Highlights of the LINEAR survey

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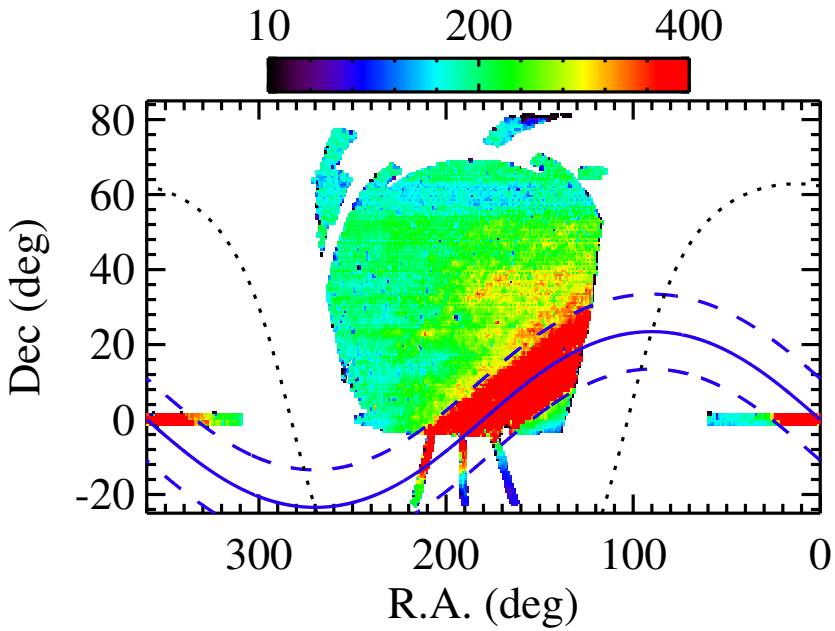
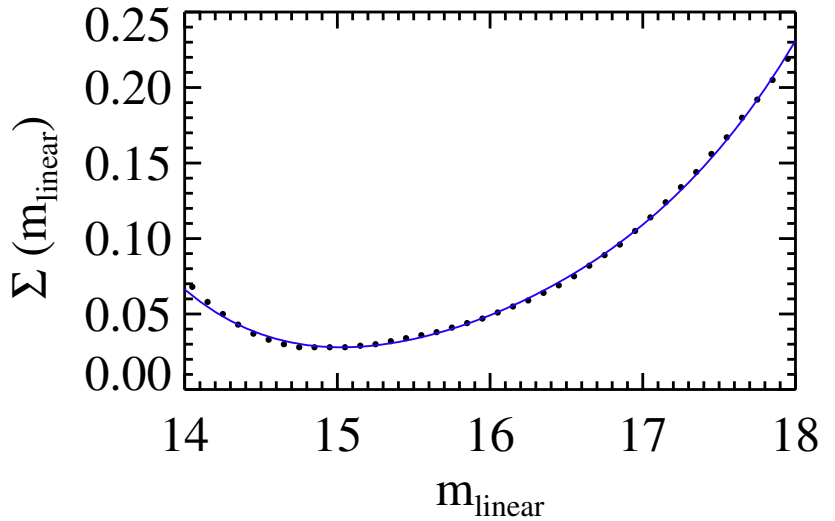
The Milky Way Unravelled by Gaia
Barcelona

LINEAR Asteroid Survey

Data

- time series 1998-2009
- 8,000 deg^2
- unfiltered observations $14 < r < 17.5$
- 5×10^9 measurements for 25×10^6 objects
- crossmatch with SDSS, 2MASS, WISE
- SDSS based photometric recalibration
- Sesar (2011)





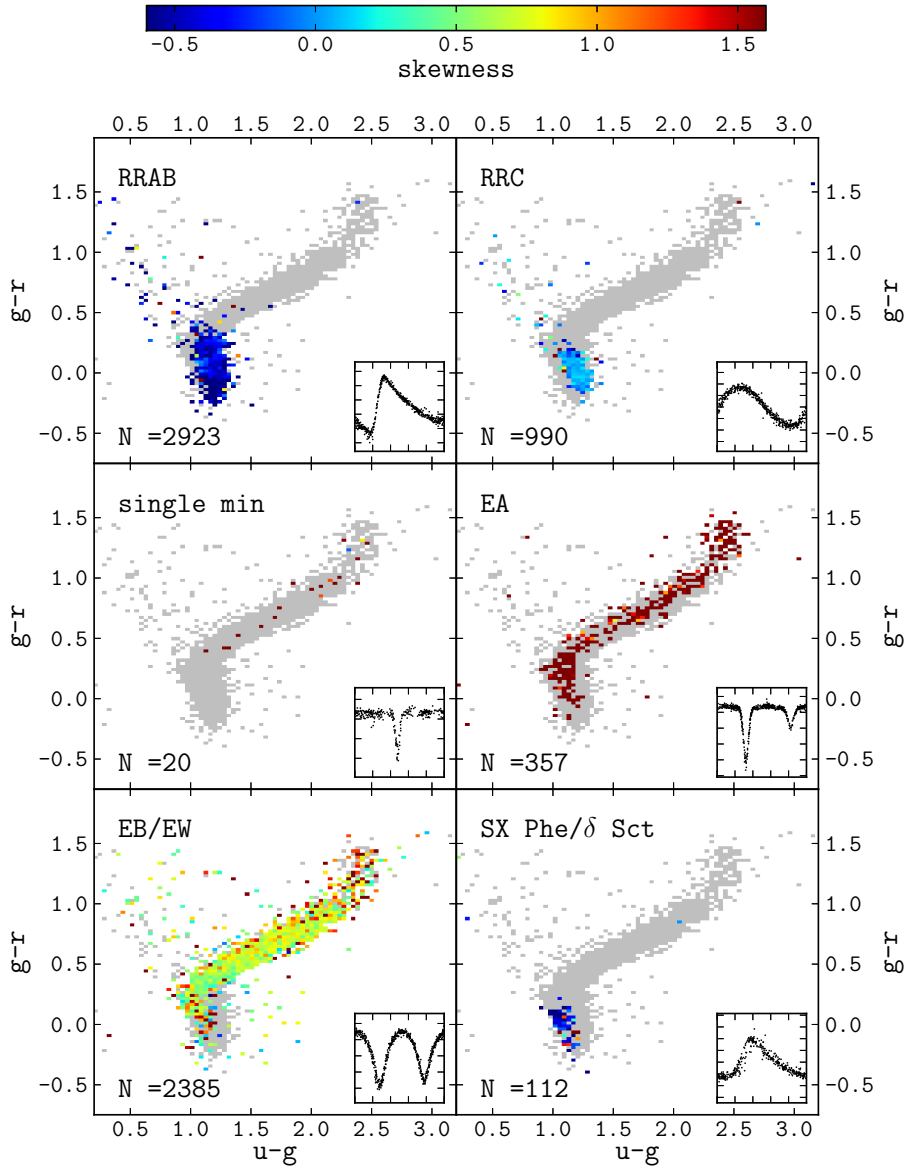
Periodic LINEAR Variables

Low level cuts

- brightness: $14 < m_L < 17.5$
- likely variability: $\chi^2_{dof} > 3$
- variability amp.: $\sigma > 0.1$ mag
  $\Longrightarrow$ **200,000 candidates**

