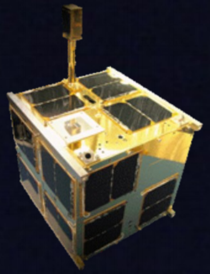


Lessons from BRITE

Gerald Handler, Nicolaus Copernicus Astronomical Center Warsaw

Thanks to contributions by:

(in alphabetical order)

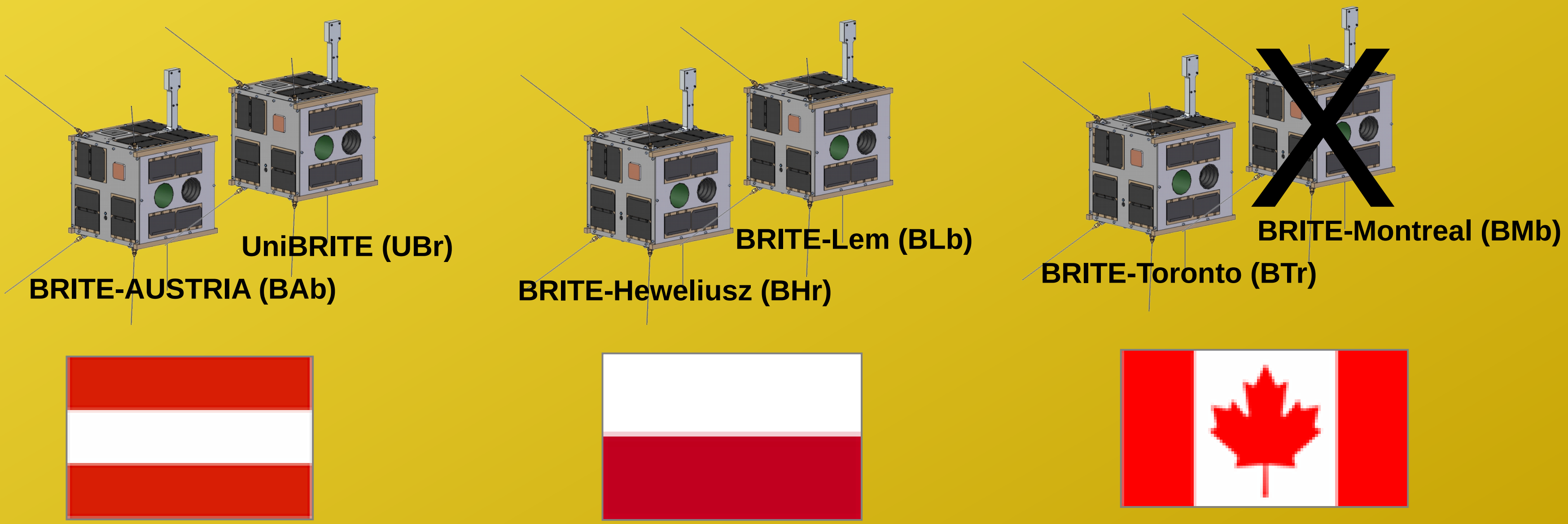
- Bram Buysschaert
- Thomas Kallinger
- Rainer Kuschnig
- Tony Moffat
- Coralie Neiner
- Bert Pablo
- Andrzej Pigulski
- Tahina Ramiaramanantsoa
- Gregg Wade

What is BRITE?

BRIght Target Explorer

- nanosatellites 20 x 20 x 20 cm
- ca. 7 kg
- 3-cm telescope for observations of bright (V < 5) stars
- time-resolved two-colour (B, R) photometry

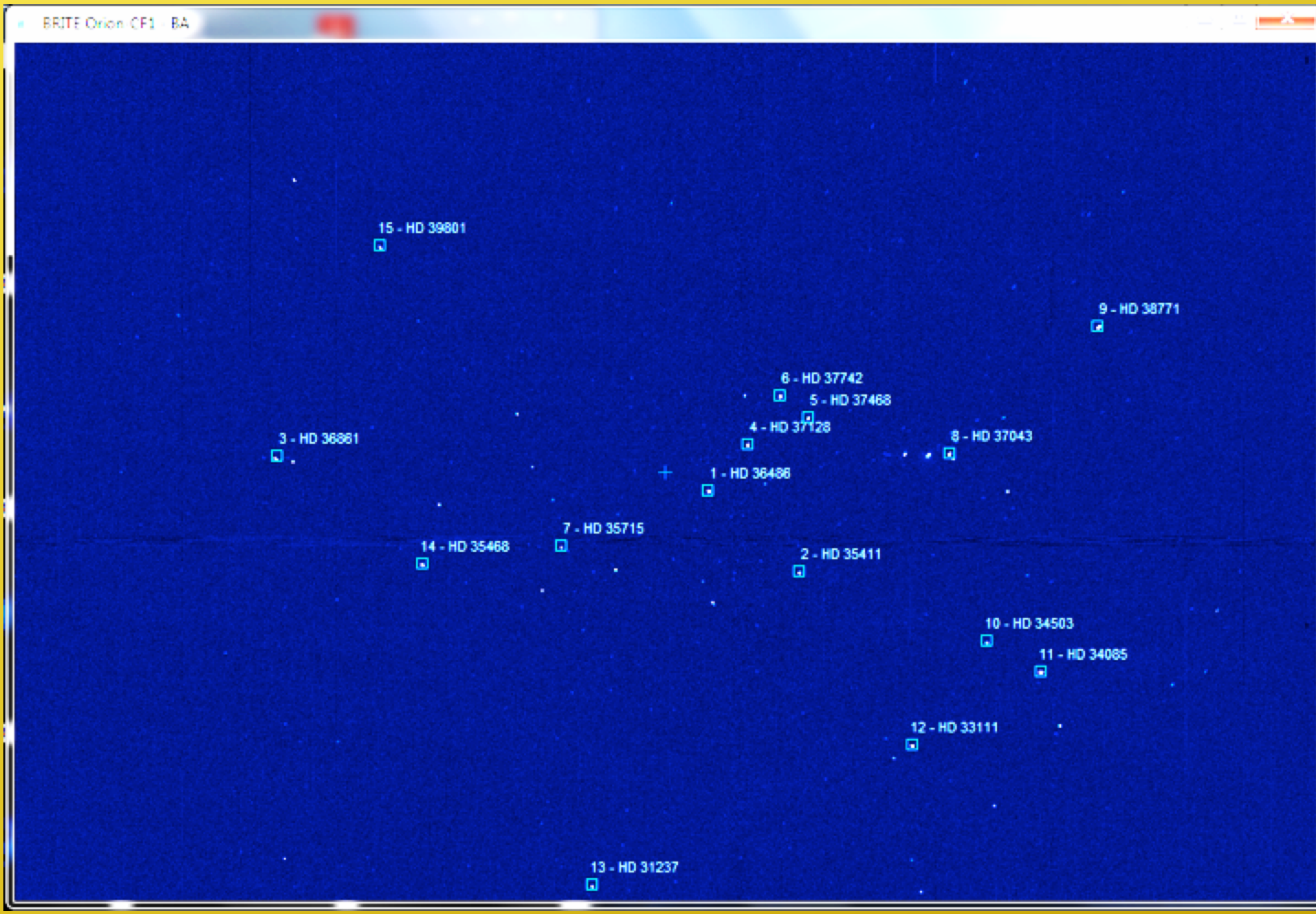
BRITE-Constellation:



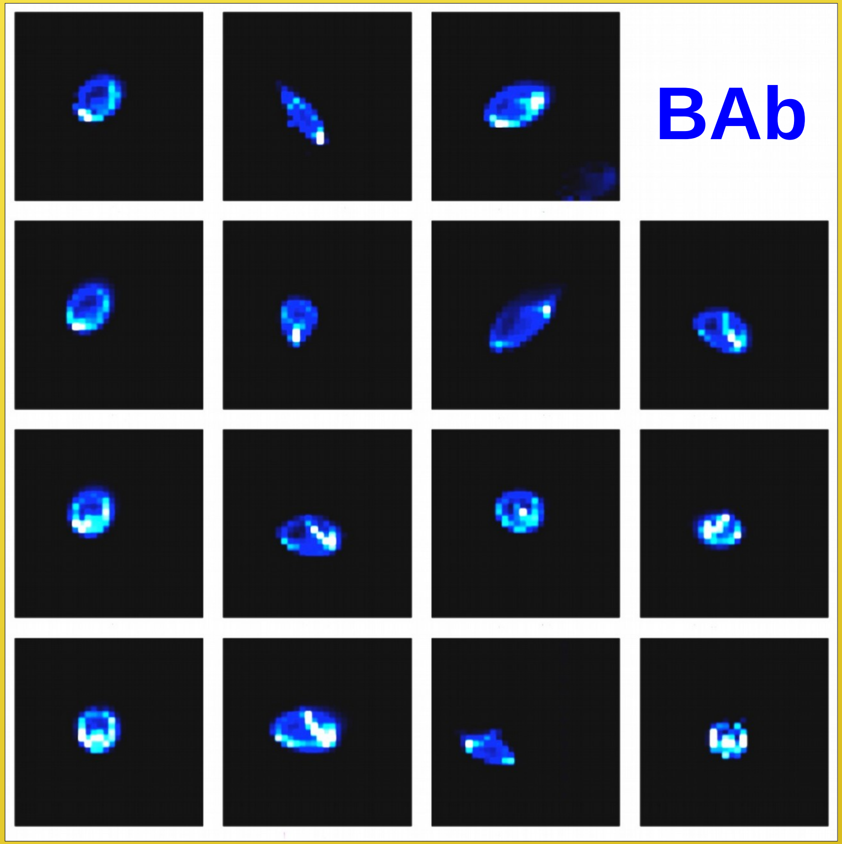
BRITE observations so far

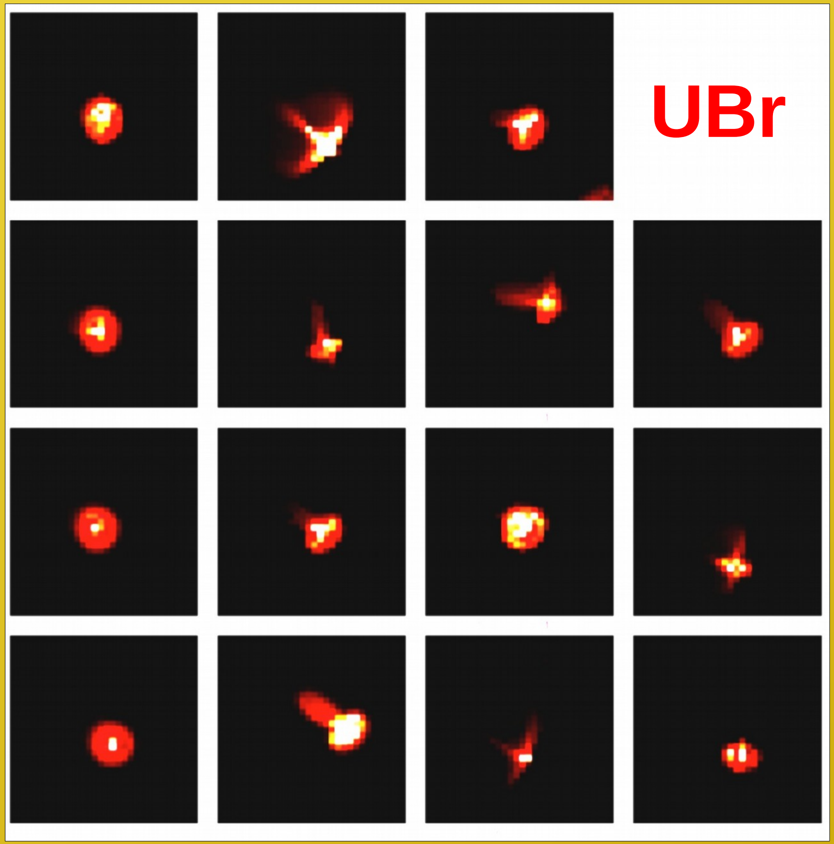
Field	from	to	ΔT [day]	# stars
Orion I	01.12.2013	18.03.2014	108	15
Centaurus	25.03.2014	18.08.2014	147	32
Sagittarius	29.04.2014	06.09.2014	42	19
Cygnus I	12.06.2014	25.11.2014	167	36
Perseus	02.09.2014	18.02.2015	170	37
Orion II	24.09.2014	17.03.2015	175	38
Vel/Pup	11.12.2014	28.05.2015	169	52
Scorpius	18.03.2015	31.08.2015	167	26
Cygnus II	01.06.2015	25.11.2015	178	27
Cas/Cep	23.08.2015	17.10.2015	55	23
CMa/Pup	18.10.2015	14.04.2016	~180	33
Cru/Car	22.01.2016	22.07.2016	183	45
Cyg/Lyr	05.04.2016	02.10.2016	177	20
Sgr II	21.04.2016	23.09.2016	158	17
Cas II	07.08.2016	03.02.2017	~174	18
Aur/Per	14.09.2016	07.03.2017	~171	25
Cet/Eri	06.10.2016	26.12.2016	83	11
Vel/Pic	04.11.2016	29.04.2017	173	21
Total				~410

Orion field


BRITE Orion CF1 - BA
15 - HD 39801
9 - HD 38771
6 - HD 37742
5 - HD 37468
4 - HD 37128
3 - HD 36861
8 - HD 37043
1 - HD 36486
7 - HD 35715
14 - HD 35468
2 - HD 35411
10 - HD 34503
11 - HD 34085
12 - HD 33111
13 - HD 31237

BRITE photometry

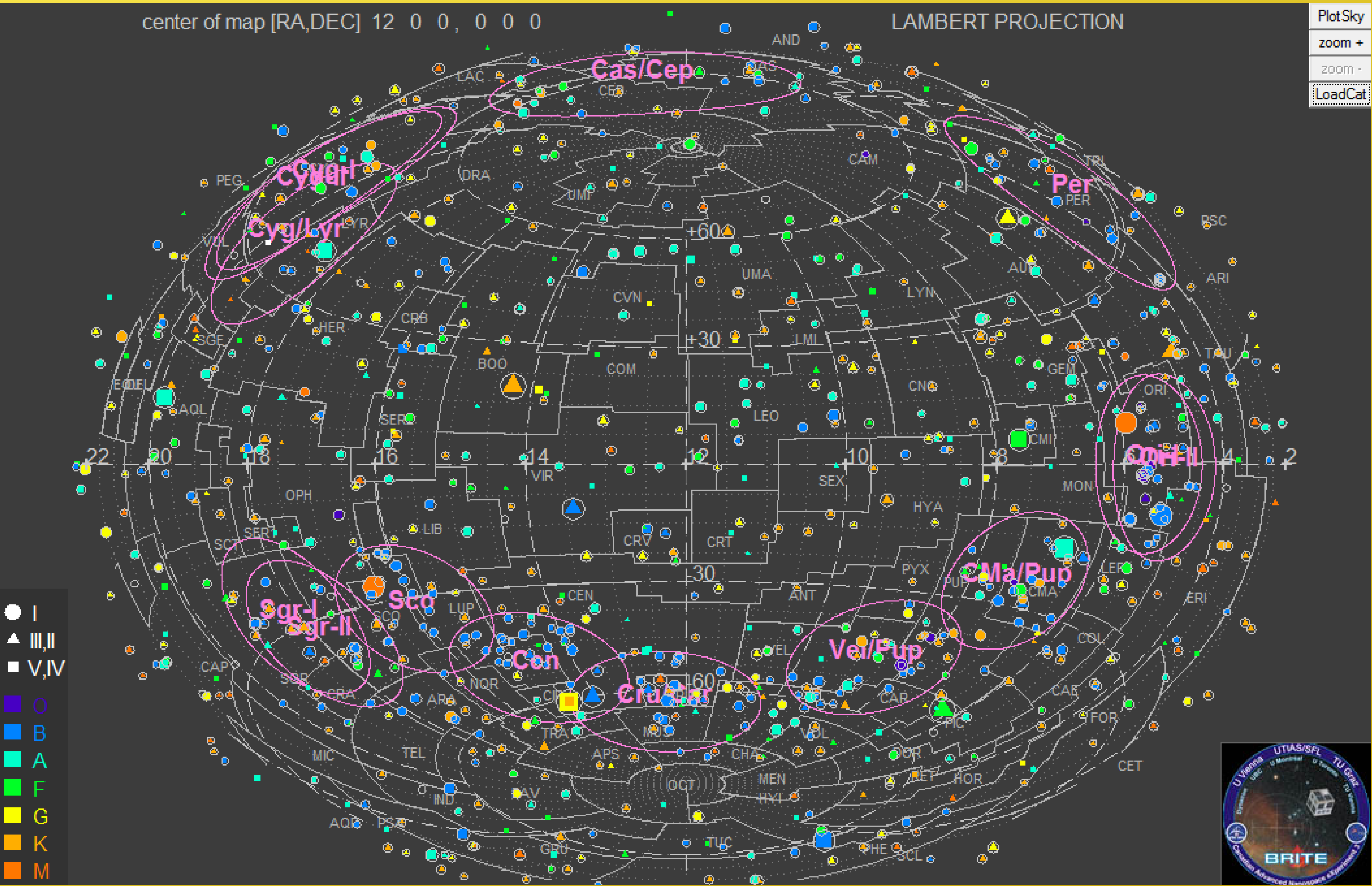




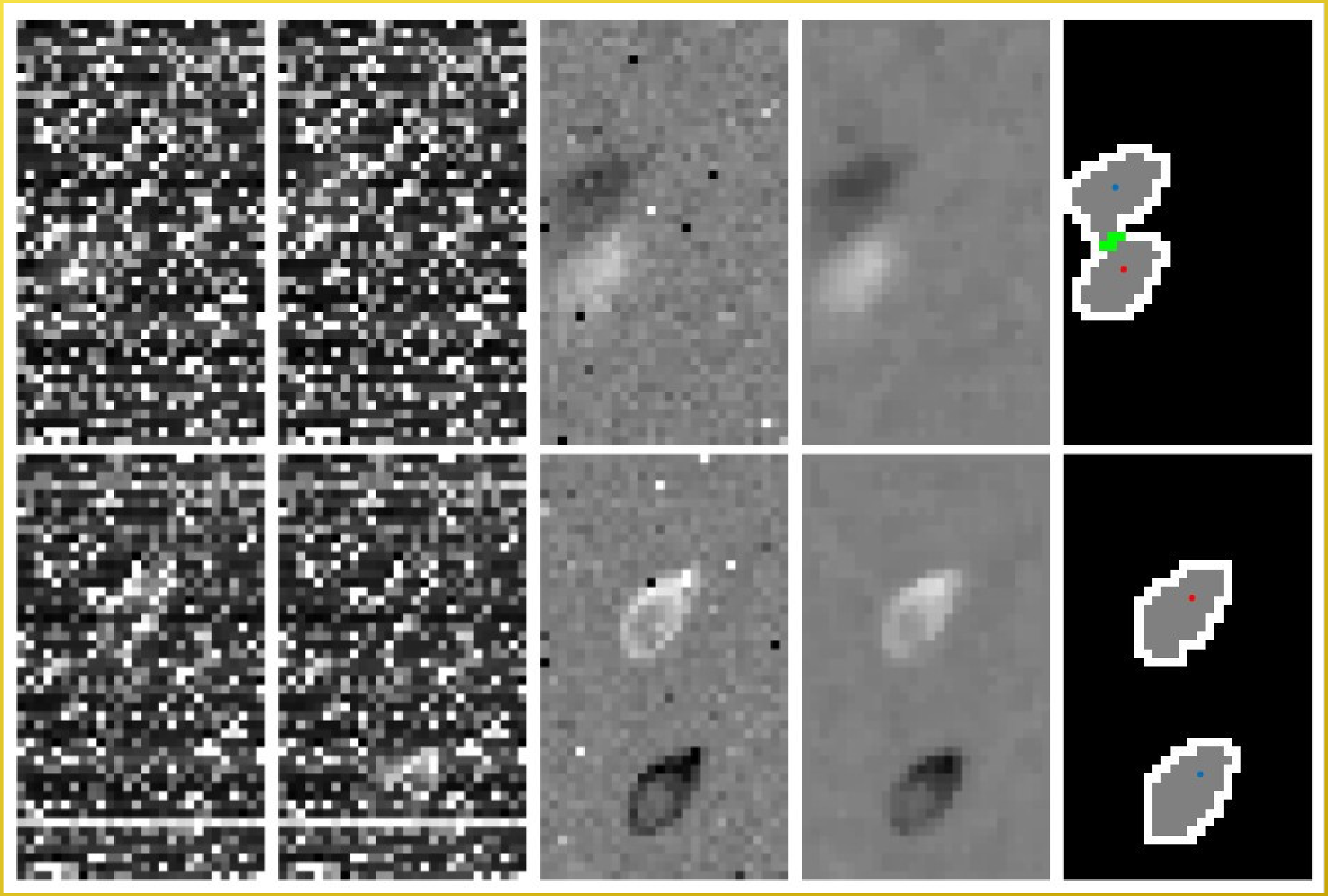
- rasters,
- defocusing,
- aperture photometry.

