### **Photometric** Classification -12.5 of Transients -10.0-7.5and Variables -5.0 $W_{JK}$ -2.50.0

Cepheids (DCEP, DCEPS, CWA, CWB, RVA) Known, Prob>0.9 Delta Scuti (DSCT, HADS) Eclipsing Binaries (EA, EB, EW) N=114299 Mira Variables (M) RR Lyrae (RRAB, RRC, RRD) Rotational Variables (ROT) Semi-regular/Irregular Variables (SR, SRD, L) Young Stellar Objects (YSO) 2.5 5.0 -1 0  $\log_{10}(P/days)$ Jayasinghe+20

Eric Bellm ASTR 597A, Winter 2023

# Time-domain classification is foundational to astronomical science.

歷 蜀 宗 星 陛 土 不 起居舍 與 崩 10 绿 乍 雨 2 边 逐見 则 畏 失 1. 用 言决 諸 还 整、國 那 者。故事不决 言為 寒乍暑欲雨 a) 寒 名臣奏議 谈 事業委注而 那早 宗 數處 服 左 其性。其為 研 宗廟 小口 瞻望之 是 右 至和 謂 犯其為論戀甚可畏也 家体 太平之風奇 灾样 也。日陽 暑 非命 安口 然。何 輔 張 及周稳至今光耀 之著那臣愚伏 婢死而 "guest star" 社稷 省示 雨不雨又有黑氣蔽日與皆人事之意院范鎮上奏曰。臣伏見去冬多南 務當得忠賢剛正之 亦 戚 乞 SN 1054 火县公益 年 卷 電視 雨雲笛焦死。民 也。陳 許 從荒其為炎 22 治 高音員 2 款 也 妖星誦變也早膜炎冷也也 一君歌 福天 和 副 侍 謂 欲 動 之三百 誠 麵 御 退宰相為是郎乞速 賢人君子者能 中 而 可駭 史趙 足 之若然則陰 への教識影之言 态。伏 伯 中 下生靈之幸。 也黑氯蔽 起視事。無使 陽所 引領而待 望陛下謹天 過相の不 當罰 願陸 也。表愛調 謂 而 人為 F 艱 言 陽 病 日者陸侵陽小 不 调 而家居 目 副 in 慎重之故 自冠猿必興 天意久 臣 使 之乃可 永所 之戒應天 雨 陰 也 令春京東 居廟 通 陽君三公之 iR 臣朝夕思憲載惟擇賢命 + 見 災異以 謂 者 執 保 不决 震祥異也。 後發聖餅 堂 12 山臣 百 自 古 中 - 石至和 北 以富郎 ×. 所感 山思 風 去 有過於法 E 32 惑君 消 京房所調欲 家暴者漫到 年 留平 彩隆 今春 西 驟 伯 路及 朝 職 動 天 五 而 谷驚裂有薩 步 世 炎 12 三者答應 R 廷 天下 会感 也 天 月 务 力 也 不 1:2 黑 靖 3 氯 陝右 燕 行 熊 公农 西 不 e 岩 當為 家 雨 九盖 诮 明 雨 御 御 德 不 除 不 EE

# How far down the classification tree you descend depends on your scientific interest.



### Photometric variability alone does not distinguish all astrophysical classes.



### Astronomers use a range of classification methods.

Simple cuts on event properties

Spectroscopy

Template fitting

Host/environment

Parametric fitting

Featurized Machine Learning

Deep Learning & friends

"Physics-aware ML"

### Astronomers use a range of classification methods.



"Physics-aware ML"

#### Simple cuts can be surprisingly effective.



V~17.5 length=24" FWHM=2.1" V~18.5 length=32" FWHM=2.6"

V~14.3 length=34" FWHM=2.4"

V~16.6 length=36" FWHM=5.0"

Waszczak+17







#### Simple cuts can be surprisingly effective.

#### 2.2. Search Procedure

Every night, the ZTF alert stream is filtered by several independent pipelines to identify young or fast-evolving transients. In this paper we focus on events discovered via the approach described by Ho et al. (2020a) and Perley et al. (2021b). In short, basic cuts are applied to remove artifacts, asteroids, and stellar flares. Remaining transients are divided into several groups, including new transients (those with no detections prior to the current night). One of us (A.Y.Q.H., D.A.P., or Y.Y.) visually inspects the new transients and determines whether any meet the following criteria for afterglows.

