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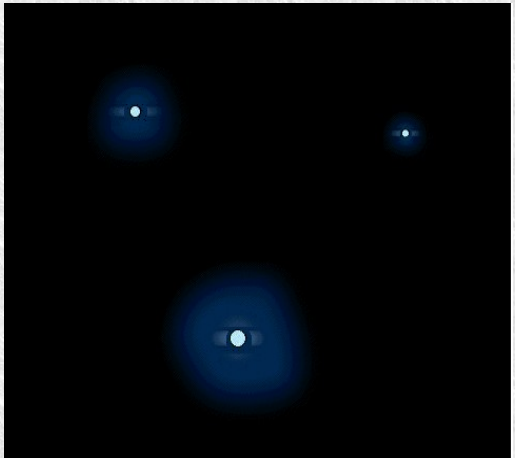
LEUVEN

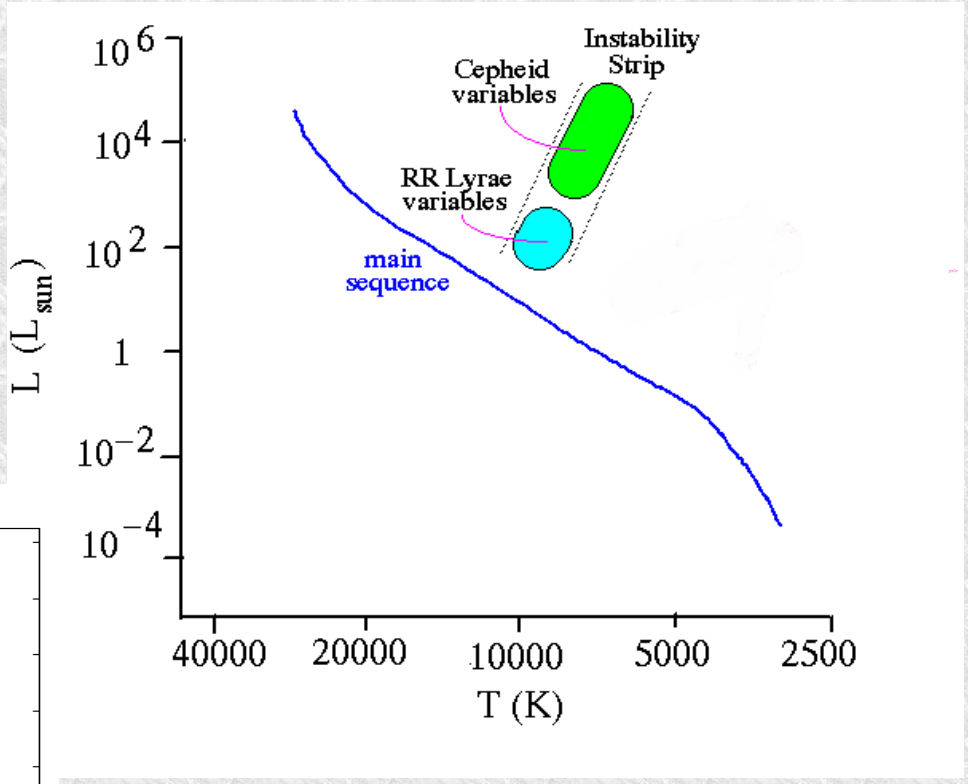
De impact van de ruimtemissies CoRoT en Kepler op het onderzoek naar variabele sterren

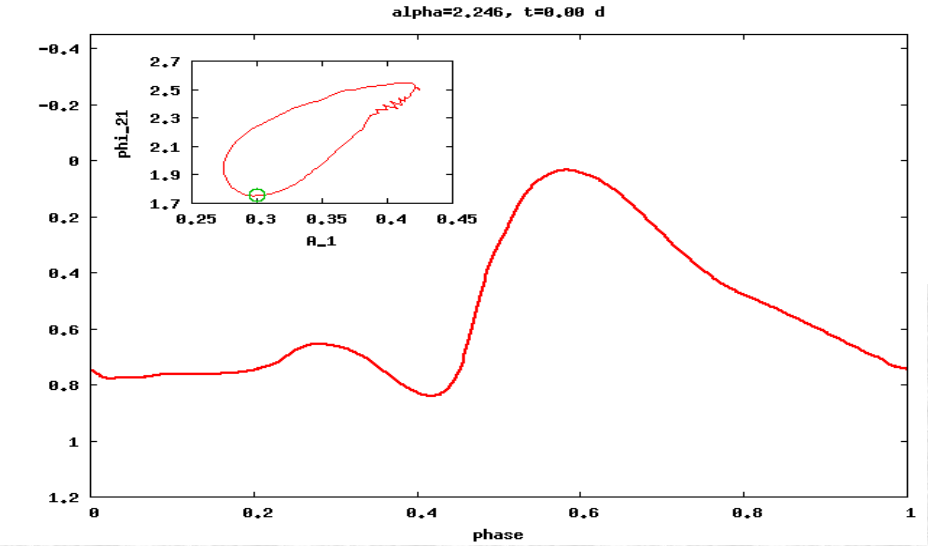
VVS werkgroep Veranderlijke Sterren, MIRA, 28 mei 2011

Historiek Veranderlijke Sterren

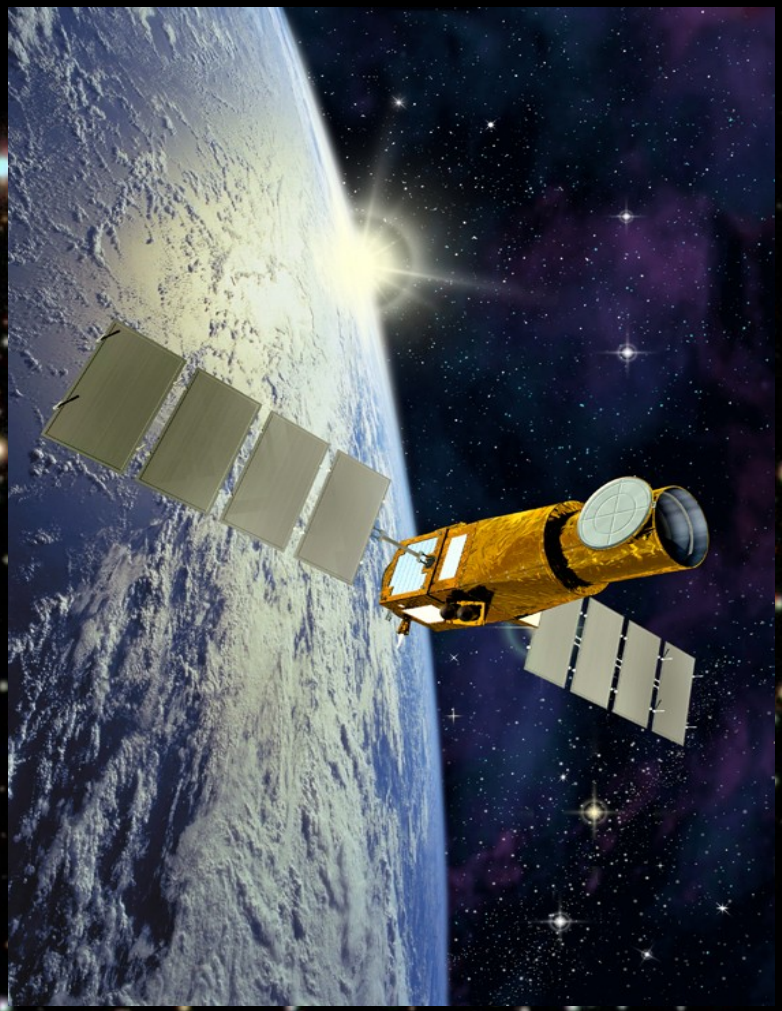
Met het blote oog is zowat 3% van de sterren variabel



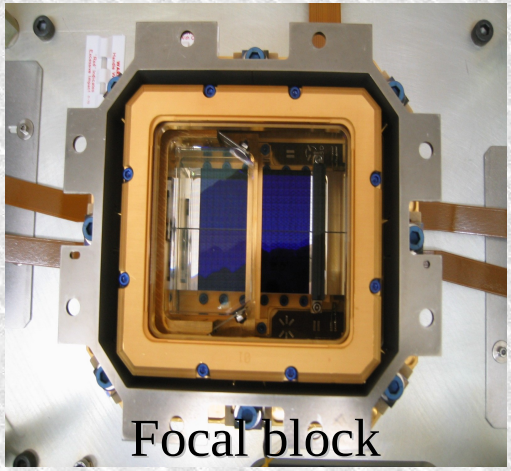




CoRoT en Kepler : van mmag naar µmag en van 10 - 40% naar 95% duty cycle gedurende maanden tot jaren

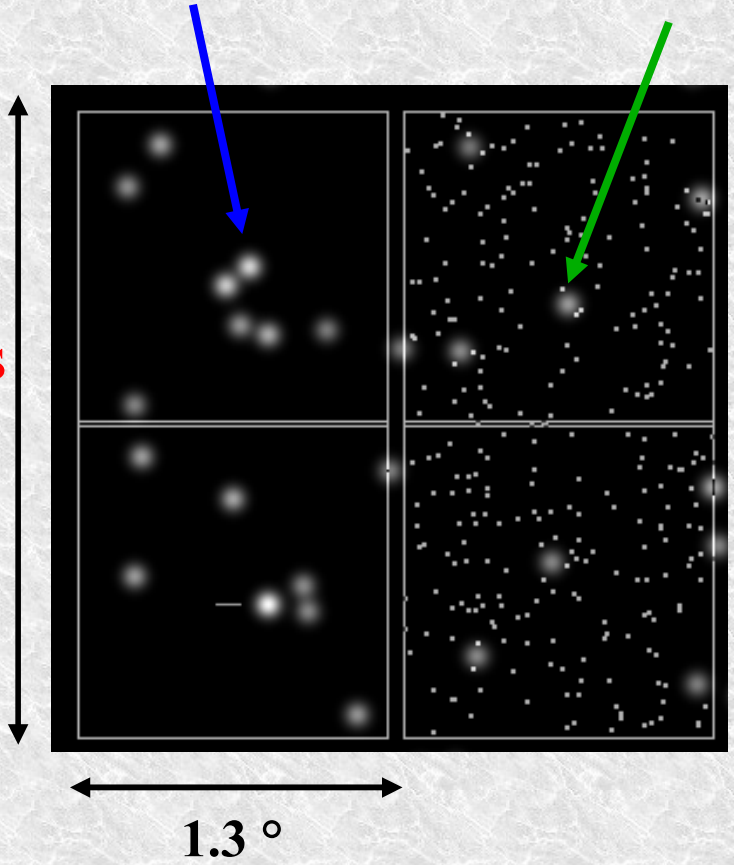


CoRoT focal plane



Seismology field
highly defocused

Exoplanet field
focused + prism

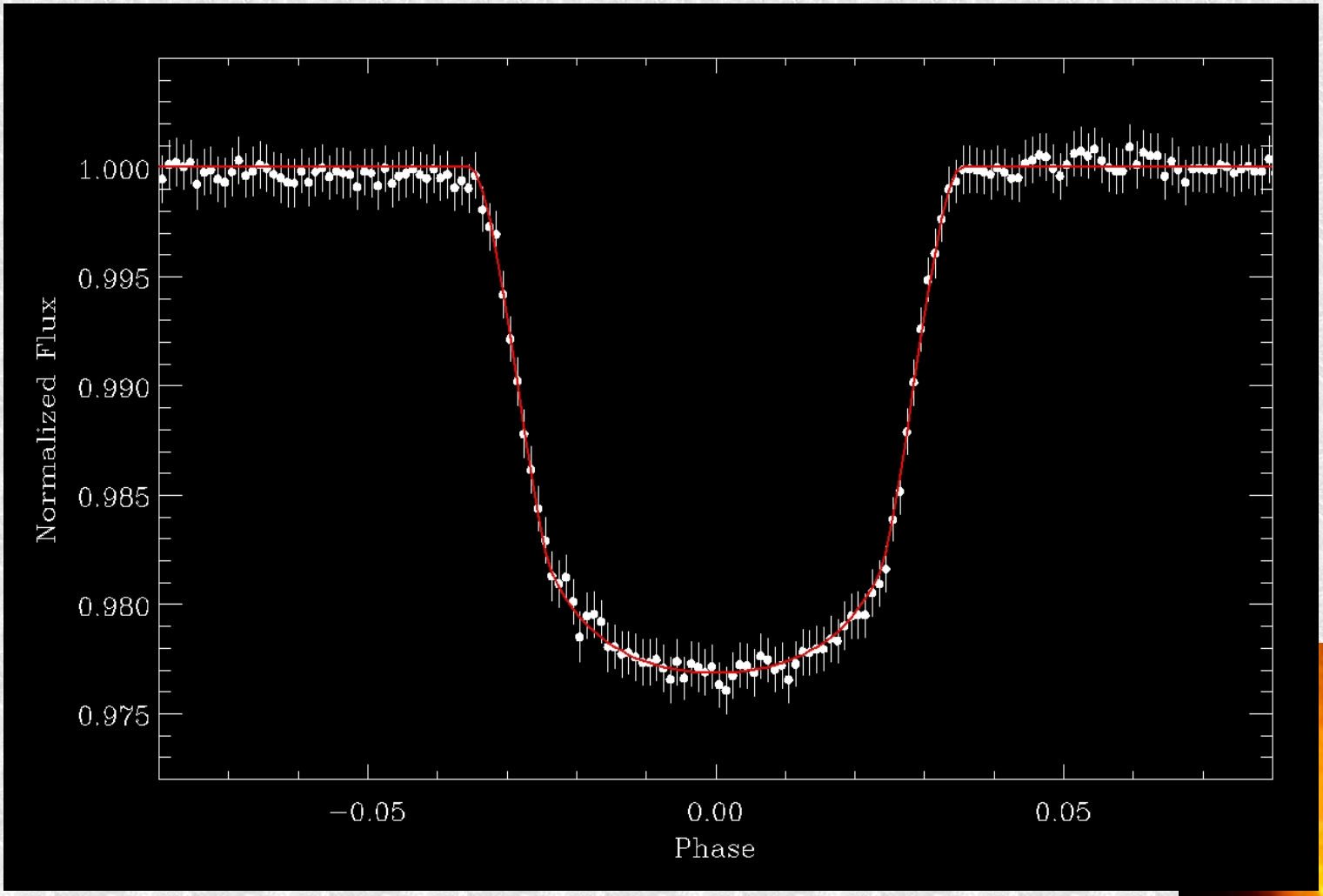


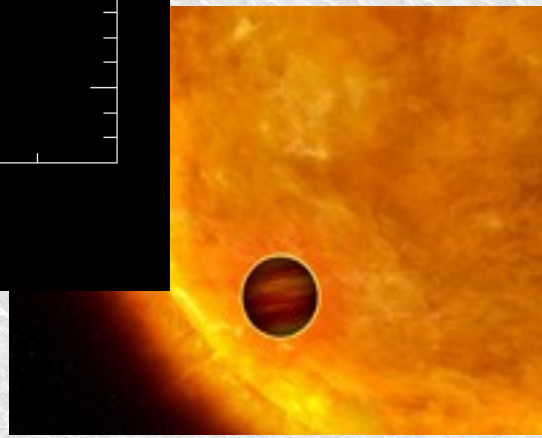
10 targets
5.4<V<9
sampling 32 s

12000 targets
11<V<16
sampling 512 s
4 CCDs 2000x4000 px
Frame transfer

> 100 stars in the Seismo-field
> 100000 stars in the Exo-field

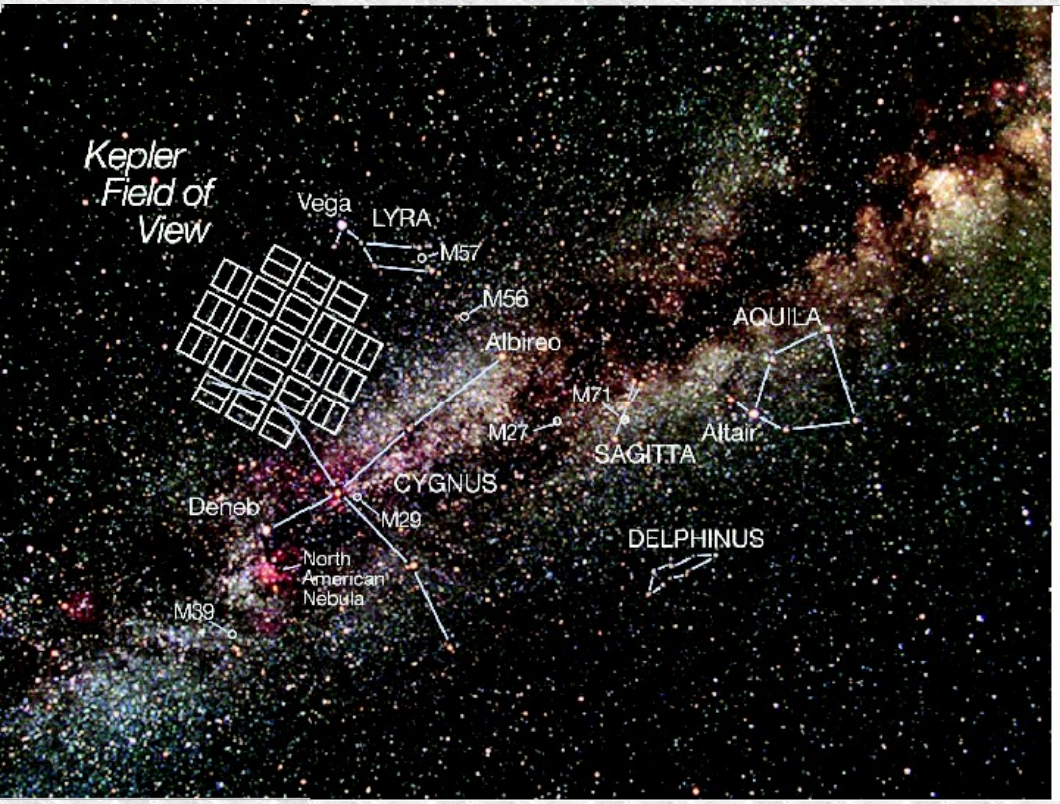
First CoRoT results (ESA PR 3/5/2007)

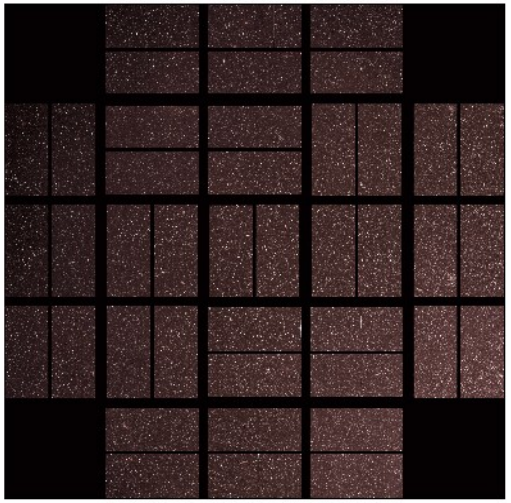




Kepler FoV bedekt met 42 CCDs

Sampling van ±1 (enkele) of ±30 min
Vast beeldveld tijdens hele missie:
150000 sterrenV tussen 9-14
Satelliet draait met 90 graden elke 3 maanden

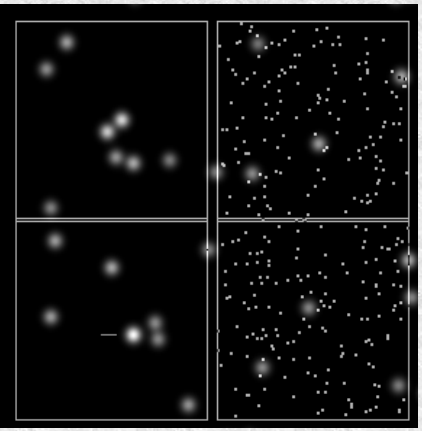




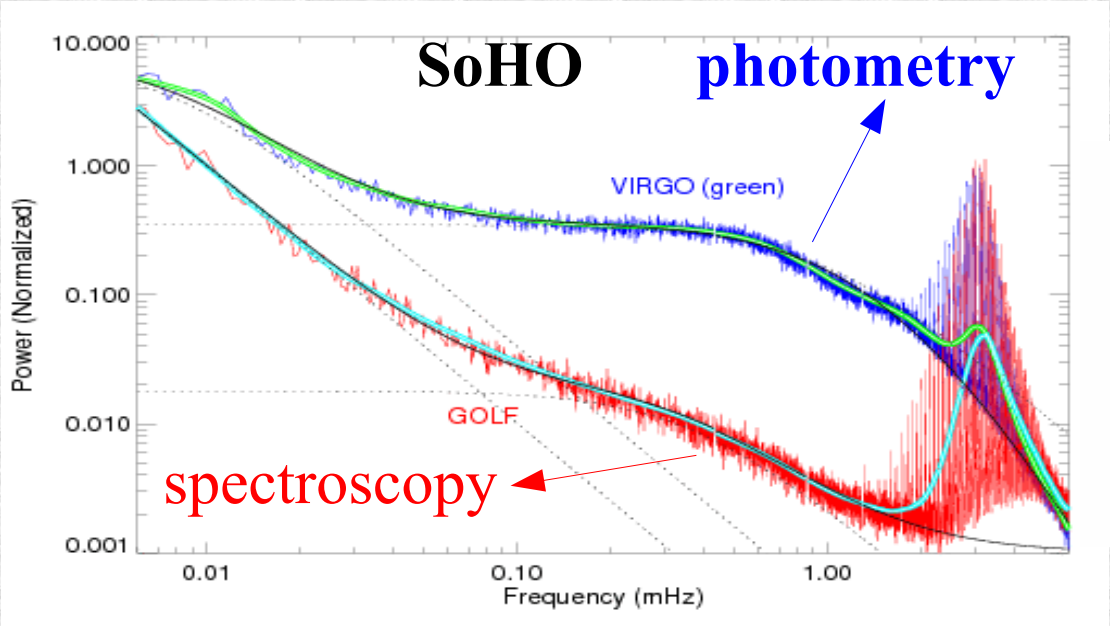
Ondanks netwerken, grote stap!