Visual classification procedure

- phased LC inspected twice
- aided by colors, LC data
- checked against VSX, GCVS, SDSS S82, CSDR2
- purity: 98%
- completeness: 55-75%

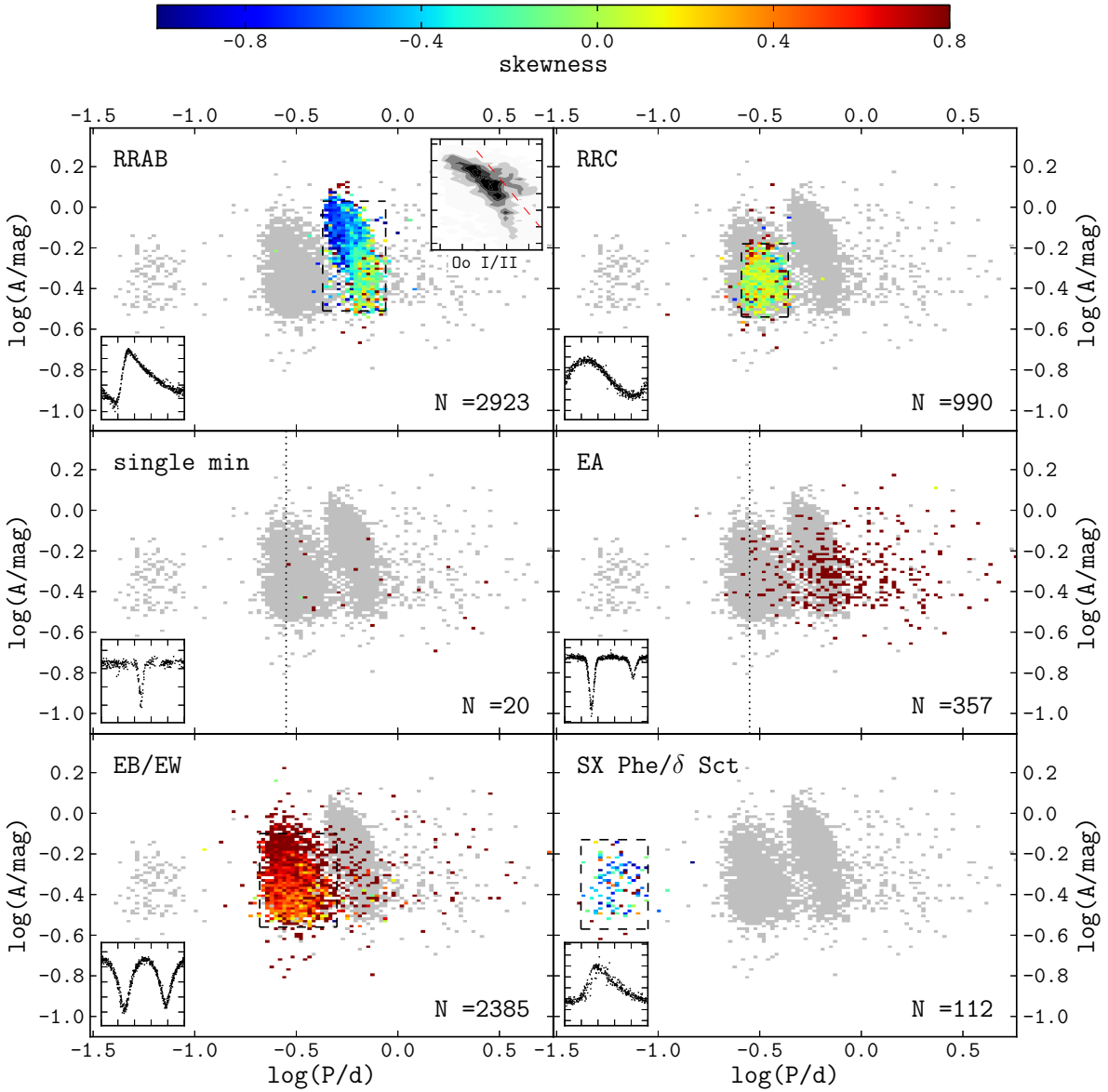


Periodic LINEAR Variables

