$F_{10.7}$: Sources of the canonical solar EUV proxy

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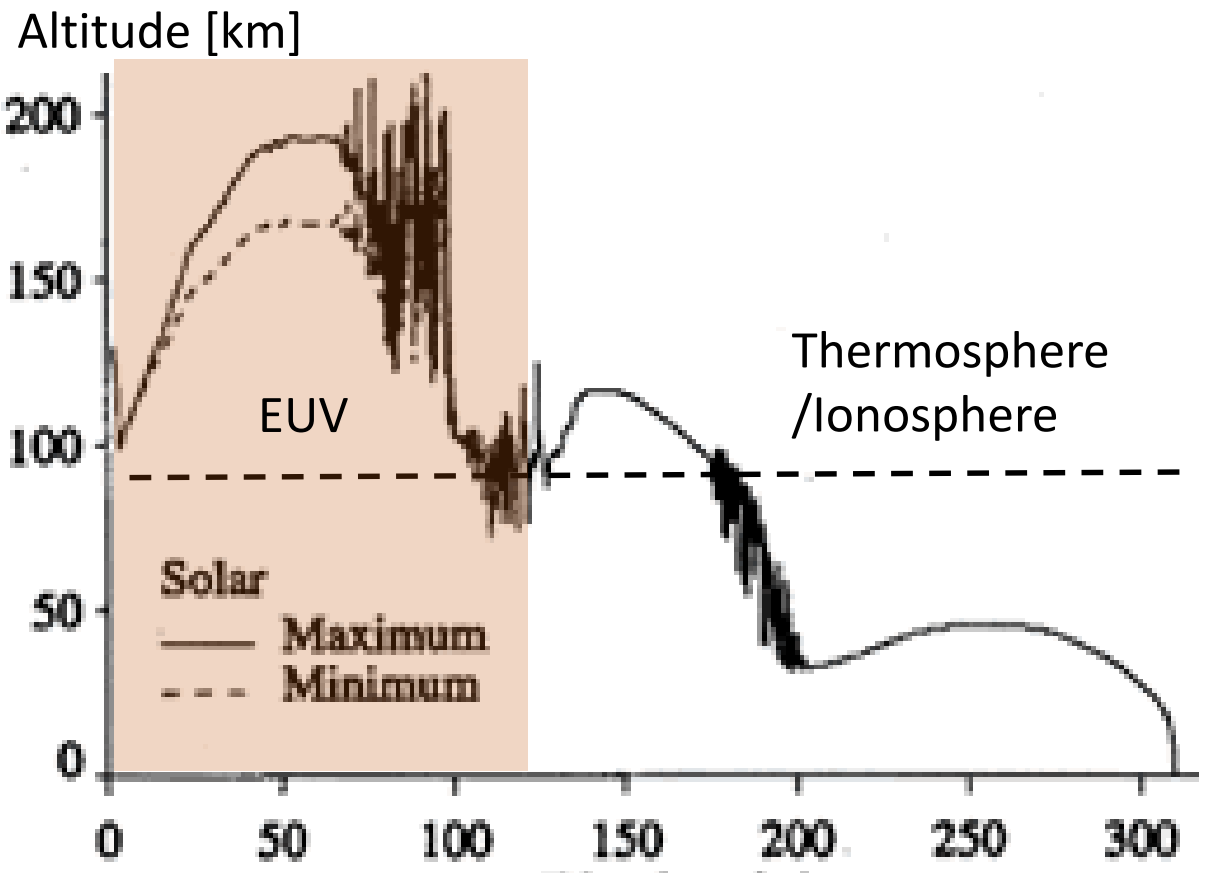
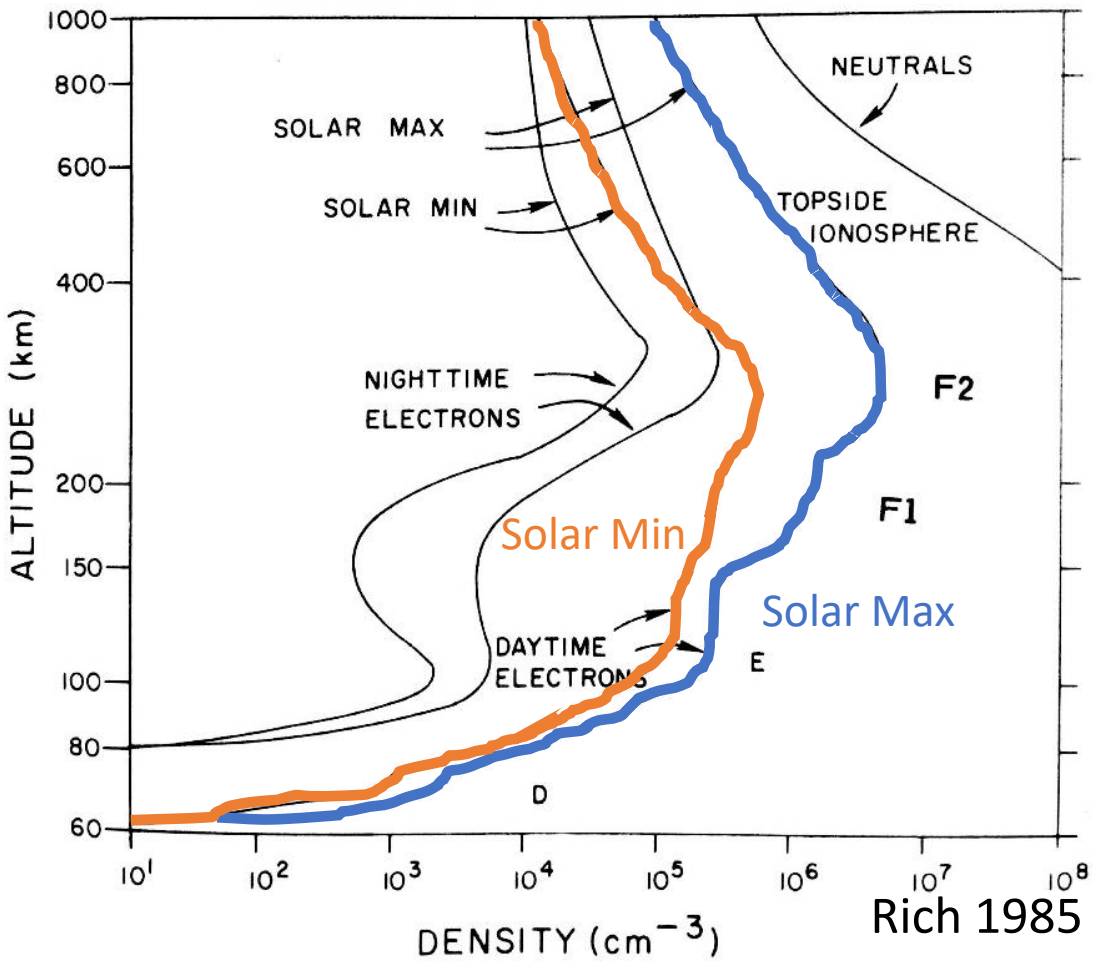
UNOOSA ISWI workshop 11/2/2021



