Study of short period variables and small amplitude periodic variables

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supervised by:
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Is Gaia able to detect short periodic phenomena?

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How to assess the performance of Gaia on short period variability?

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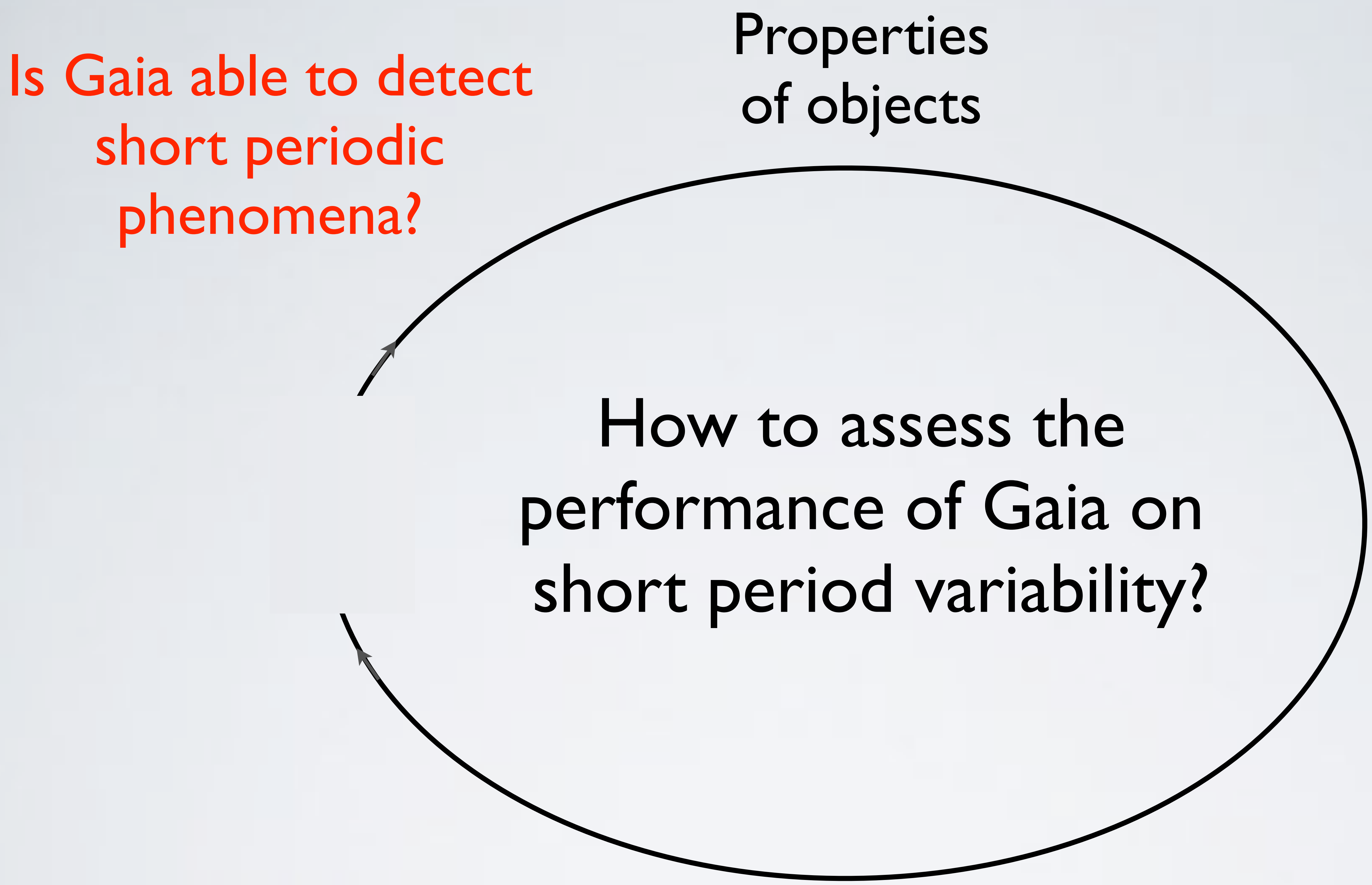
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Properties of objects
How to assess the performance of Gaia on short period variability?

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Mission Properties

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Detection Algorithm

\+

Statistics

$\Downarrow$

false positive

false negative

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Tests on simulated data

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Types & Properties Of Short Period Variables

TYPE	periods [minute]	amplitudes [mag]
β Cep	96 - 480	< 0.1
δ Scuti stars	28 - 480	0.003 - 0.9
roAp stars	6 - 21	< 0.01
EC14026 stars	1.3 - 8.3	< 0.03
Betsy stars (PG1716)	33 - 150	< ~0.01
ZZ Ceti stars (DAV)	0.5 - 25	0.001 - 0.3
V777 Her stars (DBV)	2 - 16	0.001 - 0.2
GW Vir stars (DOV + PNNVs)	5 - 85	0.001 - 0.2
Brown Dwarf pulsators	~60-~210	?
eclipsing white dwarfs	> 6	< 0.75

DQV, ...

