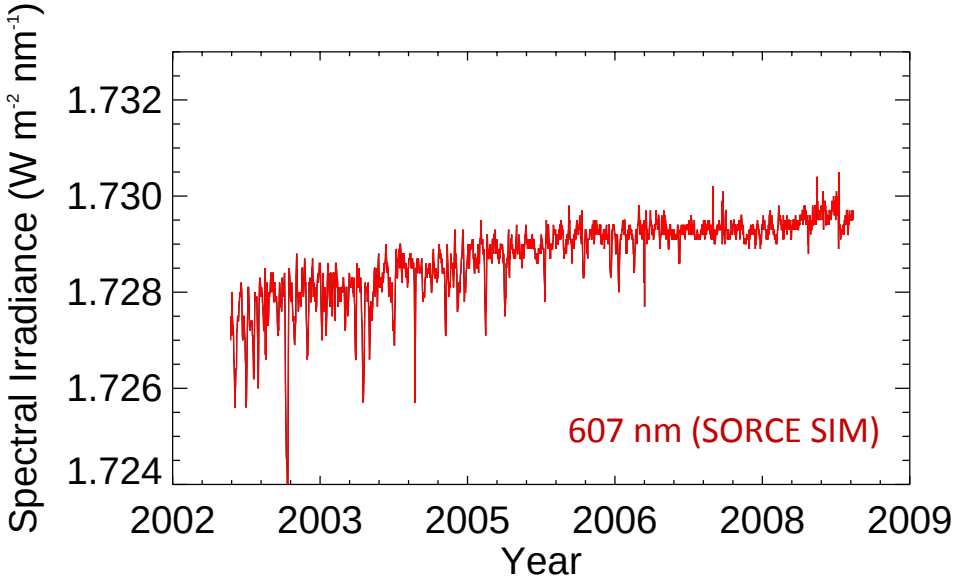
Demonstrating the Sensitivity of Long-Term Photometric Trends to the Center-to-Limb Profile

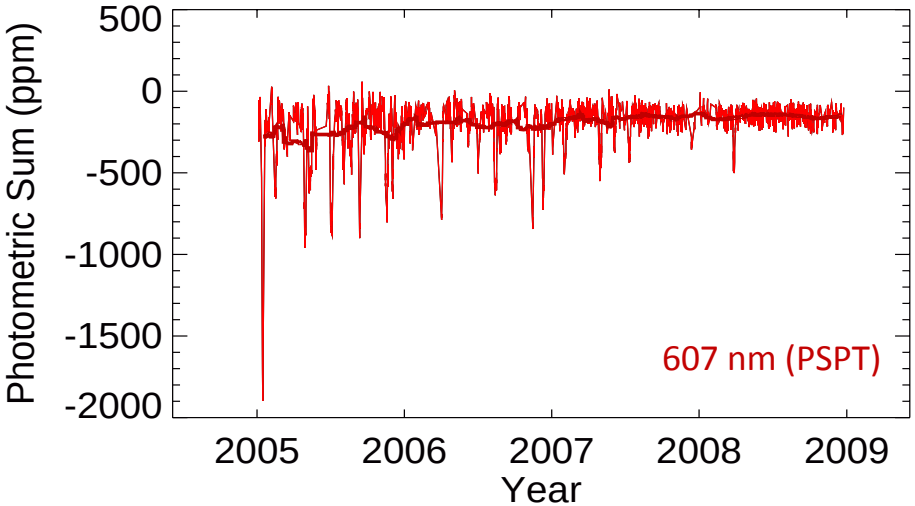
Courtney Peck[1,3] & Mark Rast[2,3]

Department of Physics[1]
Department of Astrophysical and Planetary Sciences[2]
Laboratory for Atmospheric and Space Physics[3]
University of Colorado, Boulder

