Measuring ZL brightness by means of high-resolution spectroscopy

Alexander Kutyrev

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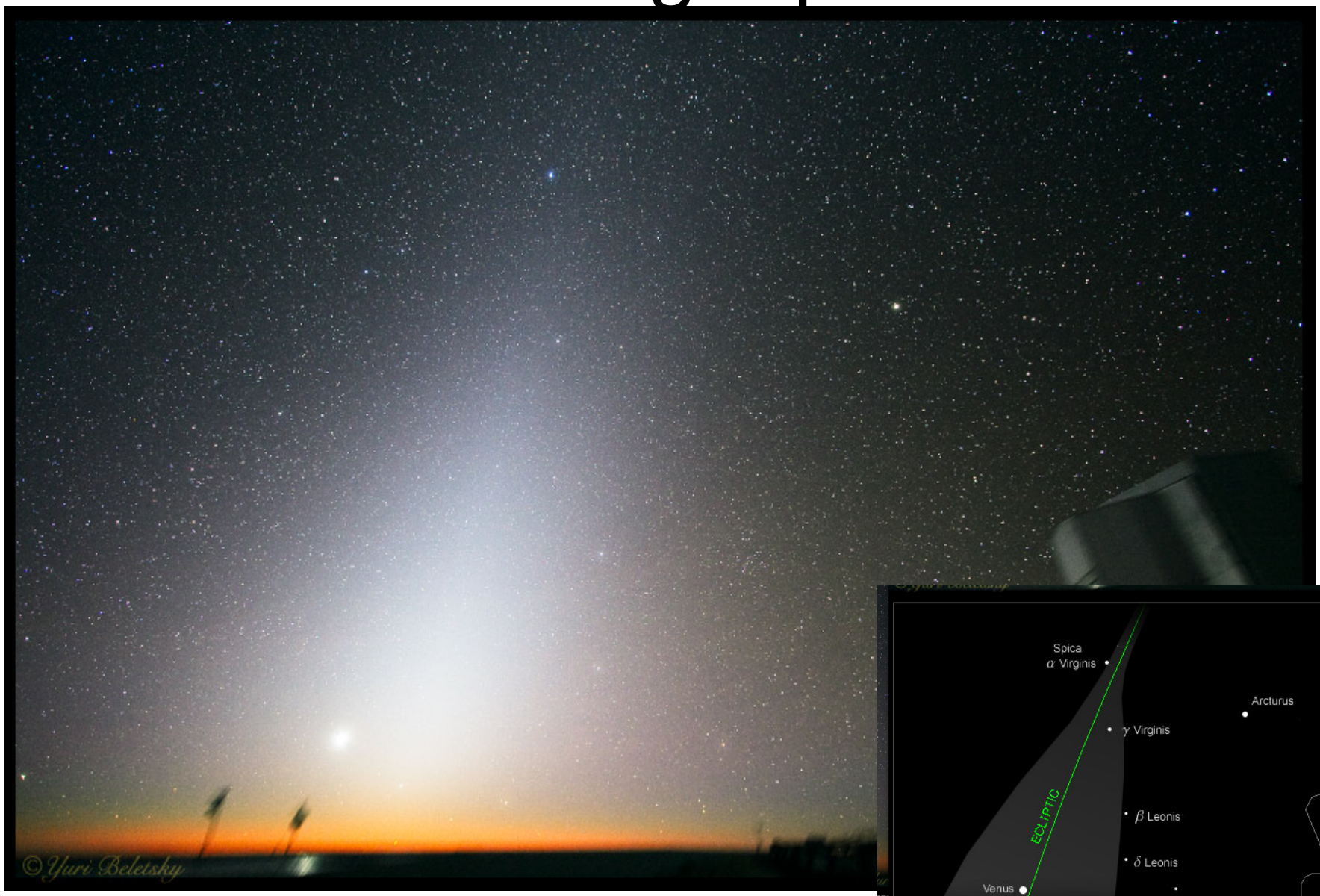
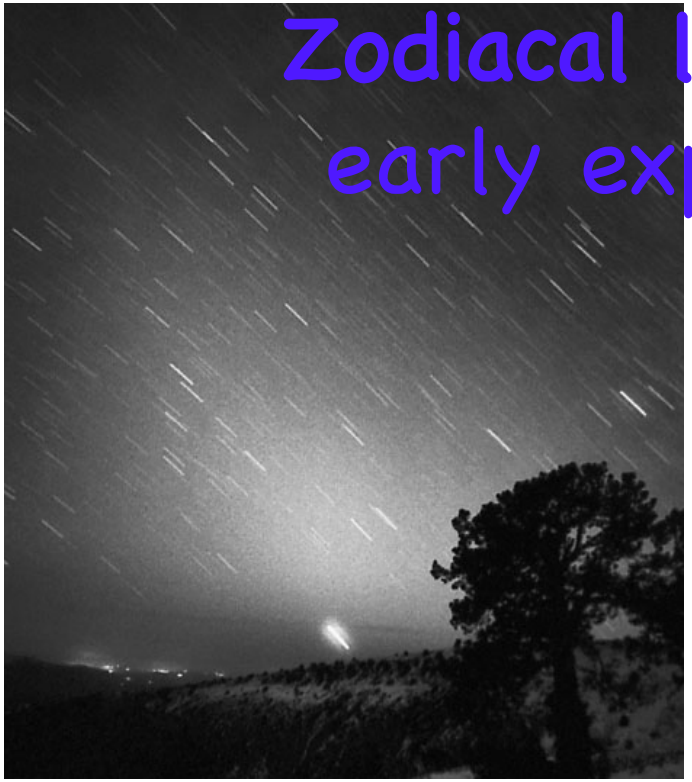
- Goal: measure zodiacal light (ZL) brightness in the near infrared DIRBE bands
- Scientific motivation:
  - accurate subtraction of ZL foreground for extragalactic background light (EBL) COBE DIRBE
  - ZL dust cloud kinematics
- Method: **high resolution (R=2 10^4) spectroscopy of single ZL Fraunhofer line**

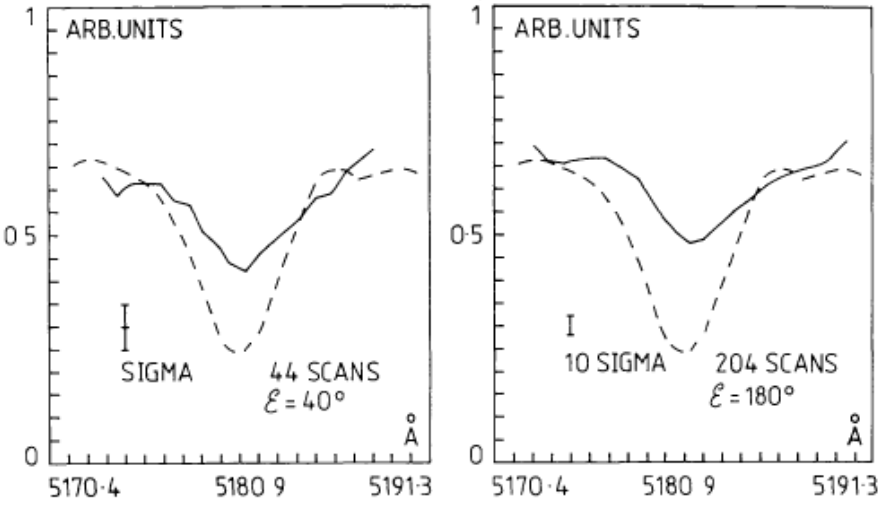
Zodiacal light pictures



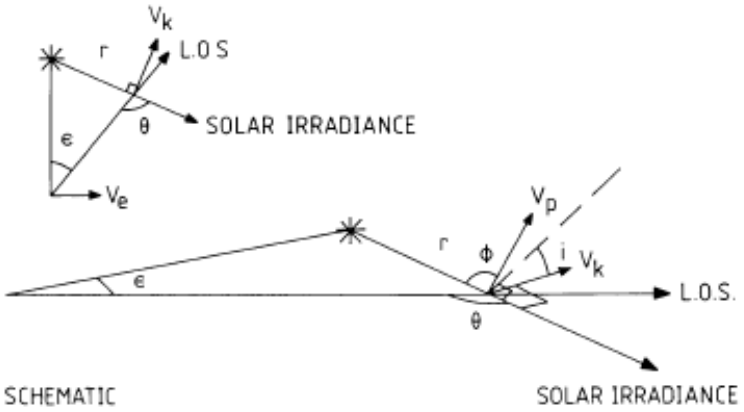
Zodiacal light spectroscopy

Zodiacal light line spectroscopy: early experiments in '60-80ies





Mg I line



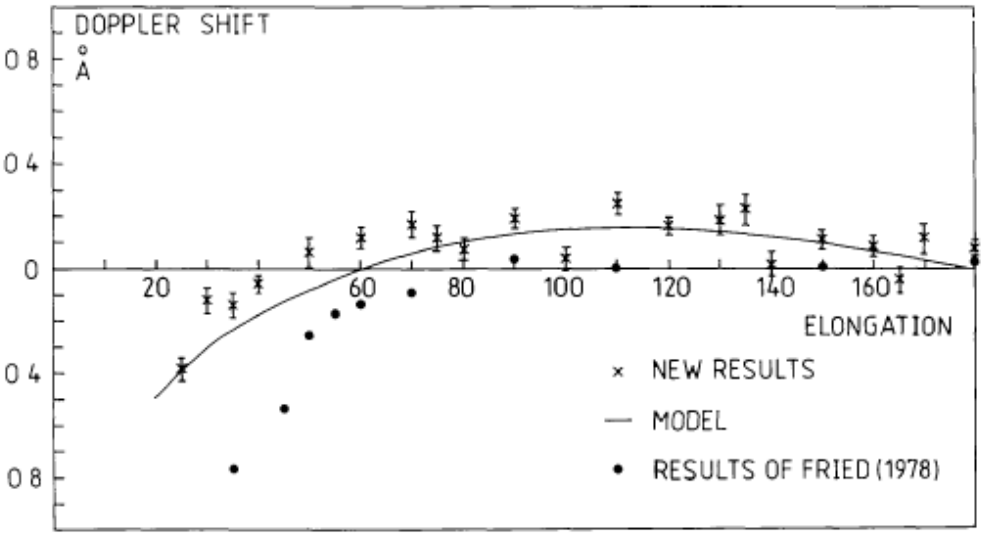
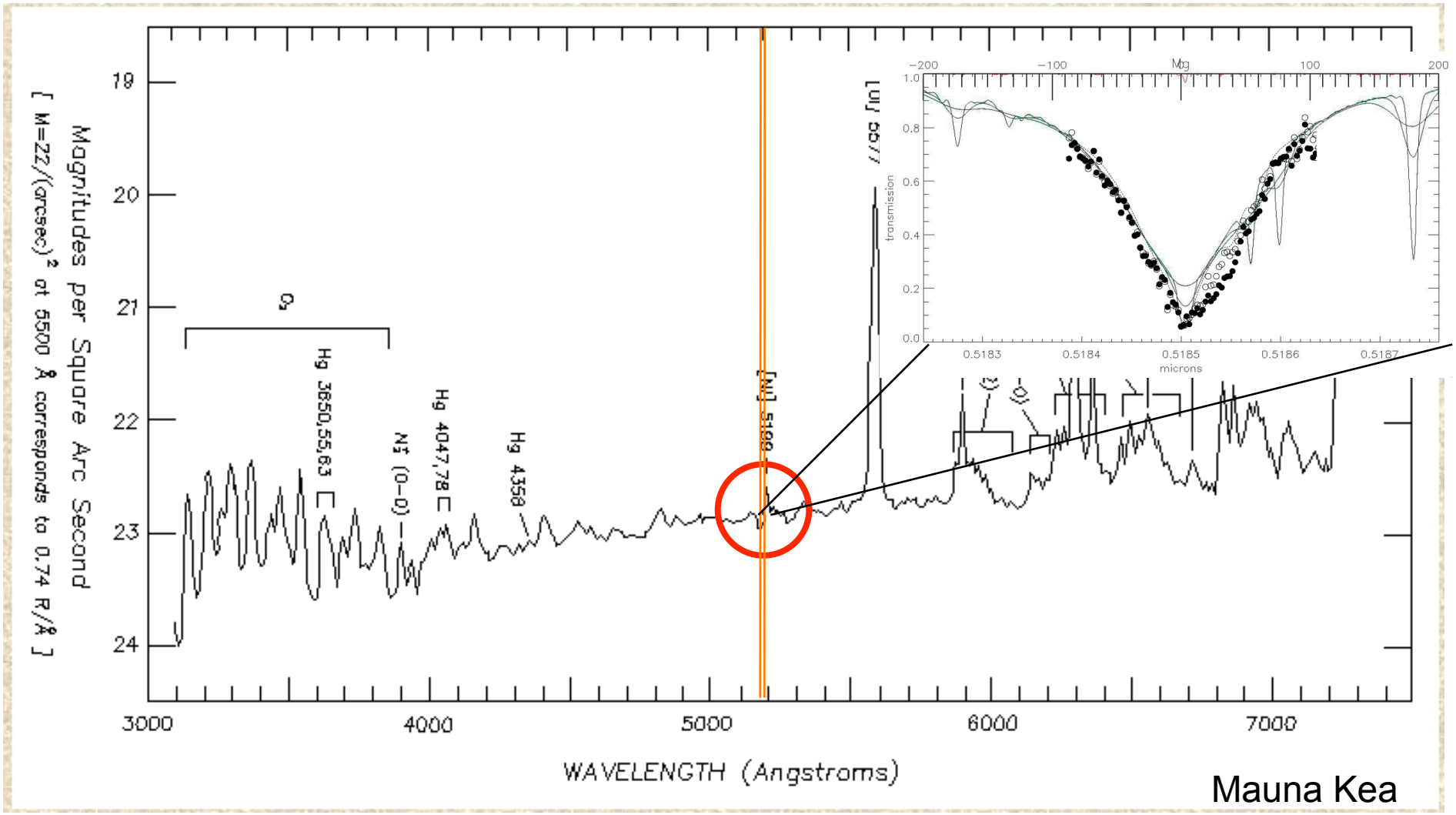


Fig. 6. New data, folded about the anti-solar point, to facilitate comparison with data of Fried and a simple model in which the dust is inclosed circular Keplerian orbits

I.R. East & N.K. Reay A&A (1984)