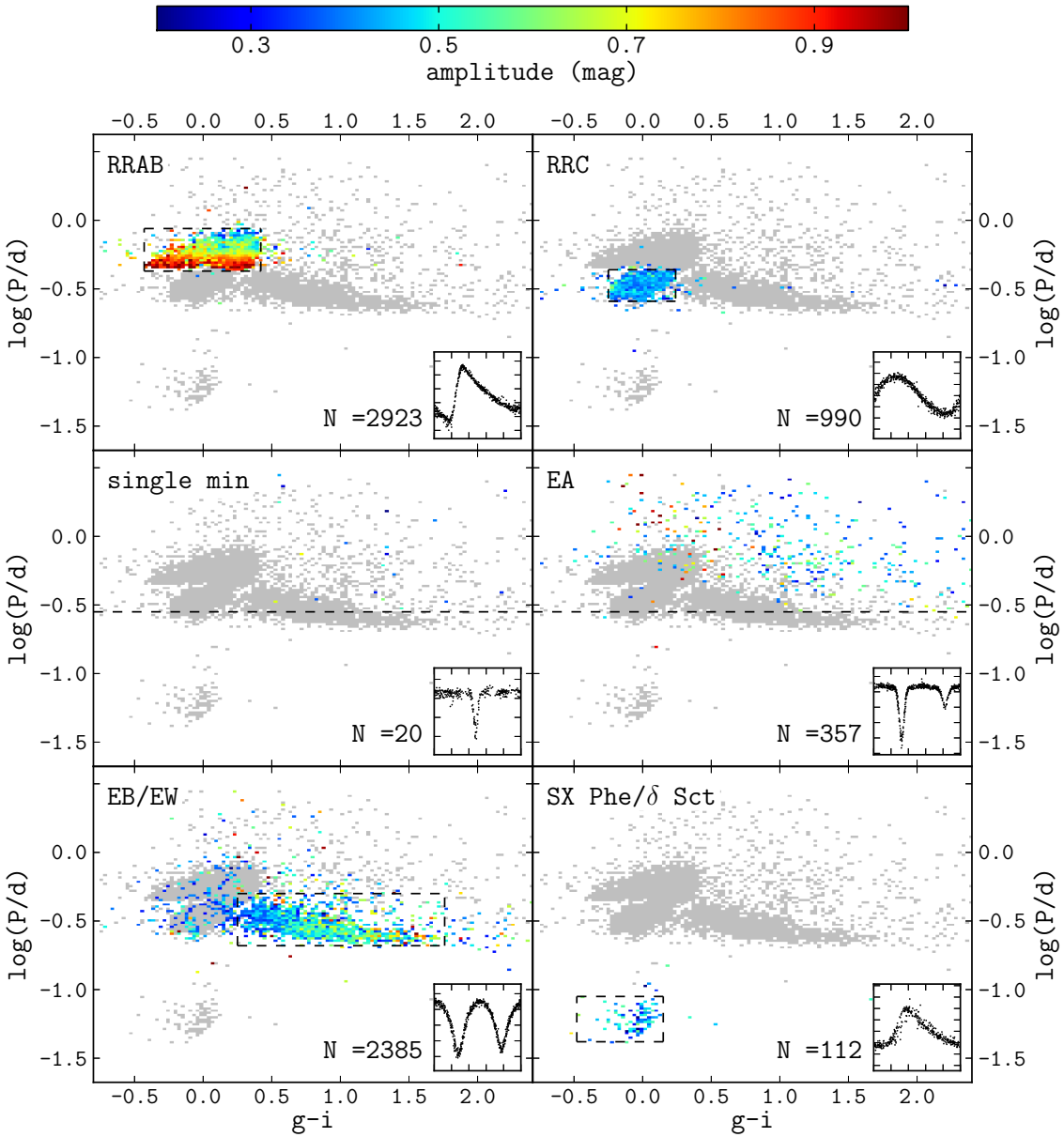
PLV catalog

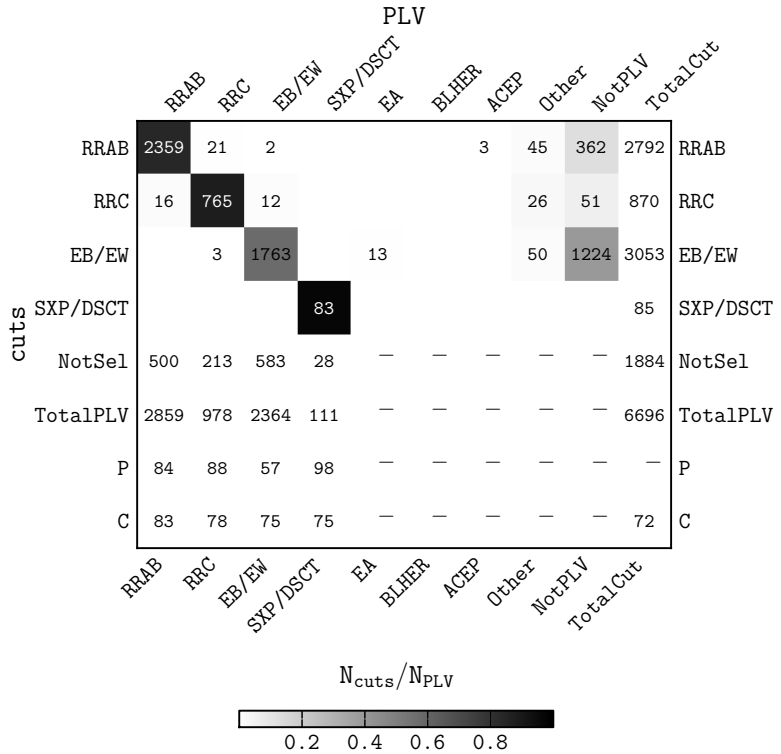
Type	F [%]	N
RRAB	41	2923
RRC	14	990
SM	<1	20
EA	5	357
EB/EW	33	2385
SXP/DSCT	2	112
LPV	1	77
BL Her	<1	6
ACEP	<1	5
Other	4	319
Total	100	7194

Palaversa et al. (2013)