Space-based



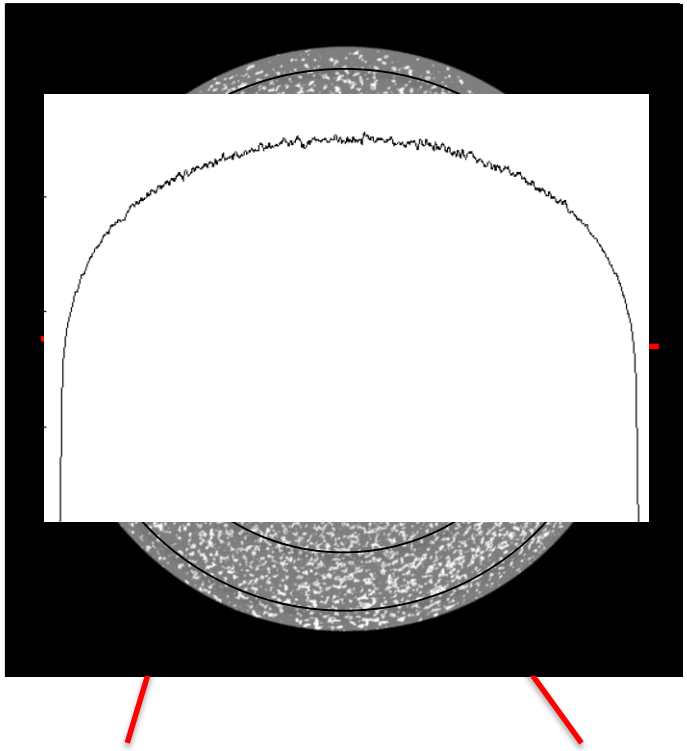
Ground-based



The center-to-limb variation (CLV) is not uniquely defined, but all definitions rely on an assumption of what constitutes the ‘quiet-sun’

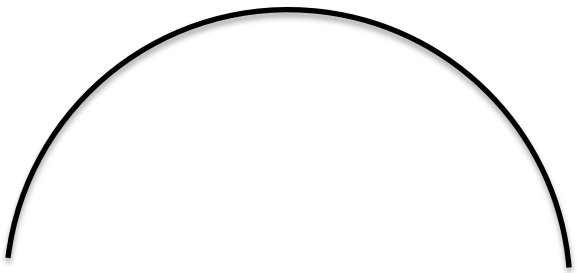
Median value of all pixels

Median value of quiet pixels



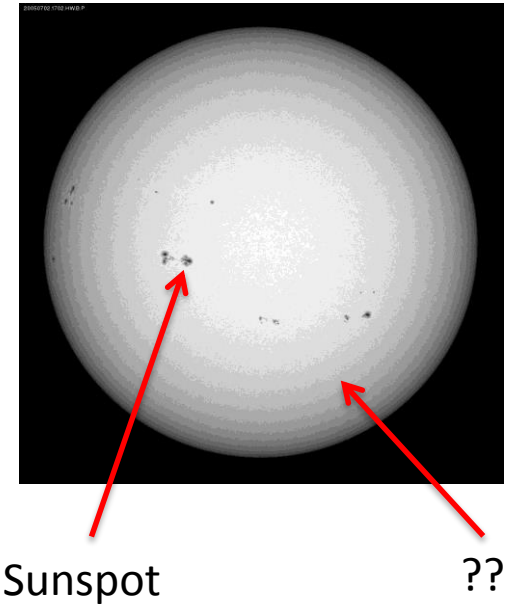
Sunspot

Not a sunspot

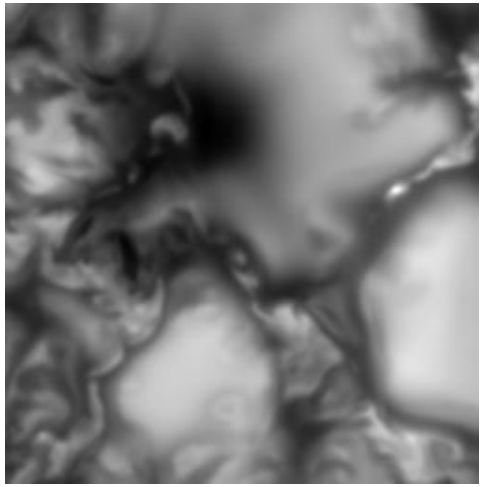


However, the definition of the CLV is inherently tied in photometric data and can introduce cycle-dependent contamination in several different ways:

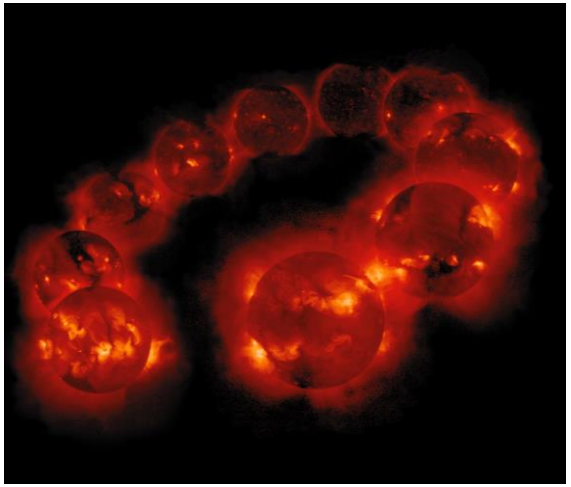
Error in CLV due to inconsistent quiet-sun definition

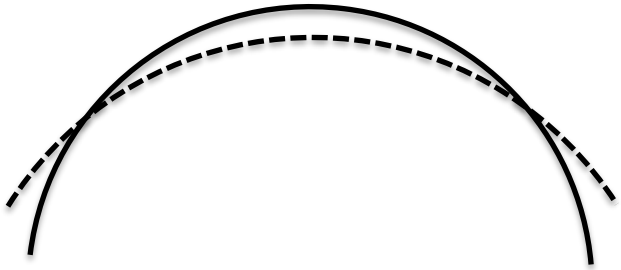


Changes in the filling factor of unresolved flux elements



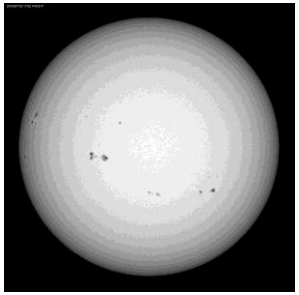
True changes in the underlying thermodynamics



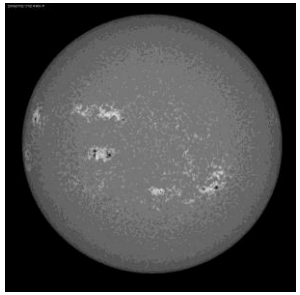


We use PSPT images to determine if the CLV contributes to the observed out-of-phase trend in the continuum

Precision Solar Photometric Telescope (PSPT)

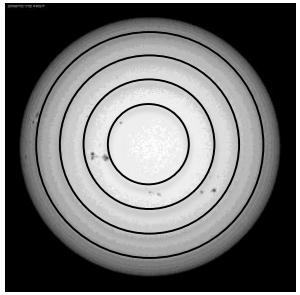


Red continuum
607.1 nm

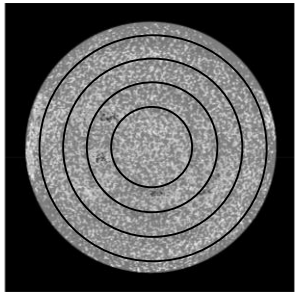


CaII K
393.4 nm

Two different CLV definitions



Median all pixels



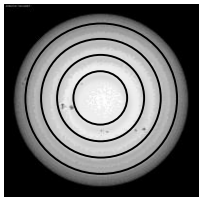
Median internetwork pixels

Photometric sum

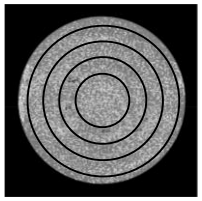
$$\Sigma = \frac{\sum_i \left(I_i - I(\mu_i)\right)}{\sum_i I(\mu_i)}$$

Disk-normalized contrast

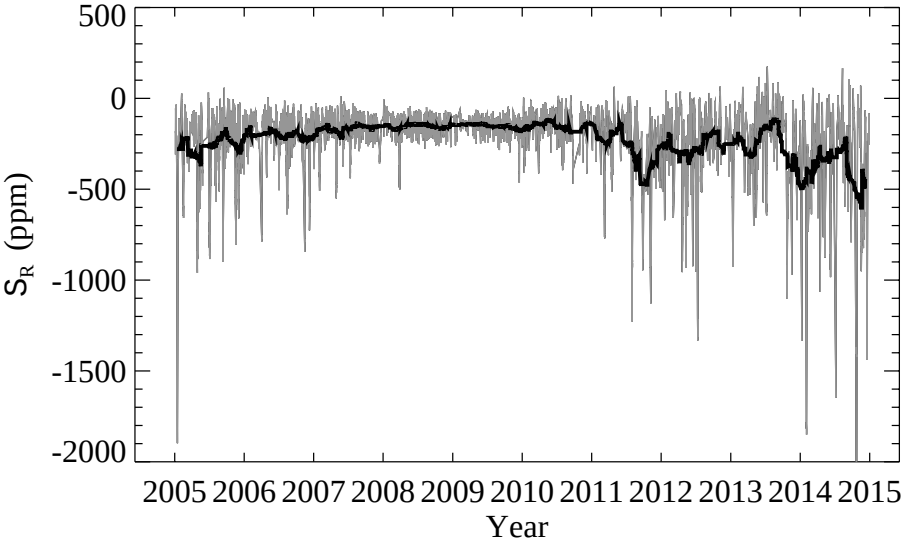
Long-term, full-disk continuum photometric trends are highly sensitive to the CLV employed, where opposing trends were found using two different definitions of the CLV