Images courtesy Rainer Kuschnig & Adam Popowicz

BRITE observations so far



BRITE observations: chopping mode



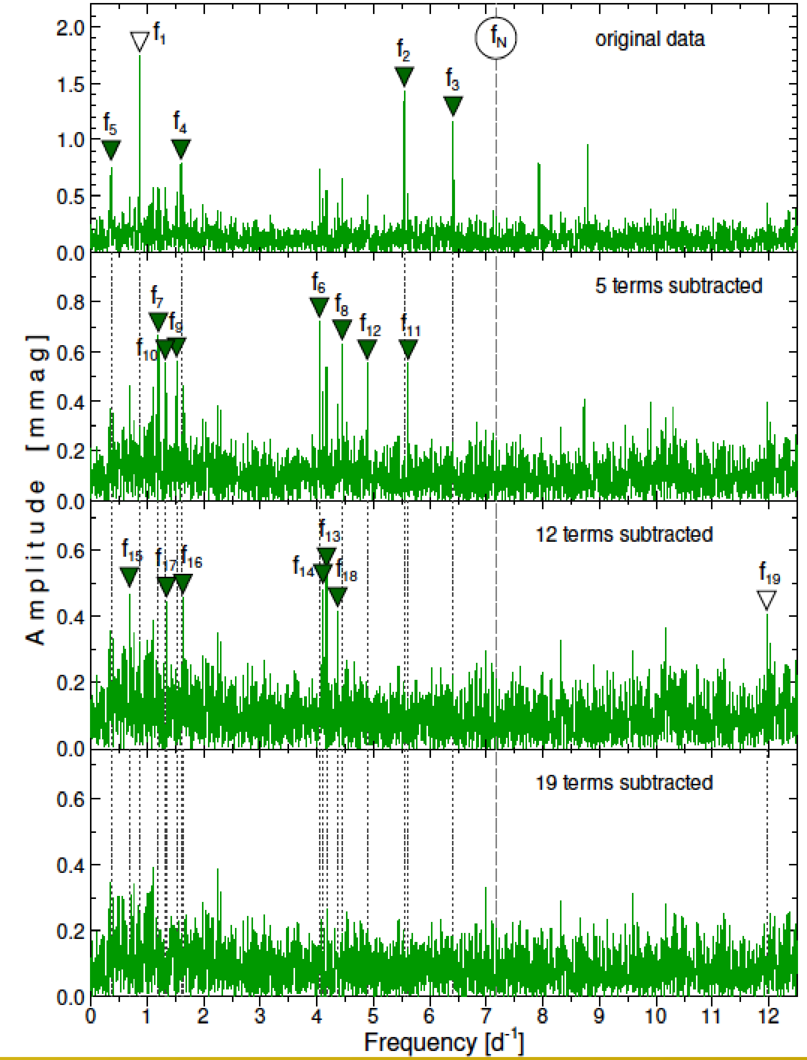
Popowicz et al. 2017, A&A, in prep.

Scientific results: asteroseismology

β Centauri (12.0 + 10.6 M_{sun}):
BRITE amplitude spectra
(Pigulski et al. 2016, A&A 588, A55)

17 pulsation modes

before BRITE: 2 modes from spectroscopy, photometry inconclusive

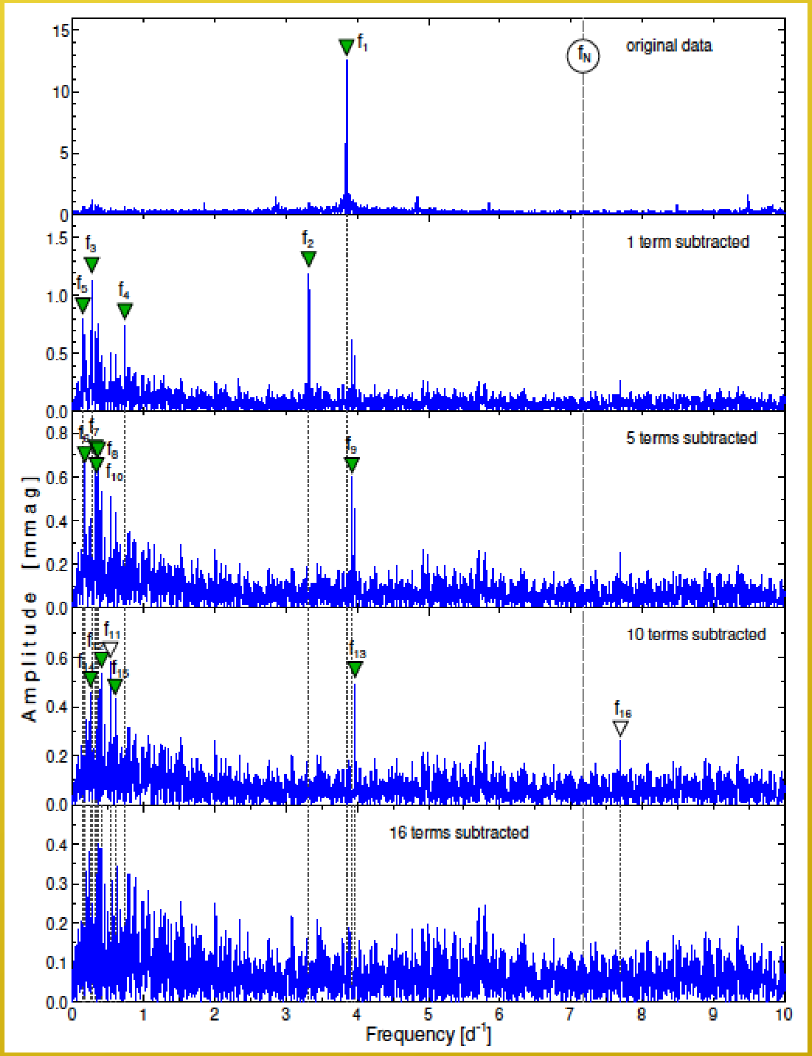


Scientific results: asteroseismology

α Lupi (10.6 M_{sun}): BRITE amplitude spectra (A. Pigulski)

14 pulsation modes

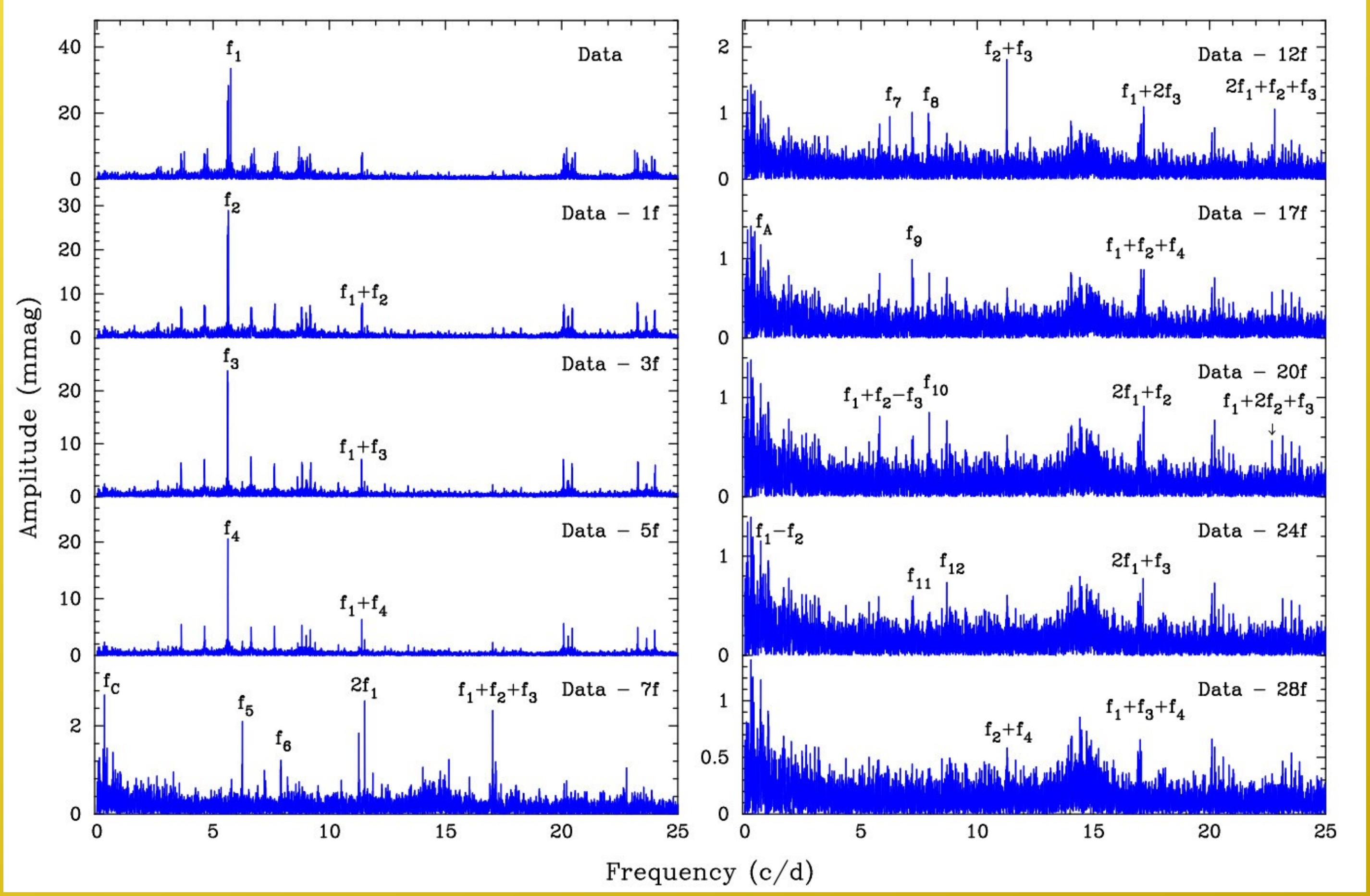
before BRITE: only one pulsation mode known