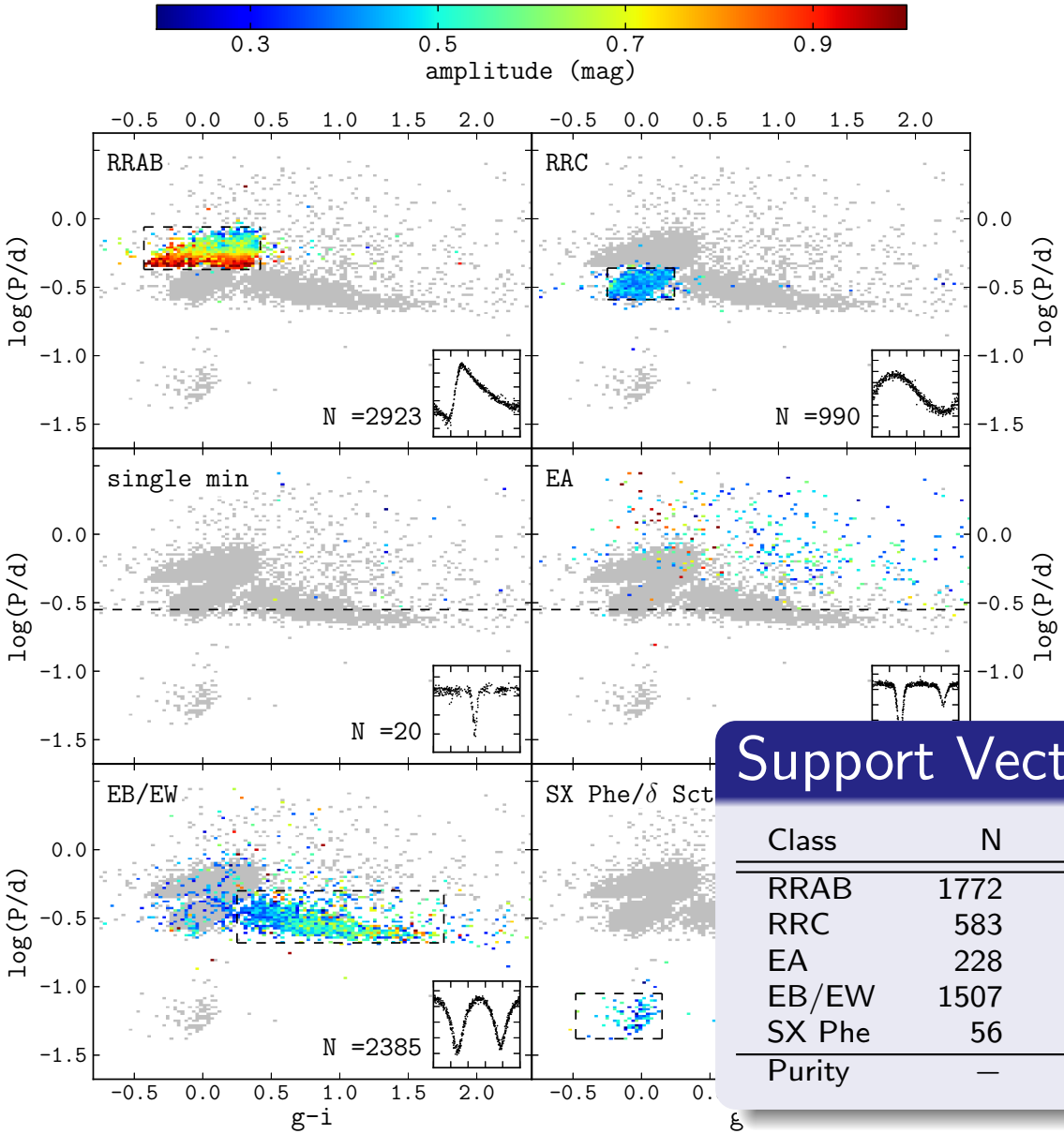
Classification comparison

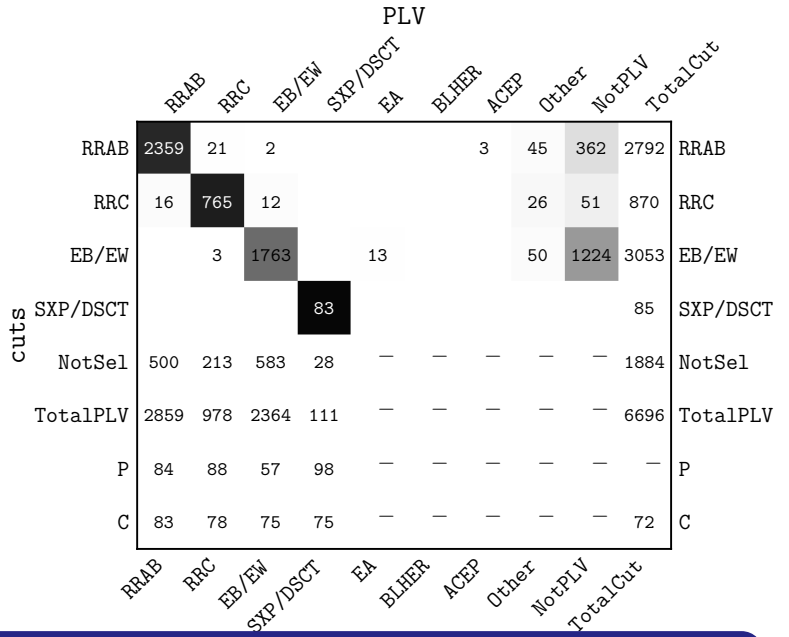




- Simple cuts as a classification tool

Classification comparison

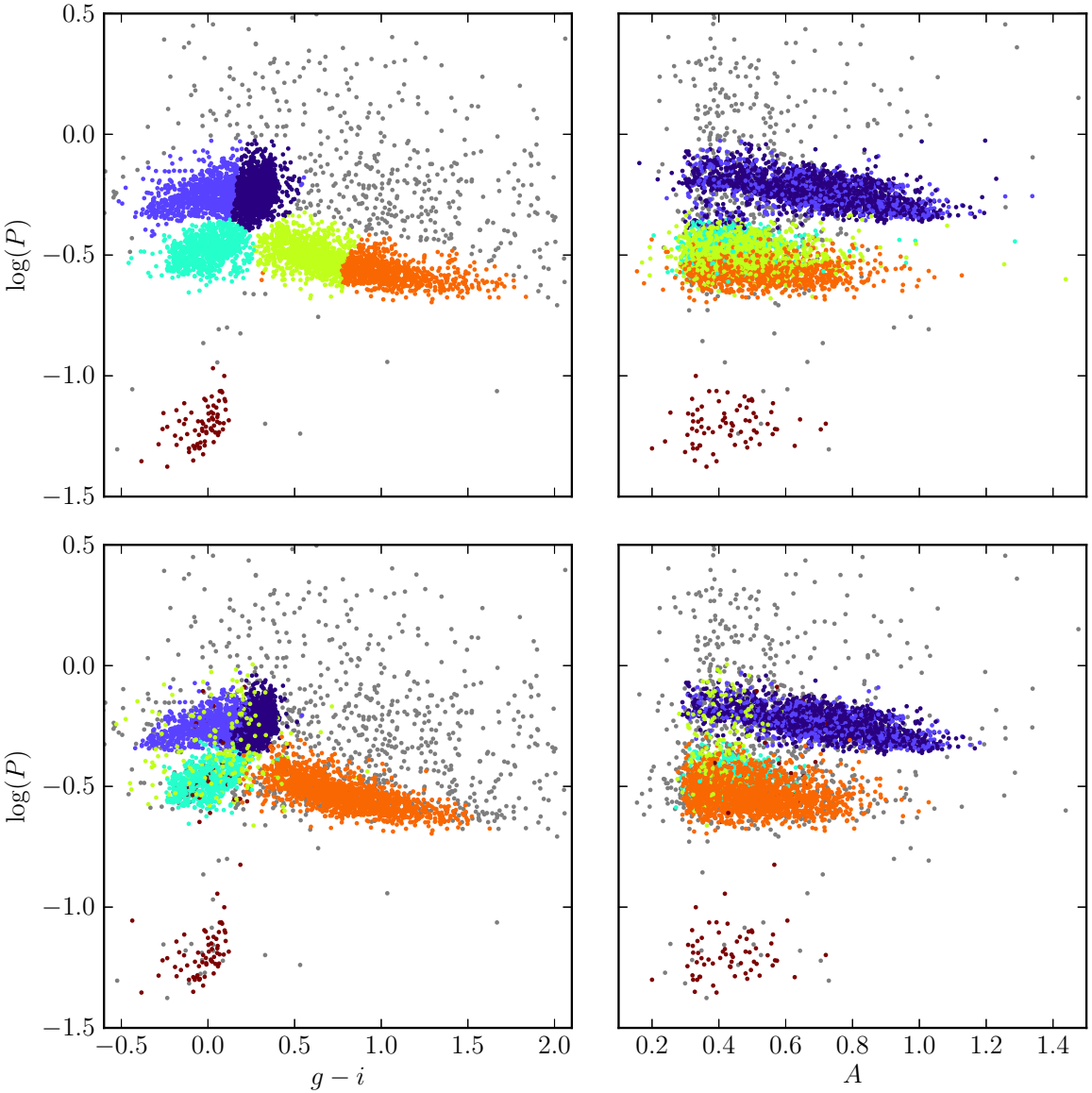




Support Vector Machine

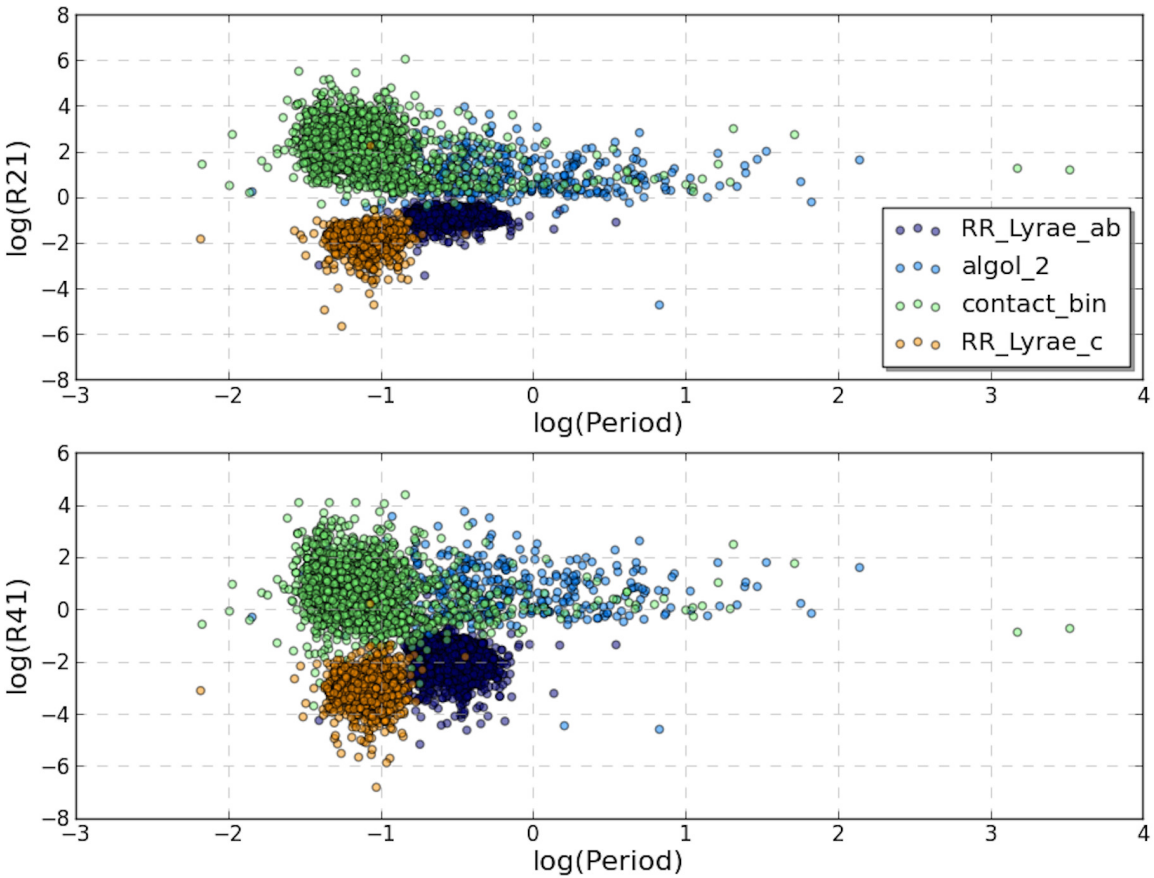
Class	N	RRAB	RRC	EA	EB/EW	SX Phe
RRAB	1772	95.9	0.3	1.4	2.4	0.0
RRC	583	1.5	91.3	0.2	7.0	0.0
EA	228	5.3	1.3	67.5	25.9	0.0
EB/EW	1507	2.1	4.0	3.1	90.7	0.1
SX Phe	56	0.0	1.8	0.0	1.8	96.4
Purity	—	97	88.4	68.4	90.5	98.2

Gaussian Mixture Model with astroML



- top row
  -attributes: g-i and logP
  -mixture of 12 Gaussians
- bottom row
  -attributes: u-g, g-i, i-K, J-K, logP, A, skewness
  -mixture of 15 Gaussians
- colors mark six most compact clusters

Decision trees & K Nearest Neighbors from astroML



- SDSS and 2MASS colors
- LC shape parametrized through three Fourier coefficient ratios
- Addition of LC shape brings the automated classification to a level at least as good as the human classification!