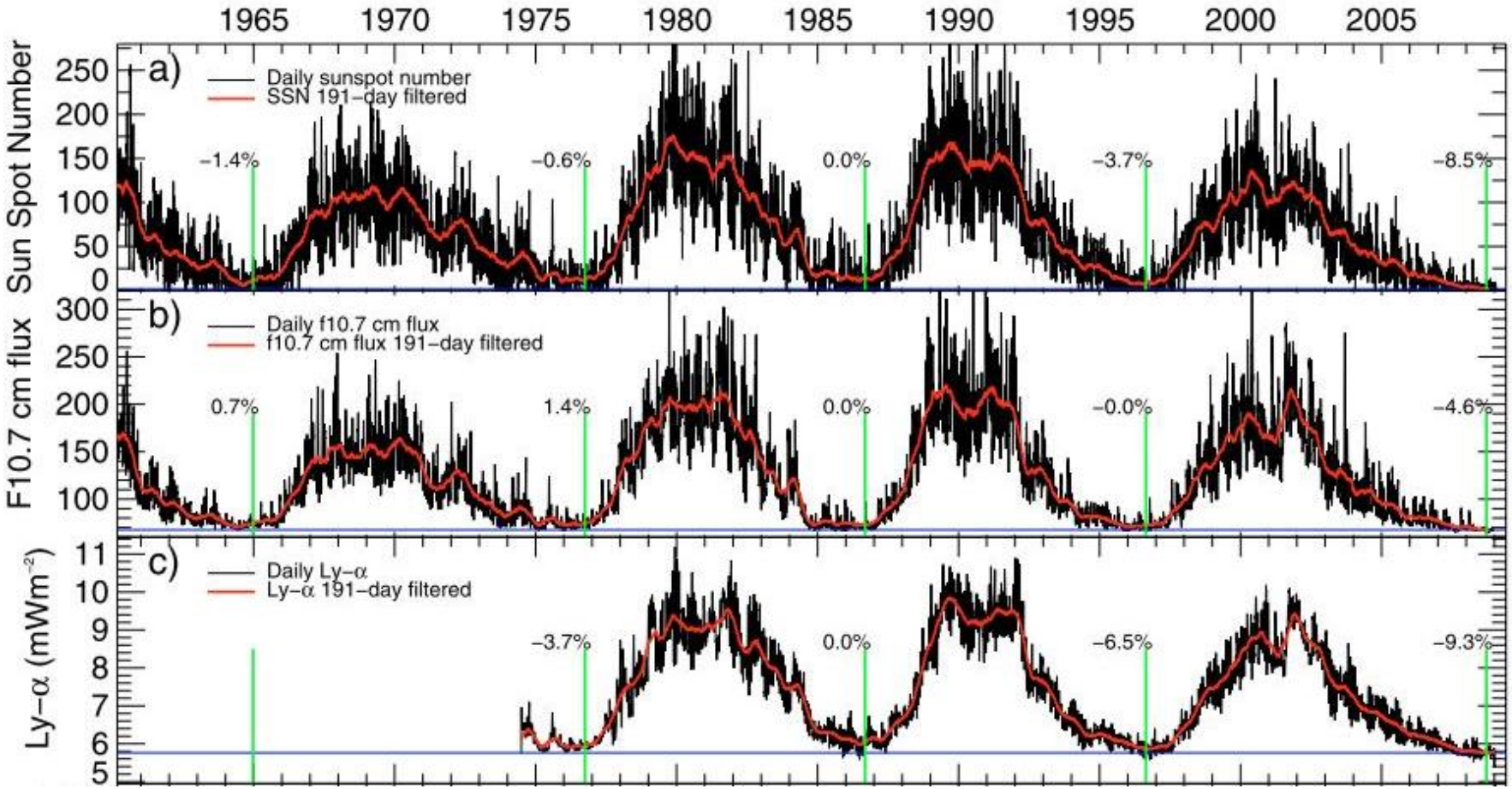
Haigh 2004



Rich 1985

$F_{10.7}$ Index

- 10.7 cm (2.8 GHz) radio flux, 70+ year dataset (Tapping 1987)
- EUV proxy used for atmospheric research