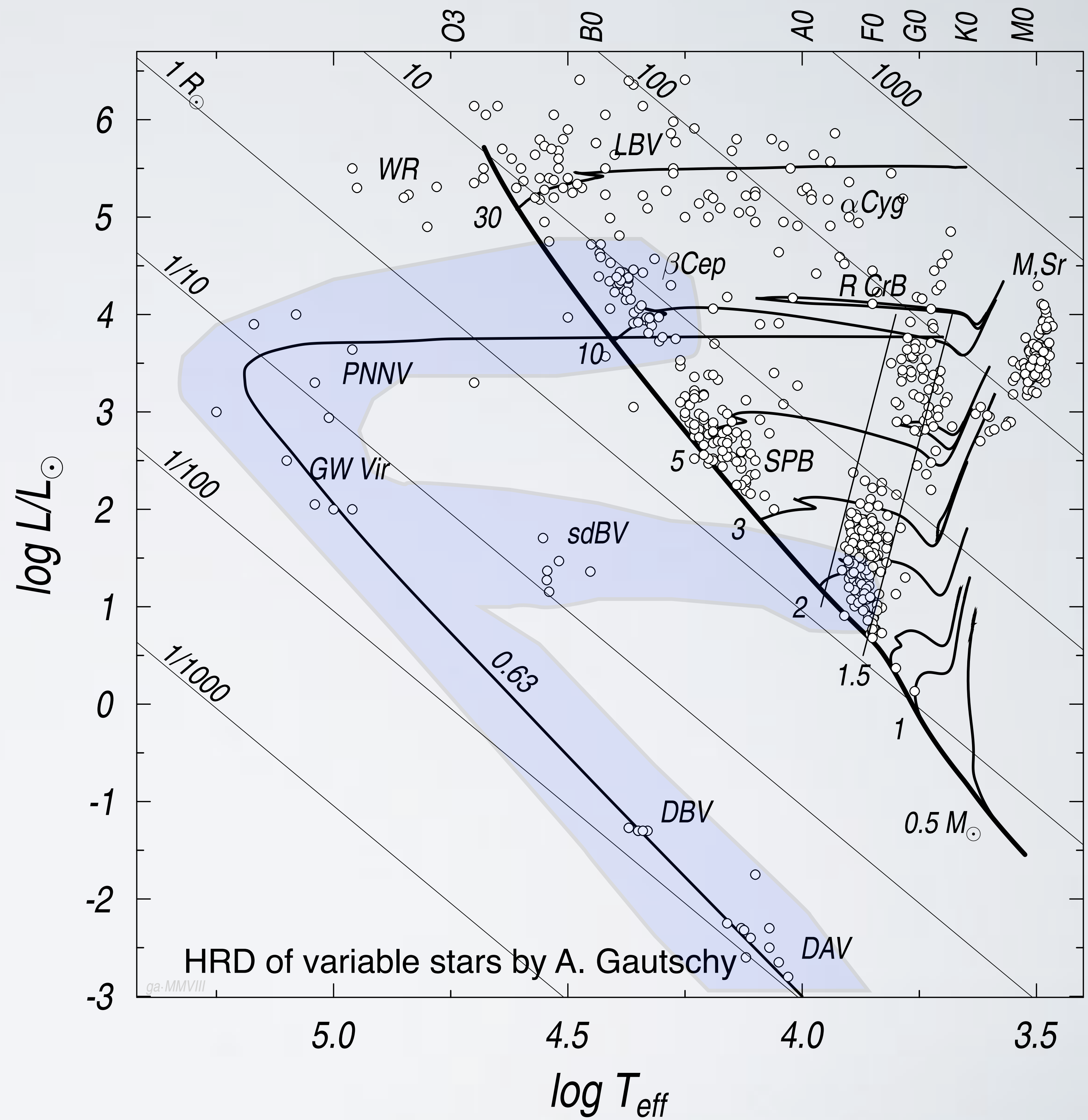
short period < 120 min

Properties Of Objects

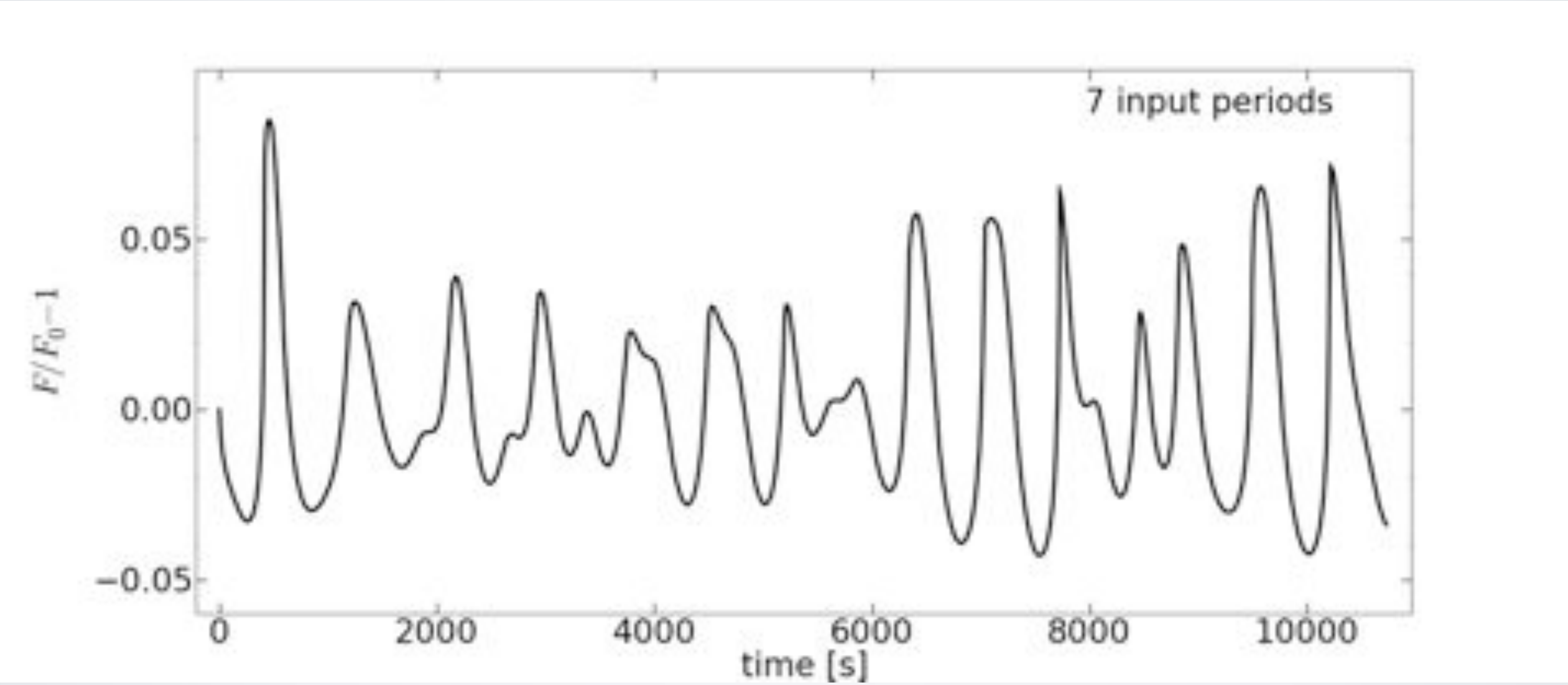
short periods: < 120 min

High astrophysical interest

- pulsation theories
- stellar evolution
- physics of degenerate matter
- gravitational waves



