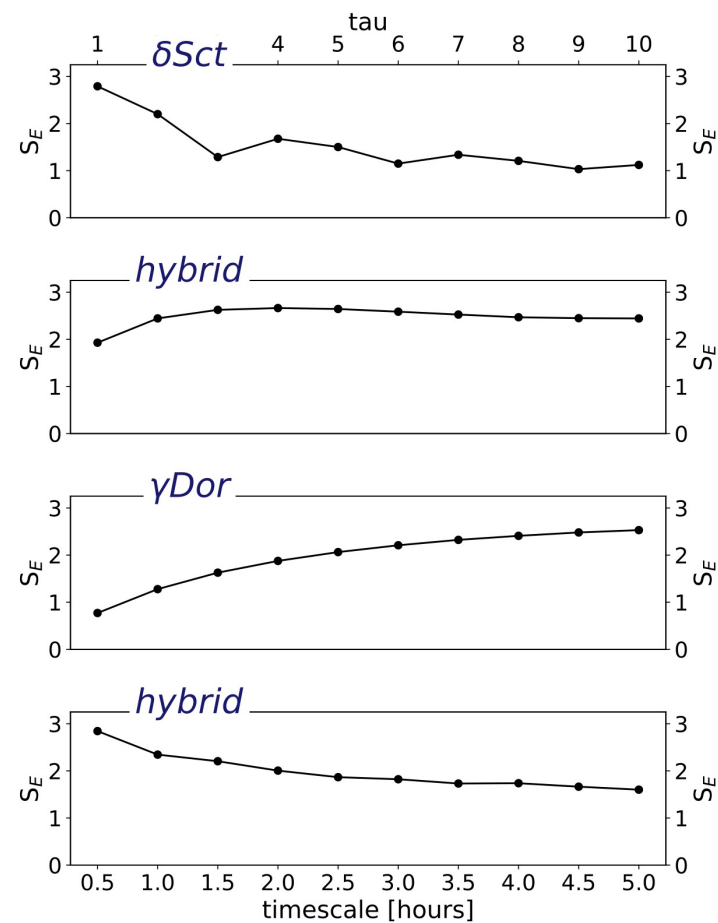


Mutiscale entropy example

Light curve / amplitude spectrum

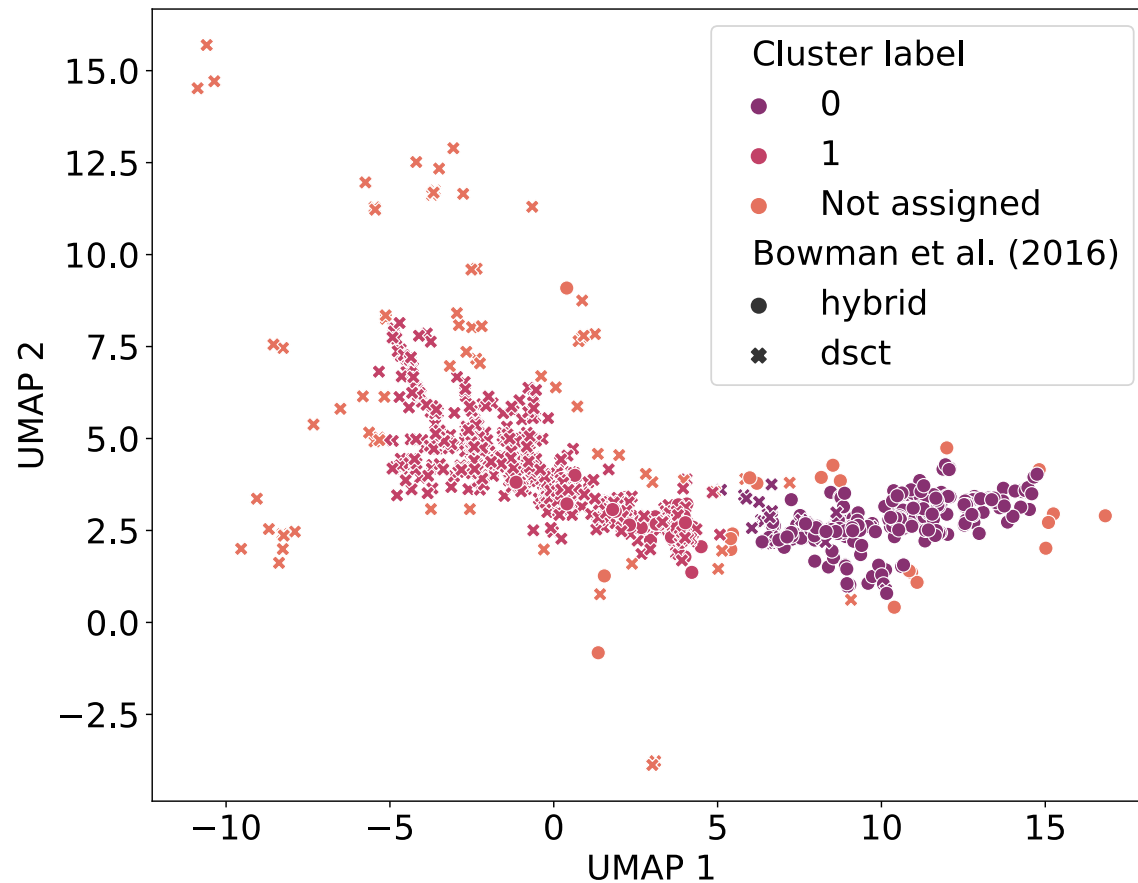


Multiscale entropy





δ Sct catalog (Bowman et al. 2016)

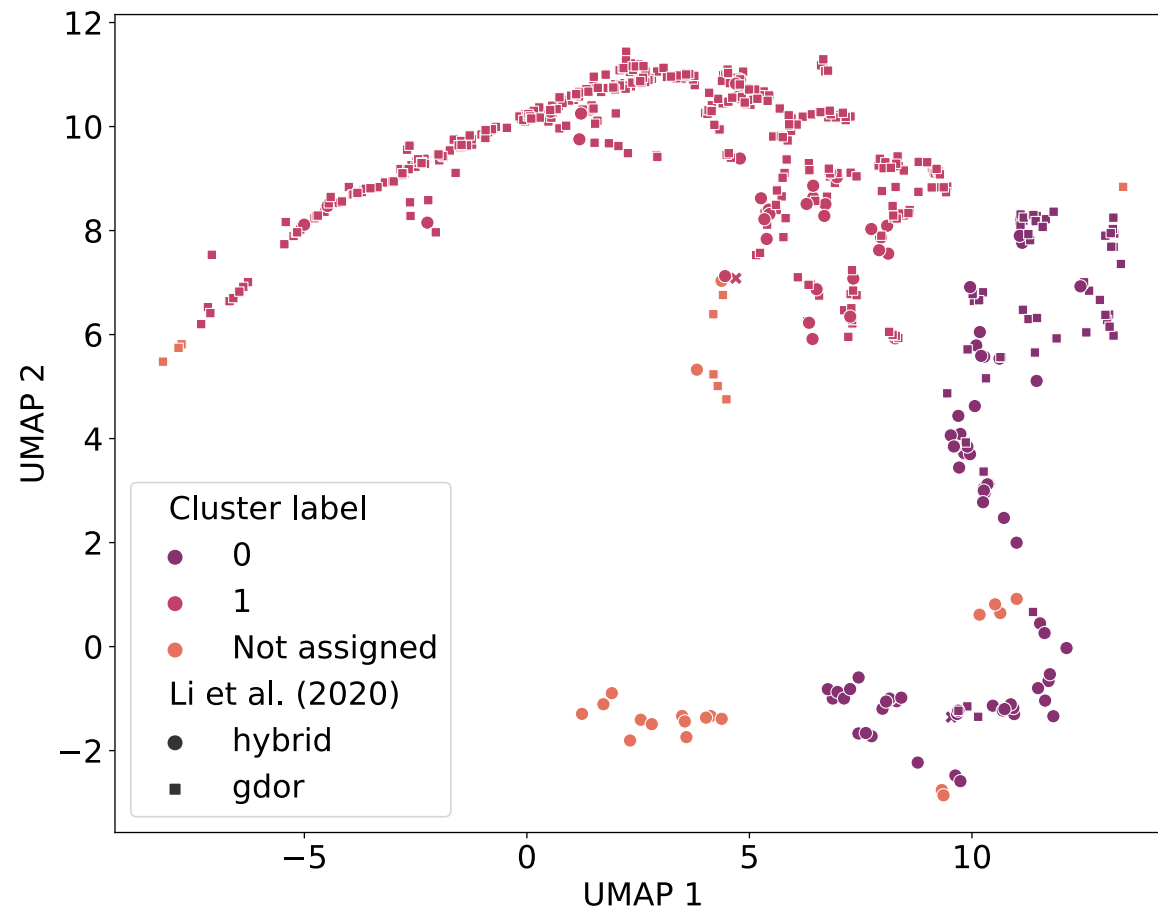


				Visual inspection from Bowman et al. (2016)		
		δ Sct	hybrid			
Cluster	0	39 (6.0%)	264 (79.0%)		303	
	1	527 (82.5%)	49 (14.7%)		576	
	Not assigned	83	21		104	
		649	334		983	

Table 1. Confusion matrix of the cluster assignments calculated with HDBSCAN and the class labels assigned by Bowman et al. (2016) based on visual inspection. The percentages are expressed in terms of the column total.