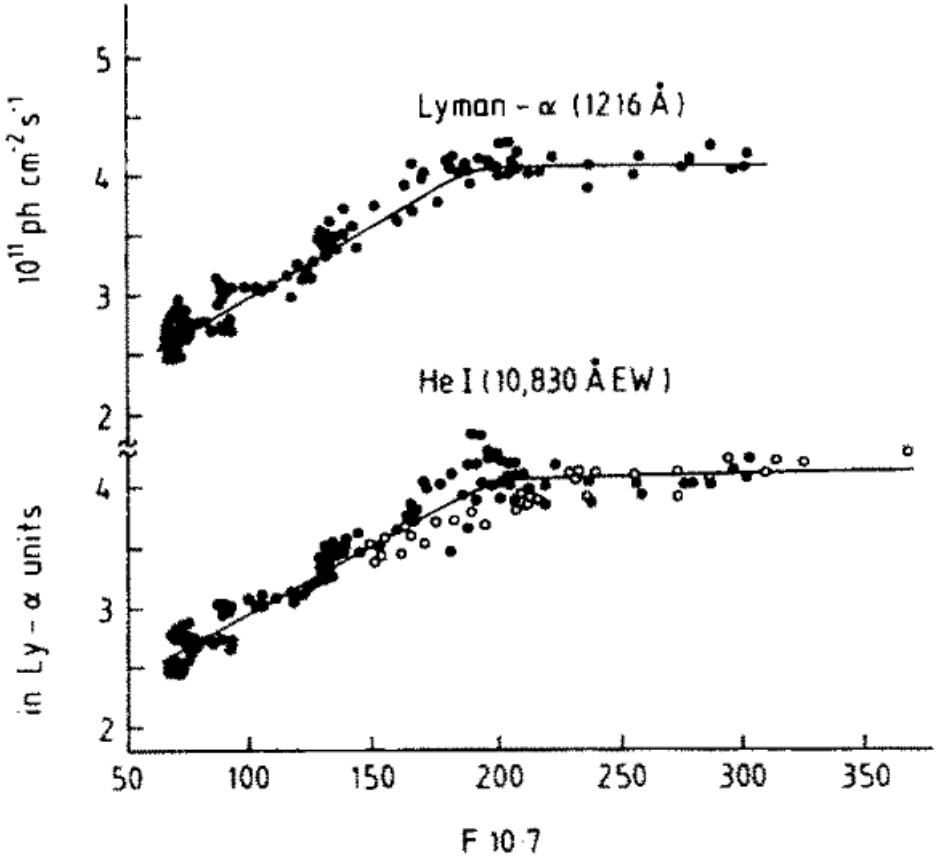


1 sfu = 10^4 Jy

Fröhlich 2009

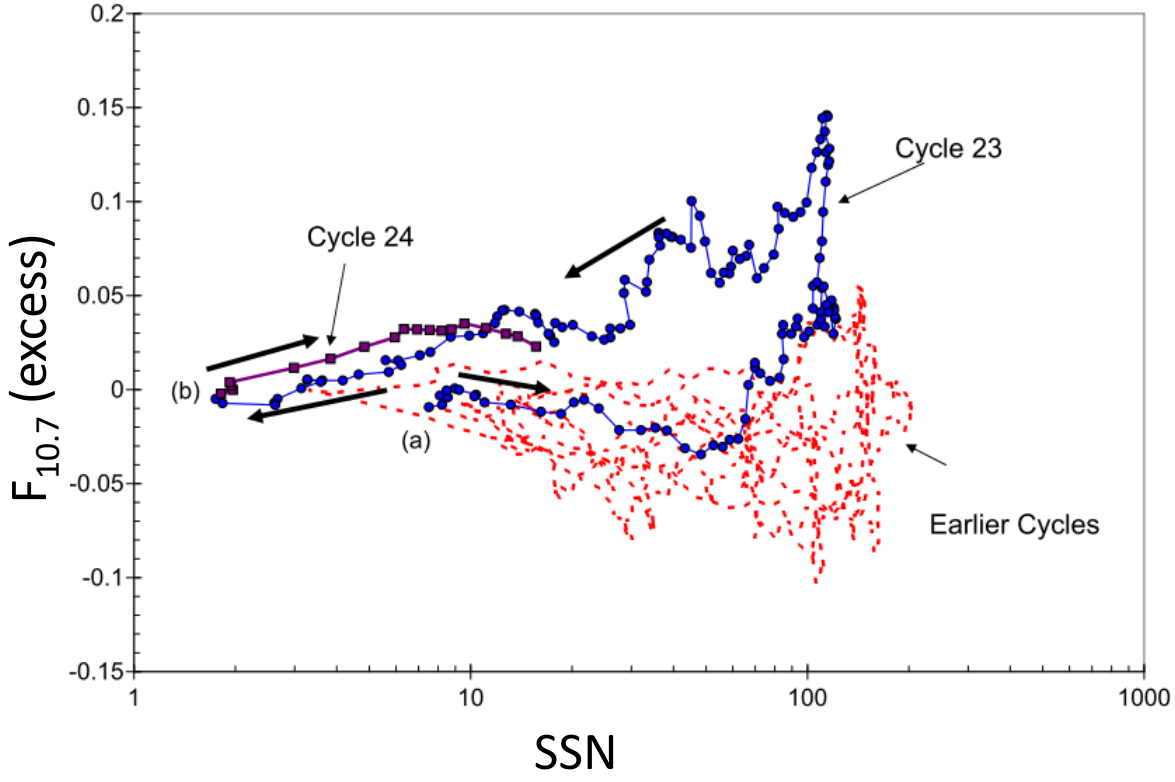
$F_{10.7}$ non-linearity with solar activity