- Vanop grond: te weinig frequenties, behalve voor WD
- Precisie gelimiteerd voor grond fotometrie (beste: WET 14 μmag – HR 1217; Kurtz et al. 2002)
- Te lage duty cycle, zelfs met netwerk campagne
- Multisite campagnes met hoge precisie (m/s) in spectroscopie hoogst uitzonderlijk

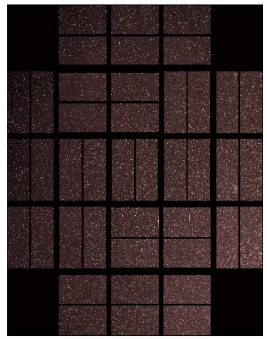
CoRoT



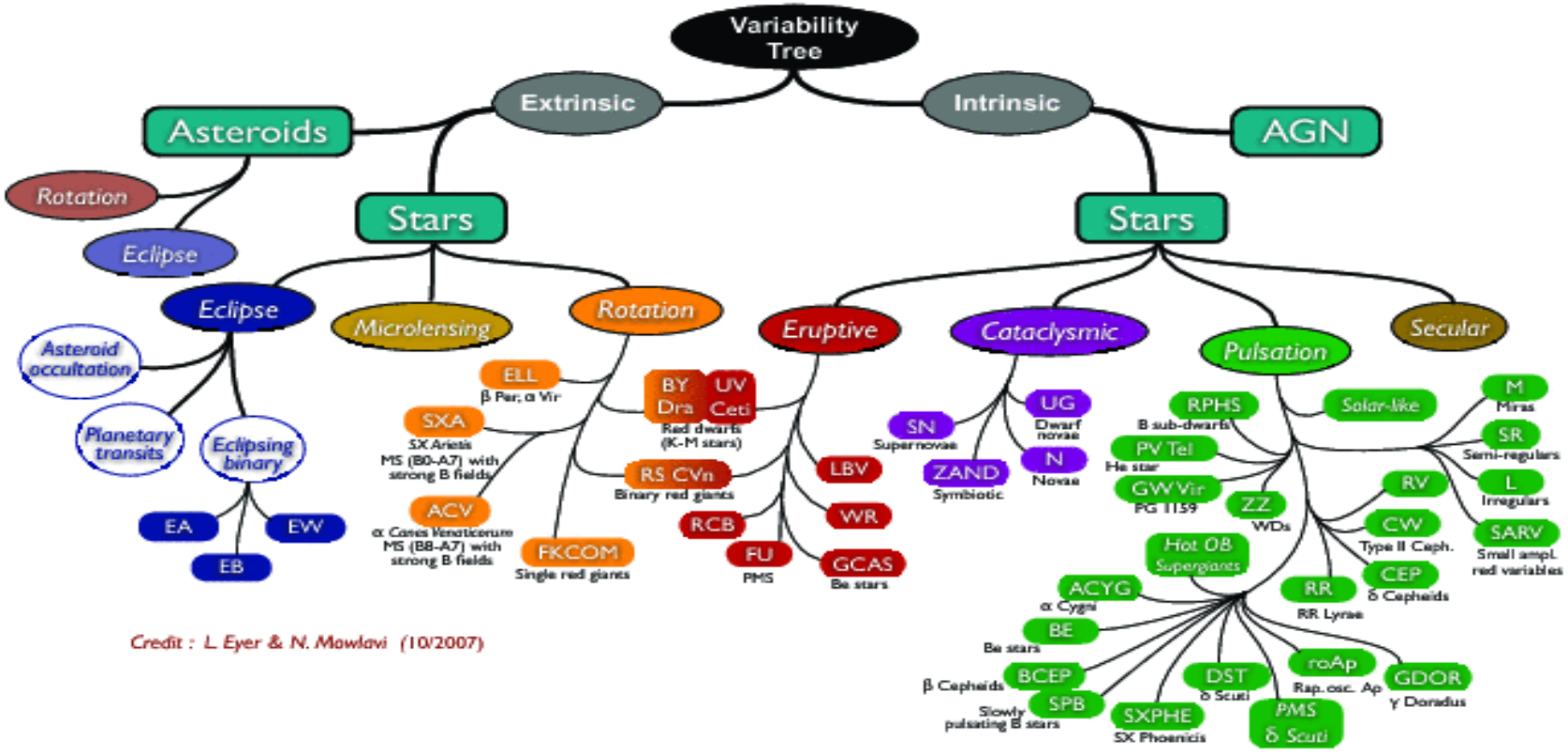
SoHO



Kepler

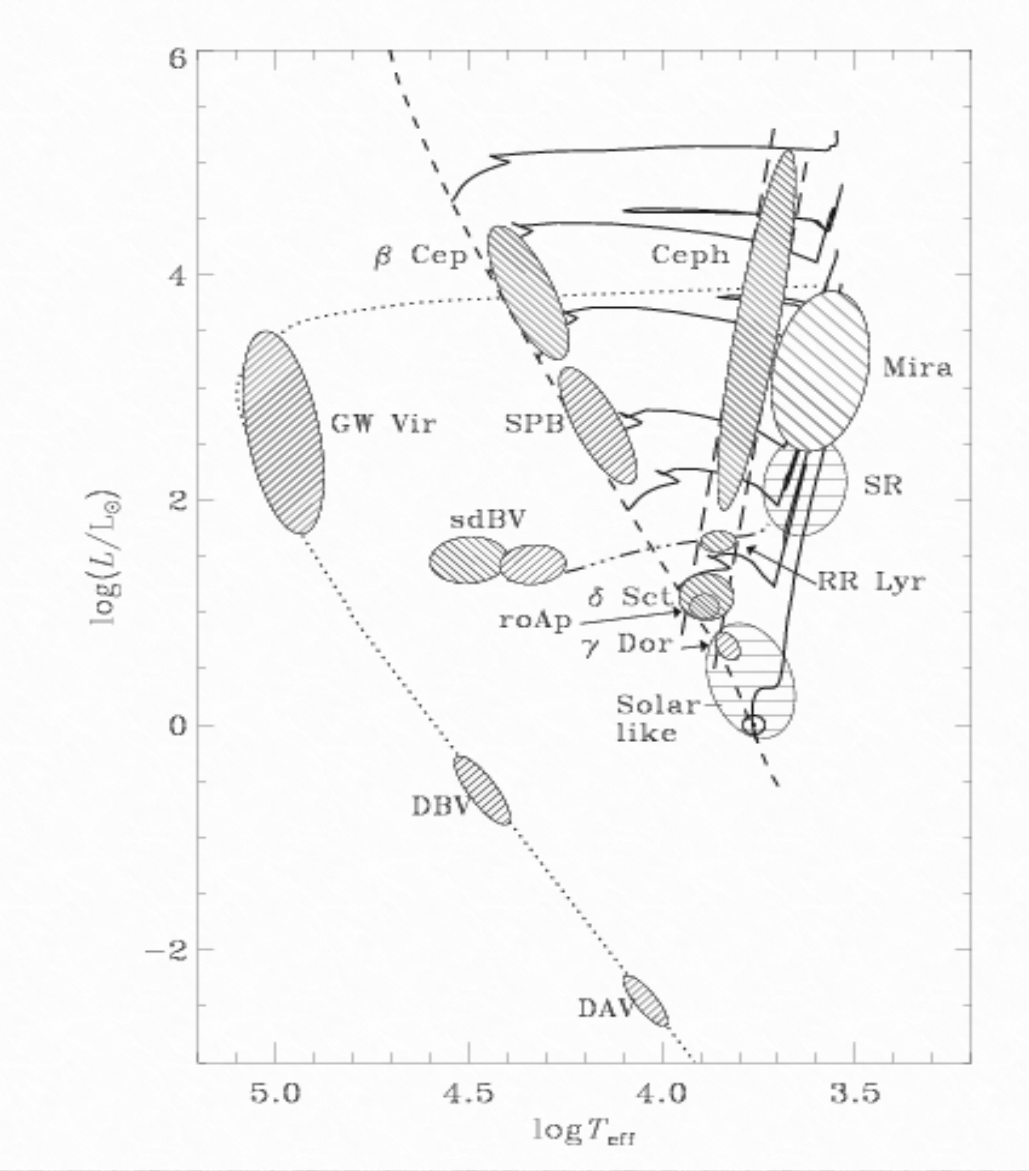


De Zoo van de Variabelen



Credit : L. Eyer & N. Mowlavi (10/2007)

Pulserende sterren vind je overal

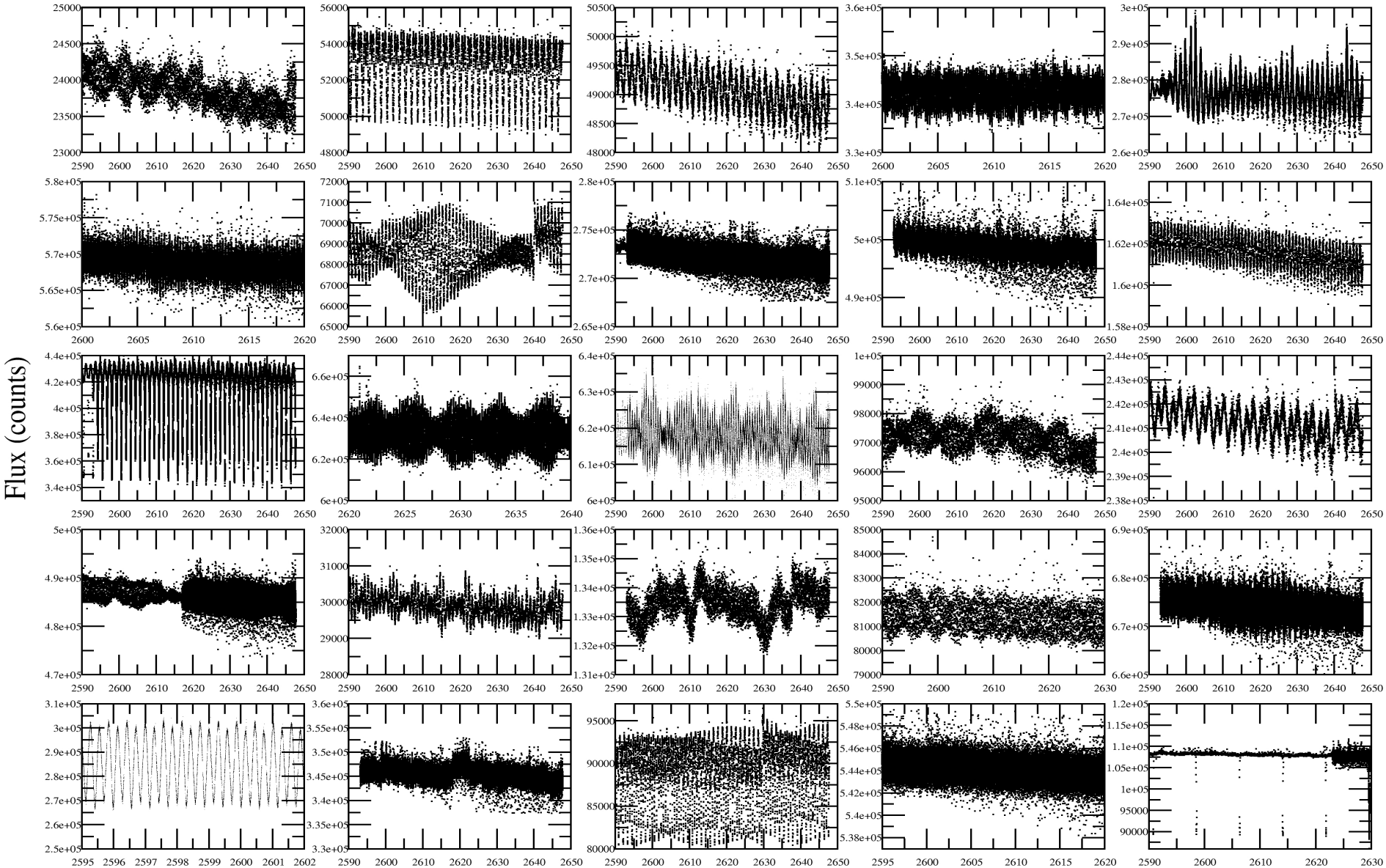


En binaries ook...

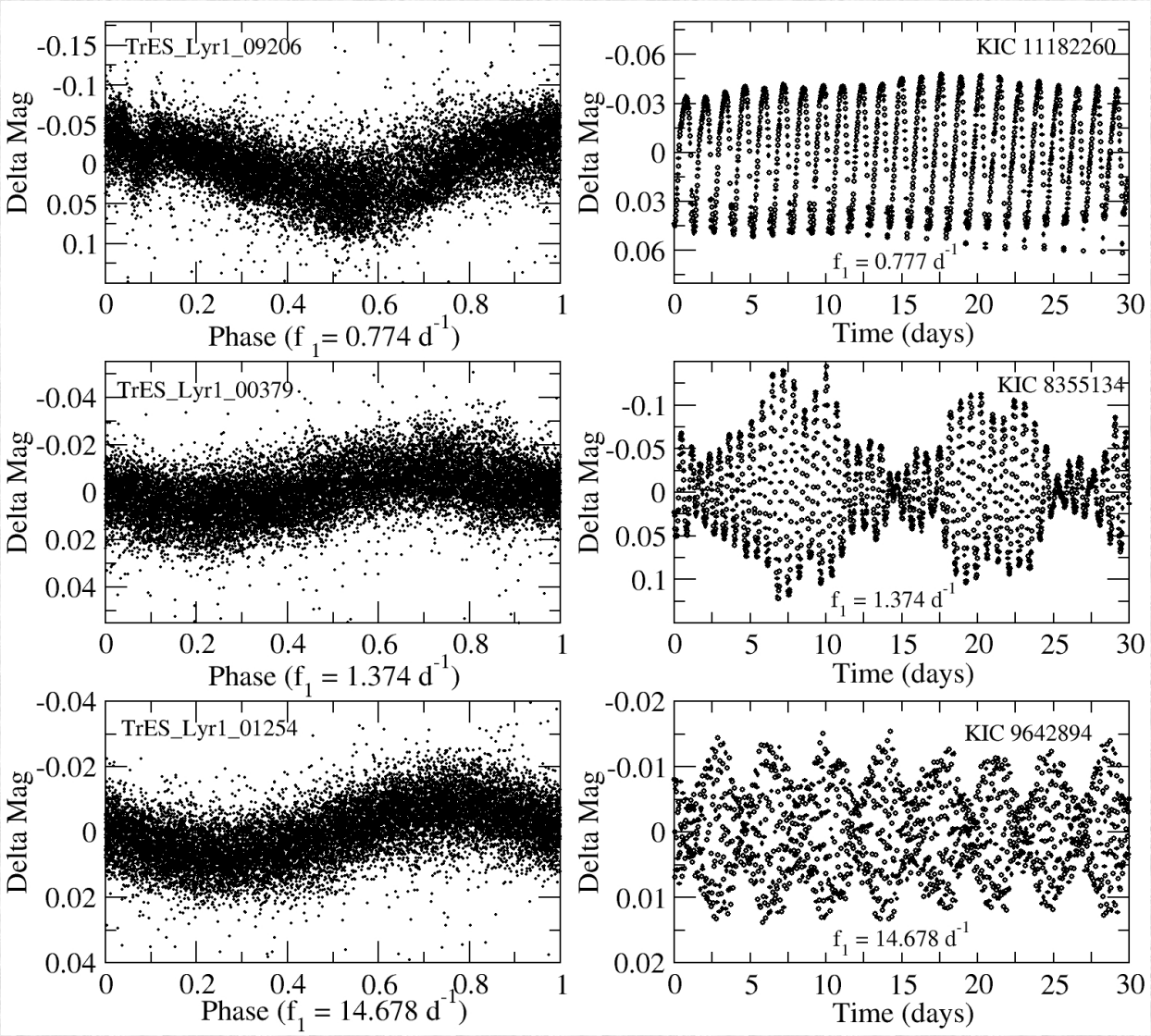
En pulsatoren in binaries ook...

Vraag: hoe verandert onze kijk op de instabiliteits-stroken door CoRoT of Kepler?

Zoektocht in >300000 lichtkrommen...