γ Dor catalog (Li et al. 2020)

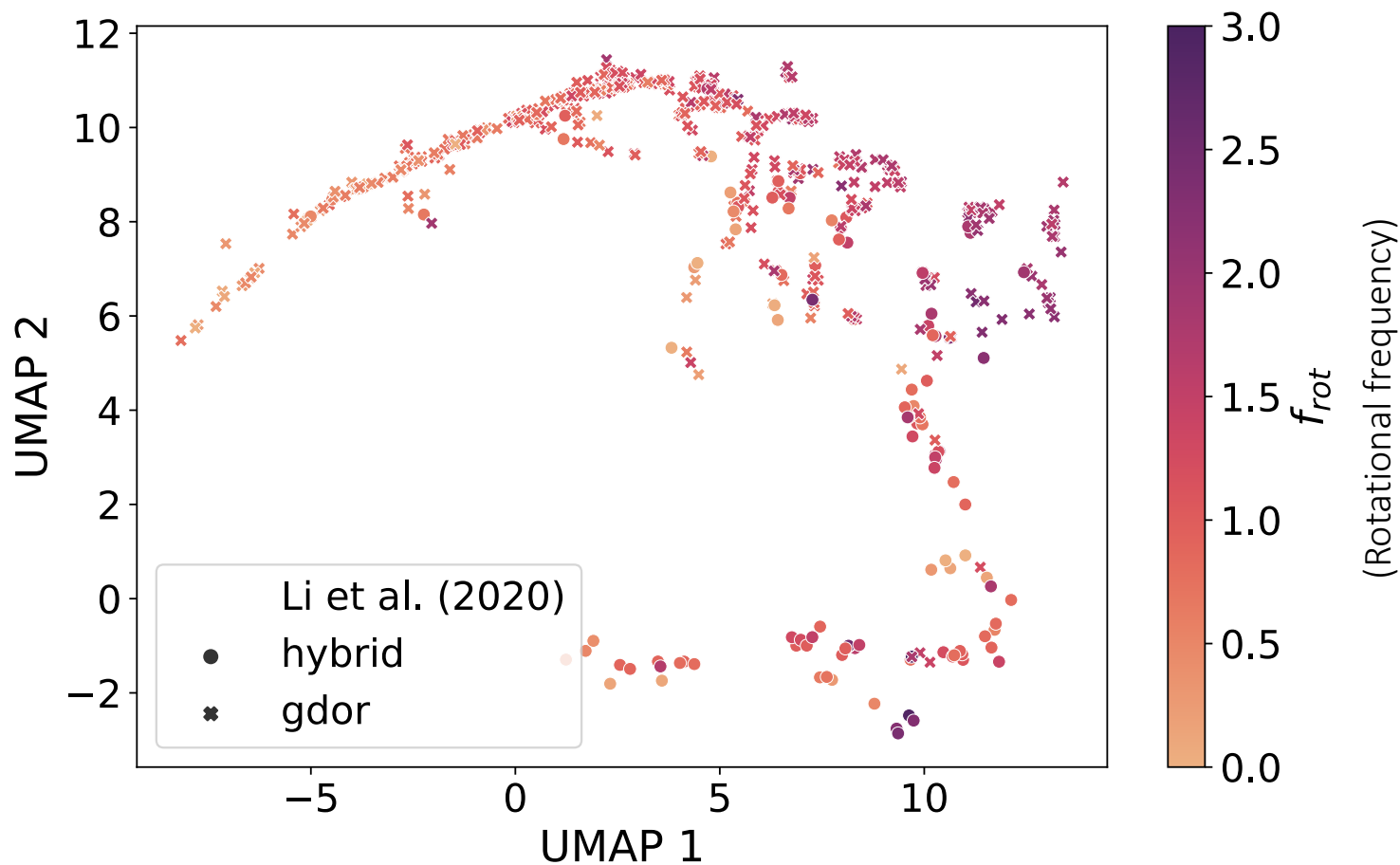


				Visual inspection from Li et al. (2020)		
		γ Dor	hybrid			
Cluster	0	59 (12.0%)	69 (59.0%)	130		
	1	426 (87.2%)	35 (29.9%)	462		
	Not assigned	3	13	16		
		488	117	605		

Table 2. Confusion matrix of the cluster assignments calculated with HDBSCAN and the class labels assigned by Li et al. (2020) based on visual inspection. The percentages are expressed in terms of the column total.



Coupling with asteroseismology for new physical insights





Conclusion

- Fast, stable and integrated pipeline for data processing (efficiency will be even more key in the future!)
- Time series processing techniques are interdisciplinary
→ Utilize the synergies across different domains
- TESS Asteroseismology pipeline & results:
 - Supervised classifier for high-level classification
 - Unsupervised classification detailed classification
 - Dimensionality reduction method captures physical information

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[arXiv:2107.06301](https://arxiv.org/abs/2107.06301)
[arxiv:2206.13529](https://arxiv.org/abs/2206.13529)



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