Night sky spectrum VIS

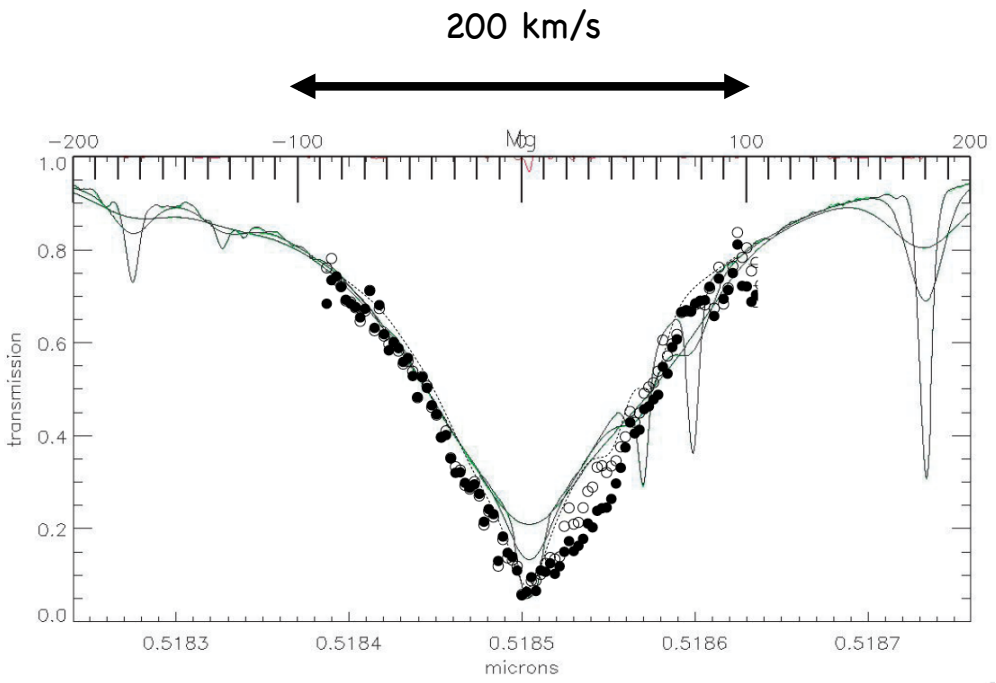


Zodiacal light spectroscopy

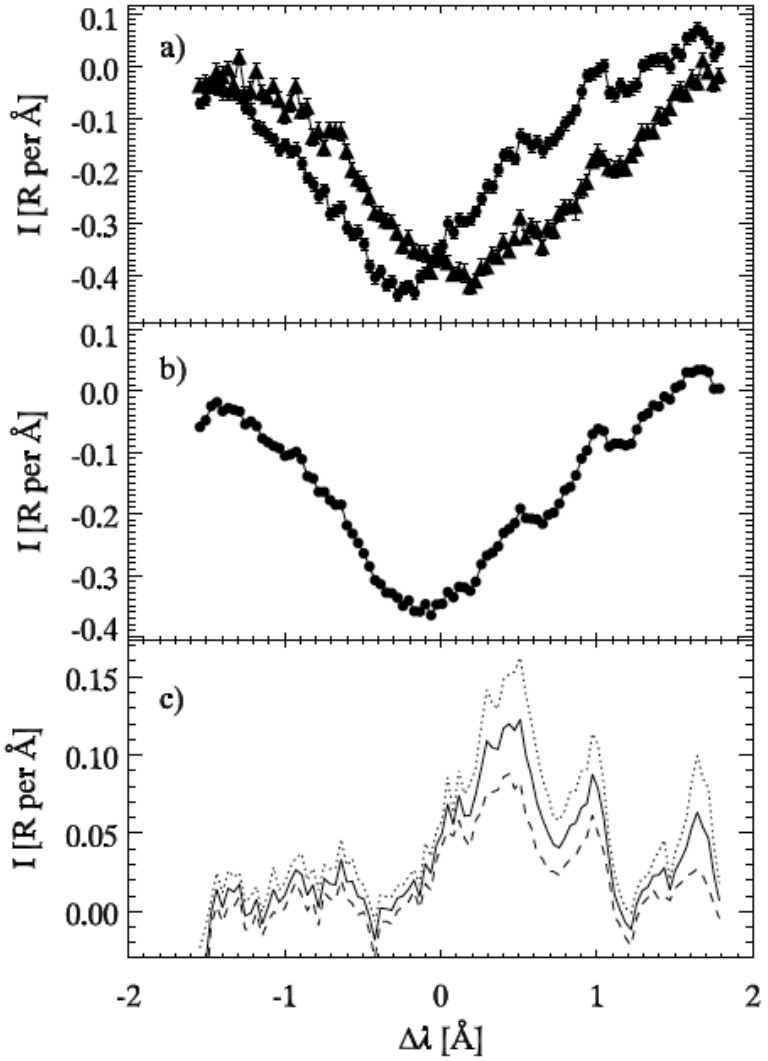
P. Hickson & A. Stockton

Zodiacal light Fraunhofer line spectroscopy by WHAM

- MgI 5184 first observations (R.Reynolds 2004)



T_{int}=30sec



Zodiacal light spec

Brian May: 2007 PhD thesis on Zodiacal light absorption spectrum

Brian May, rock band Queen guitarist completes Ph.D.

Thursday, July 31, 2008

Dream come true for Brian May. Brian May who plays the guitar and records music with the rock band Queen, has long been fascinated with astronomy. Finally, last year, he earned his PhD in astronomy from Imperial College London with his PhD thesis "A Survey of Radial Velocities in the Zodiacal Dust Cloud".

the subject of relatively little researcl
1970 and completed his research an
guitar in the well-known rock band Qu

Queen's Guitarist Publishes Astrophysics Thesis

By Space.com Staff
posted: 01 August 2008 12:36 pm ET

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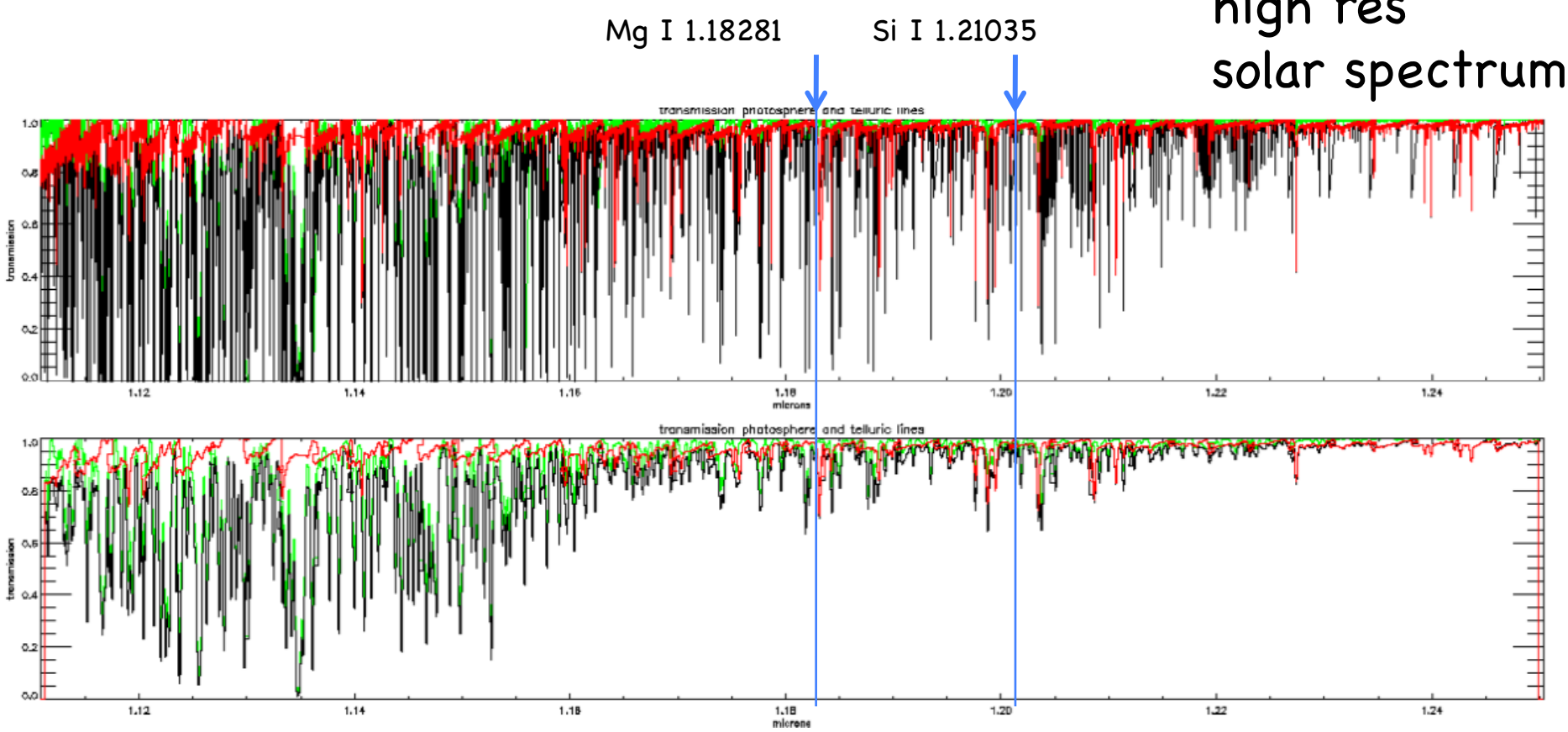
The founder of the legendary rock band Queen has completed his doctoral thesis in astrophysics after taking a 30-year break to play some guitar.

Brian May's thesis examines the mysterious phenomenon known as Zodiacal light, a misty diffuse cone of light that appears in the western sky after sunset and in the eastern sky before sunrise. Casual observers, if they live under very dark rural skies, can best see the light two to three hours before sunrise as they look east, and many people have been fooled into seeing it as the first sign of morning twilight. A Persian astronomer who lived around the 12th century referred to it as "false dawn" in a poem.

Astronomers now know that Zodiacal light represents reflected sunlight shining on scattered space debris

Dr Brian May CBE was confirmed as the new Chancellor for Liverpool John Moores University following a unanimous decision by the University's Governing Body in November 2007. The image includes Pro-Chancellor and Chairman of the Board, Sir Malcolm Thornton , LJMU's new Chancellor Dr Brian May and Vice Chancellor Professor Michael Brown. Credit: LJMU

