The scientific connection between China, Belgium, and India

Possibilities for the future?

Peter De Cat

Royal Observatory of Belgium (Brussels, Belgium)

Personalia

- Date of Birth: 19/06/1974
- Sex: male (he/him)
- Martial status: married
- Children: Sien De Cat (29/01/2004)
  Nele De Cat (19/02/2007)
  Lore De Cat (19/02/2007)
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  Ringlaan 3
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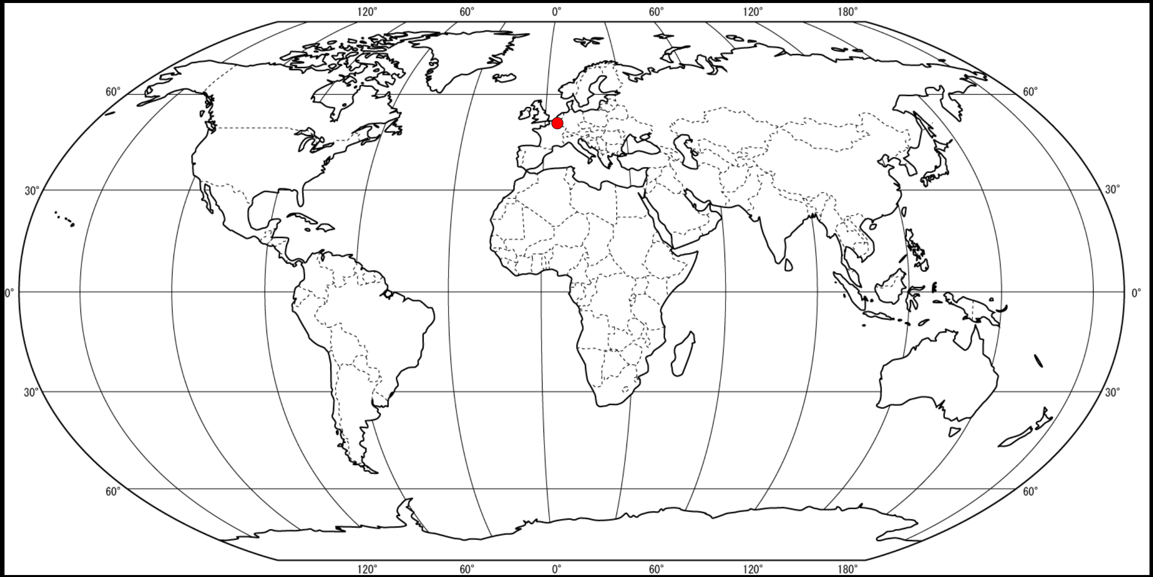
- E-mail: Peter.DeCat@oma.be

H-index: 44

- 122 papers in international refereed journals (7)
- 5 papers in international non-refereed journals
- 90 papers in proceedings of international conferences (21)

Outline

1. Scientific background
2. Connection Belgium – China
3. Connection Belgium – India
4. Connection China – India
5. Conclusions and future prospects

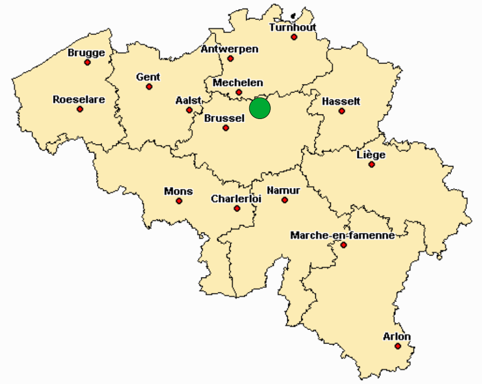


Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)
2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Scientific background

KU Leuven

- Master student (physics)



KU LEUVEN

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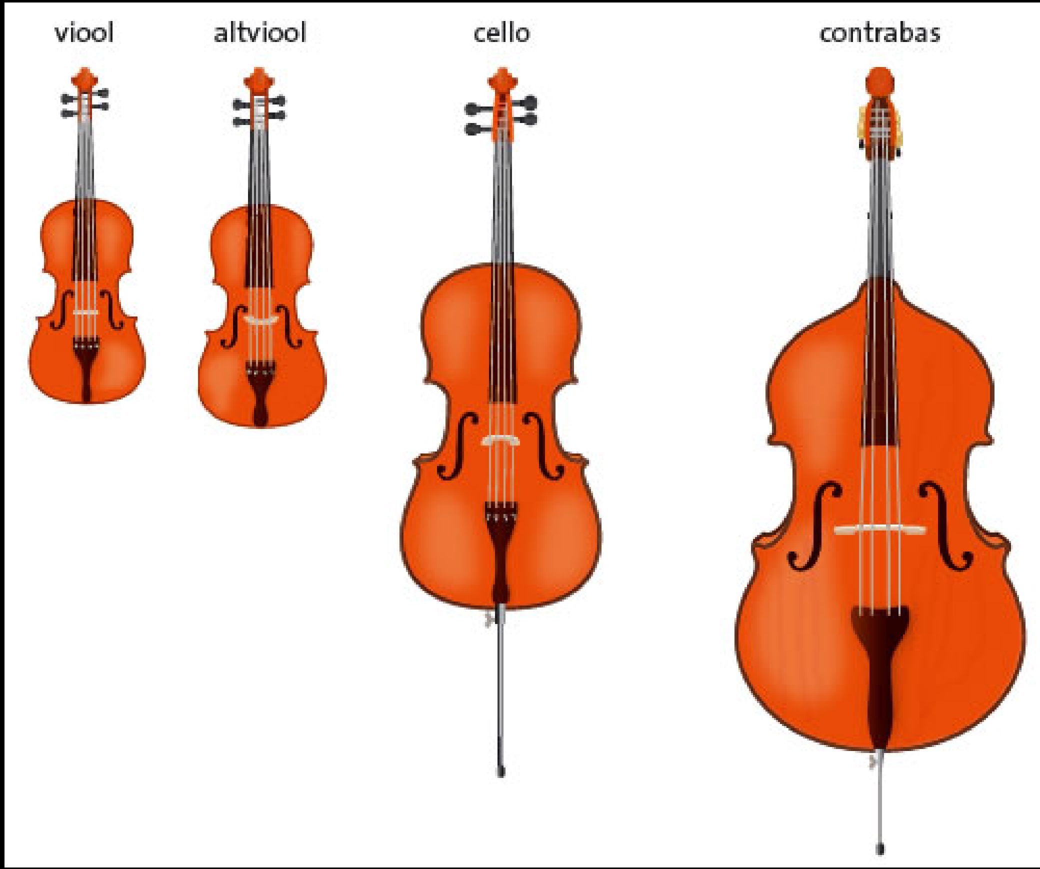
- Master student (physics)

Conny Aerts

Francqui award (2012)
Kavli prize in astrophysics (2022)

Musical instruments

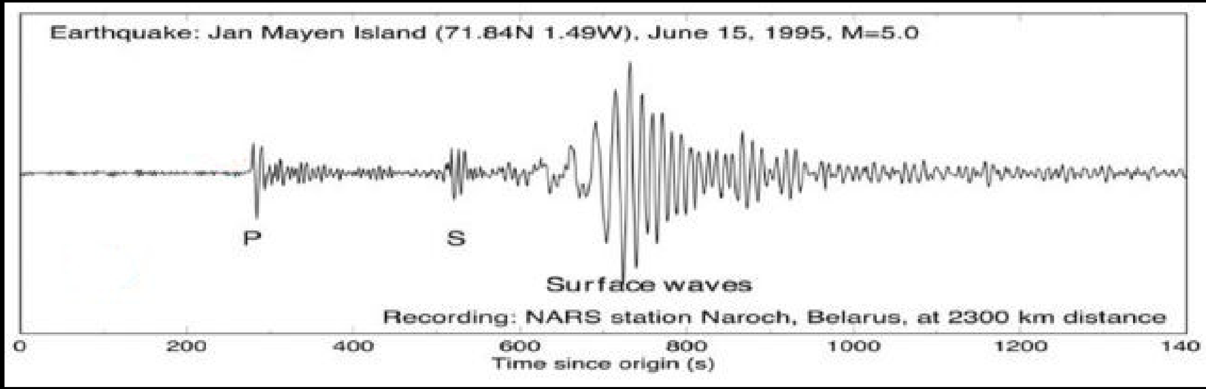


shape and material determines the sound of the instrument

Seismology

- seismo: vibration, pulsation, oscillation,...
- logy: study of,...

use earthquakes to investigate the interior of the Earth



Asteroseismology

- aster: star
- seismo: vibration, pulsation, oscillation,...
- logy: study of,...

↳ to investigate stars
by studying their pulsations and their interior!

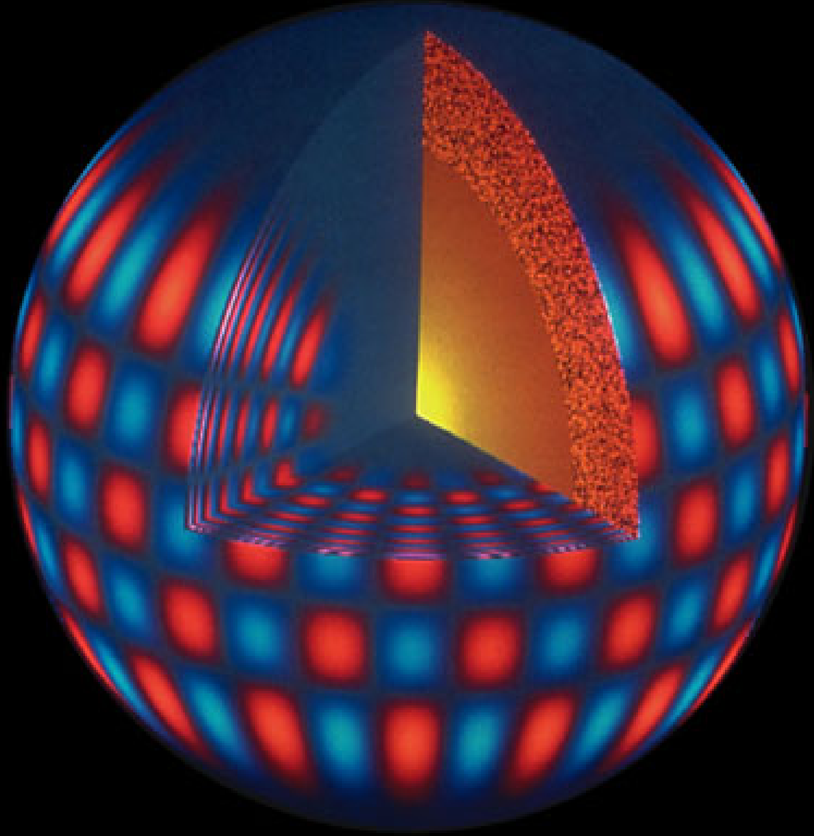
Sun

δ Scuti star HD31901

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

Asteroseismology

- aster: star
- seismo: vibration, pulsation, oscillation,...
- logy: study of,...
  - → stellar parameters
    - ➢ *M*, age, *X*, *Z*,...
  - → convection
    - ➢ size convective layers
    - ➢ convective overshoot
  - → rotation
    - ➢ surface versus core
    - ➢ rigid versus differential
  - → diffusion
  - → internal structure
    - ➢ layers
    - ➢ composition



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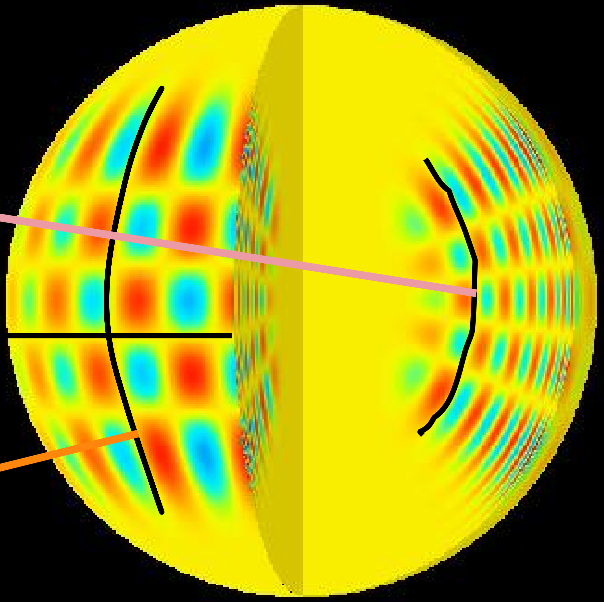
Pulsations

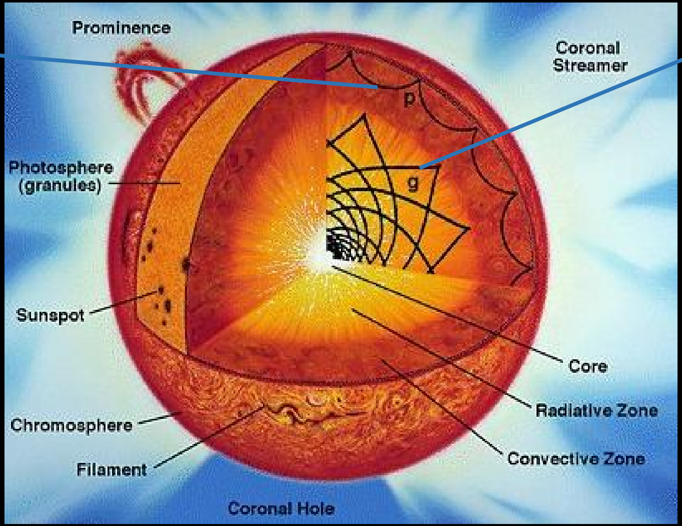
- f = frequency
- n = number of nodesurfaces between center and surface
- ℓ = total number of nodelines on surface
  - → $\ell = 0$: radial mode
  - → $\ell > 0$: non-radial mode
- $|m|$ = number of nodelines perpendicular to equator on surface
  - → $|m| \leq \ell$
  - → $m > 0$: retrograde mode
  - → $m < 0$: prograde mode



1. Frequency analysis
2. Mode identification
3. Theoretical modelling

Pressure modes (p-modes)

- Restoring force: pressure
- Short periods
- Cavity near surface
- Amplitude largest component in radial direction

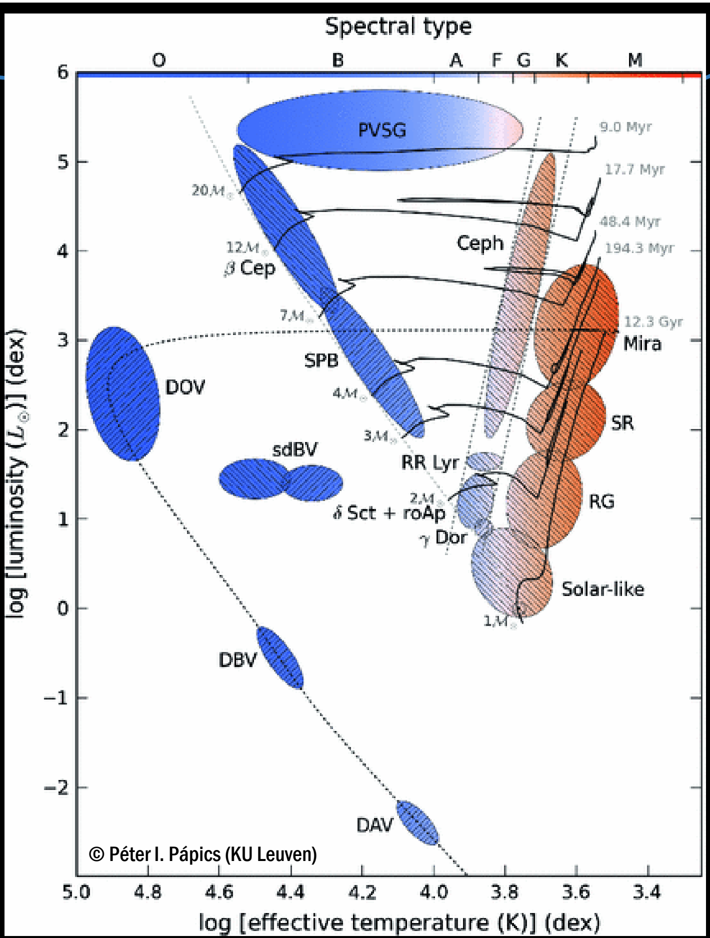


Gravity modes (g-modes)

- Restoring force: buoyancy
- Long periods
- Cavity in deep interior
- Amplitude largest component in tangential direction

Pressure modes (p-modes)

- Restoring force: pressure
- Short periods
- Cavity near surface
- Amplitude largest component in radial direction
- \\\\



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Asteroseismology

Pressure modes (p-modes)

- Restoring force: pressure
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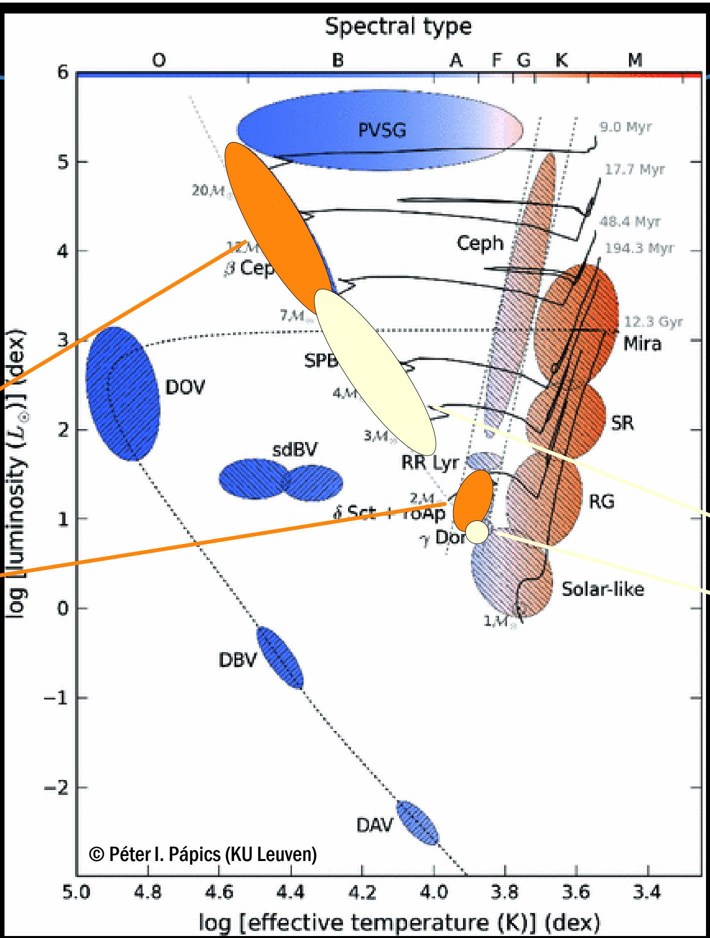
β Cephei stars (βCep)

δ Scuti stars (δSct)

- Periods order of hours

(0.3-10 hours)



Gravity modes (g-modes)

- Restoring force: buoyancy
- Long periods
- Cavity in deep interior
- Amplitude largest component in tangential direction
- ////

Slowly pulsating B stars (SPB)

γ Doradus stars (γDor)

- Periods order of days

(0.3-3 days)

Scientific background — Asteroseismology

KU Leuven

- Master student (physics)

→ Evidence for binarity and multiplicity in the β Cephei star β Crucis

- ➢ CAT/CES@ESO(LaSilla)/1.4-m
  - ✔ high-resolution (R=60000), SiIII triplet (455.26, 456.78, 457,48 nm)
  - ✔ time-series: 1193 spectra in 11 nights (1984-1995)
  - ✔ isolated observations: 14 spectra in 14 nights (1996-1997)