Scientific results: asteroseismology

ν Eri (10.6 M_{sun}): BRITE + APT

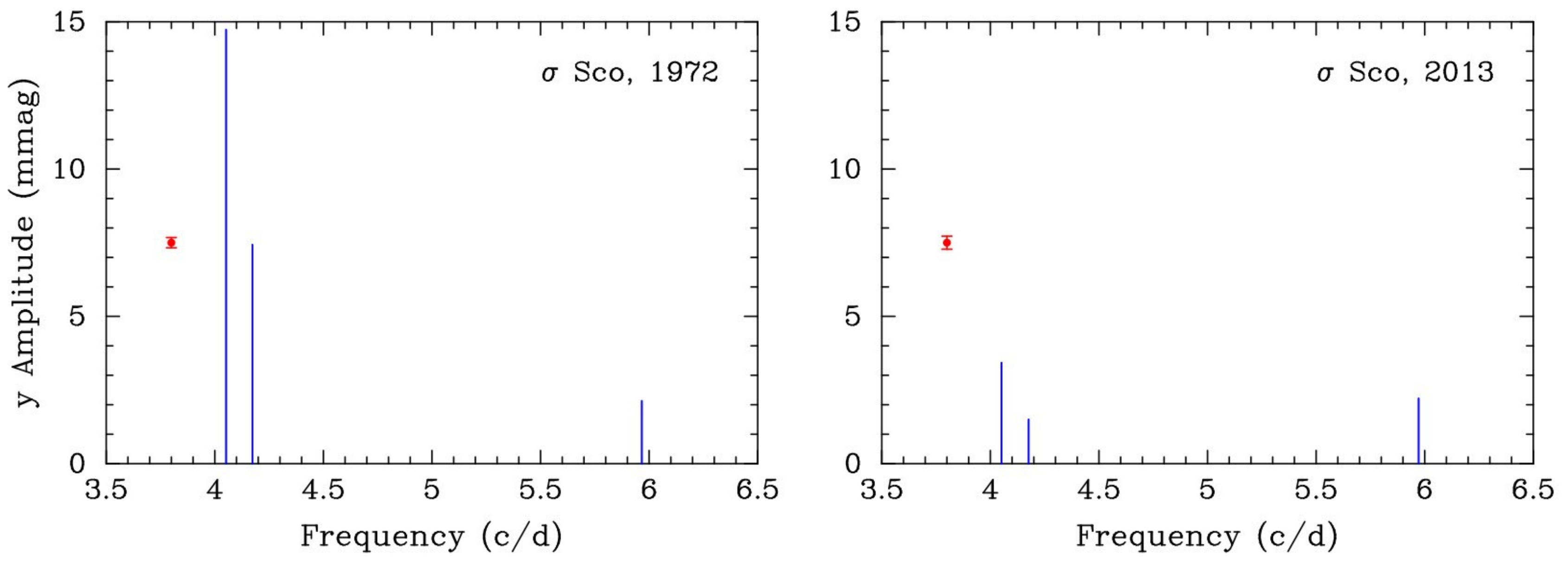
very well observed star, new modes of pulsation detected



(Handler et al. 2017, MNRAS 464, 2249)

Scientific results: asteroseismology

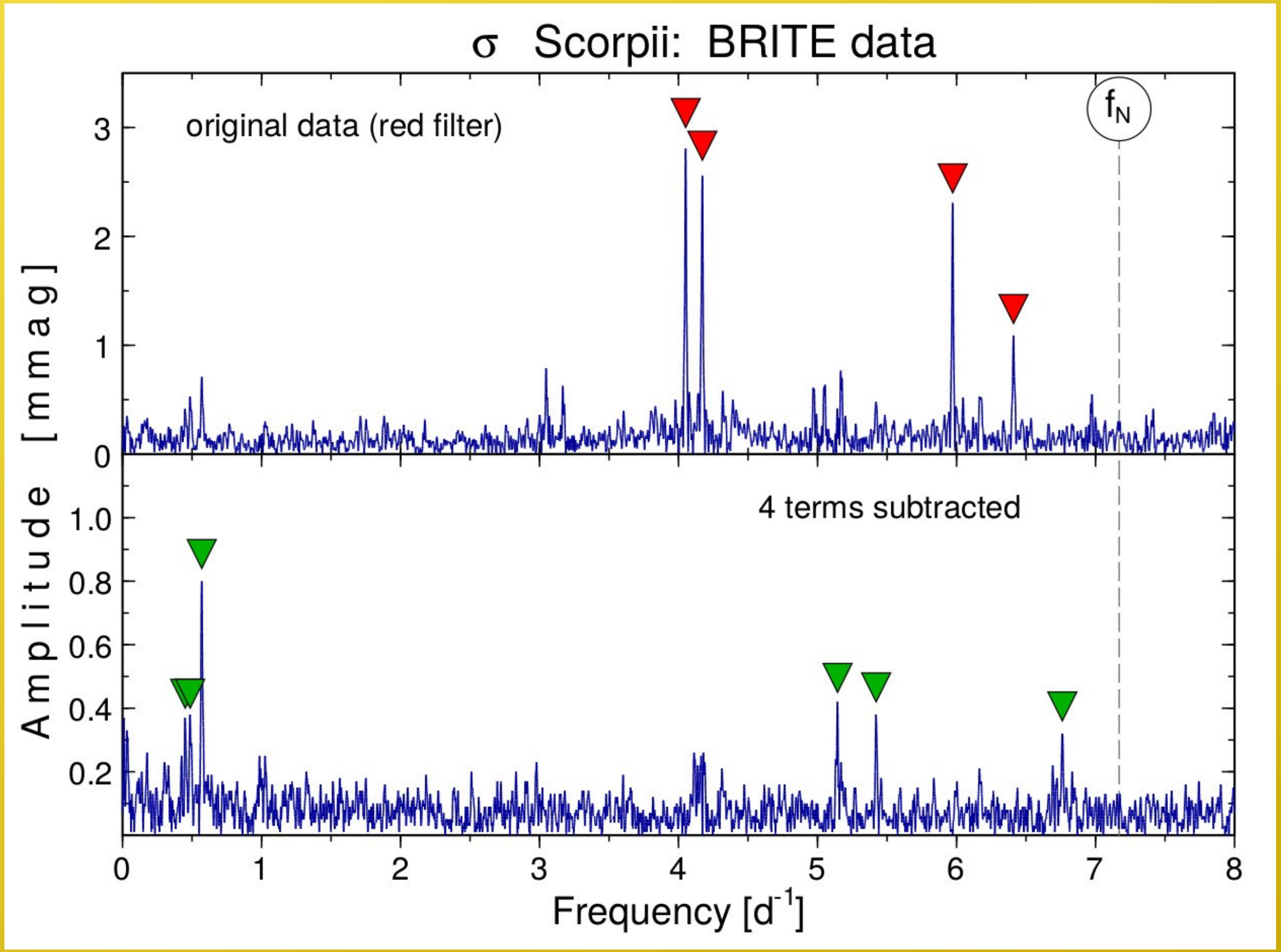
σ Sco (14.6 + 9.5 M_{sun}): BRITE + APT
strong amplitude variations detected in ground based data



(Handler 2014, Proc. IAUS 301, 417)

