Search for Chiral Signatures
by Circular Polarization Spectroscopy

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Towards Other Earths, Porto, 2009

I   Chirality as Biomarker

II Sensing Circular Dichroism:
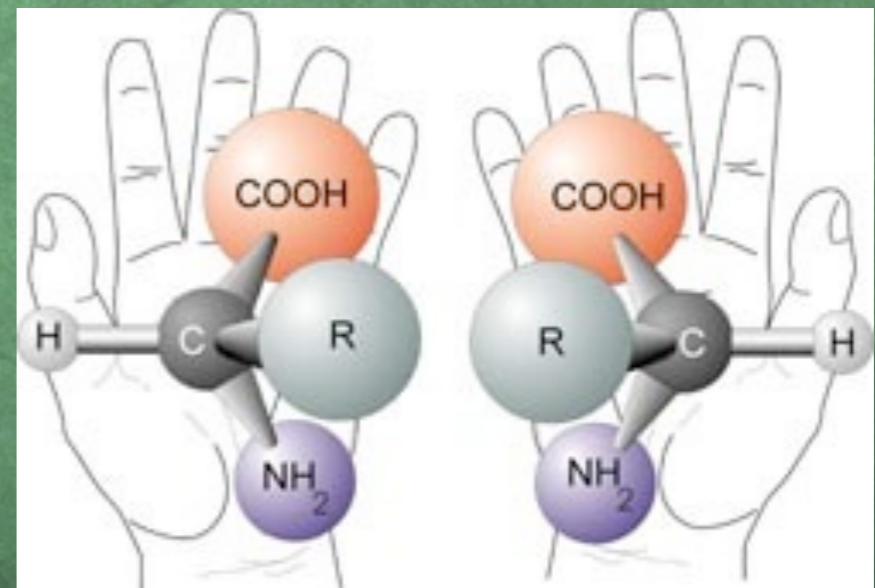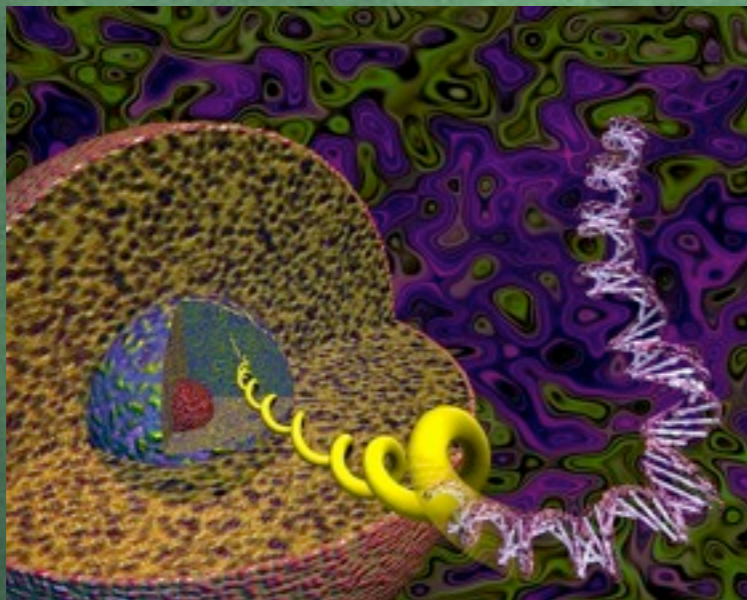
  - Laboratory

  - Earthshine

III Prospect

The Building Blocks of Life ...

C O H N

d – sugar, phosphate, base   l – amino acids

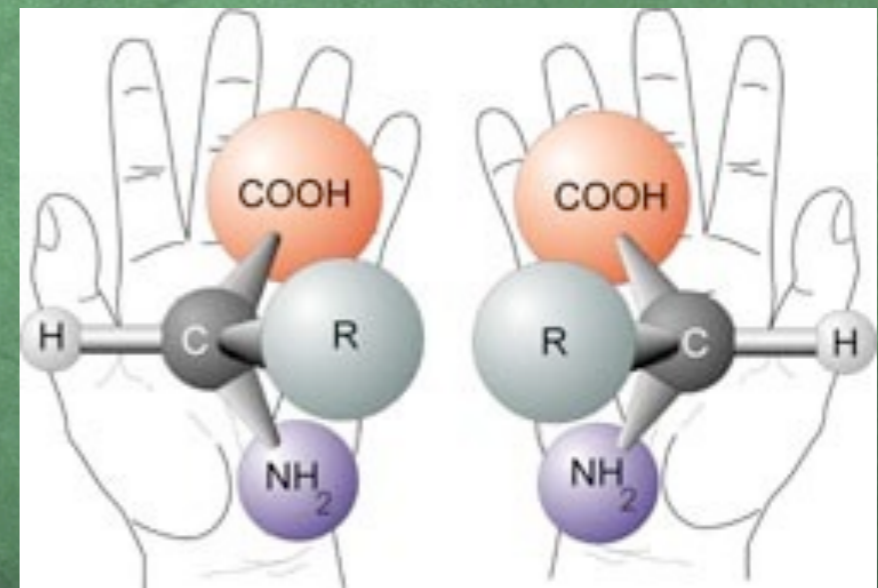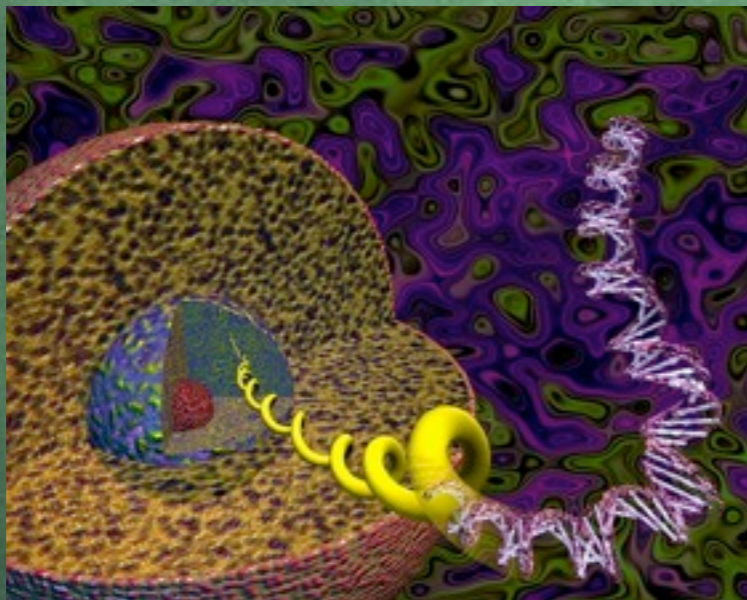RNA, DNA (information)   proteins (structure)

The Building Blocks of Life ...

C O H N

d – sugar, phosphate, base

l – amino acids

RNA, DNA (information)

proteins (structure)

... are chiral

The Building Blocks of Life ...

... are chiral

Relevance for Astrobiology

☯ Is homochirality a hallmark of life?

☯ Are homochiral monomers prerequists for initiating prebiotic chemistry?

☯ Are enantiomeric excesses produced by astro-physical processes?

☯ Are ees induced by circularly polarized light (SFR, RM)?

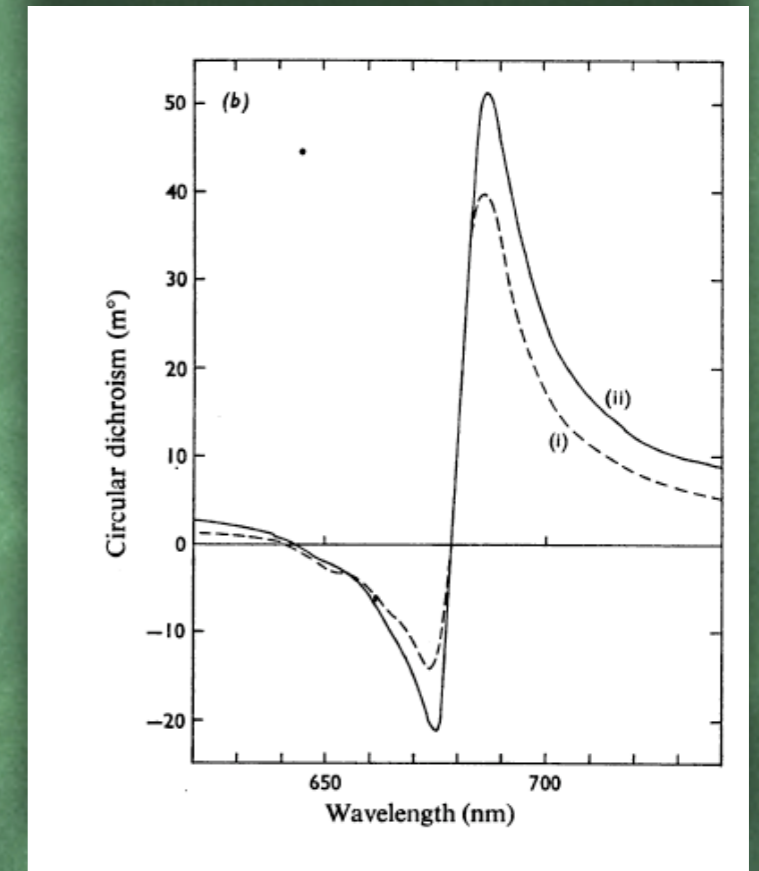☯ Or by P-violation (SN neutrinos, PVES)?

☯ Amplification mechanisms of ees?