Properties Of Objects - Complex Lightcurves

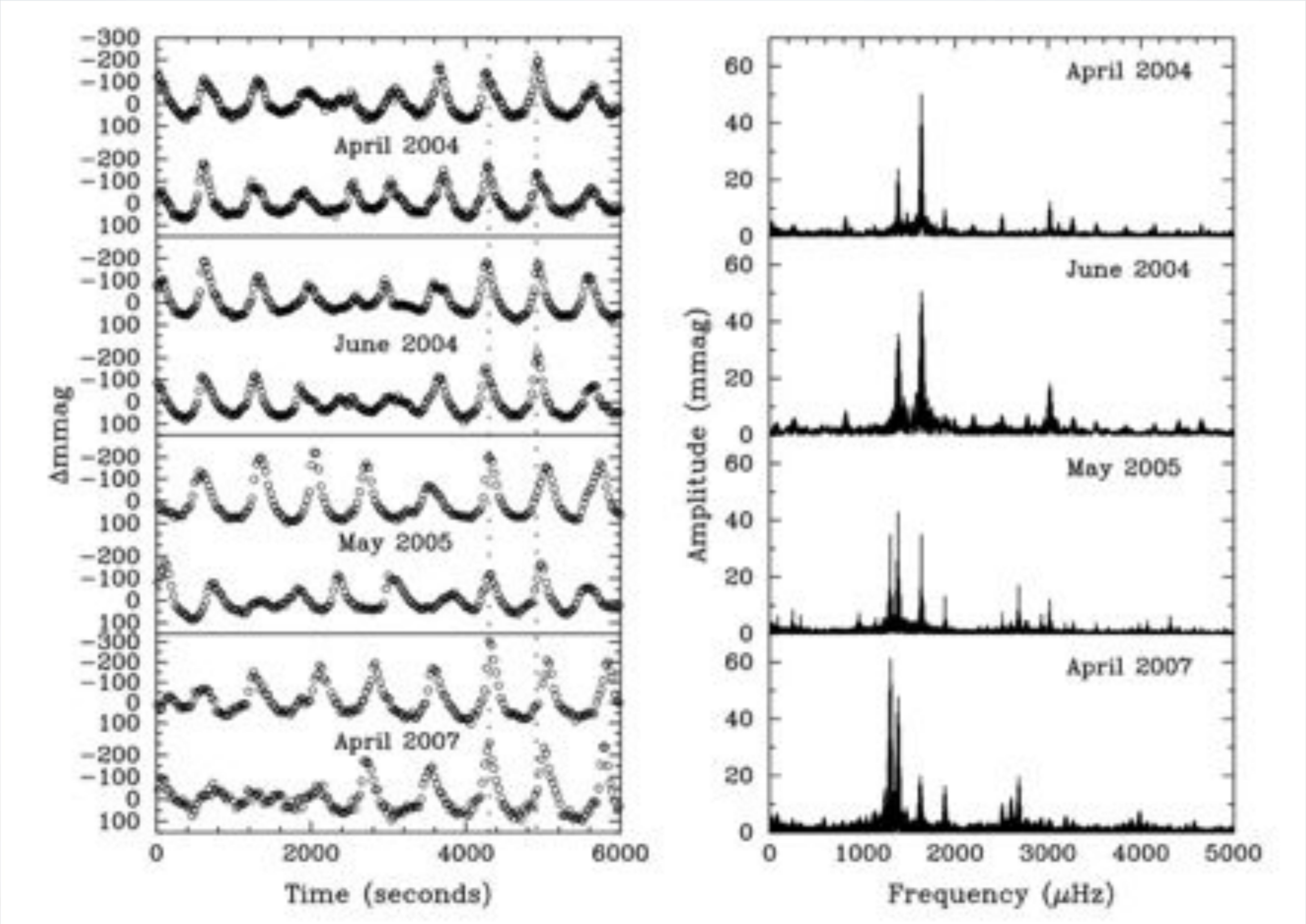


A typical ZZ Ceti star GD29-38

ZZ Ceti lightcurve simulator:

- work of D. Koester, S. Schlundt
- code implemented by M. Varadi
- collaboration with S. Jordan

Properties Of Objects - Non-Stationary Spectra



Pulsating DA white dwarf star EC 14012−1446 Handler et al. (2008)

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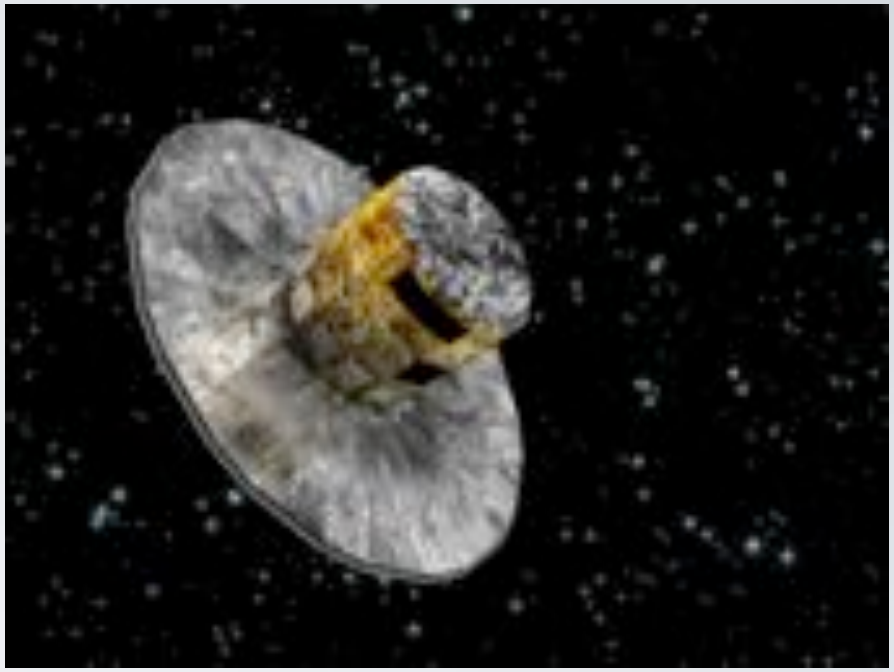
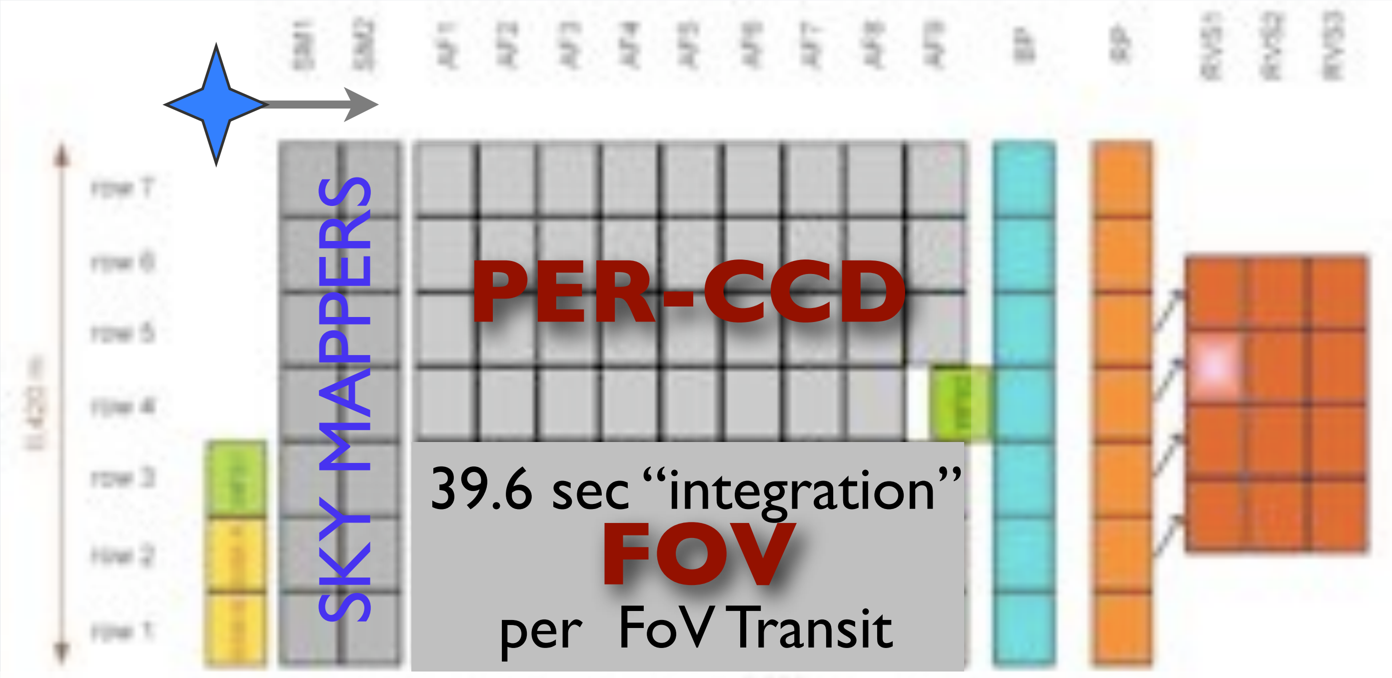
Gaia Mission Properties