During high-activity periods



Balan, Bailey, and Jayachandran 1993

During a solar cycle

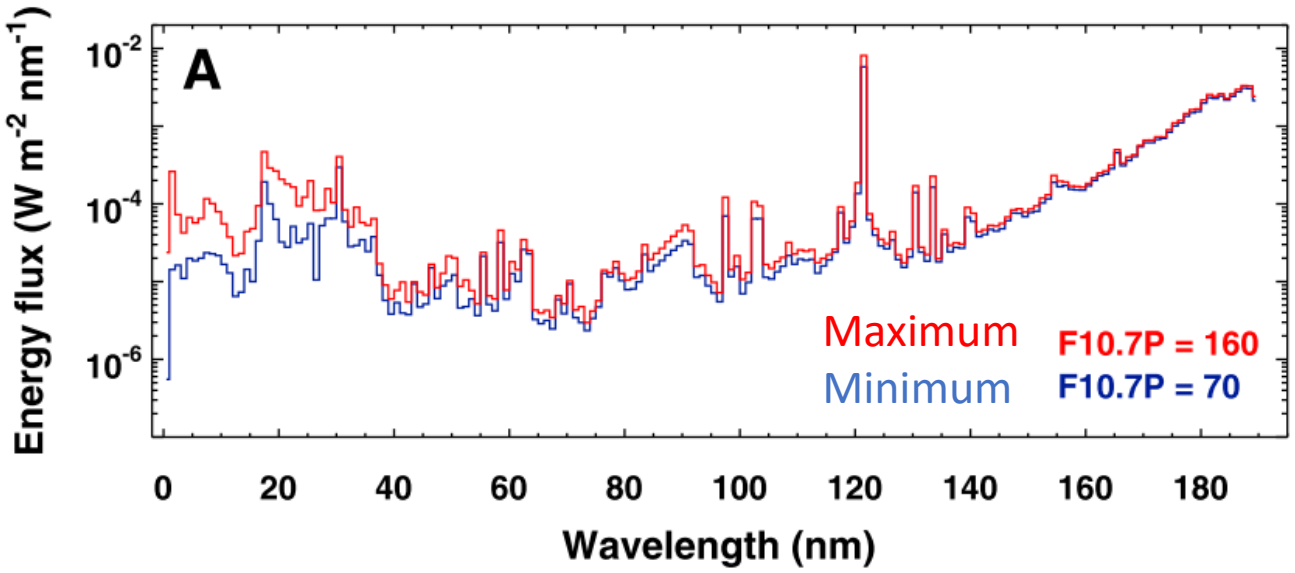


Tapping and Valdés 2011

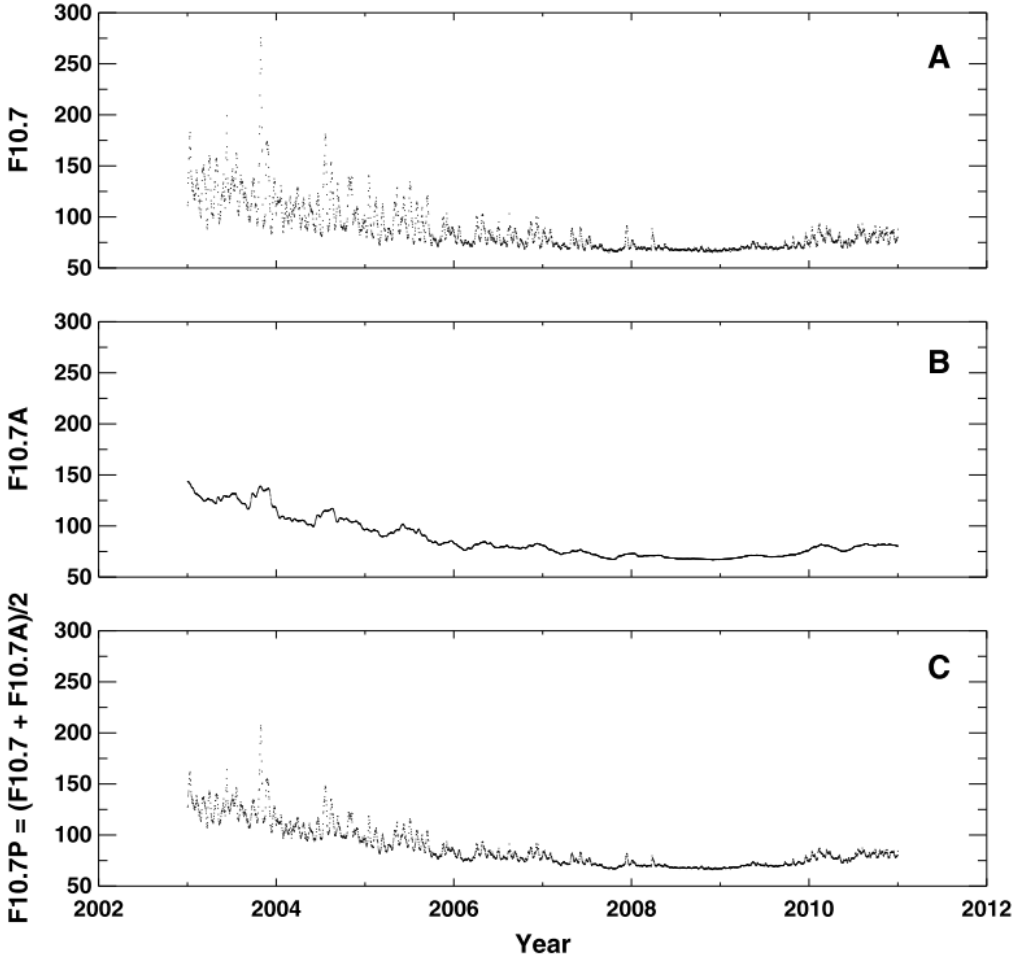
$F_{10.7}$ as an EUV Proxy

- $F_{10.7}$ averaged over 81 days
- Used to scale EUV spectrum

EUV spectra



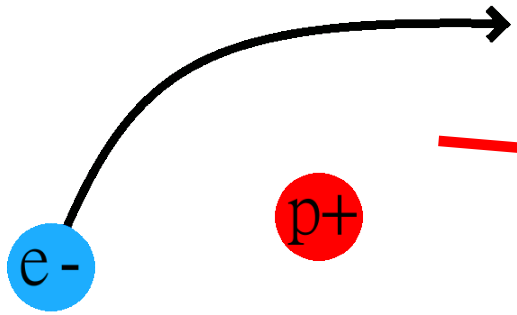
$F_{10.7}$ time series

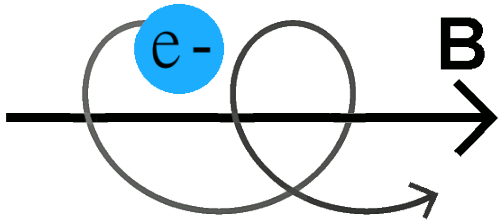