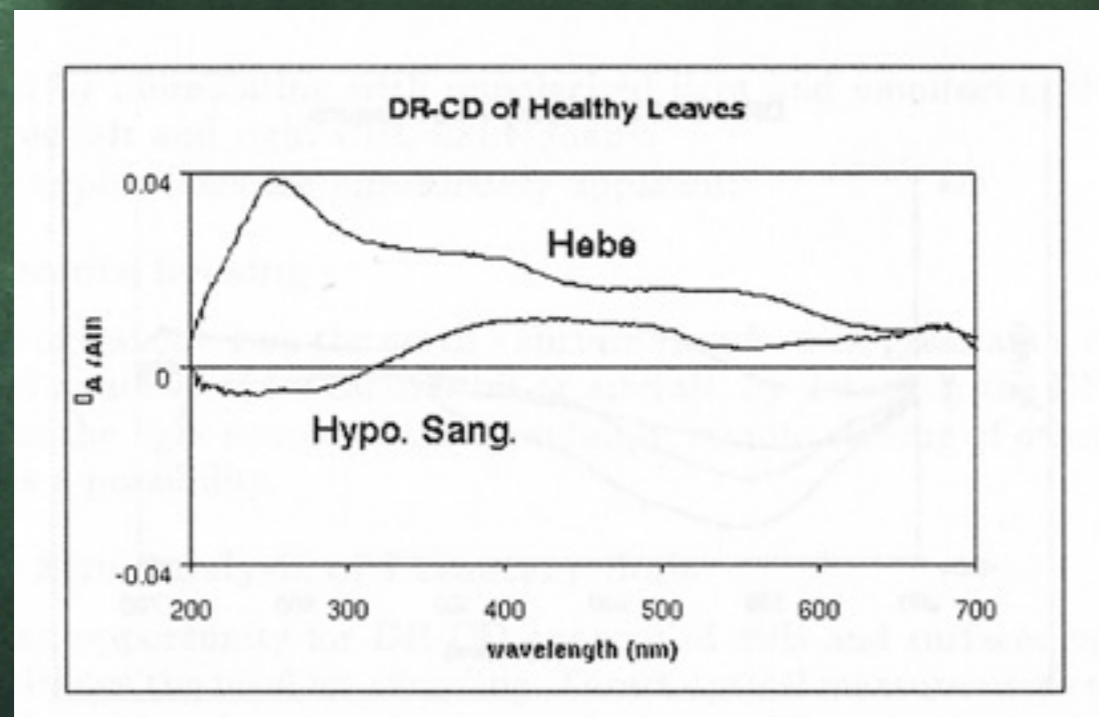# Back to Earth ...

Vegetation Red Edge (VRE)

circular dichroism of chloroplasts
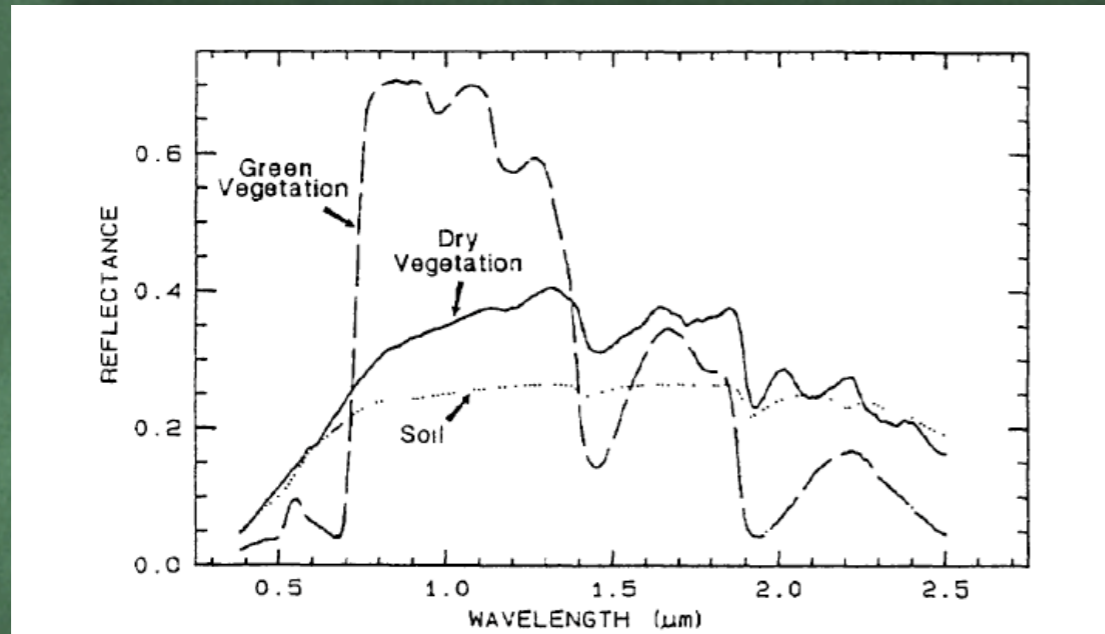
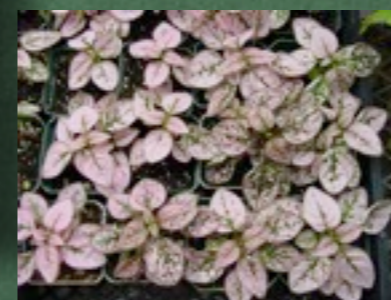Arnold et al., 2002, Proc. 36. ESLAB Symp., p.259

diffuse reflectance of plant leaves

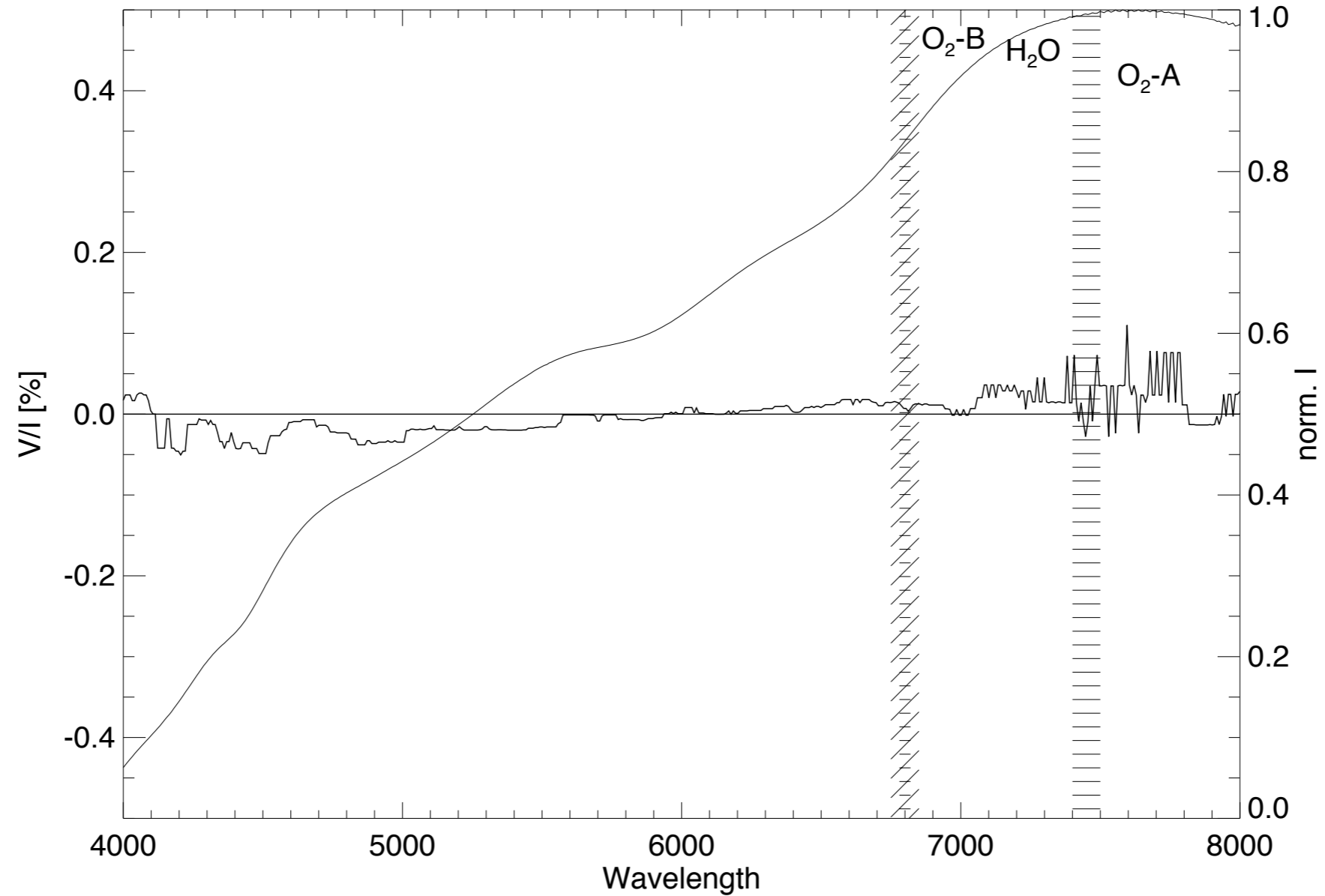Gregory et al., 1975, BioChem.J., 148, p.487