Scientific results: asteroseismology

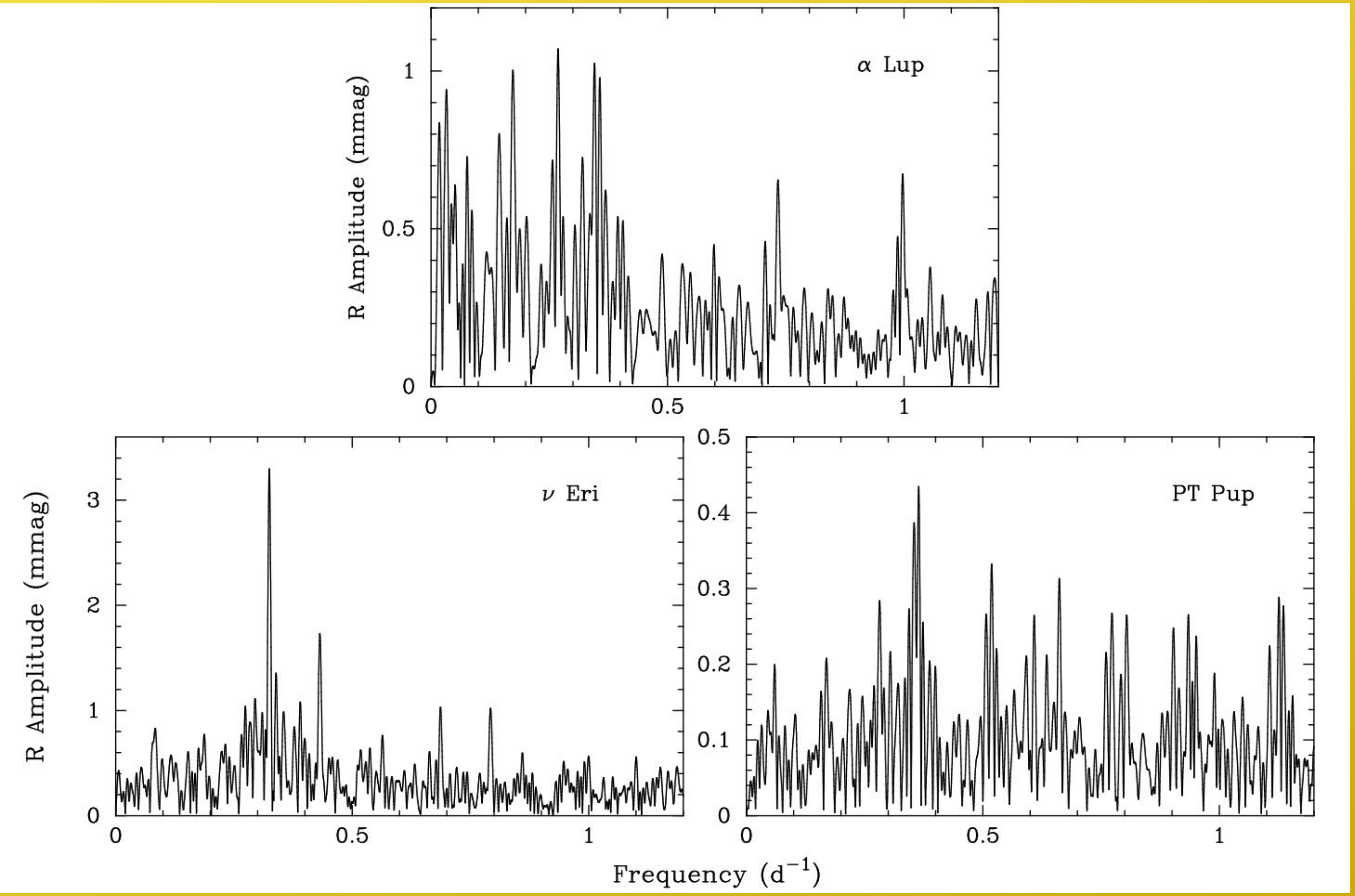
σ Sco (14.6 + 9.5 M_{sun}): BRITE + APT



(A. Pigulski)

Scientific results: asteroseismology

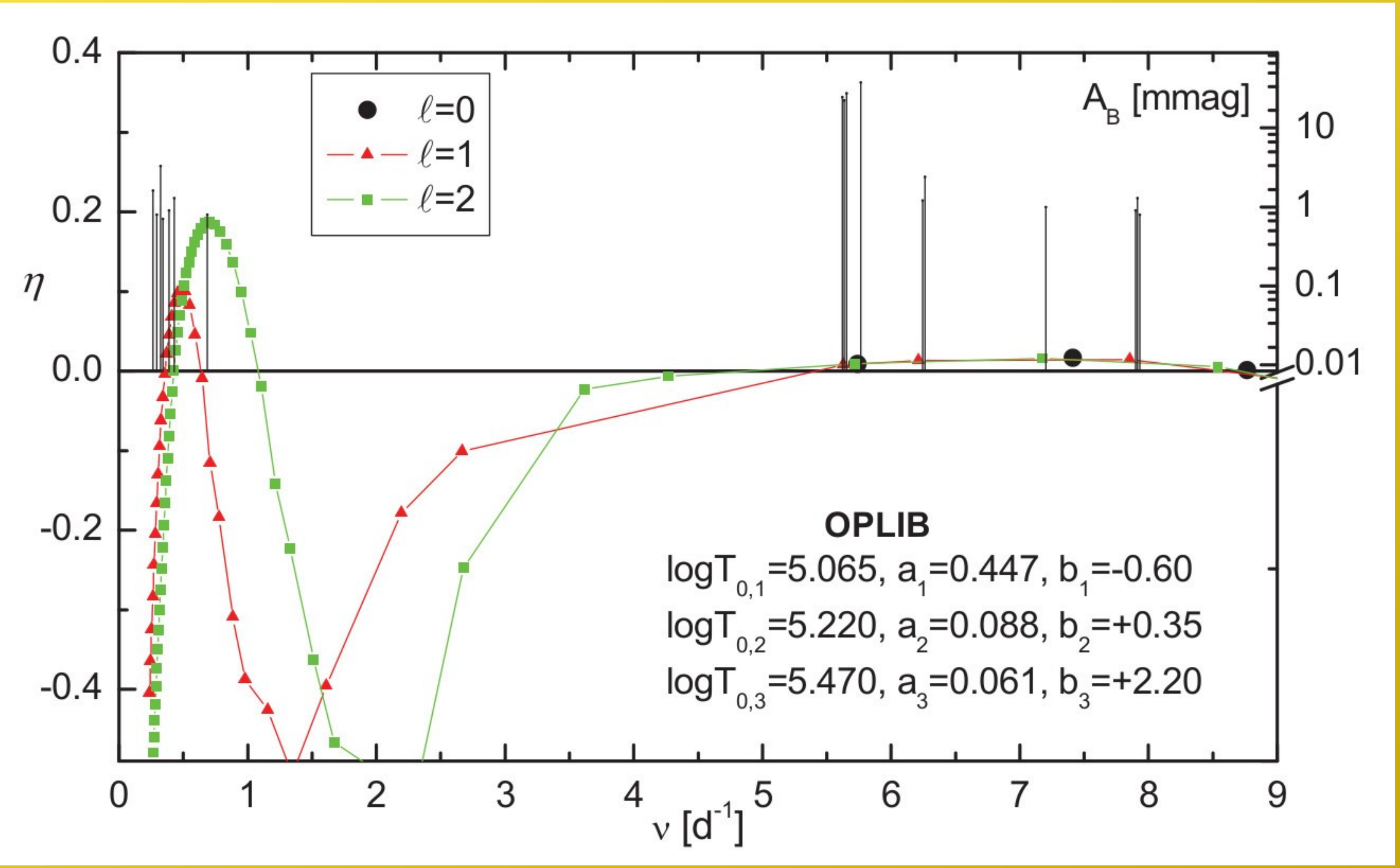
g modes, g modes everywhere!



(Handler 2016, 2nd BRITE Science Conference, Innsbruck)

Scientific results: asteroseismology

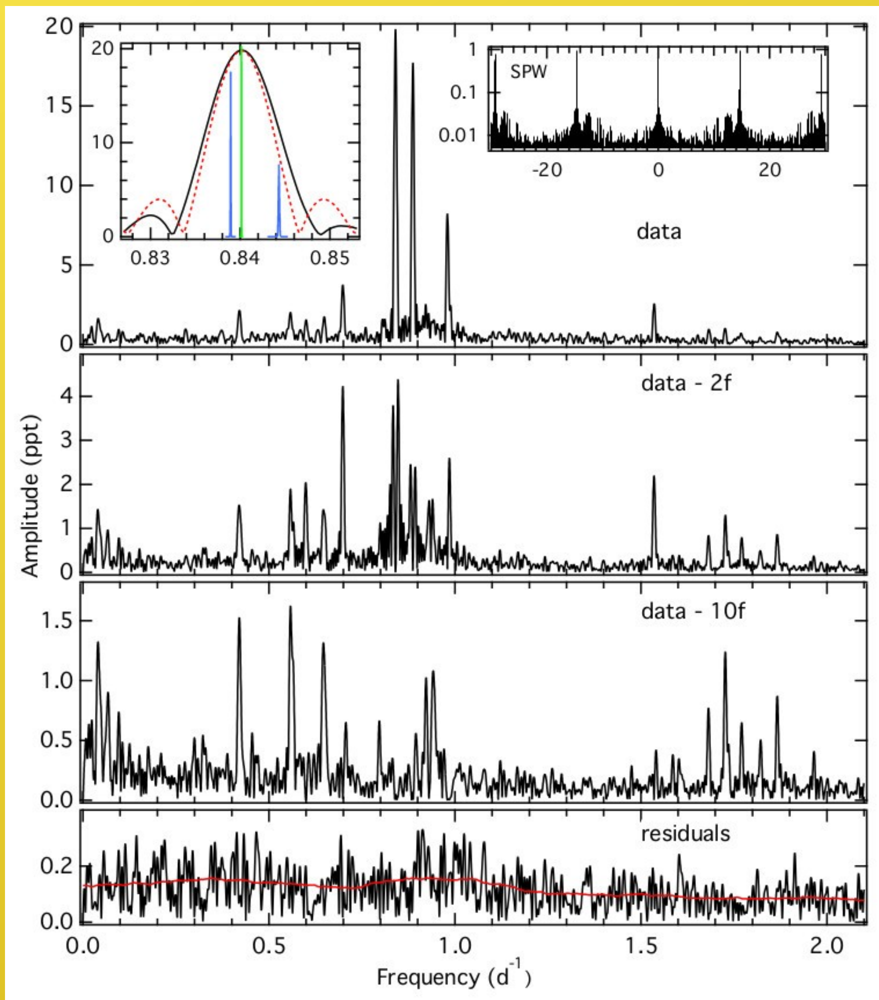
g modes, g modes everywhere!