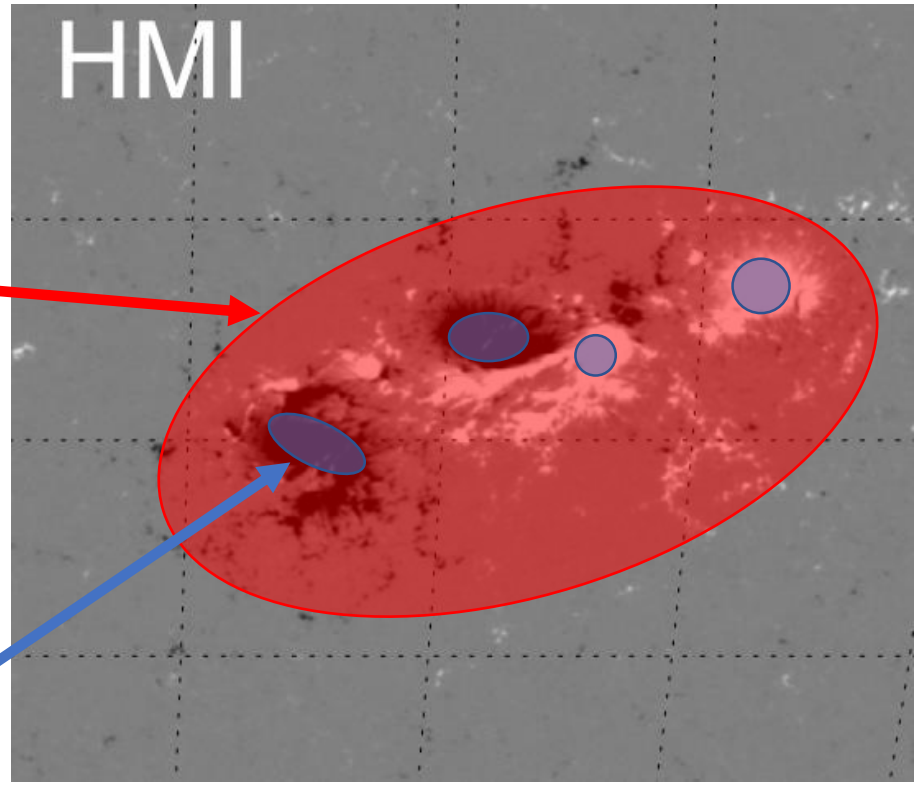
Girazian and Withers 2015

$F_{10.7}$ Generation Mechanisms

- Bremsstrahlung
  - Free-free electron-ion interactions
  - Active regions and plage
  - Traces density
  - Unpolarized
  - Spectrally “flat“
- Gyroresonance
  - Electrons spiraling around magnetic fields
  - Active region cores
  - Traces magnetic field
  - Circularly polarized
  - Spectrally peaked at 2—5 GHz