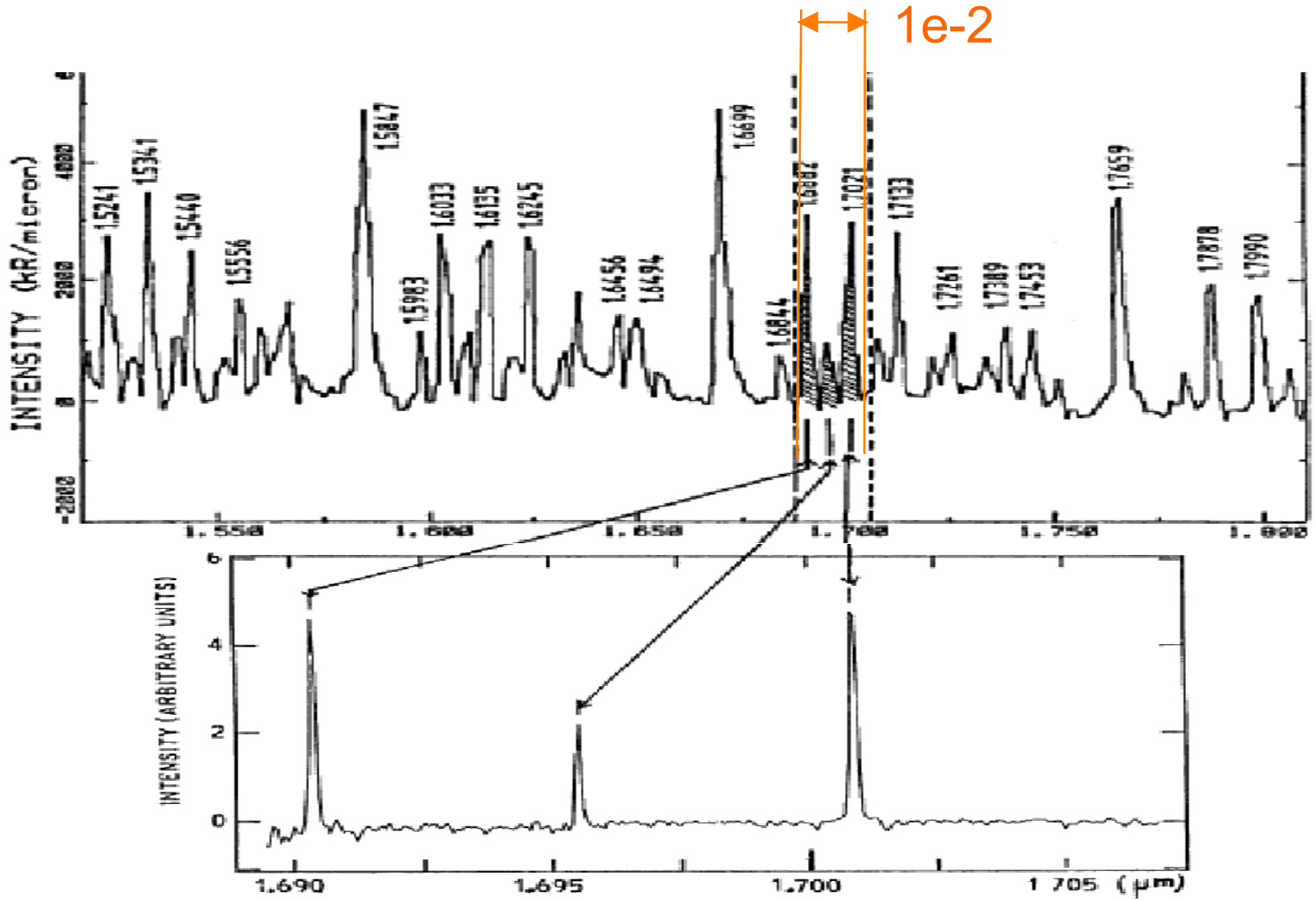
Line selection



- Solar spectrum
- Telluric lines
- solar+telluric

high res solar spectrum - convolved 25km/s FWHM profile

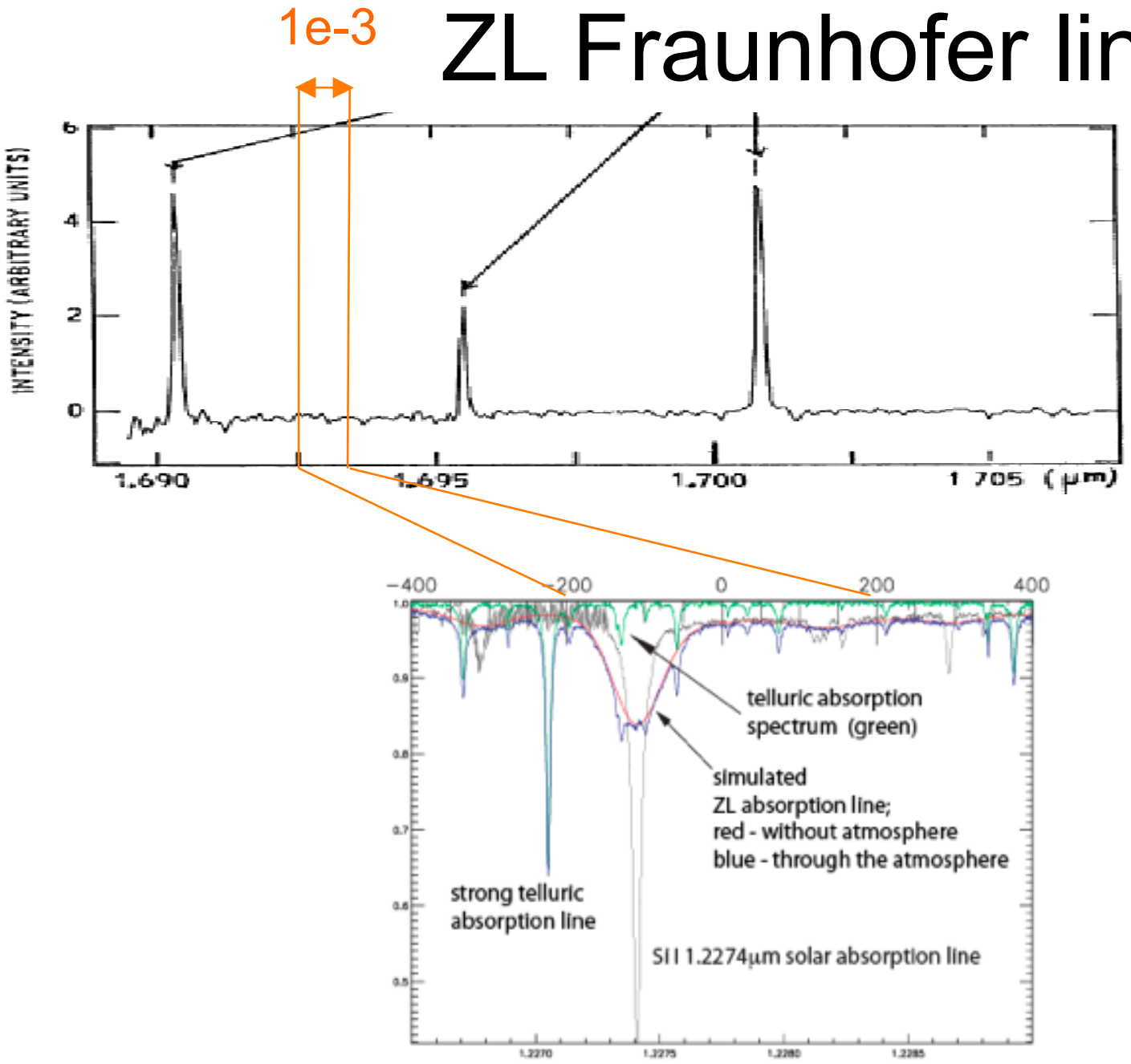
Nightglow emission lines



Zodiacal light spectroscopy

1.690 1.695 1.700 1.705

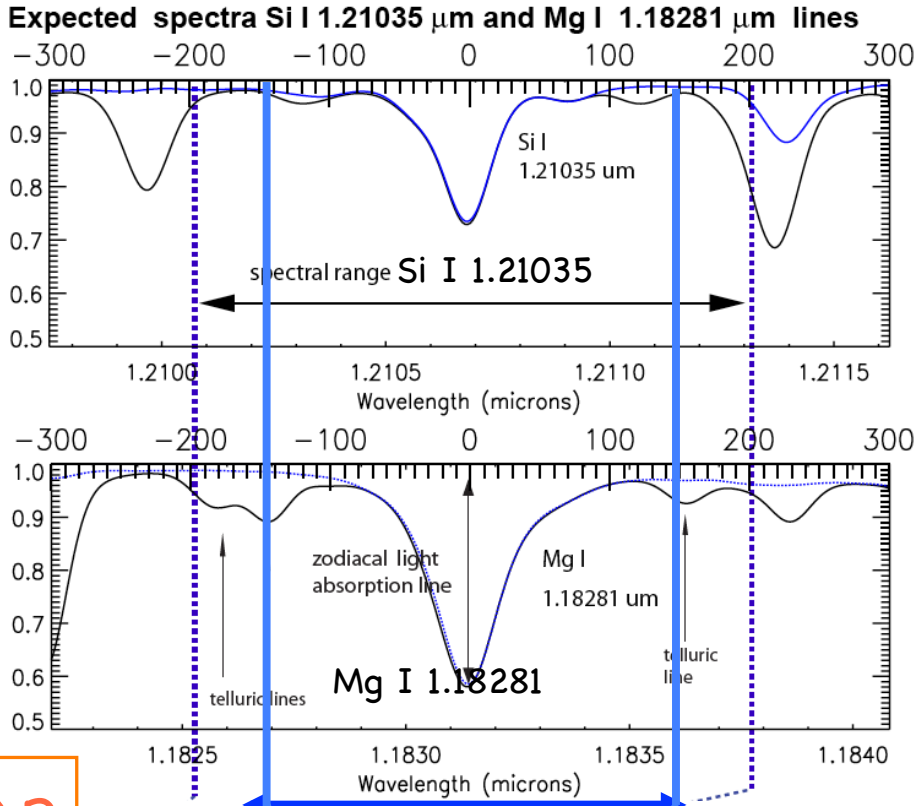
ZL Fraunhofer line



Maihara (1993)

Zodiacal light Fraunhofer line IR spectroscopy

- IR spectrometry of selected lines (J band)



continuum

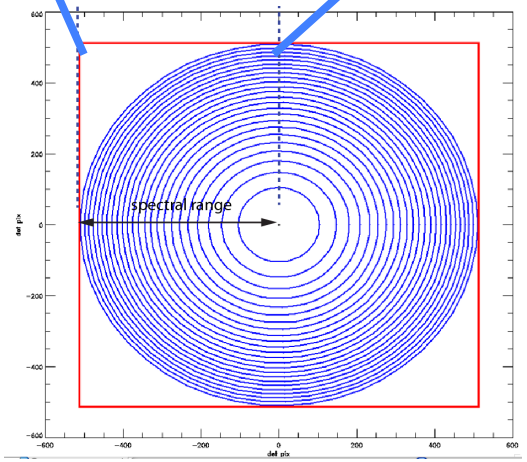
line equivalent width

continuum intensity

ZL MAP

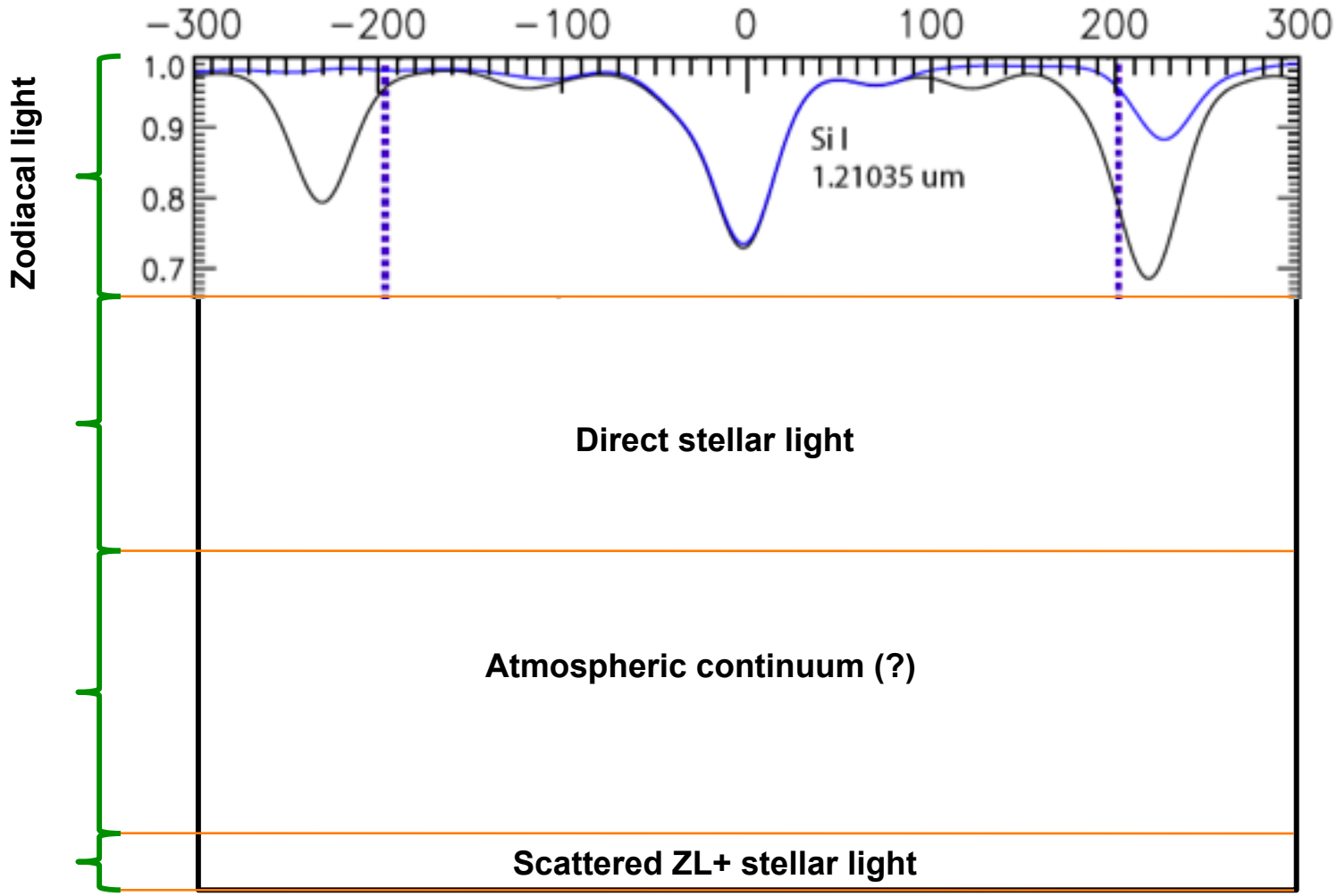
- V(λ,ε)
- Line width
- ZL kinematics
- dynamic models