Aerts, De Cat, Cuypers et al., 1998, A&A 329, 137

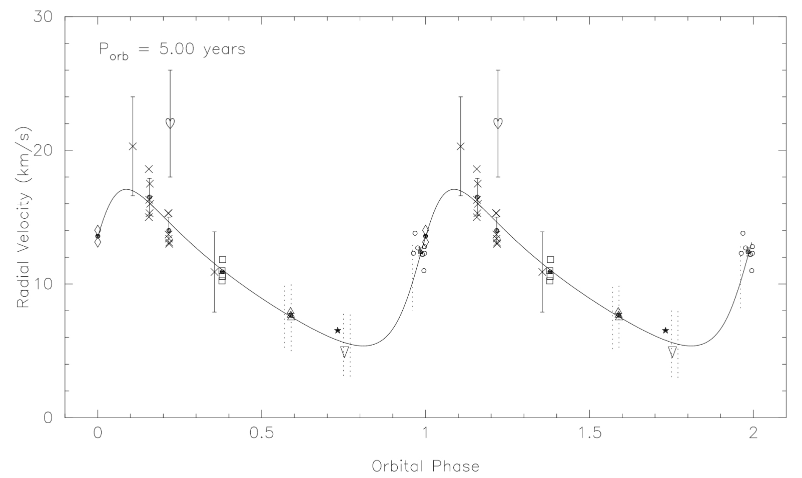
Multiperiodic pulsator

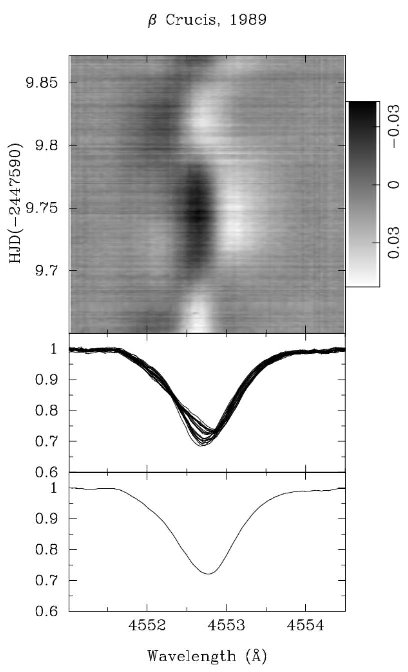
- f_1 = 5.2305468 d^{-1} (ℓ = 1)
- f_2 = 5.958666 d^{-1} ($\ell \geq 3$)
- f_3 = 5.472165 d^{-1} ($\ell \geq 3$)

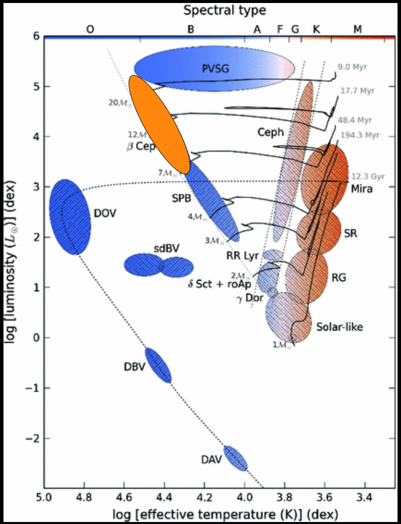
(moment method)

Single-lined binarity

- P_{orb} = 1828.0(25) days
- e = 0.38(9)
- B2V secondary







→ Polarimetric detection of non-radial oscillation modes in the β Cephei star β Crucis

Cotton, Buzasi, Aerts et al., 2021, NatAst 6, 154

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2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Scientific background

Asteroseismology

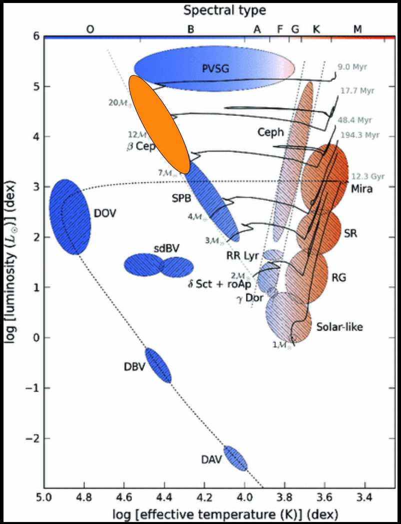
KU Leuven

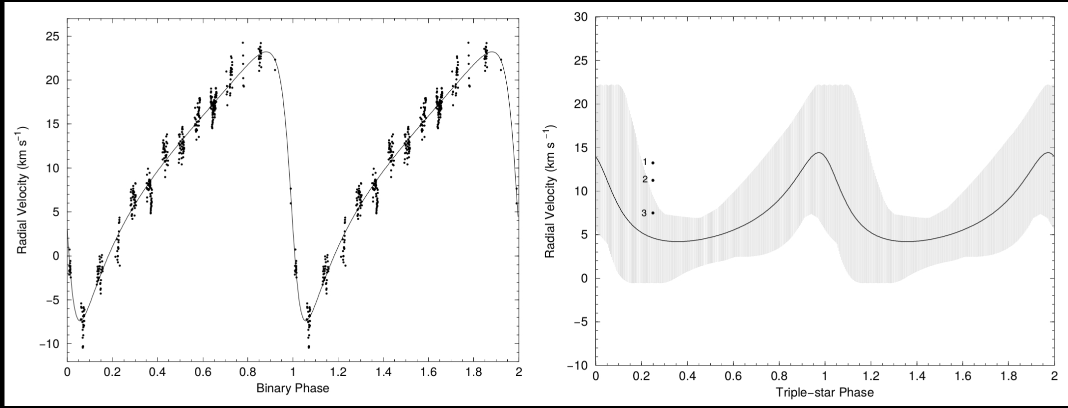
- Master student (physics)
- PhD student (physics, group astronomy)

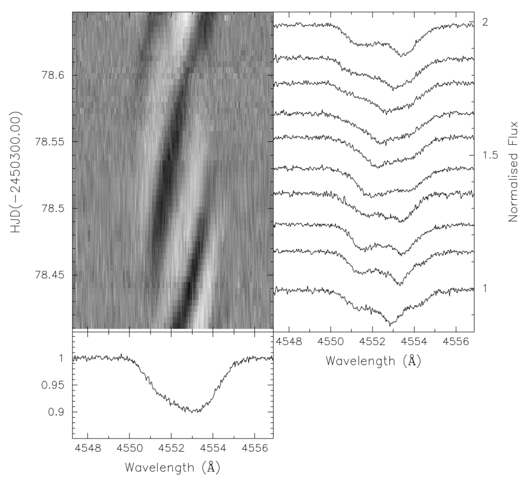
→ A detailed spectroscopic analysis of ε Per I. Determination of the orbital parameters and of the frequencies

- Aurélie@OHP/1.52-m
  - ✔ high-resolution (R=60000), SiIII triplet (455.26, 456.78, 457,48 nm)
  - ✔ time-series: 464 spectra in 14 consecutive nights (16-29/10/1996)

De Cat, Telting, Aerts, Mathis, 2000, A&A 359, 539







Multiperiodic pulsator

- f_1 = 5.300 d^{-1}
- f_2 = 5.890 d^{-1}
- f_3 = 6.250 d^{-1}
- f_4 = 6.875 d^{-1}
- f_5 = 10.585 d^{-1}

(moment method)

Triple system

(Tarsov et al., 1995, A&AS 110, 59)

- 14.0 days of inner binary confirmed
- 1456 days of triple system non-conclusive

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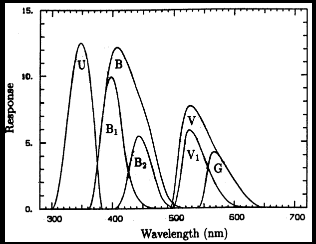
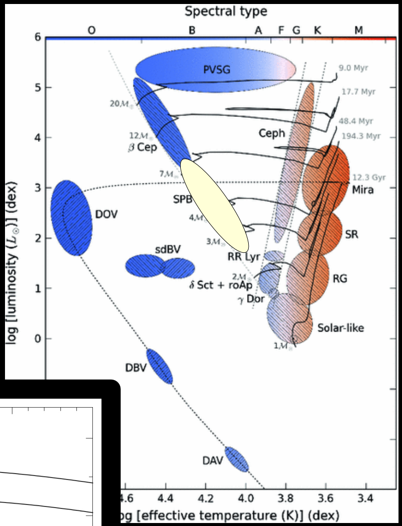
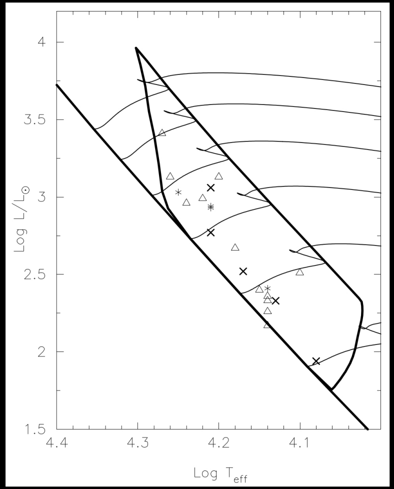


→ A study of bright southern slowly pulsating B stars

- Sample
  - ✔ 5 well-known SPBs (Waelkens, 1991, A&A 246, 539)
  - ✔ 12 candidate SPBs (thanks to Hipparcos data)
- Observations
  - ✔ Spectroscopy: high-resolution CAT/CES@ESO/1.4-m (SiII doublet: 412.8, 413.0 nm)
  - ✔ Photometry: Geneva photometry (U, B1, B, B2, V1, V, G)
    Hipparcos photometry (H_p)
- Analysis
  - ✔ Frequency analysis
  - ✔ Mode identification
    - ➔ moment method and photometric amplitude ratios

Observational characterisation of class of SPB stars





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Scientific background

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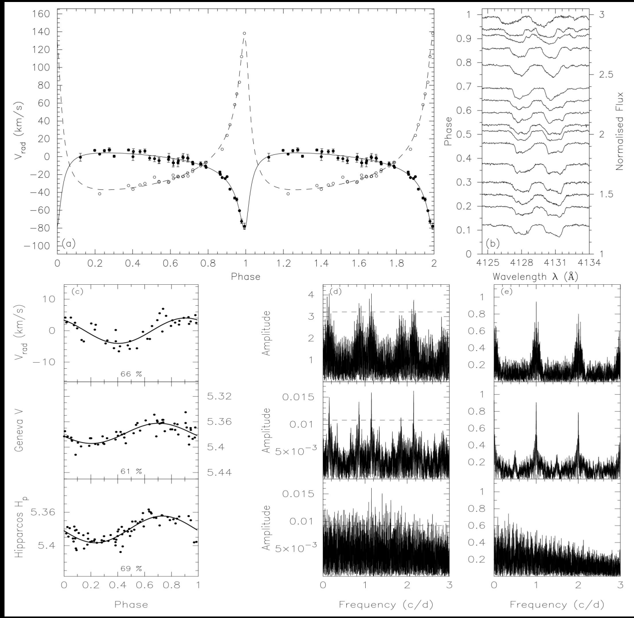
→ A study of bright southern slowly pulsating B stars

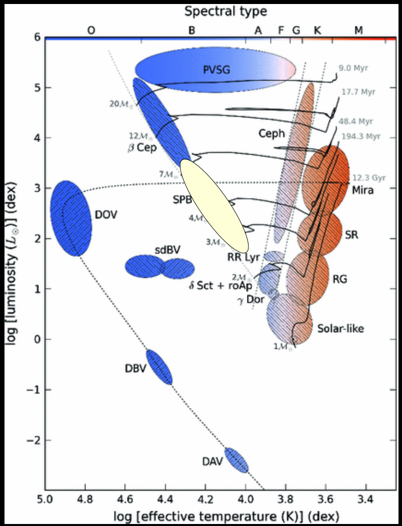
I. Determination of the orbital parameters and of the main frequency of the spectroscopic binaries

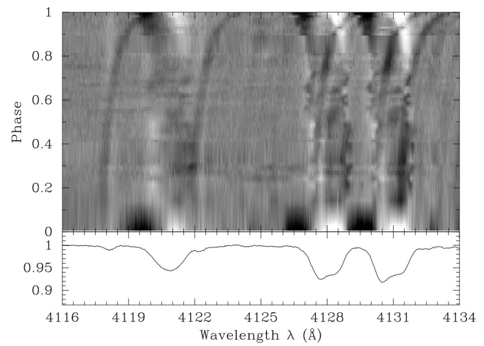
De Cat, Aerts, De Ridder et al., 2000, A&A 355, 1015

			Star	Spec N	Spec T(d)	Spec S/N	Gen N	Gen T(d)	Gen T*(d)	Hipp N	Hipp T(d)
Singles			HD26326	65	606	325	135	7367	454	85	1158
			HD74195 ∗	94	718	425	737	7792	6292	115	1157
			HD85953	71	716	300	164	6883	415	156	1180
			HD131120	83	718	400	115	7296	116	60	885
			HD138764	68	719	325	93	7726	115	95	786
			HD181558 ∗	33	470	300	320	7854	5544	72	1093
			HD215573	43	554	300	63	7350	451	146	1142
Suspected Binaries			HD53921	75	715	325	145	7270	415	123	1185
			HD55522	65	715	350	122	6588	416	222	1149
Binaries	SB2	$e \neq 0$	HD123515 ∗	78	719	325	648	6921	5846	179	1166
			HD140873	45	472	300	59	7746	106	79	1088
	SB1	$e \neq 0$	HD24587	74	606	350	142	7372	454	128	1134
			HD74560 ∗	115	719	400	721	7713	5961	127	1157
			HD177863 ∗	41	470	300	301	7854	5319	85	1055
		$e = 0$	HD69144	93	718	400	148	7190	414	109	1132
			HD92287	65	716	325	232	7110	6053	136	1158
			HD169978	48	510	375	74	7110	377	77	1123

Very eccentric double-lined binary - P_{orb} = 38.927(4) days
- e = 0.731(6)







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2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

KSB - ORB

KU Leuven

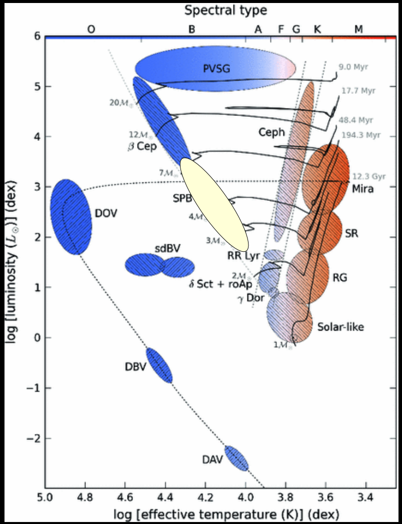
- Master student (physics)
- PhD student (physics, group astronomy)

→ A study of bright southern slowly pulsating B stars
II. The instrinsic frequencies
III. Mode-identification for singly-periodic targets in spectroscopy

De Cat & Aerts, 2002, A&A 393, 965

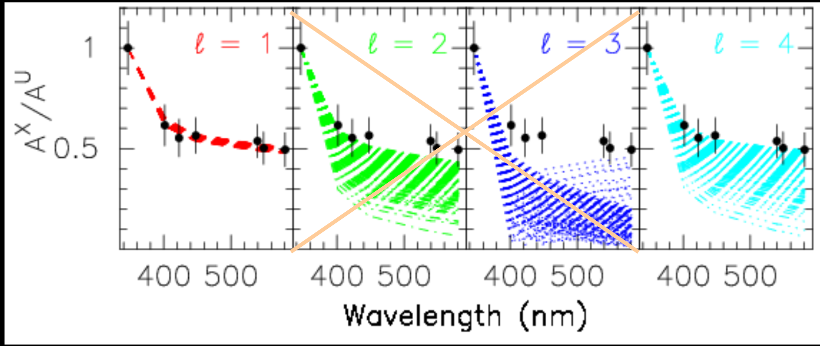
De Cat, Briquet, Daszyńska-Daszkiewicz et al., 2005, A&A 432, 1013

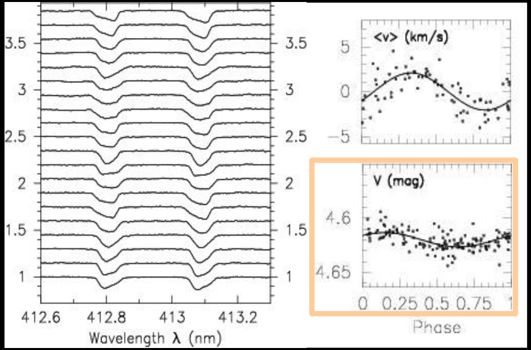
HD24587 = 33 Eridani
#137 Geneva phometry
#65 CAT spectra
f_1 = 1.1569 d^{-1}



➢ Photometry: method of photometric amplitude ratios (Dupret et al., 2003, A&A 398, 677)
- ✔ Grid: M = 2-15 $M_\odot$, Z_0=0.015, X_0=0.71, α_{conv}=1.75, α_{over}=0.0 , no diffusion + Asplund (2005)
- ✔ Selection models in (T_{eff},log$g$) error box
- ✔ Each ℓ: selection eigenfrequency closest to observed frequency
- ✔ Comparison theoretical-observed amplitude ratios relative to bluest filter

Inconclusive
… ℓ = 1 most probable





constraints on ℓ

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➢ Spectroscopy: line-profile variations

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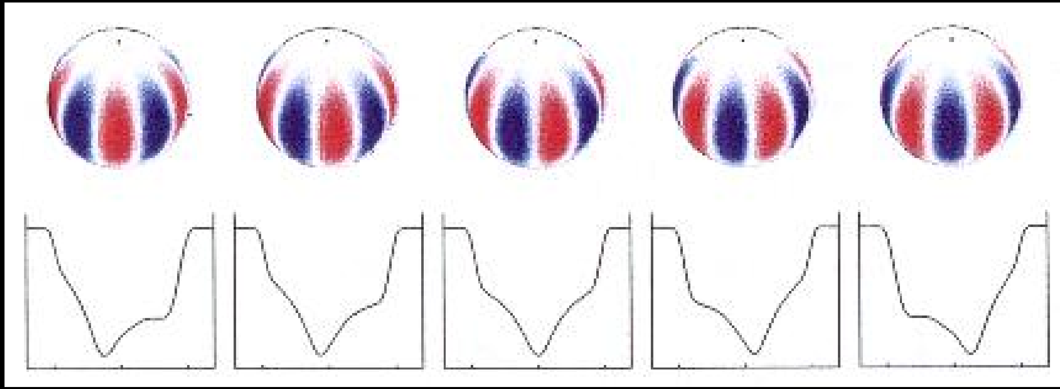
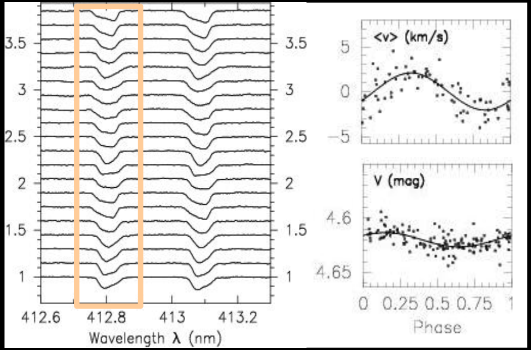
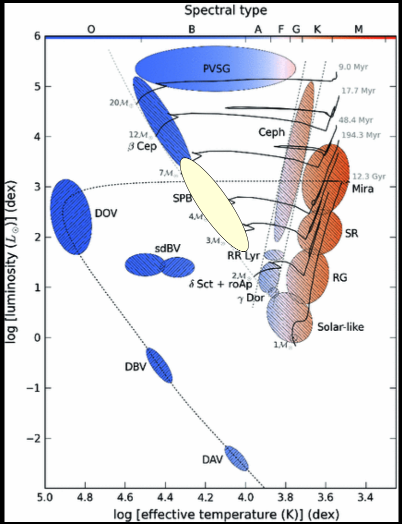


“moving bumps”





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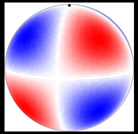
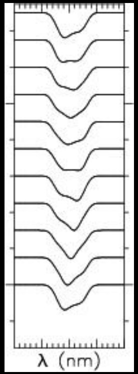




$\ell = 3$

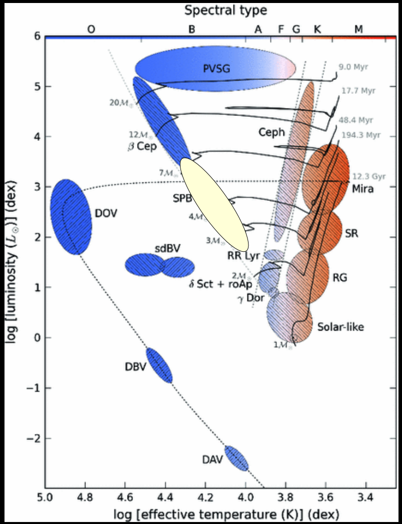
$m = 2$

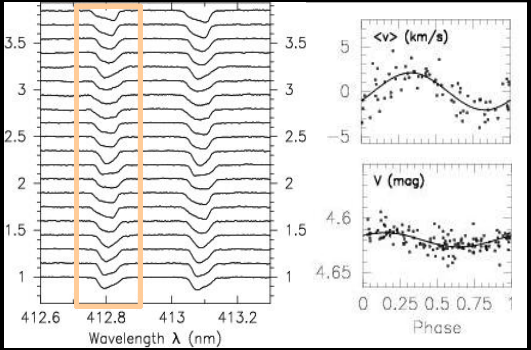
$i = 80°$

$v_\Omega = 50\ km\,s^{-1}$

$\sigma = 10\ km\,s^{-1}$

$k = 0.03$





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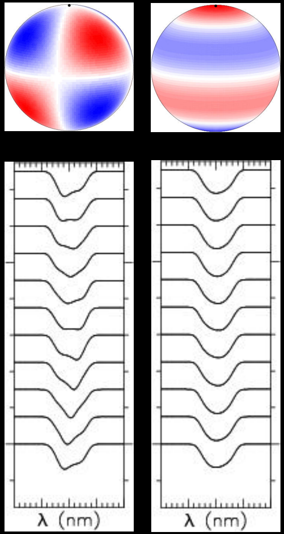