Consistentie check: grond & Kepler



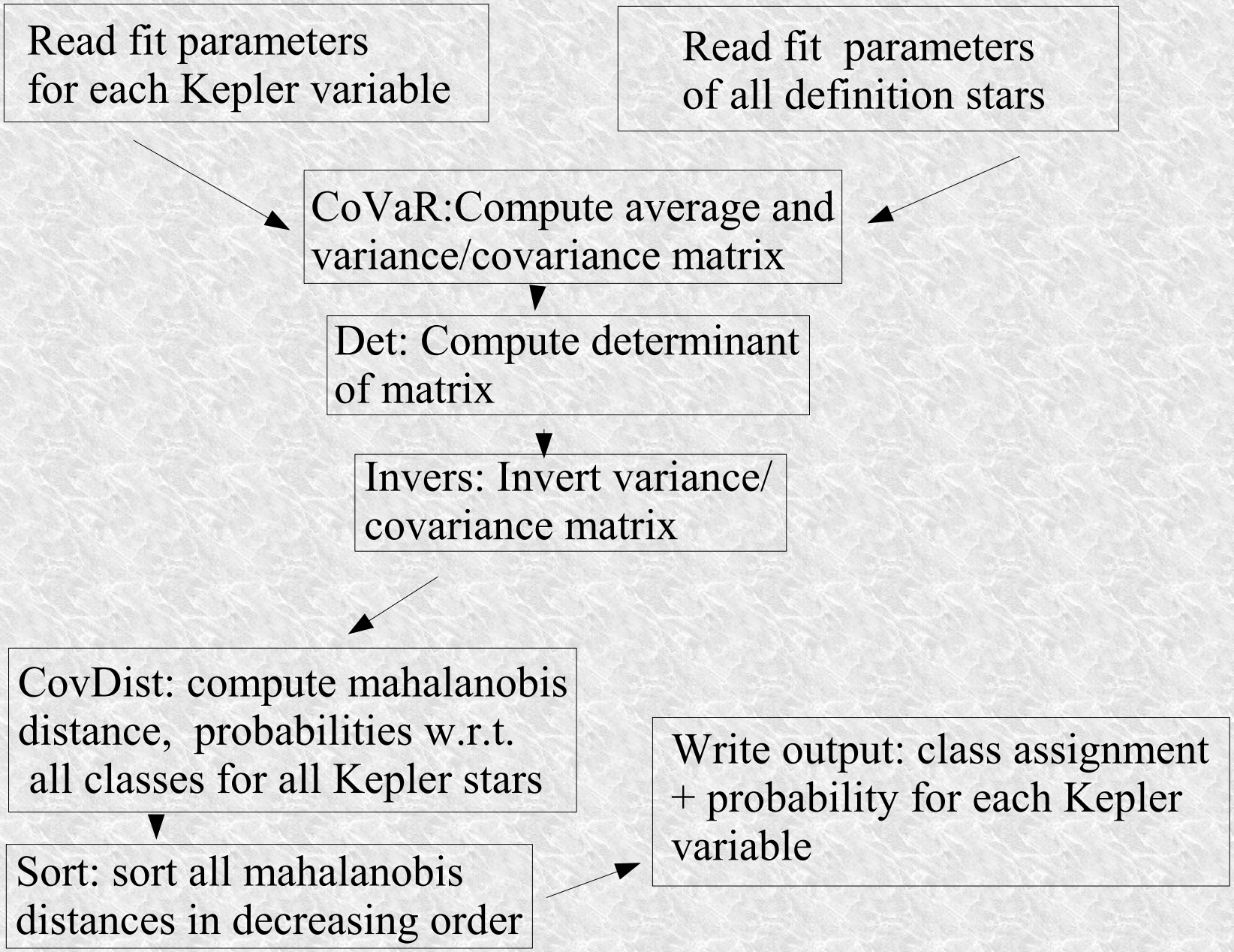
TrES survey: hints van verscheidene pulsatoren

Bevestigd door Kepler

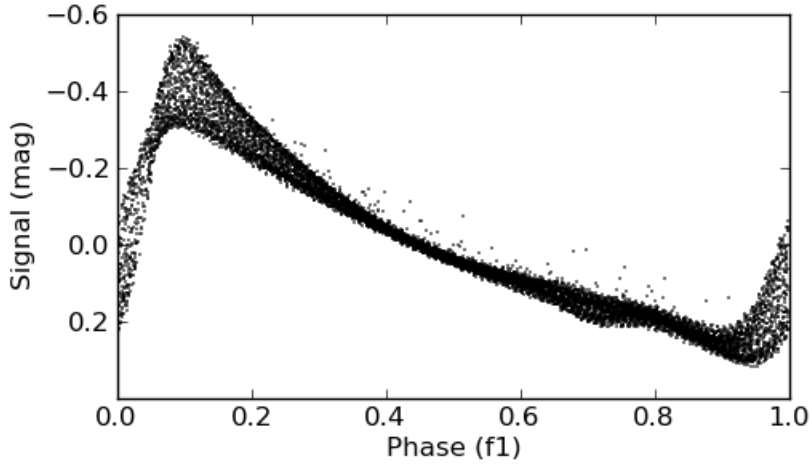
Blomme et al., Debosscher et al. (2011): publieke cataloog

CVC implementatie

- Automatische classificatie: Debosscher et al. (2007, 2011)
  - Input: Definitie sterren + CoRoT of Kepler targets ASCII lichtkrommen (HJD, flux)
  - Output:
    - Stel afgeleide parameters van de lichtkrommen, waaronder variabiliteitsindicatoren (frequenties, amplitudes, variantie reductie,...)
    - Gefaseerde lichtkrommen met hoofdperiode
    - Samenvattende resultaten: waarschijnlijkheden voor 3 meest waarschijnlijke klassen + voornaamste lichtkromme parameters
- CVC gebruikt alleen CoRoT of Kepler data
  - Stromgren kleuren of spectra zijn beschikbaar voor sommige sterren maar zeker niet voor allemaal


Read fit parameters for each Kepler variable
Read fit parameters of all definition stars
CoVaR:Compute average and variance/covariance matrix
Det: Compute determinant of matrix
Invers: Invert variance/ covariance matrix
CovDist: compute mahalanobis distance, probabilities w.r.t. all classes for all Kepler stars
Sort: sort all mahalanobis distances in decreasing order
Write output: class assignment + probability for each Kepler variable

Voorbeeld van een RRab ster (CoRoT)



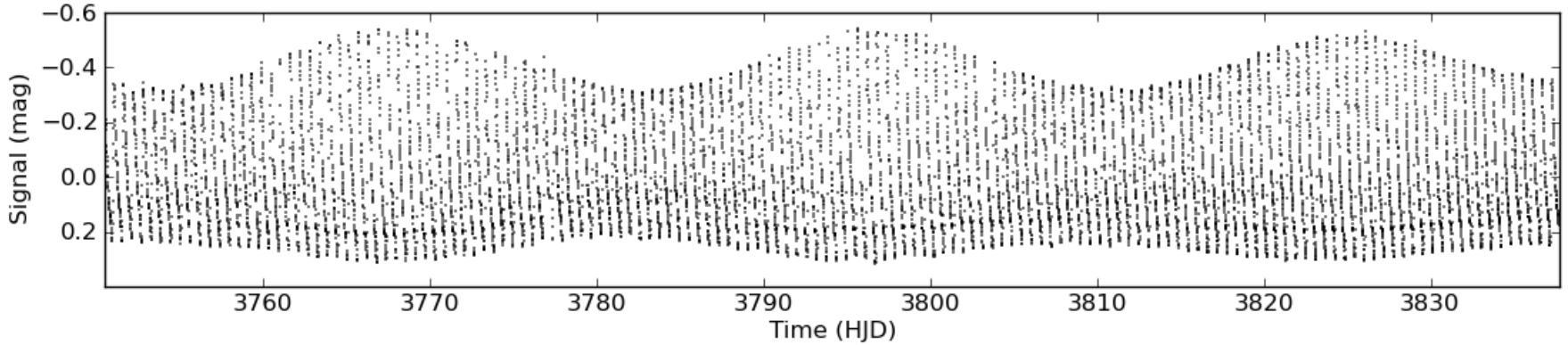
104948132

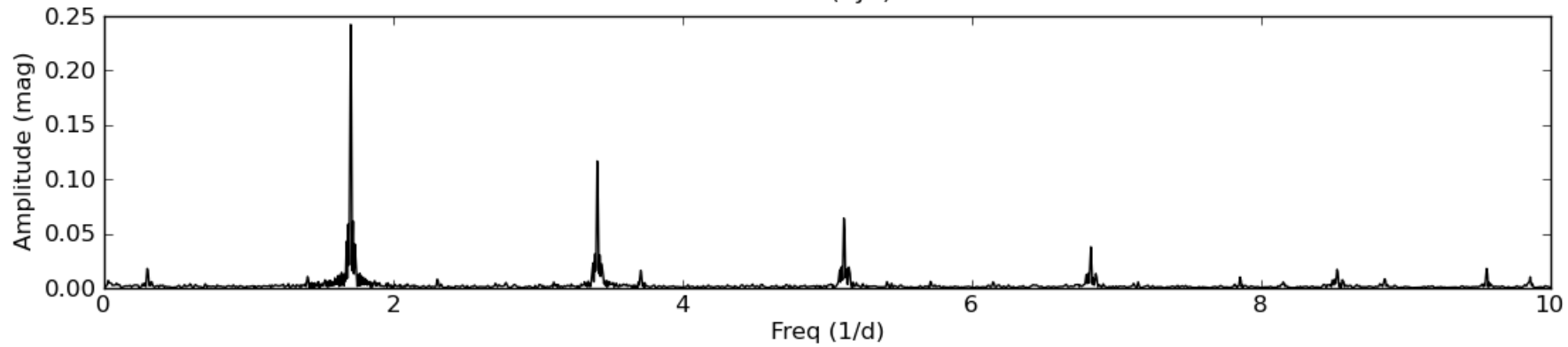
f1=1.705 c/d

f2=1.741 c/d

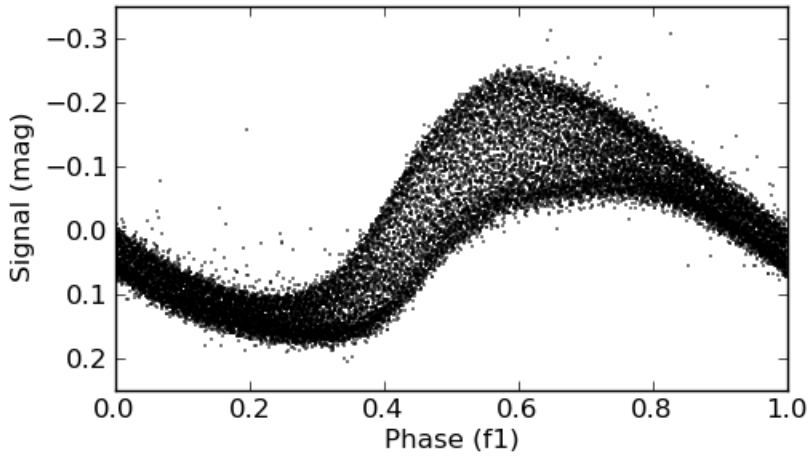
RRAB

MD=0.94 prob=1.00





Voorbeeld van een RRd (CoRoT)



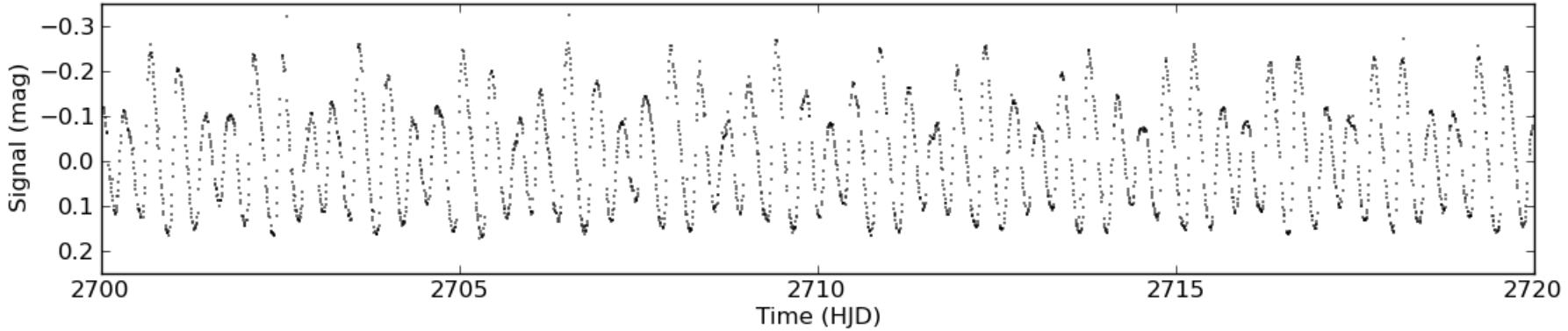
101368812

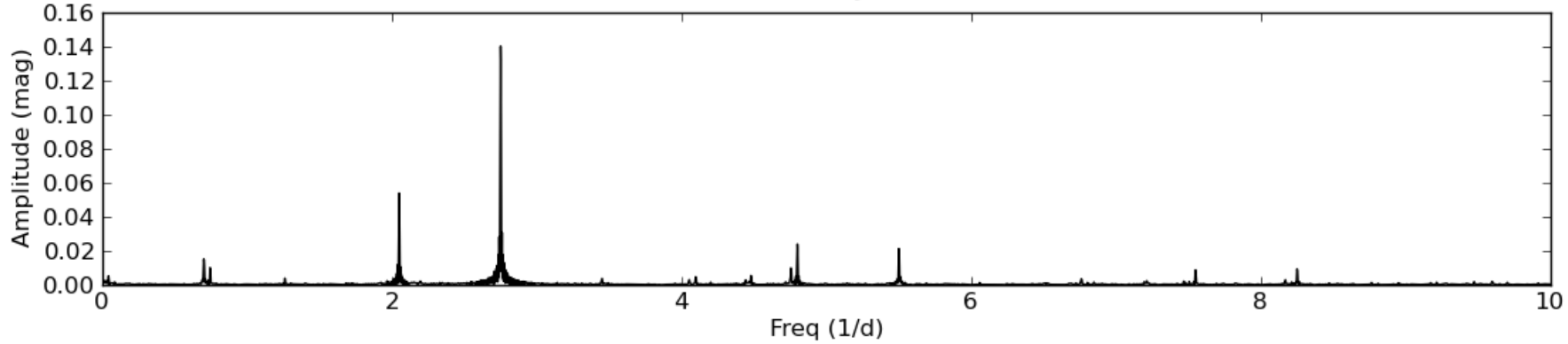
f1=2.750 c/d

f2=2.049 c/d

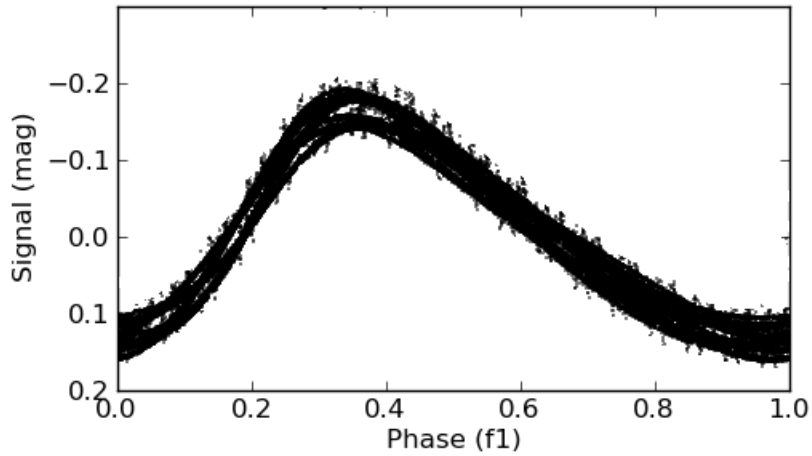
RRD

MD=1.03 prob=1.00





Voorbeeld van een DM Cepheid (CoRoT)



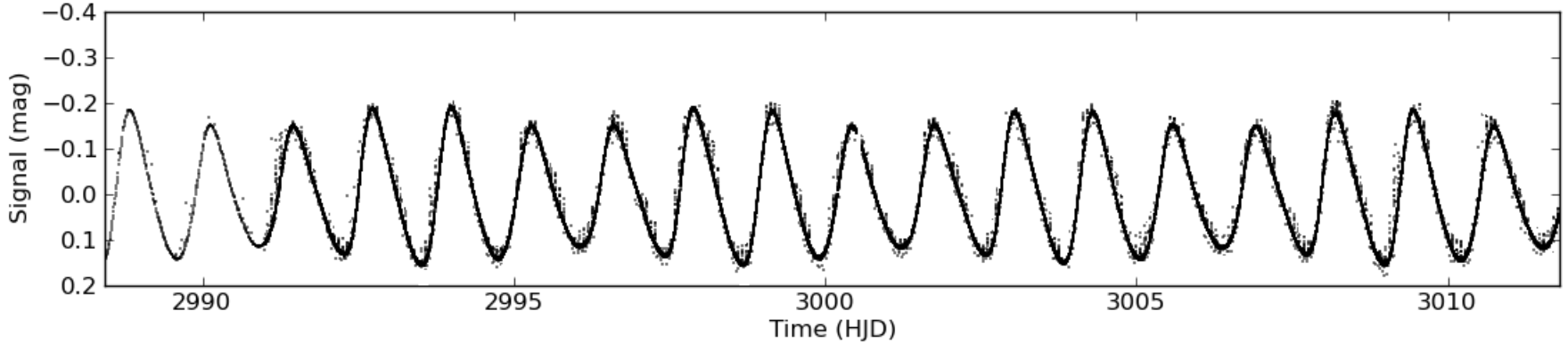
223989566

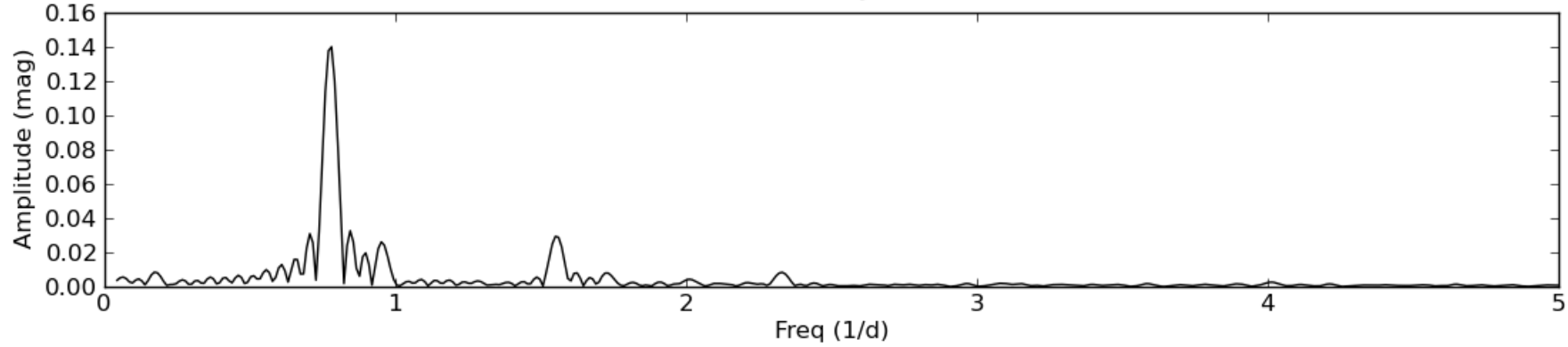
f1=0.776 c/d

f2=1.747 c/d

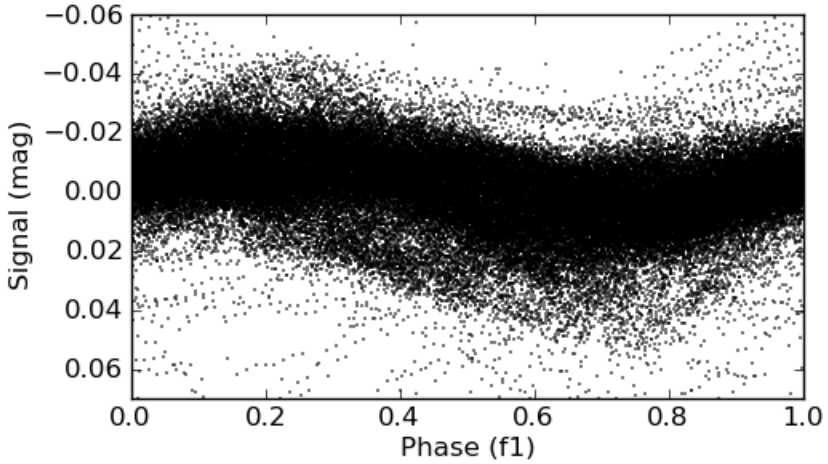
DMCEP

MD=1.62 prob=1.00





Voorbeeld van een Be ster (CoRoT)



