PiTP

Lectures on Quantum Phenomena

How science is <u>really</u> done

A tale of duels, harems, heroines, and a cold case of murder

Jaymie Matthews

UBC Physics & Astronomy

Wednesday, 10 March 7:30 pm

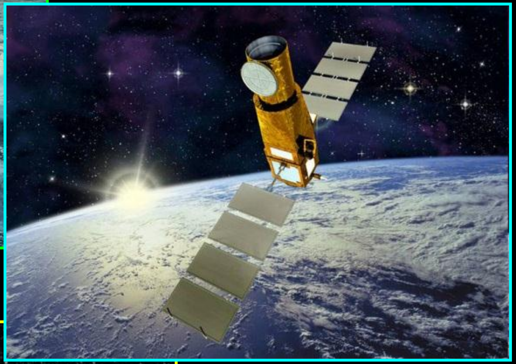
Fairmont Lounge, St. John's College

Textbooks tend to depict the pioneering scientists of history as scientific saints, known only for their contributions to knowledge, but rarely as colourful human beings – sometimes heroic, sometimes flawed, sometimes both. Who knew there were astronomers whose life stories could make Hollywood screenplays. What's the connection between alchemy, astro-dynamics and murder? Find out at this talk, when PiTP meets CSI, and traditional physics meets tabloid paparazzi.

Other planetary systems

Space missions

Three space telescopes have expanded the search and the study of exoplanets



MOST

www.astro.ubc.ca/MOST

CoRoT

smsc.cnes.fr/COROT/GP_actualite.htm

Kepler

kepler.nasa.gov

MOST at a glance

Satellite

- ✓ 54 kg, 60×60×30 cm
- ✓ Power: solar panels
  - ✓ peak ~ 38 W
- ✓ Communication: radio
  - ✓ power of a cell phone
- ✓ Attitude Control System:
  - ✓ pioneering technology
  - ✓ pointing 4000× better
- ✓ Lifetime: 7 – 11 years +?

CONTRACTORS: Dynacon Inc.
U of T Institute for Aerospace Studies

MOST at a glance

Instrument

- ✓ Maksutov telescope
  - aperture = 15 cm
  - field of view = 2° diameter
- ✓ single broadband filter
  - $380 \leq \lambda \leq 750$ nm
- ✓ twin E2V 47-20 CCDs
  - Science and Startracker
  - Fabry microlenses produce pupil images of Primary Star and sky backgrounds

University of British Columbia
CRESTech, Spectral Applied Research

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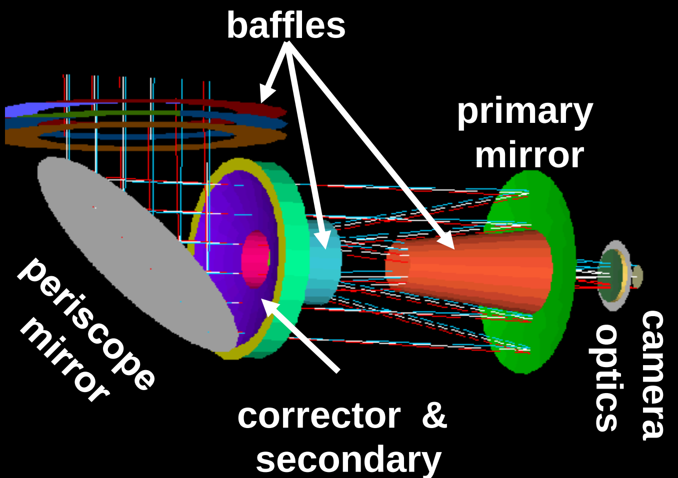
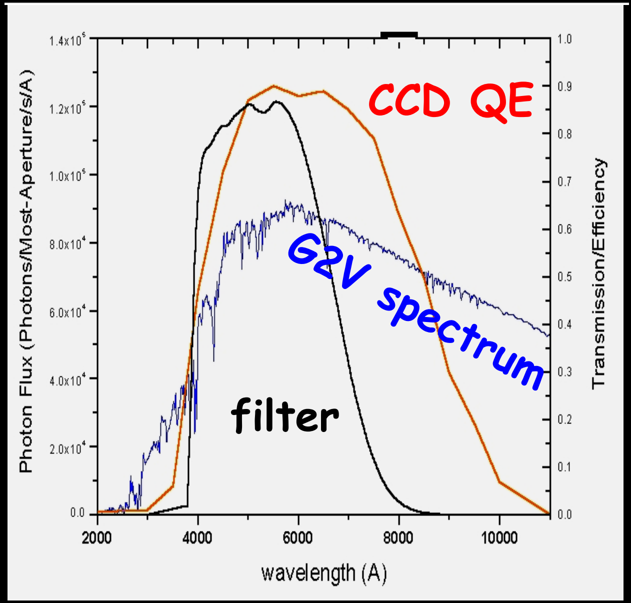
Ceravolo Optical Systems (Ottawa)
Custom Scientific (Phoenix)





MOST at a glance

Instrument

- ✓ ultraprecise photometer
  which can see oscillations
  in starlight as small as
  1 part per million (0.0001%)

University of British Columbia
CRESTech, Spectral Applied Research
Ceravolo Optical Systems

MOST at a glance

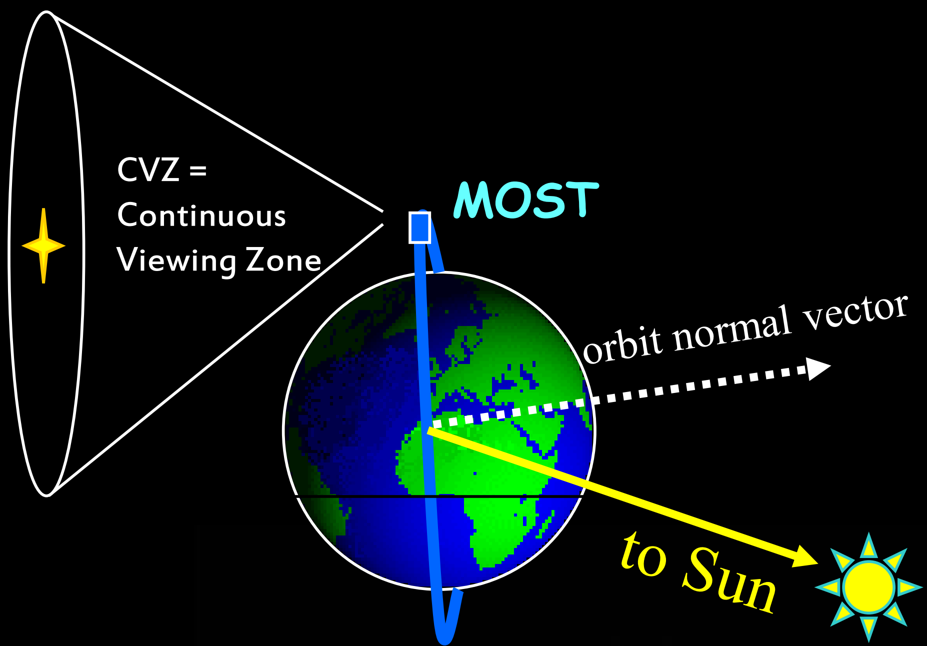
Orbit

- ✓ circular polar orbit
  - altitude *h = 820 km*
  - period *P = 101 min*
  - inclination *i = 98.6º*
- ✓ Sun-synchronous
  - *stays over terminator*
- ✓ Continuous Viewing Zone

CVZ ~ 54° wide

$-18^{\circ} < \delta < +36^{\circ}$

stars visible for up to 8 weeks without interruption

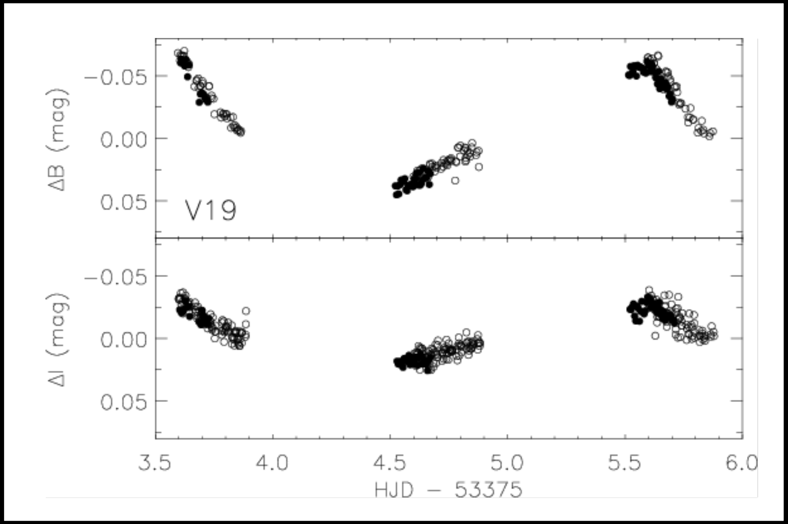


Sun-synchronous, dawn-dusk orbit

Value of continuous time coverage

Why go to all this bother?

Arentoft et al. 2007, A&A, 465,965



From the ground

Value of continuous time coverage

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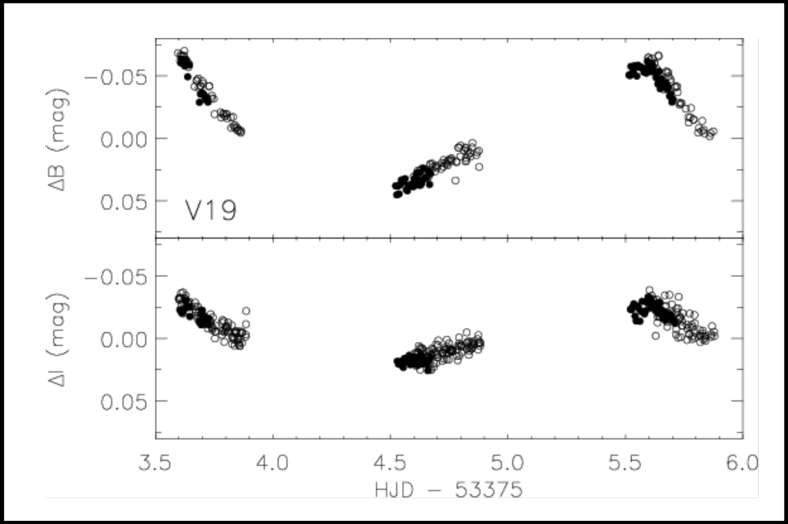
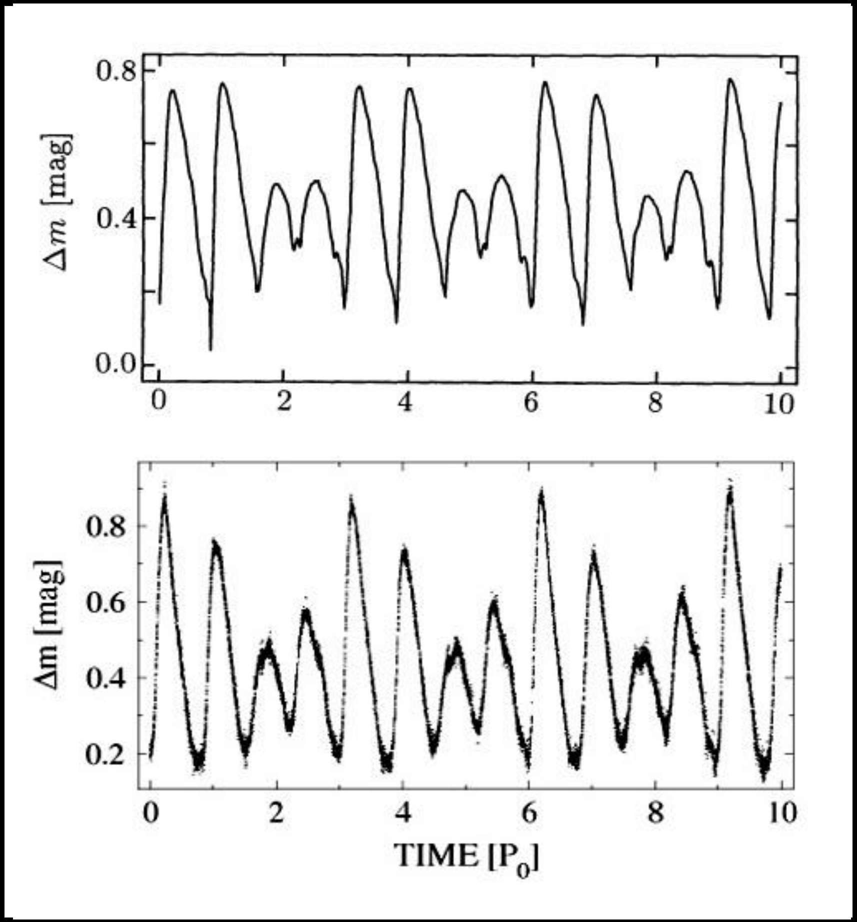




From the ground

SPOT THE SUPERCOMPUTER SIMULATION!