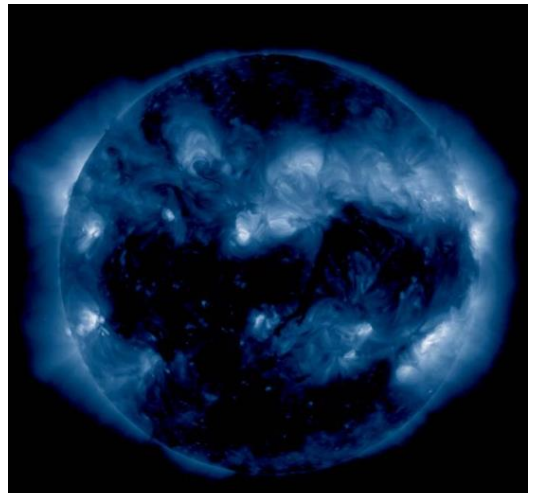


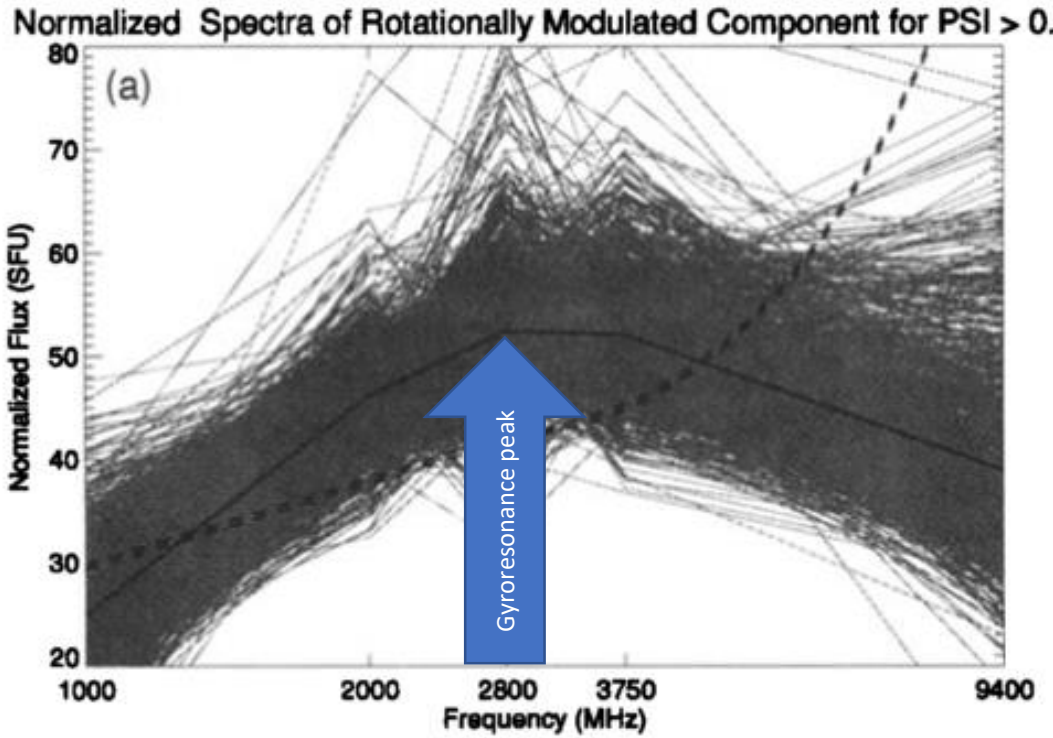


Aschwanden, Sun, and Liu 2014

Historical Source Studies

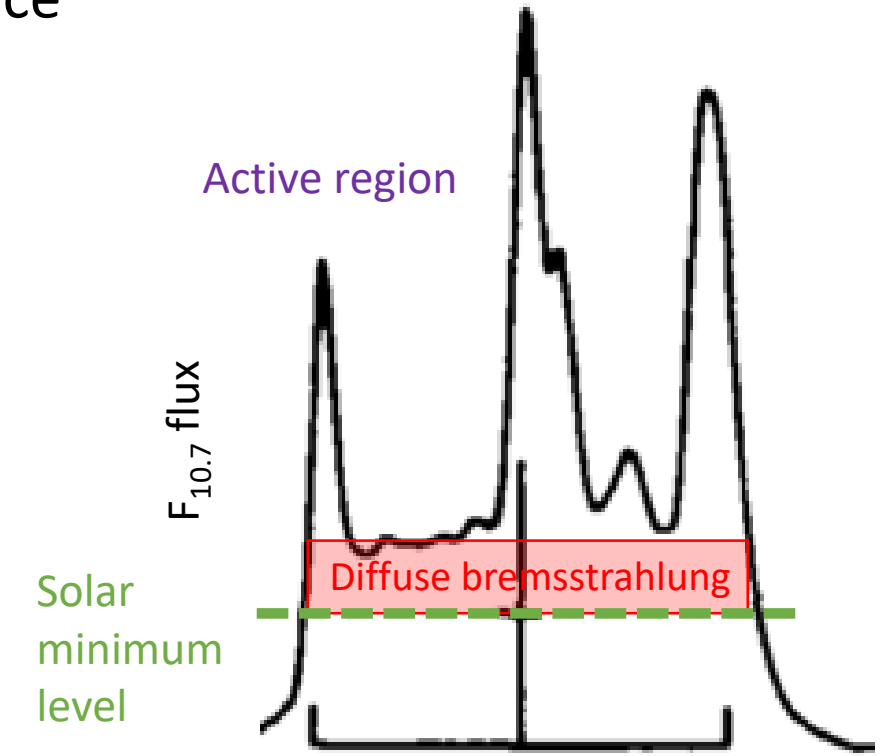
- Disagreement about source mechanism
  - Imaging typically suggests bremsstrahlung dominance
  - Spectral analysis suggests gyroresonance dominance





Schmahl and Kundu 1995

$F_{10.7}$



Tapping and DeTracey 1990

How We Separate Gyroresonance Emission

$F_{10.7}$ (ground)