300 km/s

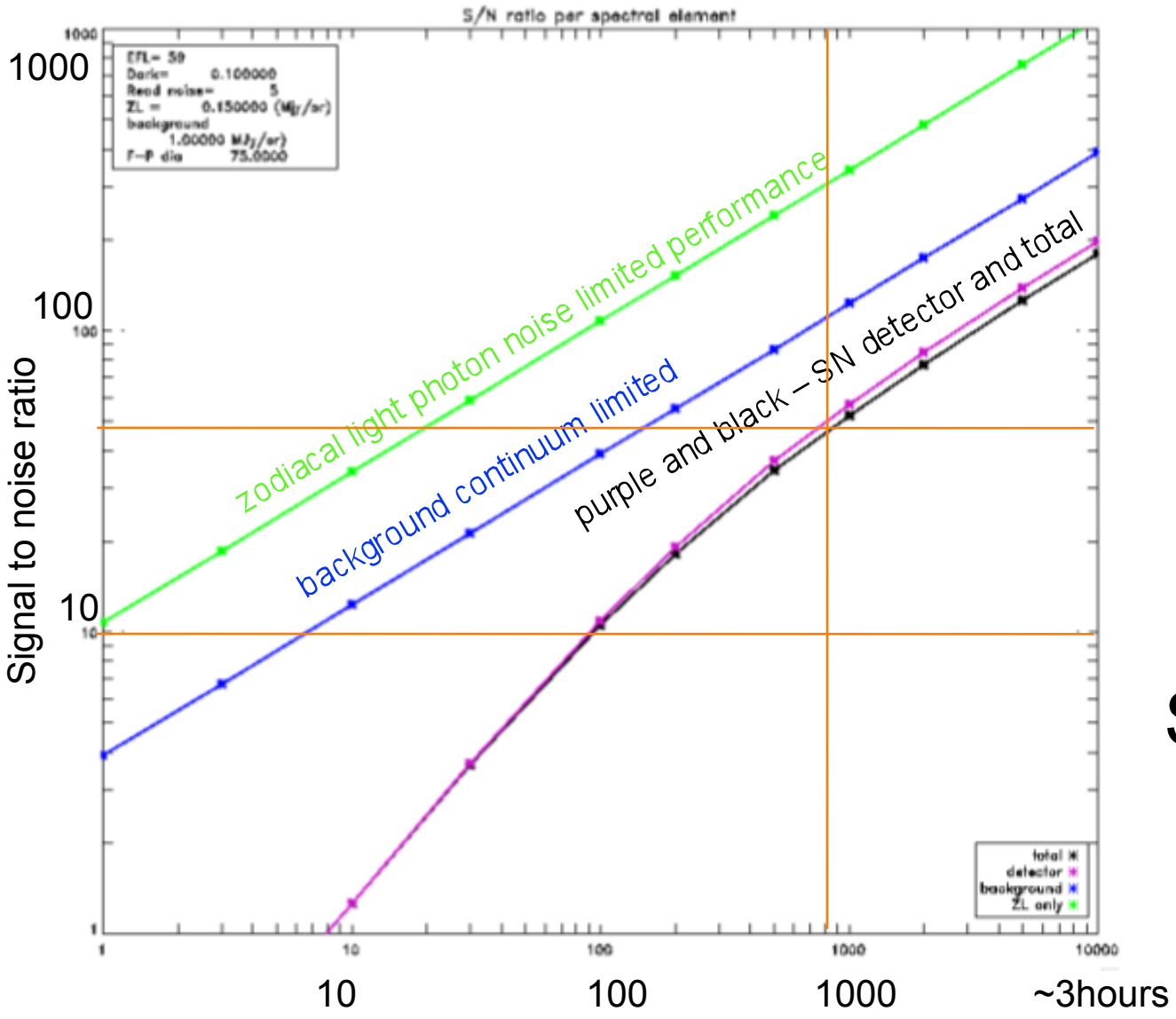


Zodiacal light spectroscopy

Contributing sources



Zodiacal light spectroscopy



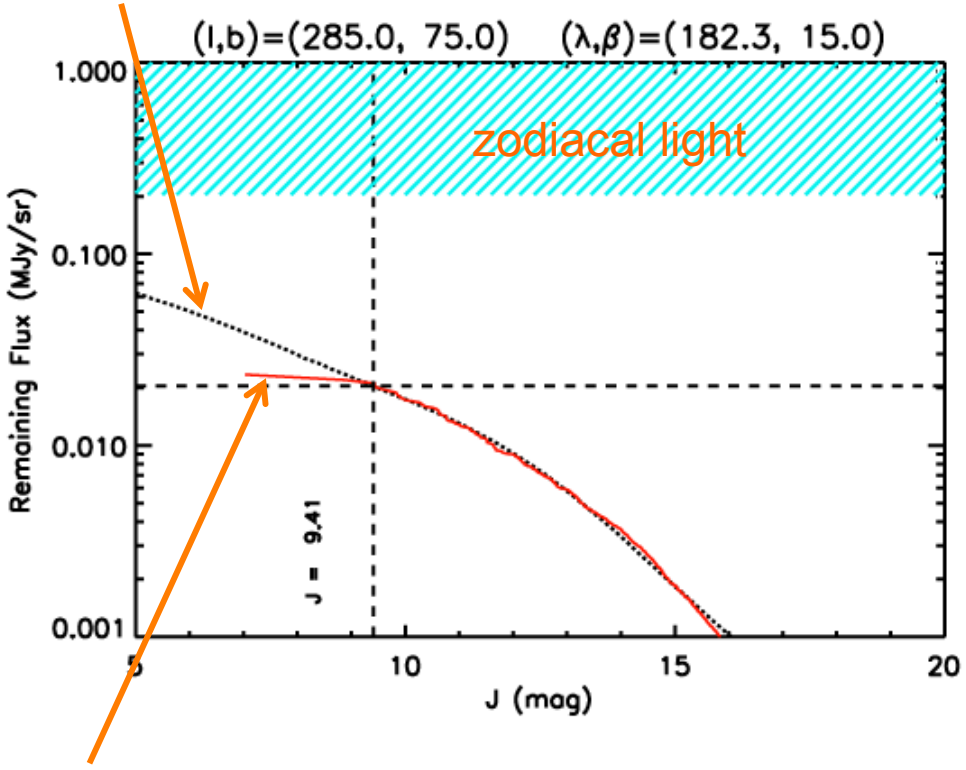
Photon noise

SN=50 in ~15 minutes

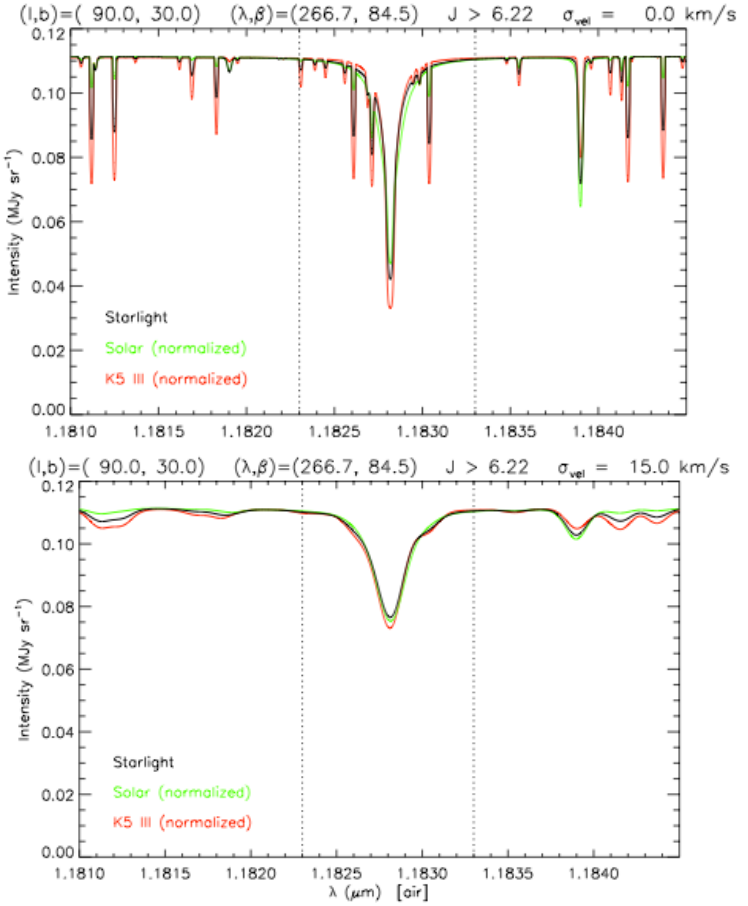
Zodiacal light spectroscopy

Stellar component background

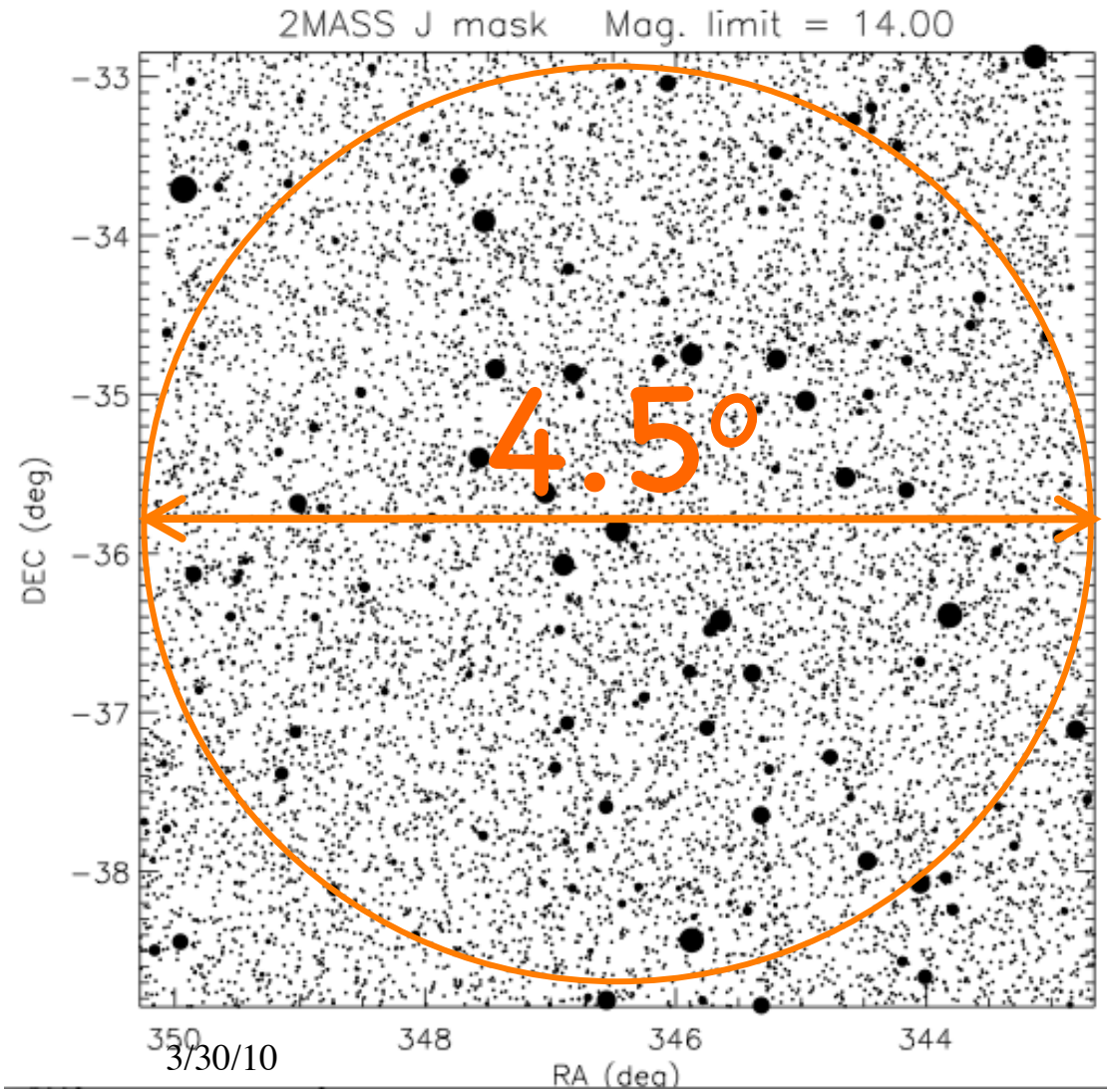
model prediction



2MASS point source count



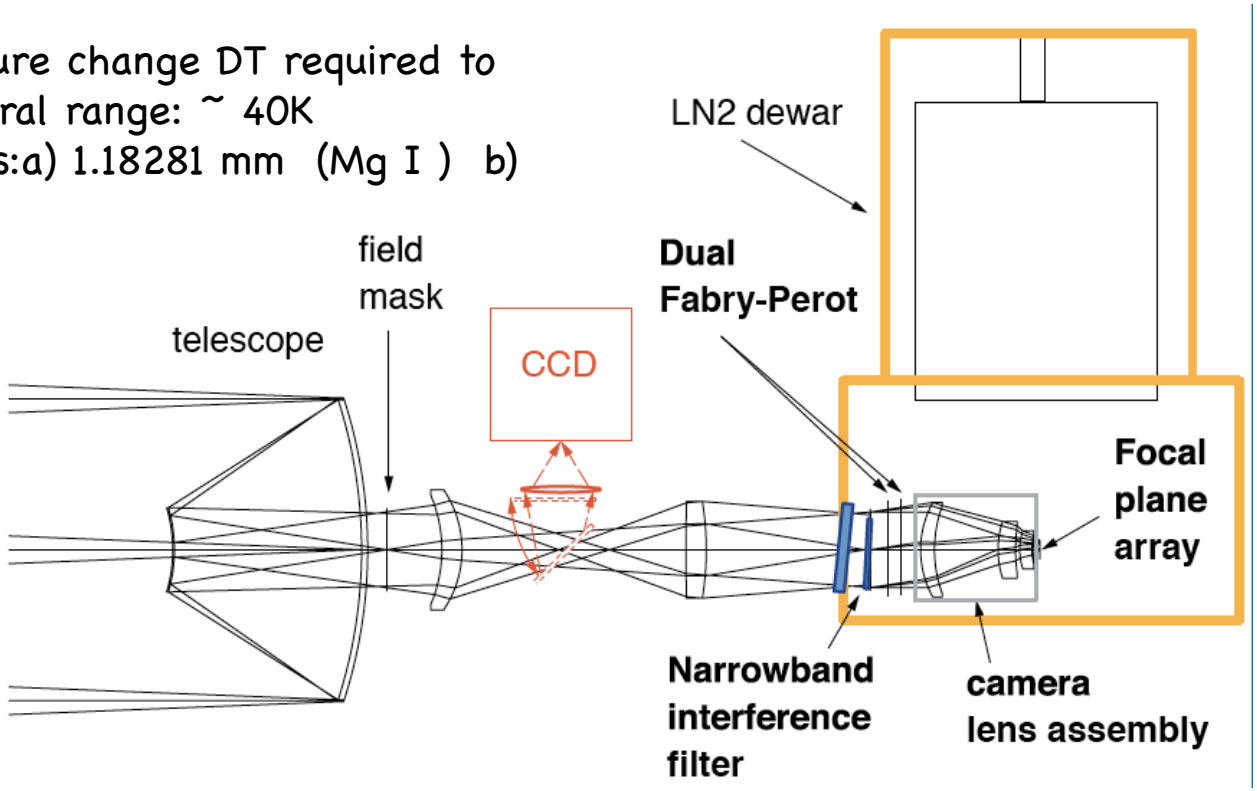
Stellar masks



- mask out stars to J_{lim} to reduce stellar contribution to ≤ 0.1 of ZL brightness
- ZL area loss: 10%-15%

ZL spectrometer - instrumentation solution

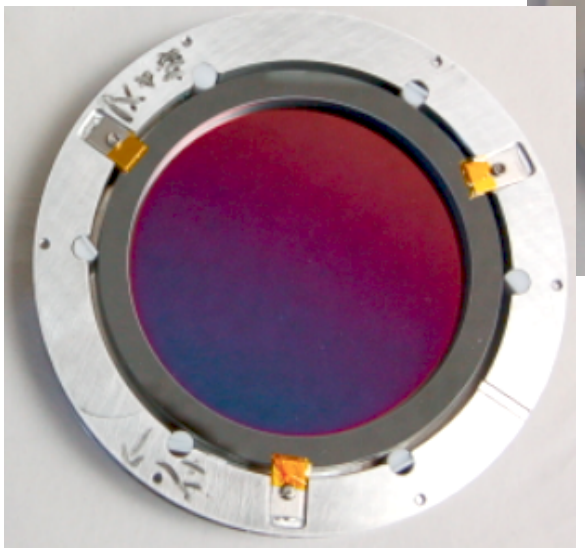
- Solid silicon dual etalon 0.25 mm and 0.3 mm thick
- High Spectral resolution - 2 x10^4
- Spectral range 300 km/s
- Clear aperture 75 mm
- Operation mode: pupil imaging (integral spectrum)
- 4.25° beam on the sky (non-imaging mode)
- Simultaneous acquisition of the whole spectrum (ring summing)
- Temperature tuning: temperature change DT required to tune over the etalon free spectral range: ~ 40K
- observing in two spectral lines:a) 1.18281 mm (Mg I) b) 1.21035 mm (Si I)
- 1024 x 1024 HAWAII I FPA