Gruberbauer et al. 2007, MNRAS

Value of continuous time coverage

Fourier transform of a time series

Discrete Fourier Transform (DFT)

$$F_N(\nu) = \sum_{i=1}^{N} f(t_i) e^{i2\pi\nu t_i}$$

Value of continuous time coverage

Fourier transform of a time series

Discrete Fourier Transform (DFT)

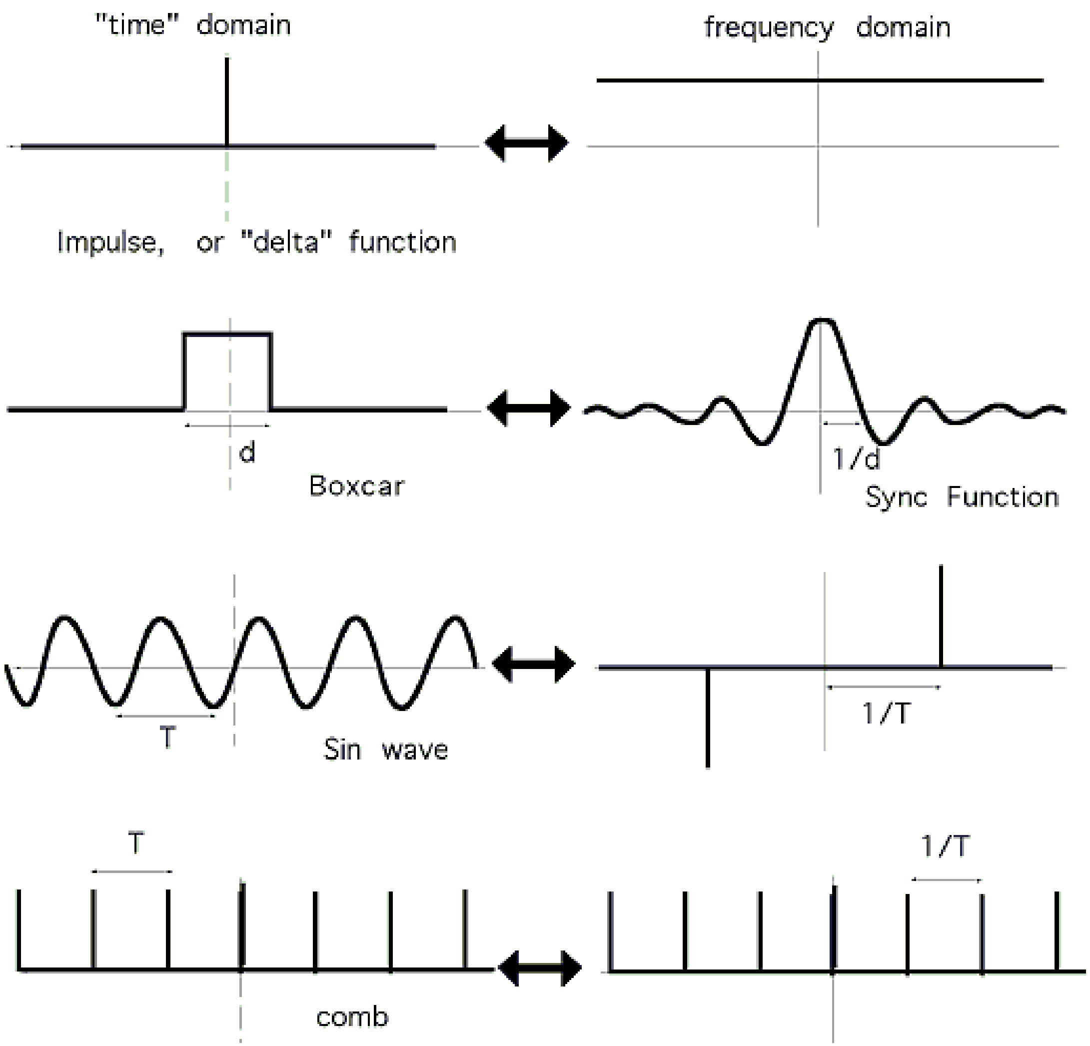
$$F_N(\nu) = \sum_{i=1}^{N} f(t_i) e^{\,i2\pi\nu t_i}$$

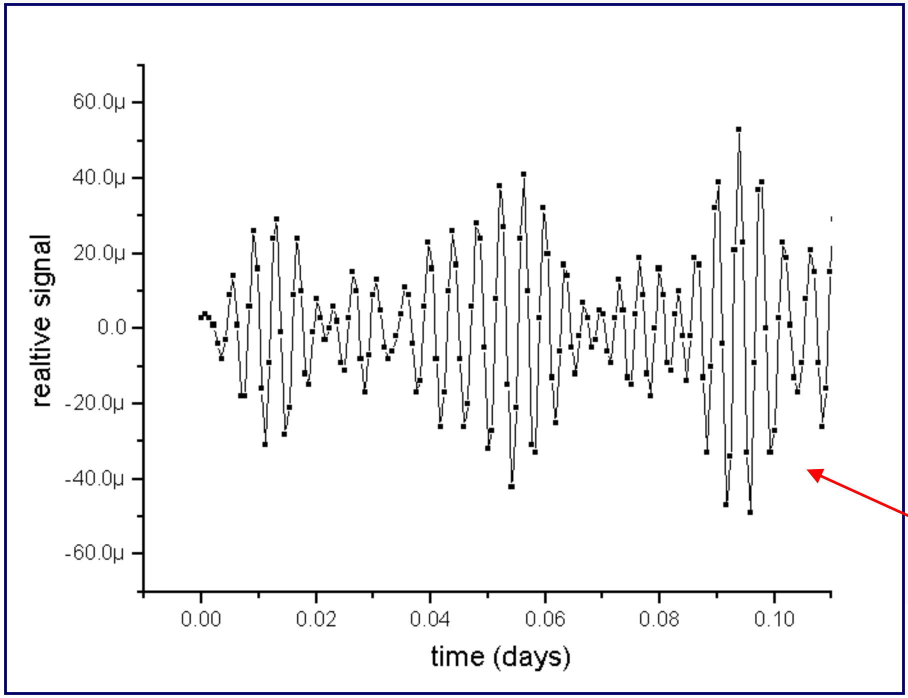
Periodogram – estimate of Fourier transform

$$P_N = \frac{2}{N}\left[\left(\sum_{i=1}^{N} f(t_i) cos(2\pi\nu t_i)\right)^2 + \left(\sum_{i=1}^{N} f(t_i) sin(2\pi\nu t_i)\right)^2\right]$$