- 1. A fast rise from the previous nondetection ( $\gtrsim 0.5$  mag day<sup>-1</sup>).
- 2. Red colors (g r > 0 mag) expected from optically thin synchrotron radiation (see Ho et al. 2020a) or rapid intranight fading in a single band.
- Either no, or a very faint, associated host in deep archival imaging from the Legacy Survey (Dey et al. 2019) or Pan-STARRS1 (Chambers et al. 2016).



# For supernovae spectroscopy provides the best classification.



Normalized flux [erg/cm²/s/Å]

### Robotic followup with the SEDM on P60 provides worldleading transient classification throughput.



### Robotic followup with the SEDM on P60 provides worldleading transient classification throughput.



# The ZTF Bright Transient Survey is the largest spectroscopic supernova survey ever.

Spectroscopic followup of all ZTF transients brighter than 18.5 mag Over 7000 classified objects to date

Fremling+20,

Perley+20

All events:												
mag ≤	19.0	18.5	18.0	17.5	17.0							
All typed	7368	4947	2614	1424	716							
All SNe	7266	4867	2562	1394	698							
la	5370	3606	1885	1035	529							
la-CSM	12	10	5	4	4							
lax	14	11	7	5	4							
lb/c	371	256	142	70	32							
lbn	24	18	12	6	2							
lc-BL	57	44	23	11	7							
SLSN-I	59	29	15	11	2							
II	1466	976	520	278	135							
llb	100	63	39	21	11							
lln	198	139	75	38	17							
SLSN-II	35	20	6	1	0							
TDE	43	30	15	5	4							
Gan	15	12	8	4	3							

https://sites.astro.caltech.edu/ztf/bts/



# Most LSST transients will be too faint for routine spectroscopy!



## Template fitting compares lightcurves to models or examplars of known transients.



#### List of built-in models %

Model name	Description	Reference(s)
default	Nickel-cobalt decay	1994ApJS92527N
CSM	Interacting CSM-SNe	2013ApJ77376C, 2020RNAAS416J
csmni	CSM + NiCo decay	See default & csm
ехрром	Analytical engine	
ia	NiCo decay + I-band	
ic	NiCo decay + radio	
magnetar	Magnetar engine w/ simple SED	2017ApJ85055N
magni	Above + NiCo decay	
rprocess	Kilonova	2017ApJ851L21V
kilonova	Kilonova	2017ApJ851L21V
bns	Kilonova + binary params + angle	2021arXiv210202229
slsn	Magnetar + modified SED + constraints	2017ApJ85055N
tde	Tidal disruption events	2018arXiv180108221

### Template fitting compares lightcurves to models or examplars of known transients.



Pros:

Conceptually straightforward Can sometimes constrain physical parameters

Can be slow to execute Need really good data/models "Searching under the lamppost"