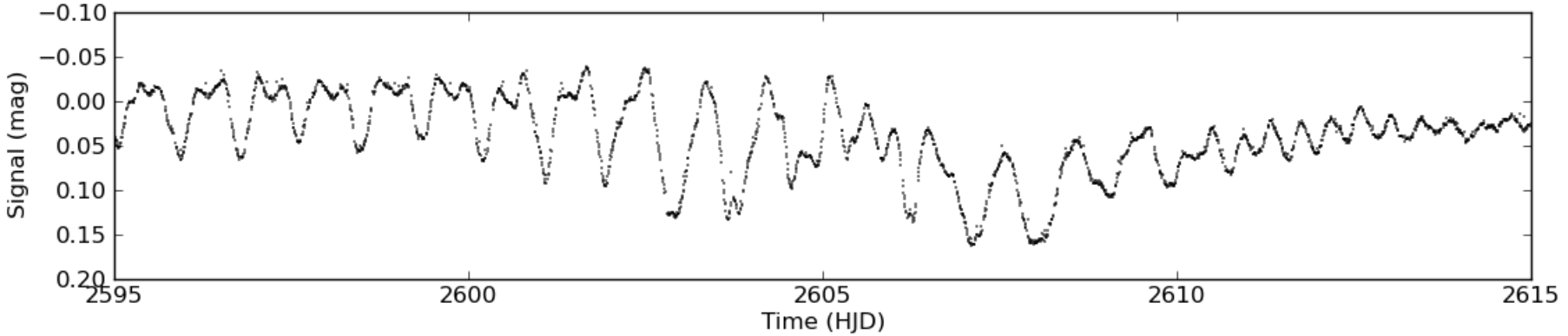
102719279

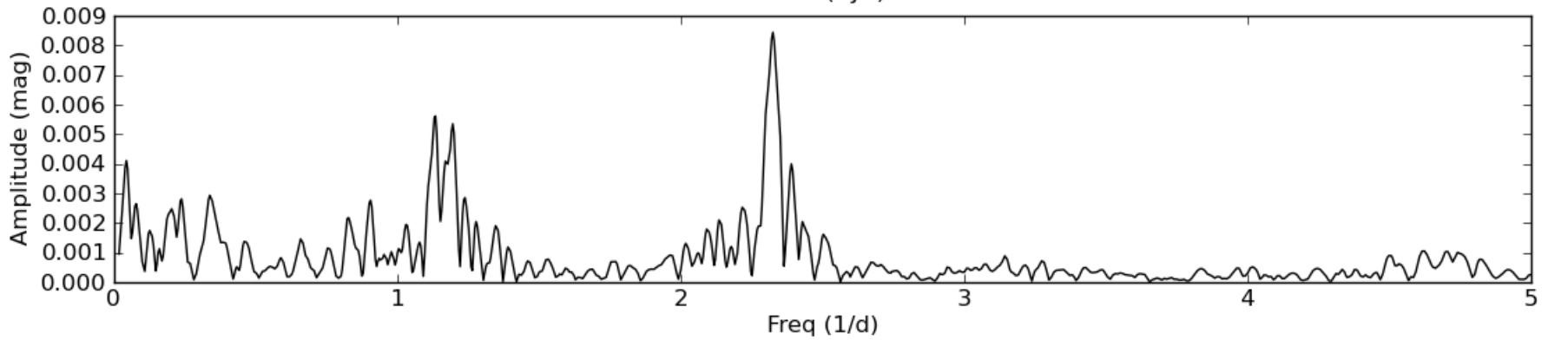
f1=2.325 c/d

f2=1.133 c/d

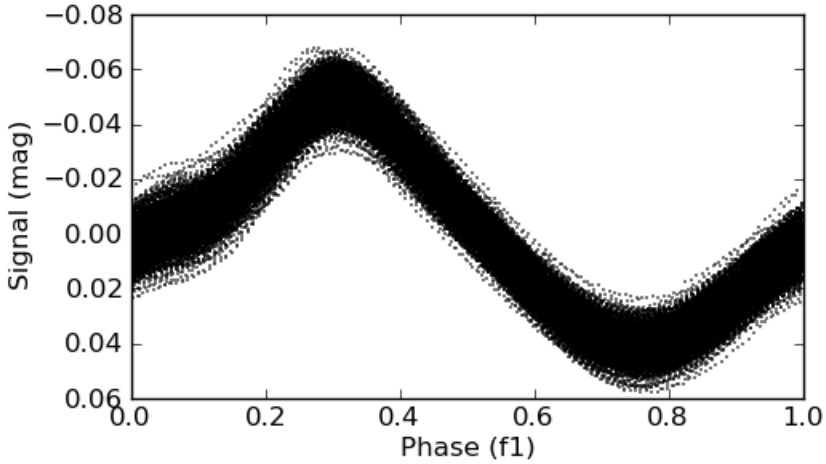
BE

MD=1.4 prob=0.92





Voorbeeld van een Beta Cep (CoRoT)



In totaal:127 frequenties (Degroote et al. 2009)

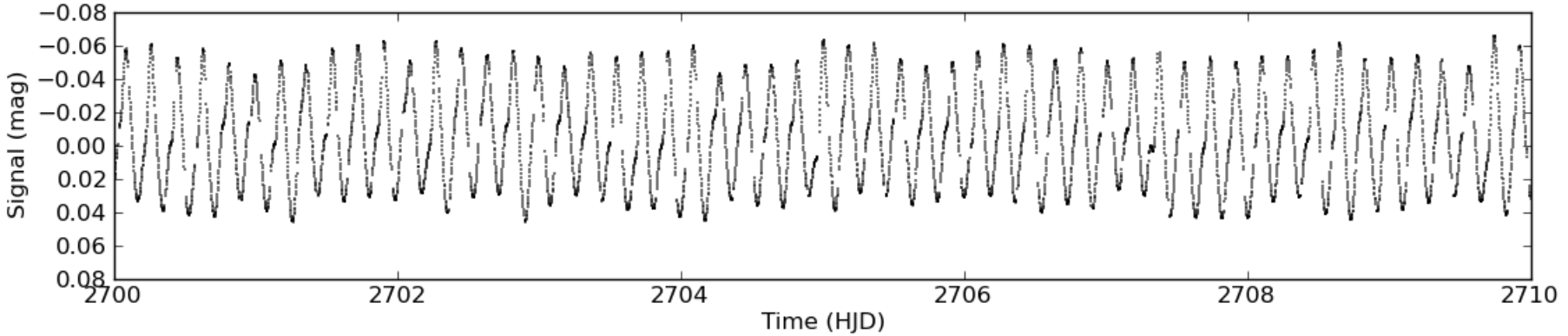
8393

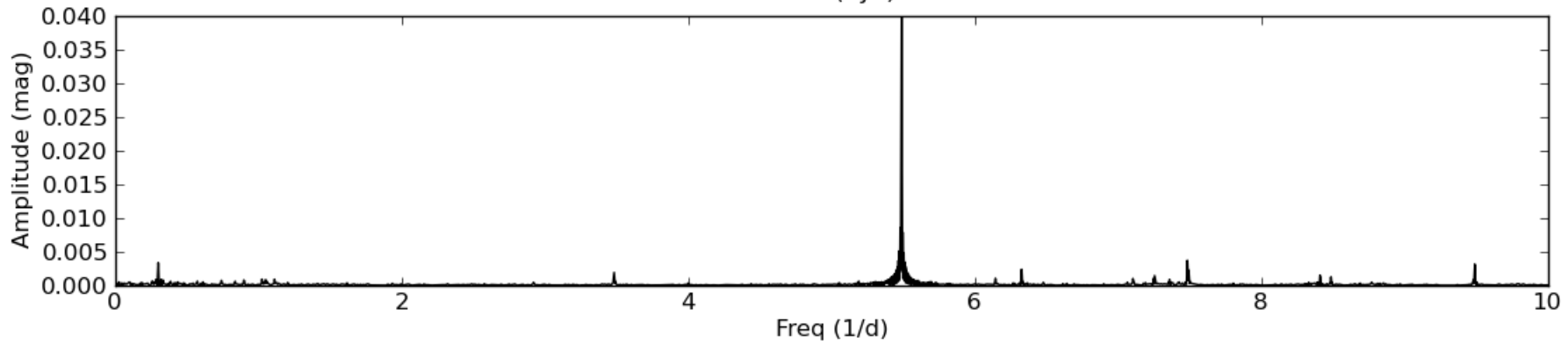
f1=5.487 c/d

f2=0.299 c/d

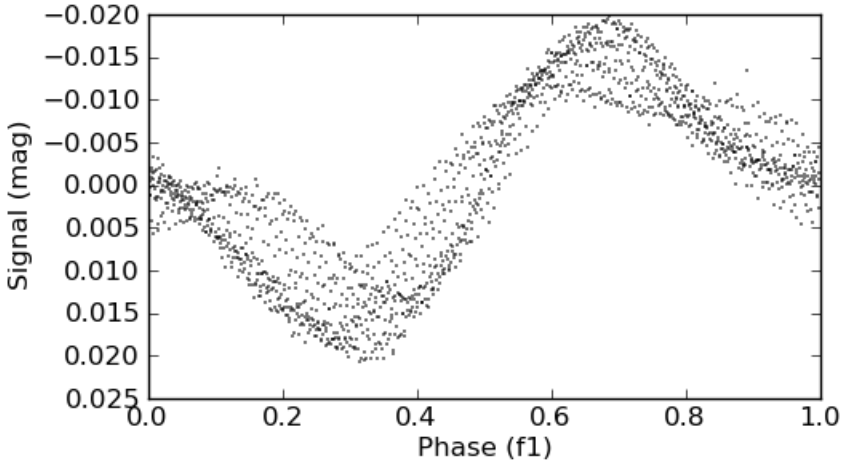
BCEP

MD=2.47 prob=1.00





Voorbeeld van rotatiemodulatie (Kepler)



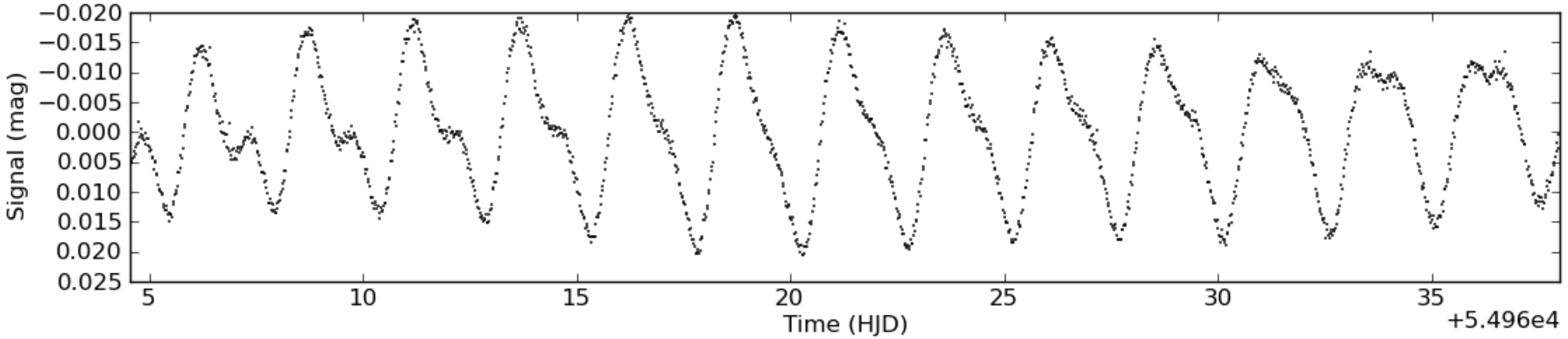
kplr009407907

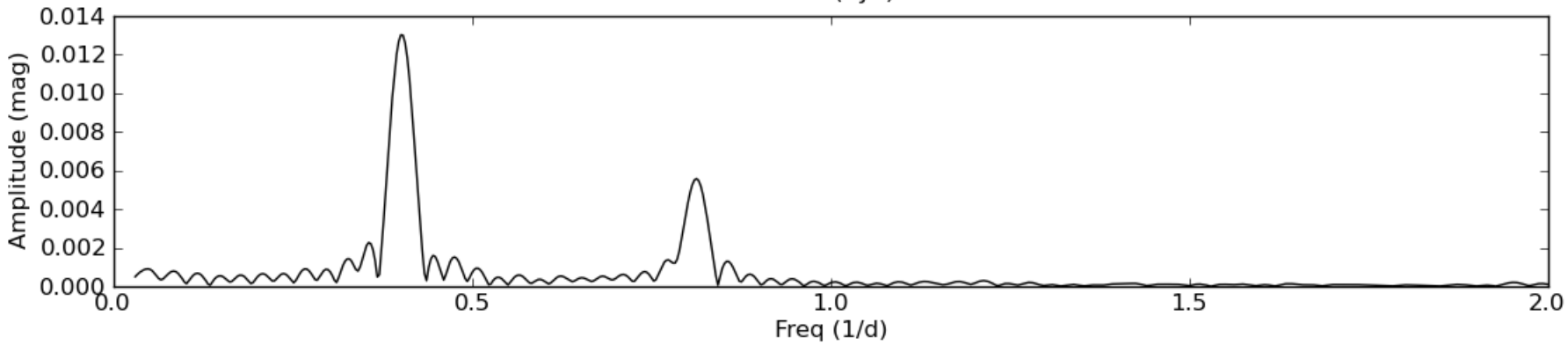
f1=0.400 c/d

f2=0.822 c/d

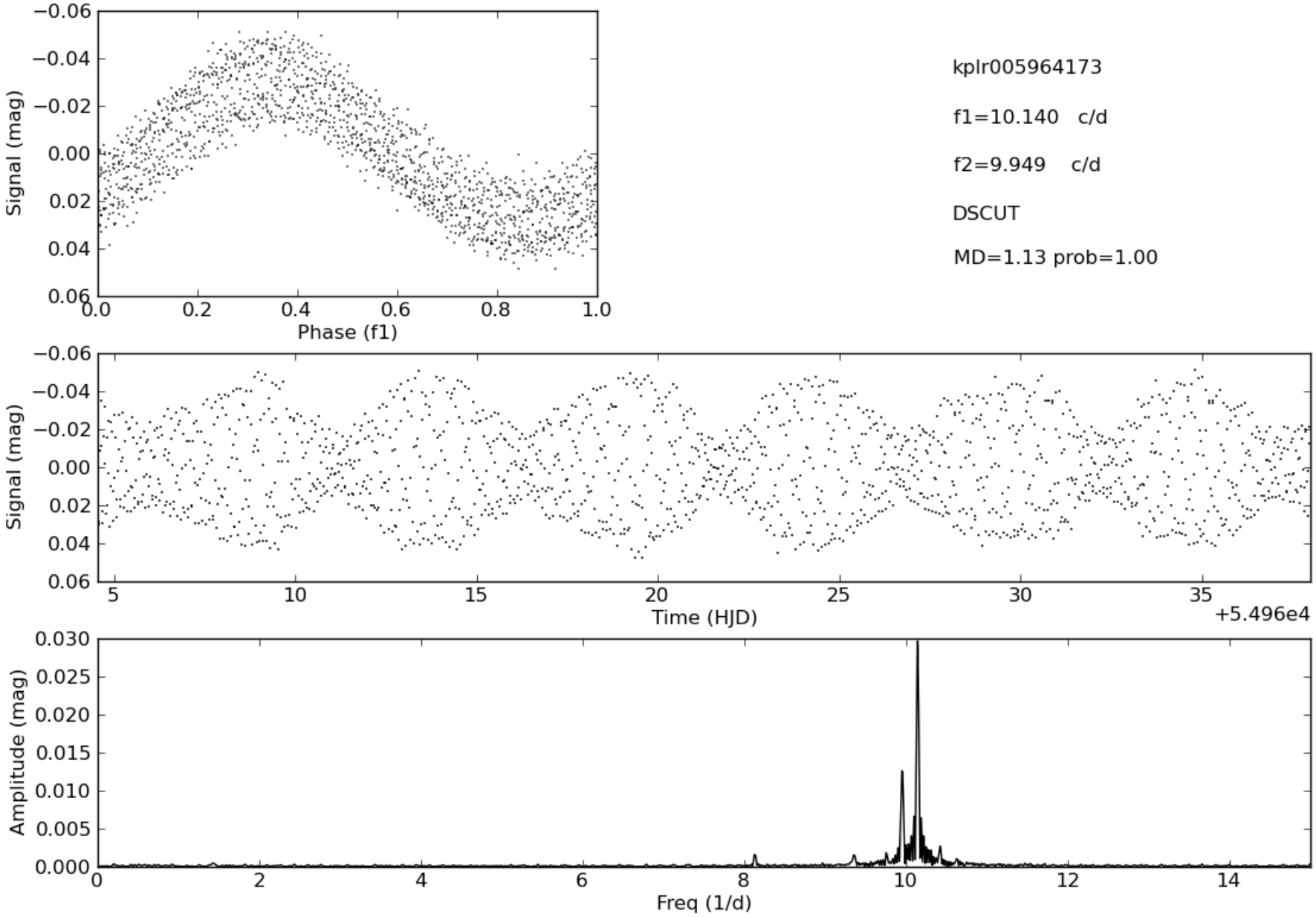
ROT

MD=1.42 prob=0.90

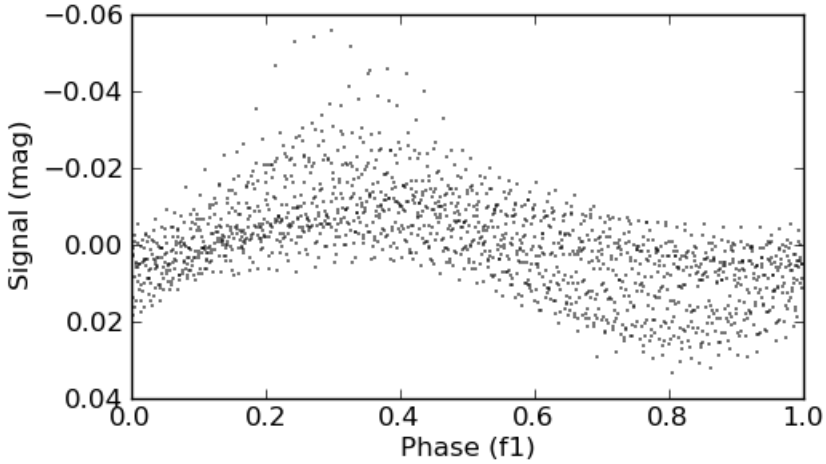




Voorbeeld van Delta Sct ster (Kepler)



Voorbeeld van Gamma Dor (Kepler)