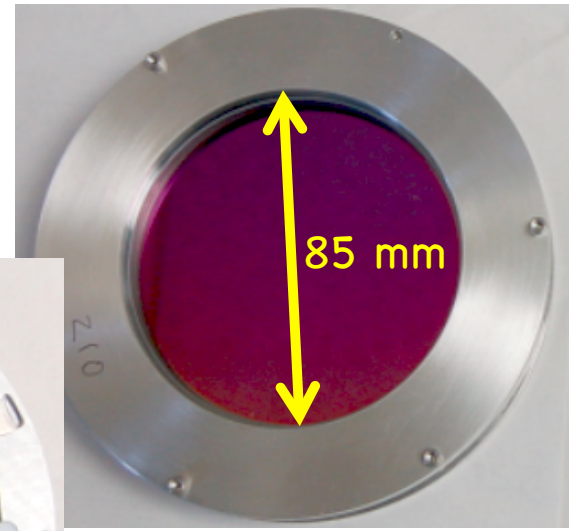


Zodiacal light spectroscopy

Dual etalon spectrometer

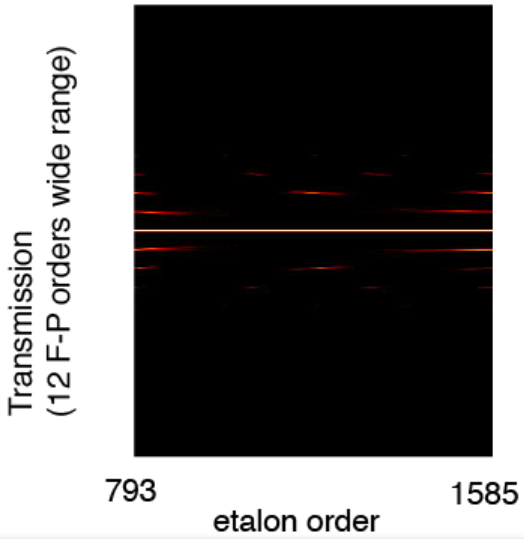
- Silicon etalons ***IMMERSION (!)***
  - 100 mm dia (85mm CA)
  - thickness 210 um and 250 um
- Temperature tuned
  - ≈10K per order

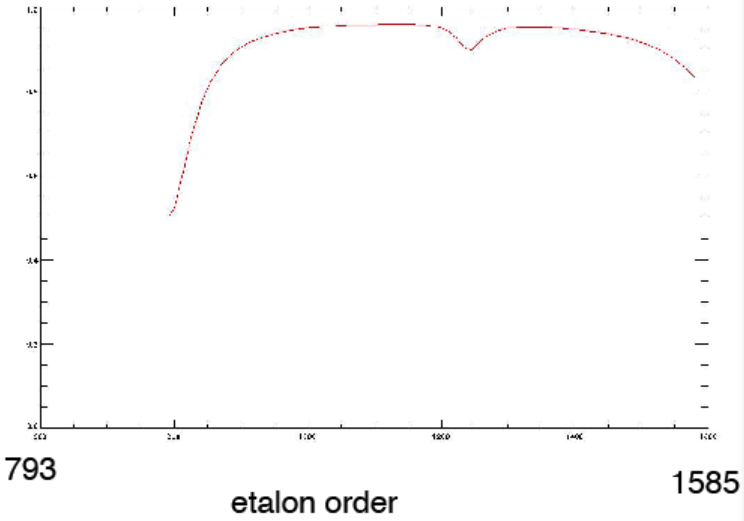




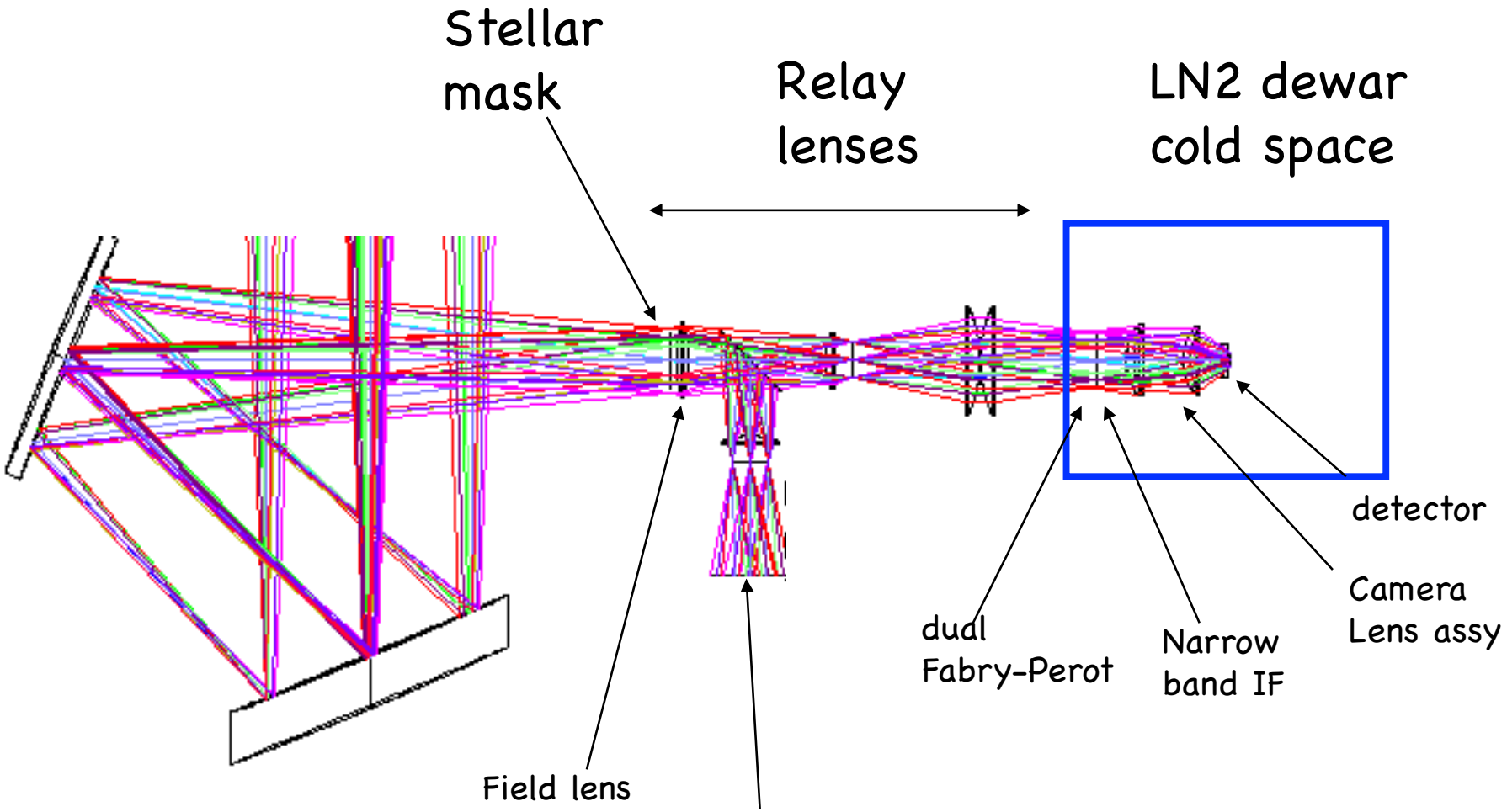
Mounted 210um (above) and 250um (left) Si etalons