Hebe - Evergreen

Hypoestes Sanguinlenta - Polka-Dot Plant
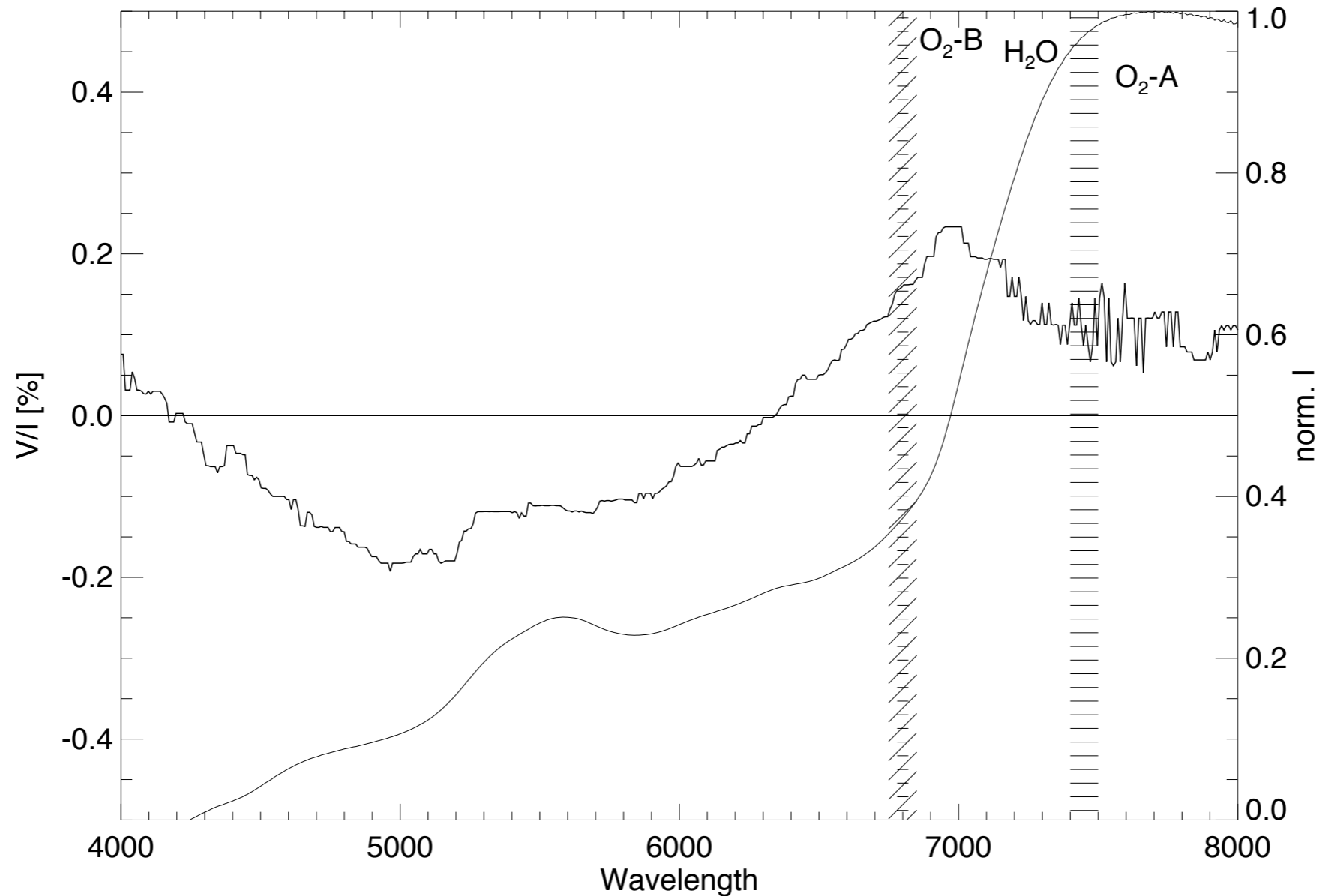
Wolstencroft, 2004, Bioastronomy 2002, IAU Symp. 213, p.149
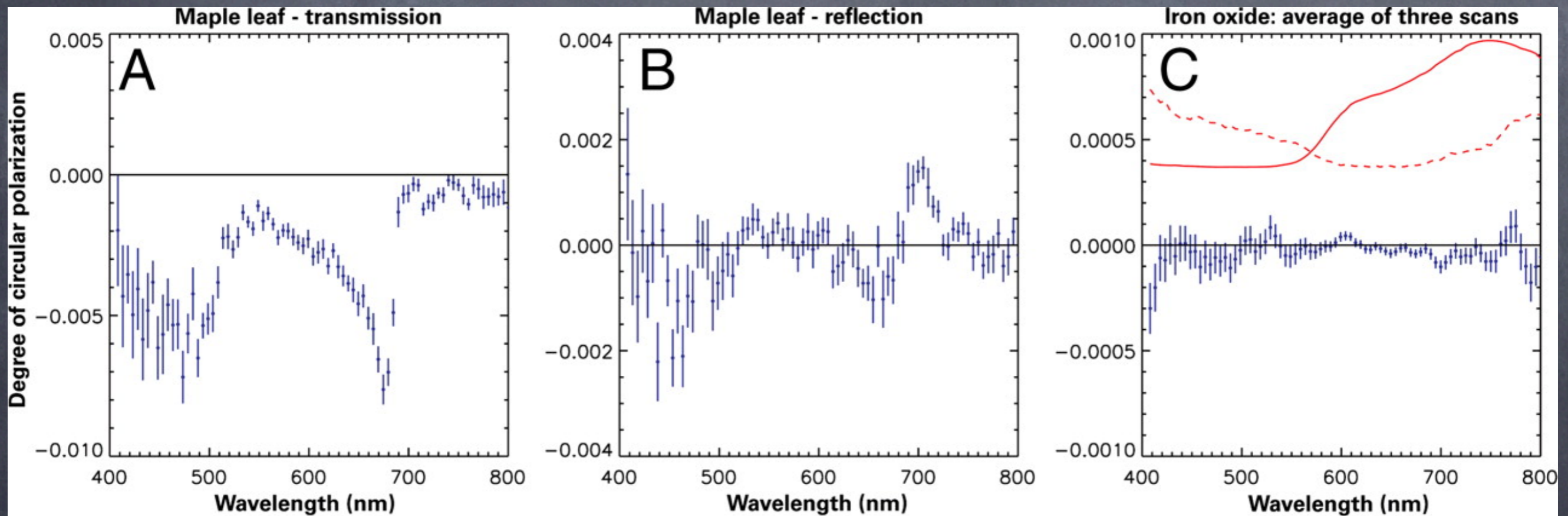
Back to Earth...

Back to Earth...

Back to Earth...

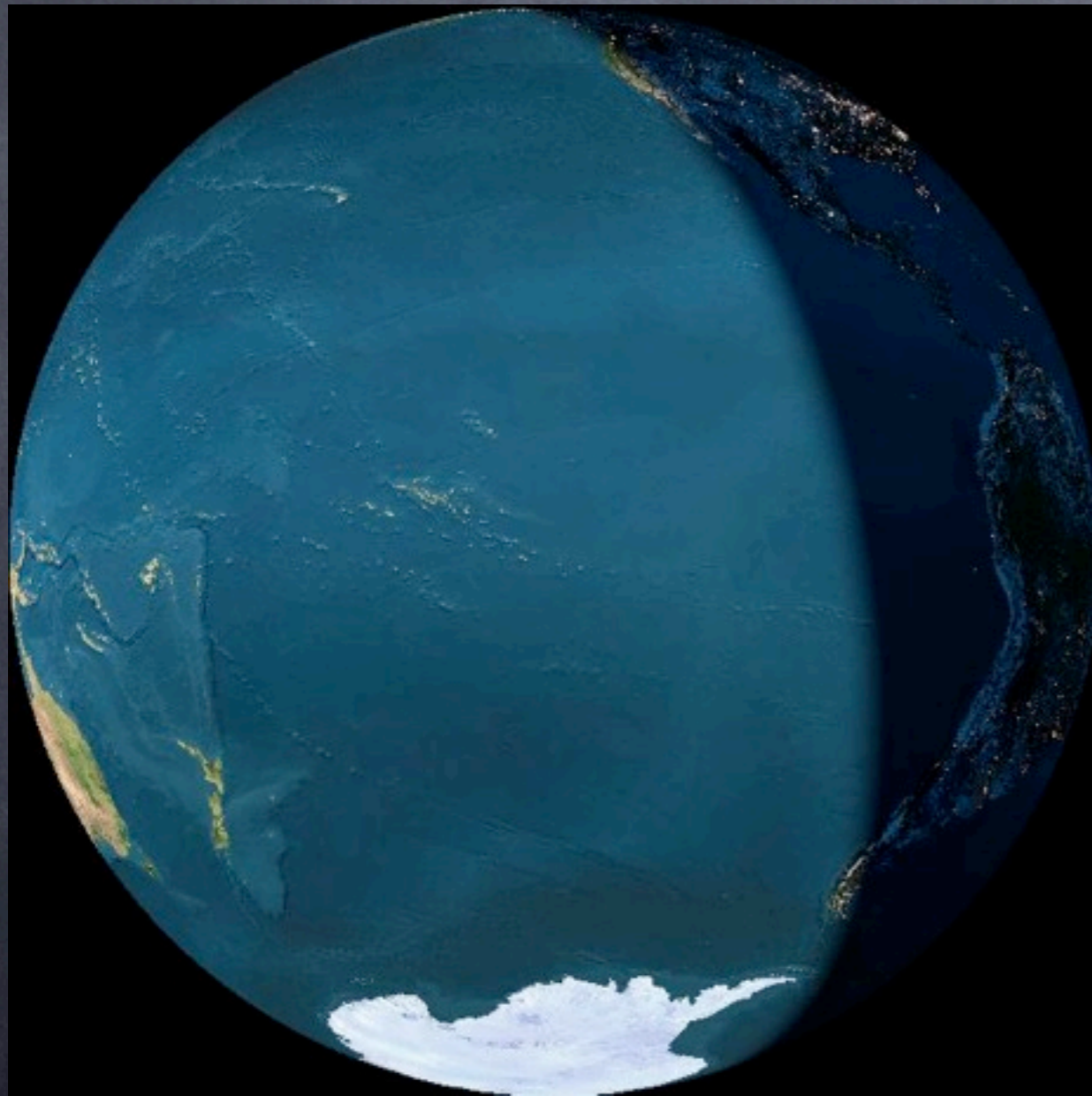
Fractional C.D.~ 10^{-3} @ 700nm

Back to Earth...