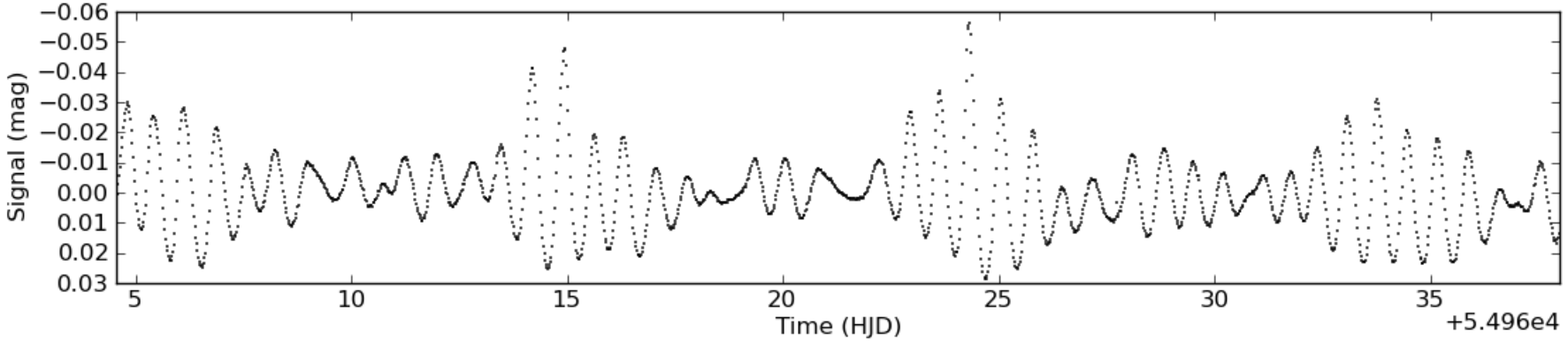
kplr002310284

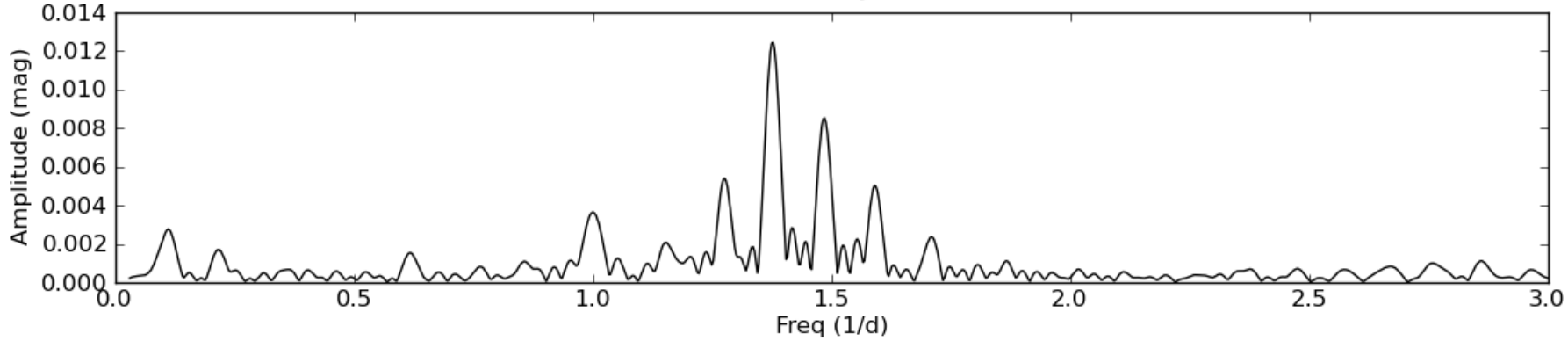
f1=1.377 c/d

f2=1.485 c/d

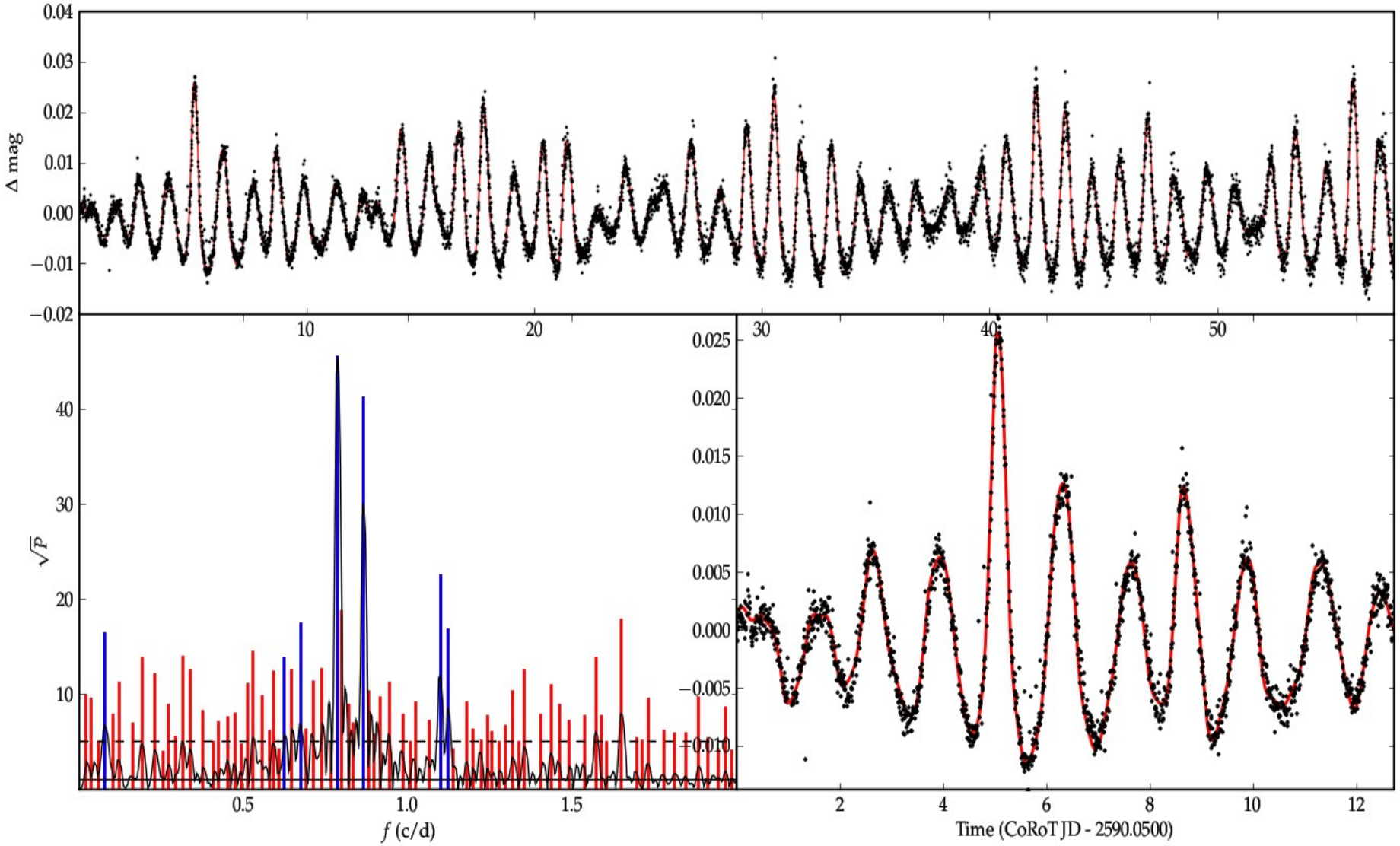
GDOR

MD=0.49 prob=1.00

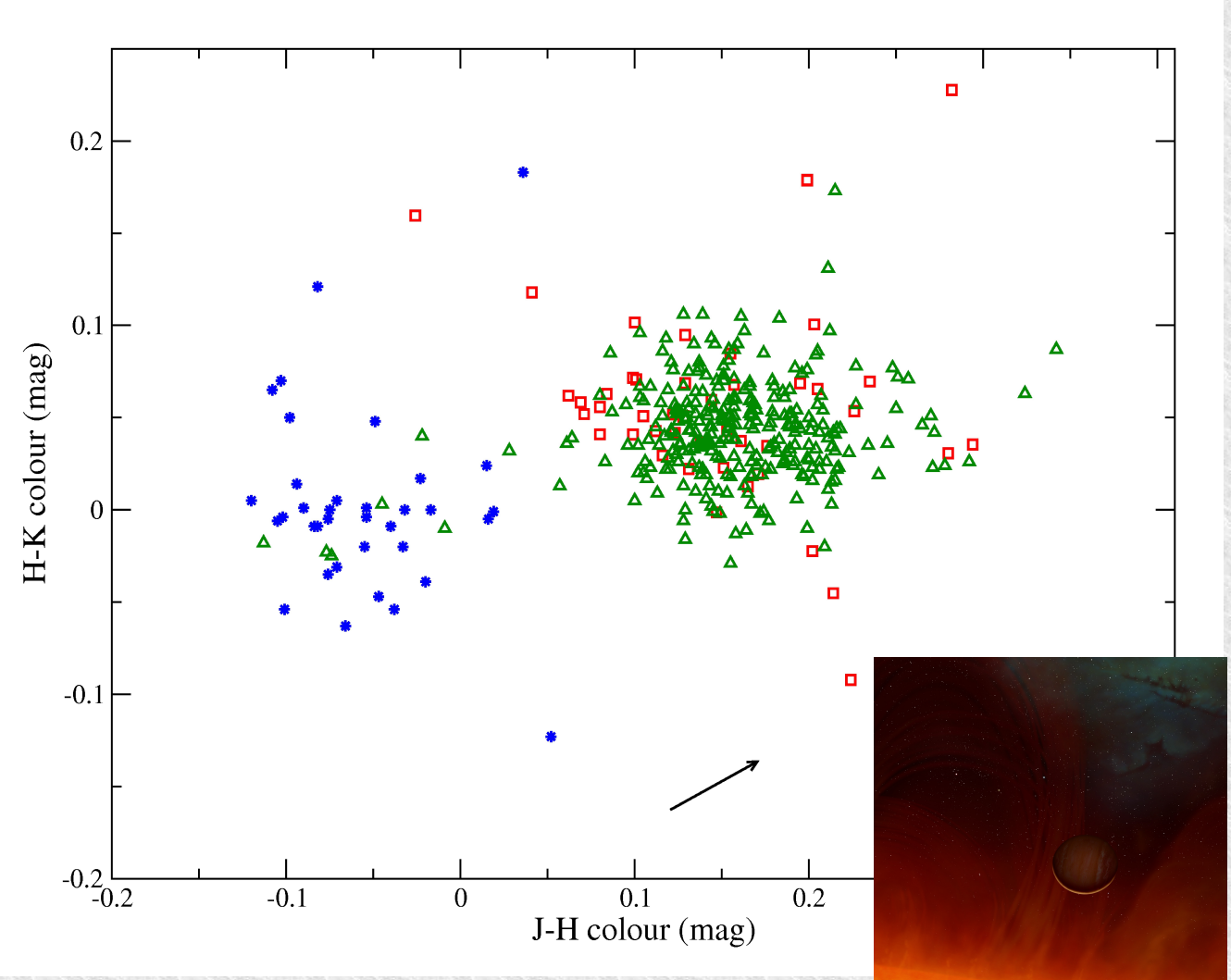




Frequentie Analyse Gamma Dor



F pulsatoren met g modi: timing...



Kepler F-type sterren:

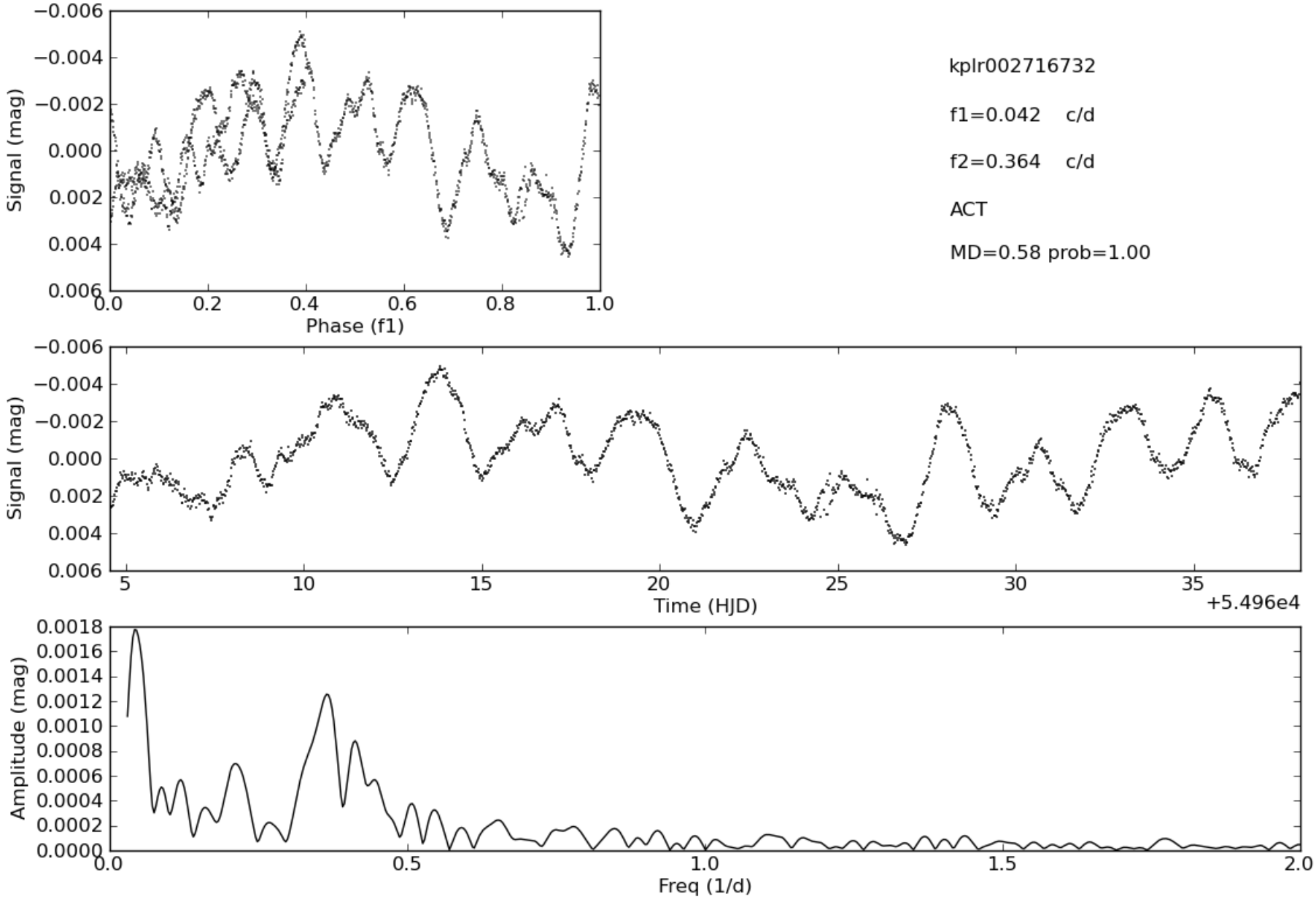
Hebben g modi

Hebben mss stochastische modi

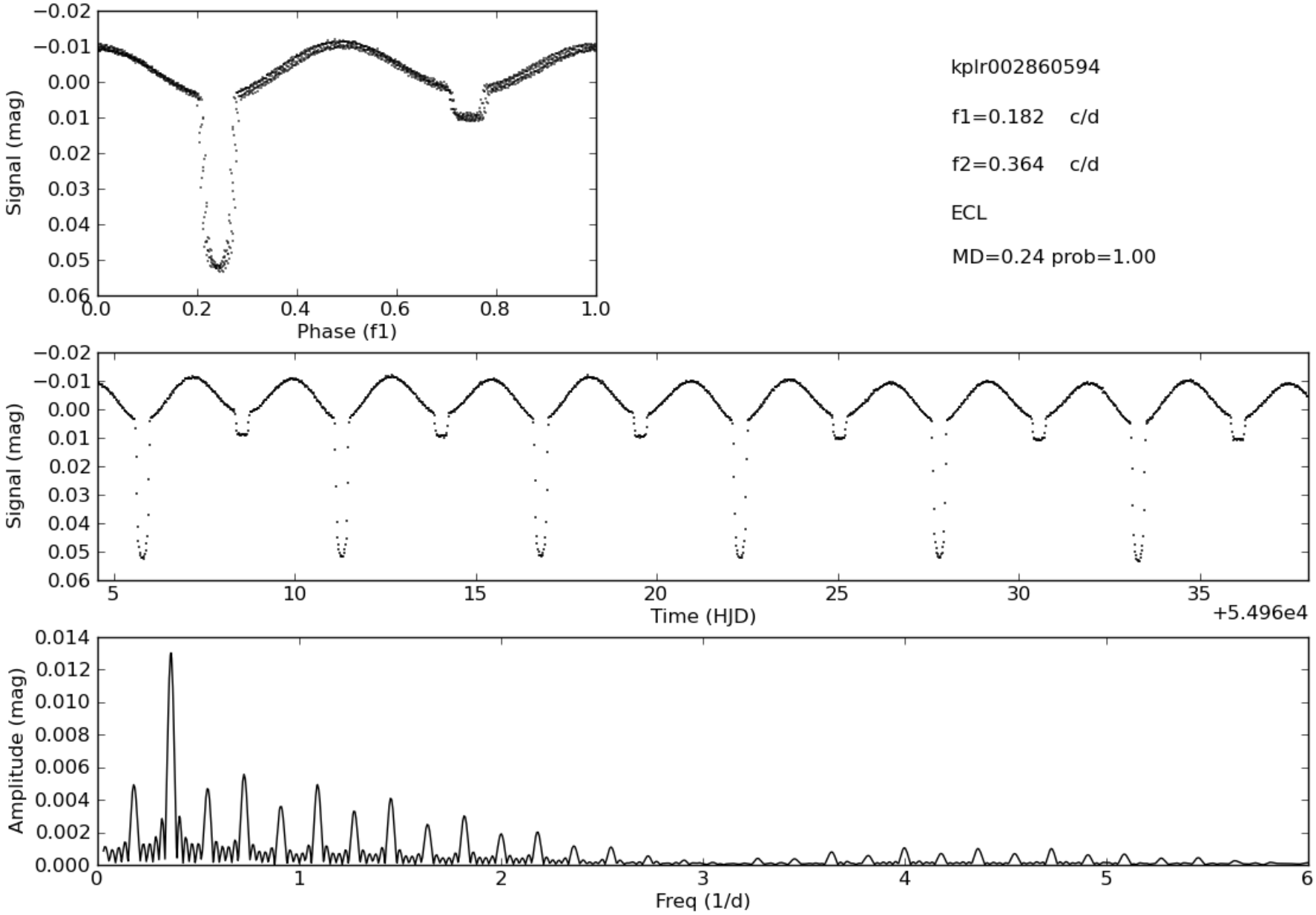
Hebben mss exoplaneten, tbd via timing

Debosscher et al. (2011)

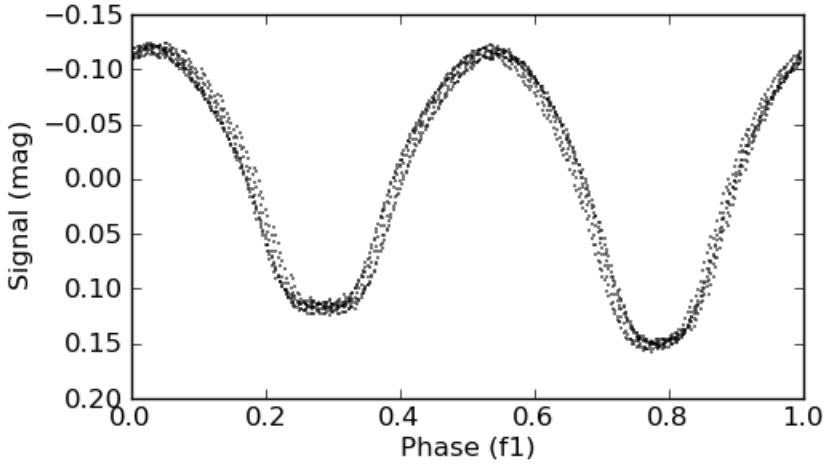
Voorbeeld van een actieve ster (Kepler)



Voorbeeld van EB met reflectie (Kepler)



Voorbeeld van ellipsoidale EB (Kepler)