- All sky observations (one billion stars)
- Multi-epoch data over 5 years
  - photometric (G band)
  - spectrophotometric
  - radial velocity (<17 mag)



Credit: ESA, http://www.rssd.esa.int/Gaia

- Resolution in time:
  - around 70 transit measurements per source in average
  - 1 transit: 9x4.4 sec integration



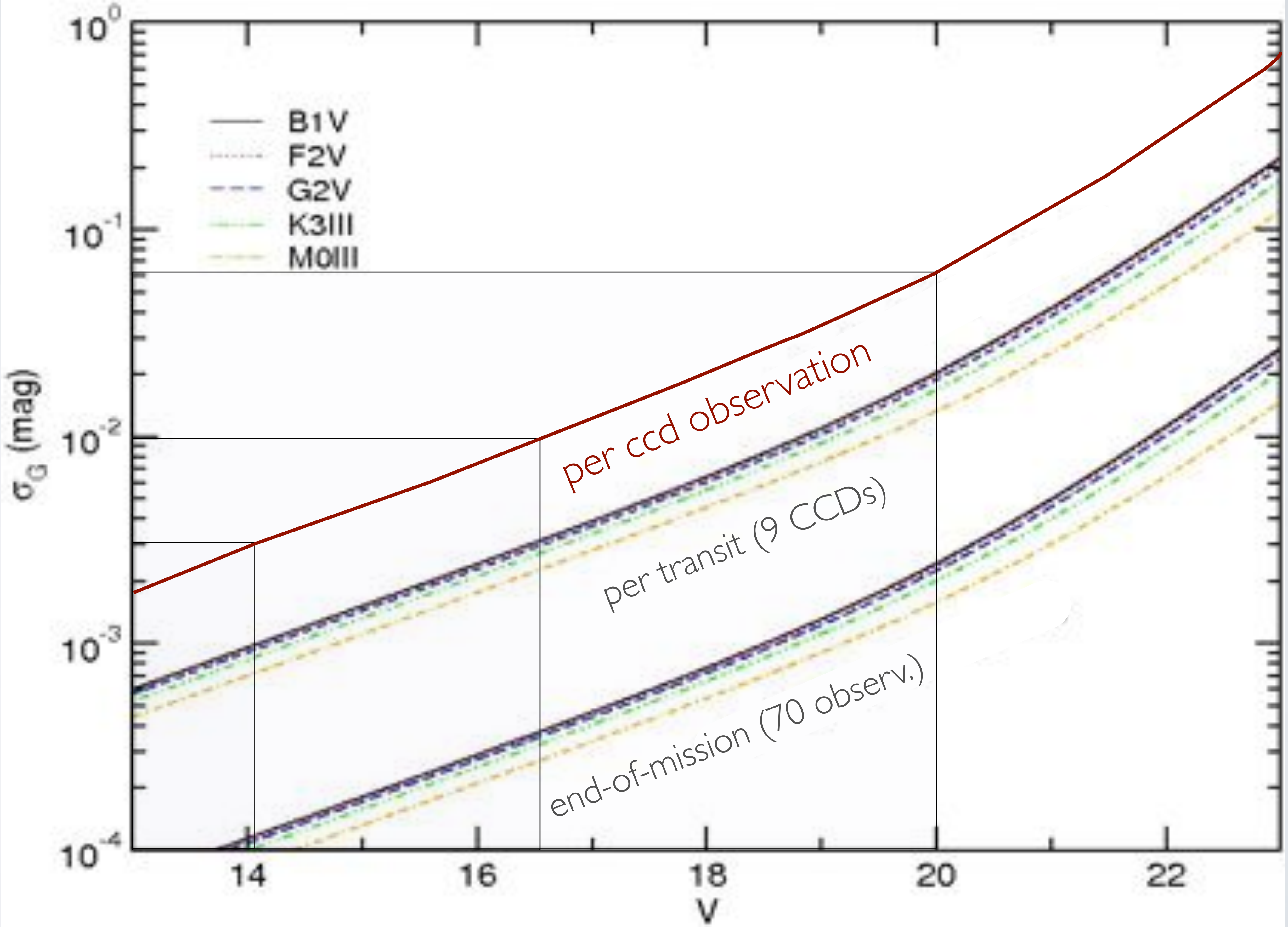
Gaia focal plane

Tens of millions of variables expected

Gaia Mission Properties: Photometric Precision

per ccd observations

V [mag]	σ [mmag]
~14	3
~16.6	10
~20	60



C. Jordi modified by M.Varadi

An example on asteroseismology: the EC14026 stars

Basic Properties of PG 0014+067 ($V = 15.9 \pm 0.1$)

Quantity	Asteroseismology	Spectroscopy
$\log g$	5.780 ± 0.008 (0.14%)	5.77 ± 0.10 (1.73%)
$T_{\rm eff}$ (K)	34500 ± 2690 (7.80%)	33550 ± 380 (1.13%)
$M_*/M_\odot$	0.490 ± 0.019 (3.88%)	...
$\log (M_{\rm env}/M_*)$	-4.31 ± 0.22 (5.10%)	...
$R/R_\odot(M_*, g)$	0.149 ± 0.004 (2.68%)	...
$L/L_\odot(T_{\rm eff}, R)$	28.5 ± 10.4 (36.5%)	25.5 ± 2.5 (9.90%)
$M_V(g, T_{\rm eff}, M_*)$	4.43 ± 0.24 (5.42%)	4.48 ± 0.12 (2.68%)
$d(V, M_V)$ (pc)	1950 ± 305 (15.6%)	1925 ± 195 (10.1%)
$P_{\rm rot}$ (hr)	29.2 ± 0.9 (3.08%)	...
$V_{\rm eq}(R, P_{\rm rot})$ (km s^{-1})...	6.20 ± 0.36 (5.81%)	...