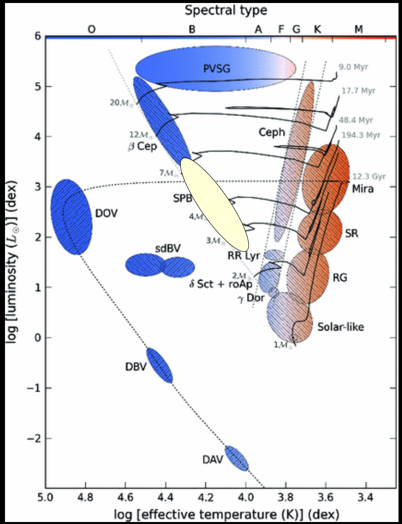

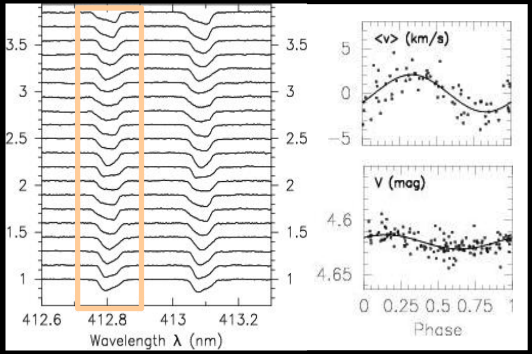

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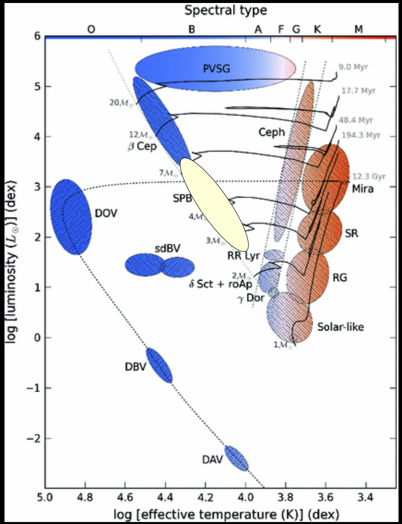


$\ell = 3$

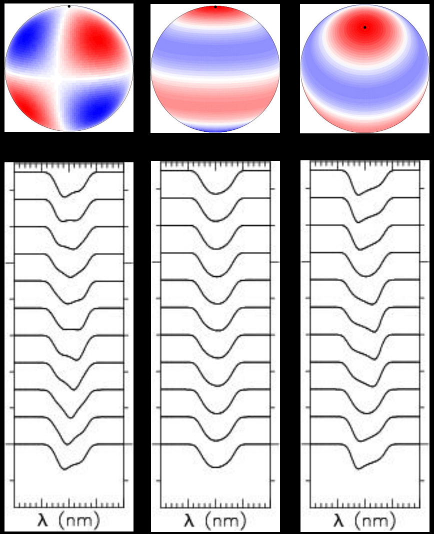
$m =$ ~~2~~ 0

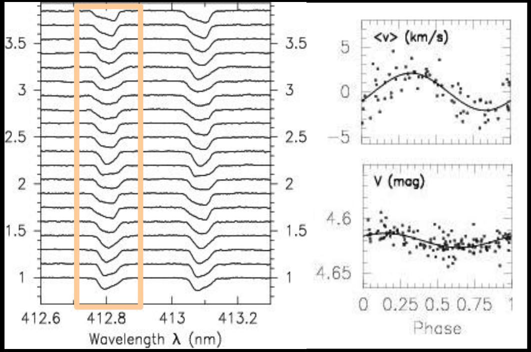
$i =$ ~~80~~ 40°

$v_\Omega = 50\ \mathrm{km\,s^{-1}}$

$\sigma = 10\ \mathrm{km\,s^{-1}}$

$K = 0.03$





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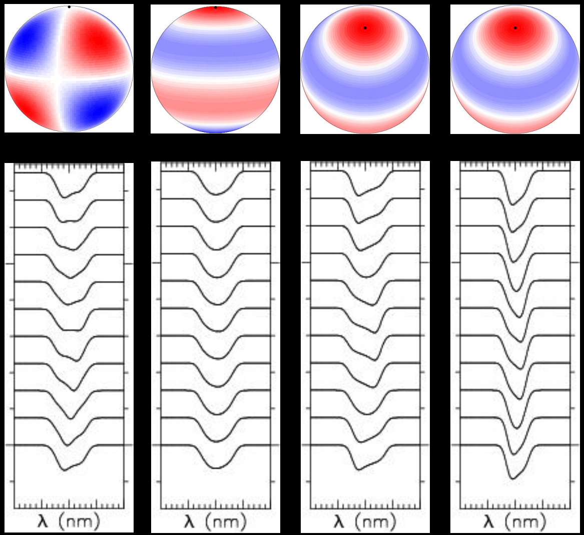
$m = ~~2~~\ 0$

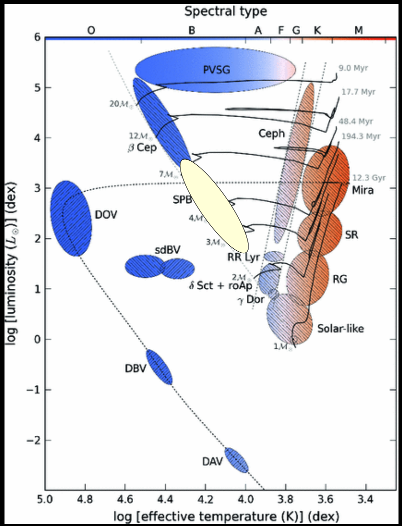
$i = ~~80~~\ 40°$

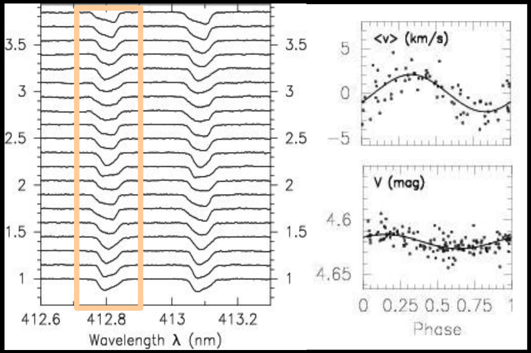
$v_\Omega = ~~50~~\ 30\ km\,s^{-1}$

$\sigma = 10\ km\,s^{-1}$

$\kappa = 0.03$







Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

KSB - ORB

KU Leuven

- Master student (physics)
- PhD student (physics, group astronomy)

→ A study of bright southern slowly pulsating B stars

II. The instrinsic frequencies

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➢ Spectroscopy: line-profile variations

De Cat & Aerts, 2002, A&A 393, 965

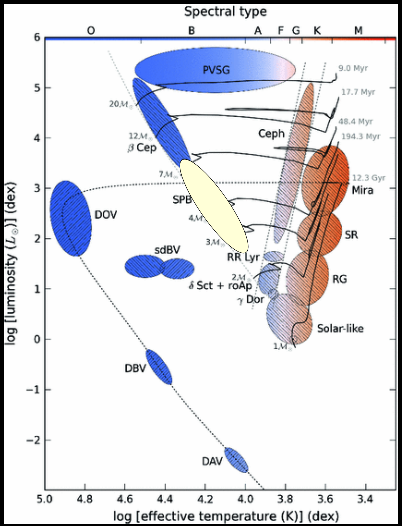
De Cat, Briquet, Daszyńska-Daszkiewicz et al., 2005, A&A 432, 1013

HD24587 = 33 Eridani

#137 Geneva phometry

#65 CAT spectra

f_1 = 1.1569 d^{-1}



ℓ = 3

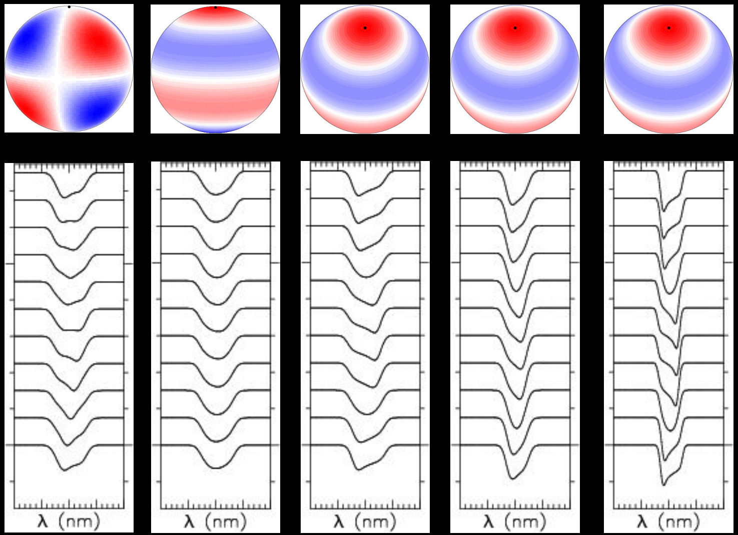
m = ~~2~~ 0

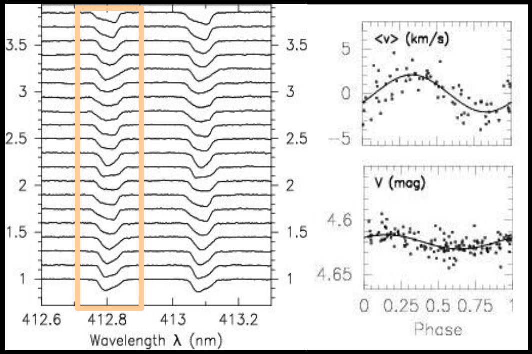
i = ~~80~~ 40°

v_Ω = ~~50~~ 30 km s^{-1}

σ = ~~10~~ 5 km s^{-1}

κ = 0.03





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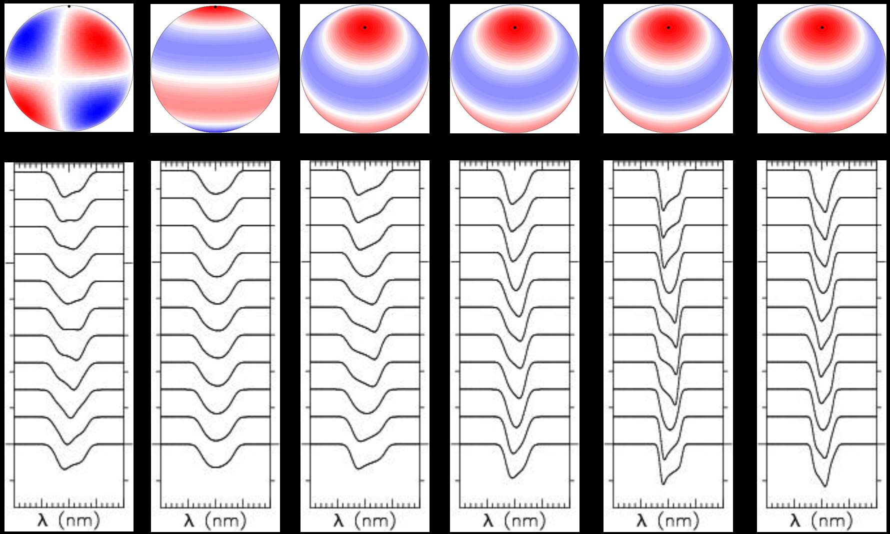
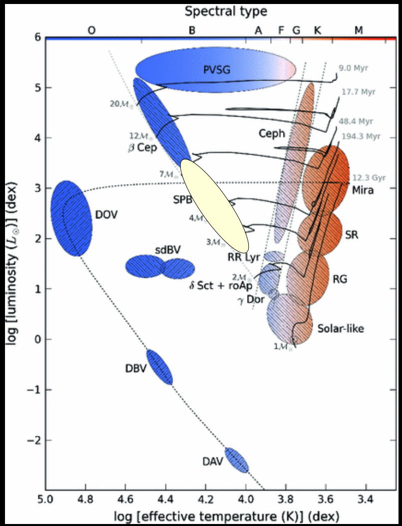
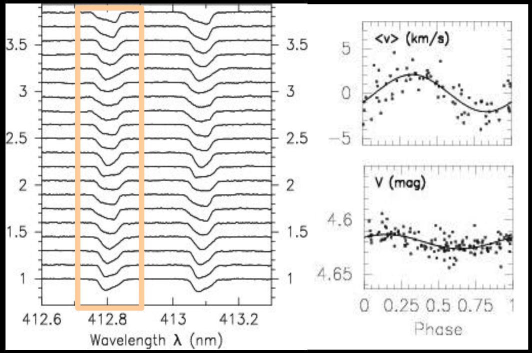
K = 0.03 → 3







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Scientific background — Asteroseismology

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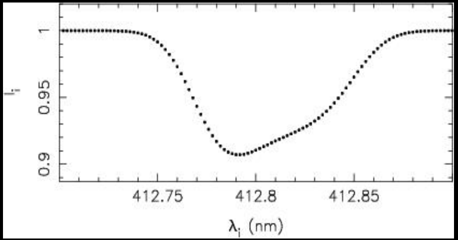
✔ Comparison theoretical – observed velocity moments of line-profiles



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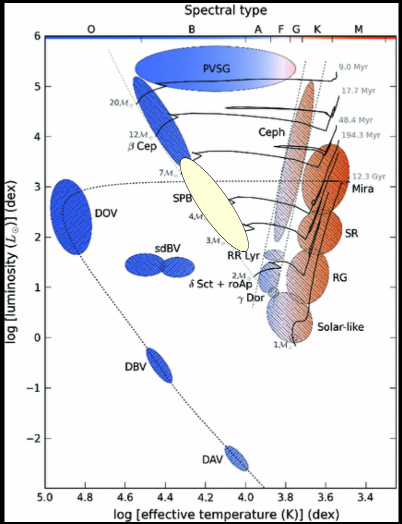

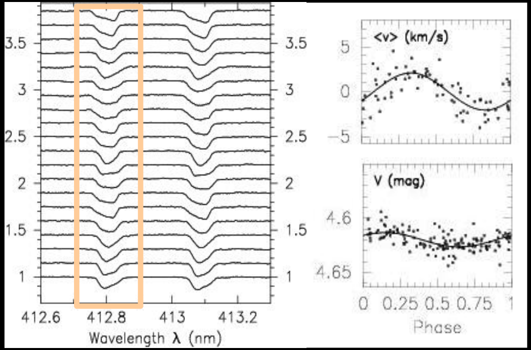

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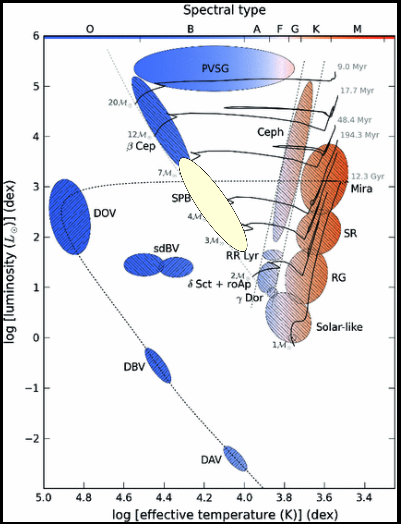
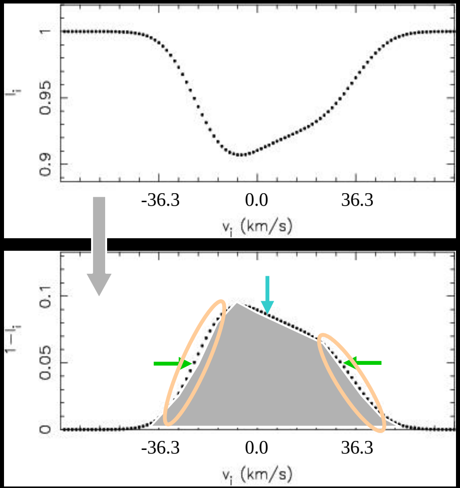




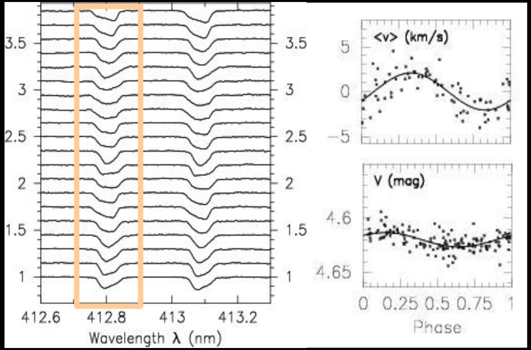
$$\langle v^n \rangle = \frac{\Sigma_i\ (1-I_i)\ v_i^n\ (v_i - v_{i-1})}{\Sigma_i\ (1-I_i)\ (v_i - v_{i-1})}$$

denominator = equivalent width

$\langle v^1 \rangle$ ~ radial velocity

$\langle v^2 \rangle$ ~ width

$\langle v^3 \rangle$ ~ skewness



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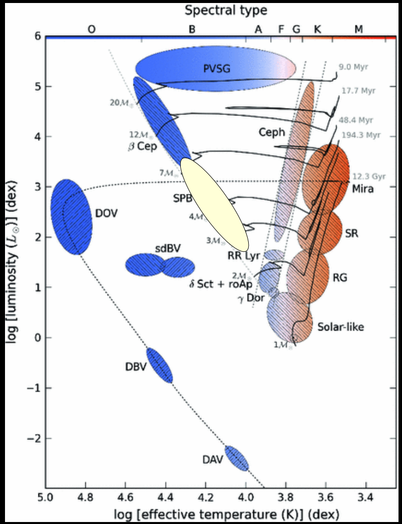
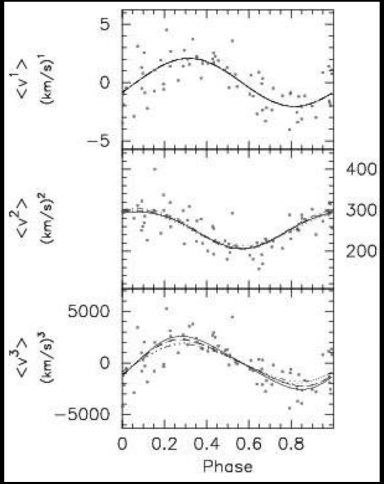
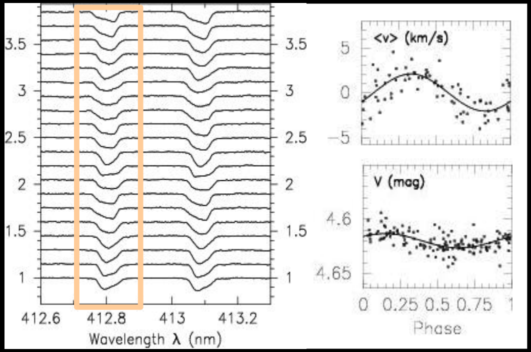


ℓ	m	disc	i	v_Ω	σ
2	-2	11.0	19	18	12
3	-1	11.1	37	32	2
2	-1	11.1	25	32	3
3	-2	11.2	15	5	2
1	+1	11.3	42	31	5

Inconclusive
Continuous parameters not well constraint





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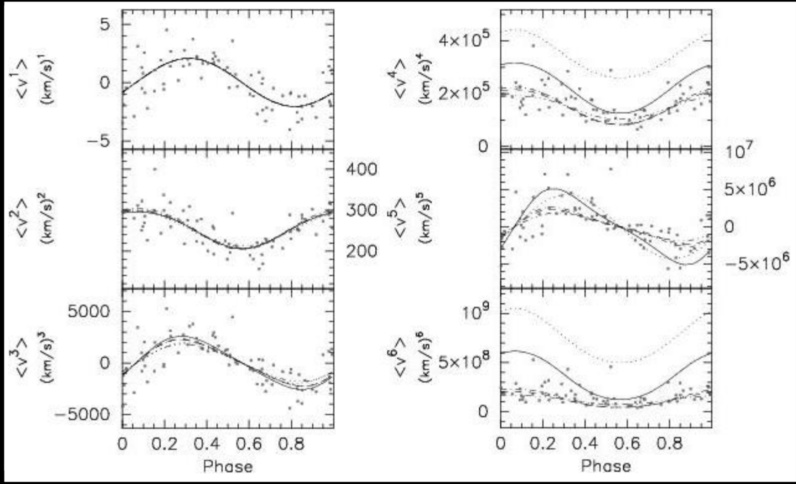
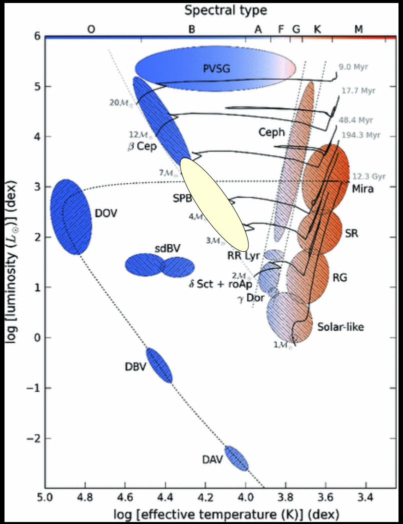
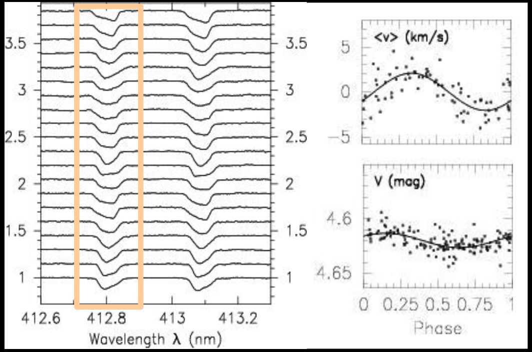
2	-1	11.1	25	32	3
3	-2	11.2	15	5	2
1	+1	11.3	42	31	5