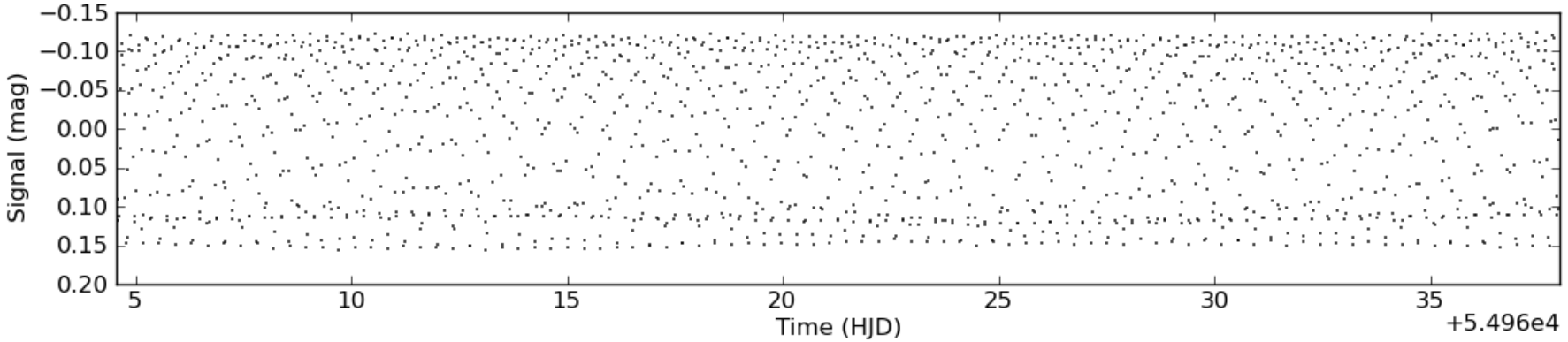
kplr004940226

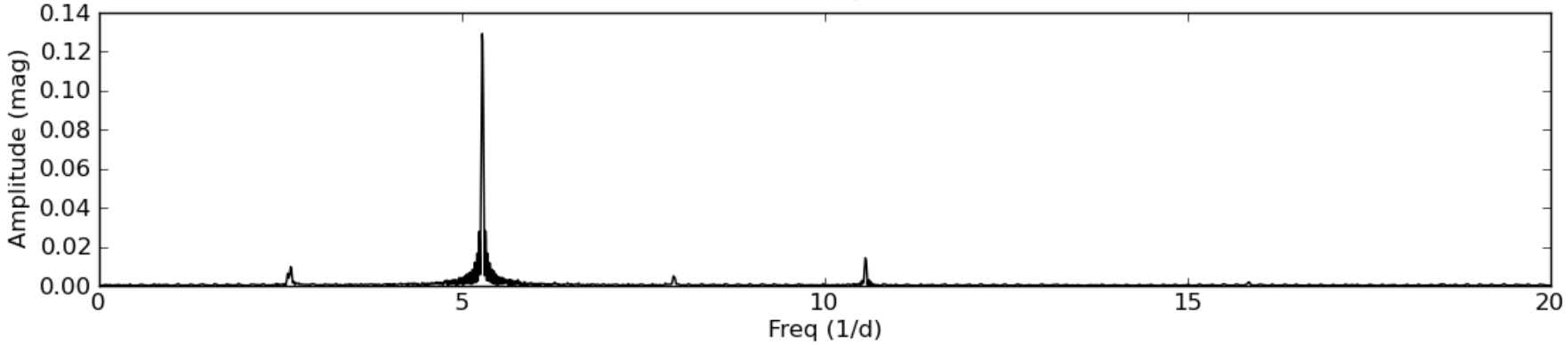
f1=2.641 c/d

f2=5.282 c/d

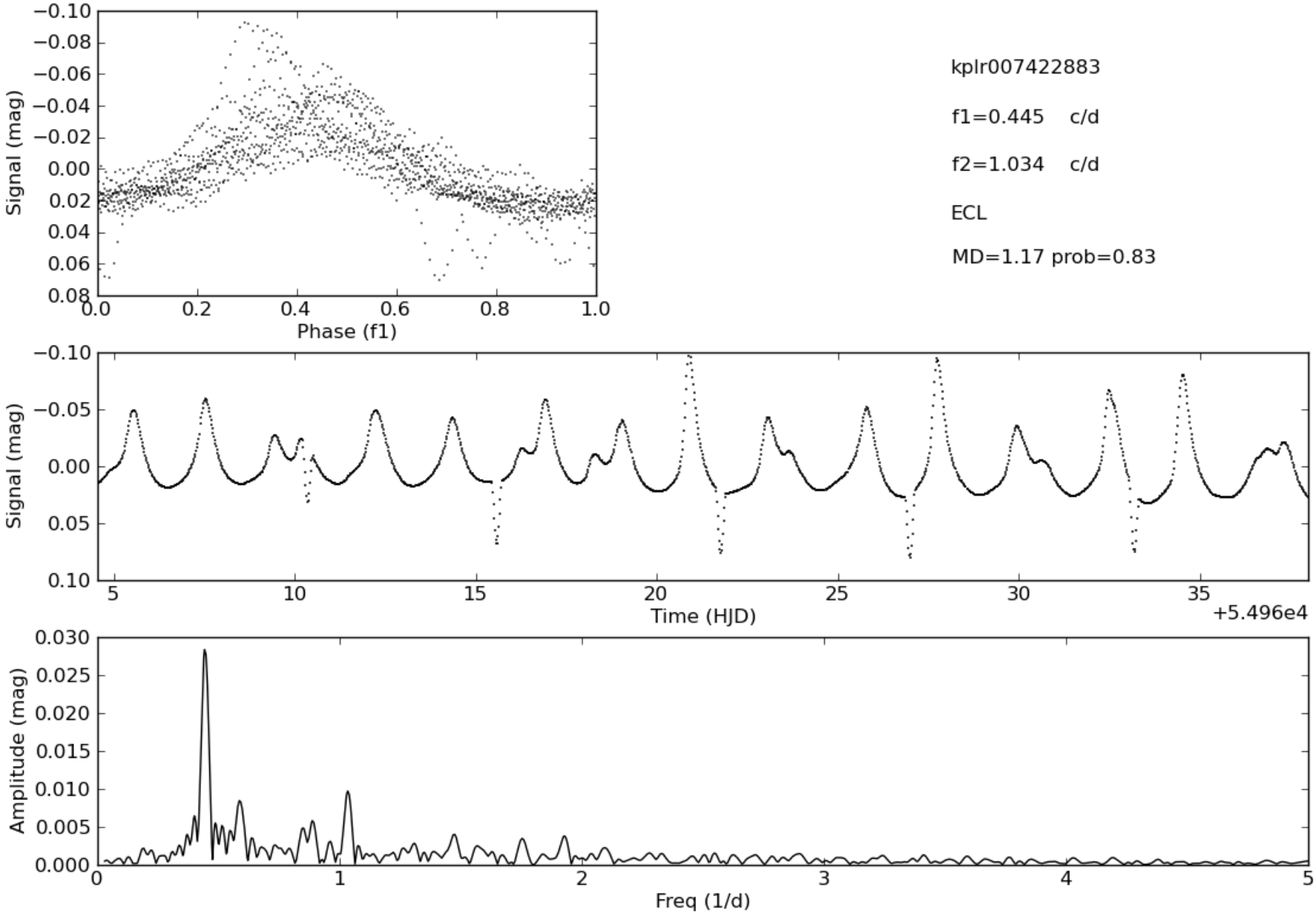
ECL

MD=0.35 prob=0.97

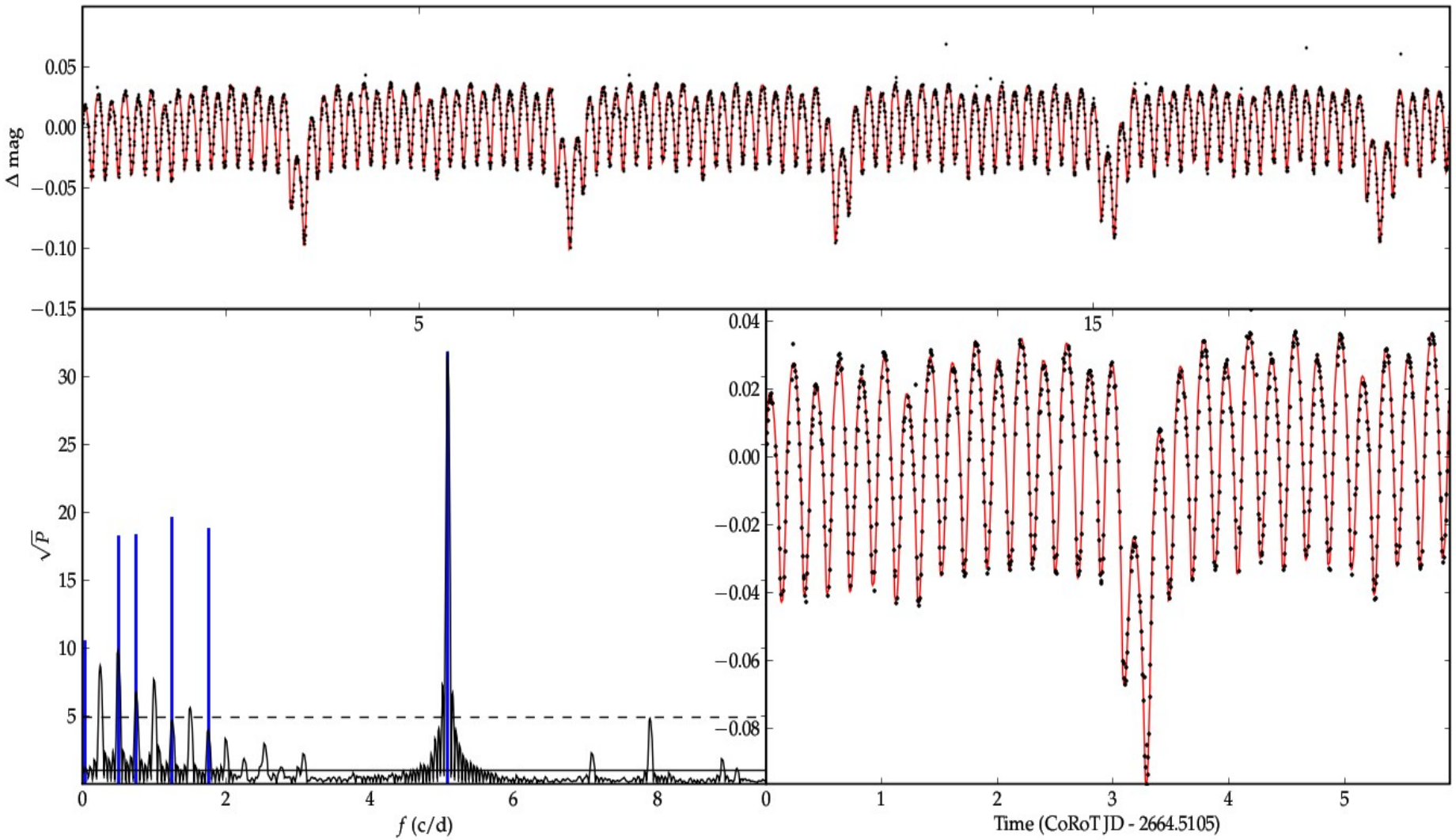




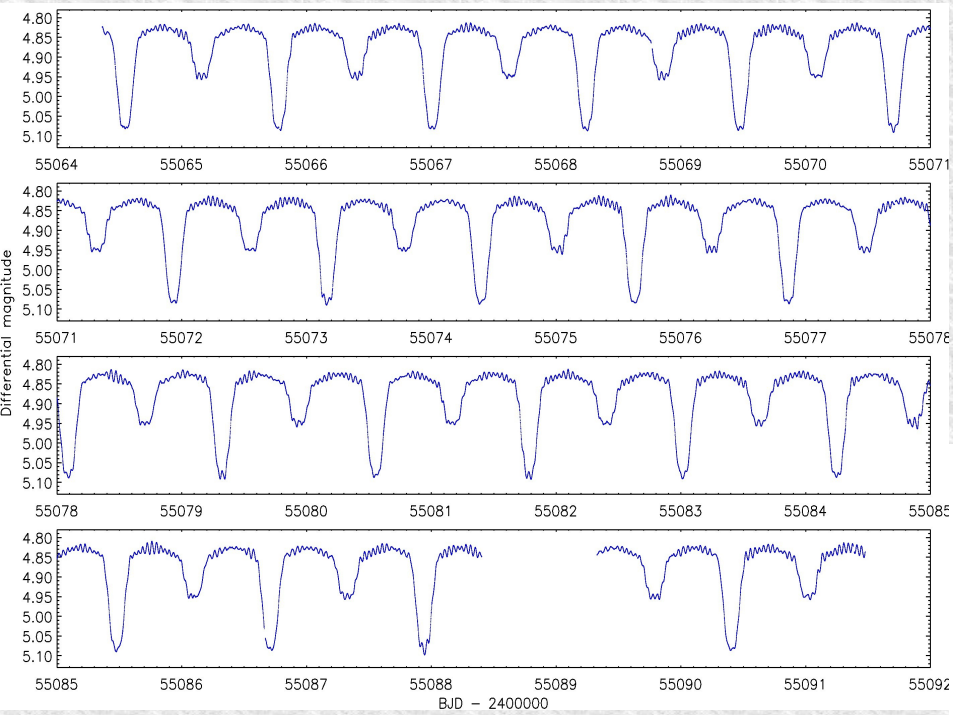
Voorbeeld van pulserende EB (Kepler)



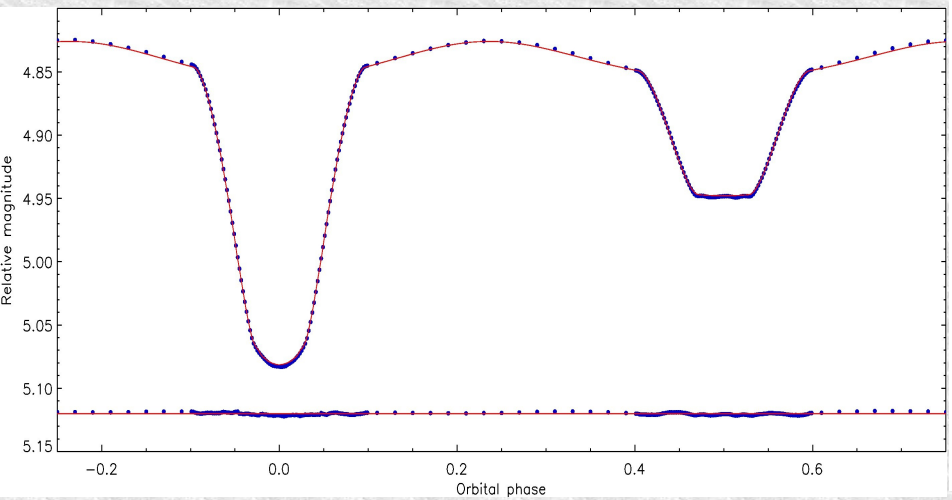
Frequentie analyse: pulserende EB

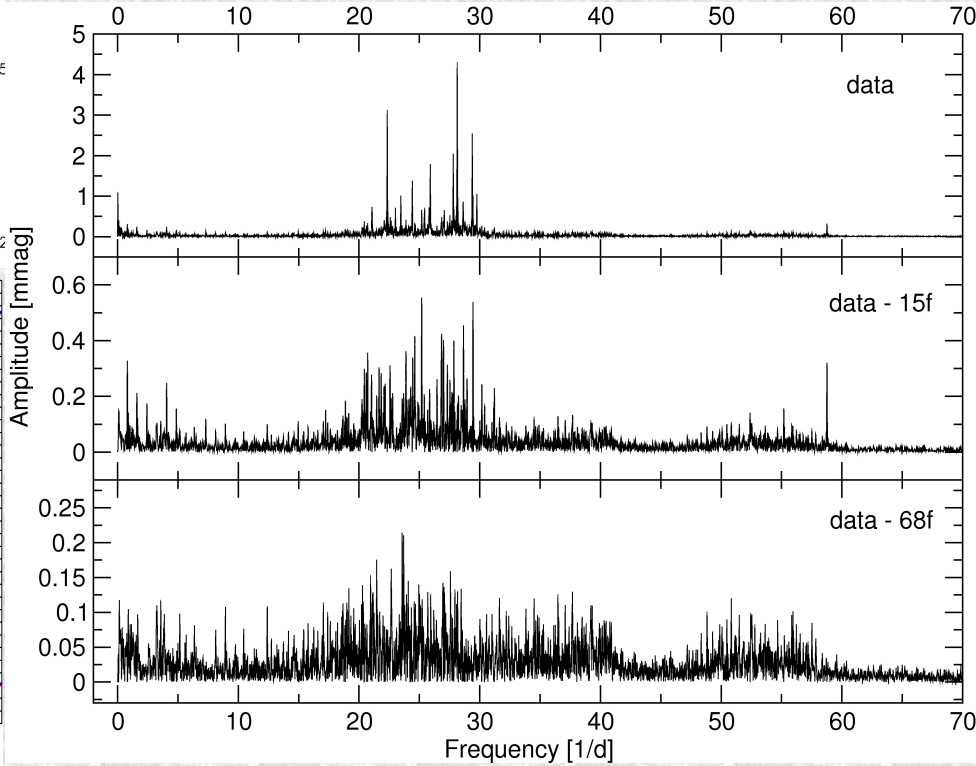


KIC10661783: totale EB Delta Sct



P=1.23d, circulair, i=82.8 deg
Teff=8000 K & 6000 K
massaverhouding = 0.063
Nood RV+betere freq.res.
(Southworth et al. 2011)





Spectaculaire EB: KOI-54, 2A sterren

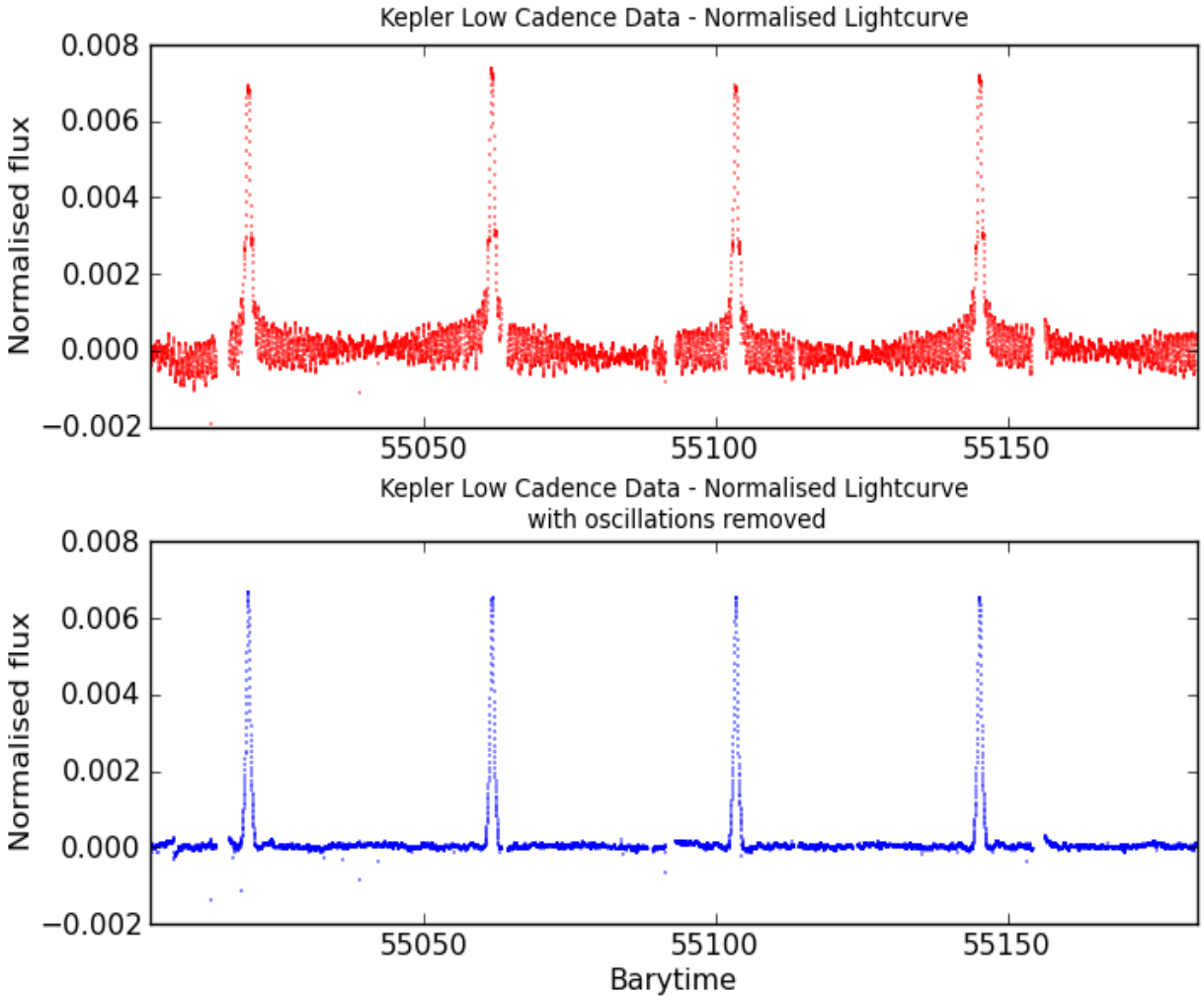
P=41.8d,e=0.83

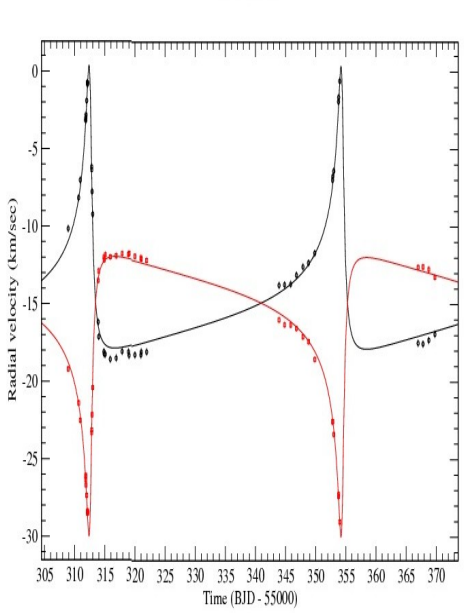
i=5.5 deg

Teff=8500K

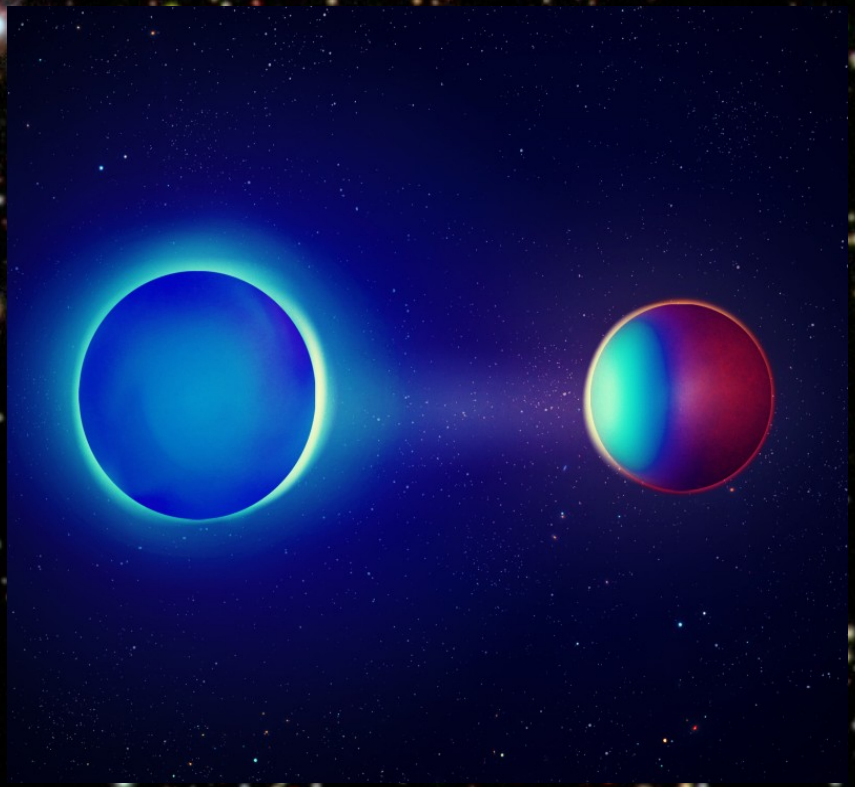
M=2.3&2.4

R=2.2&2.3





Kepler highlight: compacte (binaire) pulsatoren



Compacte Pulsator Survey

Nieuwe ontdekkingen (110 gezochte sterren)