#### Contextual/host galaxy information can aid classification.



GHOST: Gagliano+21

#### Parametric models can fit a variety of object types.



Model Phase

# Fit parameters and other lightcurve statistics can be used as features for machine learning models.

 Table 2

 List of Detection Features Used by the Light Curve Classifier

Sanchez-Saiz+21

Feature	Description	References
delta_period	Absolute value of the difference between the Multiband_period and the MHAOV period obtained using a single band	od This work
IAR_phi*	Level of autocorrelation using a discrete-time representation of a DRW model	Eyheramendy et al. (2018)
MHPS parameters*	Obtained from an MHPS analysis (three in total)	Arévalo et al. (2012)
positive_fraction	Fraction of detections in the difference images of a given band which are brighter than the template image	This work
Power_rate <sup>*</sup> ♦	Ratio between the power of the multiband periodogram obtained for the best period candidate and $2 \times P$ , $3 \times P$ , $4 \times P$ , $P/2$ , $P/3$ , or $P/4$	(P) This work
$PPE^* \blacklozenge$	Multiband Periodogram Pseudo Entropy	This work
$(g-r)_{max} \blacklozenge$	$g-r$ color obtained using the brightest lc_diff magnitude in each band	This work
(g−r)_max_corr ♦	$g-r$ color obtained using the brightest lc_corr magnitude in each band	This work
(g−r)_mean ♦	$g-r$ color obtained using the mean lc_diff magnitude of each band	This work
(g−r)_mean_corr ♦	$g-r$ color obtained using the mean lc_corr magnitude of each band	This work
delta_mag_fid	Difference between maximum and minimum observed magnitude in a given band	This work
ExcessVar**	Measure of the intrinsic variability amplitude	Allevato et al. (2013)
GP_DRW_tau**	Relaxation time $\tau$ from DRW modeling	Graham et al. (2017)
GP_DRW_sigma**	Amplitude of the variability at short timescales ( $t \ll \tau$ ), from DRW modeling	Graham et al. (2017)
Harmonics parameters**	Obtained by fitting a harmonic series up to the seventh harmonic (14 in total)	(Stellingwerf & Donohoe 1986)
Multiband_period** $\blacklozenge$	Period obtained using the multiband MHAOV periodogram	Mondrik et al. (2015)
Pvar <sup>**</sup>	Probability that the source is intrinsically variable	McLaughlin et al. (1996)
$SF_ML_amplitude^{**}$	rms magnitude difference of the SF, computed over a 1 yr timescale	Schmidt et al. (2010)
SF_ML_gamma <sup>**</sup>	Logarithmic gradient of the mean change in magnitude	Schmidt et al. (2010)
SPM features <sup>**</sup>	Supernova parametric model features (seven in total)	Villar et al. (2019)
Amplitude	Half of the difference between the median of the maximum 5% and of the minimum 5% magnitudes	Richards et al. (2011)
AndersonDarling	Test of whether a sample of data comes from a population with a specific distribution	Nun et al. (2015)
Autocor_length	Lag value where the autocorrelation function becomes smaller than Eta_e	Kim et al. (2011)
Beyond1Std	Percentage of points with photometric mag that lie beyond $1\sigma$ from the mean	Richards et al. (2011)
Con	Number of three consecutive data points brighter/fainter than $2\sigma$ of the light curve	Kim et al. (2011)
Eta_e	Ratio of the mean of the squares of successive mag differences to the variance of the light or	ITVE Kim et al (2014)
Gskew	Median-based measure of the skew	Saa dmtn_118 lest in for a
LinearTrend	Slope of a linear fit to the light curve	Dee <u>uniti-110.1351.10</u> 101 e
MaxSlope	Maximum absolute magnitude slope between two consecutive observations	raviaw of timesarias
Meanvariance	Ratio of the standard deviation to the mean magnitude	
MedianAbsDev	Median discrepancy of the data from the median data	- Daturas
MedianBRP	Fraction of photometric points within amplitude/10 of the median mag	