Higher order even moments are useful







KSB - ORB

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➢ Spectroscopy: pixel-by-pixel method (Telting & Schrijvers, 1997, A&A 317, 723)

De Cat & Aerts, 2002, A&A 393, 965

De Cat, Briquet, Daszyńska-Daszkiewicz et al., 2005, A&A 432, 1013

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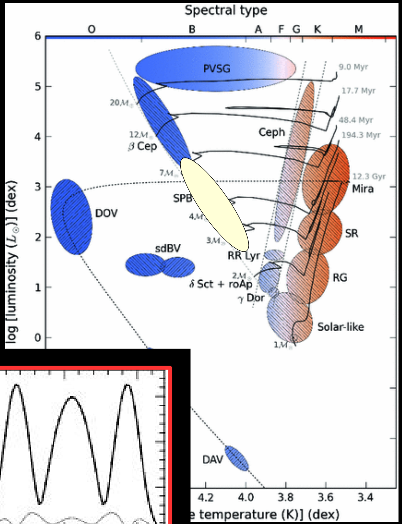
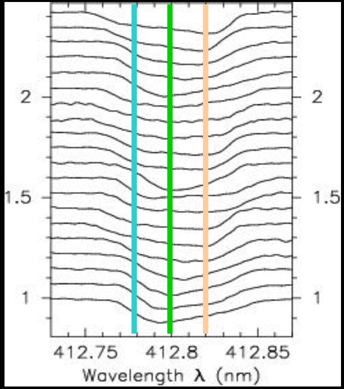
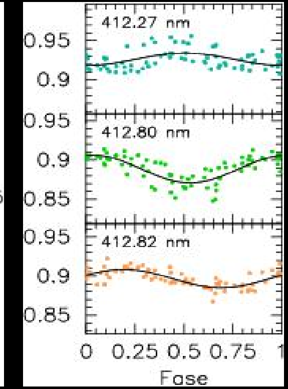
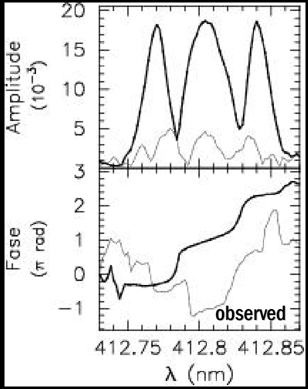
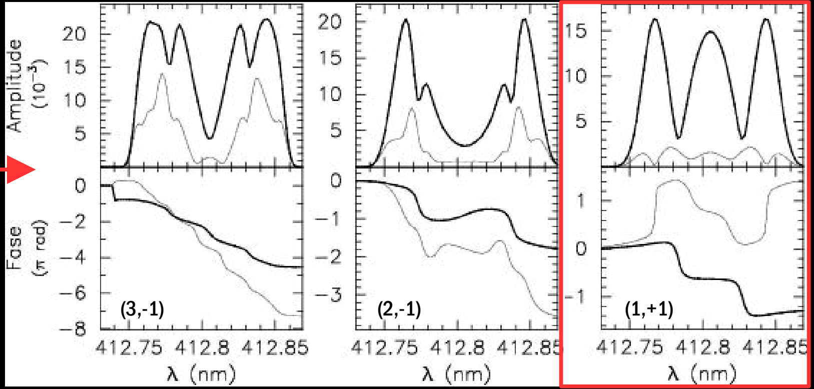


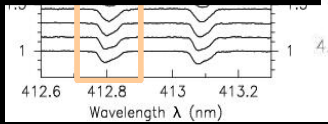


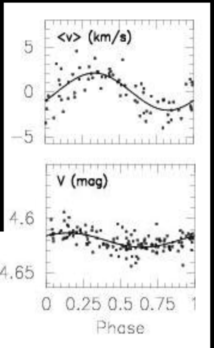




Change of amplitude and phase within profile







Unique solutions for 4 monoperiodic SPB stars

Prograde dipole modes: $(\ell,m) = (1,+1)$

KU Leuven

- Master student (physics)
- PhD student (physics, group astronomy)

→ A study of bright southern slowly pulsating B stars
II. The instrinsic frequencies
III. Mode-identification for singly-periodic targets in spectroscopy

➢ Spectroscopy: fourier parameter fit method (Zima, 2006, A&A455, 227)
- ✔ Zero point line-profile
- ✔ Amplitude variations across line-profile
- ✔ Phase variations across line-profile

} simultaneous fit

De Cat & Aerts, 2002, A&A 393, 965

De Cat, Briquet, Daszyńska-Daszkiewicz et al., 2005, A&A 432, 1013

HD24587 = 33 Eridani
#137 Geneva phometry
#65 CAT spectra
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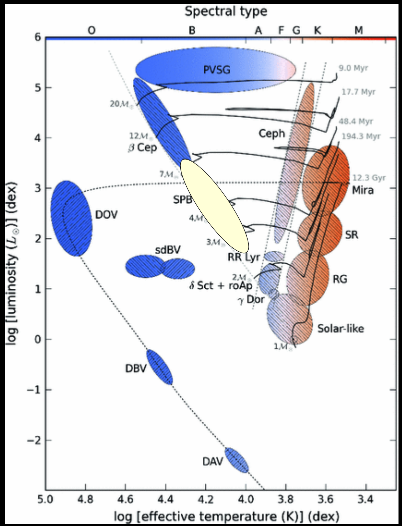
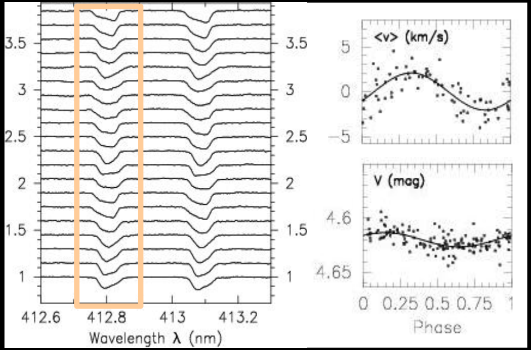
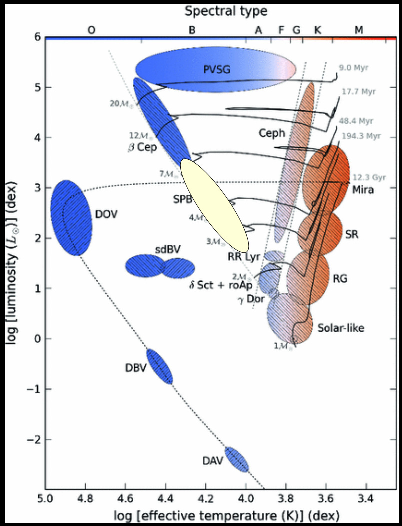




Scientific background

KU Leuven

- Master student (physics)
- PhD student (physics, group astronomy)
- Post-doctoral fellow



KU Leuven

- Master student (physics)
- PhD student (physics, group astronomy)
- Post-doctoral fellow

→ 2003/10/20: first contact with Jianning Fu (Dubrovnik, Croatia)

Jianning Fu

Royal Observatory of Belgium

- Scientific researcher

KSB - ORB

Patricia Lampens

Jan Cuypers

Martin Groenewegen

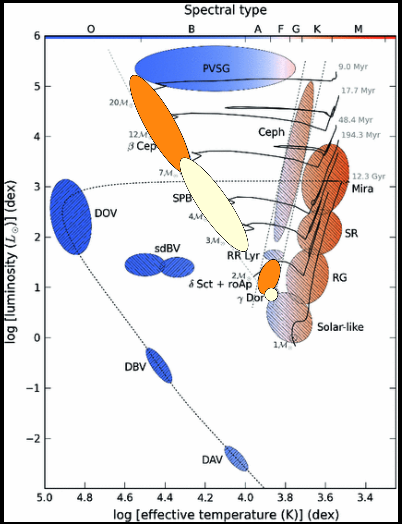
Royal Observatory of Belgium

- Scientific researcher
  - → A spectroscopic study of southern (candidate) γ Doradus stars I. Time series analysis
    - ➢ CORALIE@Euler/1.2-m
    - ➢ high-resolution spectroscopy (cross-correlation profiles)

De Cat, Eyer, Cuypers et al., 2006, A&A 449, 281

	bf γ Dor star		cand γ Dor star		rejected γ Dor star	
single	13	HD 12901, HD 14940, HD 27290, HD 40745, HD 41448, HD 48501, HD 65526, HD 112685, HD 135825, HD 149989, HD 187025, HD 216910, HD 218225	2	HD 110379, HD 112934	4	HD 7455, HD 22001, HD 33262, HD 125081[1]
suspect	0		2	*HD 111829, HD 26298*	1	HD 27604
SB1	2	*HD 167858[2], HD 209295*	1	*HD 126516*	1	HD 85964
SB2	1	*HD 34025*	7	*HD 10167, HD 27377[3], HD 35416 HD 110606, HD 111709[3,4], HD 147787, HD 214291*	3	HD 5590, HD 8393, HD 81421

[1] bf δ Sct star; [2] shows no cross-correlation profile variations but was classified as a bf γ Dor star before; [3] ellipsoidal variability instead of pulsation cannot be ruled out; [4] shows cross-correlation profile variations, but was classified as a chemically peculiar star before.



10 new bona fide γDor stars
1 new bona fide δSct
8 constant stars

  - → Long term photometric monitoring with the Mercator telescope
    - ➢ Frequencies and mode identification of variable O-B stars — De Cat, Briquet, Aerts et al., 2007, A&A 463, 243
    - ➢ Frequencies and multicolour amplitudes of γ Doradus stars — Cuypers, Aerts, De Cat et al., 2009, A&A 499, 967

Royal Observatory of Belgium

- Scientific researcher
  - → 2005/06/20: First contact with Karen Pollard (Rome, Italy)

UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND

Karen Pollard

Royal Observatory of Belgium

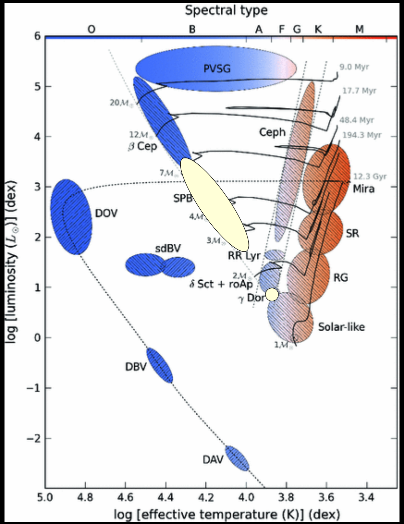
- Rotation and pulsations in main-sequence gravity mode pulsators (SPB and γDor stars)

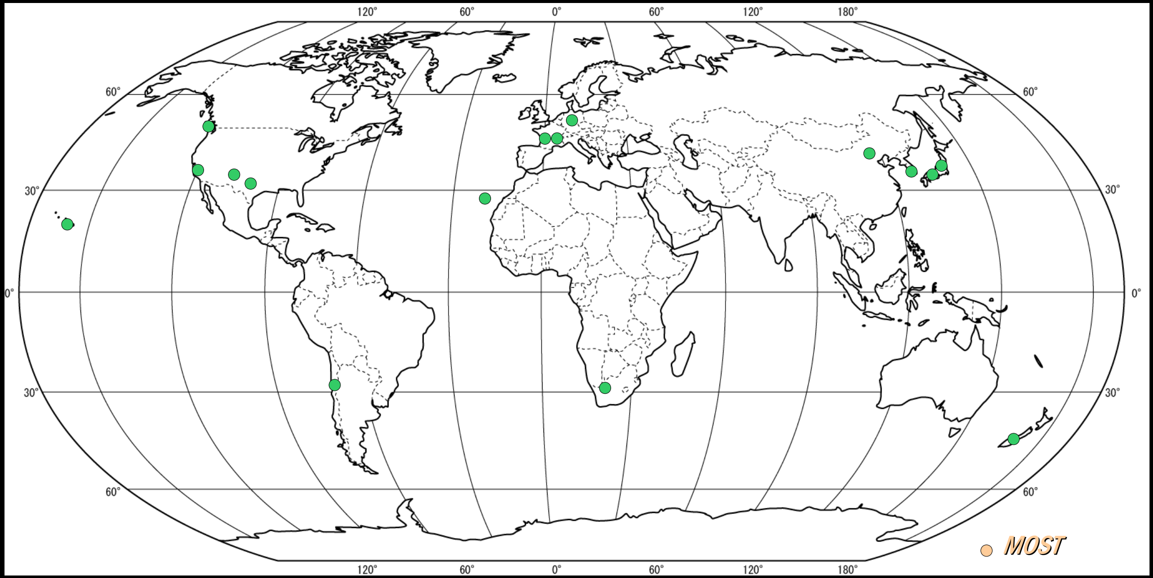
effect of rotation on pulsations?
- → isolated spectra for *v*sin*i* determination
- → spectroscopic multi-site campaignes
  - 16 ground-based and 1 space-based observatories
  - >11,000 high-resolution spectra

Action 1 project (2008-2011): Duncan J. Wright

Action 1 project (2012-2014): Ádám Sódor

De Cat, Wright, Pollard et al., 2009, AIPC 1170, 480





ESPaDOnS@CFHT/3.58-m
Hamilton@Lick/3-m
9682M@DAO/1.2-m
RA2@McDonald/2.1-m
Echelle@Fairborn/2-m
HARPS@ESO/3.6-m
FEROS@ESO/2.2-m
FIES@RMO/2.6-m
HERMES@RMO/1.2-m
SOPHIE@OHP/1.93-m
NARVAL@TBL/2-m
CES@TLS/2.0-m
GIRAFFE@SAAO/1.9-m
COUDE@Xinglong/2.16-m →
BOES@BOA/1.8-m
HIDES@OAO/1.88-m
HERCULES@MJUO/1.0-m

Jianning Fu


Duncan J. Wright


Ádám Sódor

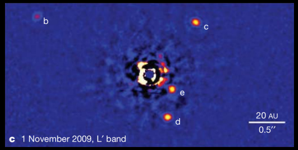

21 days HD25558 (SPB star)
47 days HD218396 (γDor star)

Royal Observatory of Belgium

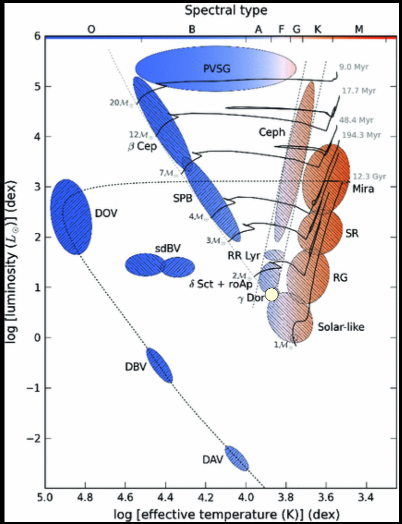
- Rotation and pulsations in main-sequence gravity mode pulsators (SPB and γDor stars)
  - → HD218396 (HR8799; γDor star; planet host)
    - ➢ Spectroscopy: SOPHIE@OHP/1.93-m

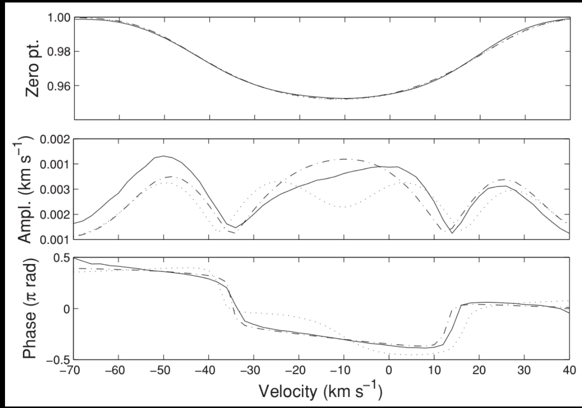
      Wright, Chené, De Cat et al., 2011, ApJL 728, L20

      - ✔ 650 spectra in time span of 2 weeks
      - ✔ Frequency analysis → $f_1 = 1.9875$ d^{-1}
      - ✔ Mode identification (fourier parameter fit method) → prograde sectoral mode $(\ell,m) = (1,+1)$, $i_{rot} > 40°$



Marois et la., 2010, Nature 468, 1080



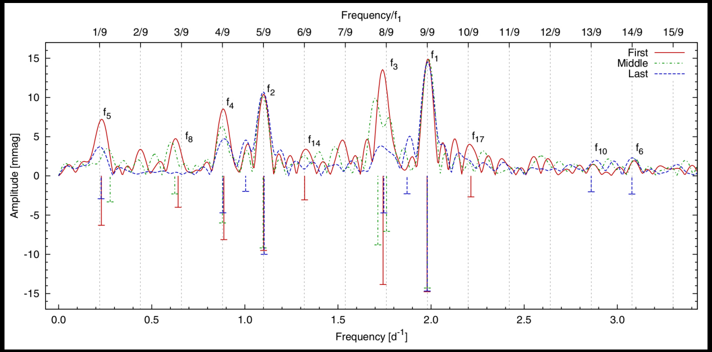


Misalignment stellar rotational inclination and planetary orbit axis

- ➢ Photometry: Microvariability and Oscillations in STars

  Sódor, Chené, De Cat et al., 2014, A&A 568, A106

  - ✔ Frequency analysis → $f_1 = 1.978$ d^{-1}



Many multiples of $f_1/9$
Strong amplitude descrease and phase changes

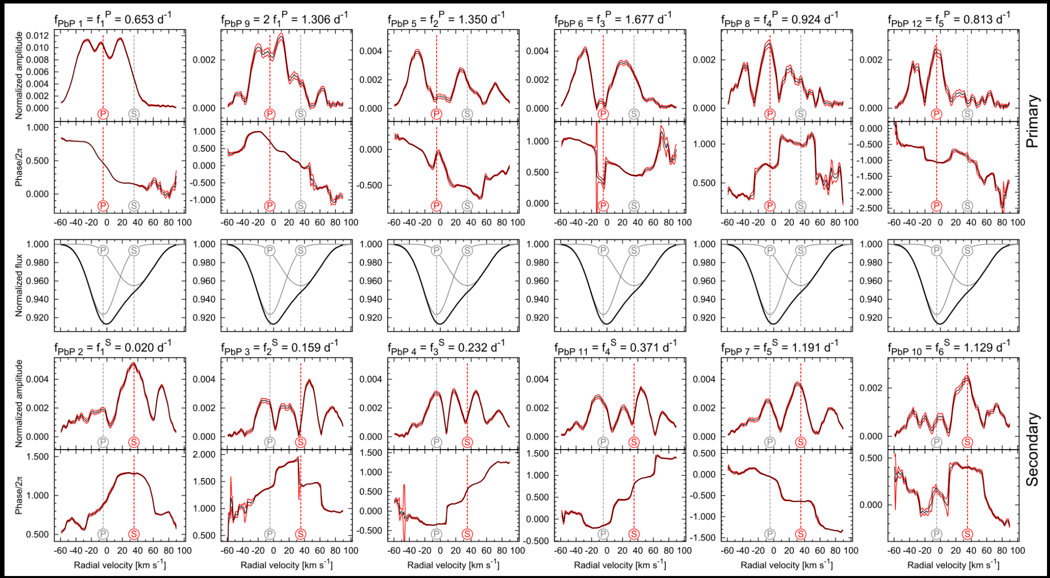
Duncan J. Wright

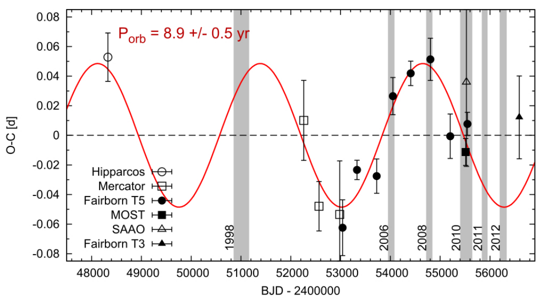
Ádám Sódor

Scientific background — Asteroseismology

Royal Observatory of Belgium

- Rotation and pulsations in main-sequence gravity mode pulsators (SPB and γDor stars)
  - → HD25558 (SPB star) — Sódor, De Cat, Wright et al., 2014, MNRAS 438, 3535
    - ➢ Spectroscopy: ~2000 high-resolution spectra
    - ➢ Photometry: ground-based and MOST lightcurves