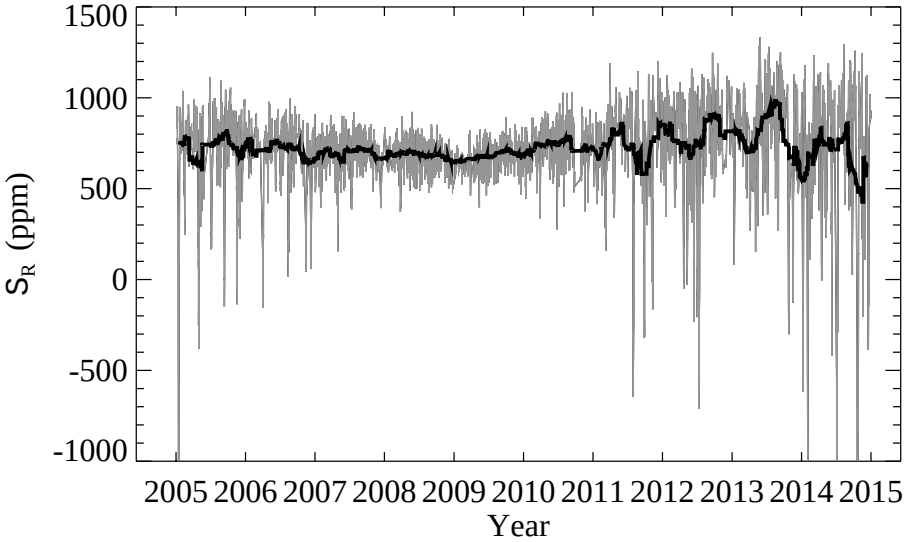


Median annular value of all pixels
(Preminger, 2011 method)



Median annular value
of internetwork pixels
(Fontenla's SRPM identification)