Sparks et al., 2009

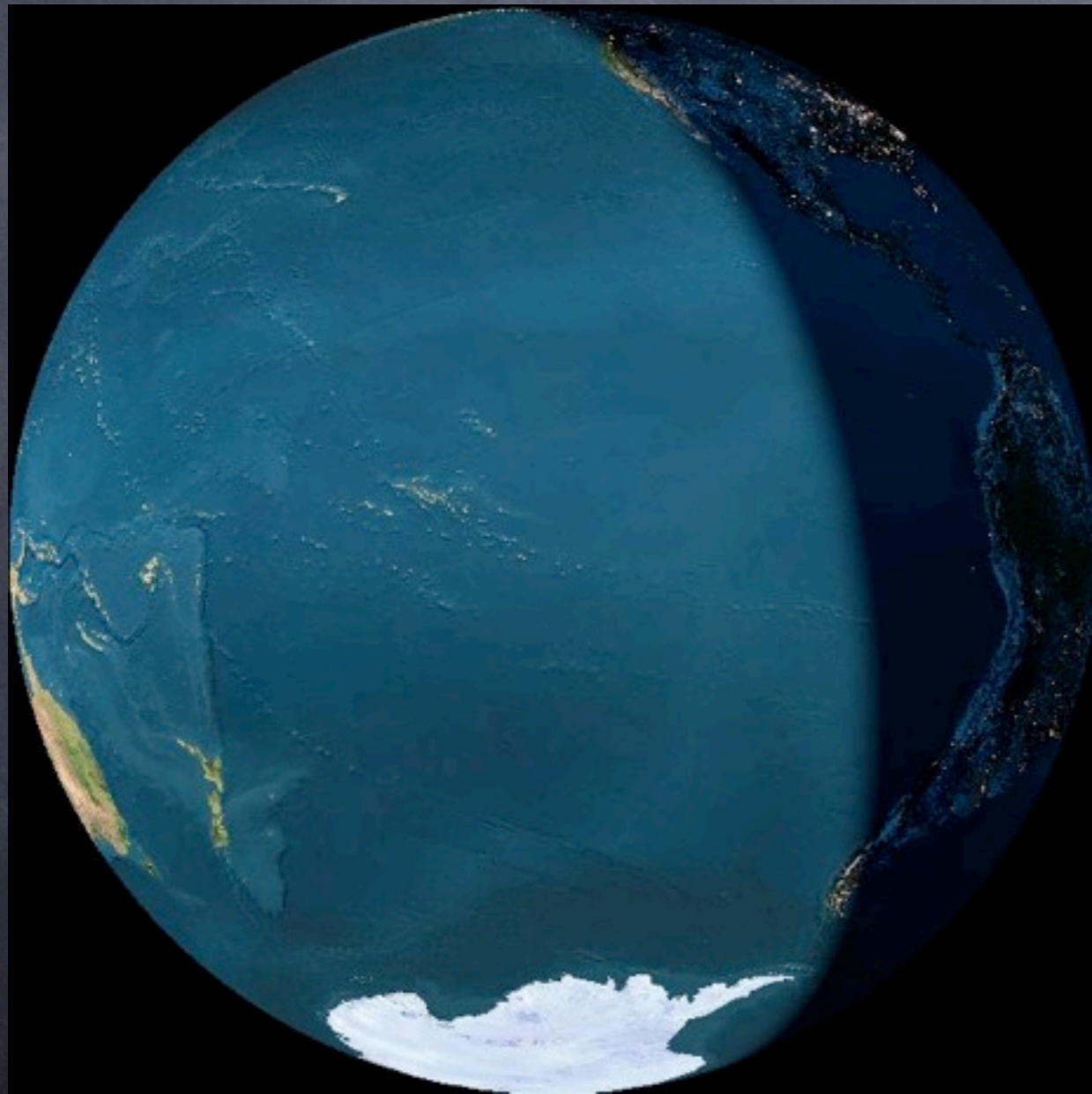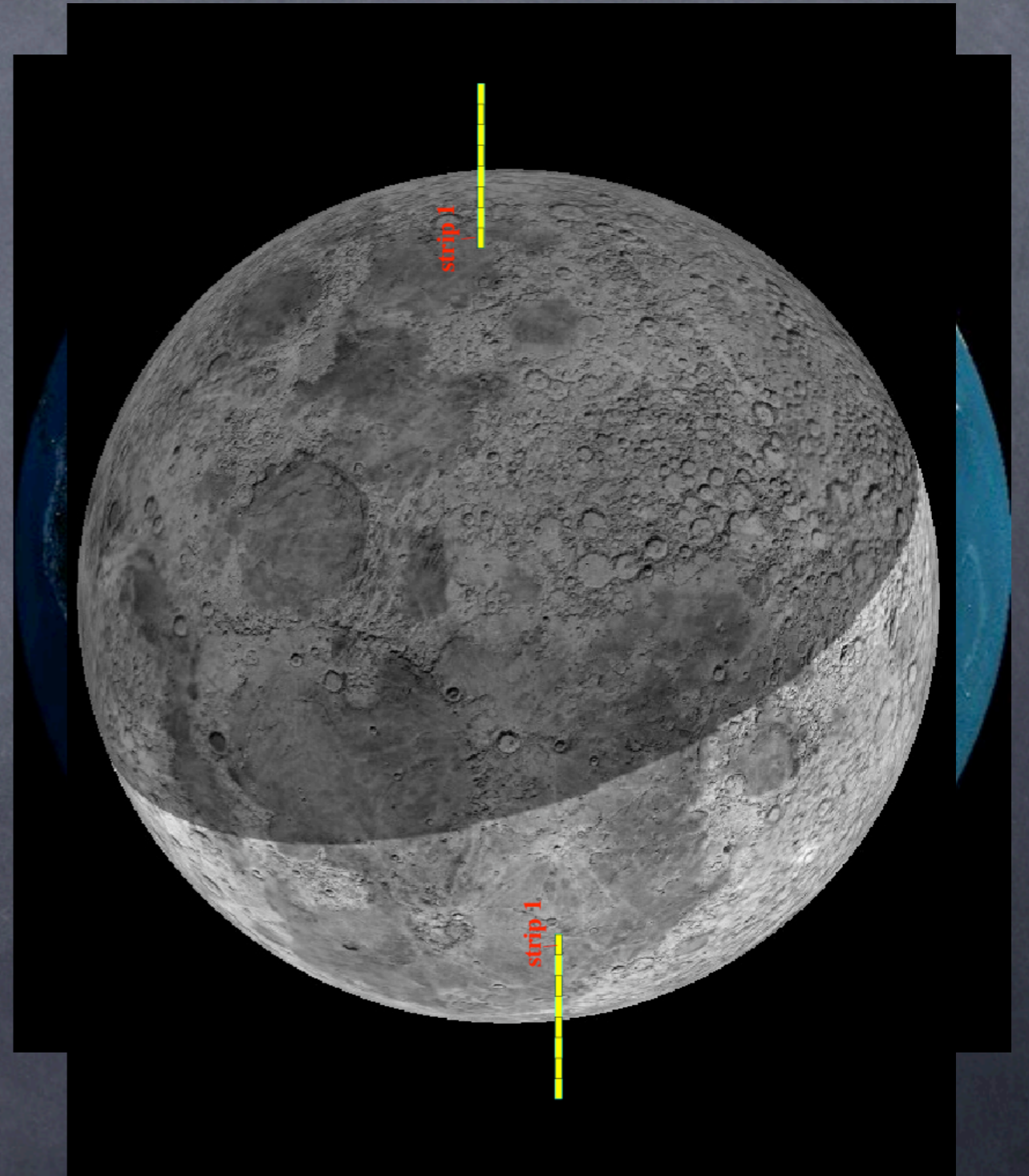# Search for circular polarization of the Earth

1,4% vegetation

13,3% vegetation

Search for circular polarization of the Earth

1,4% vegetation

Sources of Circular Dichroism

C.D. Expectation in the Earthshine

- assume 0.1% C.D. from diffuse reflectance of leaves @ VRE: 10^{-3}

- assume a dilution factor of 10 (from VRE experiments): 10^{-4}

- depolarization by lunar diffuse backscattering: $\mathbf{10^{-5}}$

DeBoo, et al., 2005, App. Opt., Vol. 44, No. 26, p.5434

C.D. other sources ("dirt effects")