Complete asteroseismological analysis of PG 0014+67 - Brassard et al. (2001)

➥Astrophysical parameters determination, mode identification

~10 hr measurements in 5 days with the 3.6m CFHT

BUT With Gaia we focus on detection of short period variables

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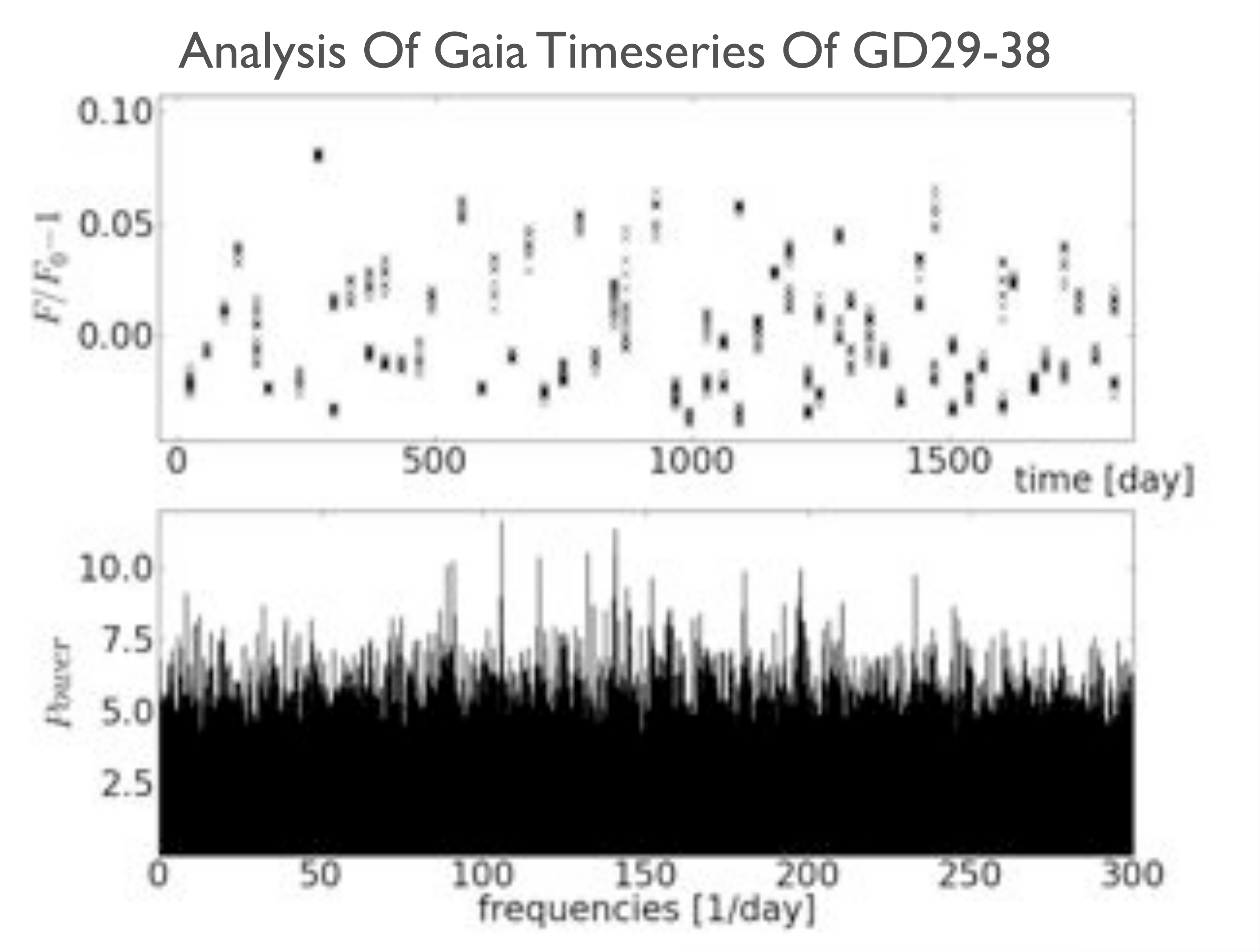
Algorithm + Statistics

Which algorithm to use to detect short period variability?