Value of continuous time coverage

Fourier transform of a time series

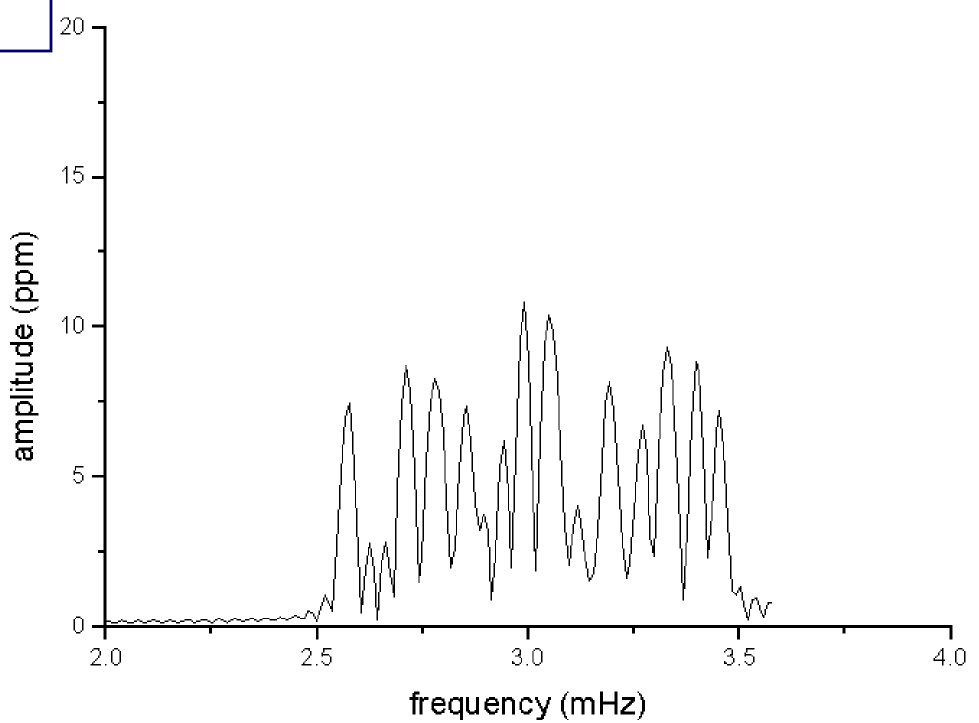


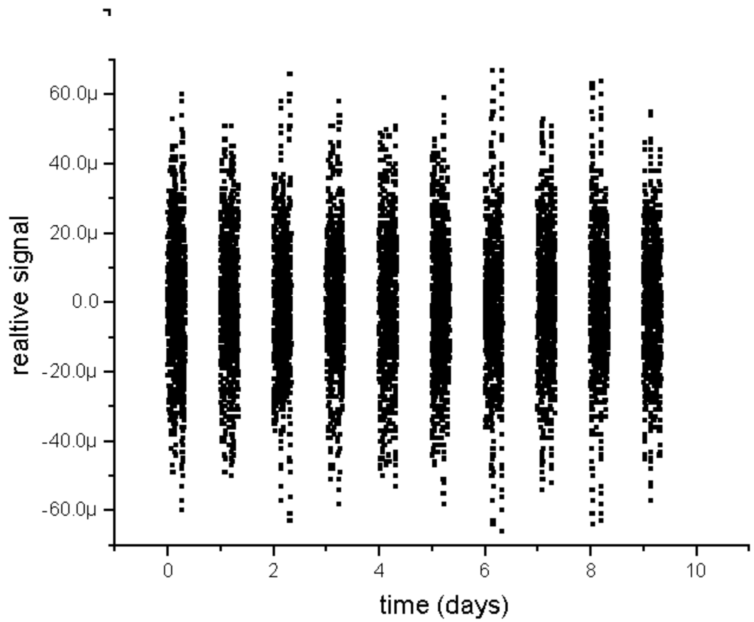


- 8 hrs of data
- no noise

expanded view of 3 hrs of data

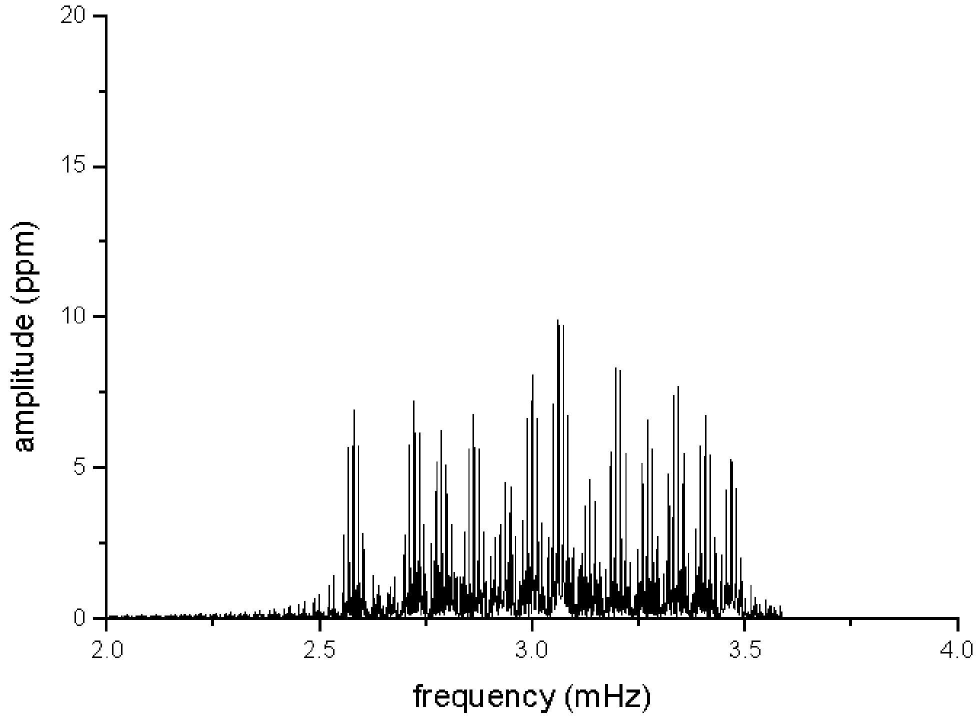
Poor frequency resolution

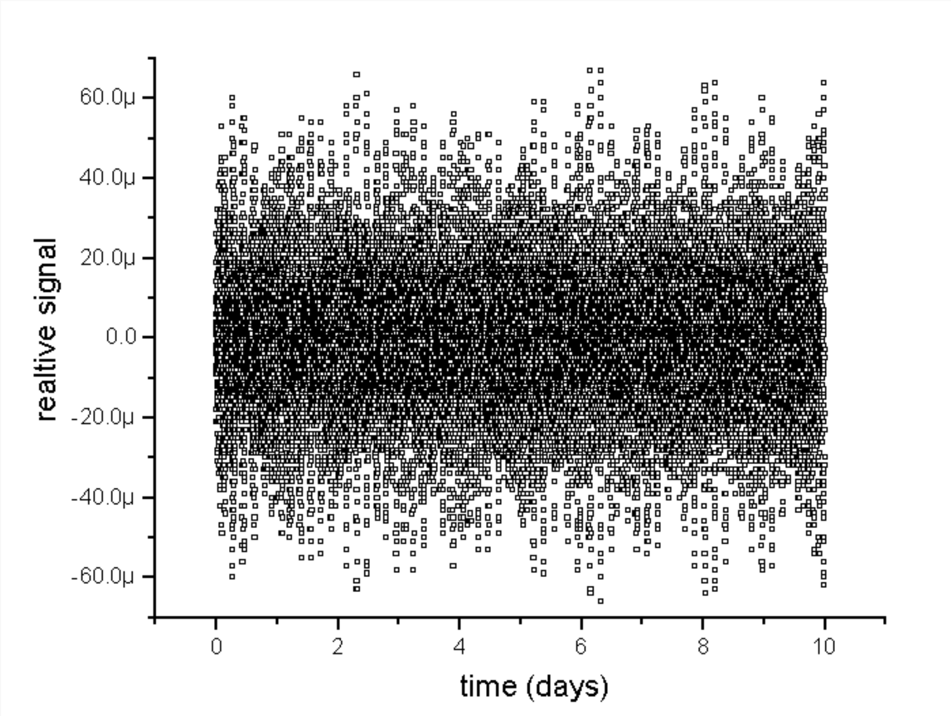




- 10 d of data
- no noise
- daily gaps

Good frequency resolution but aliasing

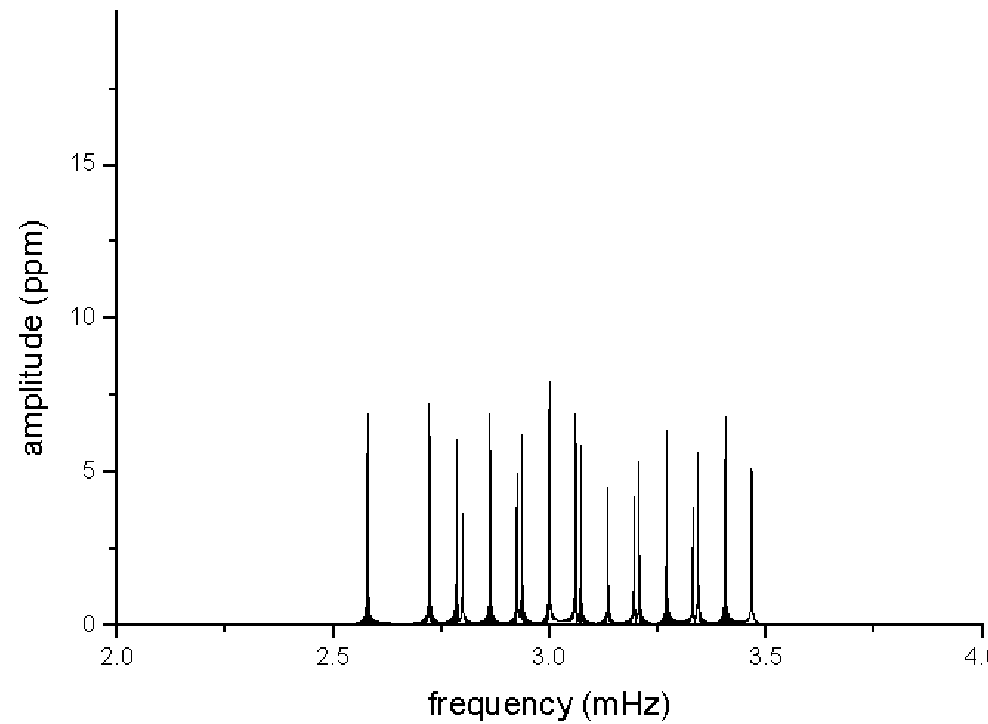


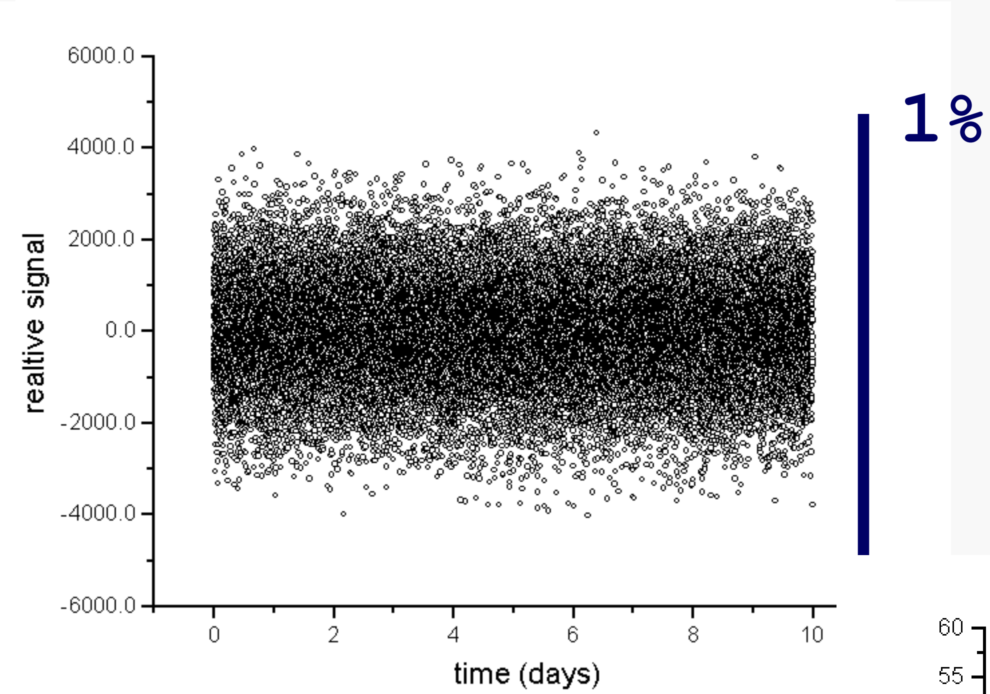


.01%

- 10 d of data
- photon noise
- no gaps

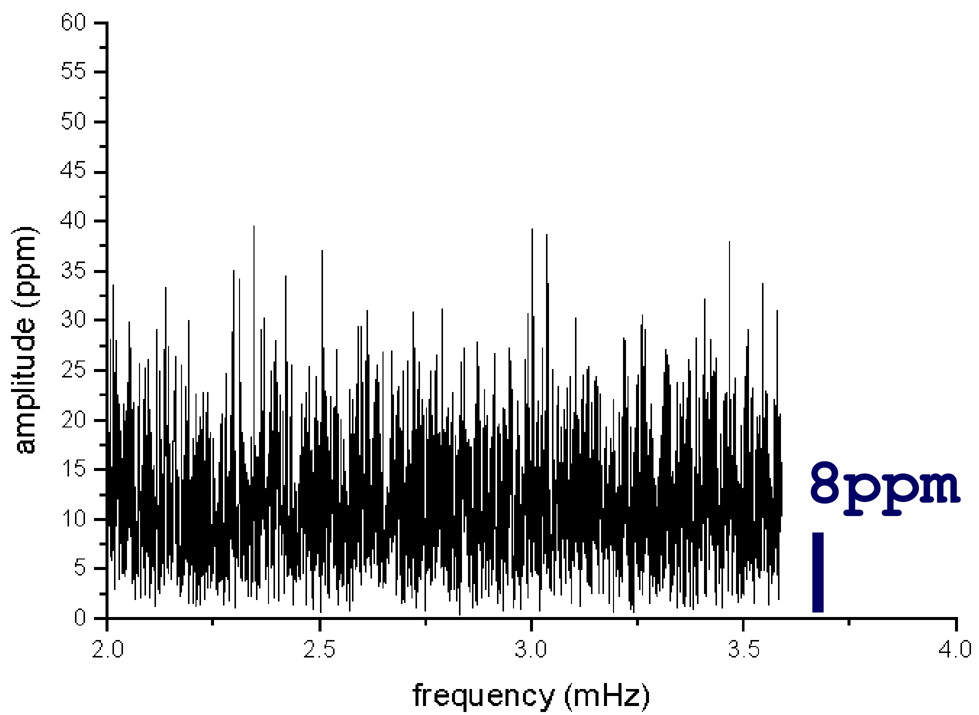
Good frequency resolution & no aliasing





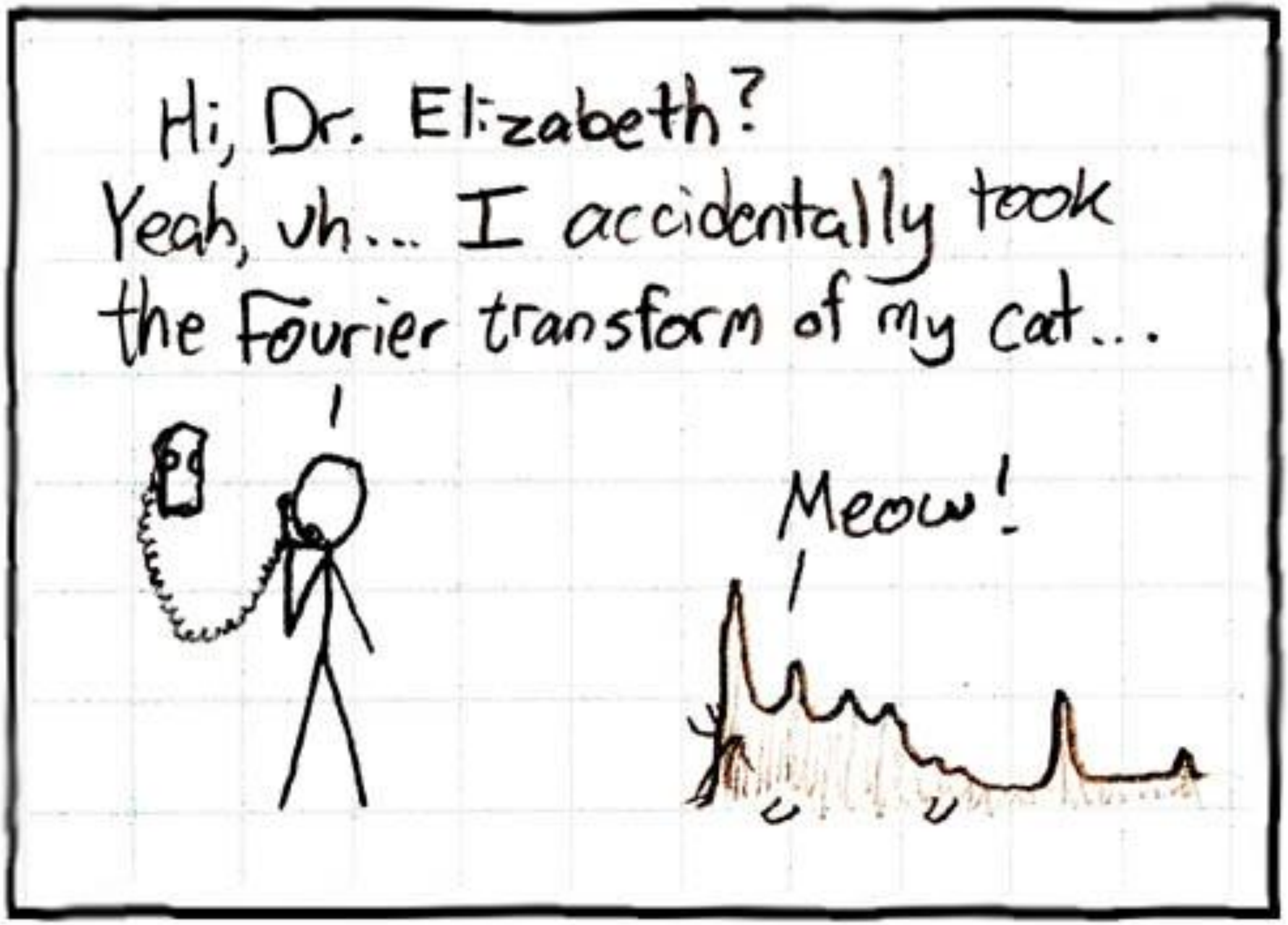
• 10 d of data
• atmospheric scintillation

NO DETECTION!



Value of continuous time coverage

A PET scan?



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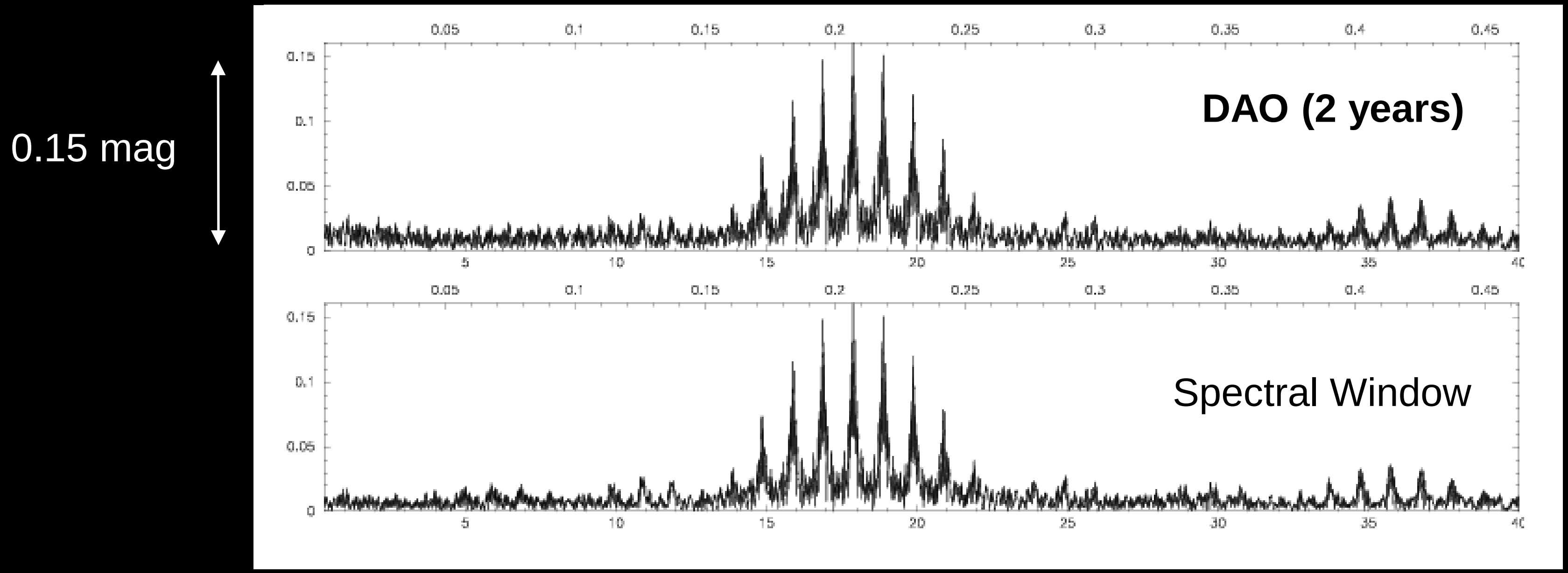
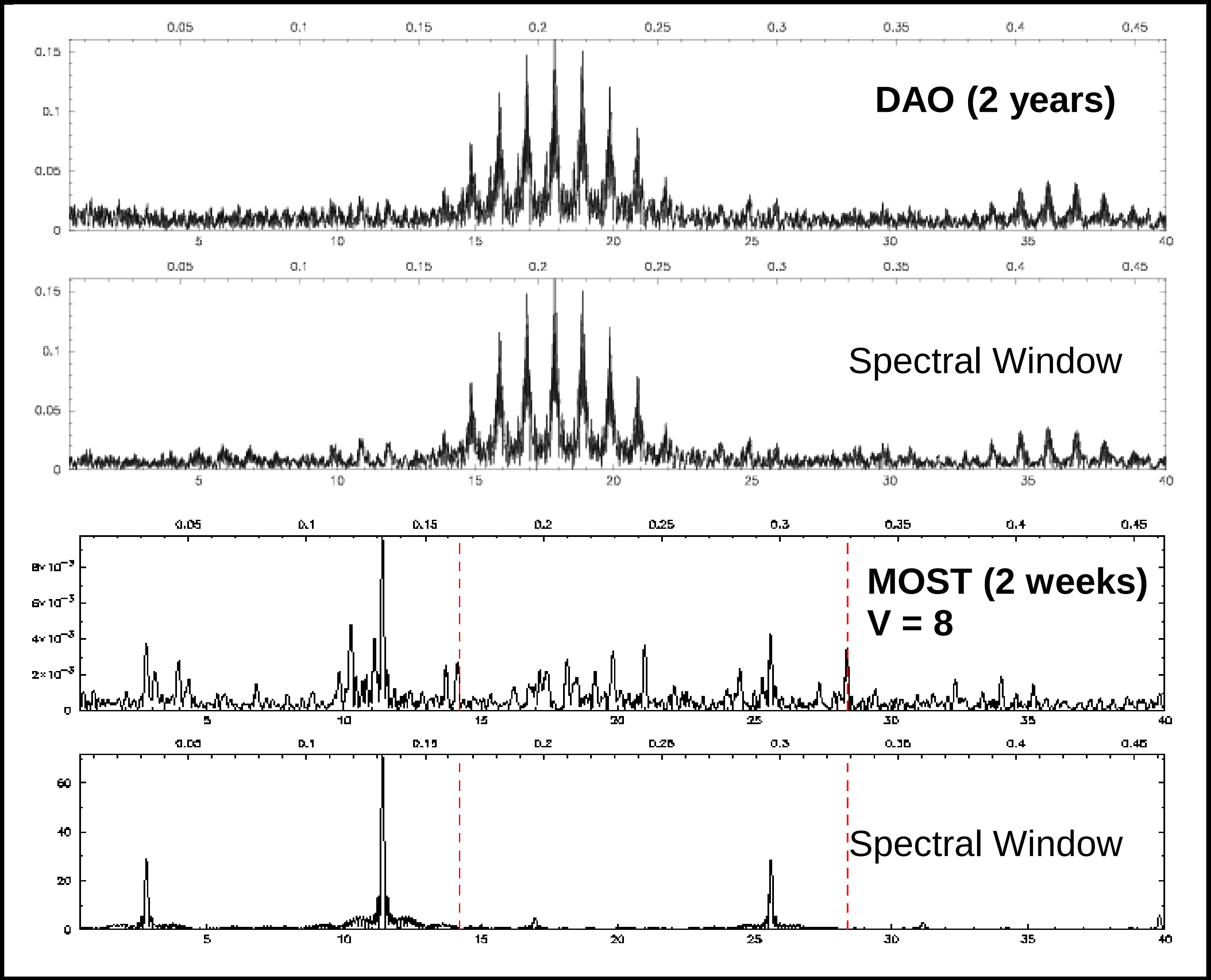