Out of band rejection quality model

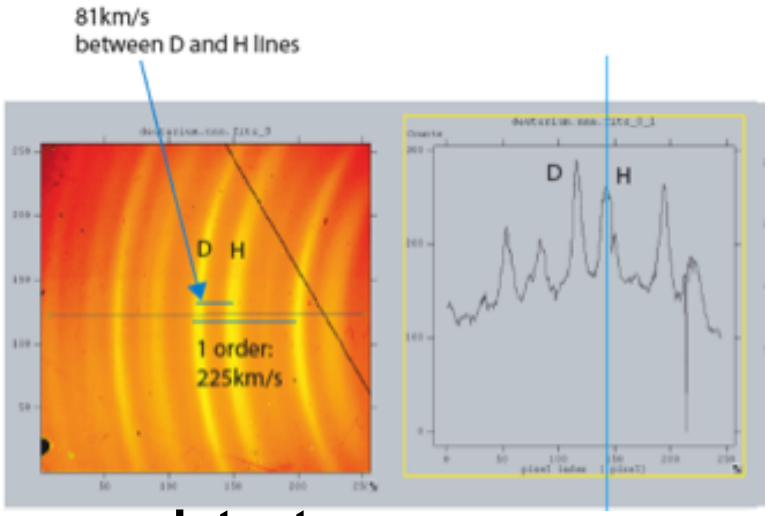




ZL spectrometer optical layout



Instrument *as of March 23, 2010*

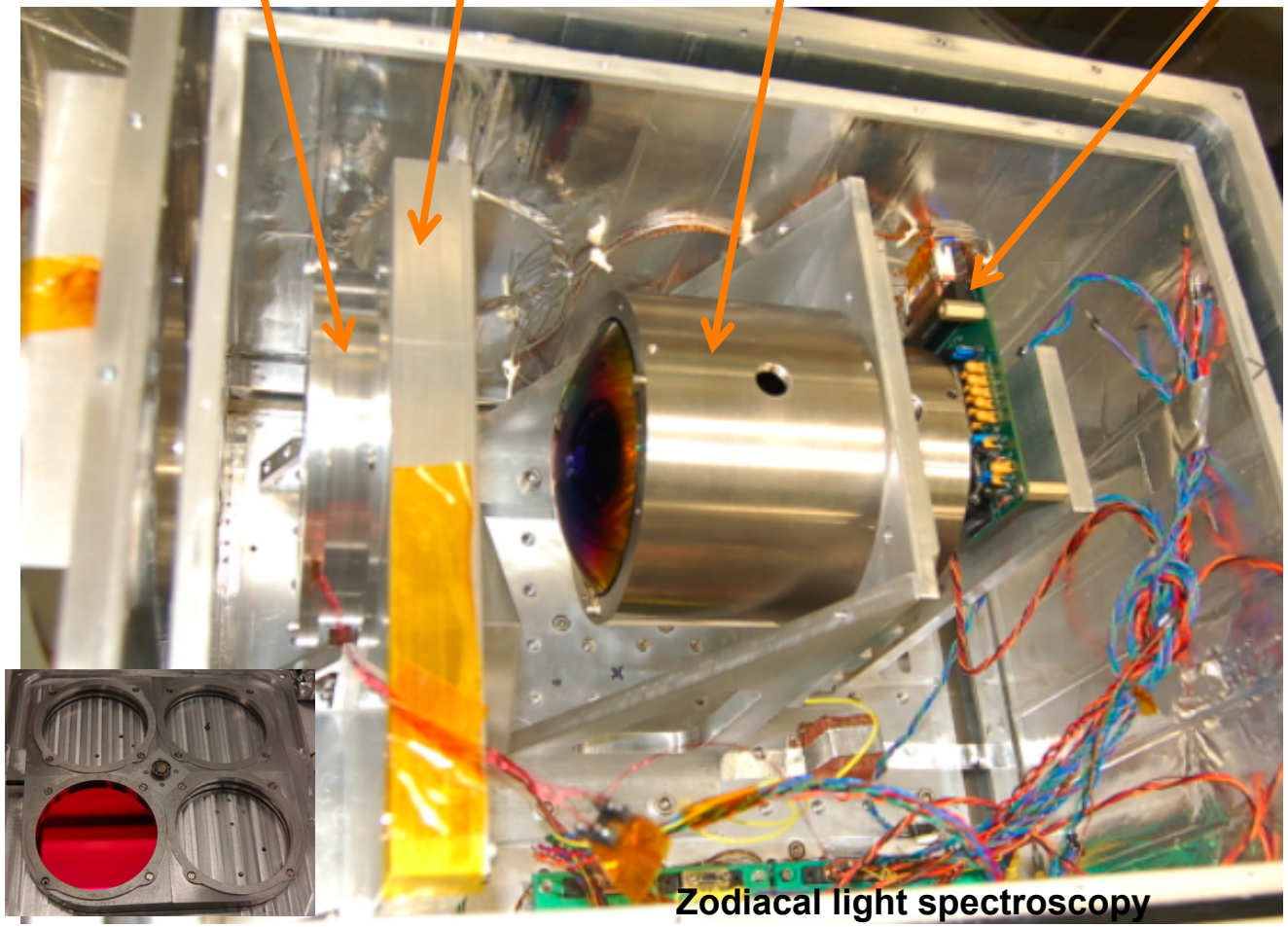


Fabry-Perot etalon

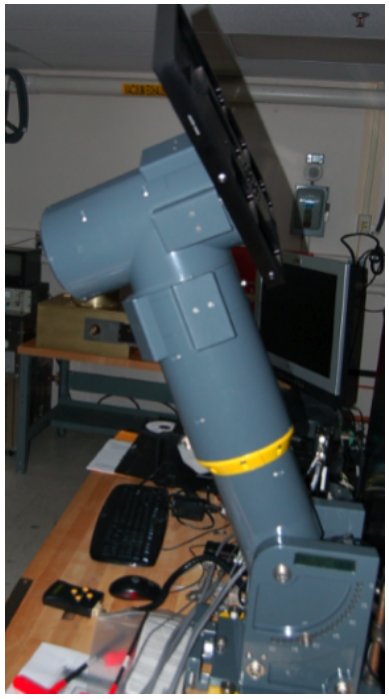
Filter box

Camera lens

detector



Zodiacal light spectroscopy



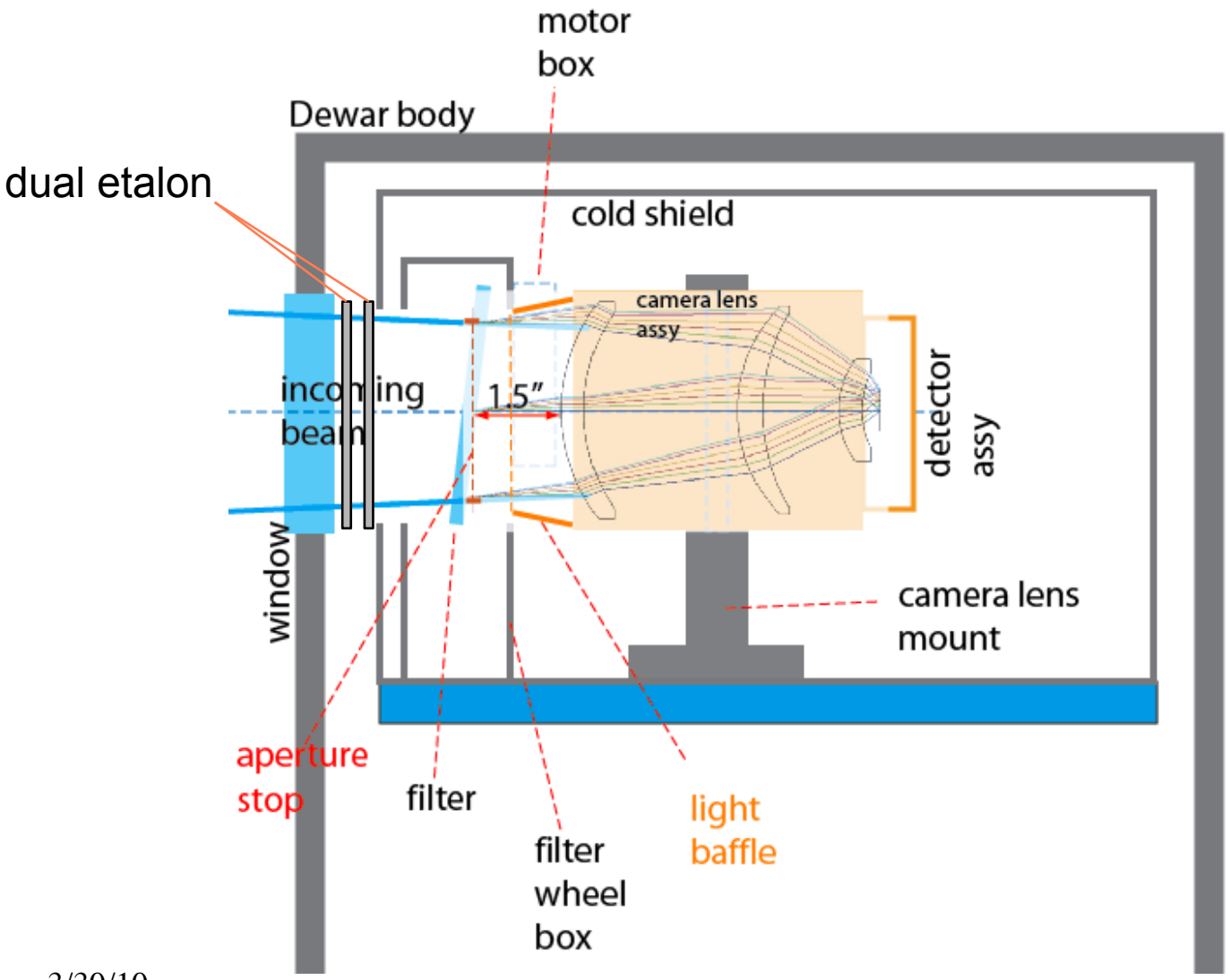
Summary

- Direct measurement of the zodiacal light brightness in COBE DIRBE J band:
  - improved accuracy of the infrared extragalactic background
  - measurements at several epoques - variability
- Zodiacal cloud kinematic and dynamics
  - V (λ,ε) maps
  - line(s) widths
- Potential for spaceborne or balloon instrument
- 5AU instrument
  - kinematics of ZL - view from the outside
  - view of "residual" ZL

- High Spectral resolution - 2 x10^4
- Large beam on the sky (non-imaging mode)
- High throughput
- Multiple lines

Backup slides

Spectrometer layout inside the dewar



Bryan May - PhD on zodiacal light after 30 years

as confirmed as the new Chancellor for Liverpool John Moores University following a unanimous decision by erning Body in November 2007. The image includes Pro-Chancellor and Chairman of the Board, Sir Malcolm ew Chancellor Dr Brian May and Vice Chancellor Professor Michael Brown. Credit: LJMU

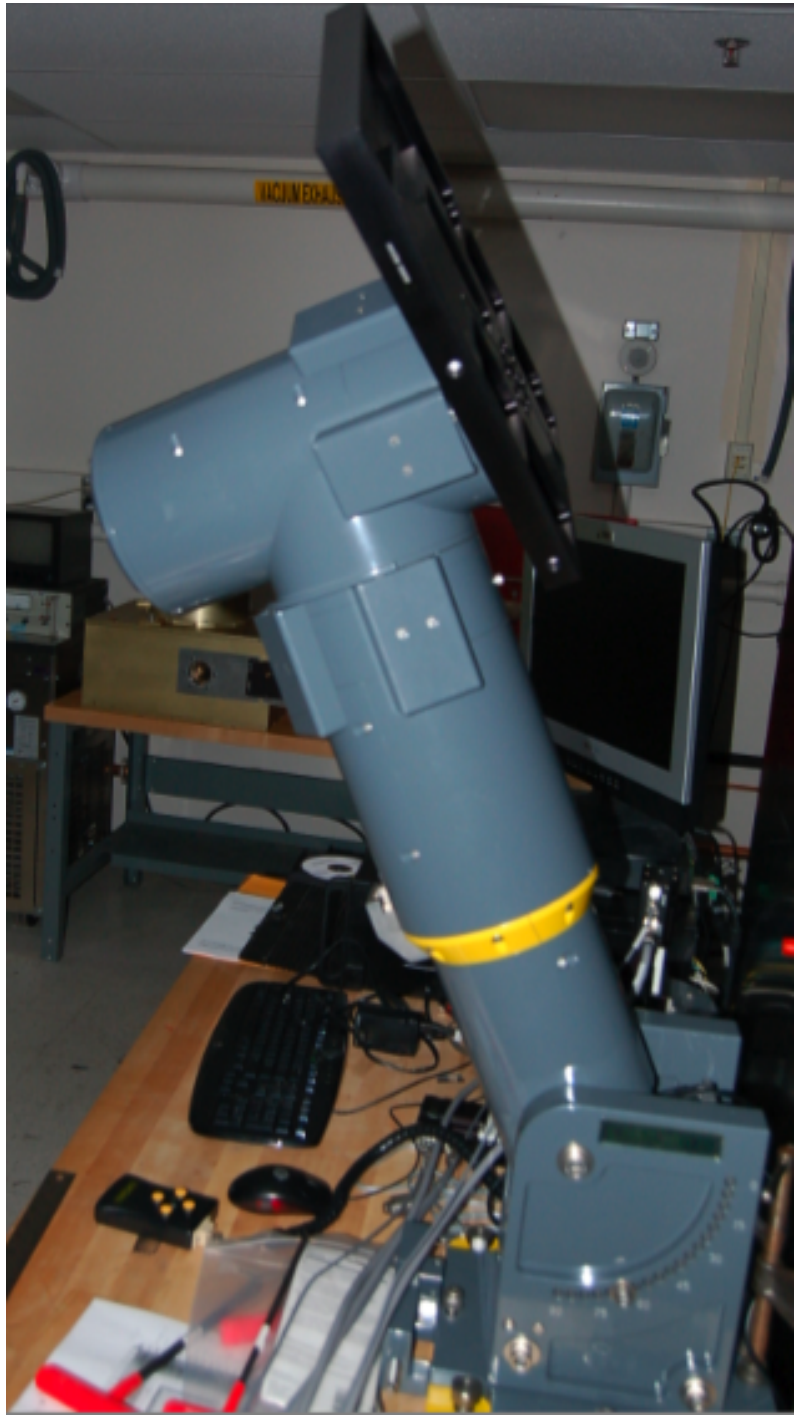
Brian May, rock band Queen guitarist completes Ph.D.

Thursday, July 31, 2008

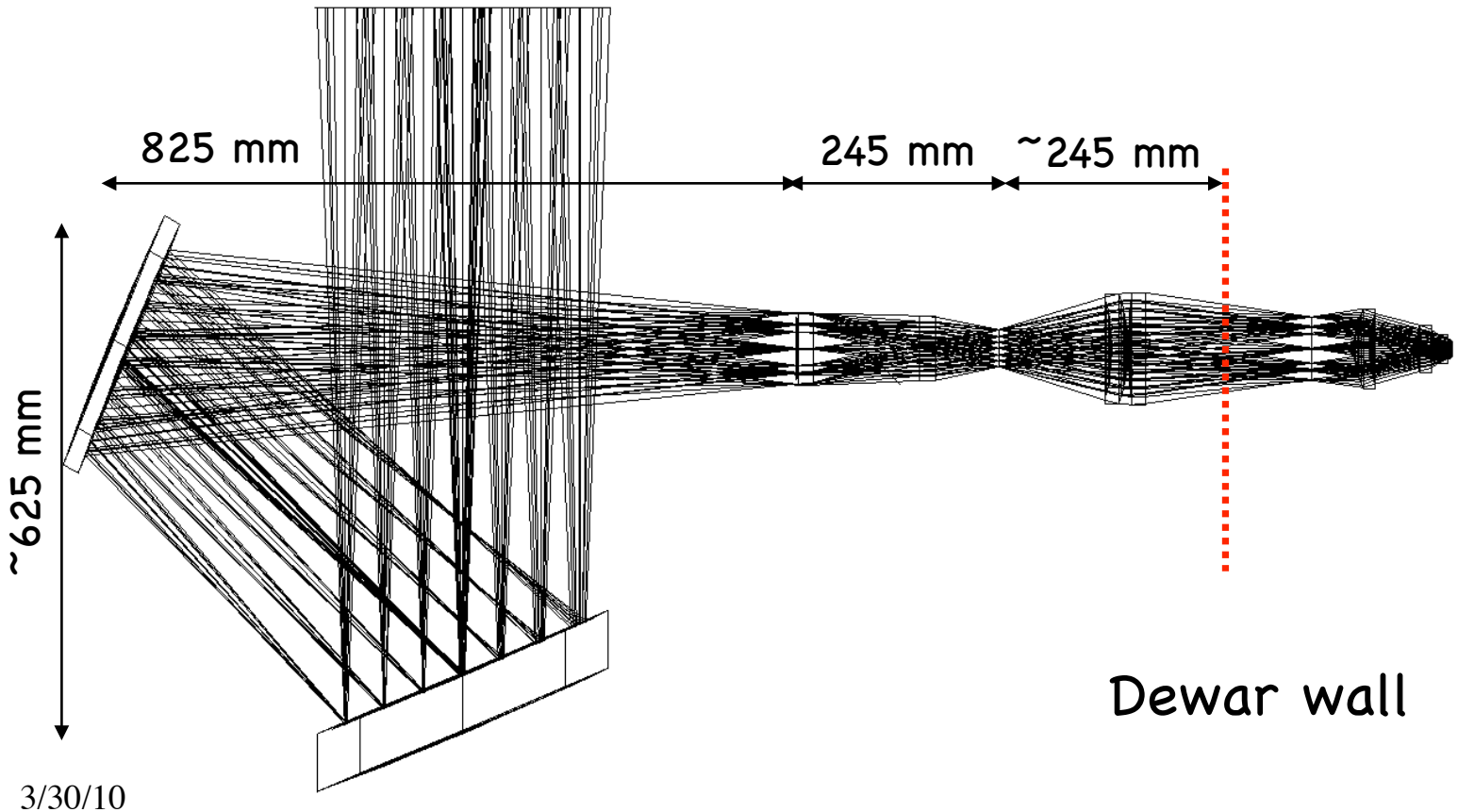
Dream come true for Brian May. Brian May who plays the guitar and records music with the rock band Queen, has long been fascinated with astronomy. Finally, last year, he earned his PhD in astronomy from Imperial College London with his PhD thesis "A Survey of Radial Velocities in the Zodiacal Dust Cloud".

May's thesis examines the Zodiacal Light, the misty diffuse cone of light seen in the West after sunset and the East before sunrise. Though anyone can see the Zodiacal Light from a suitably dark location, it is poorly understood, and has been the subject of relatively little research. May began his research of the Zodiacal Light in 1970 and completed his research and thesis in 2007, following a 30-year hiatus to play guitar in the well-known rock band Queen.

Instrument mount



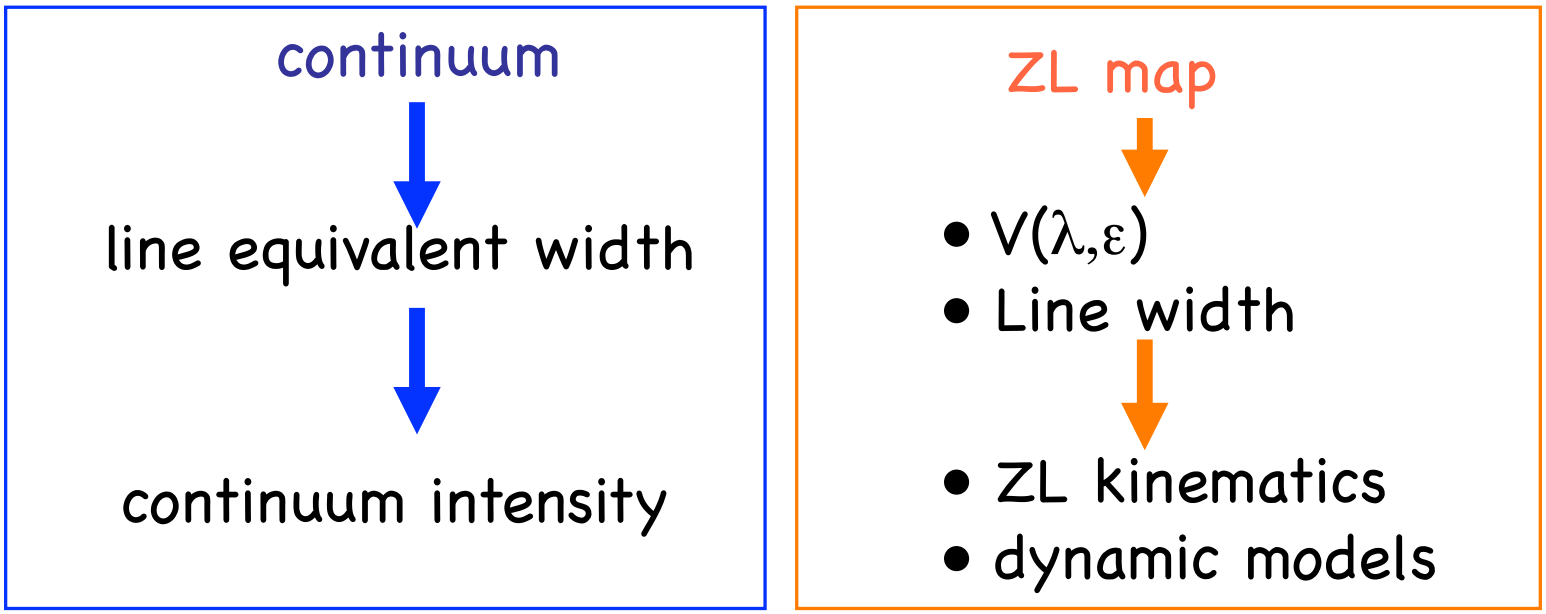
Zodiacal light spectrometer Dragone system folded