- Period search
- Chi square value
- Structure functions



Algorithm + Statistics

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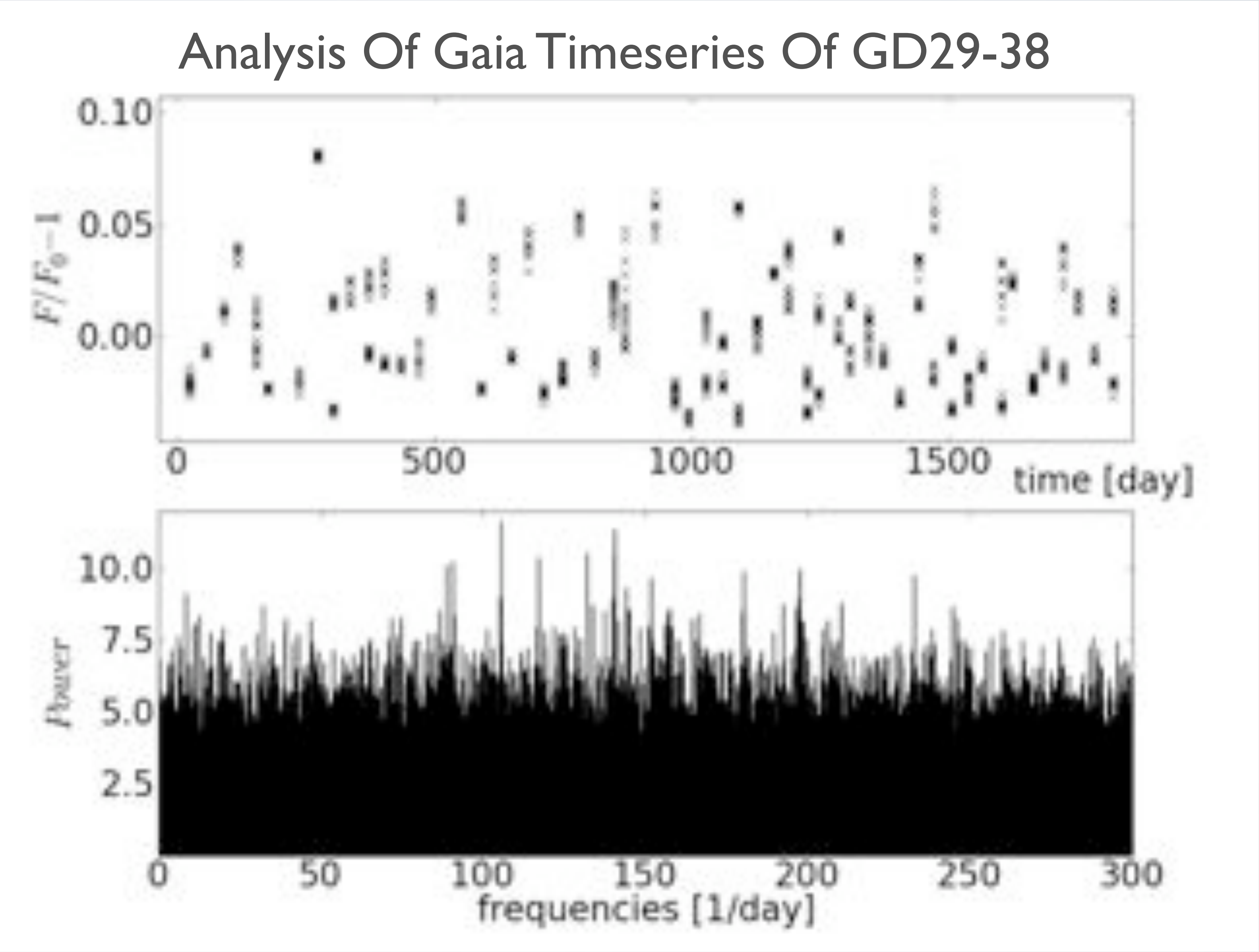
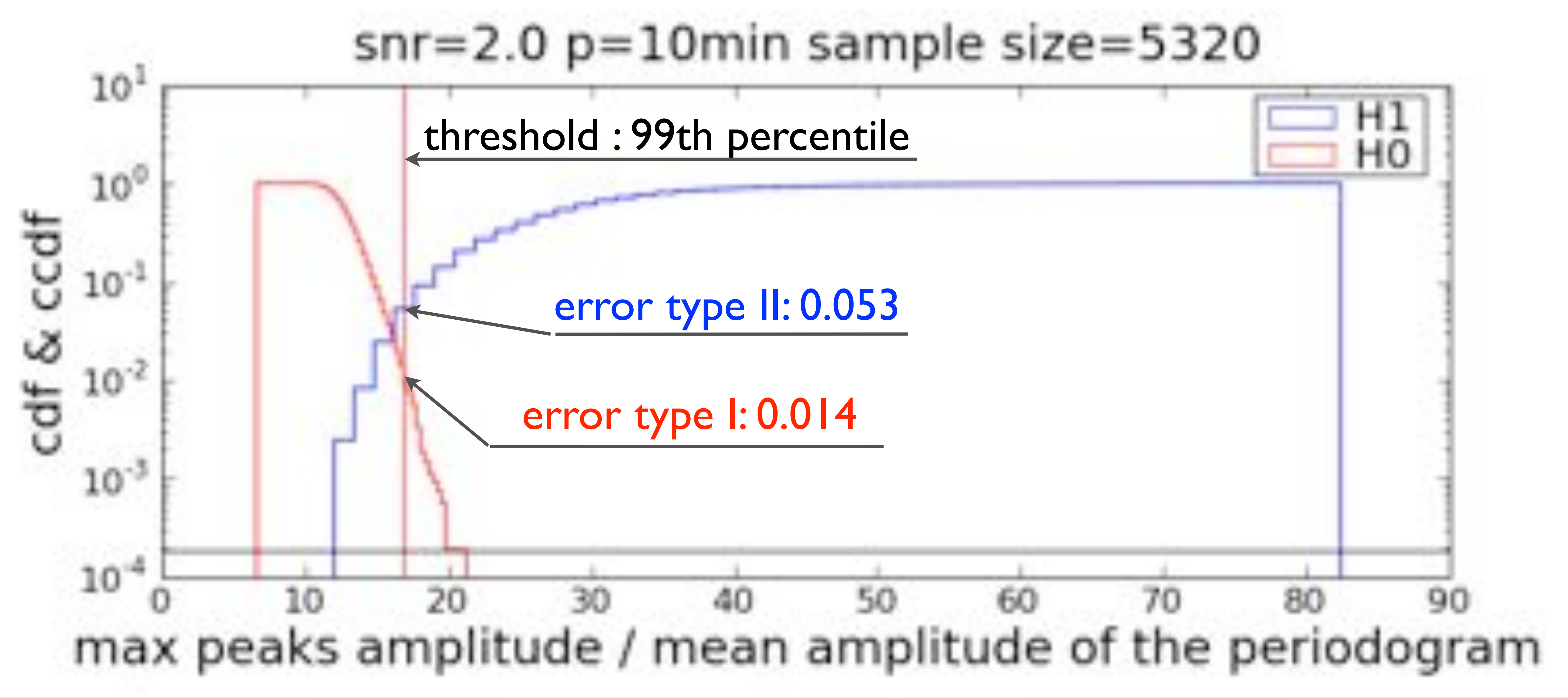


Does the maximum peak correspond to a real frequency in a star?

Algorithm + Statistics



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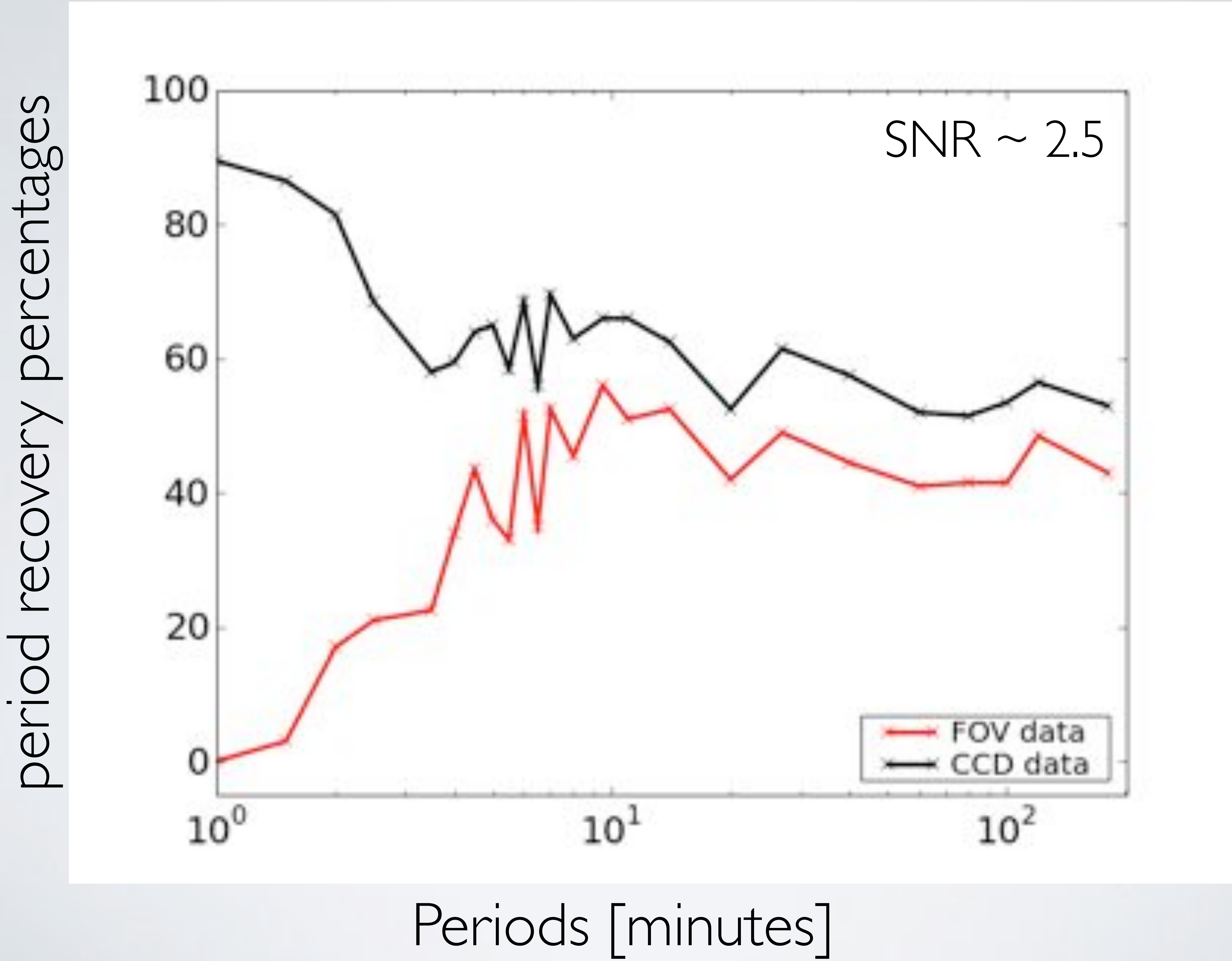
Tests on
simulated data