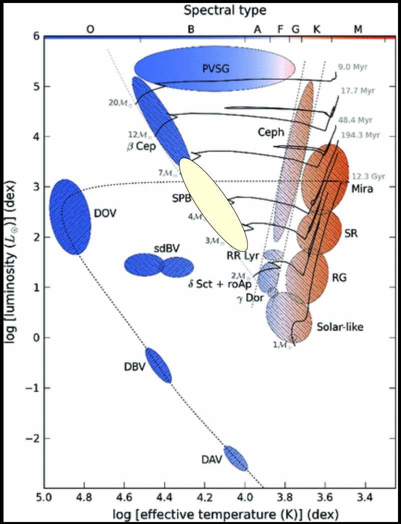


Double-lined spectroscopic binary
(P_{orb} ~ 9 years)

Both components SPB stars
(11 independent frequencies)

Inclination and rotation of the two components differ

Magnetic field for secondary component
(few hundres Gauss)




Duncan J. Wright


Ádám Sódor

KSB - ORB

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

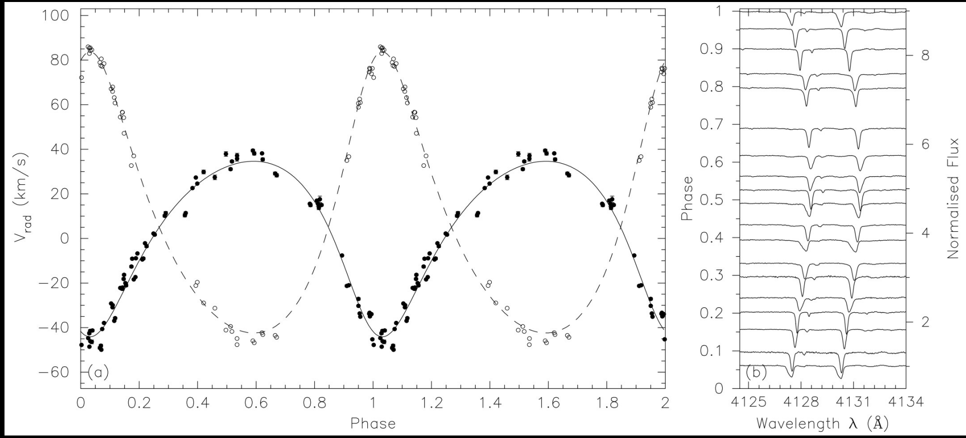
Asteroseismic requirements and tools

Status before arrival of asteroseismic space missions

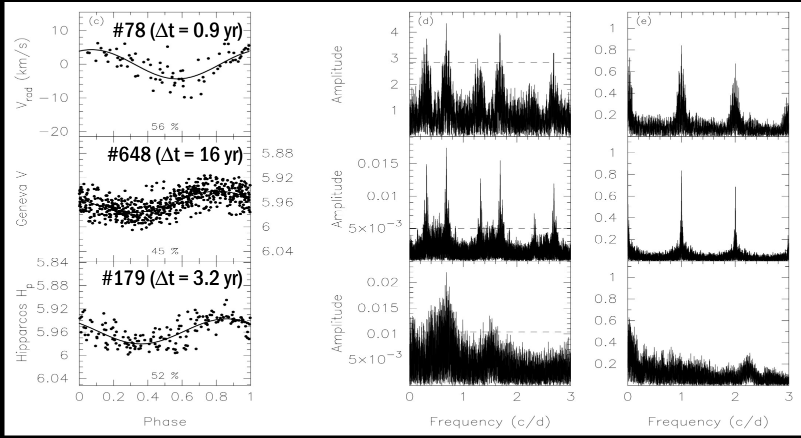
- Time series
- Observed pulsation modes
  - → Frequency f ⟶ Frequency analysis
  - → Degree ℓ
  - → Azimuthal number m

  } → Mode identification

  - ➢ Spectroscopy: moment method (Aerts, 1992, A&A 266, 294; Briquet & Aerts, 2003, A&A 398, 687)
    fourier parameter fit method (Zima, 2006, A&A 455, 227)
  - ➢ Photometry: method of photometric amplitude ratios and phase shifts (Dupret et al., 2003, A&A 398, 677)



De Cat et al., 2000, A&A 355, 1015



Asteroseismic requirements and tools

- Time series
- Observed pulsation modes

→ Frequency *f* ⟶ Frequency analysis

→ Degree *ℓ*

→ Azimuthal number *m*

} → Mode identification

➢ Spectroscopy: moment method (Aerts, 1992, A&A 266, 294; Briquet & Aerts, 2003, A&A 398, 687)

fourier parameter fit method (Zima, 2006, A&A 455, 227)

➢ Photometry: method of photometric amplitude ratios and phase shifts (Dupret et al., 2003, A&A 398, 677)

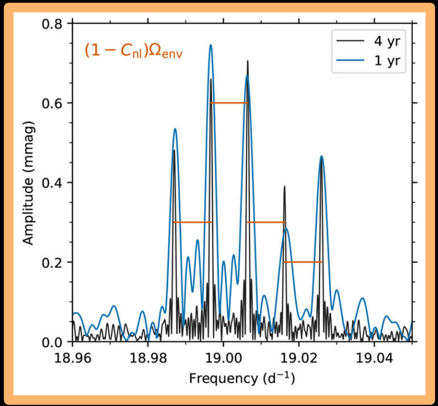
rotational multiplets

échelle diagram in frequency for p-mode and in period for g-modes (asymptotic regime)

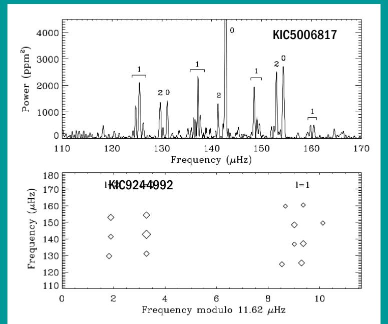
Status after arrival of asteroseismic space missions

MOST, Kepler and K2, CoRoT, BRITE, Gaia, TESS

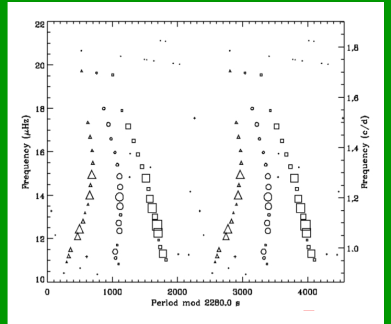
Need for accurate stellar parameters for modelling



Bowman, 2020, FrASS 7, 70



Bedding et al., 2010, ApJL 713, L176



Bedding et al., 2015, EPJW 101, 01005

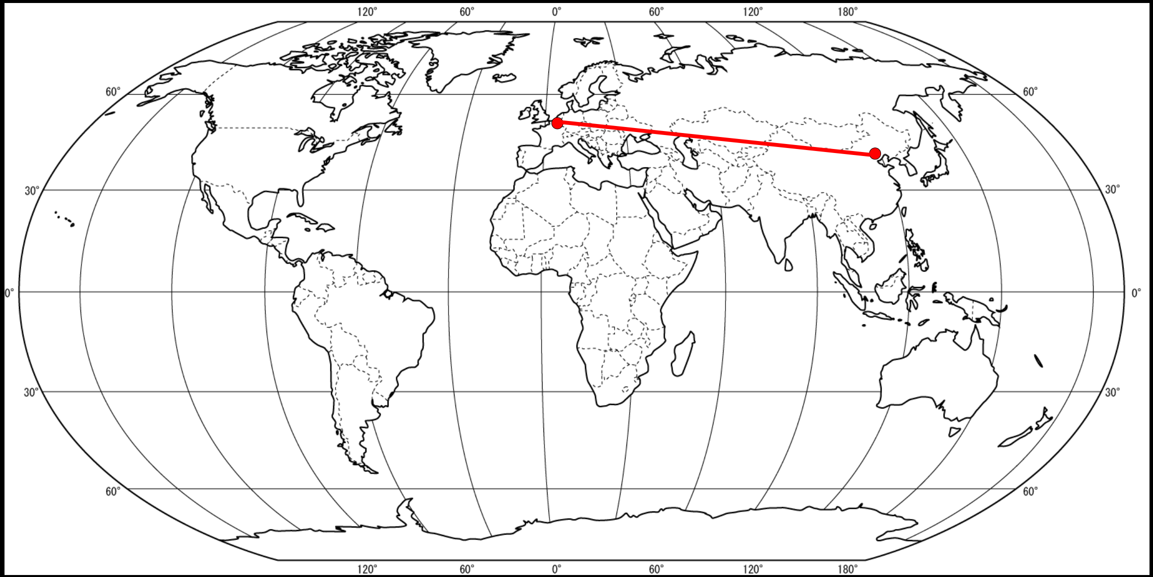
KSB - ORB

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Outline

1. Scientific background
2. Connection Belgium – China
3. Connection Belgium – India
4. Connection China – India
5. Conclusions and future prospects



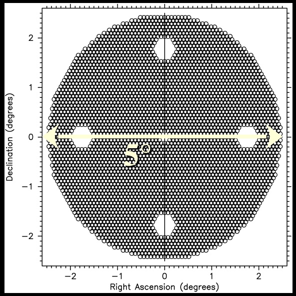
→ 2003/10/20: first contact with Jianning Fu (Dubrovnik, Croatia)

Jianning Fu

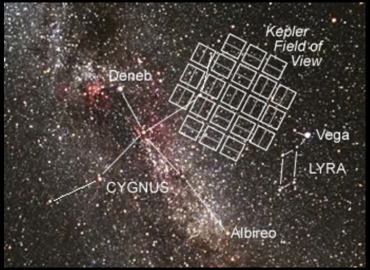
Connection Belgium - China – Italy – Poland - USA LAMOST-Kepler

→ **Large Sky Area Multi-Object Fiber Spectroscopic Telescope**

- Size: 4.0-m telescope
- Field of View: circular with diameter of 5° on sky (~20 deg^2)
- Fibers: #4000
- Wavelengths: 370 – 900 nm
- Resolution: ~1800 (low) / ~7500 (medium)
- Targets: > 5 000 000 (stars, galaxies, QSOs)

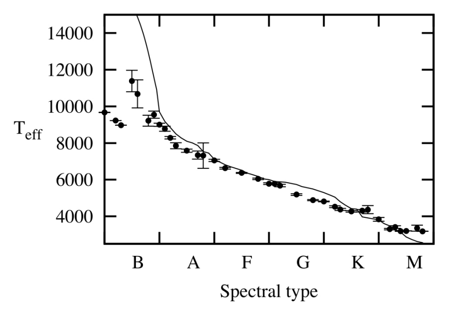


Unique combination of large multi-fiber telescope with wide field-of-view



→ **NASA mission Kepler**

- primary mirror: 1.2-m
- launch on 2009/03/07 (lifetime ~3.8 years after failure on 2013/05/14)
- continuous monitoring of 1 star field in Cygnus-Lyra region
- broad band photometry with accuracy of few ppm
- main scientific goals
  - ✔ discover Earth-size planets (transit method)
  - ✔ characterizing planet-hosting stars by means of asteroseismic methods
  - ✔ opportunity for asteroseismic investigation of stars covering H-R diagram



Balona et al. (2011, MNRAS 413, 2403)

Need for accurarte stellar parameters

KSB - ORB

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2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

LAMOST-Kepler project

- Proposal submitted in 2010

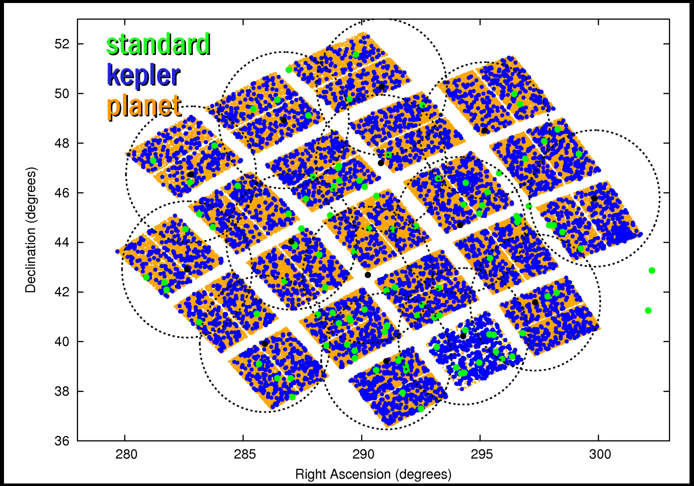
Collaboration with subchairs of Kepler Asteroseismic Science Consortium

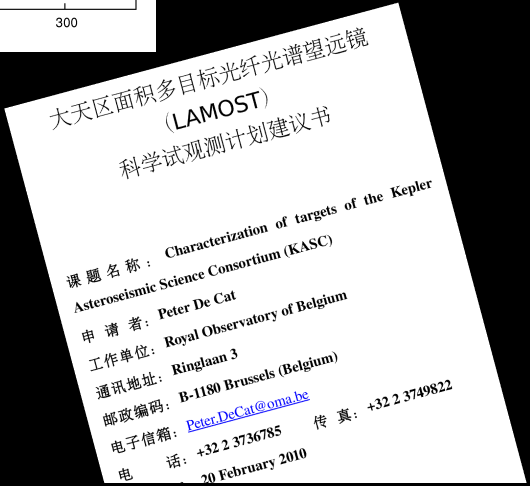
→ to cover whole Kepler field-of-view

→ to characterize targets in homogeneous way
  - spectral type
  - any peculiarities
  - T_{eff}, logg, metallicity

→ with low-resolution spectroscopy
  - radial velocity ⟹ binaries, cluster membership
  - rotation velocity ⟹ restriction on vsini

→ because it is the only instrument to observe thousands of targets efficiently
  - brightest targets ($K_p \leq 10.5$ mag): with 2-m class telescopes
  - LAMOST: focus on fainter targets




大天区面积多目标光纤光谱望远镜
（LAMOST）
科学试观测计划建议书

课 题 名 称： Characterization of targets of the Kepler Asteroseismic Science Consortium (KASC)
申 请 者： Peter De Cat
工作单位： Royal Observatory of Belgium
通讯地址： Ringlaan 3
邮政编码： B-1180 Brussels (Belgium)
电子信箱： Peter.DeCat@oma.be
电 话： +32 2 3736785 传 真： +32 2 3749822
20 February 2010

- First observations on 2011/05/30
- First reduced spectra distributed in 2012/05
- First publication with introduction of project in 2015

Win-win opportunity for both LAMOST community and Kepler community

De Cat, Fu, Ren et al., 2015, ApJS 220, 19

Connection Belgium - China – Italy – Poland - USA LAMOST-Kepler

LAMOST-Kepler project

- Asian team

BNU (Beijing)

NAOC (Beijing)

LASP (LRS)

temperature type

T_{eff} (2.75%)

log$g$ (0.215 dex)

[Fe/H] (0.152 dex)

v_{rad} (18 km s^{-1})

→ Ren et al., 2016, ApJS 225, 28: "LAMOST observations in the Kepler field: Analysis of the stellar parameters measured with LASP based on low-resolution spectra" (2012/06-2014/09)

- Detection of 115 candidate metal poor stars (106 with [Fe/H] < −1.0 dex; 9 with [Fe/H] < −2.0 dex)
- Detection of 18 high-velocity stars (v_{rad} < -300 km s^{-1})

KSB - ORB

LAMOST-Kepler project

- Asian team

BNU (Beijing)

NAOC (Beijing)

LASP (LRS)

temperature type

T_{eff} (2.75%)

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→ Fu et al., 2020, RAA 20, 167: "Overview of the LAMOST-Kepler project" (2011/05-2020/09)

- ➢ Update of the statistics of the catalogue

LAMOST-Kepler project

- Asian team

BNU (Beijing)

NAOC (Beijing)

LASP (LRS)

temperature type

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→ Zong et al., 2020, ApJS 251, 15: "Phase II of the LAMOST-Kepler/K2 survey: I. Time series of medium-resolution spectroscopic observations" (2019/01-2019/06)

LASP (MRS)

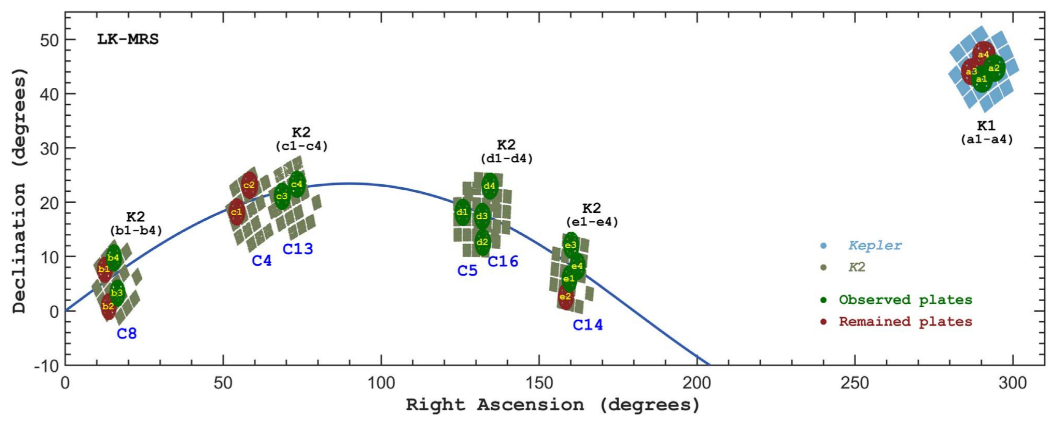
temperature type

T_{eff} (100 K)

$\log g$ (0.15 dex)

[Fe/H] (0.09 dex)

V_{rad} (1 km s^{-1})



Connection Belgium - China – Italy – Poland - USA LAMOST-Kepler

LAMOST-Kepler project

- Asian team

BNU (Beijing)

NAOC (Beijing)

LASP (LRS)

temperature type
$T_{\rm eff}$ (2.75%)
log*g* (0.215 dex)
[Fe/H] (0.152 dex)
$V_{\rm rad}$ (18 km s^{-1})

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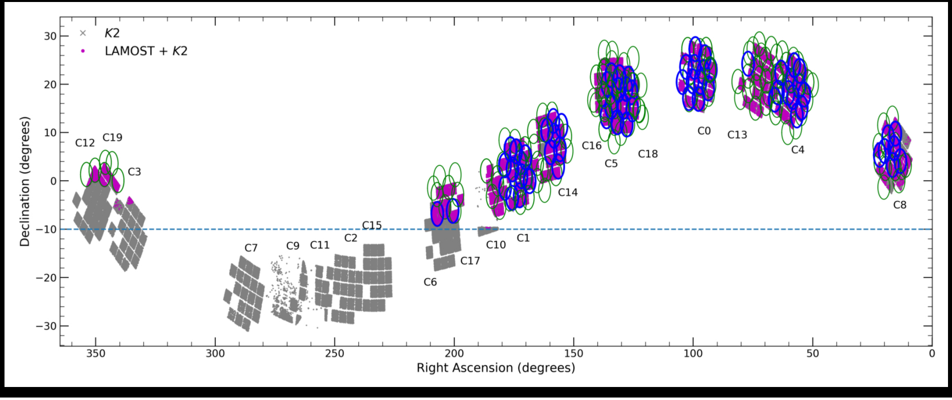
→ Wang et al., 2020, ApJS 251, 27: "LAMOST observations in 15 K2 campaigns: I. Low-resolution spectra from LAMOST DR6" (2015/12-2018/01)

LASP (MRS)

temperature type
$T_{\rm eff}$ (100 K)
log*g* (0.15 dex)
[Fe/H] (0.09 dex)
$V_{\rm rad}$ (1 km s^{-1})



KSB - ORB
Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)
2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Connection Belgium - China – Italy – Poland - USA

LAMOST-Kepler

LAMOST-Kepler project

- European team

Catania (Italy)

Wrocław (Poland)