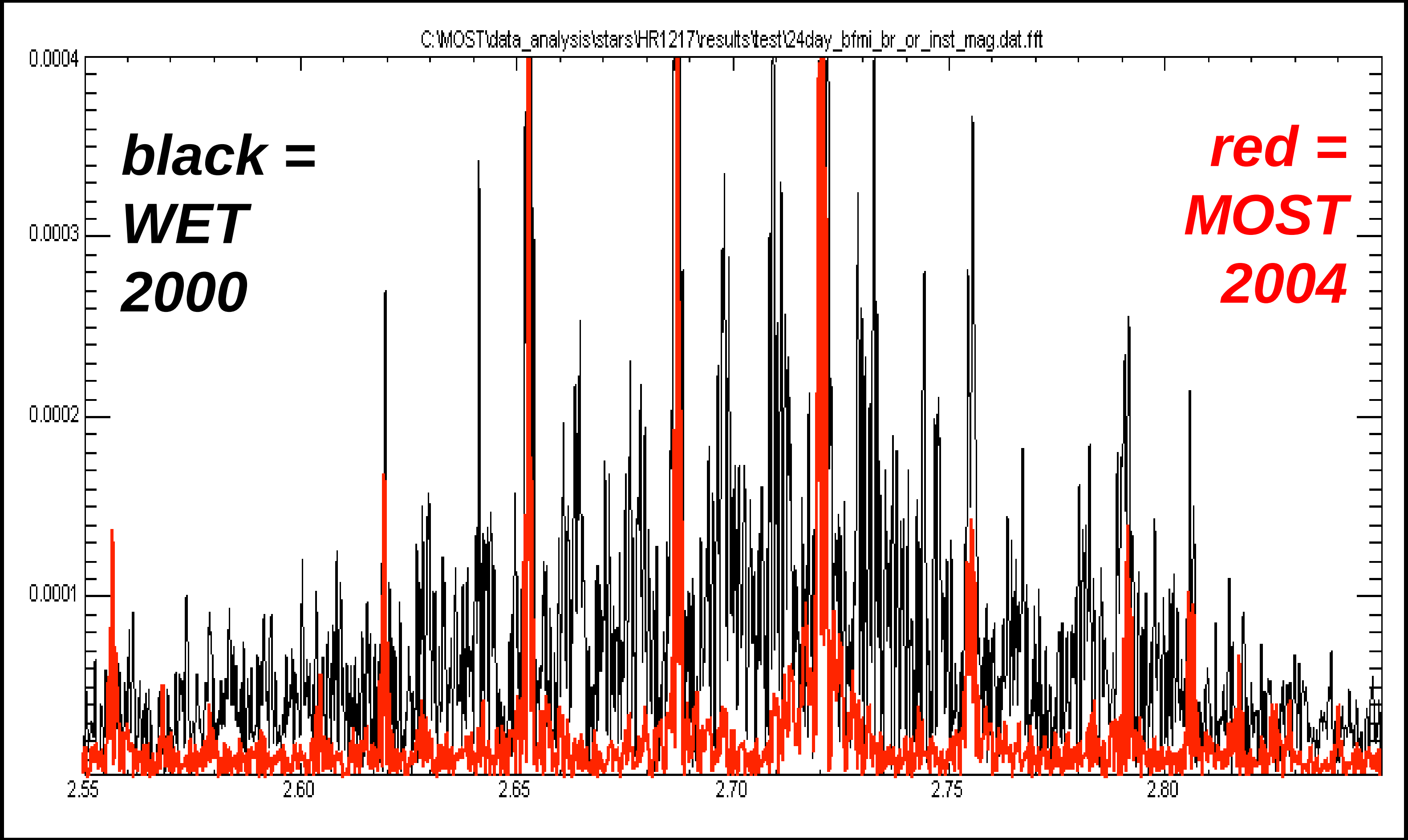
Value of continuous time coverage

0.15 mag

0.01 mag



Value of continuous time coverage



Clean spectral window – no aliasing due to sampling gaps

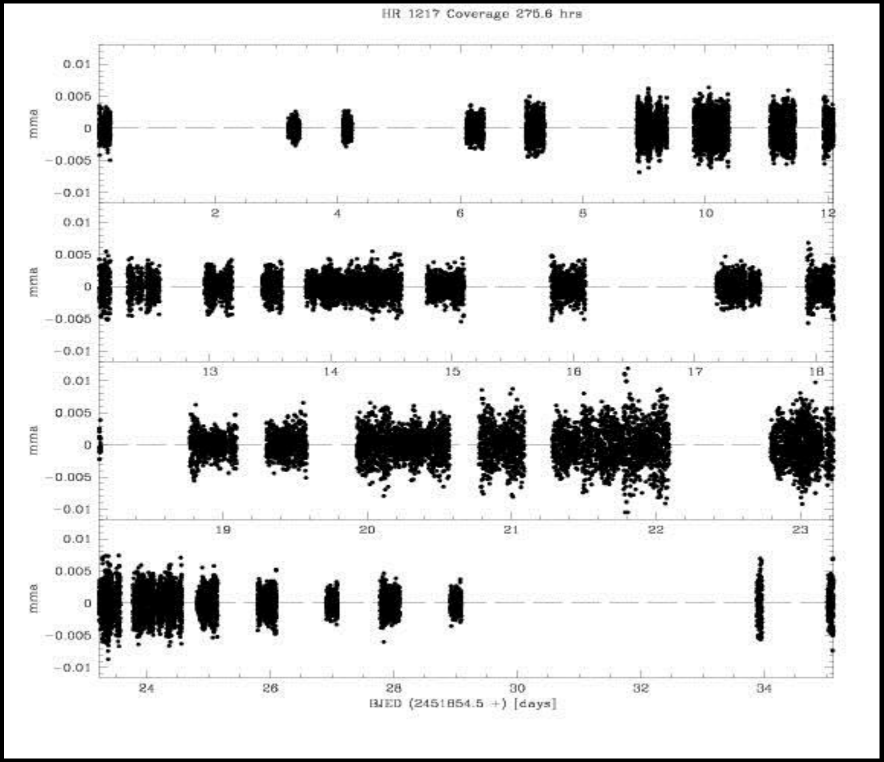
Value of continuous time coverage

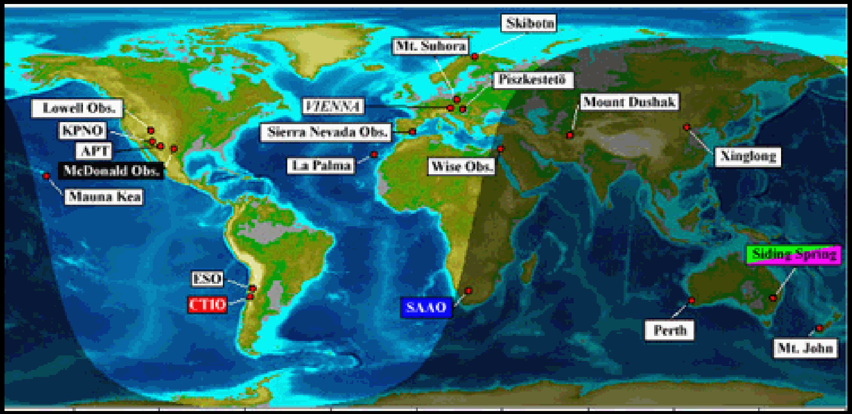
HR 1217 = HD 24712

WET campaign

Nov-Dec 2000

- ✓ *342 hr over 35 days*
- ✓ *duty cycle = 34%*
- ✓ *10-sec integrations*
- ✓ *Johnson B filter*





2000 WET campaign:

Kurtz et al. 2002, MNRAS 330, L57
Kurtz, Cameron et al. 2005, MNRAS

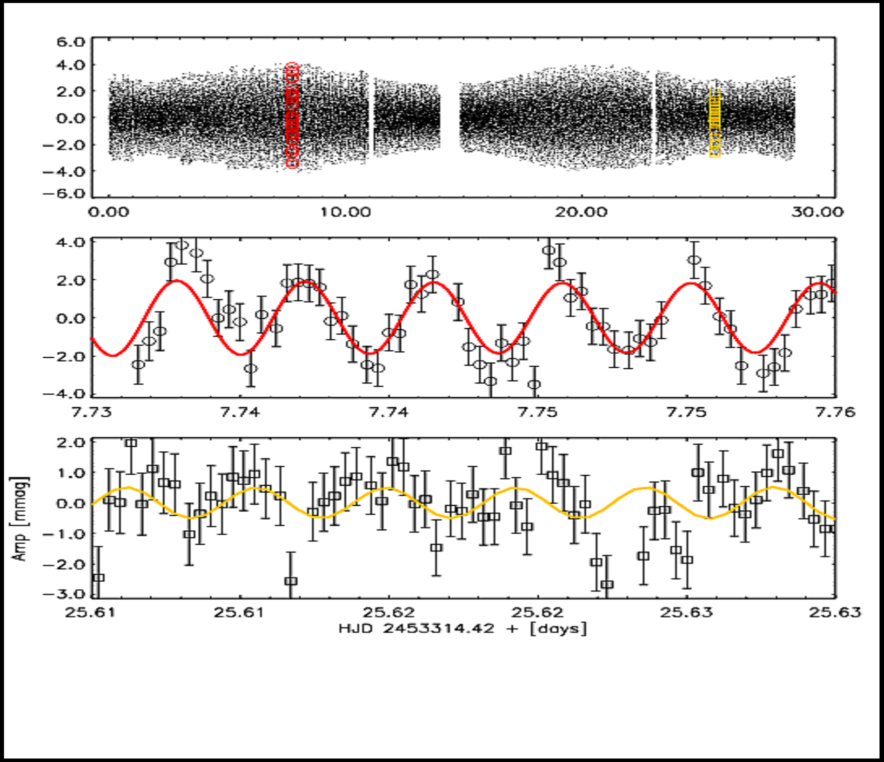
Value of continuous time coverage

HR 1217 = HD 24712

MOST campaign

Nov-Dec 2004

- ✓ *666 hr over 29 days*
- ✓ *duty cycle = 96%*
- ✓ *30-sec integrations*
- ✓ *MOST custom filter*



3 gaps

due to charged particle hits

2004 MOST campaign:

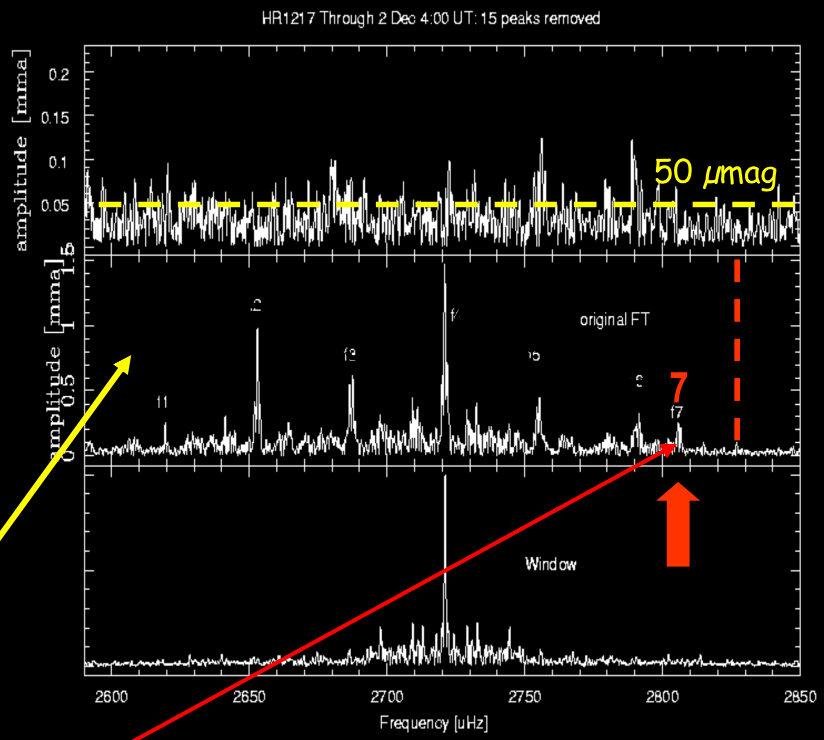
Chris Cameron et al. 2010, in preparation