(Daszyńska-Daszkiewicz et al. 2017, MNRAS 466, 2284)

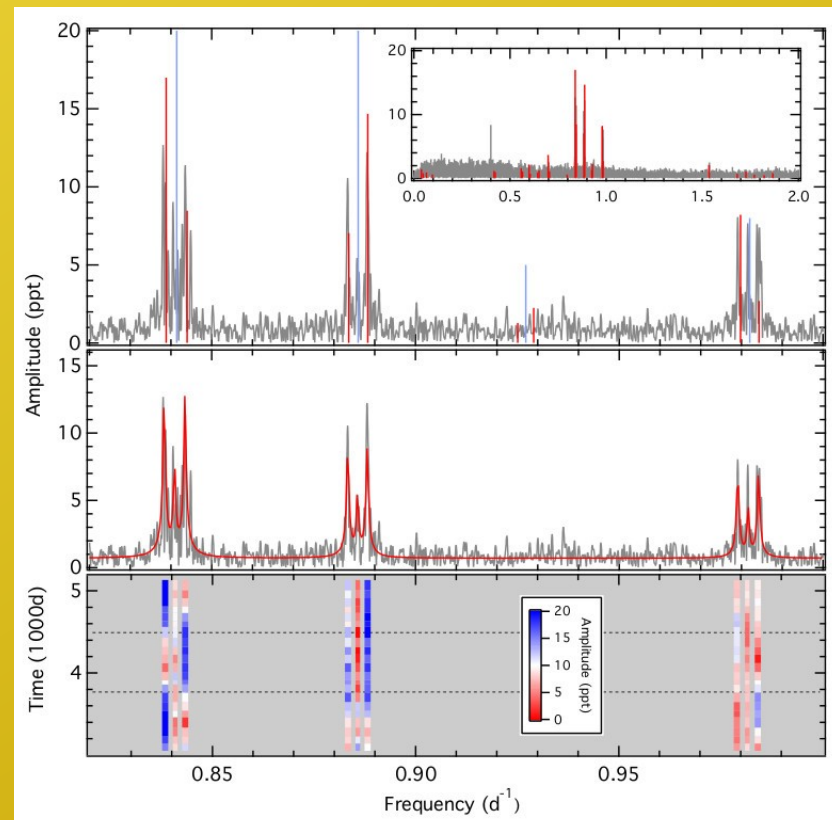
Scientific results: asteroseismology

HD 201433 (3.0 + 0.6 + ? M_{sun}): BRITE + SMEI



P_{rot} (interior) = 296 +/- 97 d

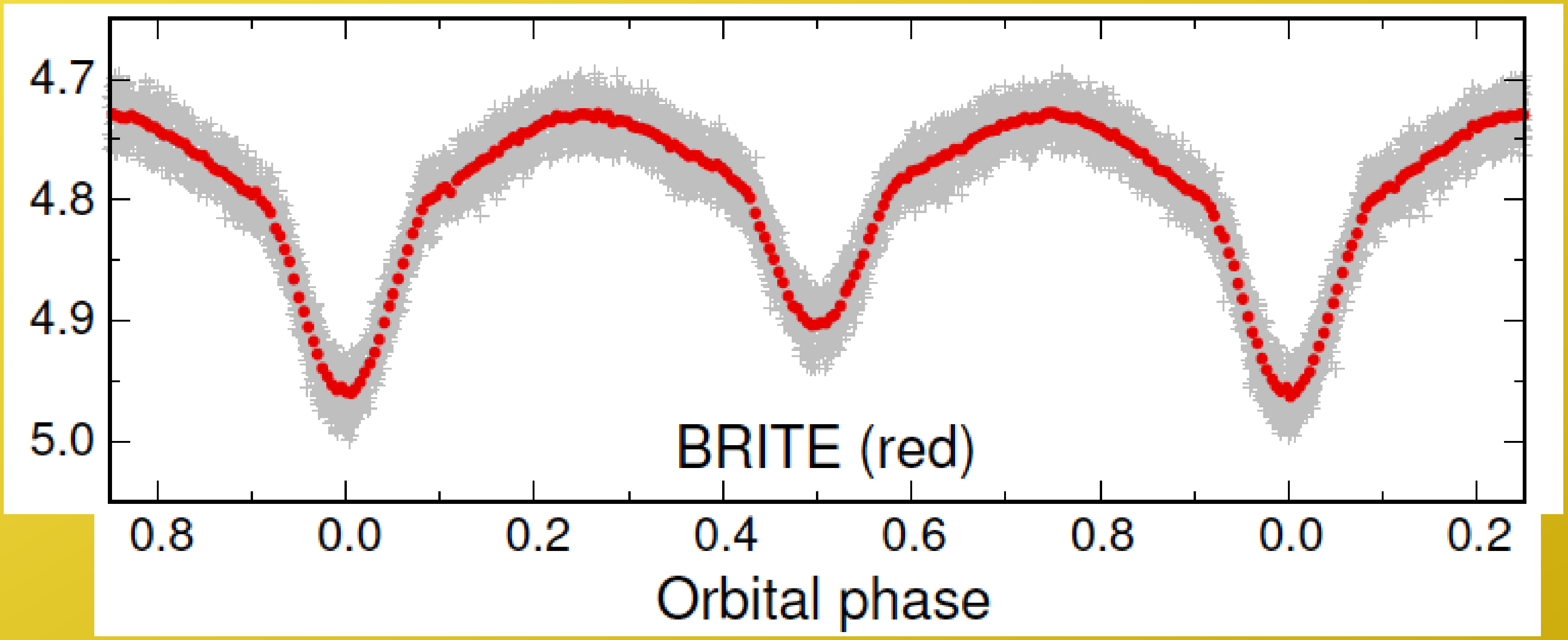
P_{rot} (surface) = ~3.3 d



(Kallinger et al. 2017, A&A, submitted)

Scientific results: binarity

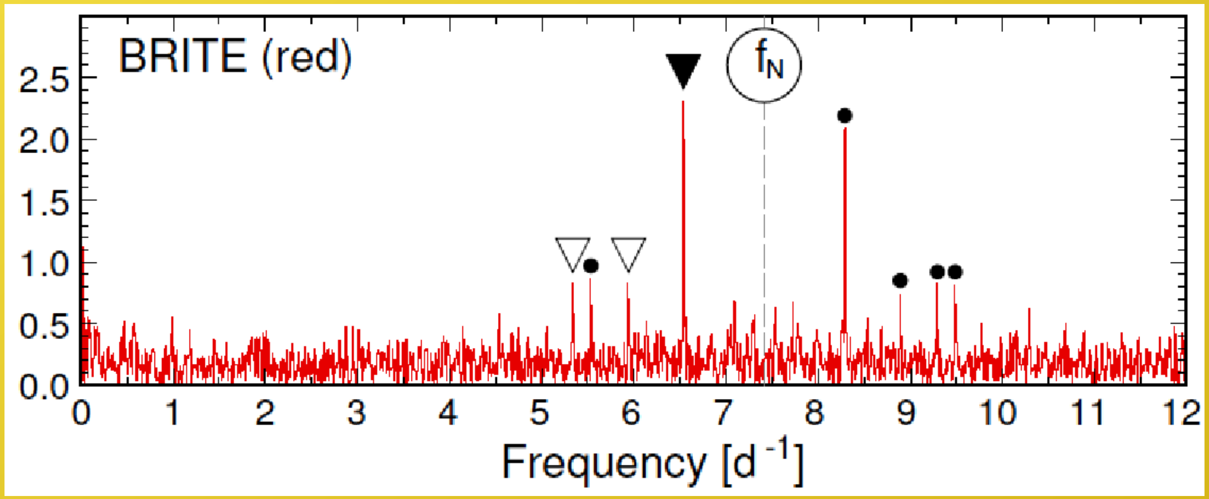
δ Pic (16 + 9 M_{sun}): BHr; P_{orb} = 1.67254 d



(A. Pigulski)