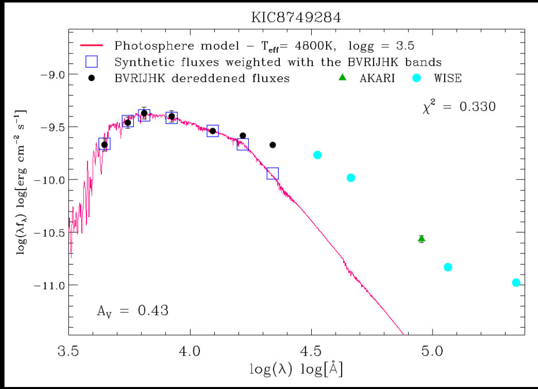
Brussels (Belgium)

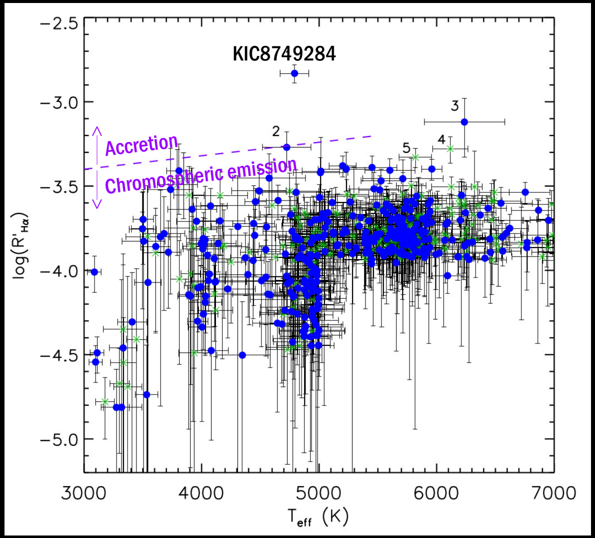
ROTFIT (LRS)

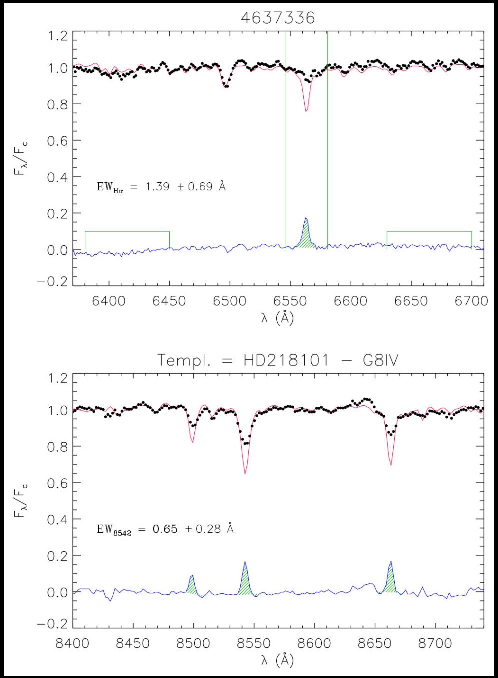
temperature type
luminosity class
T_{eff} (3.5%)
$\log g$ (0.3 dex)
[Fe/H] (0.2 dex)
V_{rad} (14 km s^{-1})
$v\sin i$ > 120 km s^{-1}

→ Frasca et al., 2016 A&A 594, A39: “Activity indicators and stellar parameters of the Kepler targets: An application of the ROTFIT pipeline to LAMOST-Kepler stellar spectra” (2011/05-2014/09)

- Search for emission line objects
- Detection of 442 chromospherically active stars
- Detection of accreting star KIC8749284 (K1V)







Connection Belgium - China – Italy – Poland - USA   LAMOST-Kepler

LAMOST-Kepler project

- European team

Catania (Italy)

Wrocław (Poland)

Brussels (Belgium)

ROTFIT (LRS)

temperature type
luminosity class
$T_{\rm eff}$ (3.5%)
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- Detection of 442 chromospherically active stars
- Detection of accreting star KIC8749284 (K1V)

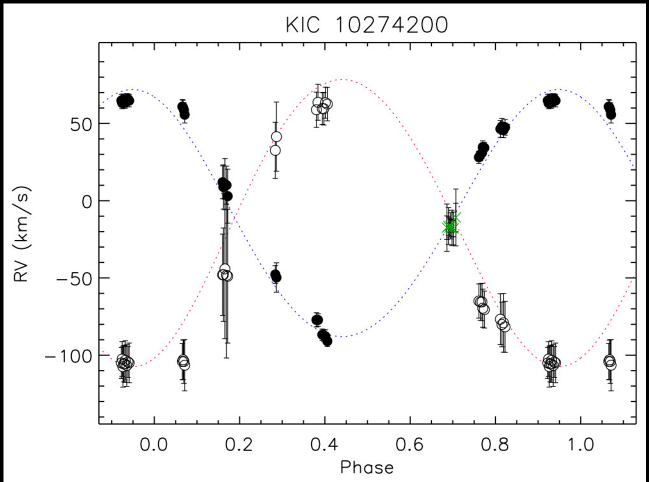
ROTFIT (MRS)

temperature type
luminosity class
$T_{\rm eff}$ (2.5%)
$\log g$ (0.25 dex)
[Fe/H] (0.15 dex)
$V_{\rm rad}$ (0.7 km s^{-1})
$v\sin i$ > 8 km s^{-1}

→ Frasca et al., 2022, A&A 664, A78: "Characterization of Kepler targets based on medium-resolution LAMOST spectra analysed with ROTFIT" (2017/09-2018/05)

- Detection of 327 chromospherically active stars
- Detection of 98 double-lined spectroscopic binaries (SB2) and 7 triple systems (SB3)
- EW measurement LiI λ6708 line for 1657 stars
  - ✔ 187 Li-rich giants (153 new ones)
  - ✔ fraction of 4-5% Li-rich giants
  - ✔ no relation between rotation and Li abundances (merging scenarios)

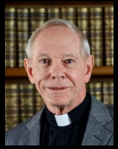
Parameter	Value
HJD0 [(a)]	58020.45 ± 0.05
$P_{\rm orb}$ (d)	4.278 ± 0.001
e	0.04 ± 0.04
ω (°)	20.0 ± 0.5
γ (km s^{-1})	-11 ± 3
K_1 (km s^{-1})	80 ± 1
K_2 (km s^{-1})	93 ± 3
$M_1 \sin^3 i$ ($M_\odot$)	1.23 ± 0.08
$M_2 \sin^3 i$ ($M_\odot$)	1.06 ± 0.05
M_2/M_1	0.86 ± 0.03
$a \sin i$ ($R_\odot$)	14.6 ± 0.2



LAMOST-Kepler project

- American team

North Carolina (USA)

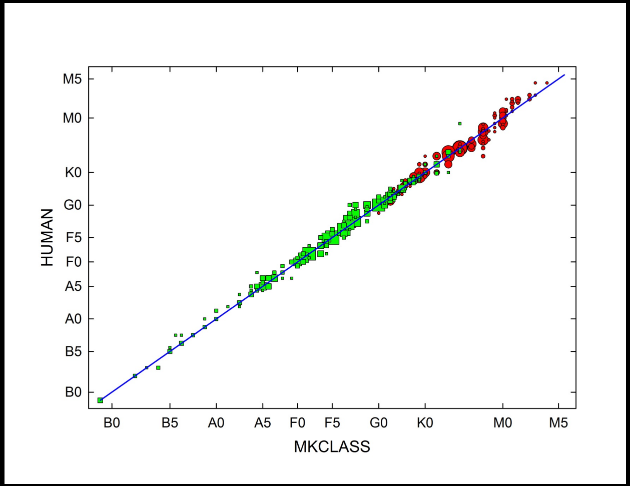

Arizona (USA)


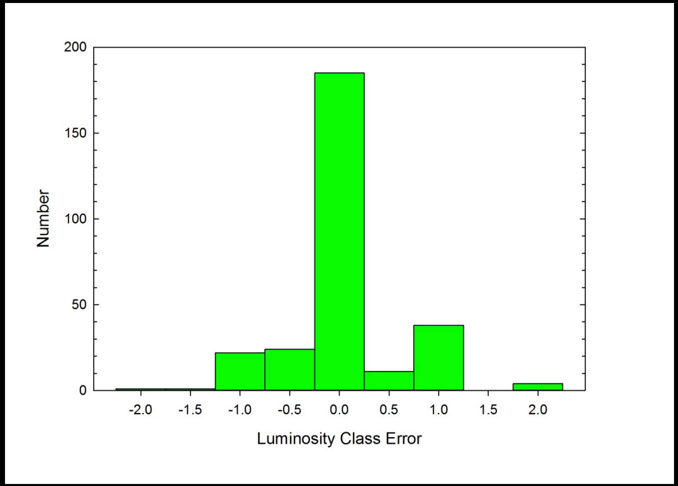
MKCLASS

temperature type (0.6)
luminosity class (0.5)

→ Grey et al., 2016, AJ 151, 13: “LAMOST observations in the Keperl field: Spectral classification with the MKCLASS code” (2011/05-2014/09)

- Classification on MK system (direct comparison with MK standards)
- Identification of peculiar and astrophysically interesting stars
  - ✔ 32 candidate Barium dwarfs (s-process enhances G-type dwarfs)
  - ✔ 34.6% of A stars are Am
  - ✔ 132 candidate λ Bootis stars (chemically peculiar late B to early-F stars: surface underabundances of most iron-peak elements, near-solar abundances of C, N, O, and S)





LAMOST-Kepler project

- LRS and MRS LAMOST spectra have shown to be useful in many different scientific fields, including:
  - → Stellar parameter determination
  - → Asteroseismology
  - → Binary stars
  - → Stellar activity
  - → Peculiar stars
  - → Exoplanets

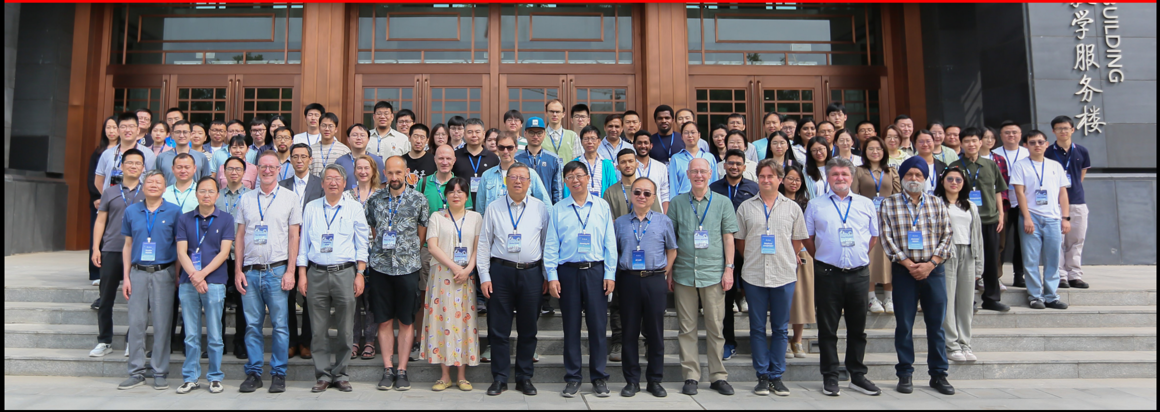
2024/05/21-24

Third LAMOST-Kepler/TESS workshop (Beijing, China)

”Synergies between ground-based spectroscopic surveys and space-based photometric missions”

The 3rd LAMOST-Kepler/TESS Workshop

Beijing, 2024.05.21-24



Outline

1. Scientific background
2. Connection Belgium – China
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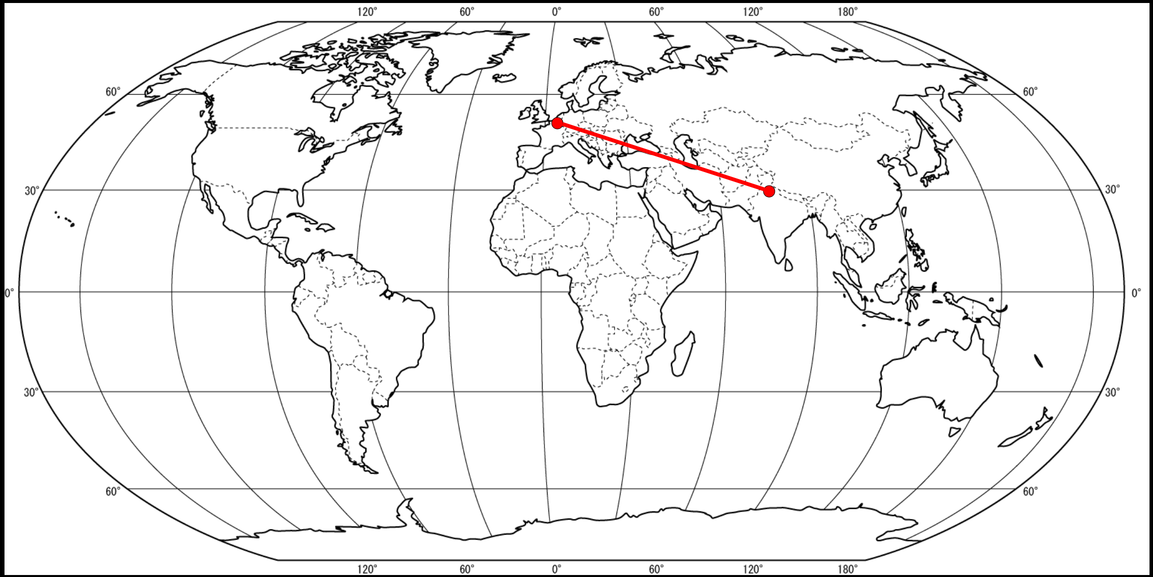


Connection Belgium – India

BINA

→ 2014/01/27: first contact with Santosh Joshi (e-mail)

Subject: Re: KASC WG3: K2 mission and other updates (reminder)
Date: Mon, 27 Jan 2014 09:25:19 +0530 (IST)
From: Dr. Santosh Joshi <santosh@aries.res.in>
To: Peter De Cat <Peter.DeCat@oma.be>

Hi Peter,
Please let me know if you are interested in the following programme:
http://www.dst.gov.in/whats_new/whats_new13/cop_belcall2014.pdf

Regards
Santosh

(http://www.aries.res.in)

Subject: Indo-Belgian Research and Technology Cooperation
Date: Tue, 28 Jan 2014 10:59:37
From: Peter De Cat <Peter.DeCat@oma.be>
To: Dr. Santosh Joshi <santosh@aries.res.in>

Dear Dr. Santosh Joshi,

Thank you very much for your message! Unfortunately it ended up in the spam mail so I didn't see it immediately! (to be on the safe side, please also send a copy to my private e-mail: peter-ke@telenet.be)

Yes, we would be very interested to submit such a proposal! We already submitted a proposal last year in collaboration with Prof. Ram Sagar in view of the DOT telescope (and the Belgian guaranteed time) but unfortunately our proposal was not successful... However, we would like to try again this year so it would be very nice to collaborate with you!

From the Belgian side, two institutes are participating:
* Royal Observatory of Belgium (Patricia Lampens, Yves Frémat and myself),
* Université de Liège (Jean Surdej).
Is there anybody else from your institute that would like to join our team? Do you know colleagues from other Indian institutes that would be interested? What are the main scientific topics you are working on? What kind of network activities would you like to introduce in the proposal?

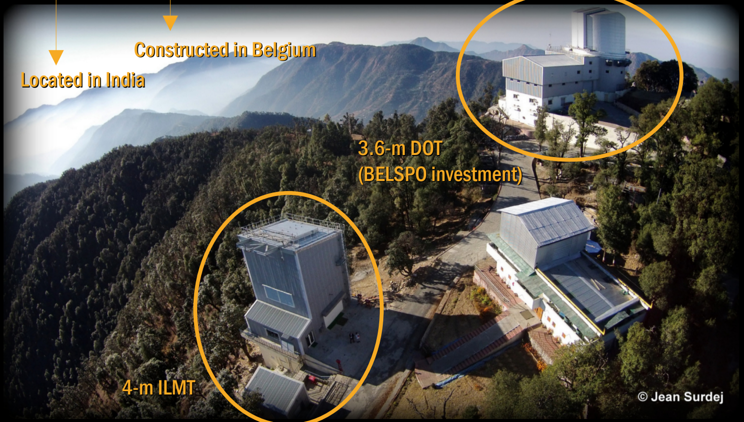
Thanks again for your proposition. We still have one month to prepare a proposal. Let's hope we will have the opportunity to start a fruitful collaboration!

Kind regards,
Peter

cc. Patricia Lampens, Yves Frémat, Jean Surdej

Santosh Joshi

Indo-Belgian telescopes



Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)
2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Connection Belgium – India

BINA

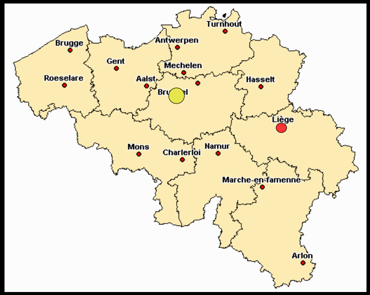
Belgo-Indian Network for Astronomy and astrophysics

- BINA-1 (2014-2018) Focus on instrument development (DOT+ILMT)

Network activities

Belgian Science Policy Office
(BELSPO; Govt. of Belgium)

International Division,
Department of Science and Technology
(DST; Govt. of India)



→ Belgian partners (PI: Peter De Cat)

- ROB (Royal Observatory of Belgium; Brussels)
- ULiège (Université de Liège; Liège)

→ Indian partners (PI: Santosh Joshi)

- ARIES (Aryabhatta Research Institute of Observational Sciences; Nainital)
- IIA (Indian Institute of Astrophysics; Bangalore)
- IIST (Indian Institute of Space Science & Technology; Trivandrum)
- IUCAA (Inter-University Centre for Astronomy and Astrophysics; Pune)
- PRL (Physical Research Laboratory; Ahmadabad)
- SNBNCBS (S.N. Bose National Centre for Basic Sciences; Kolkata)
- TIFR (Tata Institute of Fundamental Research; Mumbai)

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)
2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Connection Belgium – India

BINA

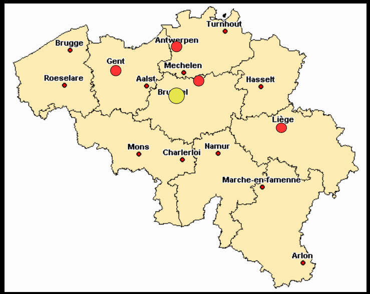
Belgo-Indian Network for Astronomy and astrophysics

- BINA-1 (2014-2018) Focus on instrument development (DOT+ILMT)
- BINA-2 (2018-2023) Focus on scientific projects (telescopes of interest)

Network activities

Belgian Science Policy Office
(BELSPO; Govt. of Belgium)

International Division,
Department of Science and Technology
(DST; Govt. of India)



→ Belgian partners (PI: Peter De Cat)

- ROB (Royal Observatory of Belgium; Brussels)
- KU Leuven (Katholieke Universiteit Leuven; Leuven)
- UAntwerp (Universiteit Antwerpen; Antwerp)
- UGent (Universiteit Gent; Ghent)
- ULB (Université Libre de Bruxelles; Brussels)
- ULiège (Université de Liège; Liège)

→ Indian partners (PI: Santosh Joshi)

- ARIES (Aryabhatta Research Institute of Observational Sciences; Nainital)
- DU (Delhi University; Delhi)
- HBCSE (Homi Bhabha Centre for Science Education; Mumbai)
- IIA (Indian Institute of Astrophysics; Bangalore)
- IIST (Indian Institute of Space Science & Technology; Trivandrum)
- ISRO (ISRO Satellite Centre; Bangalore)
- IUCAA (Inter-University Centre for Astronomy and Astrophysics; Pune)
- KU (Kumaun University; Nainital)
- NCRA (National Center for Radio Astrophysics; Pune)
- PRL (Physical Research Laboratory; Ahmadabad)
- RSU (Pt. Ravi Shankar University; Raipur)
- SNBNCBS (S.N. Bose National Centre for Basic Sciences; Kolkata)
- TIFR (Tata Institute of Fundamental Research; Mumbai)

Connection Belgium – India

BINA

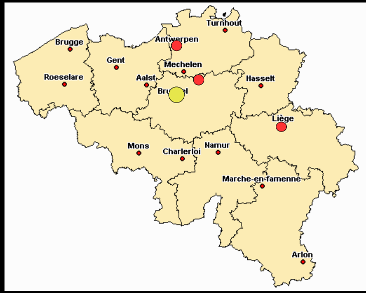
Belgo-Indian Network for Astronomy and astrophysics

- BINA-1 (2014-2018) — Focus on instrument development (DOT+ILMT)
- BINA-2 (2018-2023) — Focus on scientific projects (telescopes of interest)
- BIPASS (2022-2025) — Focus on spectroscopy (data products and science)

Network activities

Belgian Science Policy Office
(BELSPO; Govt. of Belgium)

International Division,
Department of Science and Technology
(DST; Govt. of India)



→ Belgian partners (PI: Laurent Mahy)

- ROB (Royal Observatory of Belgium; Brussels)
- KU Leuven (Katholieke Universiteit Leuven; Leuven)
- UAntwerp (Universiteit Antwerpen; Antwerp)
- UGent (Universiteit Gent; Ghent)
- ULB (Université Libre de Bruxelles; Brussels)
- ULiège (Université de Liège; Liège)
- VUB (Vrije Universiteit Brussel; Brussels)

→ Indian partners (PI: Sashikiran Ganesh)

- ARIES (Aryabhatta Research Institute of Observational Sciences; Nainital)
- DU (Delhi University; Delhi)
- HBCSE (Homi Bhabha Centre for Science Education; Mumbai)
- IIA (Indian Institute of Astrophysics; Bangalore)
- IIST (Indian Institute of Space Science & Technology; Trivandrum)
- ISRO (ISRO Satellite Centre; Bangalore)
- IUCAA (Inter-University Centre for Astronomy and Astrophysics; Pune)
- KU (Kumaun University; Nainital)
- NCRA (National Center for Radio Astrophysics; Pune)
- PRL (Physical Research Laboratory; Ahmadabad)
- RSU (Pt. Ravi Shankar University; Raipur)
- SNBNCBS (S.N. Bose National Centre for Basic Sciences; Kolkata)
- TIFR (Tata Institute of Fundamental Research; Mumbai)
- UOC (University of Calicut; Calicut)

KSB - ORB

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

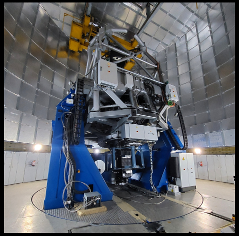
Connection Belgium – India

BINA

Belgo-Indian Network for Astronomy and astrophysics

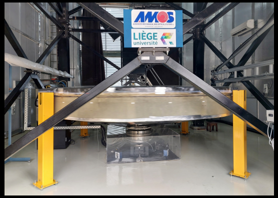
- Indo-Belgian telescopes

→ 3.6-m Devasthal Optical telescope (DOT) (Operational since 2017/04/01)



➢ IMAGER	optical imaging	2017A-Early-Science
➢ TIRCAM2	near-infrared imaging (permanent side-port1)	2017A-Early-Science
➢ ADFOSC	low-resolution spectroscopy + camera (main port)	DOT-2020-C1
➢ TANSPEC	medium-resolution spectroscopy + camera (main port)	DOT-2020-C1
➢ HRS	high-resolution spectrograph	DOT-2024-C2?
➢ Fast Photometer	multi-colour photometry	DOT-????-??