Tests on simulated data - Increasing Complexity

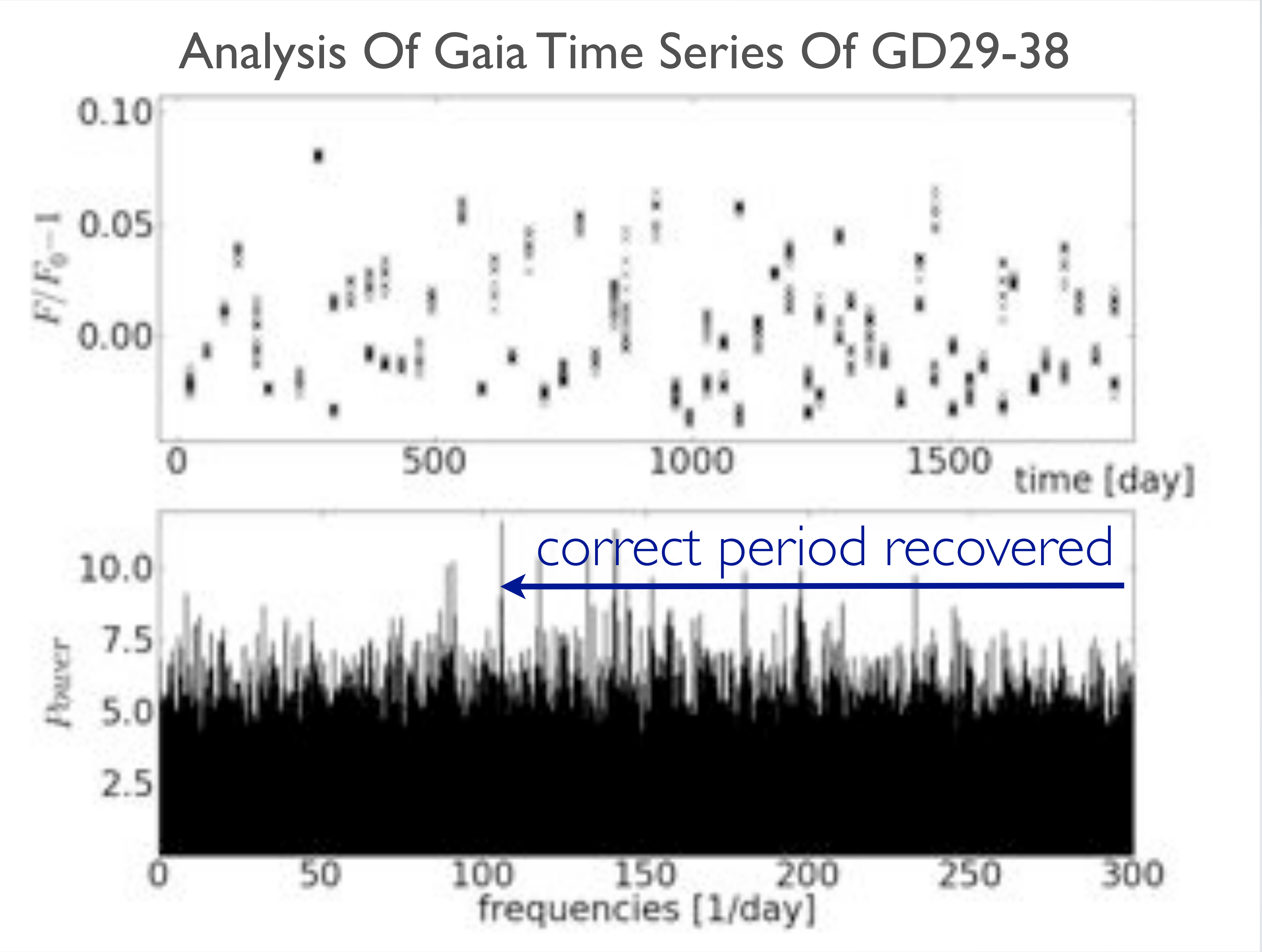
- times → inverse scanning law → AGISLab BH, LE, DH- Lund
- signal →
  1. monoperiodic
     Eyer & Mignard 2005
  2. multiperiodic
     Mary et al. 2006
  3. ZZ Ceti model
     Varadi et al. 2009
  4. Non-Stationary Spectrum
- noise → Gaussian