Scientific results: binarity

δ Pic (16 + 9 M_{sun}): BHr; P_{orb} = 1.67254 d

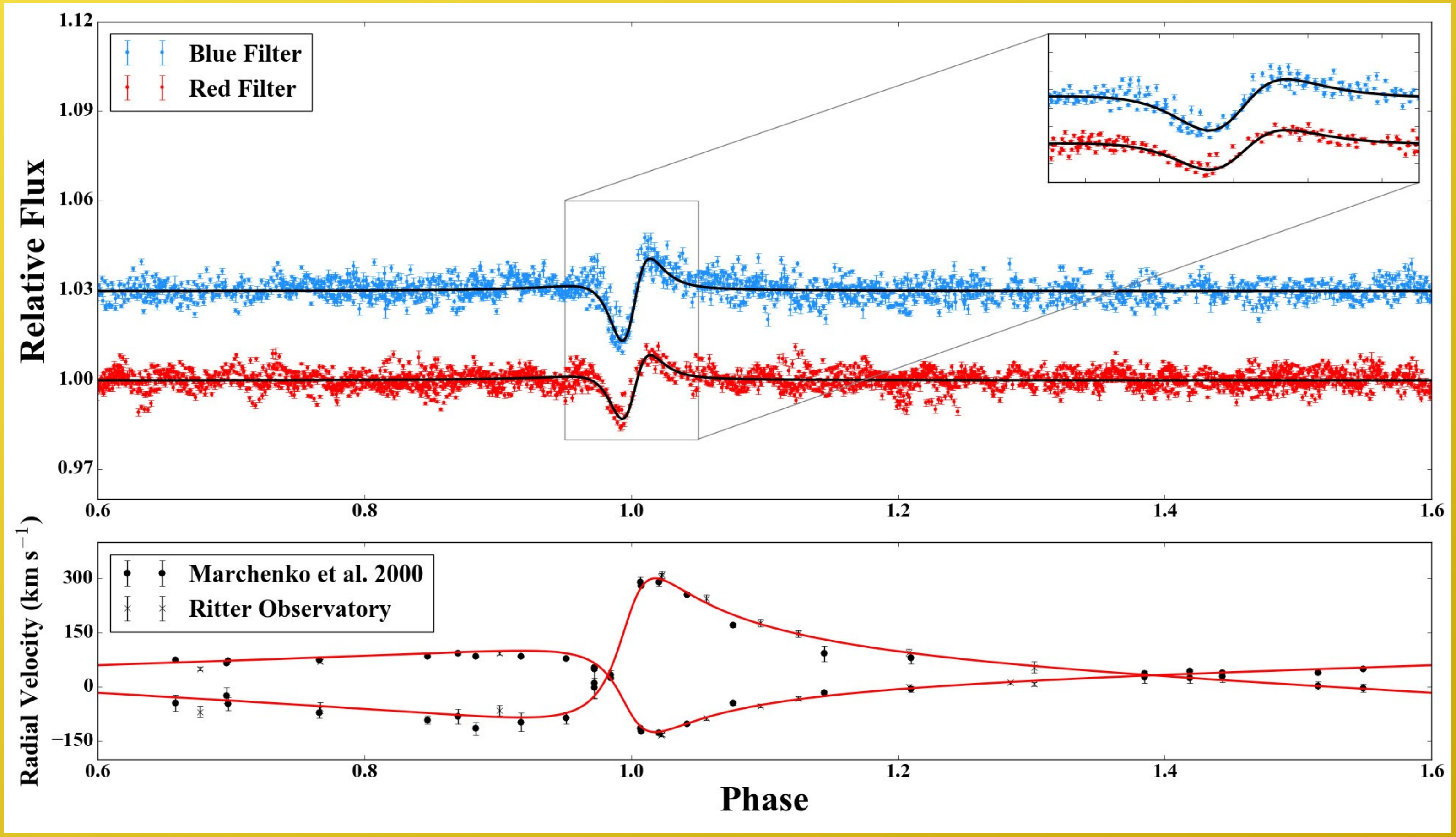


Frequency	Semi-ampl. [mmag]	Phase [rad]	S/N
f_1	2.43 ± .08	4.691 ± .033	16.5
$f_1 - f_{orb}$	0.84 ± .08	0.601 ± .096	5.7
$f_1 - 2f_{orb}$	0.75 ± .08	2.357 ± .101	5.1
$f_1 - 6f_{orb}$	0.62 ± .08	1.377 ± .133	4.2
$f_1 - 4f_{orb}$	0.43 ± .08	6.042 ± .187	2.9
$f_1 - 3f_{orb}$	0.42 ± .08	4.821 ± .187	2.8

(A. Pigulski)

Scientific results: binarity

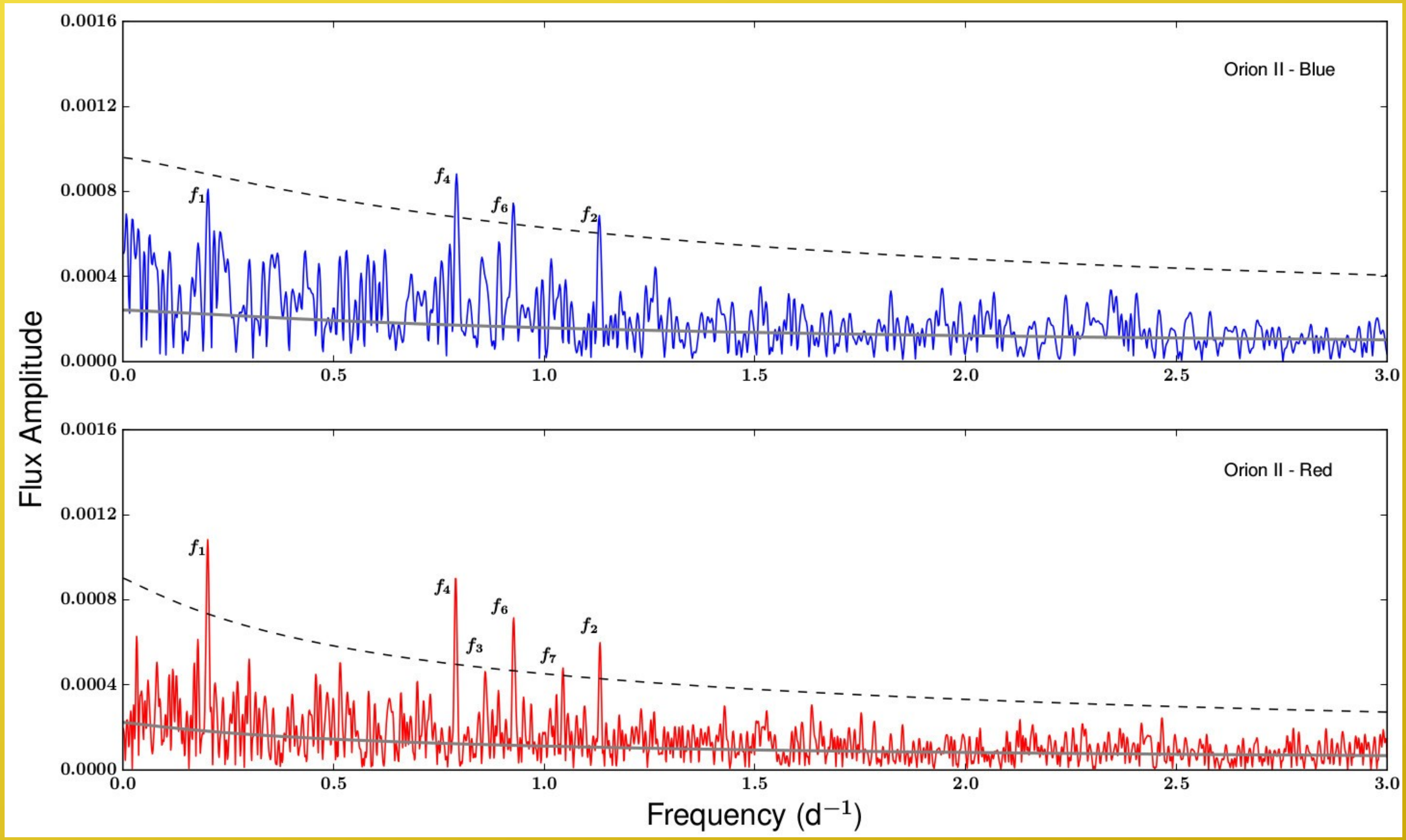
ι Ori (23.2 + 13.4 M_{sun}): BRITE + spectroscopy; P_{orb} = 29.13376 d



(Pablo et al. 2017, MNRAS 467, 2494)

Scientific results: binarity

ι Ori (23.2 + 13.4 M_{sun}): BRITE + spectroscopy; P_{orb} = 29.13376 d

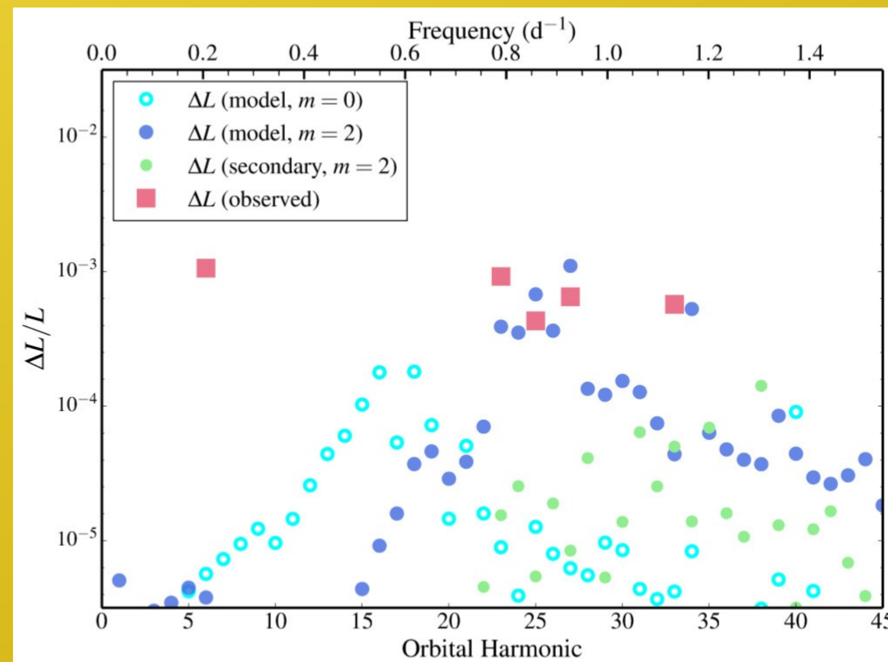


(Pablo et al. 2017, MNRAS 467, 2494)

Scientific results: binarity

ι Ori (23.2 + 13.4 M_{sun}): BRITE + spectroscopy; P_{orb} = 29.13376 d

ID	Filter	Frequency	Orb. harmonic	f (d^{-1})	A (ppt)
Orion I	blue				
		f_1	6	0.211± 0.017	1.06± 0.48
		f_2	33	1.132± 0.017	0.96± 0.4
		f_3	25	0.859± 0.017	0.75± 0.43
		f_4	23	0.789± 0.017	0.7± 0.32
Orion I	red				
		f_2	33	1.1324± 0.0097	0.82± 0.25
		f_3	25	0.8620± 0.0097	0.62± 0.18
		f_5	75	2.5724± 0.0097	0.45± 0.15
Orion II	blue				
		f_4	23	0.792± 0.010	0.97± 0.13
		f_1	6	0.202± 0.010	0.85± 0.35
		f_6	27	0.923± 0.010	0.78± 0.13
		f_2	33	1.13± 0.01	0.7± 0.22
Orion II	red				
		f_1	6.0	0.2016± 0.0059	1.07± 0.4
		f_4	23	0.7895± 0.0059	0.92± 0.09
		f_6	27	0.9271± 0.0059	0.66± 0.29
		f_2	33	1.1325± 0.0059	0.58± 0.09
		f_7	30	1.0445± 0.0059	0.45± 0.09
		f_3	25	0.8597± 0.0059	0.44± 0.09



(Pablo et al. 2017, MNRAS 467, 2494)

Scientific results: magnetic stars

Table 1. Known magnetic massive pulsators, having N detected pulsation modes.