Cameron UBC PhD thesis

p-modes in magnetic stars

HR 1217

- rapidly oscillating Ap star
  - ✓ *periods near 6 min*
    discovered by Kurtz (1982)
  - ✓ *0 < B field < 1.2 kG*
  - ✓ *P_{rot} = 12.45877(16) d*
    Ryabchikova et al. 2005, A&A



A rich p-mode spectrum

- 6 dominant modes
  + 1 anomalous one

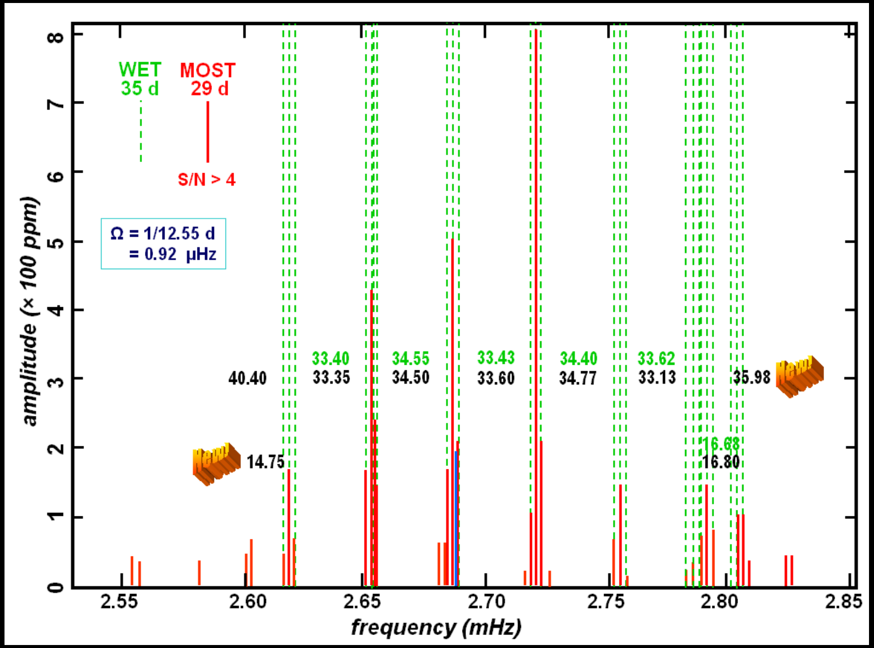
2000 WET campaign:

Kurtz et al. 2002, MNRAS 330, L57
Kurtz et al. 2005, MNRAS

p-modes in magnetic stars

HR 1217: A magnetohydrodynamic lab in space

- ✓ MOST finds…
  - ✓ *second magnetically perturbed (?) mode*
  - ✓ *new p-modes matching ~34-μHz spacing*
  - ✓ *evidence for small spacing*
  - ✓ *tracking of amplitude & phase modulation*
- ✓ Implication…
  - ✓ most severe test yet of magnetic perturbation theories



schematic of 2004 MOST amplitude spectrum

p-modes in magnetic stars

"magnetoasteroseismology"

Pulsation amplitudes and phases modulated with magnetic (= rot'n) period

- Oblique Pulsator Model

  Kurtz 1982 MNRAS 200, 807

- magneto-acoustic coupling

  Dziembowski & Goode 1996

  eigenfunction expanded with $Y_\ell^m(\theta,\phi)$

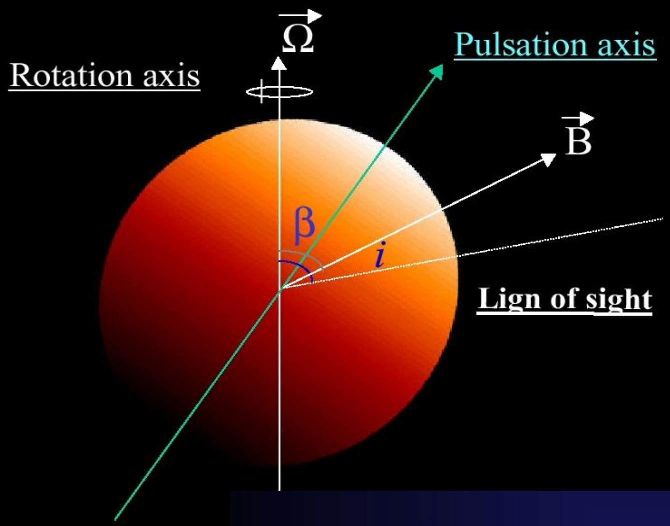
  Cunha & Gough 2002, MNRAS 333, 47 *Cunha 2006*

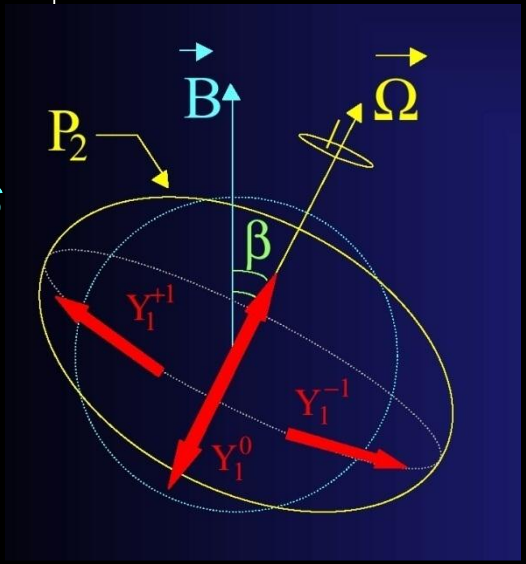
  variational principle and WKB approximation

  Saio & Gautschy 2004, Saio 2005

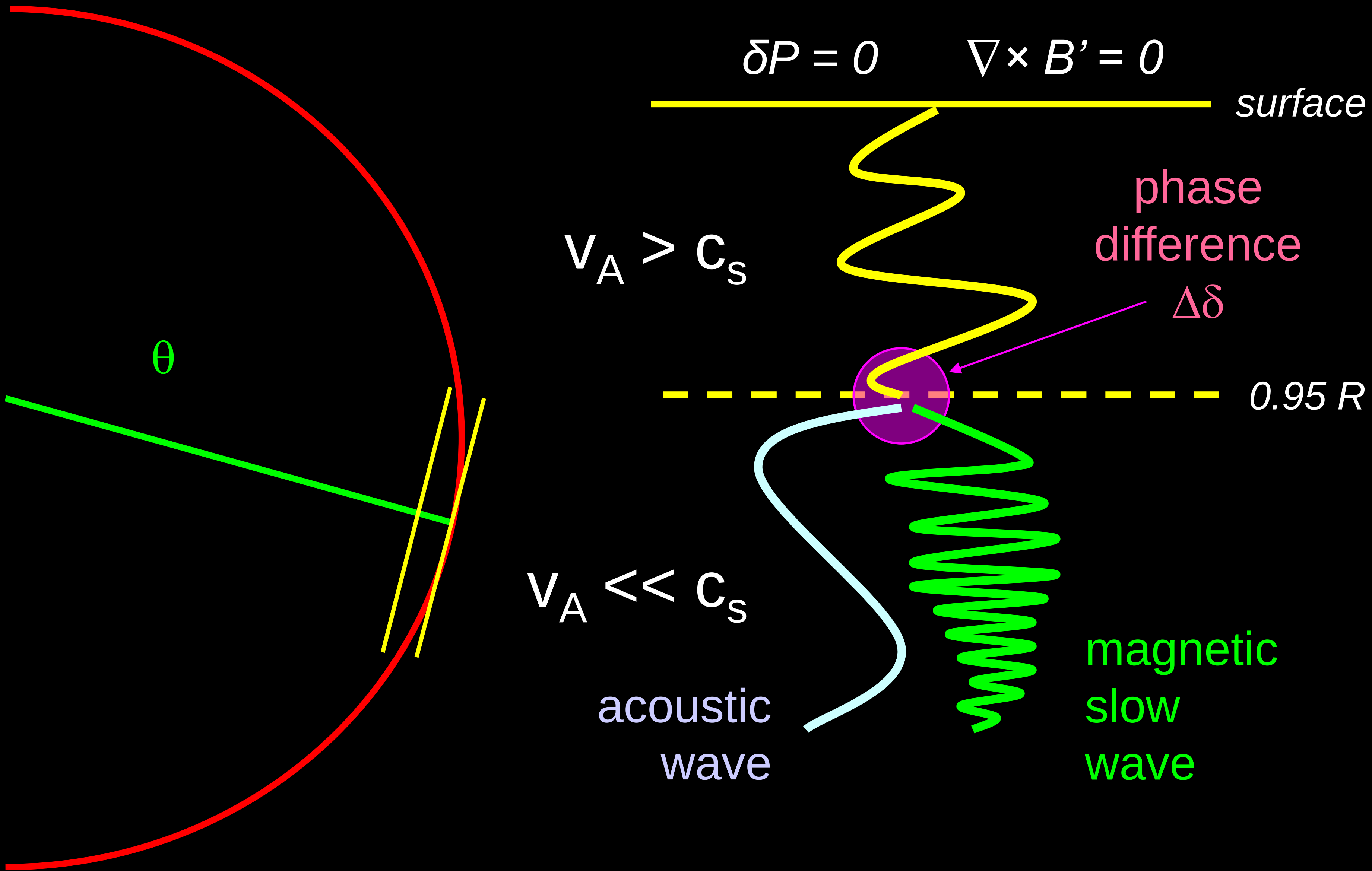
  Including rotation

  Bigot & Dziembowski 2002, A&A 391, 235





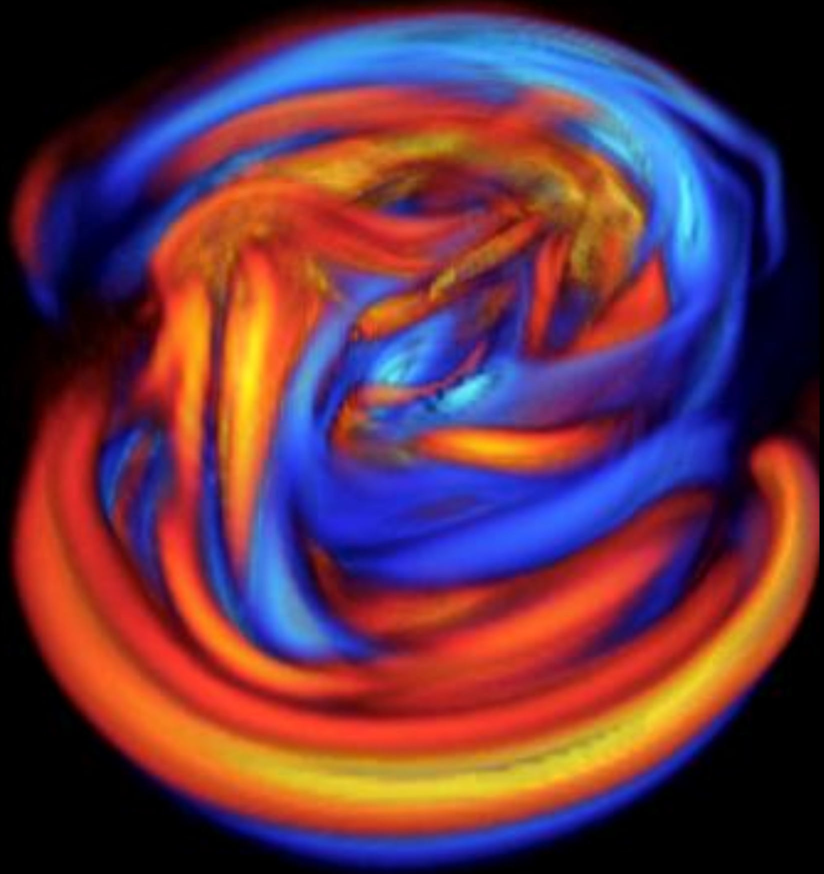
p-modes in magnetic stars



“Peering into the convective core of an A star”