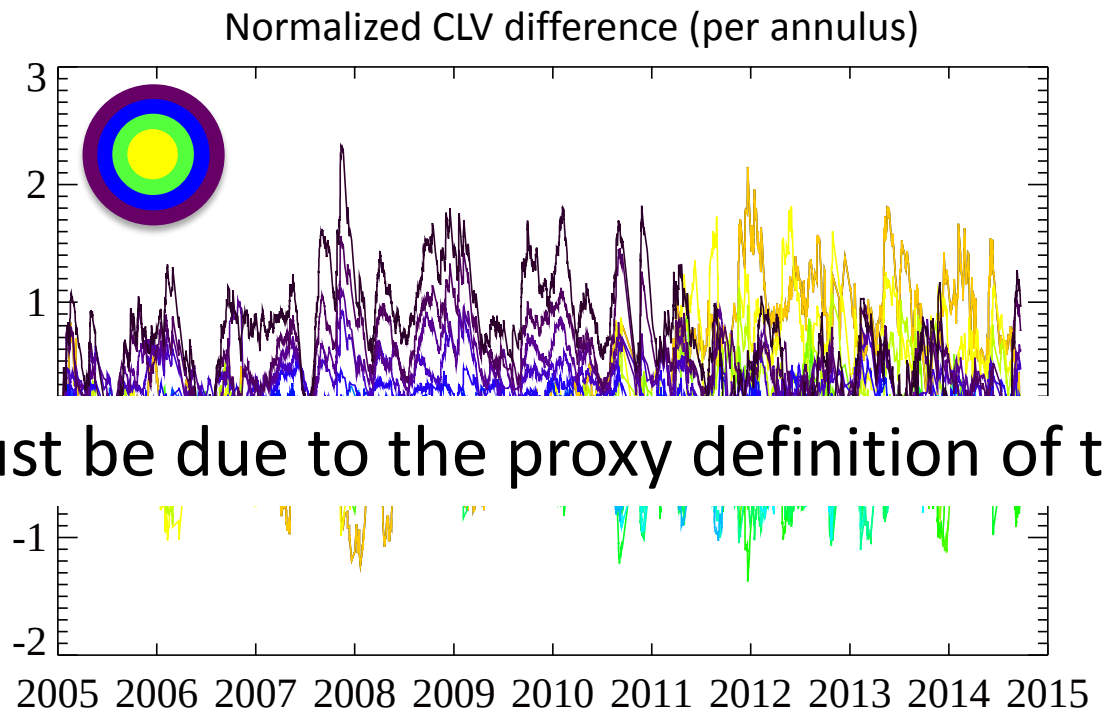




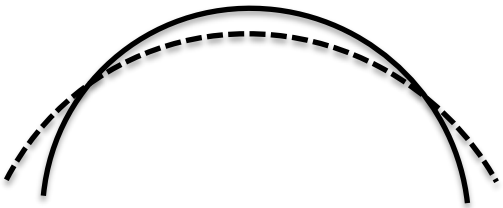
~500 ppm difference between trends

Can't know which, if any, CLV is correct

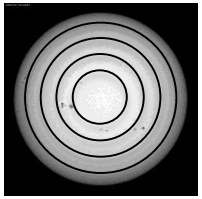
Solar cycle dependent difference between the two CLV definitions demonstrates that one or both CLVs introduce magnetic contamination



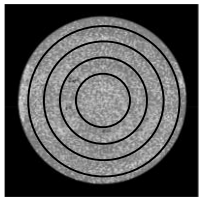
Could this just be due to the proxy definition of the 'quiet-sun'



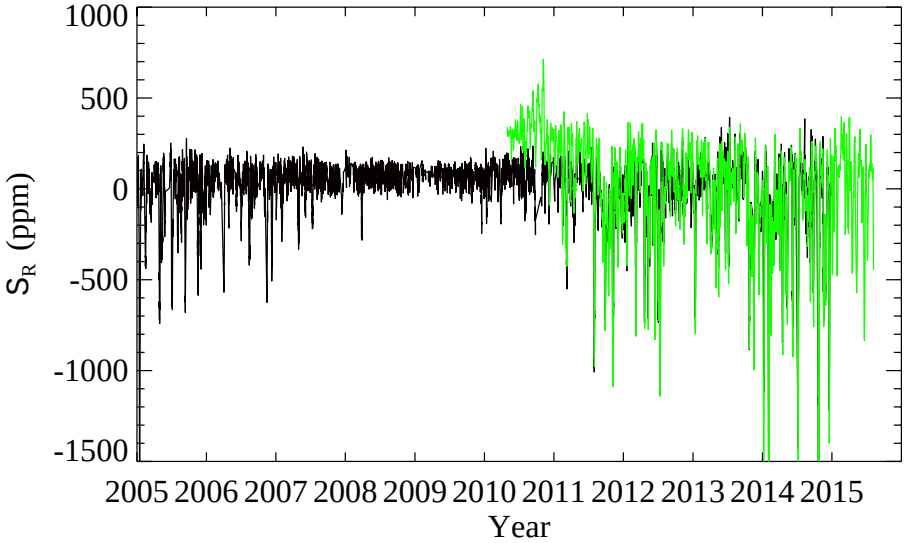
HMI observations remove the CLV dependence on 'quiet-sun' structure identification, further demonstrating the sensitivity of the CLV to cycle-dependent contamination