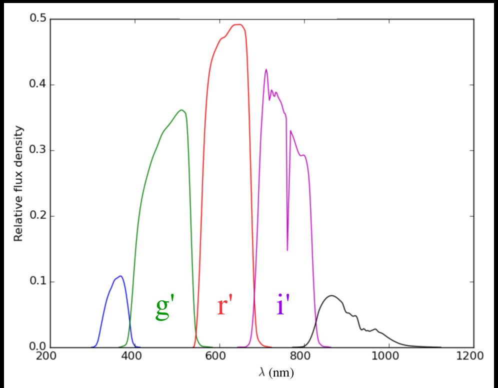
→ 4-m International Liquid Mirror telescope (ILMT) (First light: 2022/04/29; Inauguration: 2023/03/21)



➢ Rotating container with liquid mercury

➢ Zenithal telescope

➢ Nominal phase: 5 years of scientific operations



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Belgo-Indian Network for Astronomy and astrophysics

- Indo-Belgian telescopes
- Telescopes of interest

→ Access through Indian partners

- ➢ 1.04-m@ARIES = 1.04-m telescope (Nainital, India)
  - ✔ CCD & polarimeter
- ➢ 1.3-m@ARIES = 1.3-m Robotic Telescope (Devasthal Observatory, Devasthal, India)
  - ✔ multi-colour photometry
- ➢ 2.01-m@IIA = 2.01-m Himalayan Chandra Telescope (Indian Astronomical Observatory, Leh, Ladakh, India)
  - ✔ Himalaya faint object spectrograph, near-IR imager & optical CCD imager
- ➢ 2.5-m@PRL = 1.2-m Infrared Telescope (Mount Abu Observatory, Rajasthan, India)
- ➢ 1.2-m@PRL = 1.2-m Infrared Telescope (Mount Abu Observatory, Rajasthan, India)
  - ✔ NICMOS Infrared Camera and Spectrograph, Imaging Fabry-Perot Spectrometer, high time resolution Infrared Photometer, Optical Polarimeter, Fibre-linked Grating Spectrograph & high resolution optical spectrometer ‘PRL Advanced Radial-velocity All-sky Search’
- ➢ GMRT@NCRA-TIFR= Giant Metrewave Radio Telescope (Pune, India)
  - ✔ 30 parabolic 45-m dishes spread over up to 25 km for radio interferometry
- ➢ ASTROSAT@ISRO = Satellite (Space)
  - ✔ Ultra Violet Imaging Telescope, Soft X-ray imaging telescope, Large Area X-ray Proportional Counter, Cadmium Zinc Telluride Imager, Scanning Sky Monitor, Charged Particle Monitor (observations from far UltraViolet to hard X-rays)

India’s first dedicated multi-wavelength space telescope

Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

Connection Belgium – India

BINA

Belgo-Indian Network for Astronomy and astrophysics

- Indo-Belgian telescopes
- Telescopes of interest
  - → Access through Indian partners
  - → Access through Belgian partners
    - ➢ 1.2-m@KULeuven = 1.2-m Mercator telescope (Roque de los Muchachos Observatory, La Palma, Canary Islands, Spain)
      - ✔ HERMES: high-resolution spectroscopy
    - Transiting Planets and Planetesimals Small Telescope:
      - ➢ 0.6-m@ULiège = 0.6-m TRAPPIST-North telescope (Oukaïmeden Observatory, Maroc)
      - ➢ 0.6-m@ULiège = 0.6-m TRAPPIST-South telescope (European Sourthern Observatory, La Silla, Chile)
      - ✔ Multiband photometry (Johnson/Cousins BVRcIc, Sloan z, NIR exoplanet filter, NaI, H_2O+/OH, NH, CN, CO+, C3, BC, C2, GC, RC)
    - Search for habitable Planets Eclipsing Ultra-cOOl Star:
      - ➢ 1.0-m@ULiège = 4x1.0-m SPECULOOS-North telescope (Teide Observatory, Tenerife, Canary Islands, Spain)
      - ➢ 1.0-m@ULiège = 1x1.0-m SPECULOOS-South telescope (European Southern Observatory, Paranal, Chile)
      - ➢ 1-0-m@ULiège = 1x1.0-m SAINT-EX telescope (National Astronomical Observatory of Mexico, San Pedro Mártin, Mexico)
      - ✔ Camera sensitive in the very-near-infrared
    - ➢ many@ESO = European Southern Observatory (Chile)

Connection Belgium – India

Long term view

Belgian partners

- ROB (Peter De Cat & Laurent Mahy)
- ULiège (Michaël De Becker)
- UAntwerpen
- KULeuven
- UGent
- ULB
- VUB

Indian partners

- ARIES (Santosh Joshi)
- DU
- HBCSE
- IIA
- IIST
- ISRO
- IUCCA
- KU
- NCRA
- PRL (Sashikiran Ganesh)
- RSU
- SNBNCBS
- TIFR
- UOC

Belgo-Indian Network for Astronomy and astrophysics

Gather all joint Indo-Belgian initiatives related to astronomy and space science

Network actvities
BINA-1
BINA-2
BIPASS
(DST/BELSPO)

Outreach
Citizen Science

PhD students

Mrinmoy Sarkar (ARIES)
Athul Dileep (ARIES)
Bhavya Ailawadhi (ARIES)
Naveen Dukiya (ARIES)
Vibhore Negi (ARIES)
Kumar Pranshu (ARIES)
Monalisa Dubey (ARIES)

Nikita Rawat (ARIES)
Anindya Saha (IIST)

Brajesh Kumar (ULiège)
Bikram Pradhan (ULiège)

Otto Trust (Mbarara, Uganda)

Post-docs

Bharti Arora (ULiège)
Priyanka Jalan (Warsaw)

Joint funding?

Connection Belgium – India

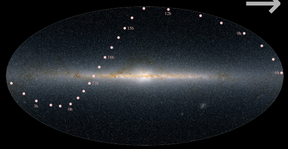
BINA

Science

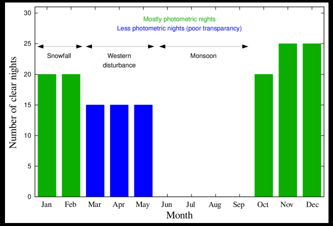
- Instumentation

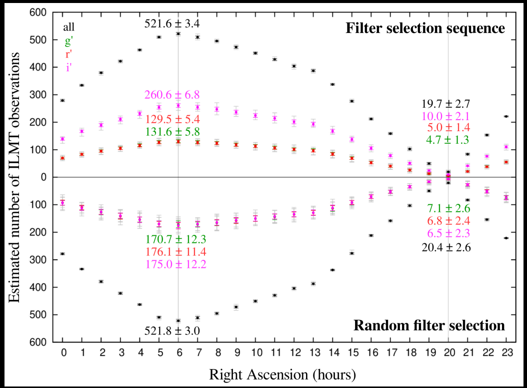
→ Prospects of pulsating star studies with the 4-m ILMT

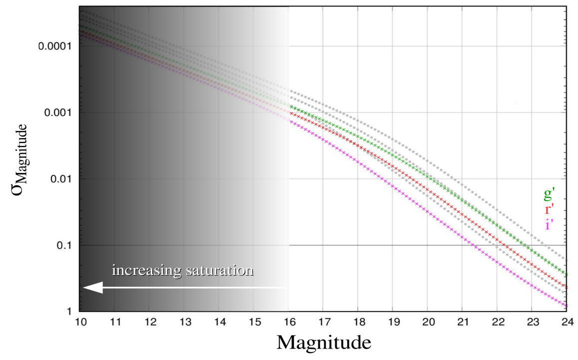
De Cat, Surdej & Kumar, 2024, BSRSL 94, in press

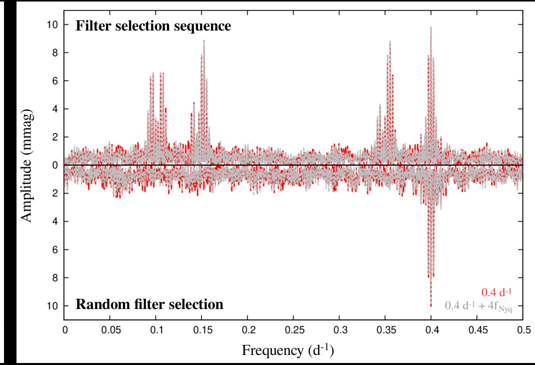


- ➢ Assumptions time series
  - ✔ 5 years of observations
  - ✔ Targets: declination 29h22m26s ± 13m30s passing through meridian (1 obs/night)
  - ✔ Integration time: 102 sec (should be at maximum 5% of pulsation period)
  - ✔ Filters: g', r', i'
  - ✔ Observing strategy: filter selection sequence (i', g', i', r', i', g', i', r',...) or randon filter selection
  - ✔ Weather statistics Devasthal
  - ✔ Random selection of nights within month
- ➢ Estimated error in magnitude
  - ✔ Pulsation amplitudes above 0.01 mag
  - ✔ Magnitude range roughly 16-22 mag
- ➢ Period analysis
  - ✔ Longest detectable period ~ 10 years
  - ✔ Shortest detectable periode ~ 2 days
  - ✔ Strong aliasing for filter selection sequence









Best prospects for
RA around 6h
Faint targets
Long pulsation periods
(Cepheids, Mira variables, Semi-regular variables)
Randon selection filters

KSB - ORB

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Connection Belgium – India

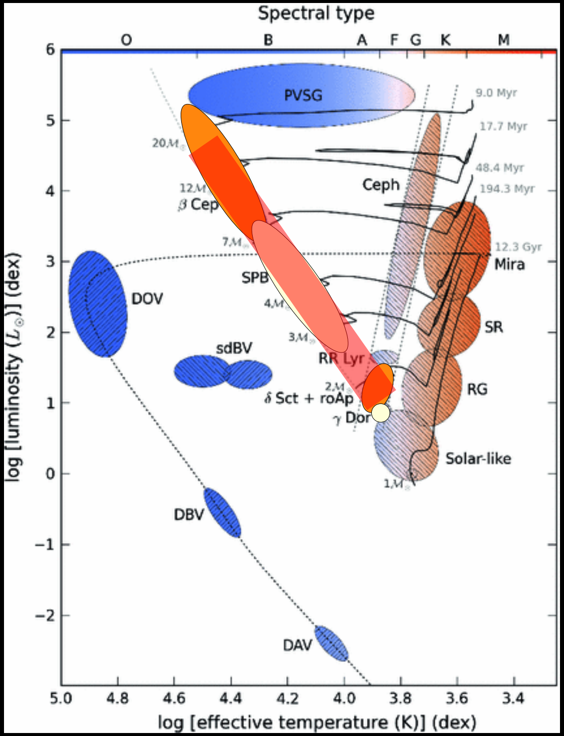
BINA

Science


Santosh Joshi (ARIES)

- Chemically peculiar stars (main-sequence BAF-stars stars with abnormal surface abundances)
  - → CP1 (Am/Fm stars)
    - ➢ Overabundance iron group elements
    - ➢ Underabundance He, Ca, Sc
    - ➢ Magnetic field: weak or non-detectable
  - → CP2 (Ap stars)
    - ➢ Overabundance Si, Cr, Sr, and rare-Earth elements (Sr, Cr, Eu, Nd, Pr,…)
    - ➢ Magnetic field: strong (up to tens of kG)
  - → CP3 (HgMn stars)
    - ➢ Overabundance HgII and/or MnII
    - ➢ Underabundance light elements (He, Al, N)
    - ➢ Magnetic field: weak or non-detectable
    - ➢ Slow rotators
  - → CP4 (He weak stars)
    - ➢ Underabundance HeI
    - ➢ Magnetic field: moderate (order 1kG)
    - ➢ Slow rotators

Nainital–Cape survey project
(Ashoka et al. 2000; Martinez et al. 2001; Joshi et al. 2003, 2006, 2009, 2010, 2012, 2016, 2017)



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2024/06/04, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China

Connection Belgium – India

Science

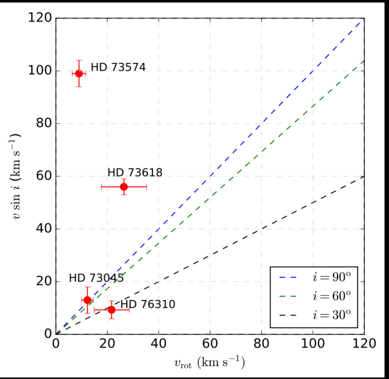
- Chemically peculiar stars (main-sequence BAF-stars stars with abnormal surface abundances)

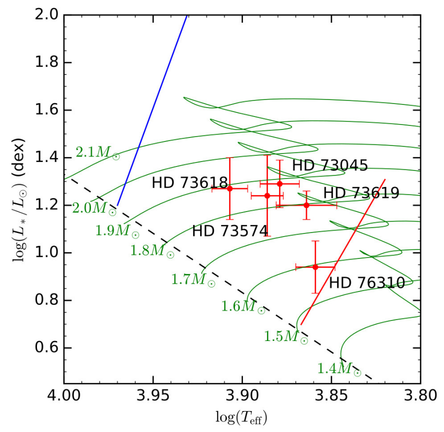
Joshi, Trust, Semenko et al., 2022, MNRAS 510, 5854

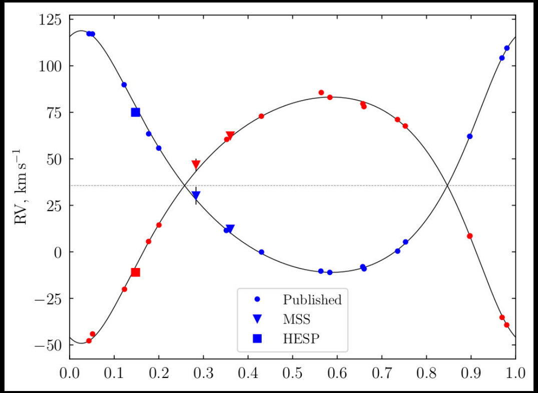
- High-resolution spectroscopy and K2 photometry of Am stars in the region of M44 (5 stars)

→ All targets now identified as (potentially) variable

- HD73045
  - ✔ Rotational variable with period of about 12.5 days (at least two dominant starspots)
  - ✔ Pulsationally stable (previously reported δSct-like frequencies not confirmed)
- HD73574
  - ✔ Periodic variations of unknown origin with period of about 14 days
- HD73618
  - ✔ Periodic variations of unknown origin with period of about 4 days
- HD73619
  - ✔ Orbital variations with period of 12.91 days
    - ➔ Heartbeat system without tidally induced pulsations
    - ➔ Two components with similar properties
  - ✔ No magnetic field above 200G
- HD76310
  - ✔ Rotational variable with period of about 5 days







Connection Belgium – India

BINA

Science

- **Chemically peculiar stars** (main-sequence BAF-stars stars with abnormal surface abundances)

Sarkar, Dupret, Semenko et al., 2024, MNRAS, submitted

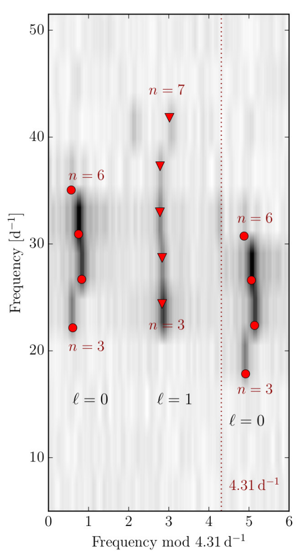
- Asteroseismology of the Am δSct star HD118660 : TESS photometry and modelling
  - → Mild Am star
  - → δSct pulsations (near red edge of instability strip)
  - → TESS time series (sectors 23 and 50)
  - → Identification of pulsation modes
    - ➢ Échelle diagram
    - ➢ Peterson diagram
  - → Overshooting parameter

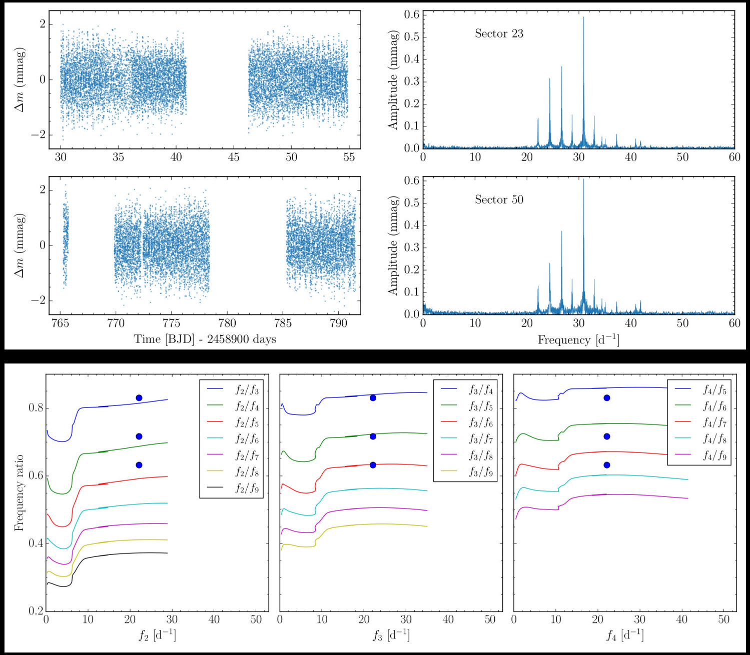
Radial modes order n from 3 to 6

α_{ov}	$\frac{M}{M_\odot}$	$\frac{R}{R_\odot}$	Age (Gyr)	$\frac{M}{R^3}$ [solar]	v_{eq} (km s^{-1})
0.1	1.77	2.06	1.15	0.20	114
0.2	1.80	2.07	1.21	0.20	115
0.3	1.75	2.06	1.35	0.20	114

Similar results for α_{ov} values

f = 1.091 d^{-1}





Science

Trust, 2022, PhD thesis (co-supervisors: Jurua, Joshi & De Cat)

Otto Trust (Mbarara)

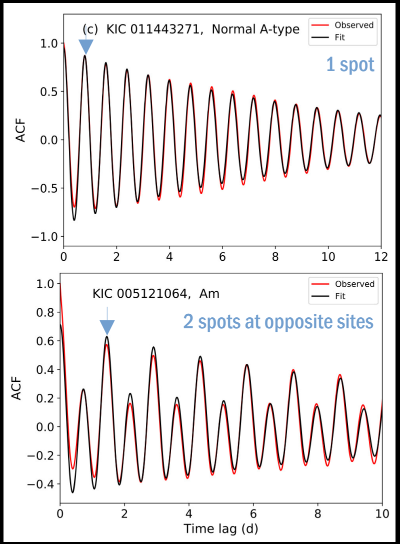
Santosh Joshi (ARIES)

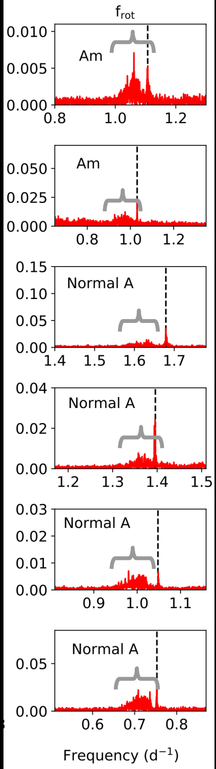
- "Hump-and-spike" stars (observed for normal A and Am/Fm stars)
  - → hump: unresolved Rossby modes (curly bracket)
  - → spike: rotational frequency (dashed line)
    - ➢ theoretical evidence for this interpretation

Trust, Jurua, De Cat & Joshi, 2020, MNRAS 492, 3143

- Kepler photometry (170 normal A and Am/Fm stars)
  - → determination of
    - ➢ rotational velocity — from frequency spike + radius via Gaia parallaxes
    - ➢ spot radius — from assumption dark spot + amplitude spike
    - ➢ rotational frequency — from frequency spike
    - from autocorrelation funcion
    - ➢ decay-time scale — from autocorrelation function

(autocorrelation function: underdamped simple harmonic oscillator)





	Am/Fm stars	Normal A stars
No significant differences in spot radii	1.01(13) R_E	1.16(12) R_E
Significant difference in decay-time scale	3.6(2) days	1.5(2) days

Spots are smaller than GKM-type stars → weak magnetic fields?