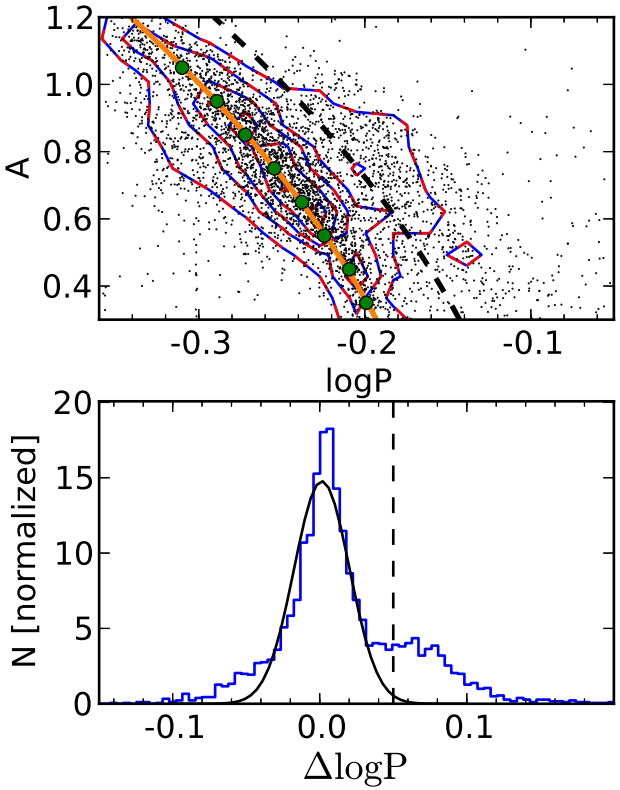
Next Step

Evaluate performance of Gaia CU7 classification pipeline

Pulsating stars

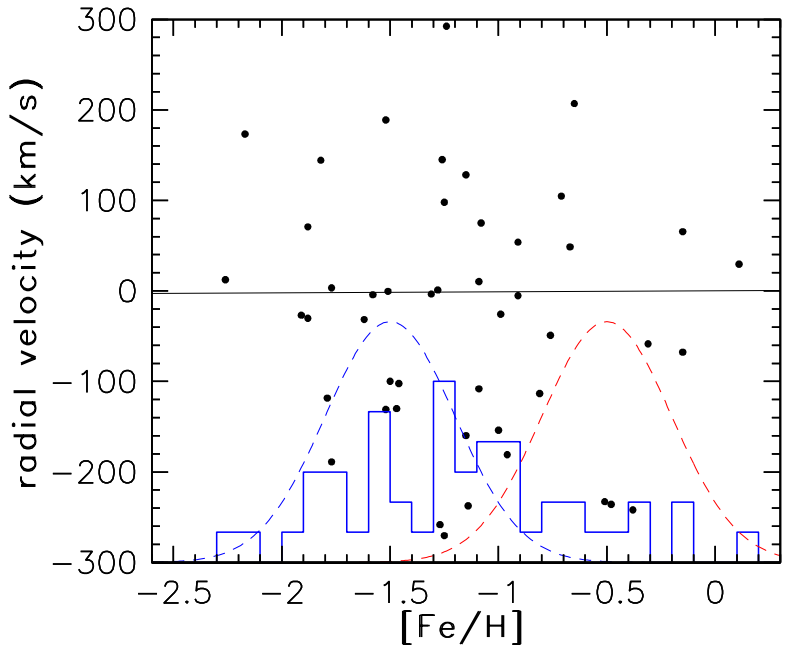
Halo RR Lyrae

- Oosterhoff dichotomy
- structure & substructure up to 23kpc
- Sesar et al. (2013)



SX Phoenicis stars

- blue stragglers, $1h < P < 2.5h$
- Population I counterparts of δ Sct
- $\sim$ 250 in GC, $\sim$ 17 field SX Phe
- LINEAR: 112 candidates, all field
- 35 confirmed (SDSS spectra)



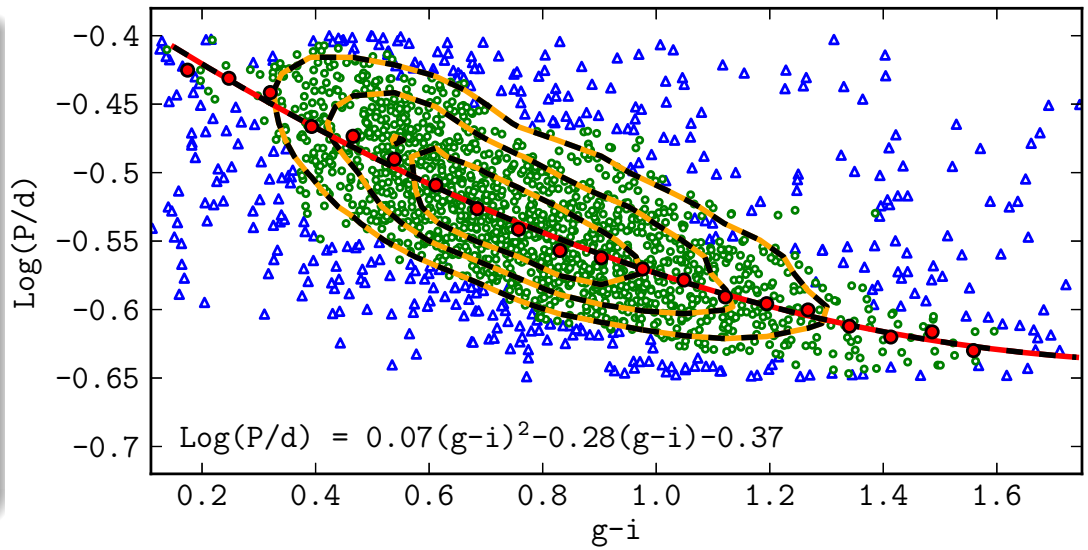
Contact binaries

Color-period relation for EW binaries

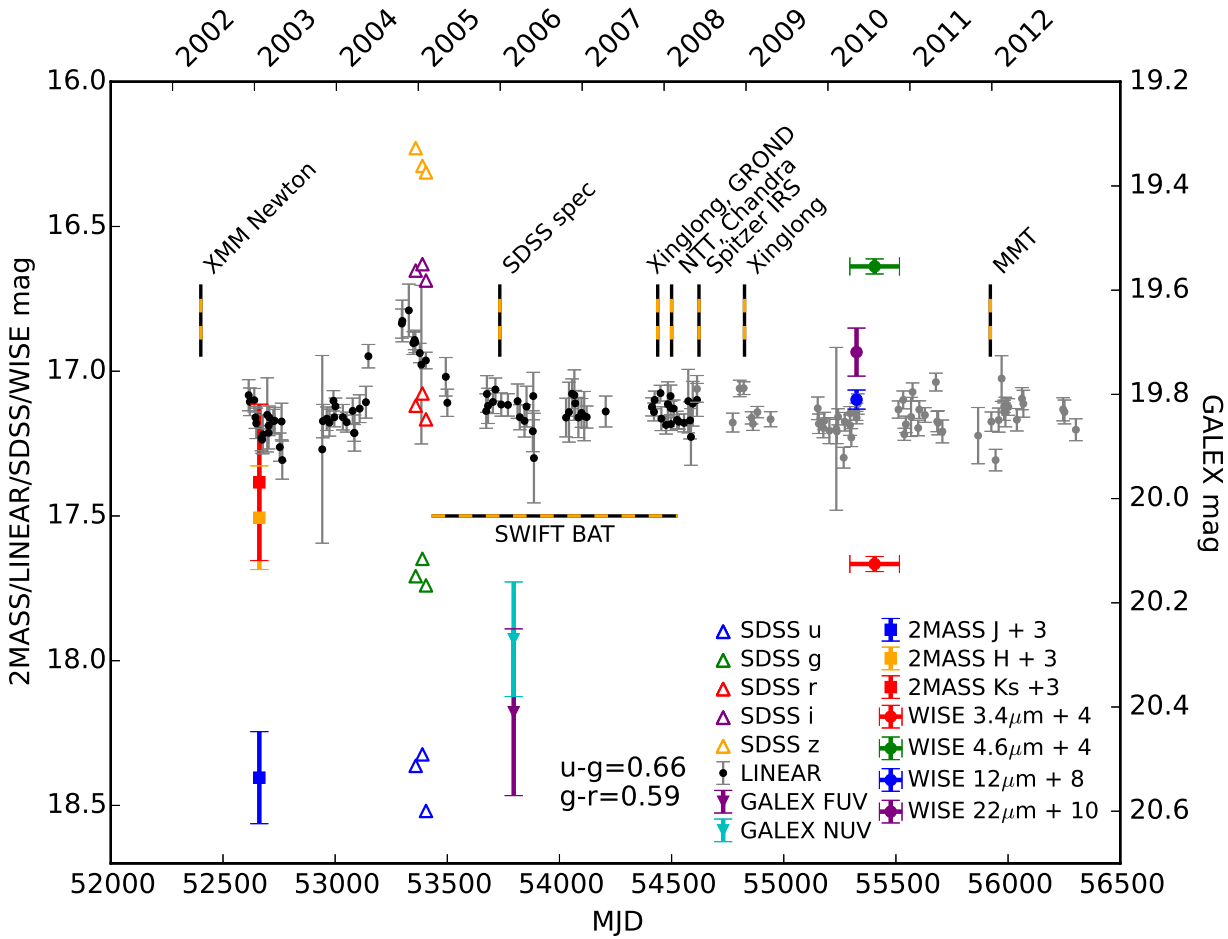
- $(g - i = 0.3)$ F5 $\longrightarrow$ K4 $(g - i = 1.4)$ [Covey (2007)]
- Period: 8.8h $\longrightarrow$ 5.9h
- similar relation found by Eggen (1967) (small sample)
- $1 < M_V < 6$ [Rucinski & Duerbeck (1997)]