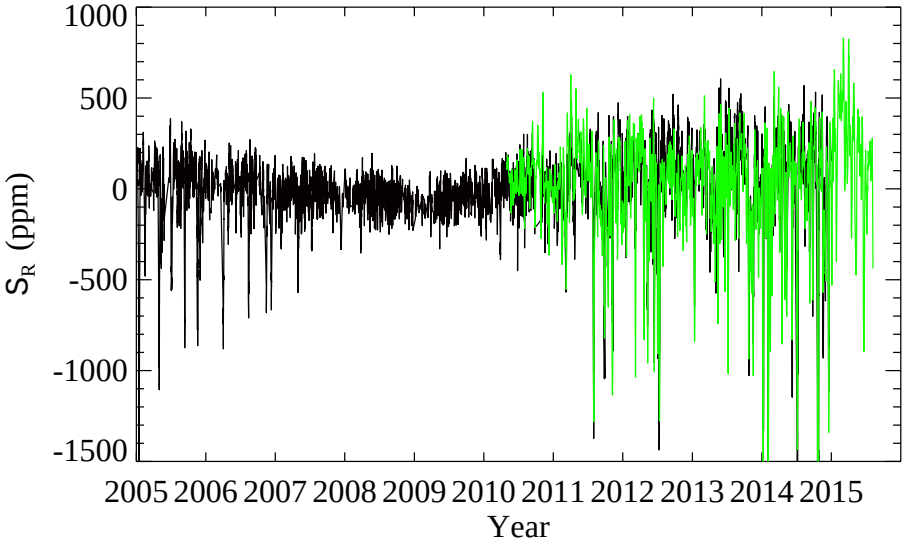


Median annular value of all pixels (Preminger, 2011 method)



Median annular value of all pixels with |B|/μ < 15G

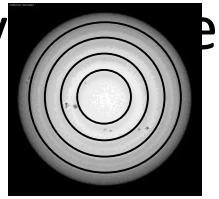




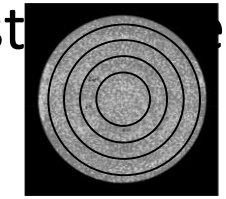
PSPT

HMI

Long-term photometric trends of individual structures are also sensitive to the CLV, but lower contrast structures are most sensitive



Median annular value of all pixels
(Preminger, 2011 method)



Median annular value
of internetwork pixels
(Fontenla's SRPM identification)