Zodiacal light Fraunhofer line spectroscopy in NIR

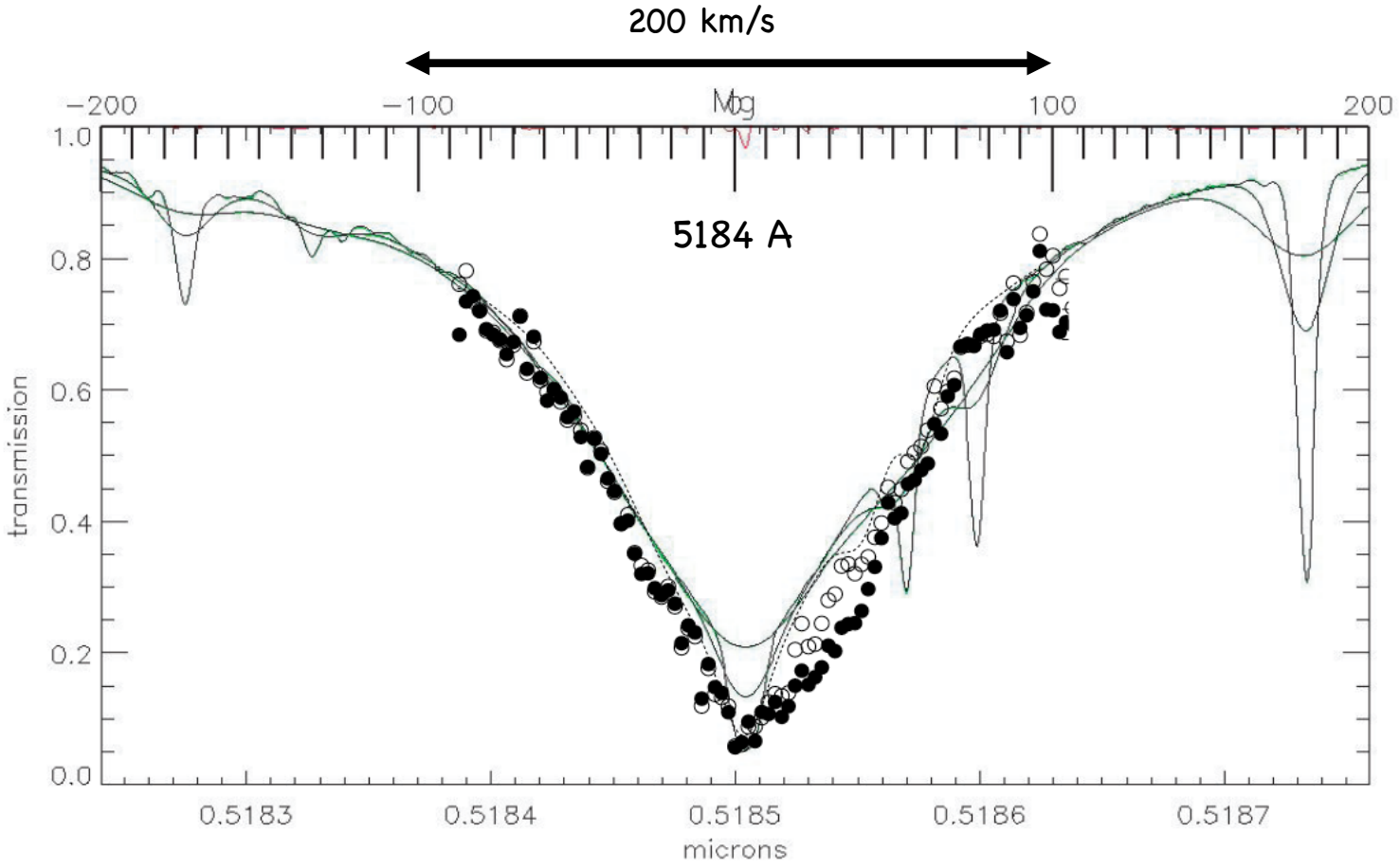
- IR spectrometry of selected lines

  J band



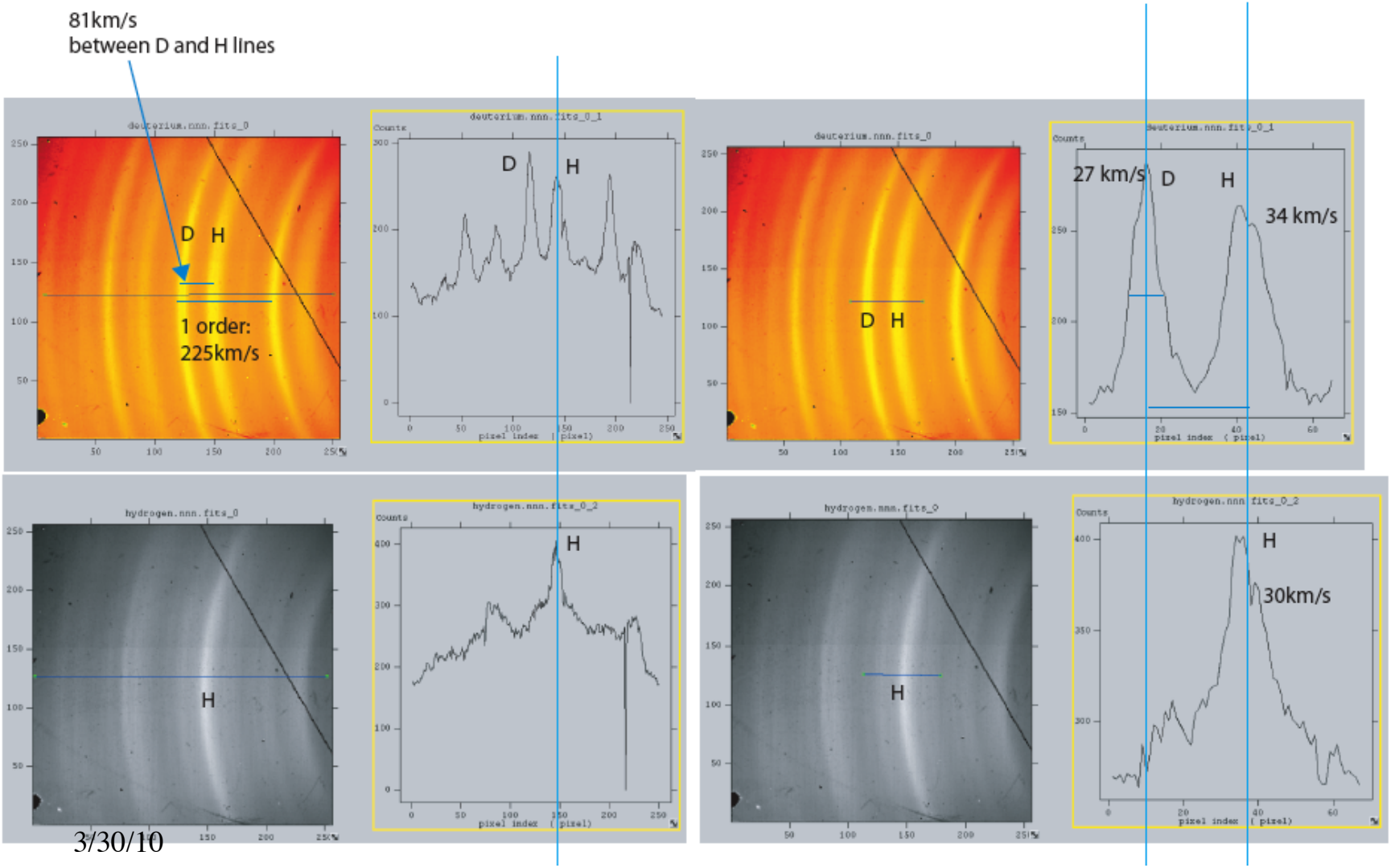
Zodiacal light Fraunhofer line spectroscopy

- MgI 5184 first observations (R.Reynolds 2004)

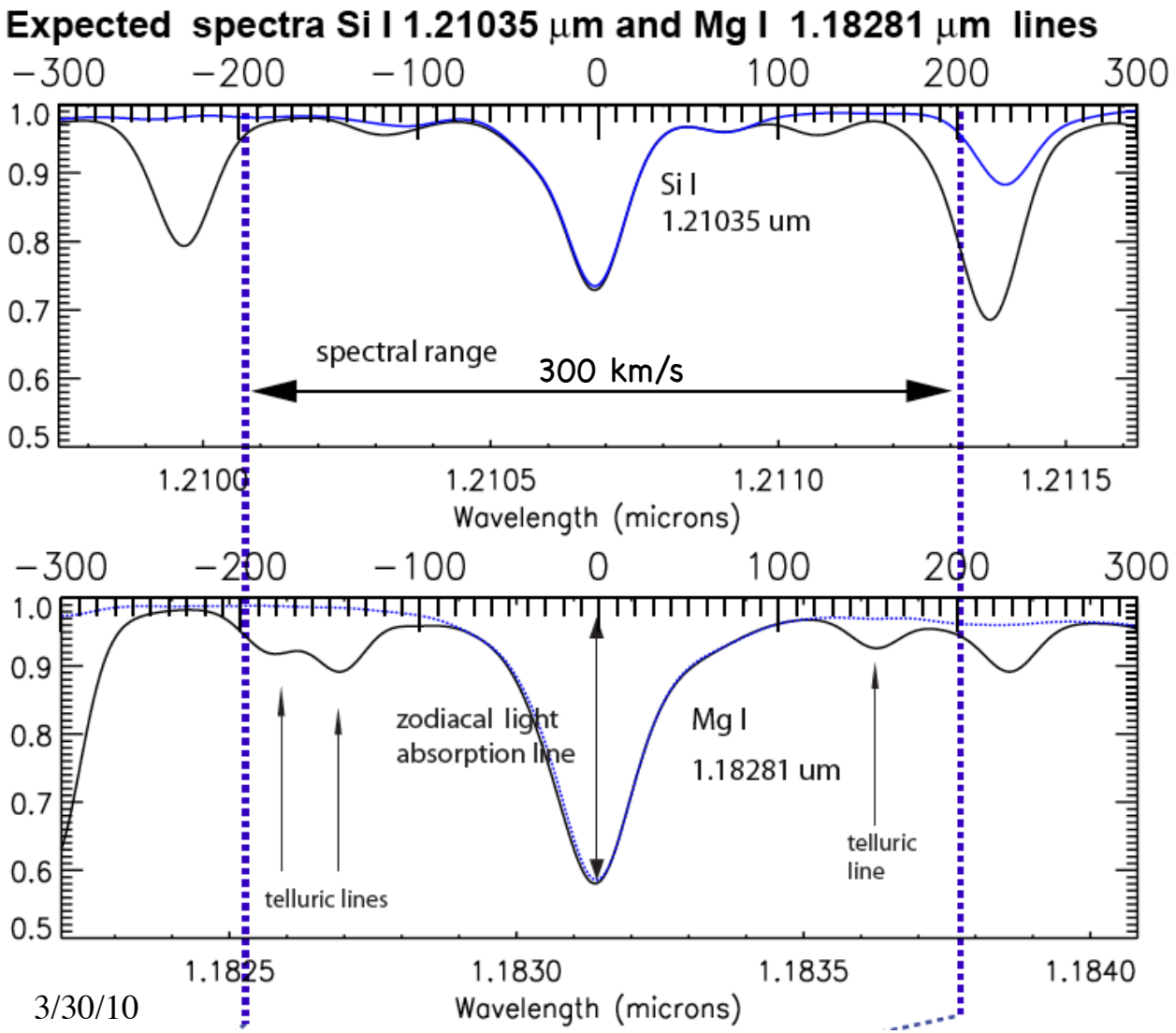


Etalon lab spectra

Deuterium+hydrogen spectral source



Selected Lines

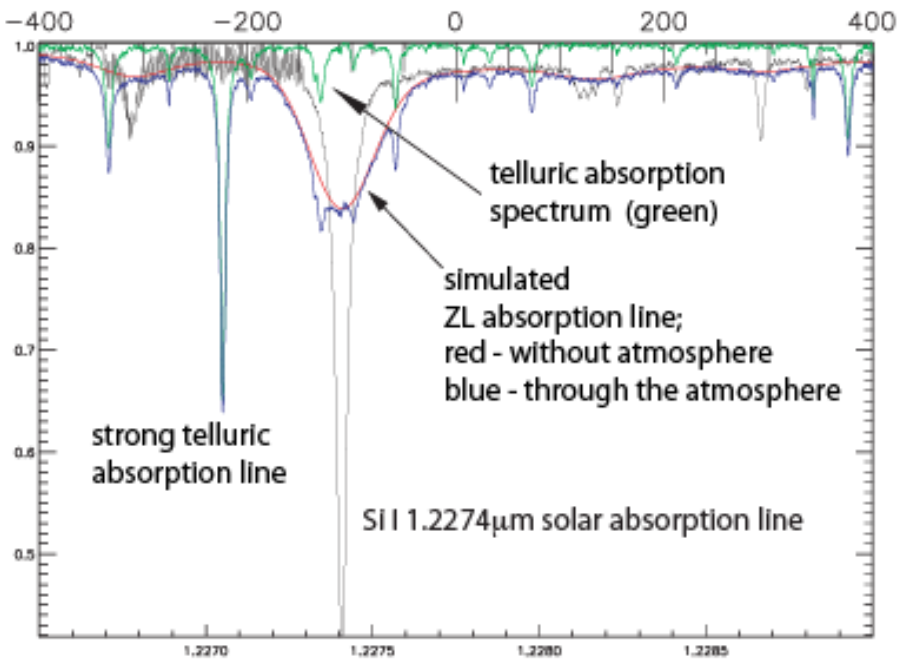


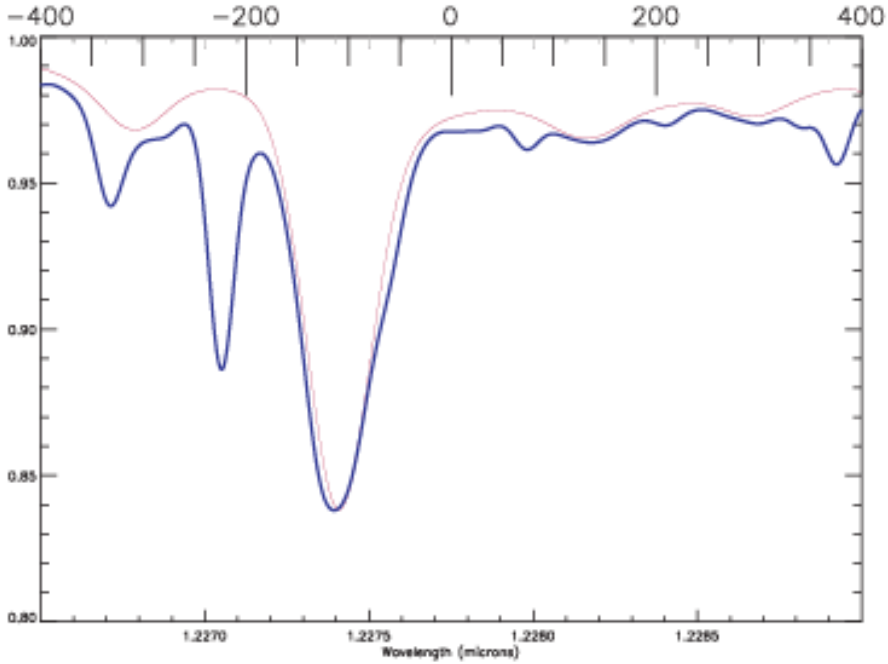
Si I 1.21035

Blue – solar spectrum
Black – solar+telluric
(both are convolved with 25km/s line profile)