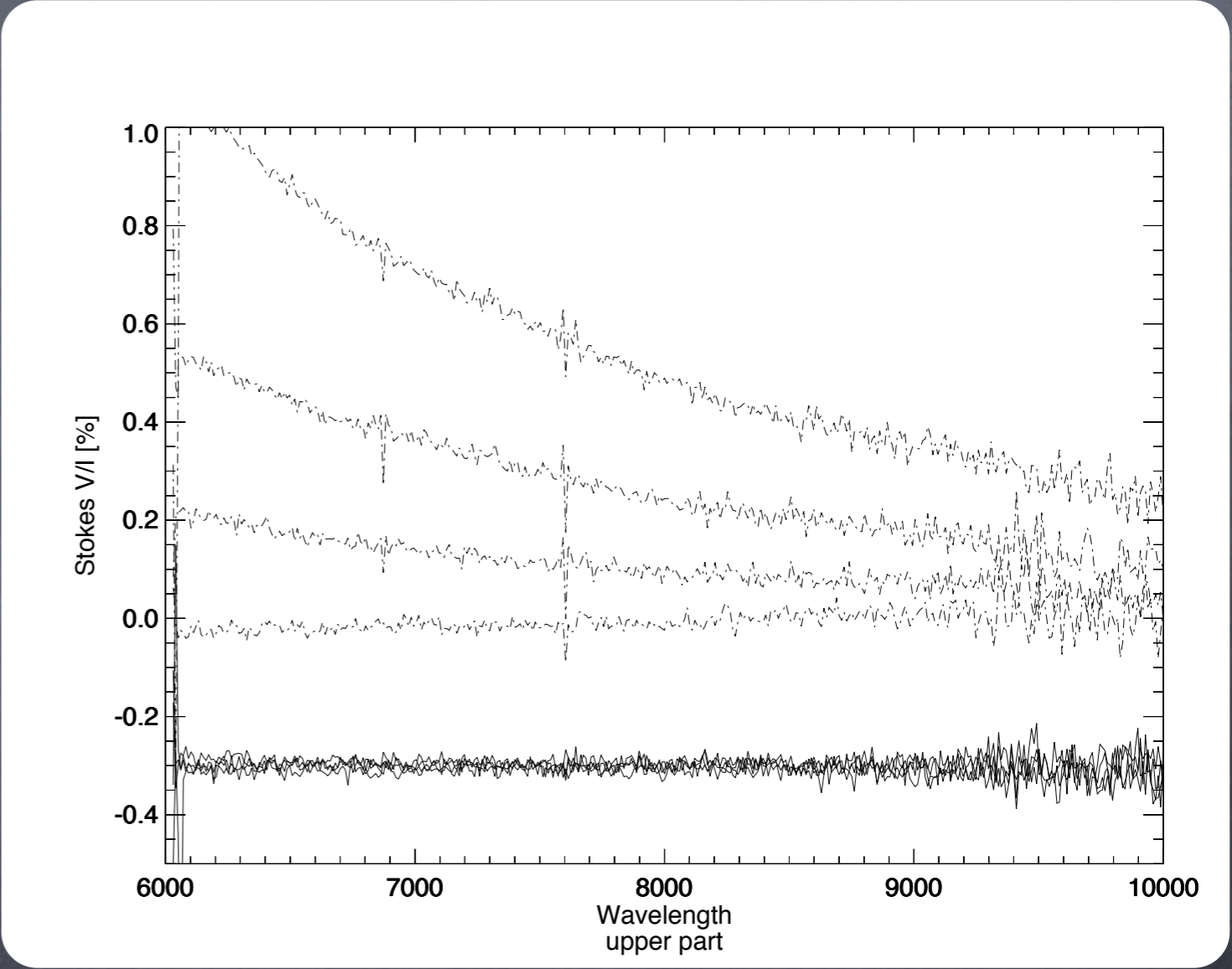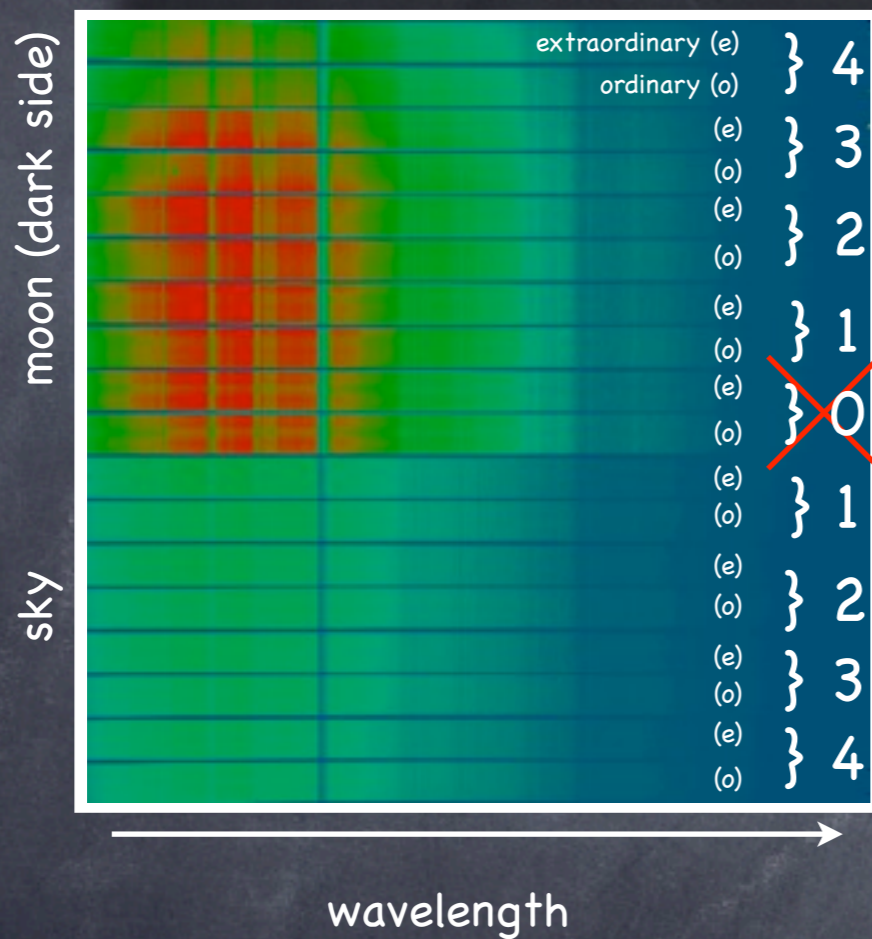- scattering from lunar surface ($|V/I| < 3-4 \times 10^{-5}$ at the poles)