P lower limit

- $\approx$ 0.22 d Rucinski (1992)
- $\approx$ 0.20 d Dimitrov & Kjurkchieva (2010), Davenport (2013)
- <0.2 d Drake (2014)

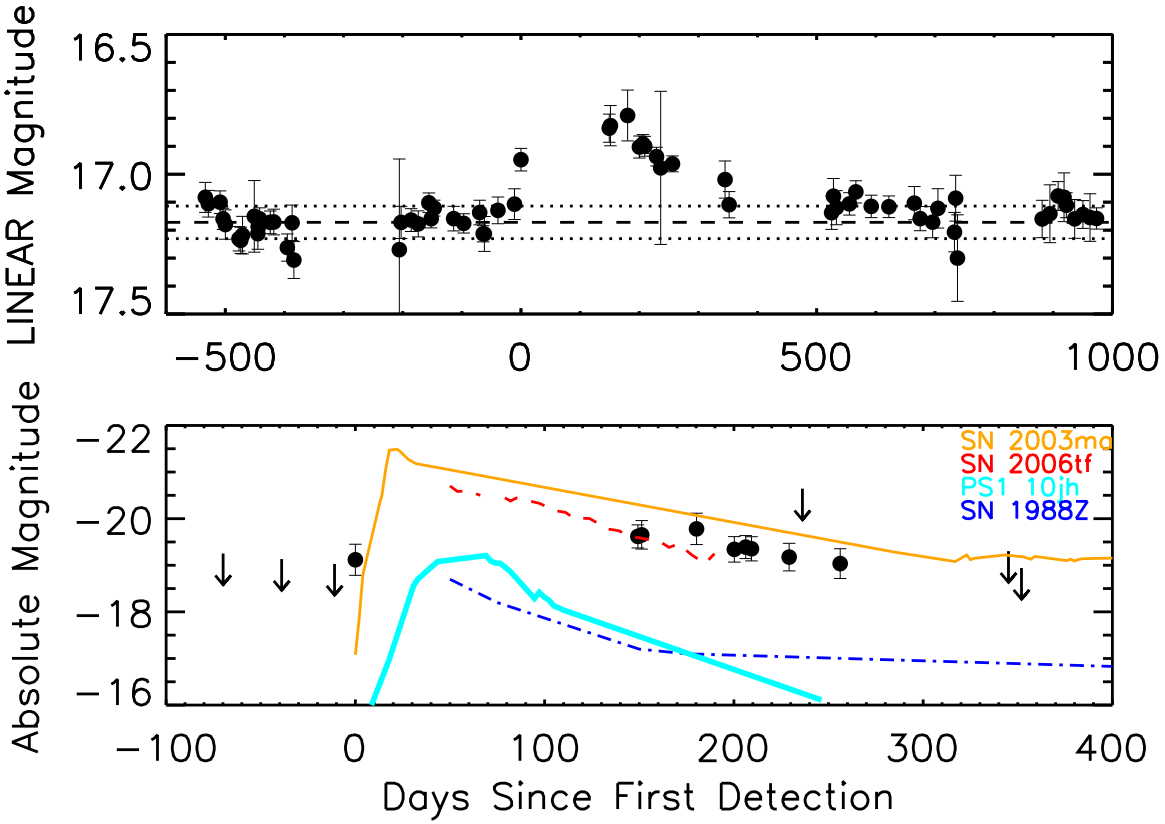


Transient science and alerts from large surveys



- baseline $\approx$ 11yr
- check for historical variability and/or existing classification
- to be included in Gaia science alerts pipeline