# Fit parameters and other lightcurve statistics can be used as features for machine learning models.

SNIa -	$76^{+7}_{-6}$	18 <sup>+5</sup>	5 <sup>+2</sup> <sub>-2</sub>	1+2	0+0	0+0	0+0 -0	$0^{+0}_{-0}$	0+0 -0	0+0 -0	0+0	0+0 -0	0+0	0^{+0}_{-0}	0+0
SNIbc -	33 <sup>+11</sup>	50 <sup>+17</sup>	$11^{+11}_{-6}$	$6^{+11}_{-6}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0_00+0	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0_0^+6
SNII -	$15^{+8}_{-4}$	$16^{+10}_{-5}$	53 <sup>+7</sup> -9	$17^{+9}_{-6}$	0+0	$0^{+2}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+2}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$
SLSN -	$0^{+28}_{-0}$	$0^{+1}_{-0}$	0+25	$100^{+0}_{-26}$	0+0	$0^{+1}_{-0}$	0_00+25	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$
QSO -	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0+0	87 <sup>+1</sup>	8 <sup>+0</sup> _0	$5^{+0}_{-1}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$
AGN	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0+0 -0	9 <sup>+2</sup> <sub>-1</sub>	85 <sup>+2</sup>	5 <sup>+2</sup> -1	$0^{+1}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$
Blazar-	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	17 <sup>+2</sup>	7 <sup>+1</sup> <sub>-2</sub>	74 <sup>+5</sup>	$1^{+1}_{-1}$	$1^{+2}_{-1}$	$0^{+1}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+1}_{-0}$
YSO -	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0+0 -0	0+0	$0^{+1}_{-0}$	$1^{+0}_{-1}$	78 <sup>+3</sup>	$0^{+1}_{-0}$	$4^{+1}_{-1}$	$1^{+1}_{-0}$	$0^{+1}_{-0}$	$1^{+2}_{-0}$	$3^{+1}_{-1}$	$11^{+2}_{-1}$
CV/Nova-	4 <sup>+5</sup> <sub>-3</sub>	2 <sup>+3</sup> 2 <sup>-1</sup>	$1^{+1}_{-0}$	0+0 -0	$0^{+1}_{-0}$	$0^{+0}_{-0}$	$1^{+1}_{-1}$	$1^{+2}_{-1}$	68 <sup>+5</sup> _5	$1^{+1}_{-1}$	3 <sup>+2</sup> <sub>-1</sub>	4 <sup>+2</sup> <sub>-2</sub>	$10^{+3}_{-3}$	$2^{+2}_{-1}$	$2^{+2}_{-1}$
LPV -	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0+0 -0	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$1^{+0}_{-0}$	0 <sup>+0</sup> <sub>-0</sub>	98 <sup>+0</sup>	0+0	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$1^{+0}_{-1}$	$1^{+0}_{-1}$
E	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$1^{+0}_{-0}$	$0^{+0}_{-0}$	74 <sup>+0</sup>	$7^{+0}_{-1}$	$3^{+0}_{-0}$	$4^{+0}_{-1}$	$12^{+1}_{-1}$
DSCT-	0+0	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	5 <sup>+3</sup> <sub>-2</sub>	89 <sup>+3</sup> -6	2 <sup>+3</sup> 2 <sup>-1</sup>	$1^{+1}_{-1}$	3+2
RRL-	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+1}_{-0}$	$0^{+0}_{-0}$	$4^{+1}_{-0}$	$4^{+0}_{-1}$	87 <sup>+0</sup>	$2^{+0}_{-0}$	$2^{+1}_{-0}$
CEP -	$0^{+0}_{-0}$	$0^{+1}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+1}_{-0}$	$1^{+1}_{-1}$	$0^{+1}_{-0}$	$0^{+2}_{-0}$	3+2	$1^{+2}_{-1}$	$11^{+5}_{-5}$	76 <sup>+4</sup> -5	9 <sup>+3</sup>
Periodic-Other -	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$0^{+0}_{-0}$	0+0	$0^{+0}_{-0}$	$0^{+0}_{-0}$	$1^{+1}_{-1}$	$1^{+1}_{-1}$	2 <sup>+0</sup> <sub>-1</sub>	$11^{+2}_{-3}$	3+1	5 <sup>+2</sup> <sub>-2</sub>	5 <sup>+2</sup> <sub>-2</sub>	73 <sup>+4</sup>
	SMIB	SNIDC	Shill	SISN	050	AGN	Blazar	150	CULNOVS	324	÷.	ost.	RRY	Æ	dic Ot
	Predicted label													NOL.	

Sanchez-Saiz+21

True label

# Deep learning approaches avoid the need for feature engineering.



20

# Deep learning approaches avoid the need for feature engineering.



See Jamal & Bloom 2020 for a review of network architectures.