Meierhenrich et al., 2002, ESA SP-518, p.243

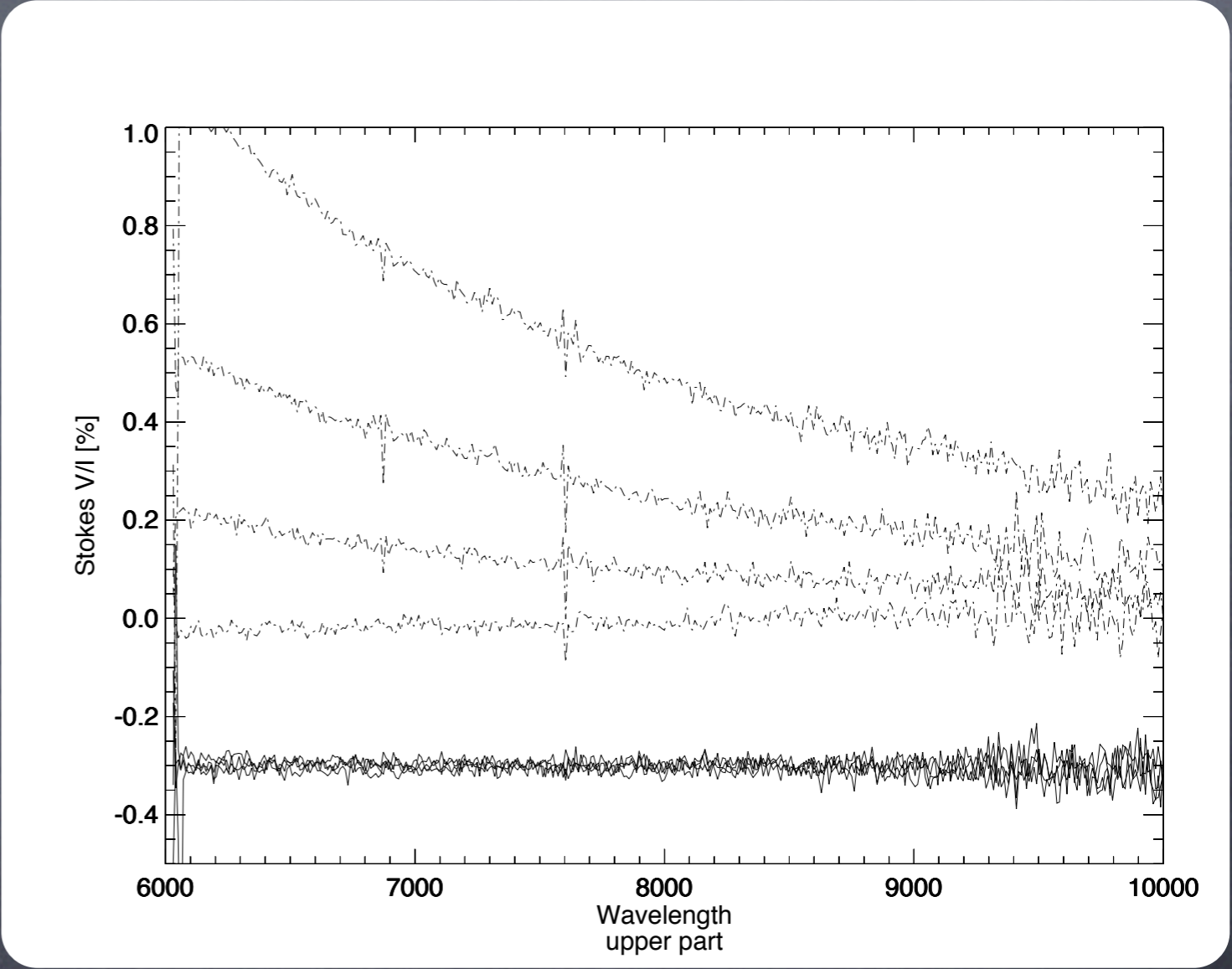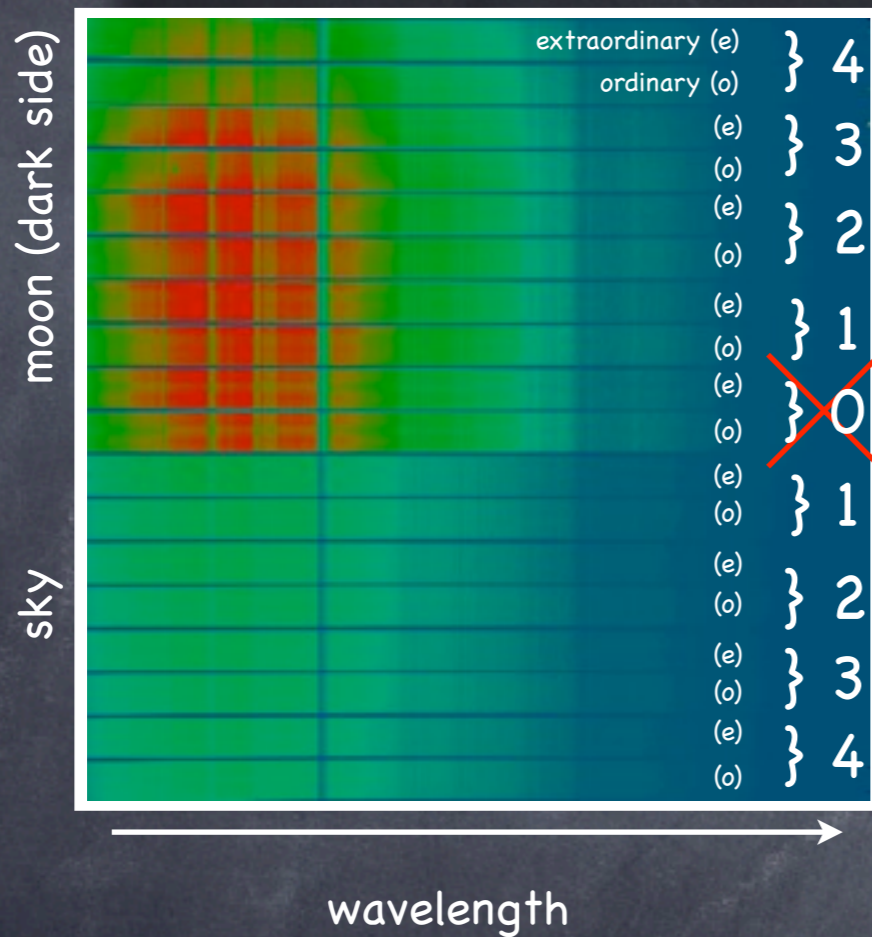- zodiacal dust scattering, aerosols: negligible $< 10^{-6}$

Wolstencroft, 1985, IAU Symp. 112, p.171

- instrument! crosstalk from linear polarization: spatial + chromatical

< 1% requires careful calibration, characterization, MM modeling...

Earthshine Observations

Earthshine Observations

X-talk from lin. pol. (Rayleigh scattering)

Instrument X-talk Calibration

... prompted its
own study ...

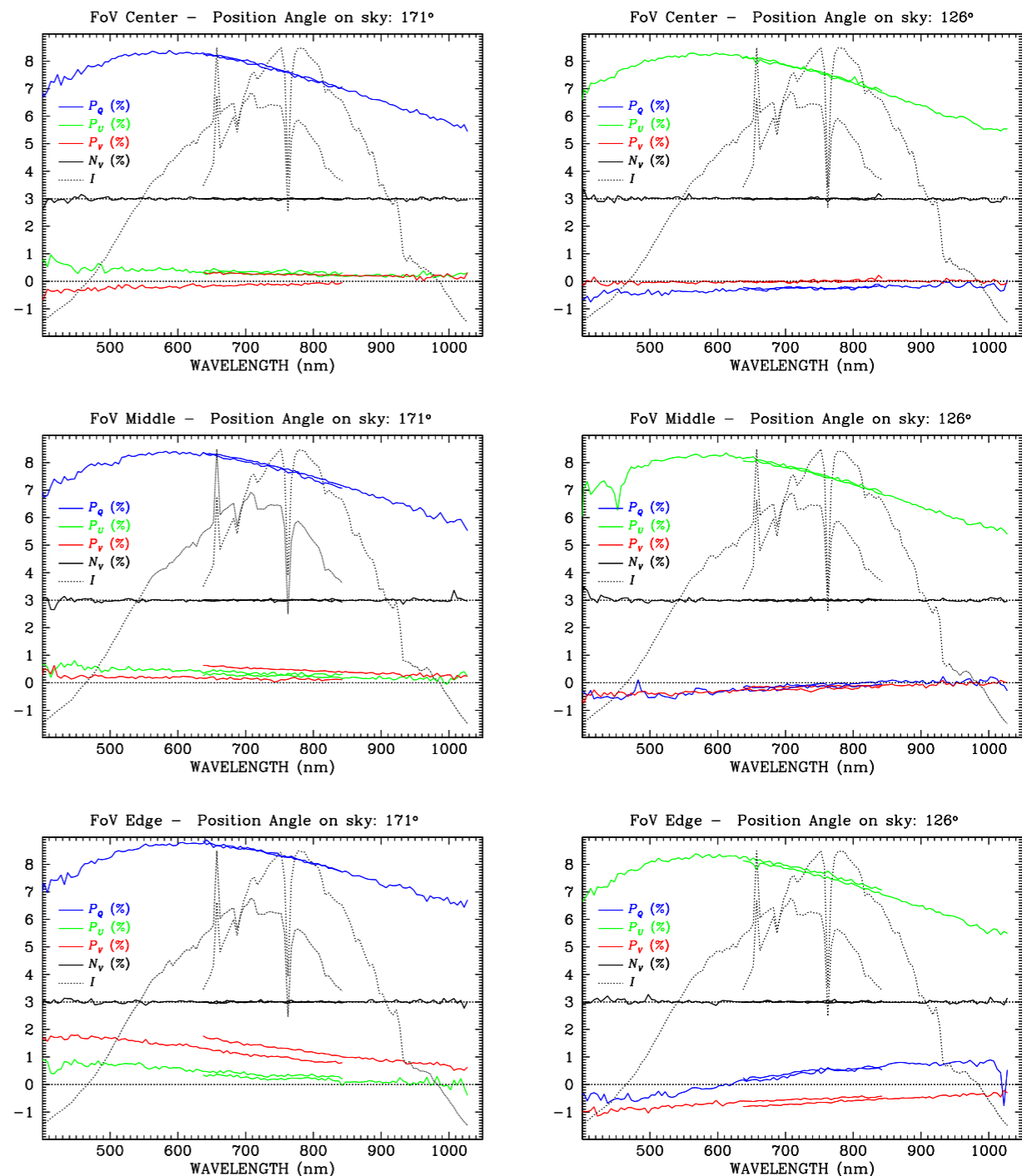X-talk caused by
birefringenance of
the collimator lense