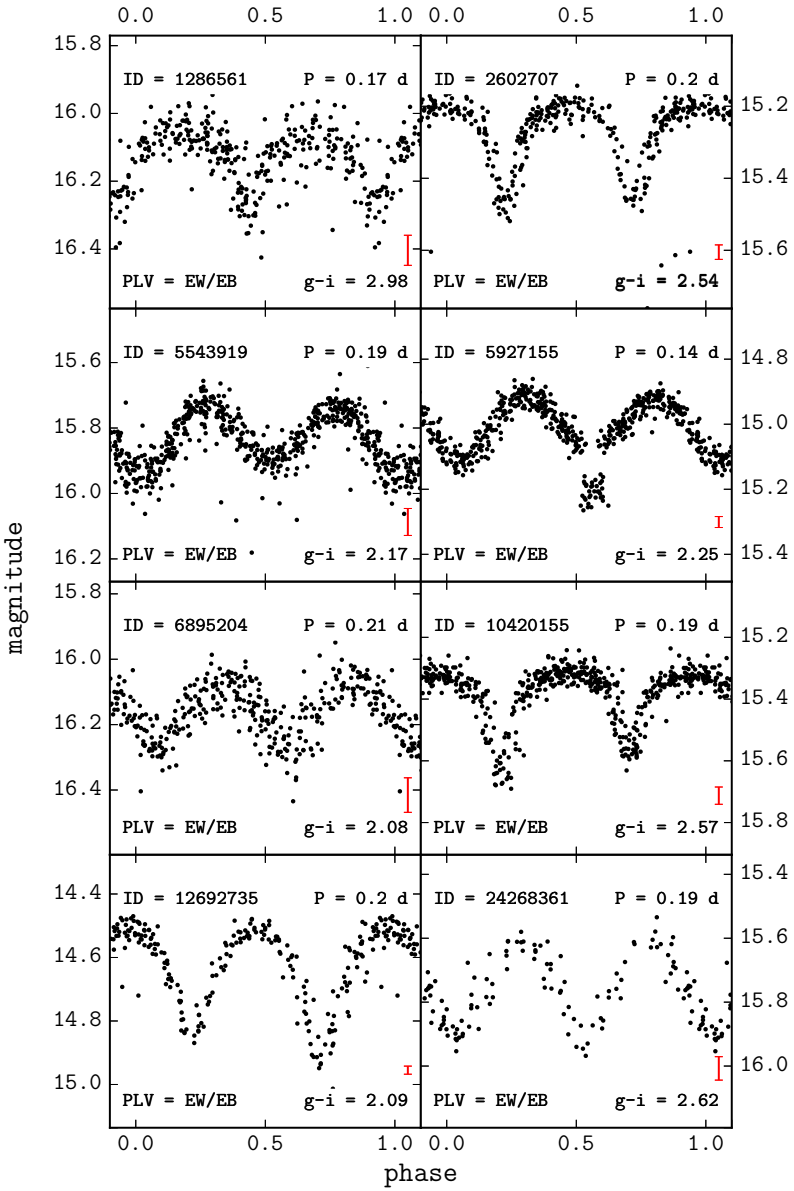
Extreme coronal-line emitter SDSS J095209.56+214313.3

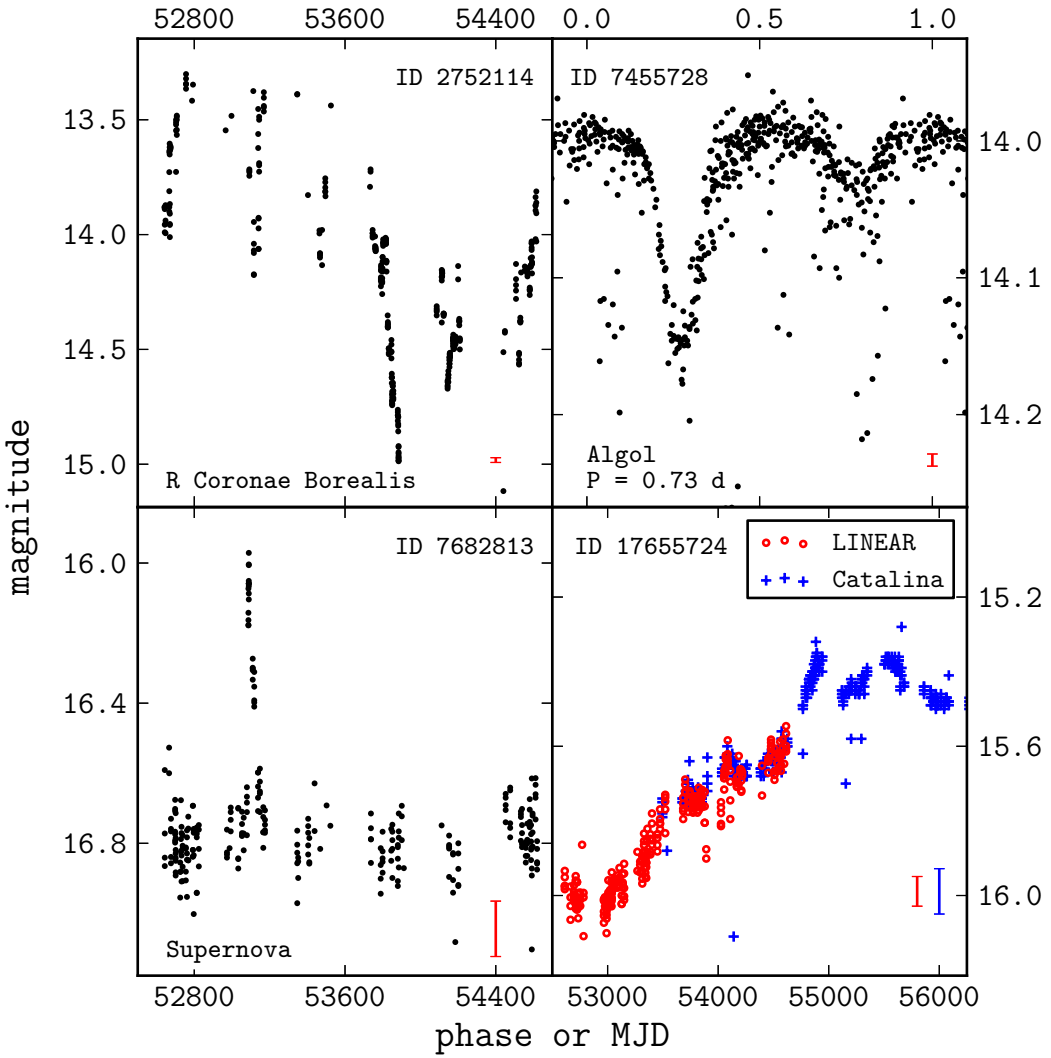


SNIIn ~~or TDE?~~

- difference imaging $\Rightarrow$ flare $\approx$ 340pc from host galaxy core
- exact event date
- likely scenario: extreme supernova

Some noteworthy objects





PLV catalog

Conclusion

- very clean sample of halo variable stars (faint, wide)
- physics of binary & pulsating stars
- machine learning training sample for large surveys
- good baseline for transients (GSA)
- data available online via http://skydot.lanl.gov/, Vizier
- "lost data set" brought back to life

Thanks

Thanks

- Željko Ivezić, Laurent Eyer, Branimir Sesar, Suvi Gezari, Przemyslaw Wozniak, J. Scott Stuart, Lorenzo Rimoldini, Domagoj Ruždjak, Davor Sudar, Mario Galin, Andrea Kroflin, Martina Mesarić, Petra Munk, Dijana Vrbanec, Hrvoje Božić, Sarah Loebman, Nicholas Hunt-Walker, Jacob VanderPlas, David Westman, Andrew C. Becker, Gregor Srdoč, Hakeem Oluseyi