Structure sensitivity

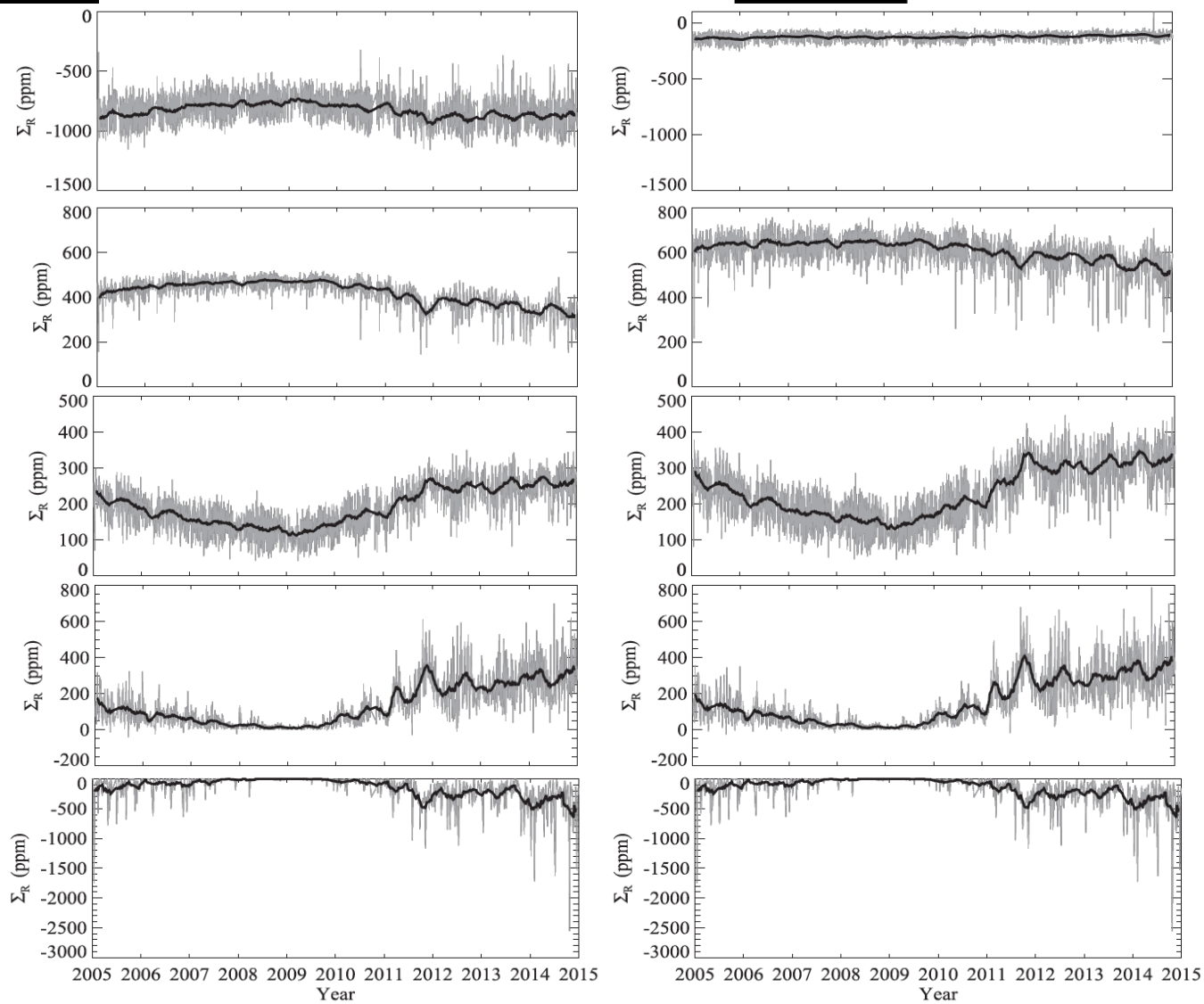
Internetwork

Network

Active network

Faculae

Sunspots



330 ppm

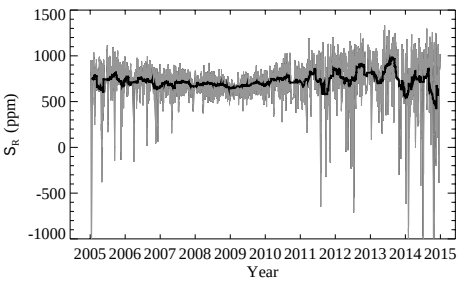
500 ppm

5000 ppm

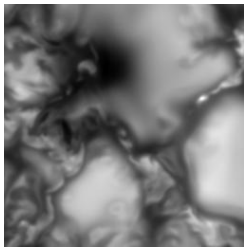
30,000 ppm

500,000 ppm

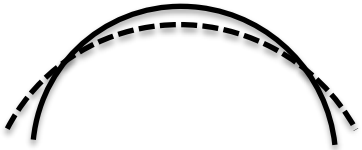
In summary, the use of photometric images in deducing spectral irradiance trends faces inherent difficulty in distinguishing actual structure trends from variations in the CLV profile



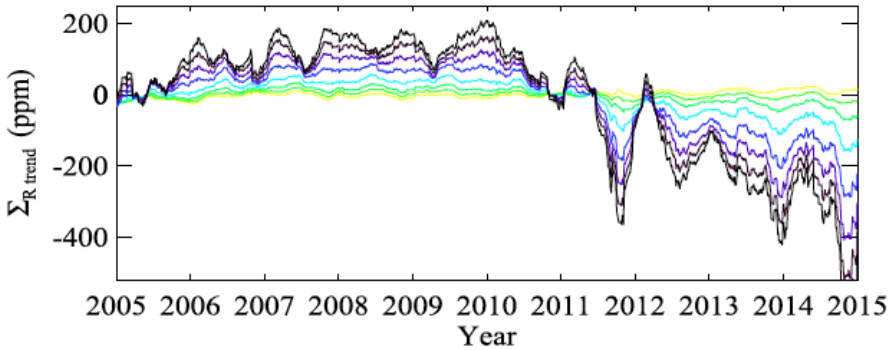
Photometric sum highly sensitive to definition of CLV employed, seen in both ground- and space-based observations