Bagnulo et al., 2009

Fig. 10.— Observations of linear and circular polarization of Ve-6-23 obtained with grisms 300 V and 300 I at different positions of the FoV and different values of the instrument position angle, as indicated at the top of each panel. Different lines represent P_Q (blue), P_U (green), P_V (red), expressed in %, and Stokes I (dotted lines, in arbitrary units). The null spectra $\mathcal{N}_V$ (black solid lines) are also expressed in %, and offset by +3 % for display purpose.
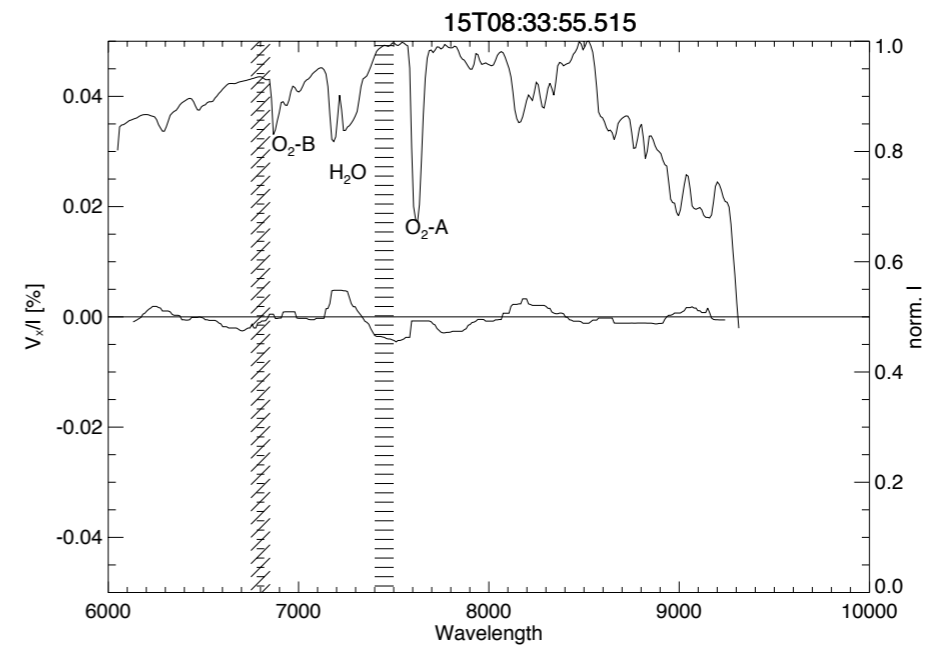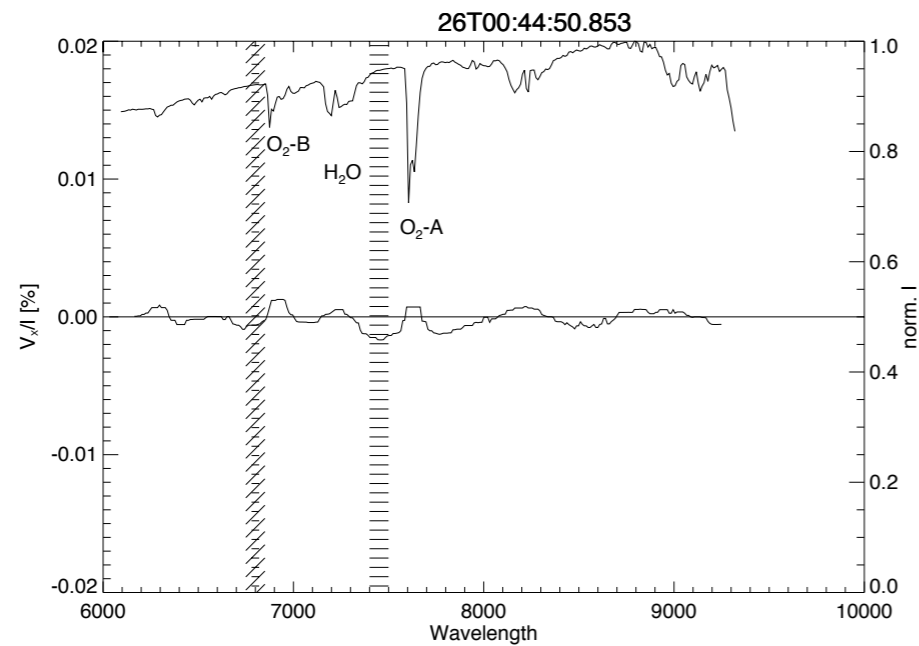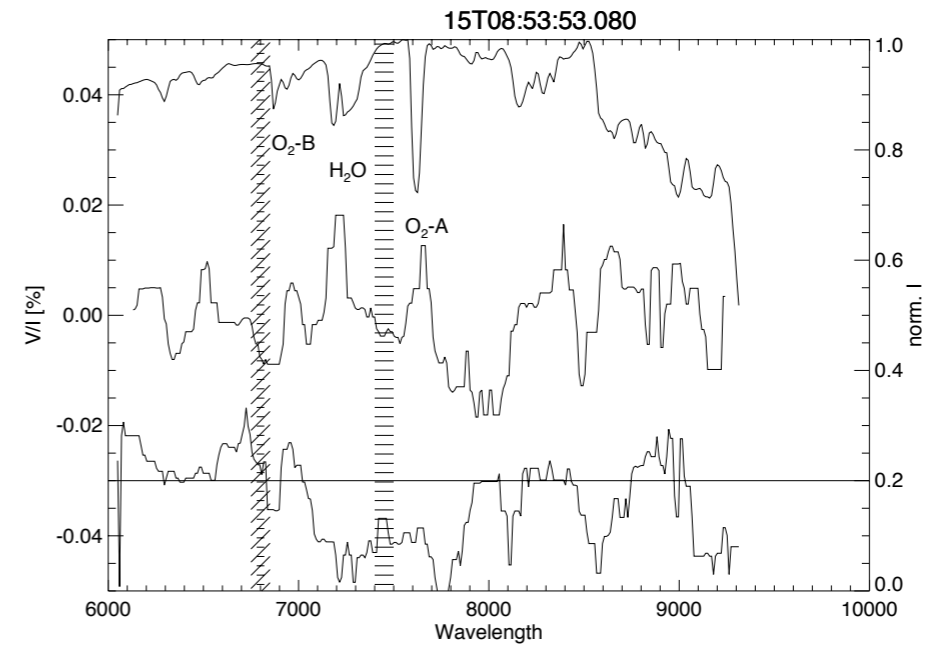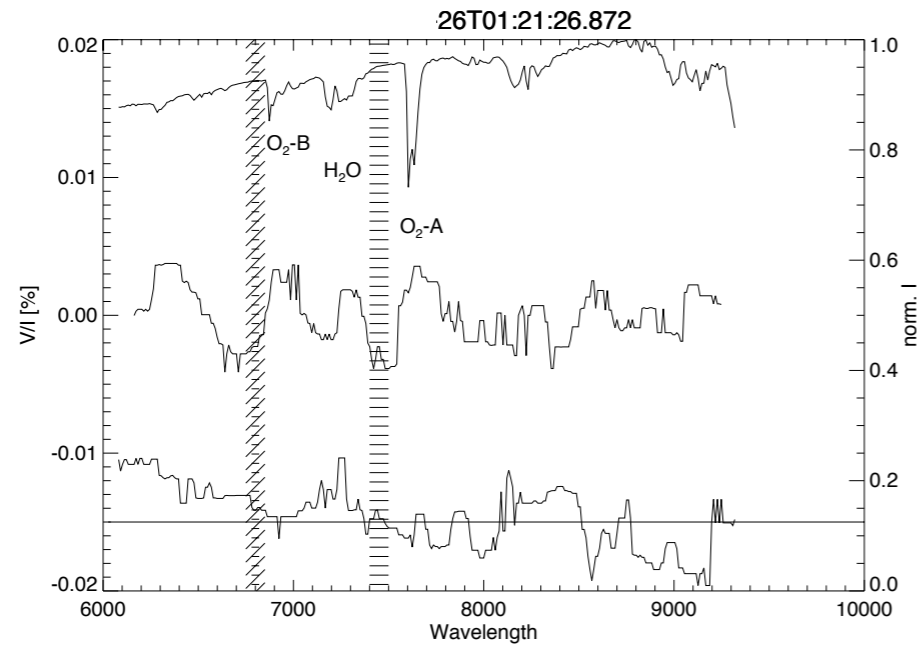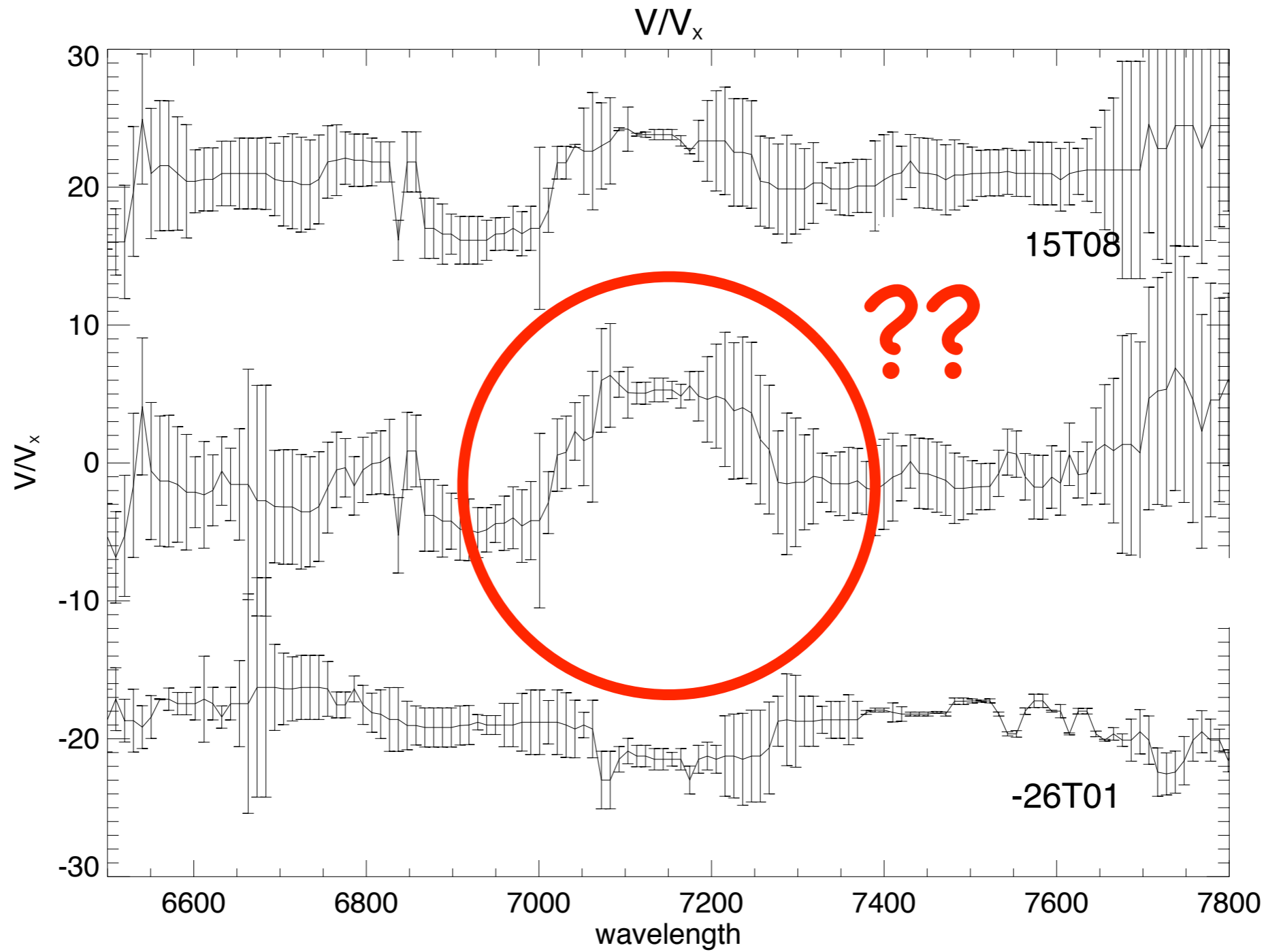