Browning, Brun & Toomre (JILA, Boulder) 2002

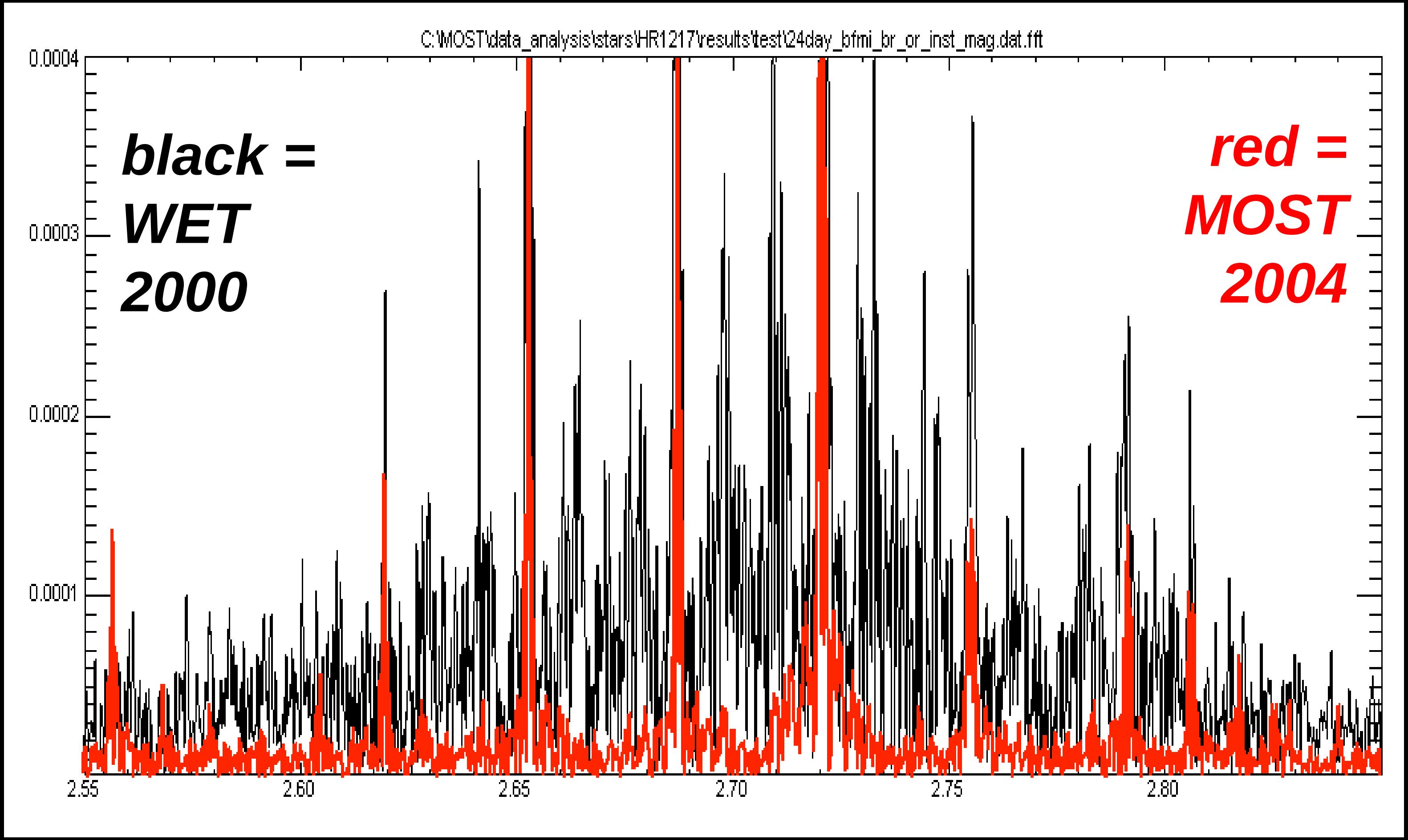
> numerical simulations of a core-convection dynamo



azimuthal component of B field

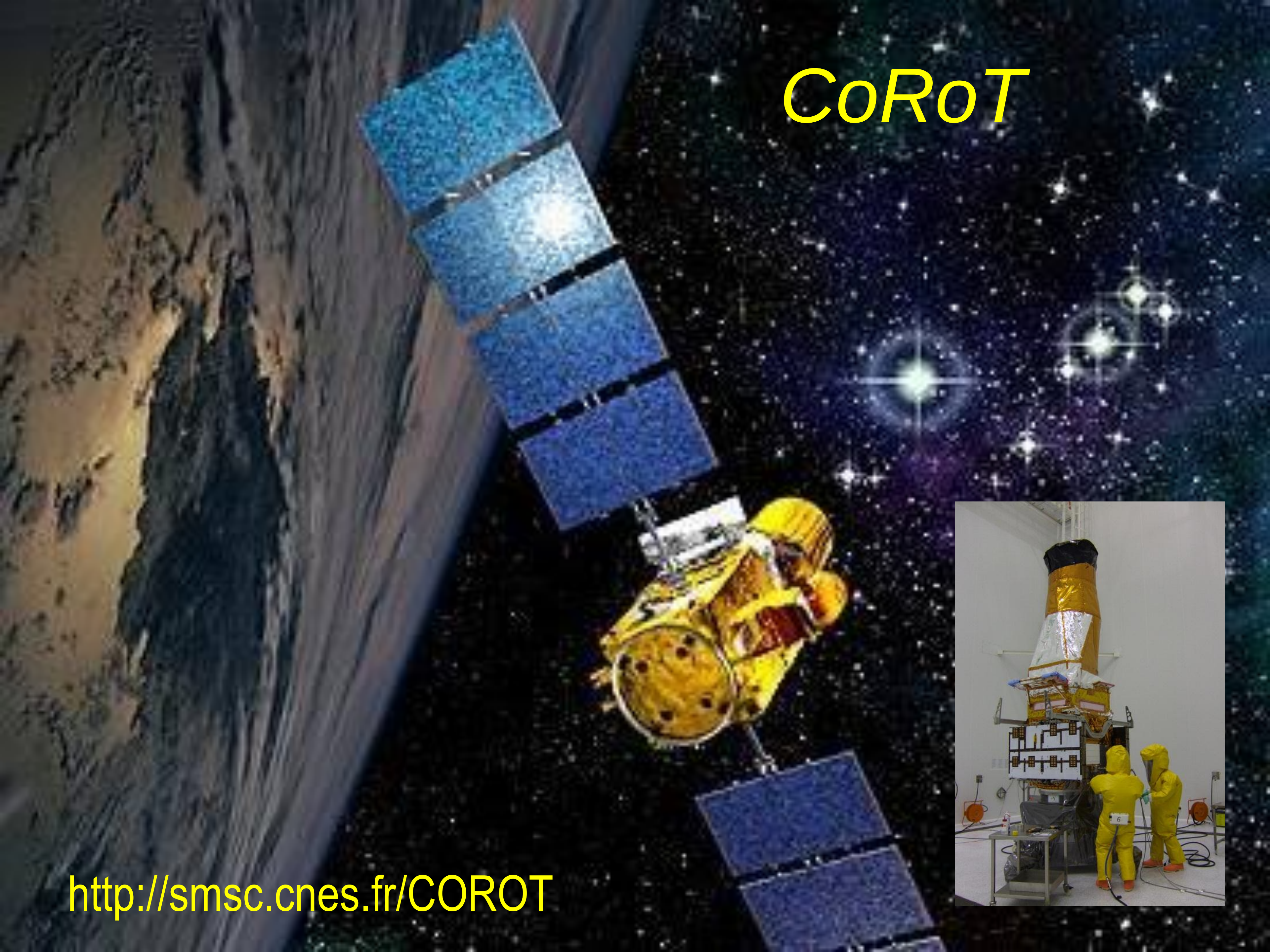
radial velocity

Value of continuous time coverage



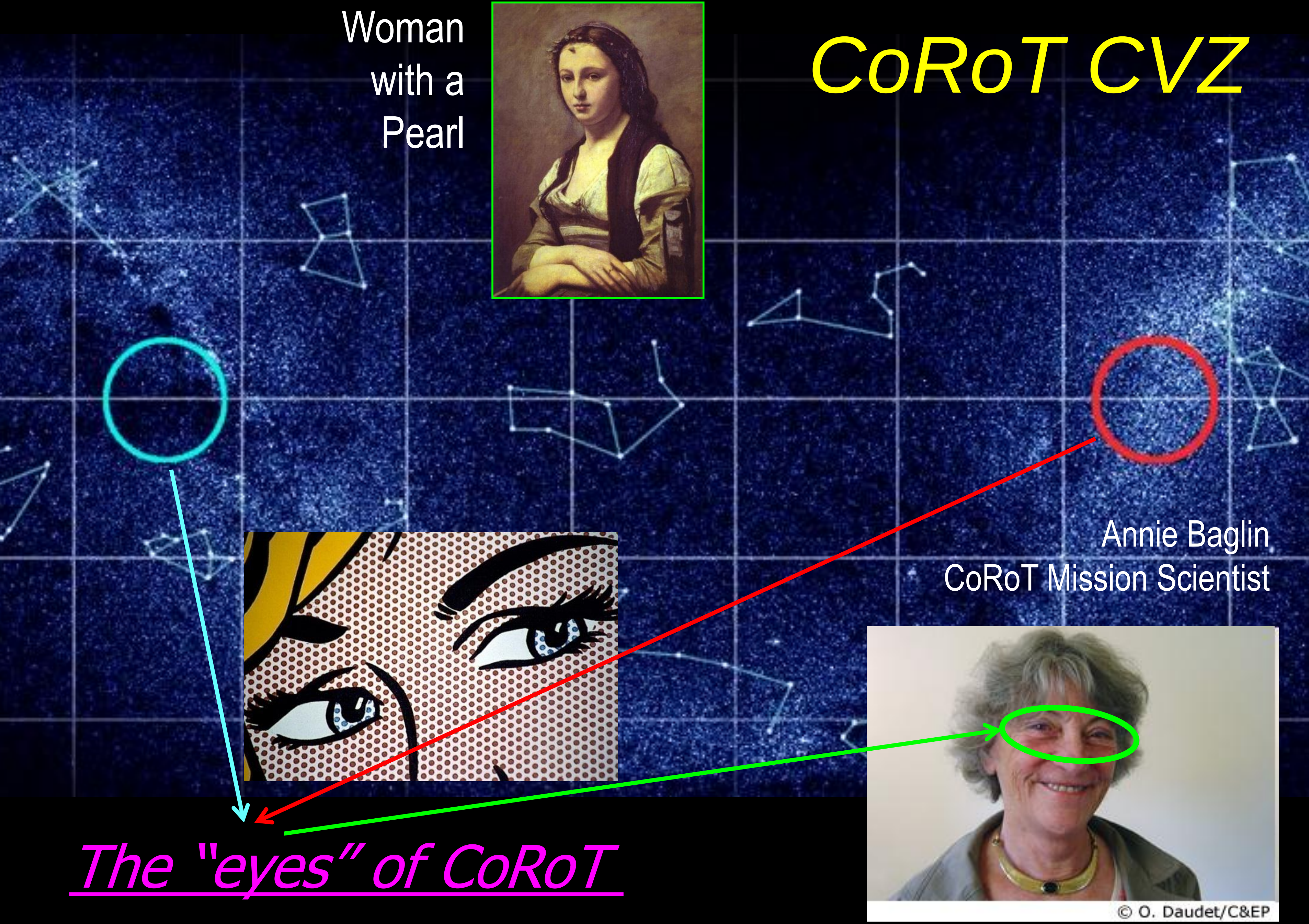
Clean spectral window – no aliasing due to sampling gaps