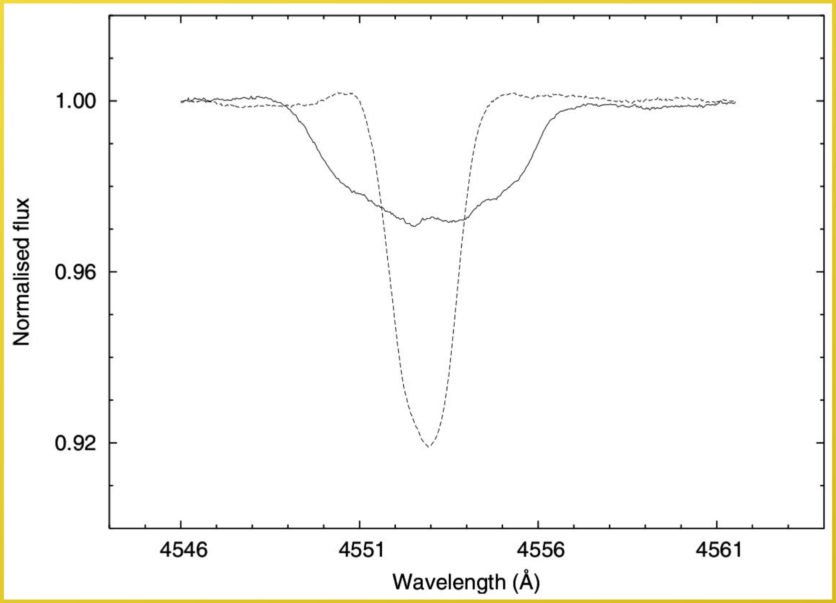
	Star	N	Type	$P_{\rm rot}$ [d]	$B_{\rm pol}$ [G]	Magnetic characterization	Binary?	SpT	References
1	HD 43317	> 100	both	0.90	~ 900	dip.; $i \in [20, 50]^\circ$; $\beta \in [70, 86]^\circ$		B3IV	(1), (2)
2	β Cen Ab	< 17	β Cep		~ 250		Y	+ B1III	(3), (4)
3	β Cep	5	β Cep	12.0	~ 300	dip.; $i \sim 60^\circ$; $\beta \sim 95^\circ$	Y	B0III +	(5), (6)
4	V2052 Oph	3	β Cep	3.64	~ 400	dip.; $i \sim 70^\circ$; $\beta \sim 35^\circ$		B2IV/V	(7), (8), (9)
5	β CMa	3	β Cep		< 30			B1II/III	(10), (11), (12)
6	16 Peg	3	β Cep	1.44	~ 500	dip.; $i \sim 70^\circ$; $\beta \sim 70^\circ$		B3V	(13), (14), (15)
7	ϵ Lup A	'LPV bump'	β Cep		~ 600		Y	B2V +	(16), (17)
	ϵ Lup B	> 2	β Cep		~ 300		Y	+ B3V	(16), (18)
8	ξ^1 CMa	1	β Cep	2.18	~ 600			B1V	(19), (20)
9	HD 96446	1	β Cep	23.4	~ 7500			B2IIIp	(21), (22), (23)
10	ζ Cas	1?	SPB	5.37	~ 150	dip.; $i \sim 30^\circ$; $\beta \sim 105^\circ$		B2IV/V	(24), (25)
11	σ Lup	1?	SPB	3.09	~ 300	dip.; $i \sim 60^\circ$; $\beta \sim 90^\circ$		B2III	(26), (14)
12	ϕ Cen	'LPV bump'	β Cep	1.14	~ 900			B2IV	(27), (28)

(Buysschaert, Neiner & Aerts 2017, Proc. IAUS 329, in press)

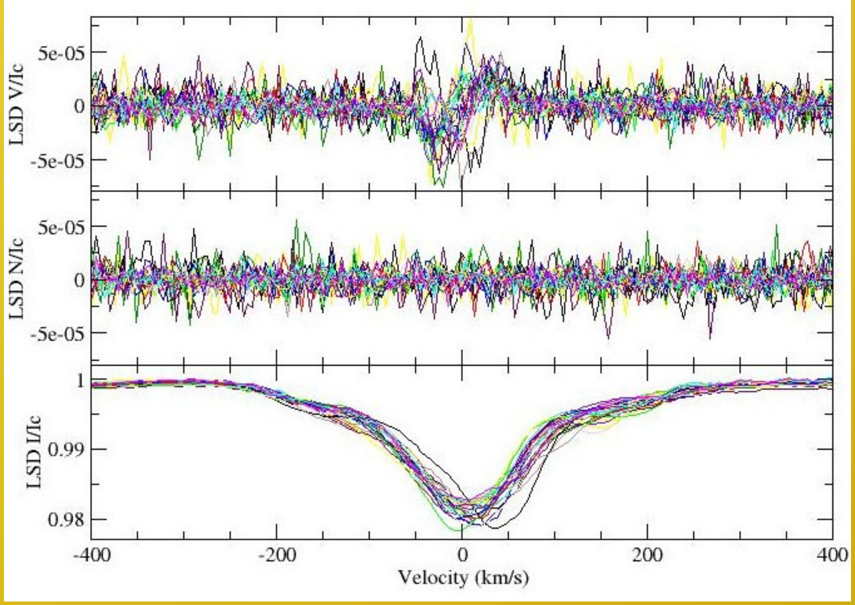
Scientific results: magnetic stars

The BRITEpol survey (C. Neiner)

β Centauri (12.0 + 10.6 M_{sun}):



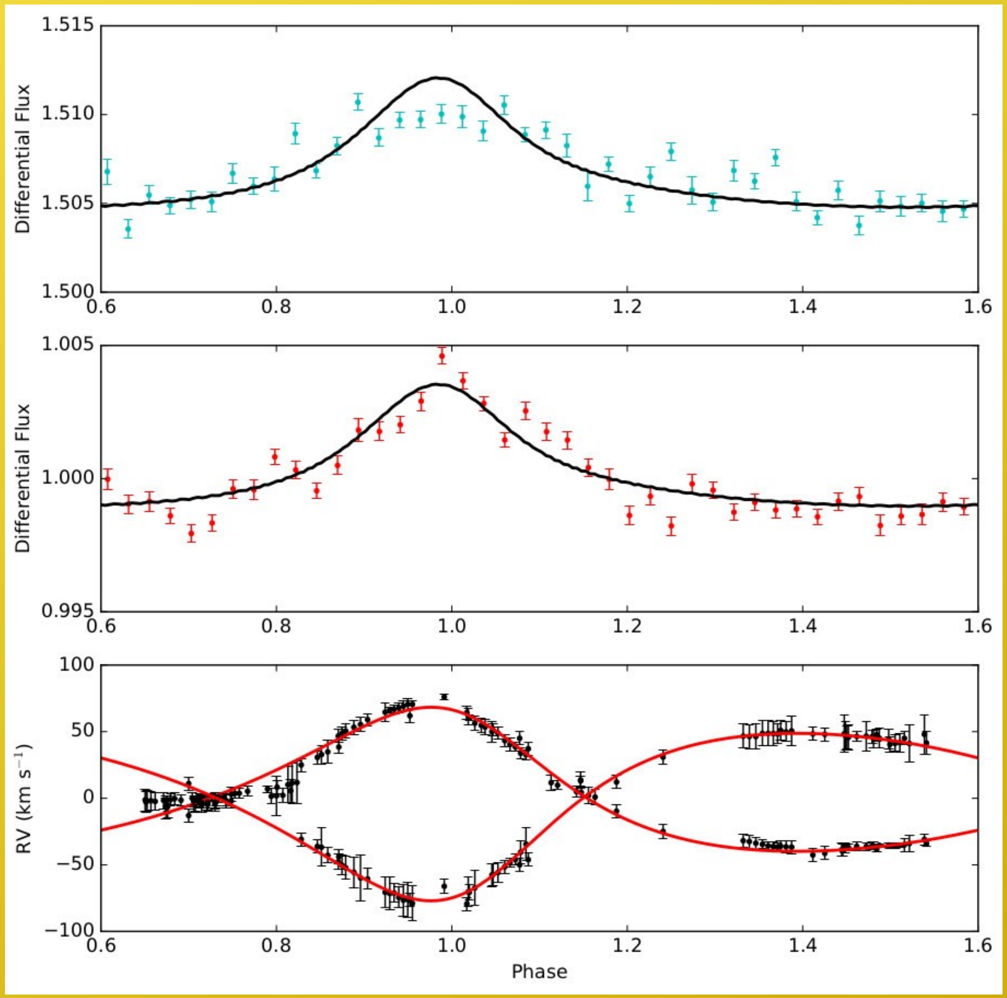
Disentangled spectra
(Ausseloos et al. 2005, A&A 455, 259)



HarpsPol LSD profiles (-50 G < B_l < 20 G):
(C. Neiner)

Scientific results: magnetic stars

ε Lupi (10.3 + 8.9 M_{sun}): BRITE + spectroscopy; P_{orb} = 4.55959 d



(Wade et al. 2016, 2nd BRITE Science Conference, Innsbruck; Pablo et al., in prep.)

Scientific results: the most massive BRITE star

(T. Ramiaramanantsoa et al., MNRAS, in prep.)

Lessons from BRITE:

(not in alphabetical order)

- Precision photometric studies with nanosatellites in low Earth orbits are possible
- gravity mode pulsation among β Cep stars is rather common
- interior rotation of SPB stars can be studied
- magneto-asteroseismology is on the horizon
- pulsation-mass loss interaction in Be stars
- massive heartbeat stars are around and can be investigated
- a link between large-scale wind structures and their photospheric origin has been found