Test On Simulated Data: Monoperiodic



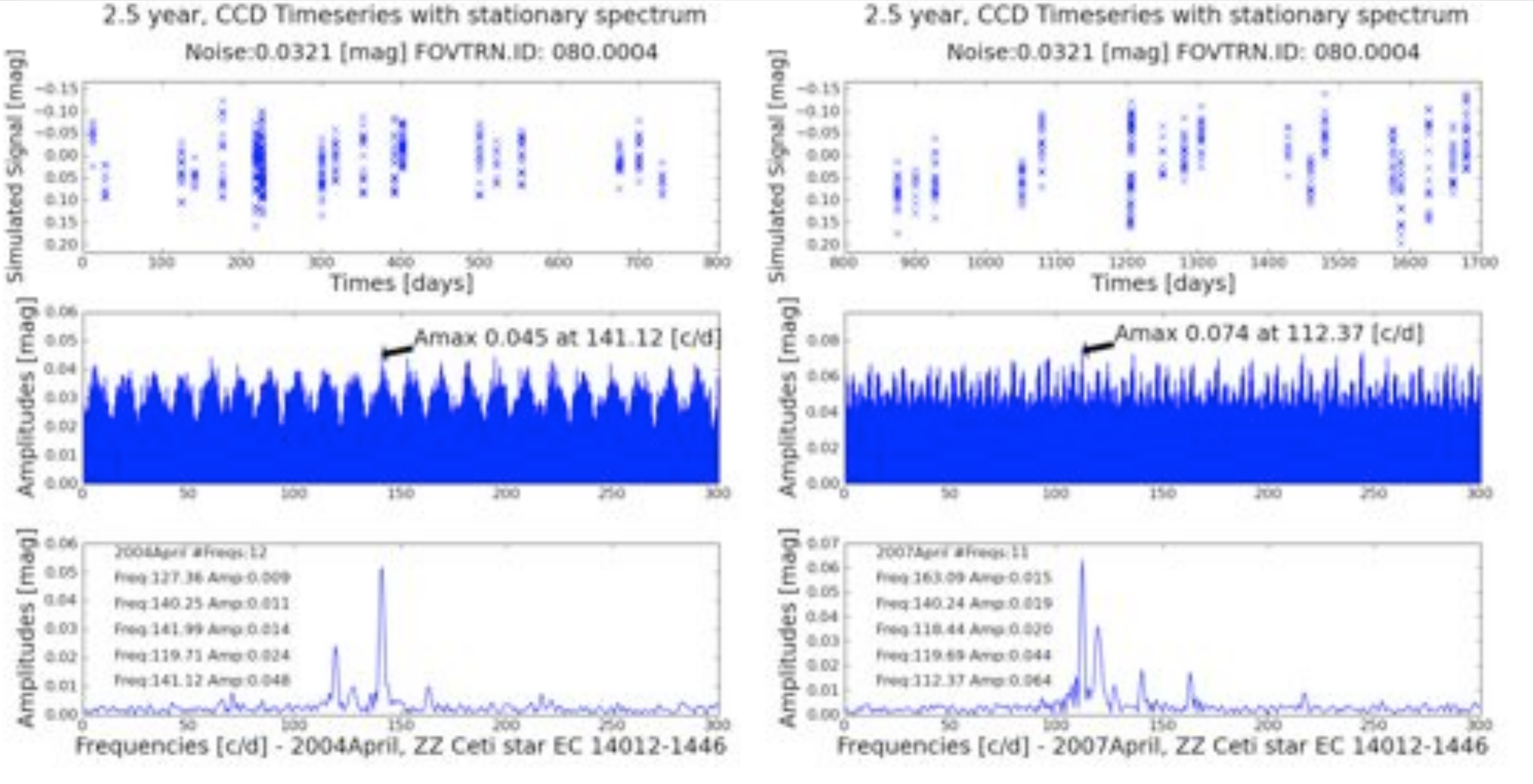
Test on simulated data: Example 1

- 7 input periods
- 5 year long data set
- 82 field transits
- 738 ccd observations
- ZZ Ceti light curve with noise

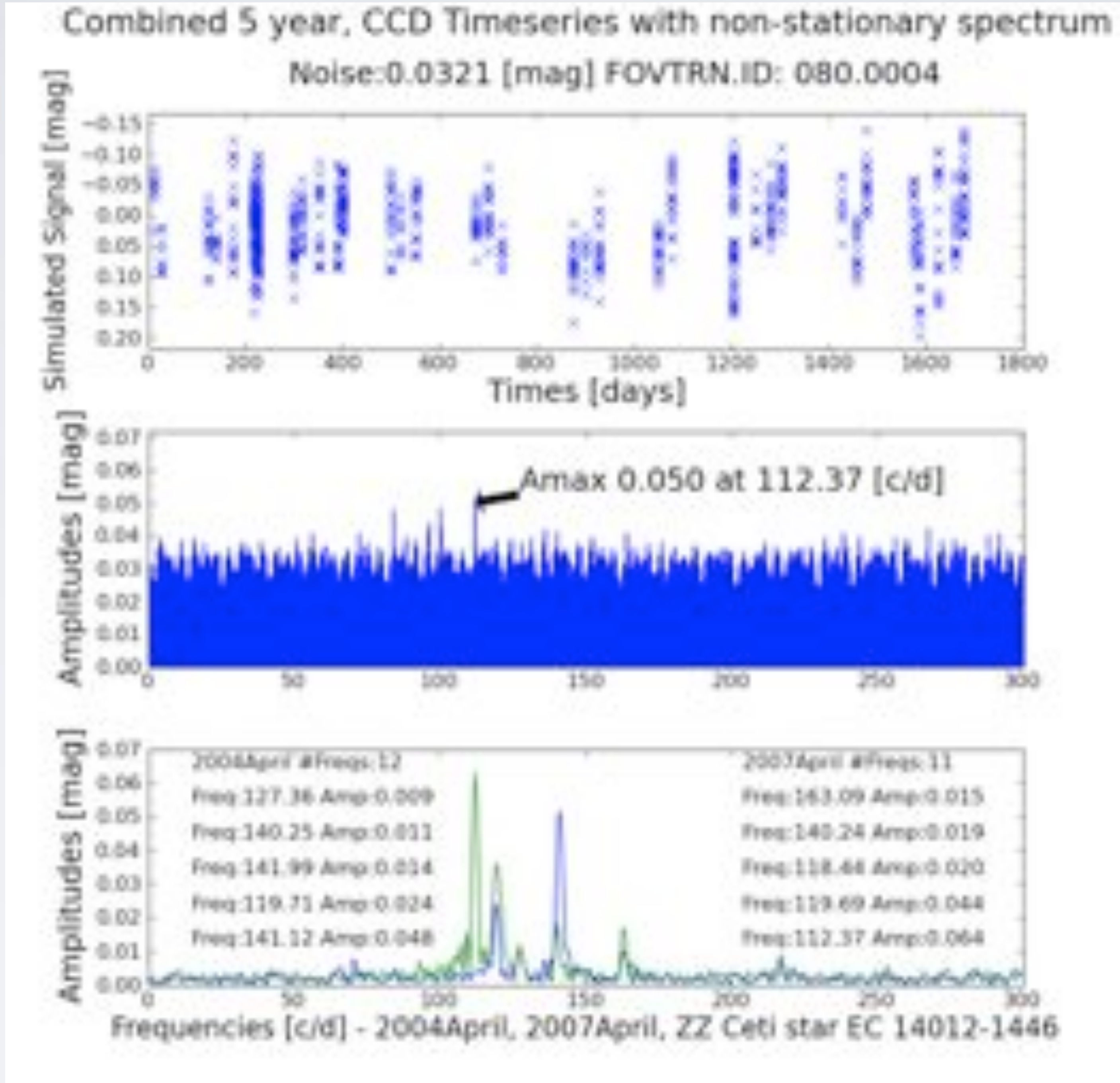


Up to 3 frequencies with highest amplitudes can be recovered

Example 2: Partial data with stationary spectra



Example 2: Combined Non-Stationary Spectrum



Success! Gaia photometric error corresponds to 19 mag

Test On Simulated Data: Period Recovery Statistics

signal	periods	recovery rate [percentages]		
		noise-free	noise for 15 mag	noise for 18 mag
multiperiodic sum of sines 7 periods	P1 P2 P3	74.5 57.5 56.5	73.5 53.5 54.5	69.0 43.5 40.0
ZZ Ceti model 7 periods	P1 P2 P3	**72.0** 41.0 30.0	72.0 39.0 28.5	**65.0** 26.5 11.5
Non-Stationary Spectrum	P1 P1 partial		17.5 52.5 44.0	

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Yes

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Summary & Conclusion

- We assessed the performance of Gaia on short period variables $\rightarrow$ short periodic phenomena can be detected

Future work

- On variability detection method:
  - per-ccd slopes
  - calibrate the detection threshold

- Do complete asteroseismological study of a short period variable

Thank You For Your Attention!

Questions ?