CoRoT



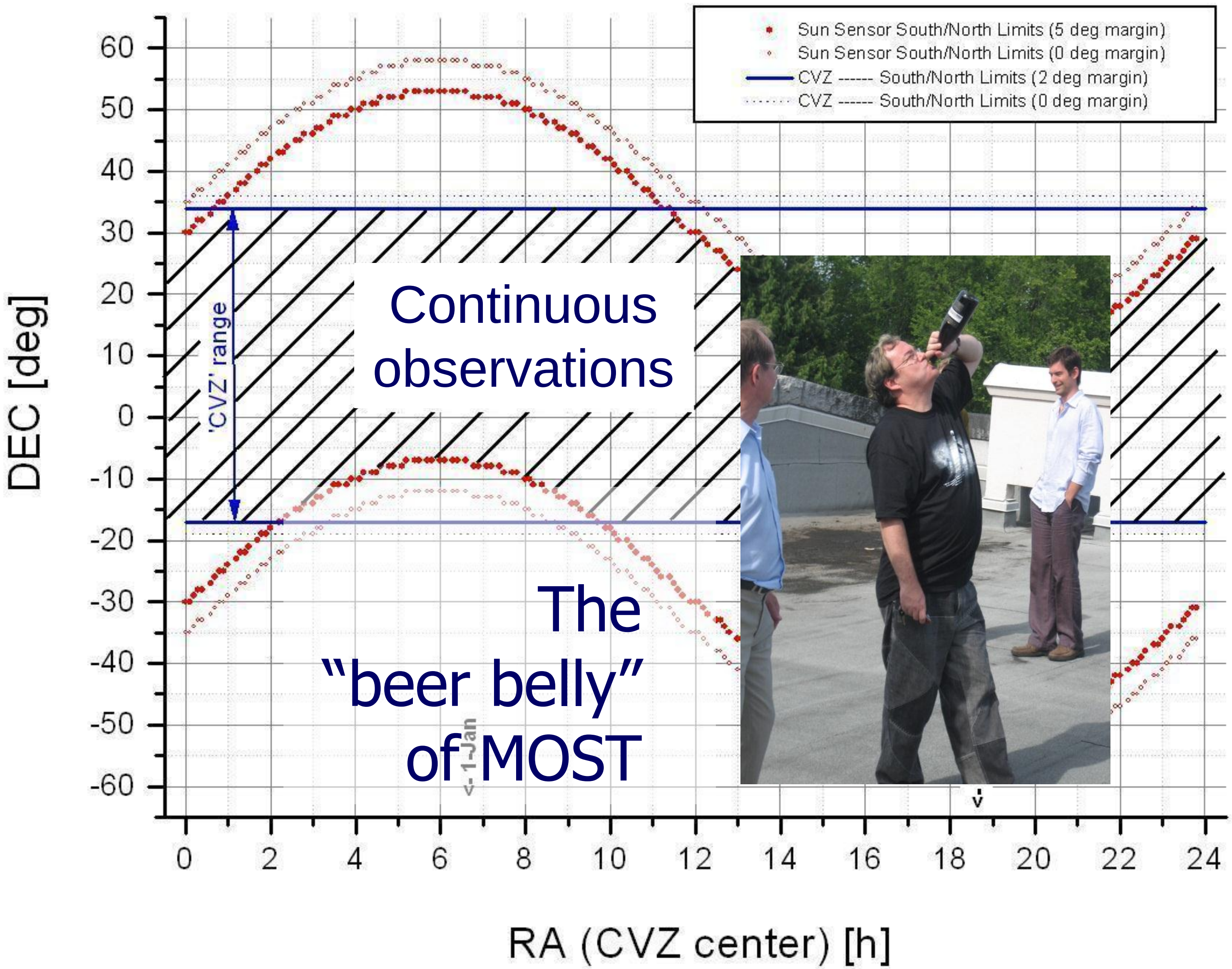
http://smsc.cnes.fr/COROT

CoRoT CVZ



The "eyes" of CoRoT

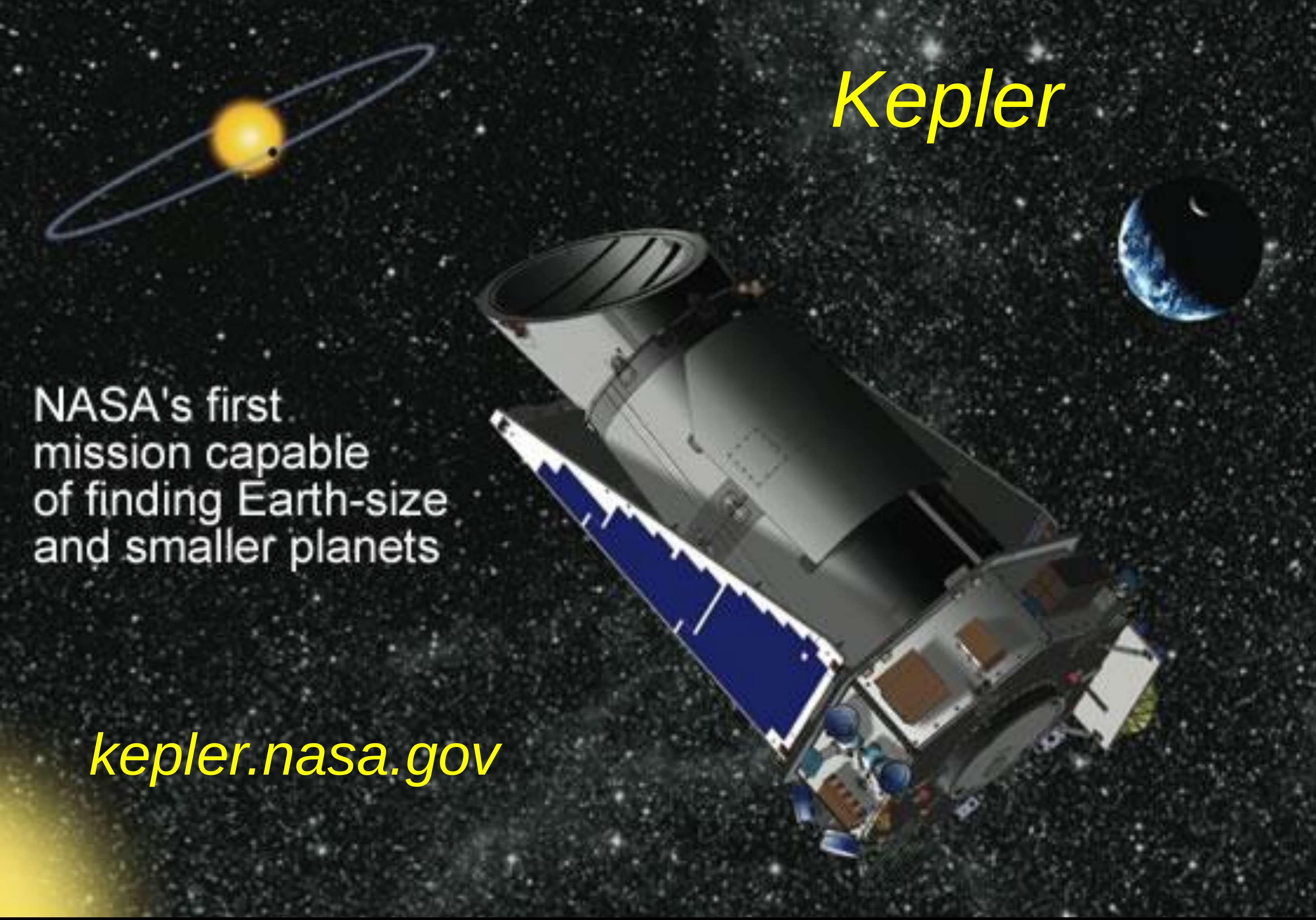
MOST CVZ



Continuous observations

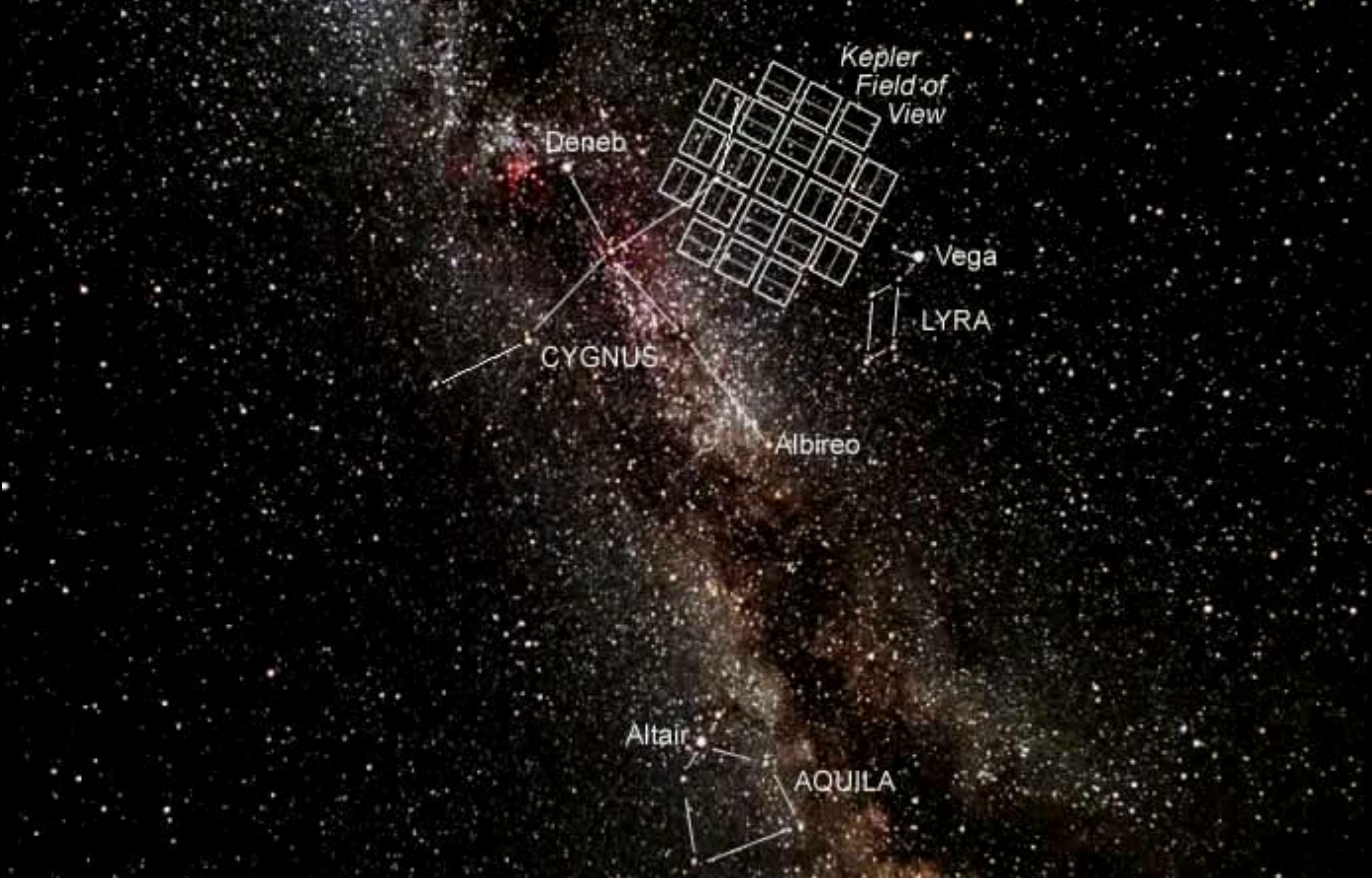
The "beer belly" of MOST

Kepler

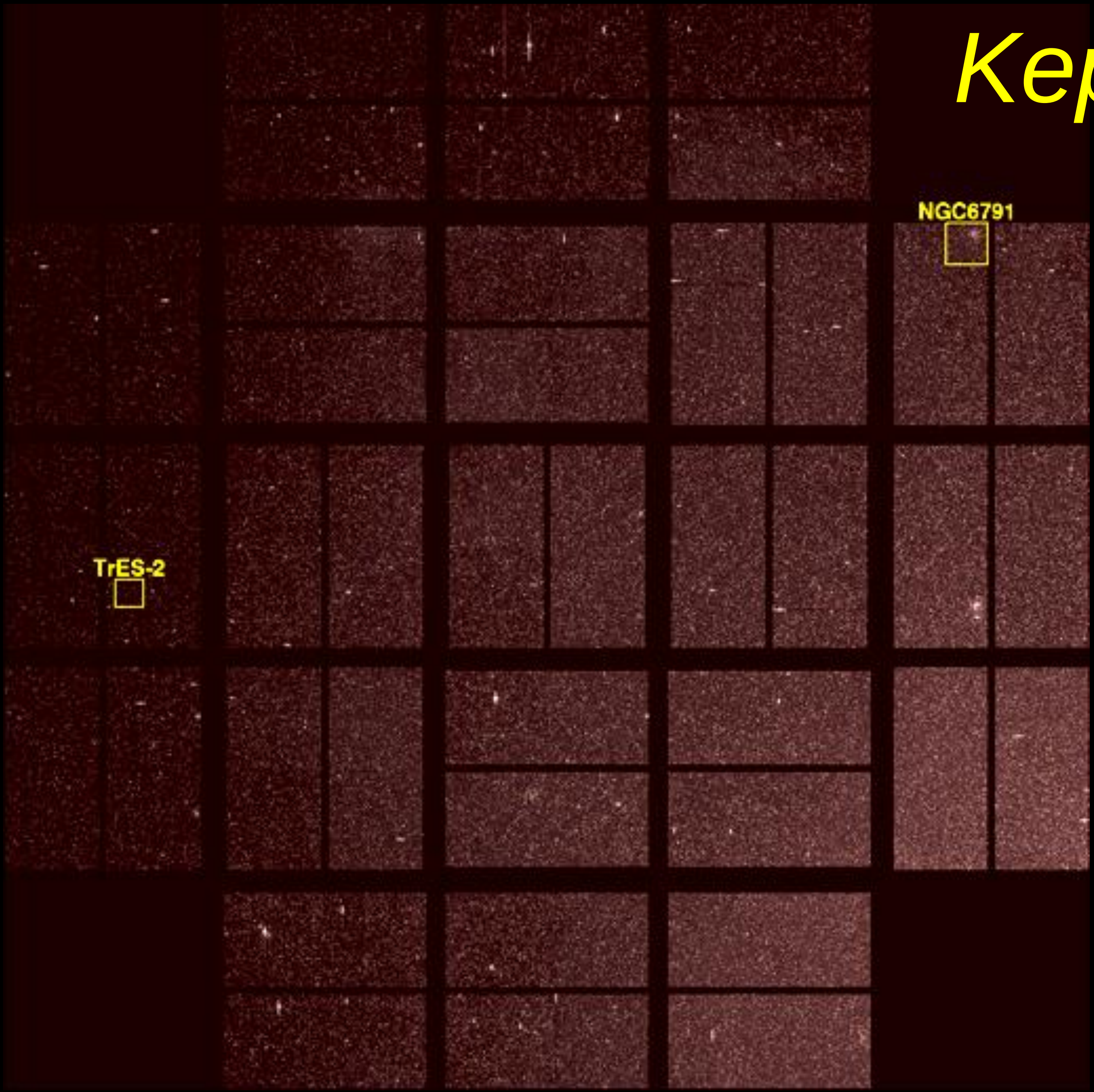


kepler.nasa.gov

Kepler CVZ


Kepler
Field of
View
Deneb
Vega
LYRA
CYGNUS
Albireo
Altair
AQUILA

Kepler CVZ



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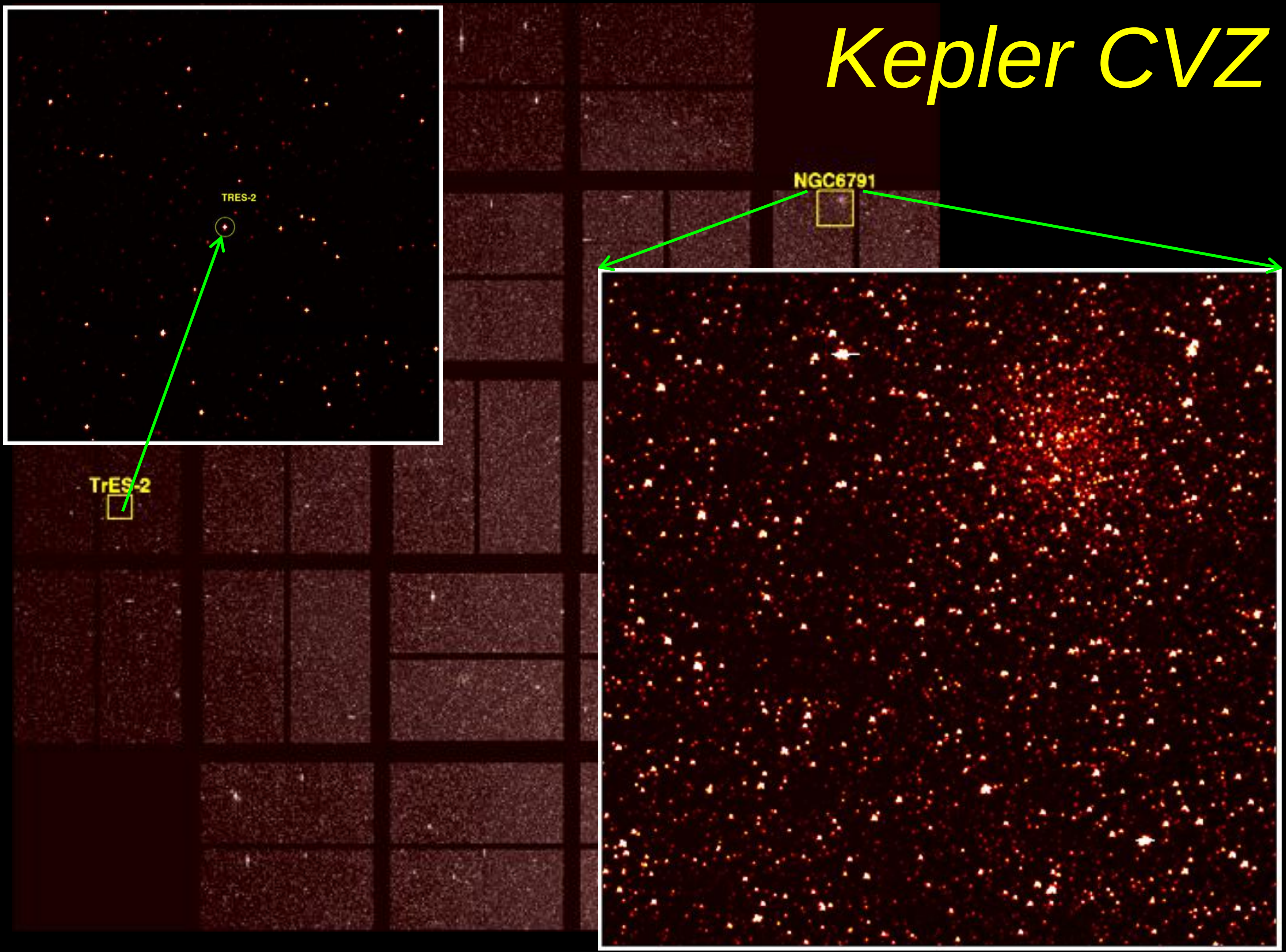
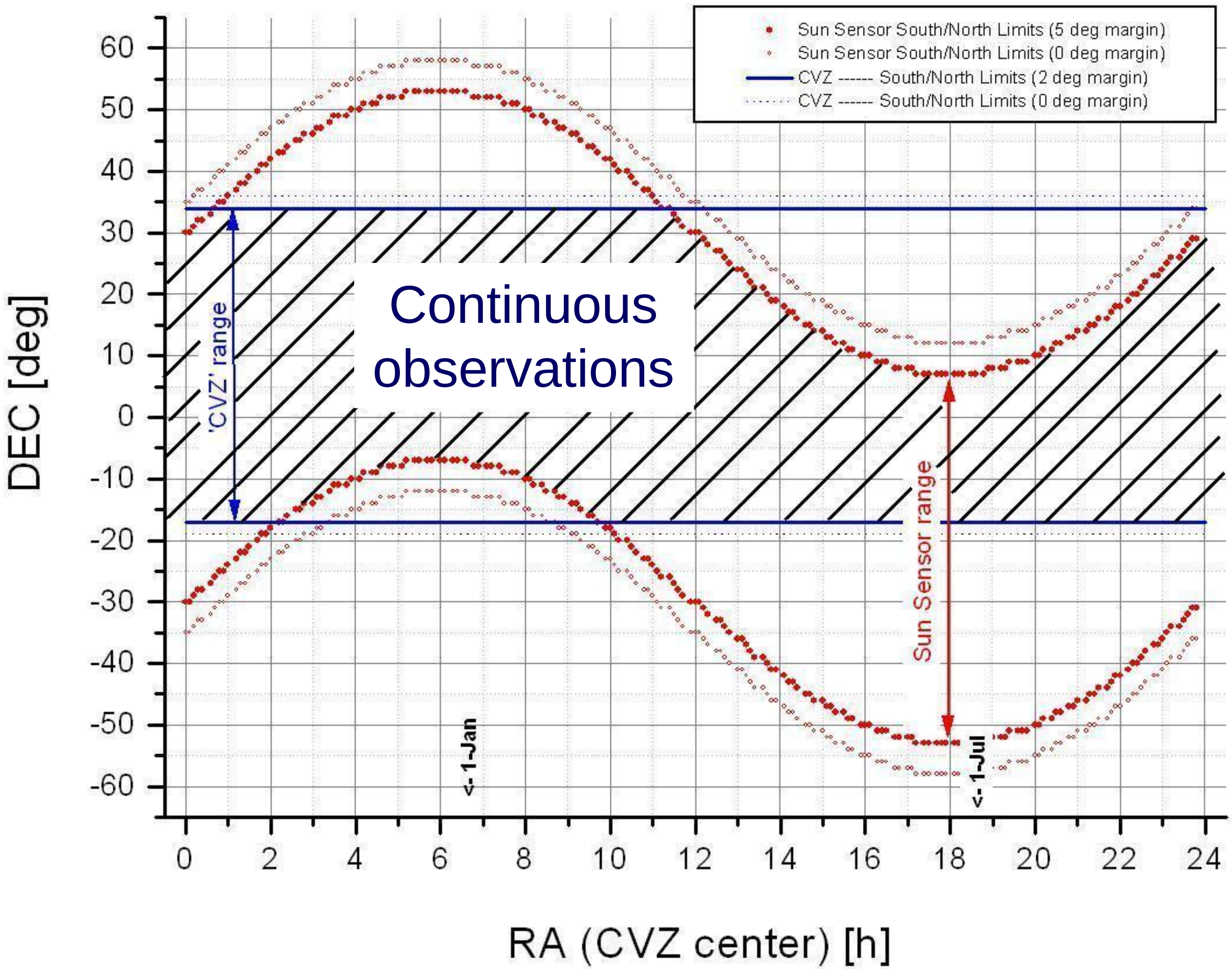


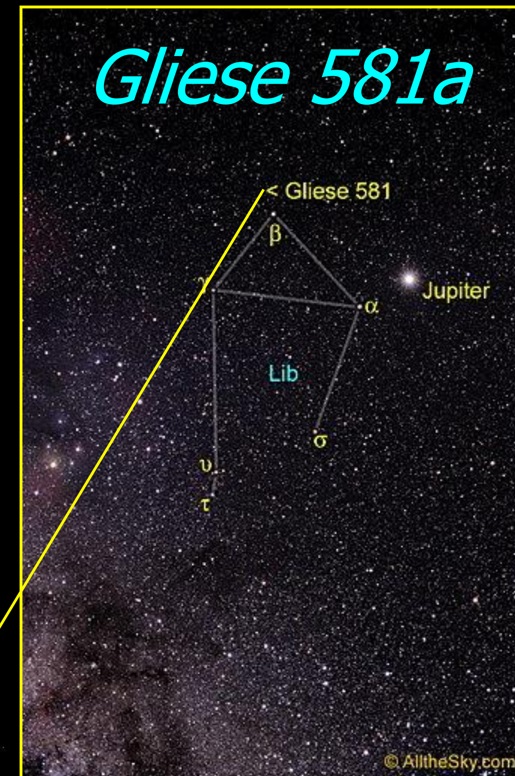
MOST CVZ

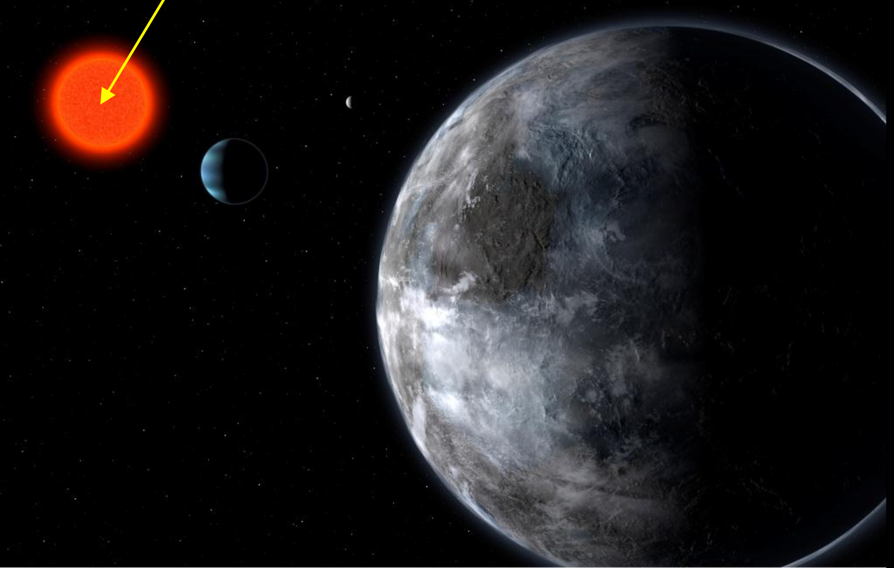


Sun Sensor South/North Limits (5 deg margin)
Sun Sensor South/North Limits (0 deg margin)
CVZ ------ South/North Limits (2 deg margin)
CVZ ------ South/North Limits (0 deg margin)
Continuous observations
'CVZ' range
Sun Sensor range
<- 1-Jan