1. Cataclysmische variabelen:

- **Nova like: 2**
- **AM CVn: 1 (Porb=938s, Prot=16.8u)**

2. Compacte dubbelsterren:

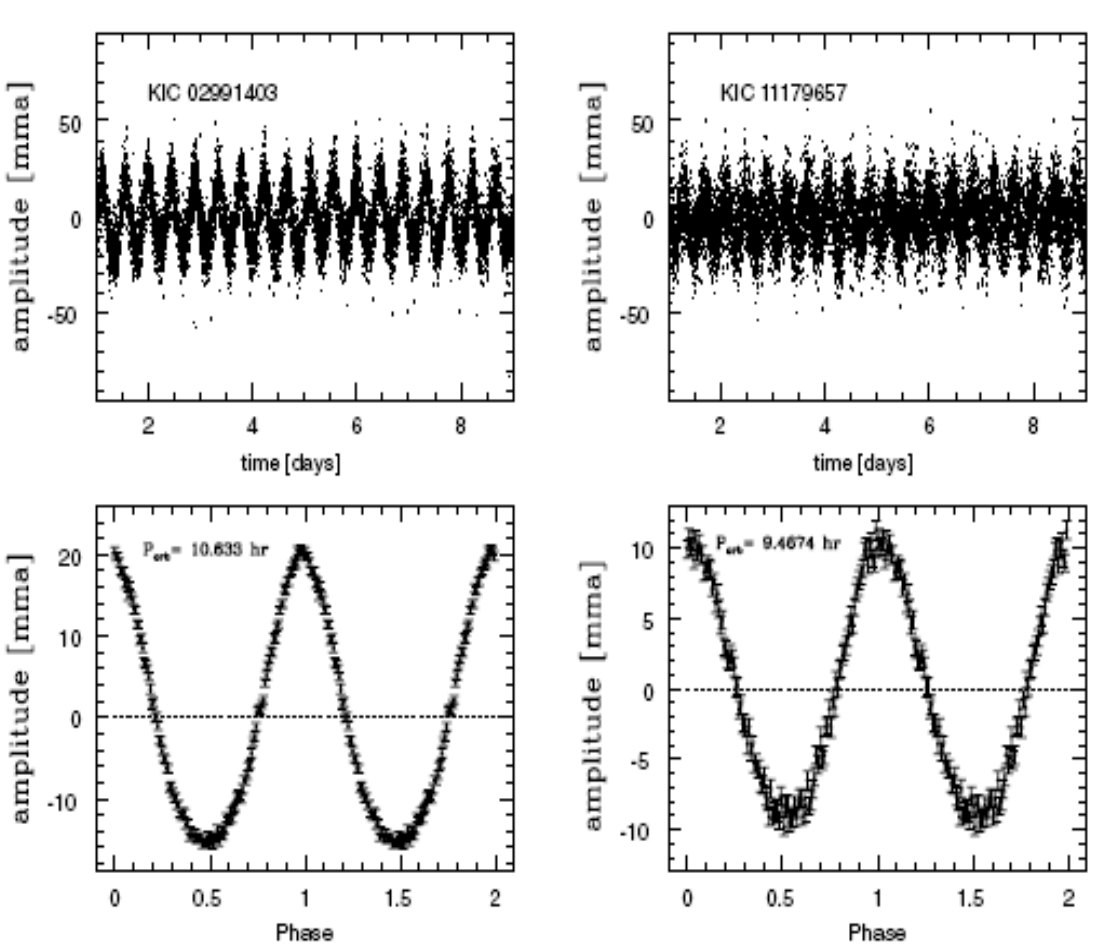
- **eclipserende sdB+DM: 1**
- **niet-eclipserende beaming sdB+DM: 2**
- **eclipserende pulserende sdB+DM: 1**
- **niet-eclipserende sdO+dM: 1**
- **pulserende sdO/B+ F/G/K secundaire: 10**

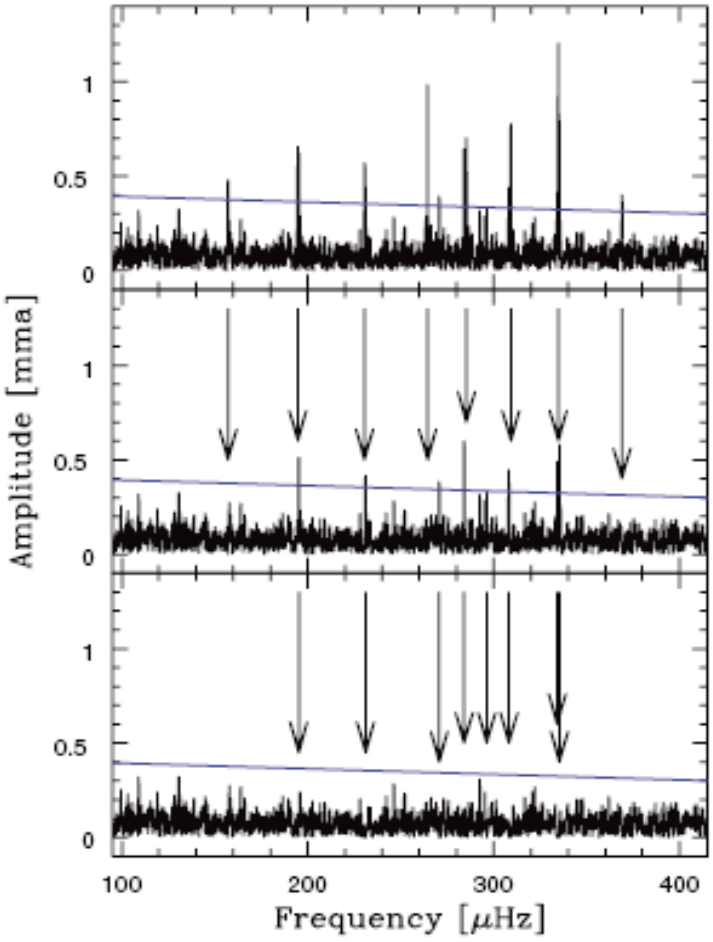
(Roy Østensen et al. 2010, 2011)

Enkele binaire sdB + DM

Graviteitsmodi in compacte dubbelsterren

Kawaler et al. (2010)



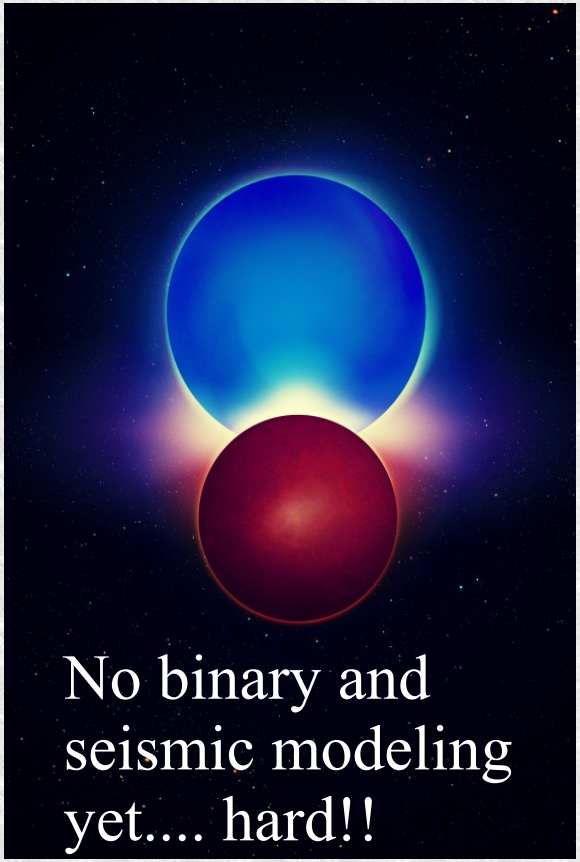


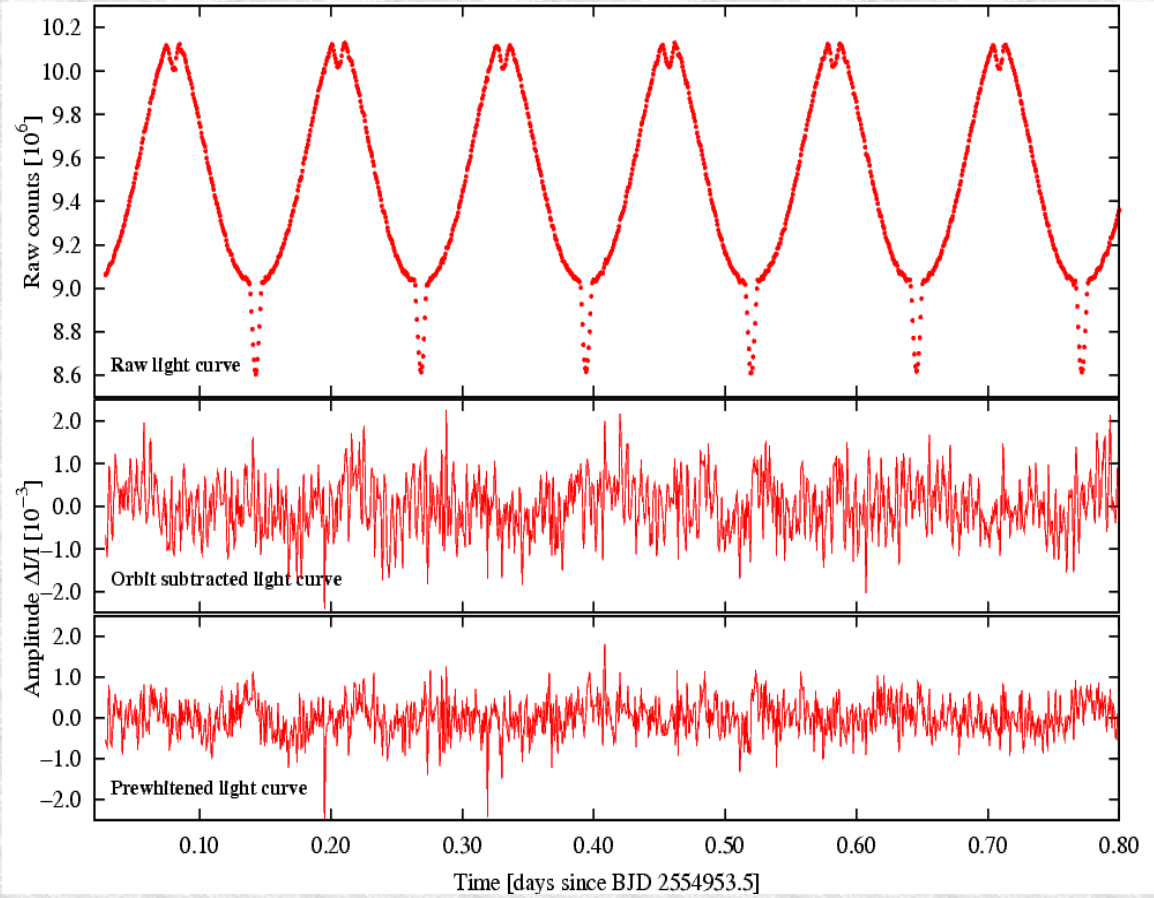
Hybride subdwerg B pulsator EB

Meer dan 50 druk en graviteitsmodi, NRP

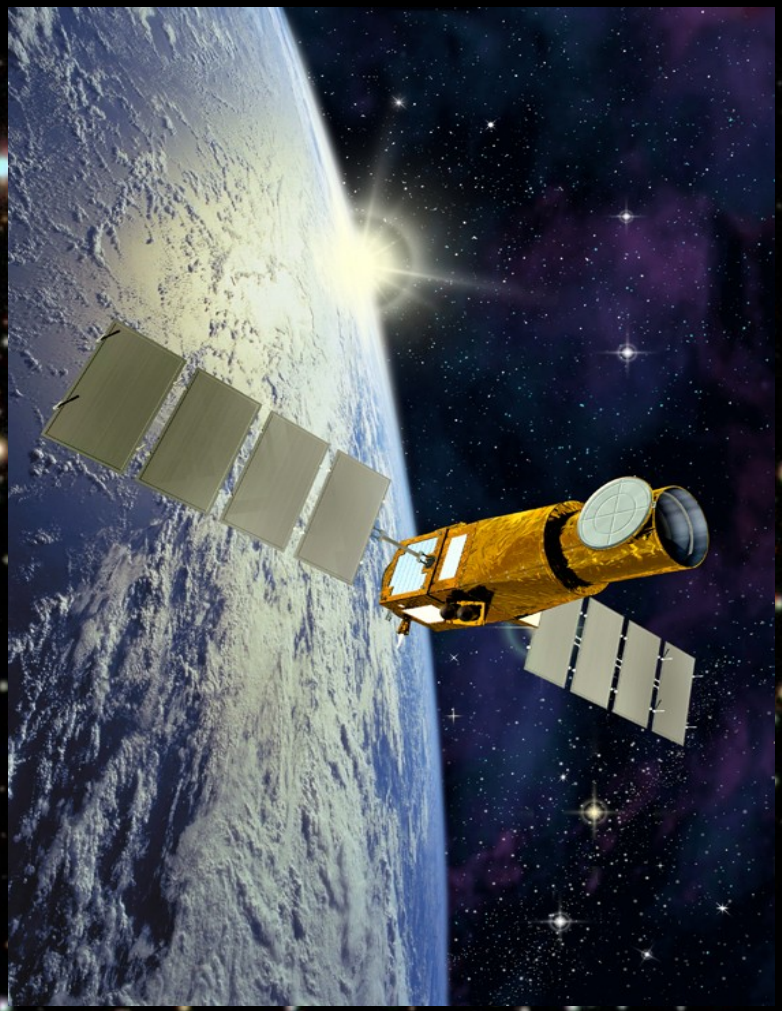
Fysica van NRP bij extreme irradiatie?

Porb = 0.125765300(21)d, (Østensen et al. 2010)

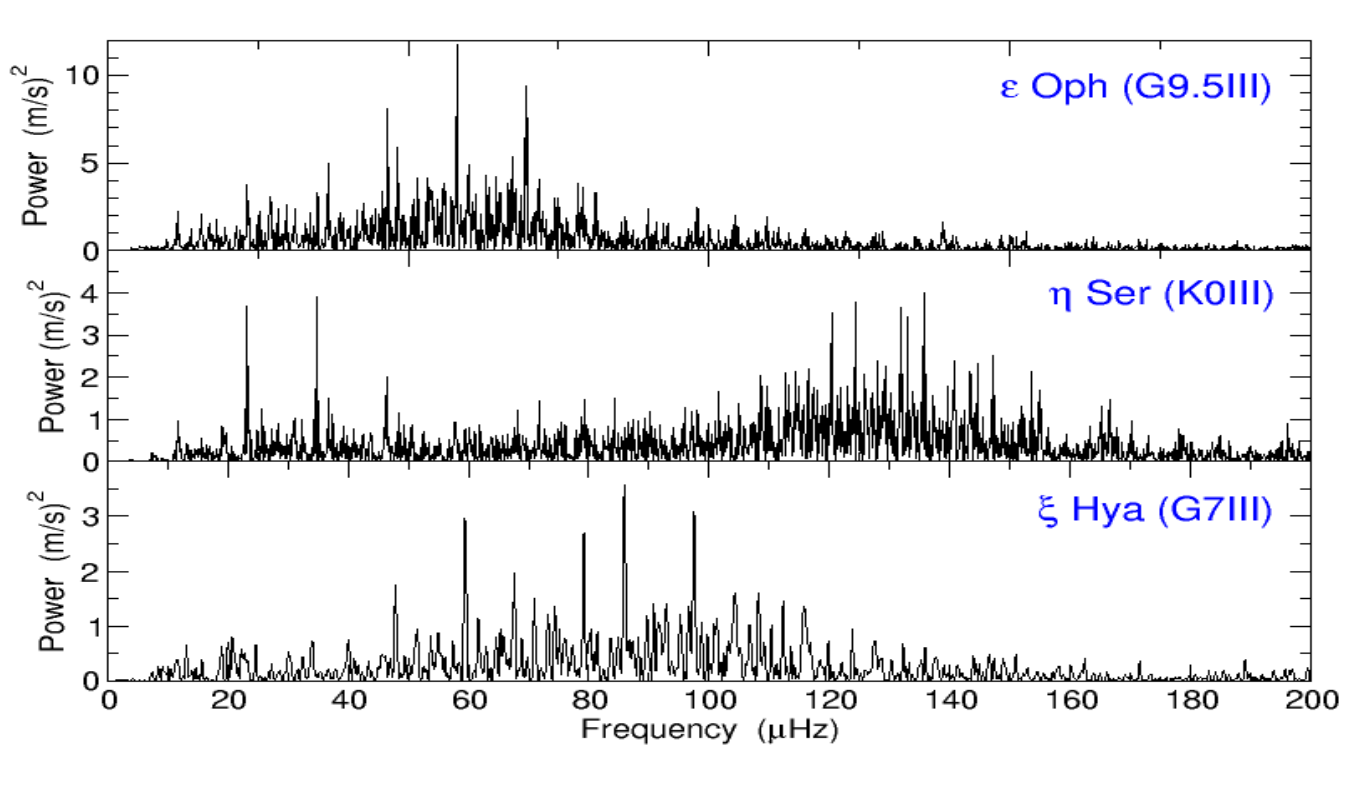


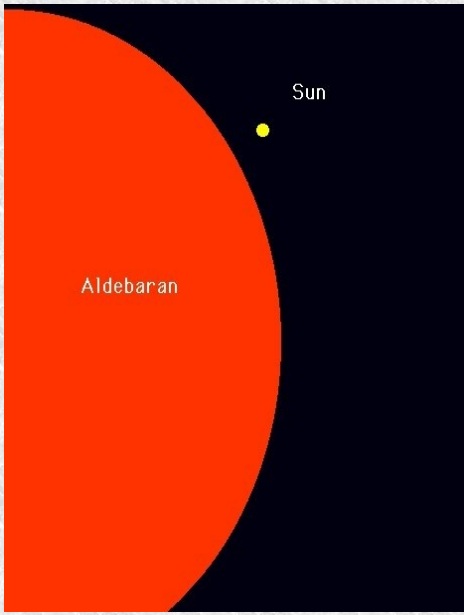


Red-Giant Asteroseismology : van sterren tot populaties



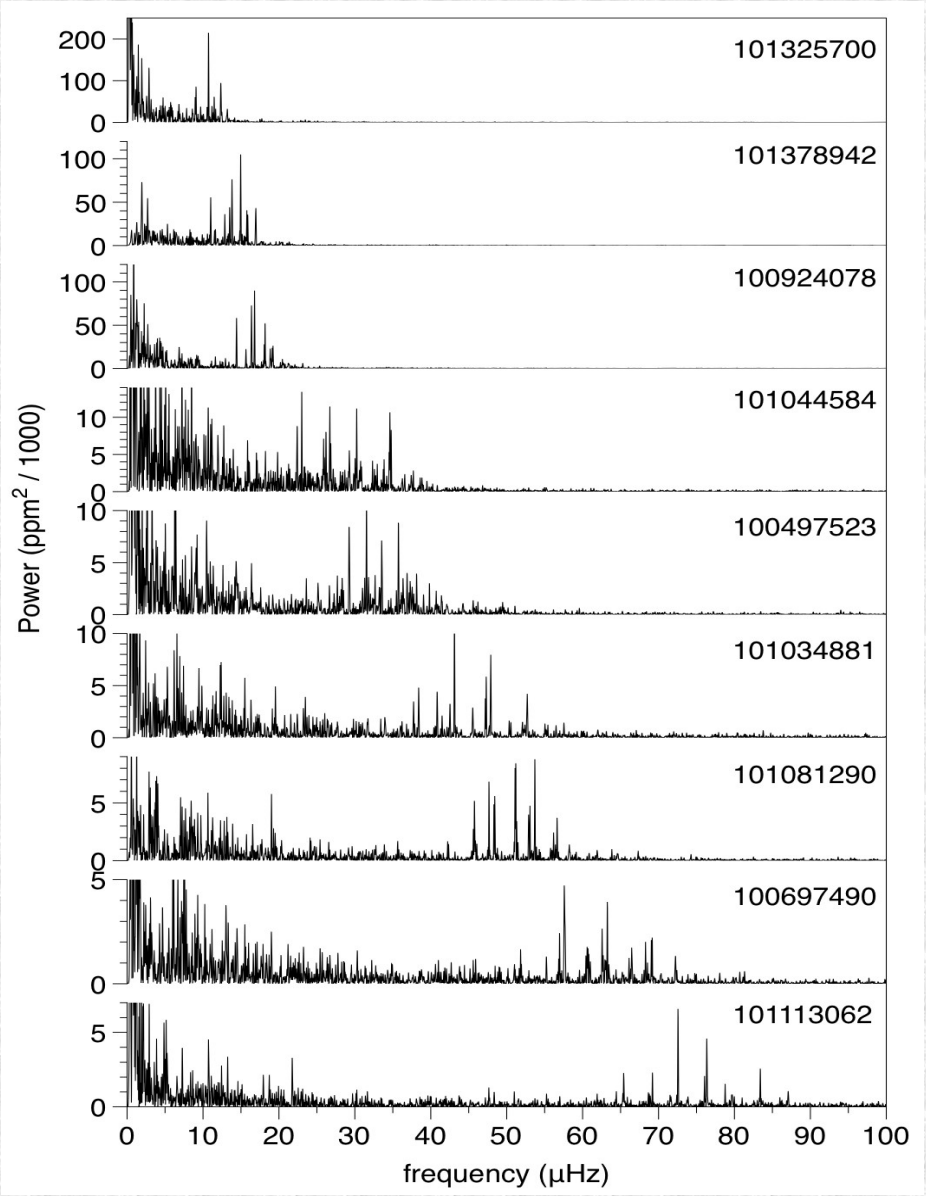
Ontdekking van RR oscillations





Uitvoerige ground-based RV campagnes: Frandsen et al. (2002); De Ridder et al. (2006); Hekker et al. (2006): enkel radiale modi of ook NRP?