# Separating known physics from unknown or nuisance parameters appears powerful.



# Separating known physics from unknown or nuisance parameters appears powerful.



ParSNIP Boone 2021

# Separating known physics from unknown or nuisance parameters appears powerful.



& can aid la cosmology by marginalizing over classification

ParSNIP Boone 2021

# The ELAsTiCC classification challenge is currently preparing community alert brokers for LSST.



### **Brokers & Alerts**

Alerts generated from simulations are streamed to the **ZTF alert distribution server**, and from there to brokers. DESC ingests classifications into a database which also holds truth tables from the original simulation.

https://portal.nersc.gov/cfs/lsst/DESC\_TD\_PUBLIC/ELASTICC/

# The ELAsTiCC classification challenge is currently preparing community alert brokers for LSST.

#### AMPEL v0.4



Show ElasticcLiveSNGuessParsnip (XGBUnified+Parsnip05)

Show ElasticcLiveSNGuessParsnipPrior (XGBUnified+Parsnip05)

#### ANTARES 2.0.0

Show Astrorapid\_filter (known\_redshift=True)



Show LightGBM\_filter (v3)

Show REFLECT\_subclass\_v1 (v1)

Show REFLECT\_v1 (v1)

#### **Fink 2.4**

Show AGN classifier version 1.0 (Probability to NOT be an AGN based on a Random Forest classifier)

Show AGN classifier version 1.0 (Probability to be an AGN based on a Random Forest classifier)

Show CATS broad classifier version 1.0 (Level 1 classifier based on the CBPF Algorithm for Transient Search)