<- 1-Jul
DEC [deg]
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
2
4
6
8
10
12
14
16
18
20
22
24
RA (CVZ center) [h]

A habitable world?

- ✓ *Swiss astronomers discovered three planets around a dim red dwarf*
  - *one of these planets may be in the habitable zone*





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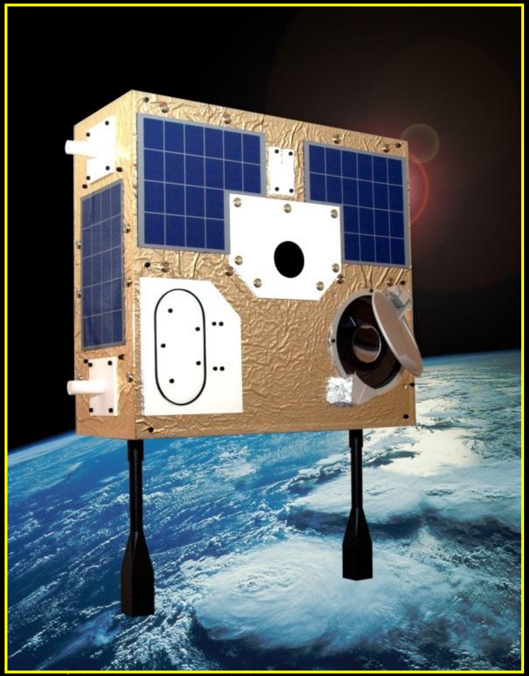
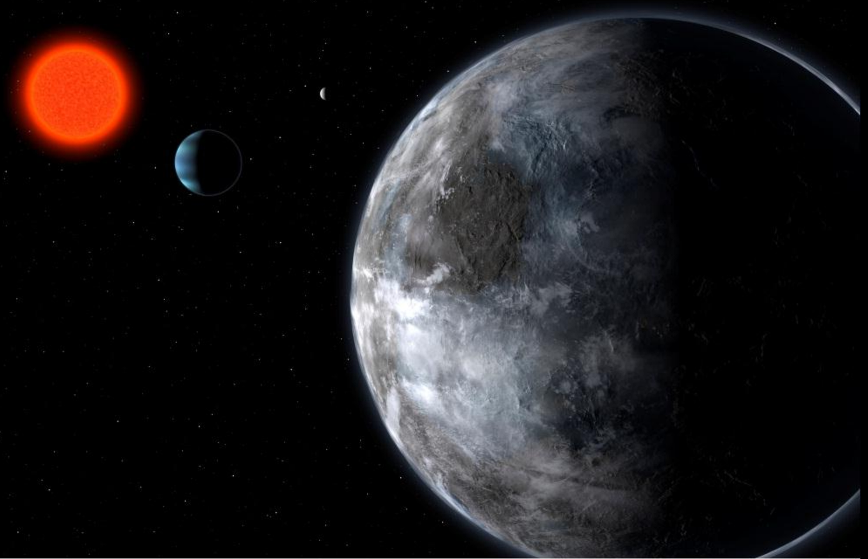
- ✓ Canada’s MOST space telescope put this planetary system under a stakeout for eight weeks





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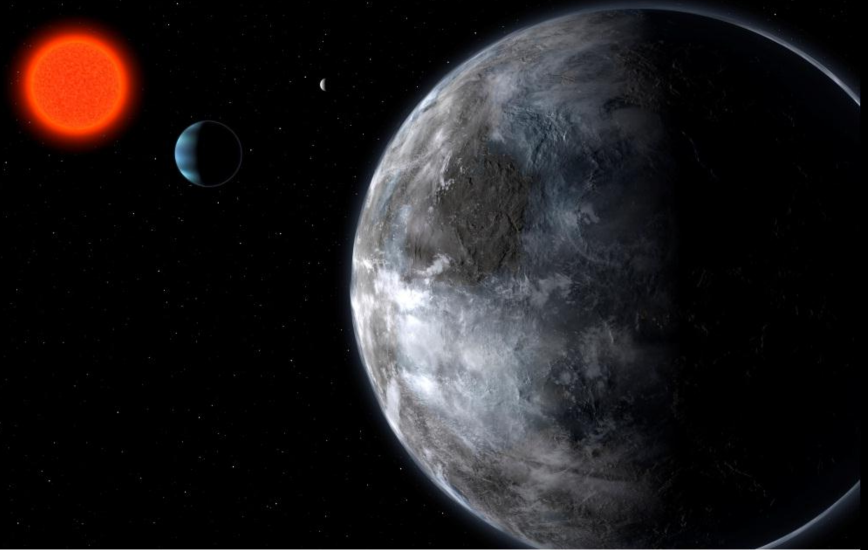
- ✓ *The results were boring*



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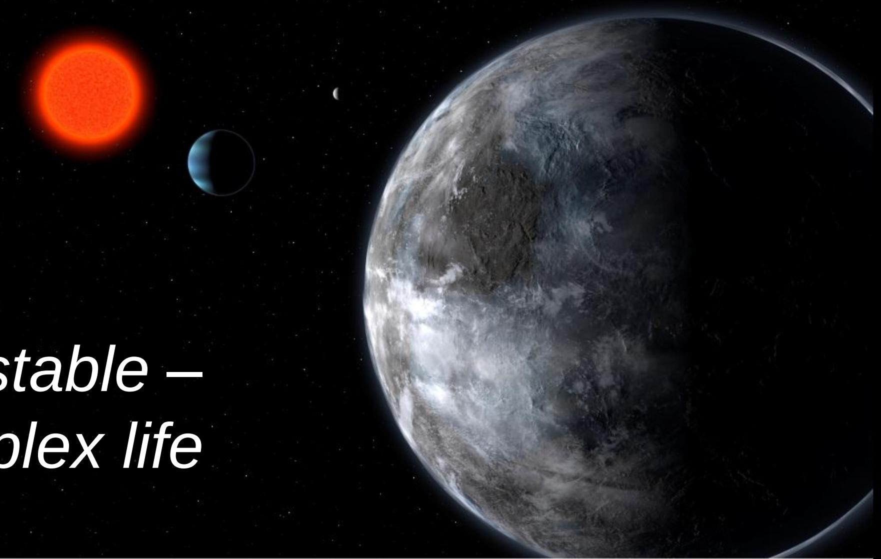
- *"Boring" is good for life*
  The red dwarf star is old and stable – conditions favourable for complex life



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