V and V$_{x-talk}$
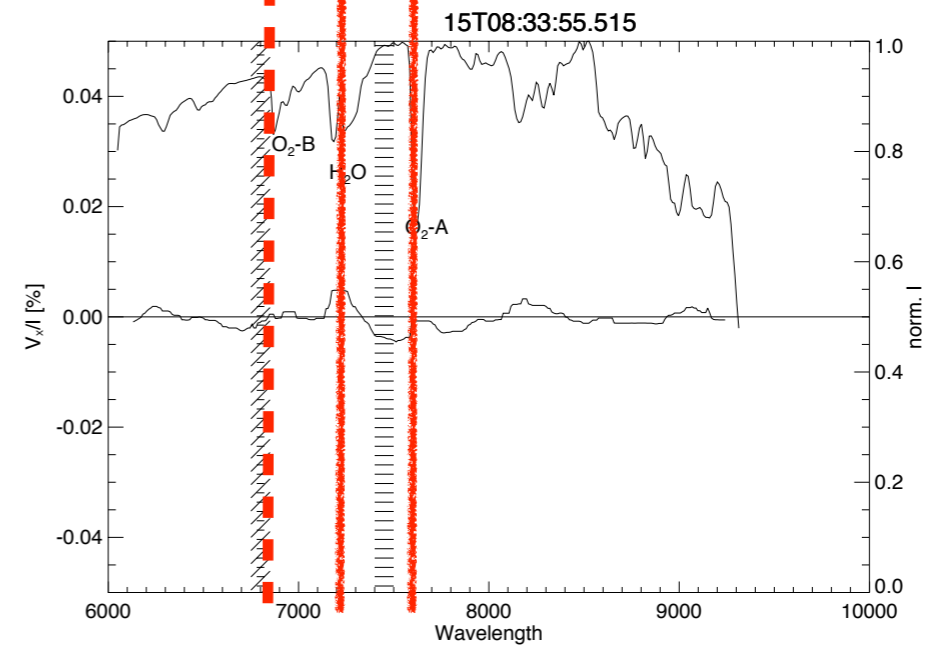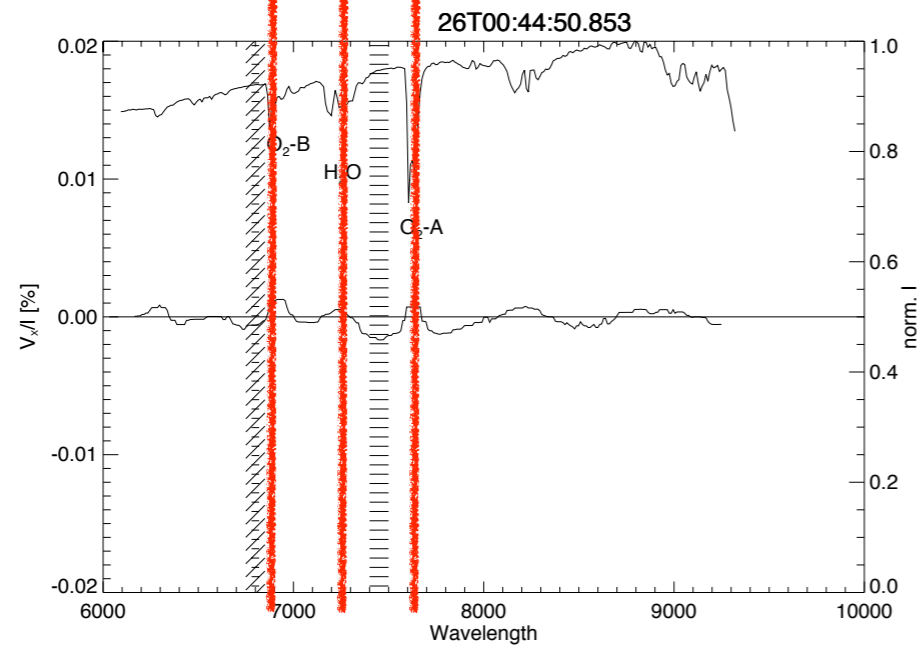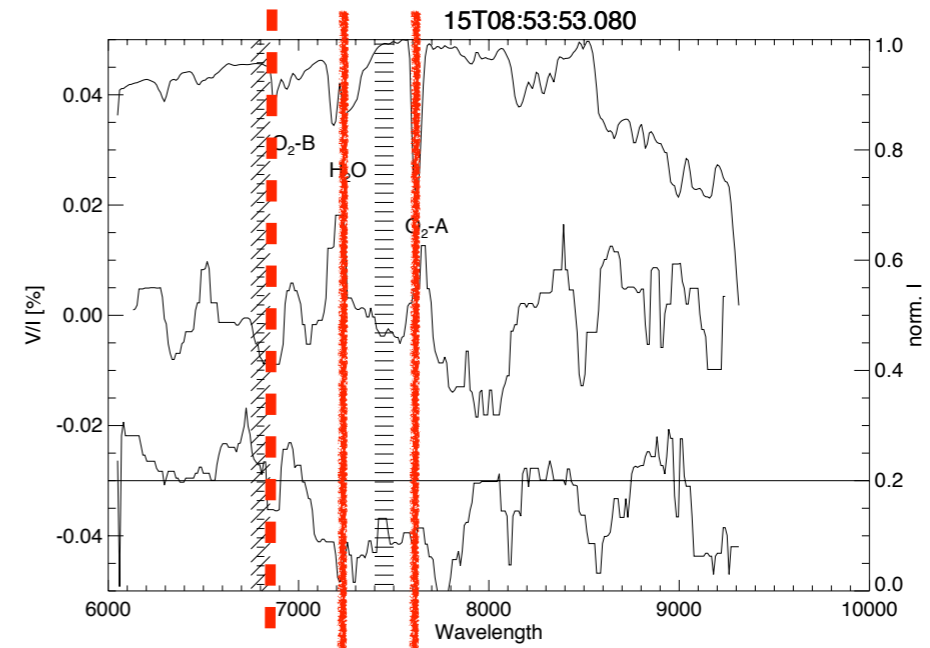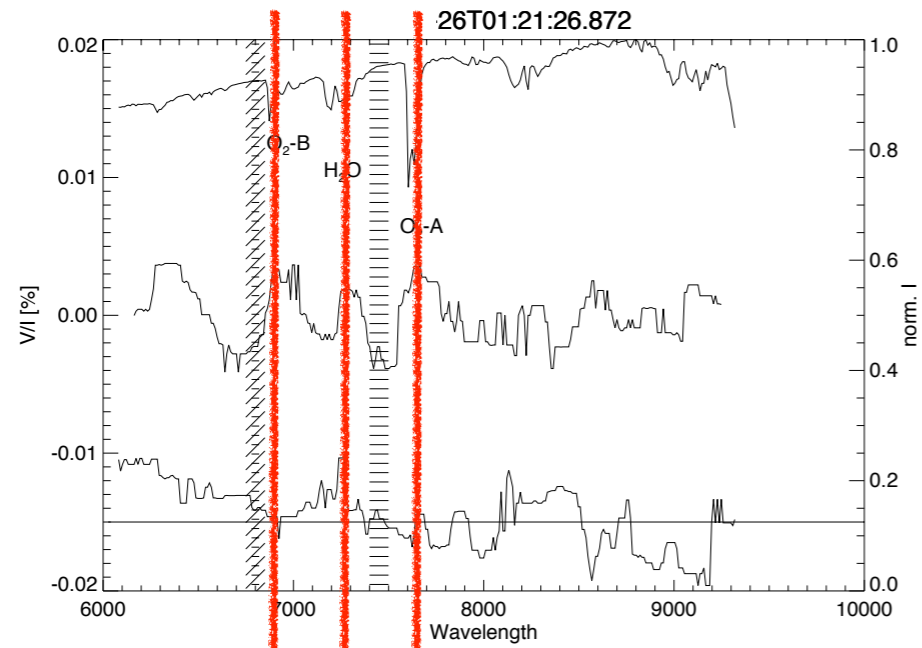
V and V$_{x-talk}$

V and V$_{x\text{-talk}}$

Prospect

w/ 8m telescopes:

- remote sensing of Life on Earth w/ C.D. seems feasible

- systematic search for C.D. on solar systems objects down to $10^{-(5-6)}$

w/ ELT (and high-contrast...)

- search for C.D. in debris/zodi disks (20mag/$\square^2$) and brightest imaging exoplanets (23 mag) if they have high C.D....