### The ELAsTiCC classification challenge is currently preparing community alert brokers for LSST.

	ALERCE 3.1.0 balto																			
la -	1.0% 13393	29.0% 490432	10.0% 165706	27.0% 455702	2.0% 28356	0.0% 702	0.0% 50	0.0% 86	0.0% 71	0.0% 55	14.0% 231881	3.0% 52497	0.0% 7253	0.0% 4498	13.0% 219322	0.0% 9	0.0% 13	0.0% 25	0.0% 10	2.0% 40621
Ib/c -	2.0% 6228	12.0% 42022	32.0% 112642	14.0% 50171	3.0% 10295	0.0% 780	0.0% 53	0.0% 34	0.0% 12	0.0% 30	12.0% 43826	3.0% 12091	1.0% 2077	2.0% 7175	13.0% 44901	0.0% 1	0.0% 7	0.0% 5	0.0% 6	6.0% 22281
II -	2.0% 32592	5.0% 97607	6.0% 108315	40.0% 720939	2.0% 35617	0.0% 1205	0.0% 161	0.0% 92	0.0% 34	0.0% 87	14.0% 250882	17.0% 295909	1.0% 13508	1.0% 15763	6.0% 104631	0.0% 7	0.0% 9	0.0% 32	0.0% 34	6.0% 104174
lax -	1.0% 684	14.0% 6716	5.0% 2250	20.0% 9461	12.0% 5691	0.0% 60	0.0% 8	0.0% 1	0.0% 0	0.0% 5	12.0% 5664	13.0% 6445	0.0% 232	1.0% 629	17.0% 8237	0.0% 0	0.0% 1	0.0% 0	0.0% 0	4.0% 1995
91bg -	3.0% 1059	4.0% 1488	35.0% 13811	6.0% 2326	5.0% 1852	8.0% 2989	0.0% 50	0.0% 6	0.0% 2	0.0% 3	7.0% 2927	3.0% 1192	1.0% 207	2.0% 653	18.0% 6902	0.0% 0	0.0%	0.0% 2	0.0% 0	9.0% 3676
KN -	2.0% 1	0.0%	10.0% 5	10.0% 5	4.0% 2	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	12.0% 6	12.0% 6	6.0% 3	0.0% 0	10.0% 5	0.0% 0	0.0% 0	0.0% 0	0.0% 0	31.0% 15
M-dwarf Flare -	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	39.0% 514	5.0% 68	23.0% 303	0.0% 6	0.0% 0	0.0% 0	0.0% 0	0.0% 0	5.0% 66	5.0% 72	11.0% 141	11.0% 151	0.0%
Dwarf Nova -	0.0% 1	0.0% 0	0.0%	0.0% 0	0.0%	0.0%	0.0% 0	0.0% 9	81.0% 2330	9.0% 262	0.0% 1	0.0% 1	0.0% 0	0.0%	0.0% 0	2.0% 55	4.0% 107	2.0% 65	1.0% 35	0.0%
uLens -	0.0%	0.0%	0.0%	0.0% 0	0.0%	0.0%	0.0%	0.0% 1	2.0% 43	94.0% 1690	0.0% 3	0.0%	0.0%	0.0%	0.0%	1.0% 11	2.0% 27	1.0% 15	0.0% 8	0.0% 0
SLSN -	0.0% 53	0.0% 155	2.0% 542	8.0% 2628	1.0% 400	0.0% 10	0.0% 1	0.0%	0.0% 7	1.0% 292	67.0% 22835	2.0% 686	0.0% 87	6.0% 1971	13.0% 4341	0.0%	0.0% 0	0.0% 5	0.0% 26	1.0% 184
j≞ TDE -	0.0% 12	0.0% 50	0.0% 16	4.0% 638	1.0% 91	0.0% 9	0.0% 0	0.0%	0.0% 0	0.0% 0	6.0% 862	80.0% 11658	0.0% 20	0.0% 8	2.0% 359	0.0%	0.0%	0.0% 0	0.0%	5.0% 768
ILOT -	0.0% 5	1.0% 8	1.0% 15	9.0% 106	3.0% 31	1.0% 6	0.0% 1	0.0%	0.0% 0	0.0% 1	21.0% 242	16.0% 186	8.0% 97	0.0% 5	30.0% 352	0.0% 0	0.0%	0.0% 0	0.0% 0	10.0% 122
CART -	1.0% 114	3.0% 291	5.0% 428	20.0% 1810	6.0% 514	0.0% 23	0.0% 3	0.0%	0.0% 1	0.0% 0	20.0% 1800	19.0% 1716	1.0% 54	5.0% 445	13.0% 1160	0.0% 0	0.0%	0.0% 1	0.0% 0	7.0% 586
PISN -	0.0%	0.0% 0	1.0% 2	1.0% 3	0.0%	0.0% 1	0.0%	0.0%	0.0%	0.0%	17.0% 60	1.0% 3	1.0% 4	0.0% 1	79.0% 275	0.0% 0	0.0%	0.0% 0	0.0%	0.0% 1
Cepheid -	0.0%	0.0% 0	0.0%	0.0% 0	0.0% 0	0.0% 0	0.0%	0.0%	0.0%	1.0% 9	0.0% 0	0.0% 0	0.0% 0	0.0%	0.0% 0	97.0% 1226	0.0% 3	2.0% 28	0.0% 2	0.0% 0
RR Lyrae -	0.0%	0.0% 0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% 1	0.0% 5	0.0% 115	0.0% 1	0.0%	0.0%	0.0%	0.0% 0	0.0% 106	92.0% 43070	6.0% 2983	1.0% 408	0.0%
Delta Scuti -	0.0%	0.0%	0.0%	0.0% 0	0.0%	0.0%	0.0%	0.0%	0.0% 2	0.0% 19	0.0%	0.0%	0.0%	0.0%	0.0%	2.0% 203	2.0% 140	95.0% 8401	1.0% 48	0.0%
EB -	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0% 6	0.0% 10	1.0% 1299	0.0% 97	0.0%	0.0%	0.0%	0.0%	0.0% 85	2.0% 1749	3.0% 3003	94.0% 102389	0.0%
AGN -	0.0% 54	0.0% 188	0.0% 146	0.0% 193	1.0% 574	1.0% 600	0.0%	0.0%	0.0%	0.0%	0.0% 79	4.0% 3806	0.0% 192	0.0%	0.0%	0.0%	0.0%	0.0% 7	0.0% 22	94.0% 90370
	- Jer -	- -	- 2/c		- xe	- 6q	NX	- au	- ev	- SU	- NS	- JOE -	- TO	RT -	- NS	- pia	- ae	uti -	EB	Z
	SN-like/Oth		2		-	91	-	M-dwarf Fla	Dwarf No	nLe	SLS	F	Ϋ́.	CA	Ы	Cephé	RR Lyr	Delta Sci	-	AC

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