Connection Belgium – India

BINA

Science

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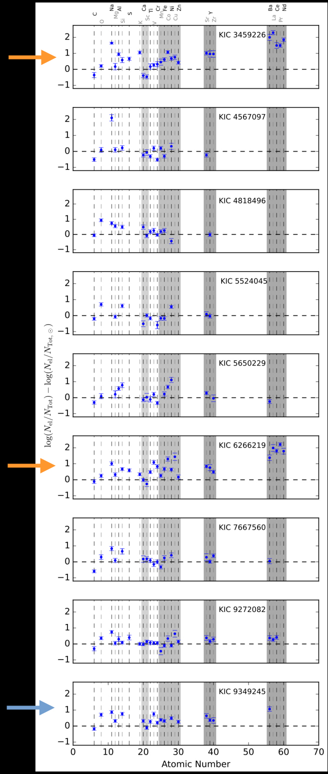
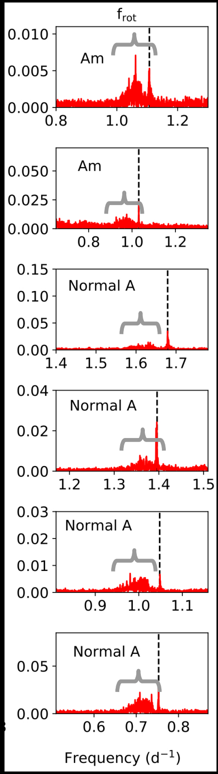
  - → spike: rotational frequency (dashed line)
    - ➢ theoretical evidence for this interpretation

Trust, Jurua, De Cat et al., 2021, MNRAS 504, 5528

- HERMES spectroscopy (9 stars)
  - → determination of
    - ➢ atmospheric parameters — from photometric indices (*ubvy*β, 2MASS, Strümgren); from spectral energy distributions; from spectroscopy
  - → individual chemical abundances

2 Am stars:	KIC3459226, KIC6266219
1 marginal Am star:	KIC 9349245
6 non-Am stars:	KIC4567097, KIC4818496, KIC5524045, KIC5650229, KIC7667560, KIC9272082





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KSB - ORB

Connection Belgium – India

BINA

Science

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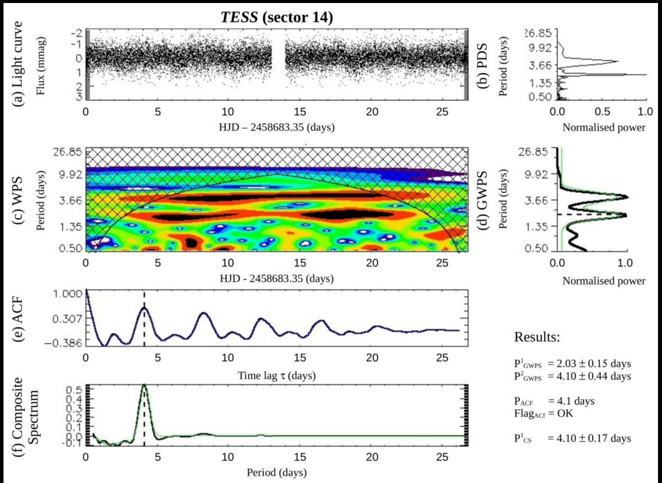
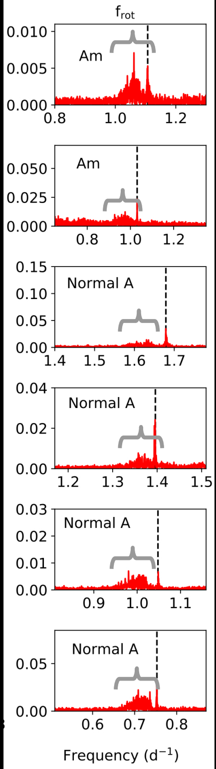
- "Hump-and-spike" stars (observed for normal A and Am/Fm stars)
  - → hump: unresolved Rossby modes (curly bracket)
  - → spike: rotational frequency (dashed line)
    - ➢ theoretical evindence for this interpretation

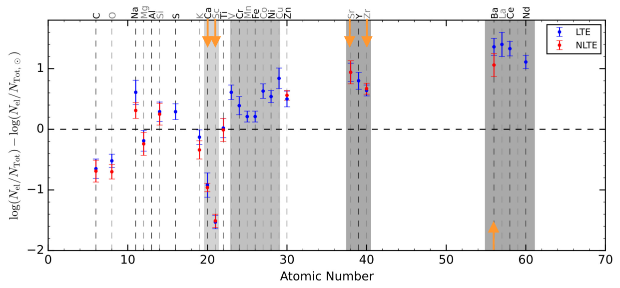
Trust, Jurua, De Cat et al., 2023, MNRAS 524, 1044

- HD180347
  - → TESS sectors 14, 15, and 26
    - ➢ Rotational variable with P_{rot} = 4.1(2) days
    - ➢ No evidence for pulsations
  - → HERMES spectrum
    - ➢ Determination of stellar parameters
    - ➢ Determintation of abundances of 25 chemical elements
      - ✔ LTE for all
      - ✔ NLTE for C, O, Na, Mg, Si, K, Ca, Sc, Ti, Zn, Sr, Zr, Ba





NLTE improves accuracy of derives abundances
Classification as Am (kA1hA8mA8) star



Science

- **ORBIT** (Optical characterisation and Radial velocity monitoring with Belgian and Indian Telescopes) — Joshi, De Cat, Panchal et al., 2019, BSRSL 88, 82

Yogesh Joshi (ARIES)

→ Study of exoplanet and eclipsing binary candidates

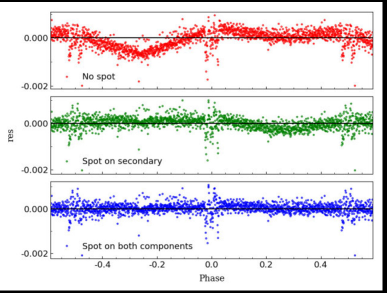
- ➢ Detection and characterisation of exoplanets (by determining accurate physical parameters through constraining the orbital inclination)
- ➢ Alleviation of the mass-radius problem of the low-mass stars (by significantly increasing the number of low-mass eclipsing binaries with accurate masses, radii and metallicities)

→ Observations

- ➢ Photometry: TIRCAM2@DOT/3.6-m (Devasthal, India), DFOT@ARIES/1.3-m (Nainital, India), ASAS-3, K2
- ➢ Spectroscopy: HERMES@Mercator/1.2-m (La Palma, Spain), HESP@HTC/2-m (Hanle, India

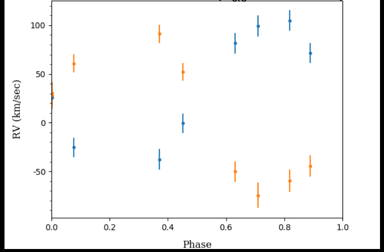
→ Analysis EPIC211982753 and EPIC21191547 — Panchal, Joshi, De Cat et al., 2019, BSRSL 88, 82

- ➢ No evidence for orbital period changes over a timespan of 3.2 years
- ➢ Modelling with PHOEBE
  - ✔ Spot on both components needed for EPIC21191547
  - ✔ Characterisation of the components
    - ➔ Both stars are high mass-ratio eclipsing binaries (q > 0.85)

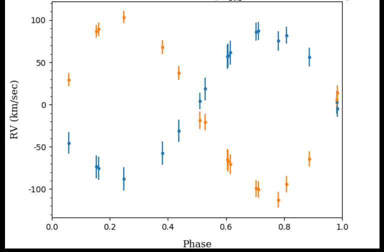


	EPIC211982753		EPIC211915147	
	Primary	Secondary	Primary	Secondary
Mass ($M_\odot$)	1.69(2)	1.59(2)	1.48(1)	1.27(1)
Radius ($R_\odot$)	1.66(2)	1.53(2)	1.80(5)	1.42(5)
Distance	238(4) pc		199(5) pc	
Age	100-224 Myr		1.6-2.5 Gyr	

EPIC 211982753 (P_{orb} = 5.3901 d)



EPIC 211915147 (P_{orb} = 3.62154 d)



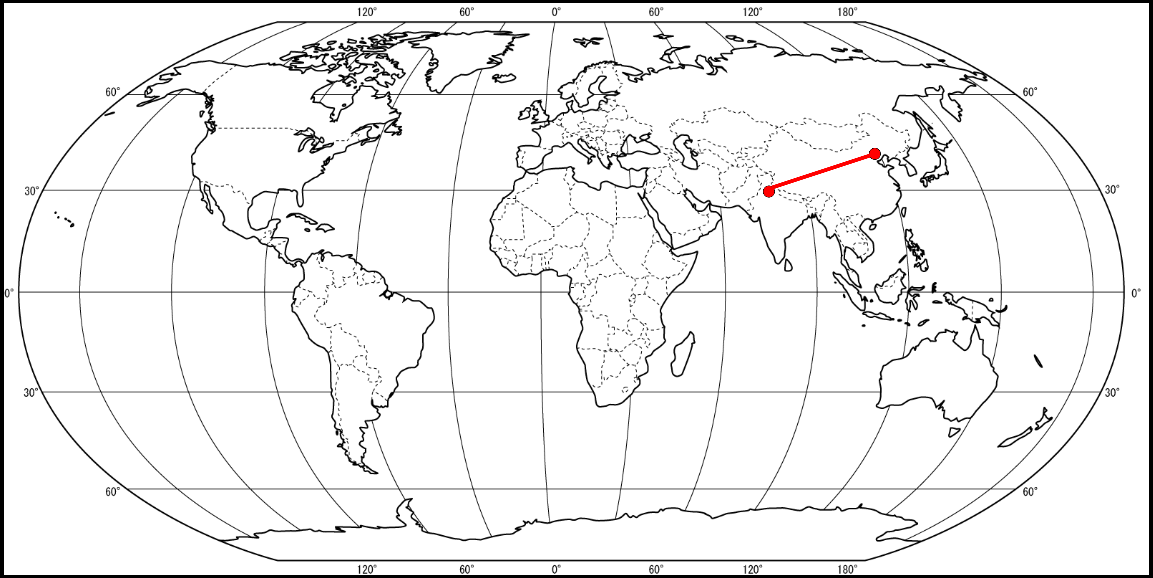
Connection Belgium – India

Science

- Summary of publications
  - → Refereed: #38 published + #3 in press
  - → Proceedings: #18 published + #27 in press
    - ➢ Instrumentation — ULiège – ROB – ARIES
    - ➢ Solar physics — ROB – ARIES
    - ➢ Solar system objects — ULiège – PRL
    - ➢ Exoplanets — ROB – ARIES and ULiège – PRL
    - ➢ Peculiar stars — ROB – ULiège - ARIES
    - ➢ Multiple systems — ROB – ARIES
    - ➢ Abundances — ULB – UOC
    - ➢ Massive stars — ULiège – IIST
    - ➢ Star forming regions
    - ➢ Compact objects
    - ➢ Transients — ULiège - ARIES
    - ➢ Extragalactic astrophysics

Outline

1. Scientific background
2. Connection Belgium – China
3. Connection Belgium – India
4. Connection China – India
5. Conclusions and future prospects



Peter De Cat (Royal Observatory of Belgium, Ringlaan 3, B-1180 Brussels, Belgium; Peter.DeCat@oma.be)

Connection China – India – Russia

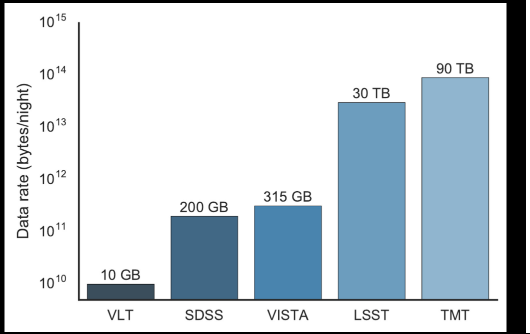
SAPTARISI

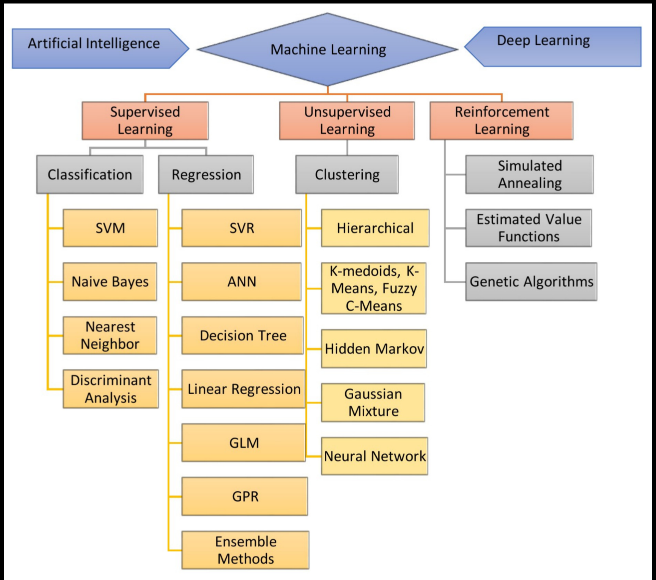
Search and Follow-up Studies of Time-domain Astronomical Sources using Sky Surveys, BRICS Telescopes and Artificial Intelligence

Ali Luo (NAOC)

Santosh Joshi (ARIES)

- Context
  - → Explosion of the amount of incoming data from new generation of instruments (including LAMOST and ILMT)
  - → Beyond the capacity of researchers to manually process, manipulate and explore these massive data sets
- Goals
  - → Create machine learning and artificial intelligence based methodologies for automated searching, identification, and classification of galitic and extragalactic transients and variable sources
  - → Produce catalogues for indexing and fast retrieval of transients (public domain)
  - → Follow-up science
- Partners
  - → India (incl. Santosh Joshi: PI and coordinator)
  - → China (incl. Ali Luo: CoI)
  - → Russia





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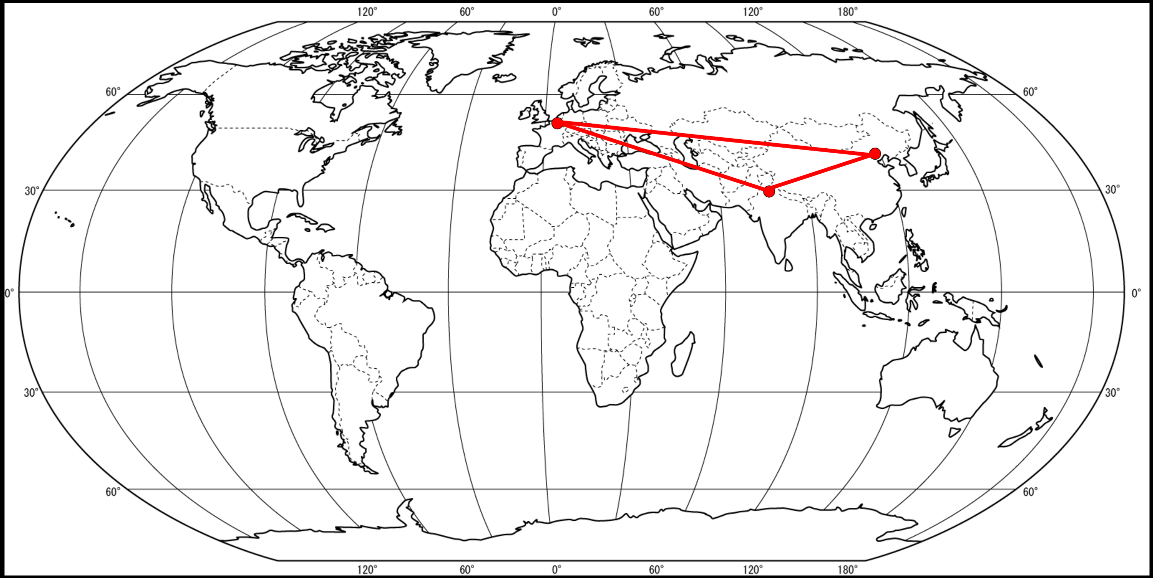


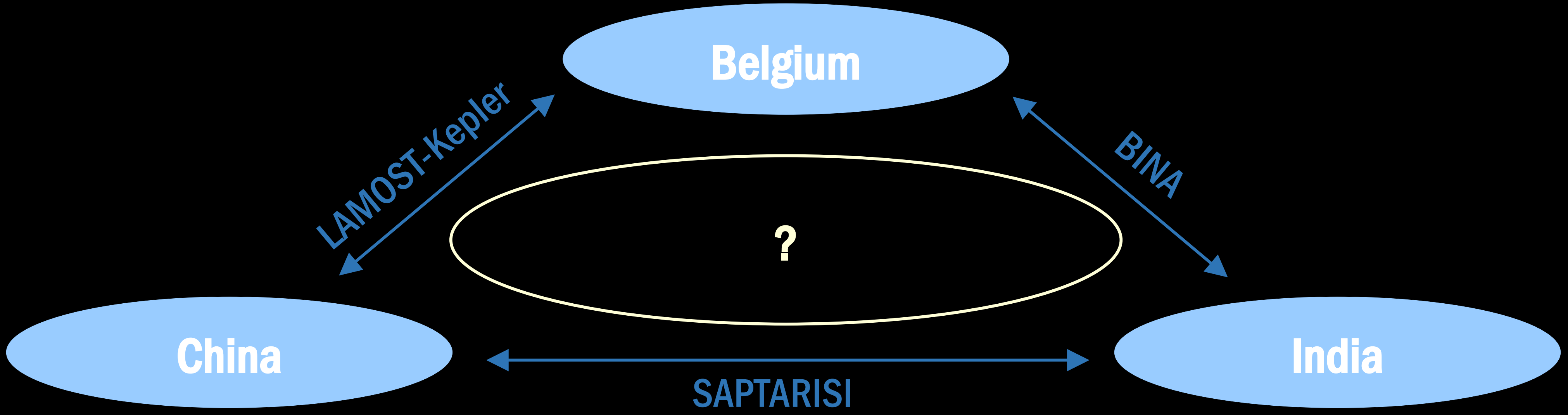
Conclusions and future prospects

Take away messages

- Network activities are extremely important
  - → New collaborations
    - ➢ Coincidental encounters can lead to the start of new scientific endeavours
  - → New scientific ideas
    - ➢ Deepen your view
    - ➢ Broaden your view
  - → Meet your peers
    - ➢ It might open opportunities in the future
    - ➢ Present your results (write papers, progress results for collaborators, talks at international conferences)
  - → Treat your colleagues as your collaborators (not as your opponents) because 1 + 1 > 2
- Know your own strengths and weaknesses
  - → Use your strong points and keep them strong
  - → Search for collaborators to improve your weak points
- Work to live (not live to work)
  - → Take time to reload and relax

Conclusions and future prospects

Summary of connections by ongoing two-by-two international network projects



Open question

Are there possibilities to strengthen the scientific connections
Between China, Belgium, and India
by starting a joint international network project?

Thank you for your attention!