CoRoT resultaten RR



De Ridder et al. (2009, Nature):

Waarnemingen in CoRoT sismo en exo CCDs

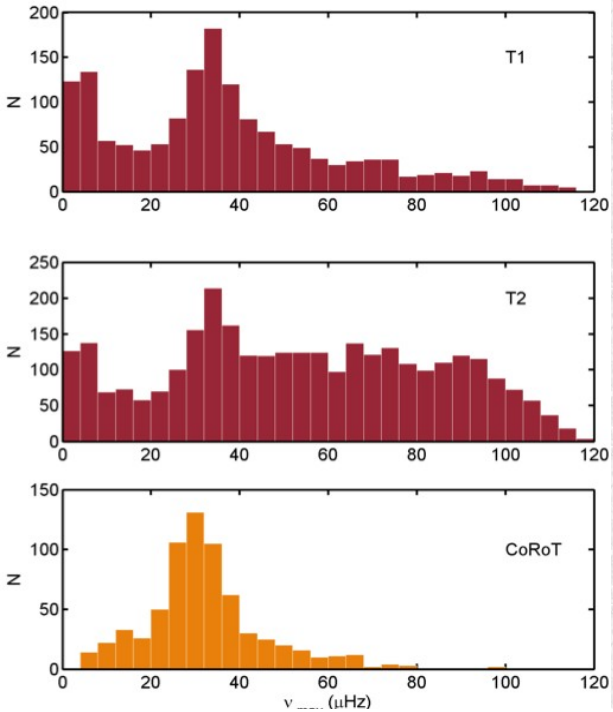
Vele RG pulsatoren gevonden in exo data

Niet-radiale pulsaties!!

Modi met zowel korte als lange duurtijd: van enkele tot tientallen dagen

Heeft asteroseismologie van RR mogelijk gemaakt

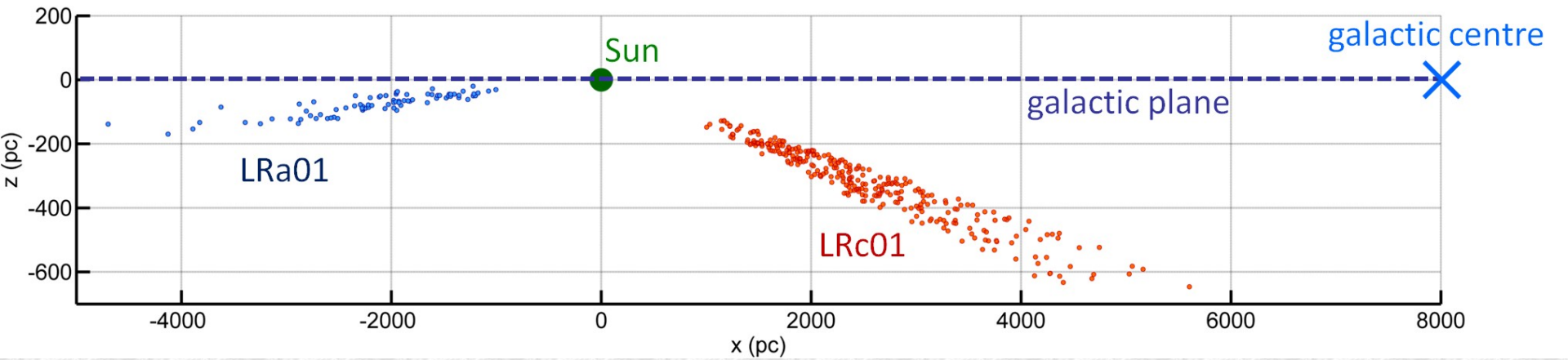
CoRoT: RG populatie seismologie



Miglio et al. (2009): populatiesynthese gecombineerd met asteroseismologie in grote steekproef

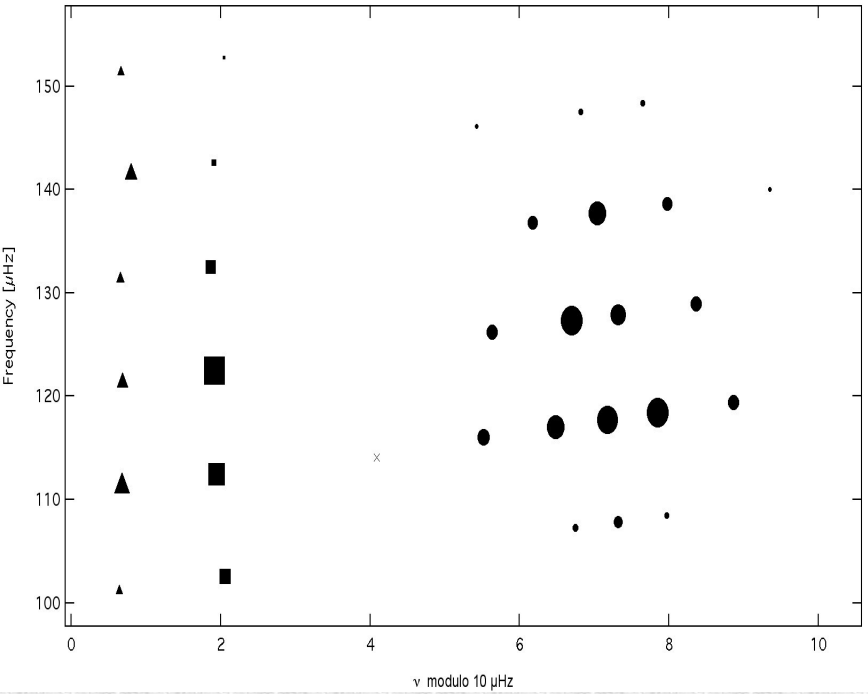
recente starburst in Melkweg of niet?

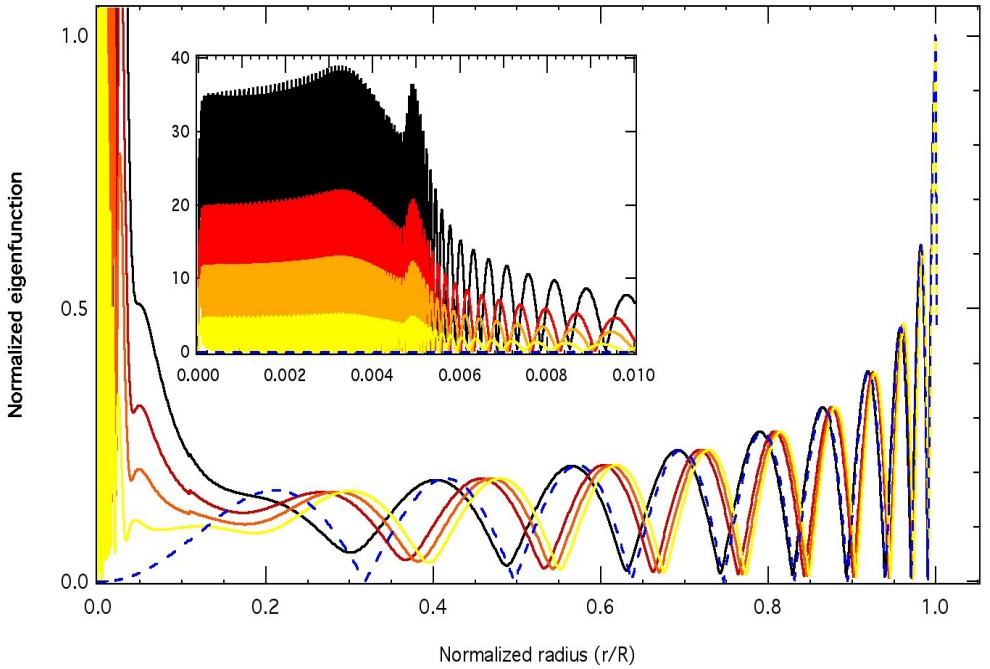
Astero niet langer beperkt tot individuele sterren, maar gehele populaties: toetsing van de structuur en evolutie van de Melkweg!



Kepler resultaten van een RR

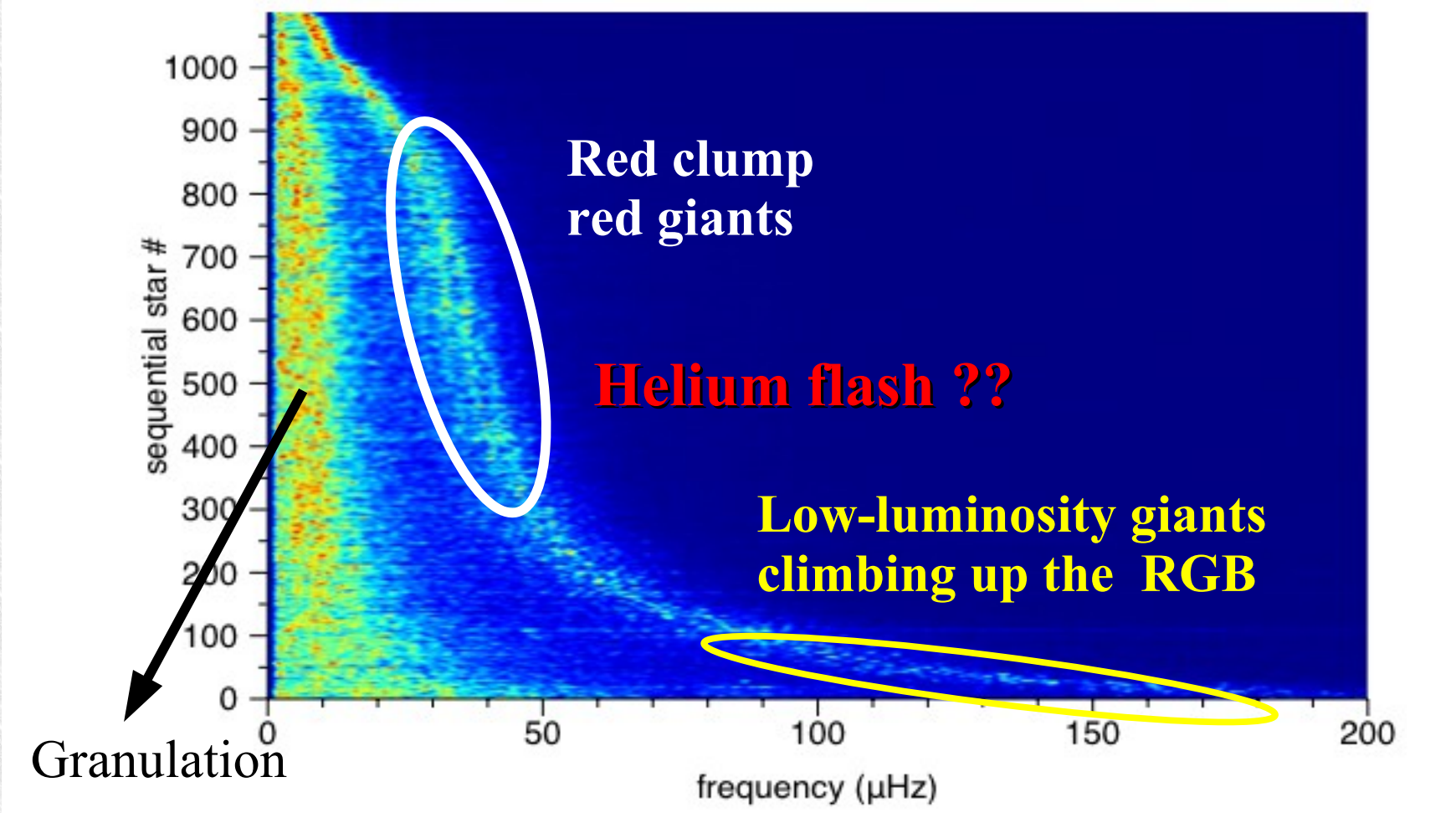
Ontdekking van mixed modes met periode spatieringen : directe toetsing van de kern !!





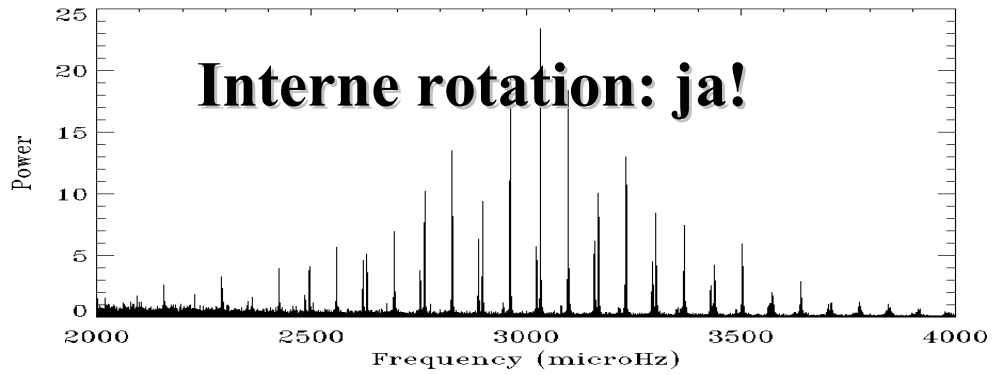
Beck et al., 2011, Science + APOD 8/4/2011

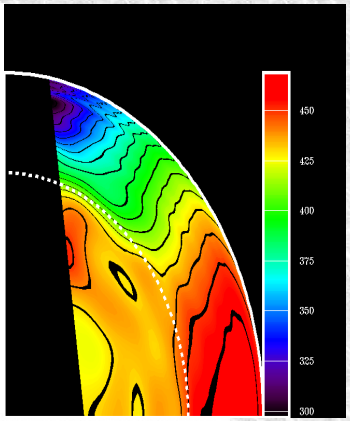
Ensemble astero RG: evolutietoetsing!



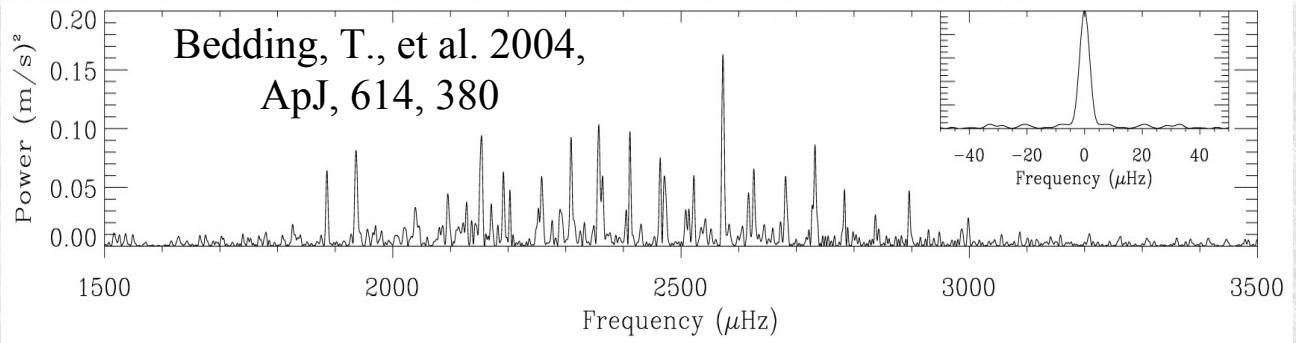
Bedding et al. (2010), Hekker et al. (2010), Huber et al. (2010), Kallinger et al. (2010), Bedding et al. (2011, Nature)

Kepler RG asteroseismology

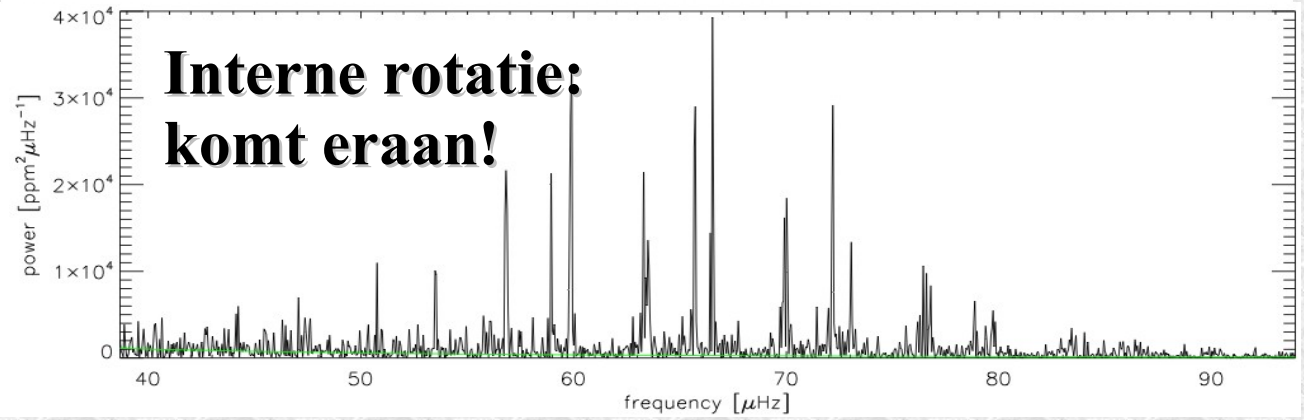




Sun as star (SoHO)



α Cen A+B bisite RV VLT + AAT



Kepler RG Q0-Q7

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LEUVEN

Ultieme doel: statistische hoge-precisie afleiding van de randen van de instabiliteitsstroken van pulsatoren: gevoelig voor opaciteiten, convectieve bewegingen, chemische vermenging, rotationele bewegingen,...

Nu is een goed moment om een stap te wagen in de wereld van