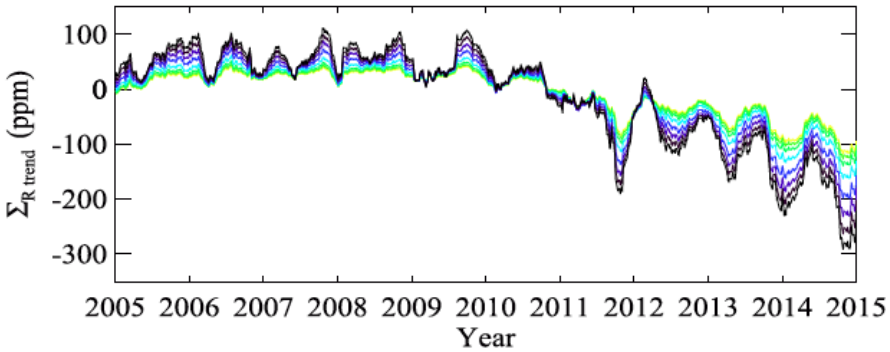


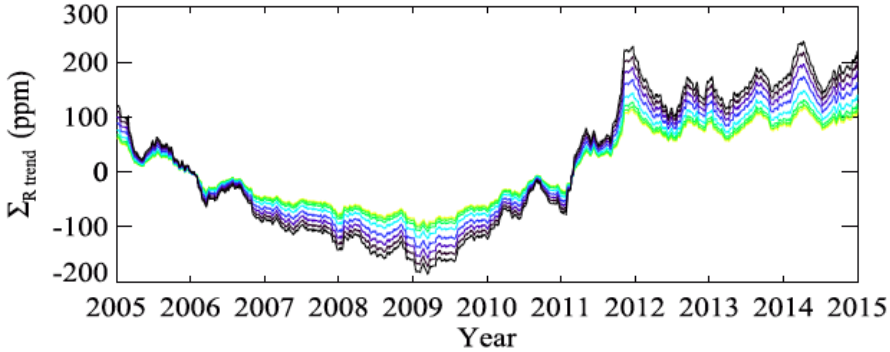
The most abundant, low-contrast structures are most sensitive to the definition of the CLV employed

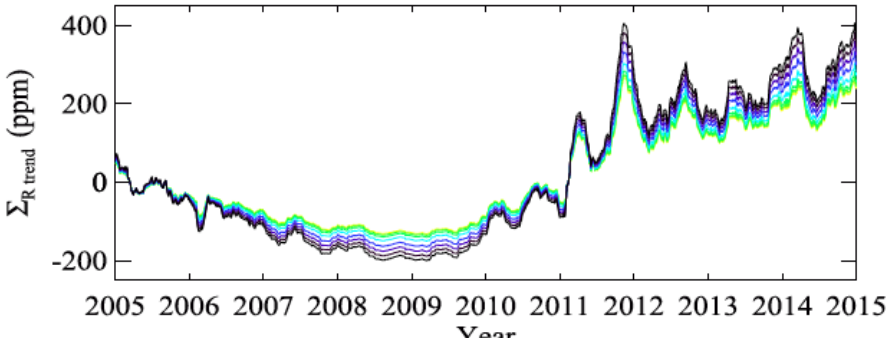


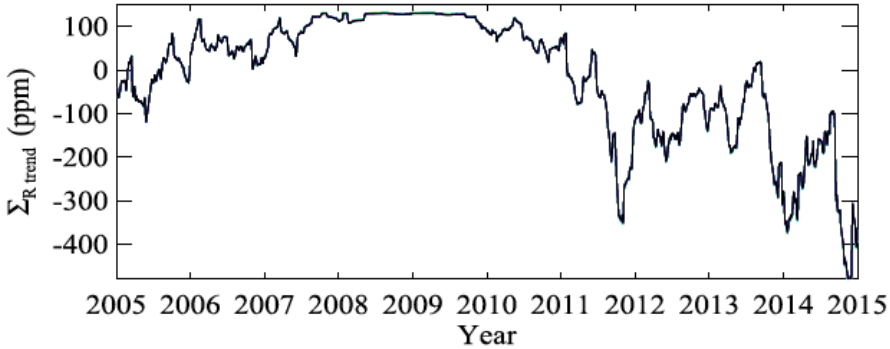
The ‘true’ CLV cannot be known and therefore non-radiometric observations face inherent difficulty distinguishing real trends from those in the CLV


200
0
-200
-400
$\Sigma_{R\ trend}$ (ppm)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year


100
0
-100
-200
-300
$\Sigma_{R\ trend}$ (ppm)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year


300
200
100
0
-100
-200
$\Sigma_{R\ trend}$ (ppm)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year


400
200
0
-200
$\Sigma_{R\ trend}$ (ppm)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015


100
0
-100
-200
-300
-400
$\Sigma_{R\ trend}$ (ppm)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year