Mg I 1.18281

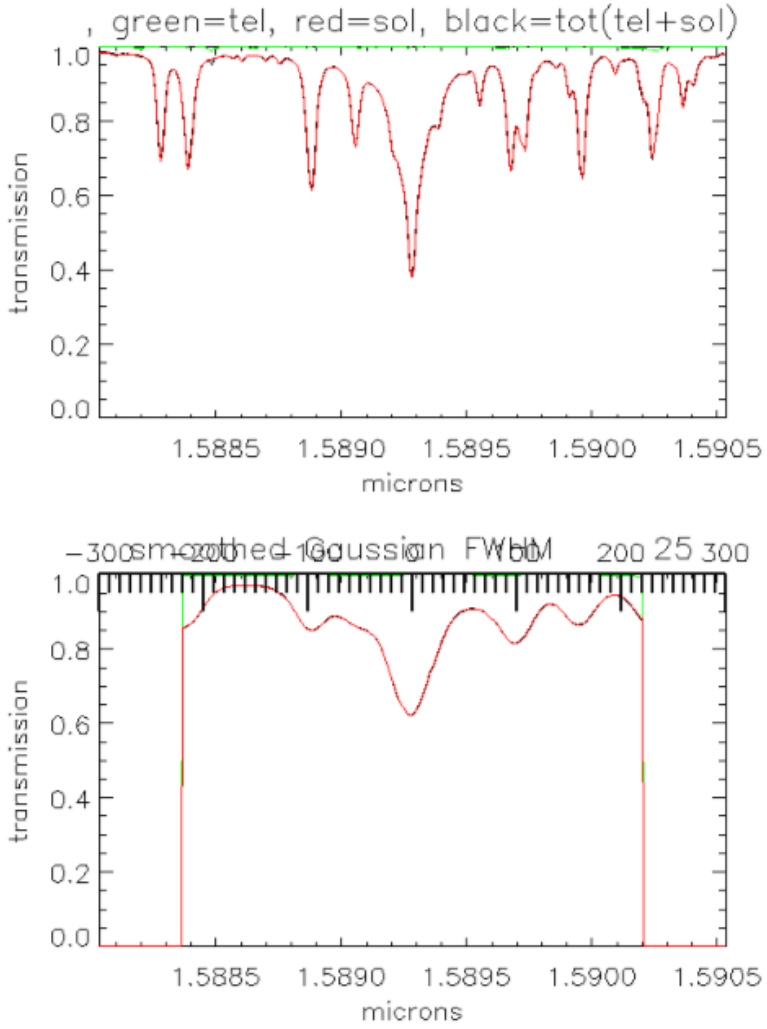
IR Fraunhofer line selction

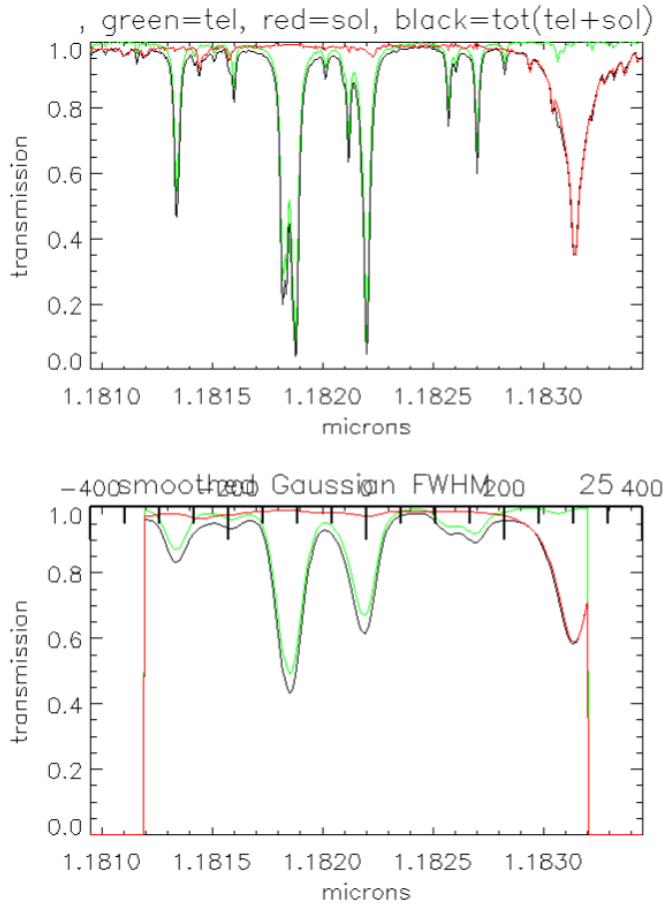




Zodiacal light spectroscopy

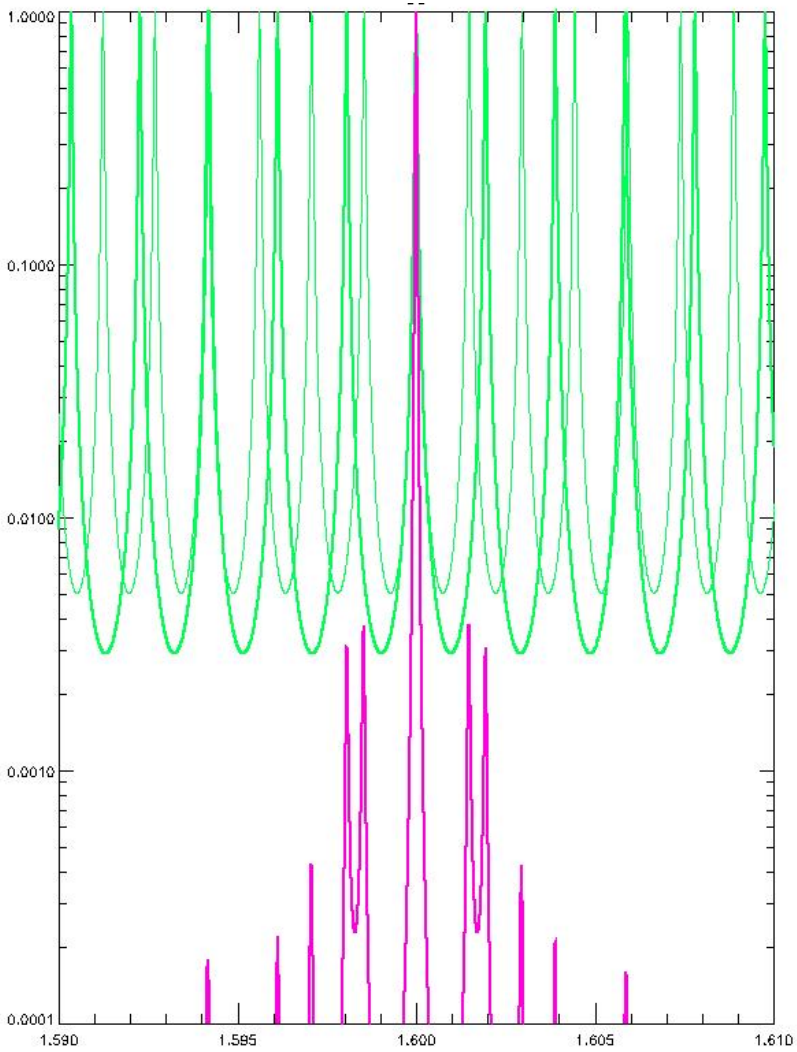
Lines selection

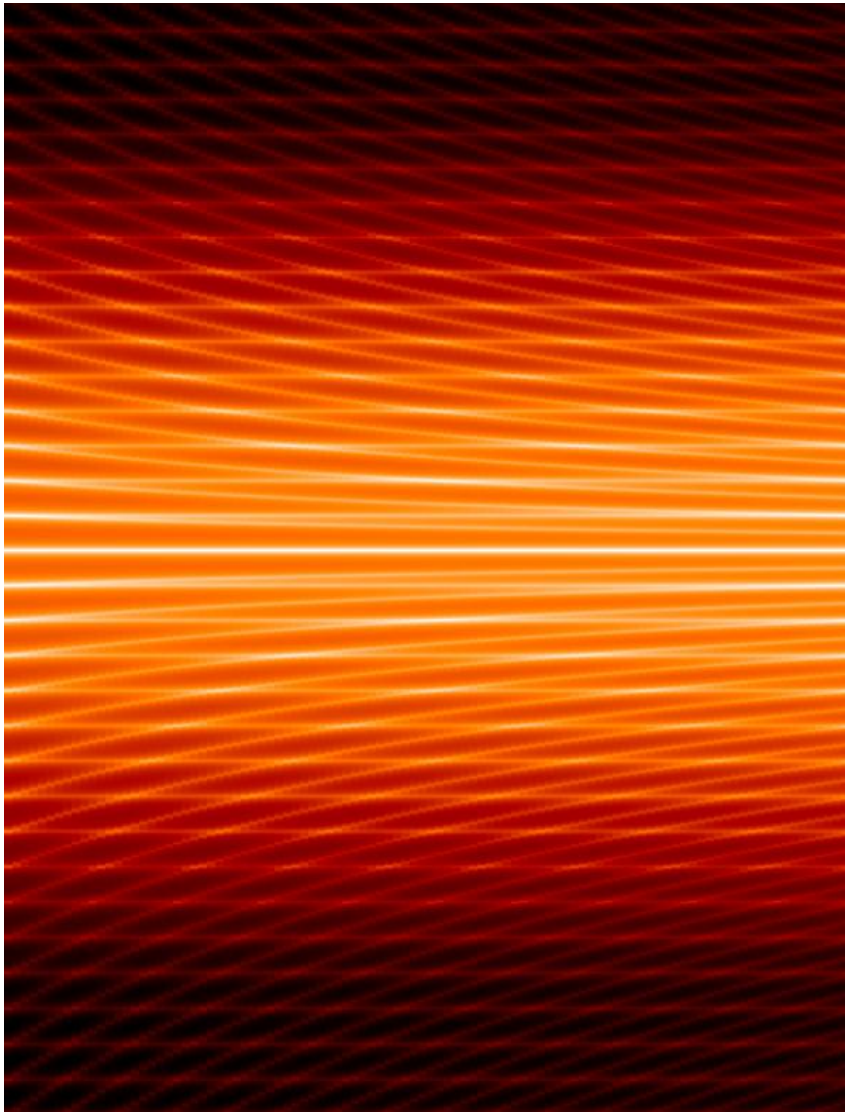




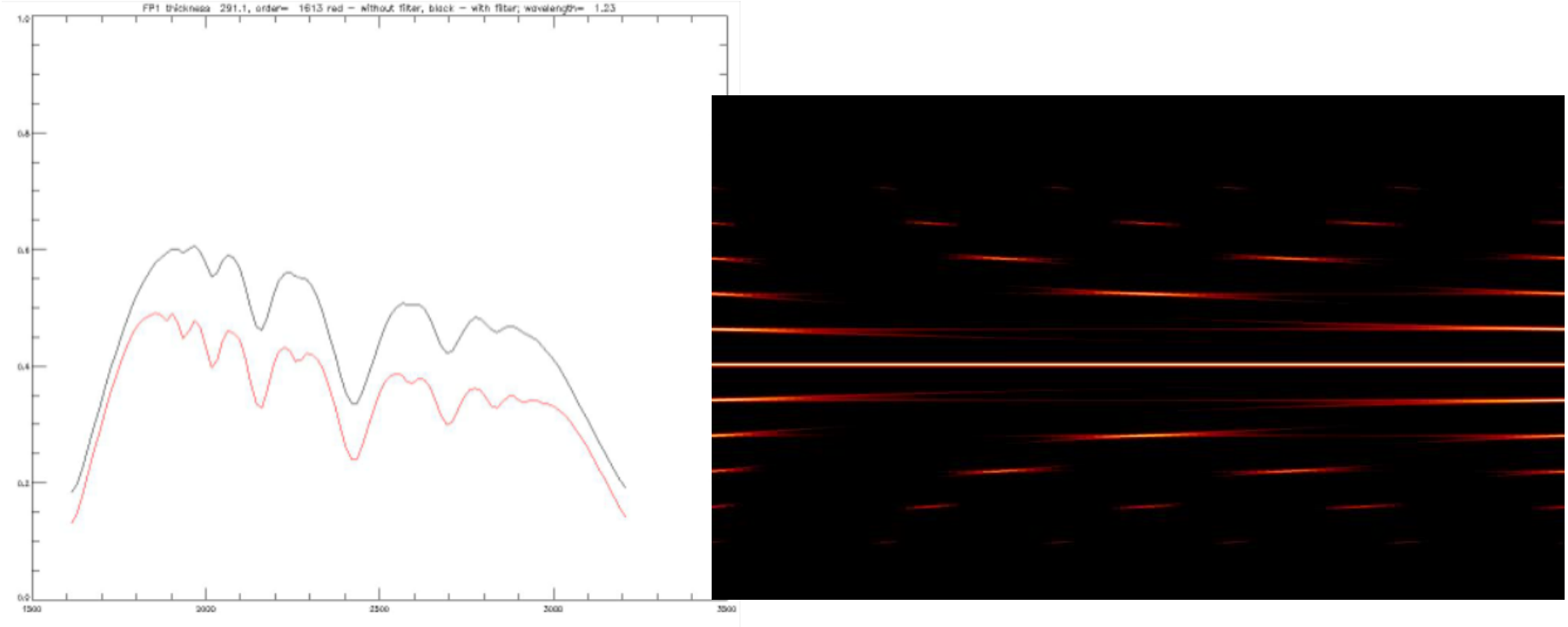
Zodiacal light spectroscopy

Dual etalon transmission





Zodiacal light spectroscopy



Zodiacal light spectroscopy