Predict Bremsstrahlung

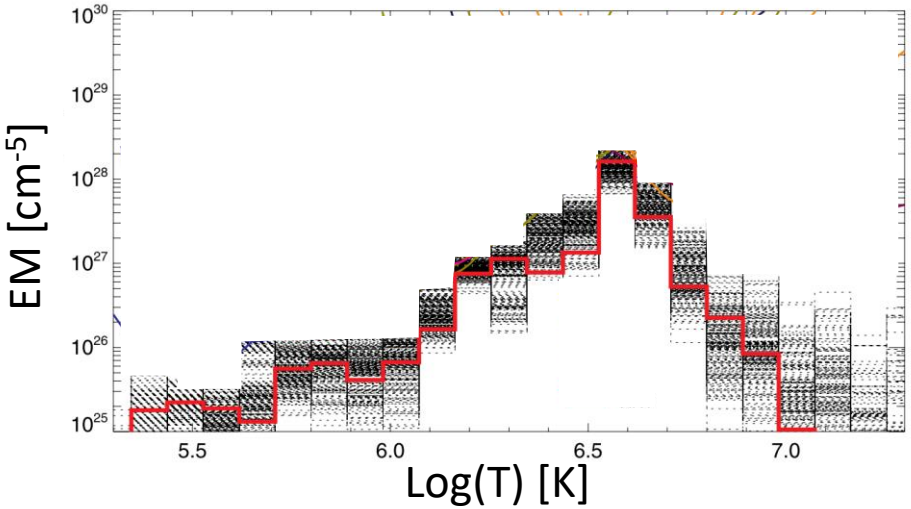
Detected Gyroresonance

Observe

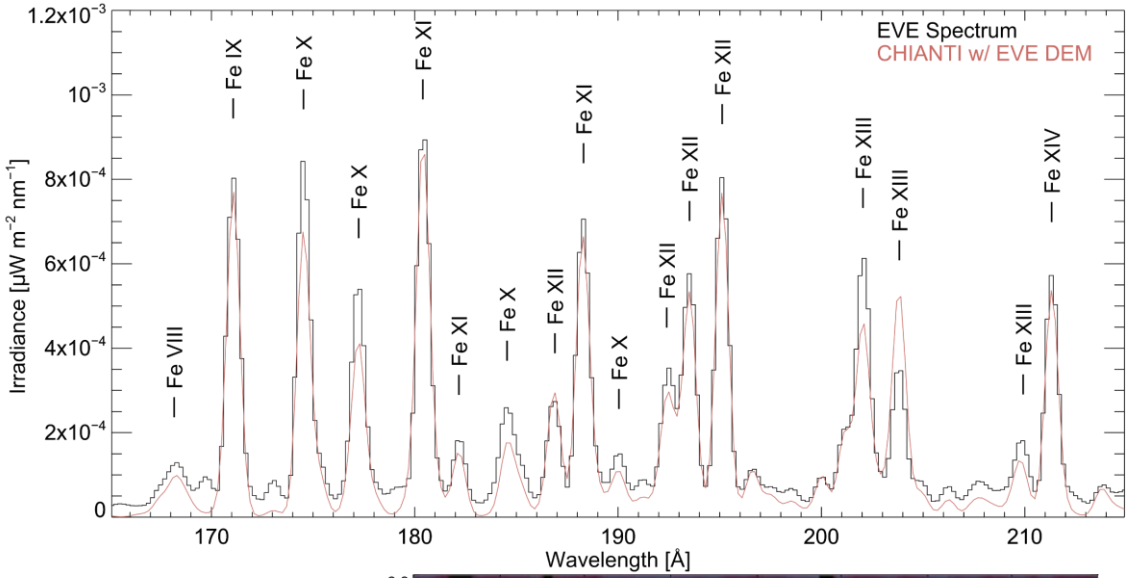
EUV (space)

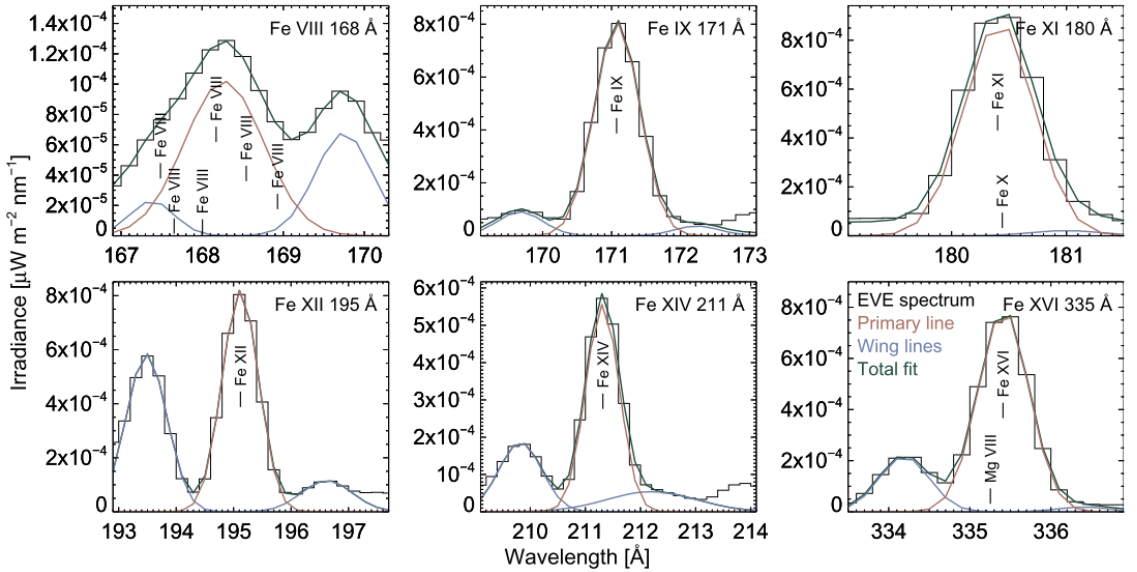
Compute DEM

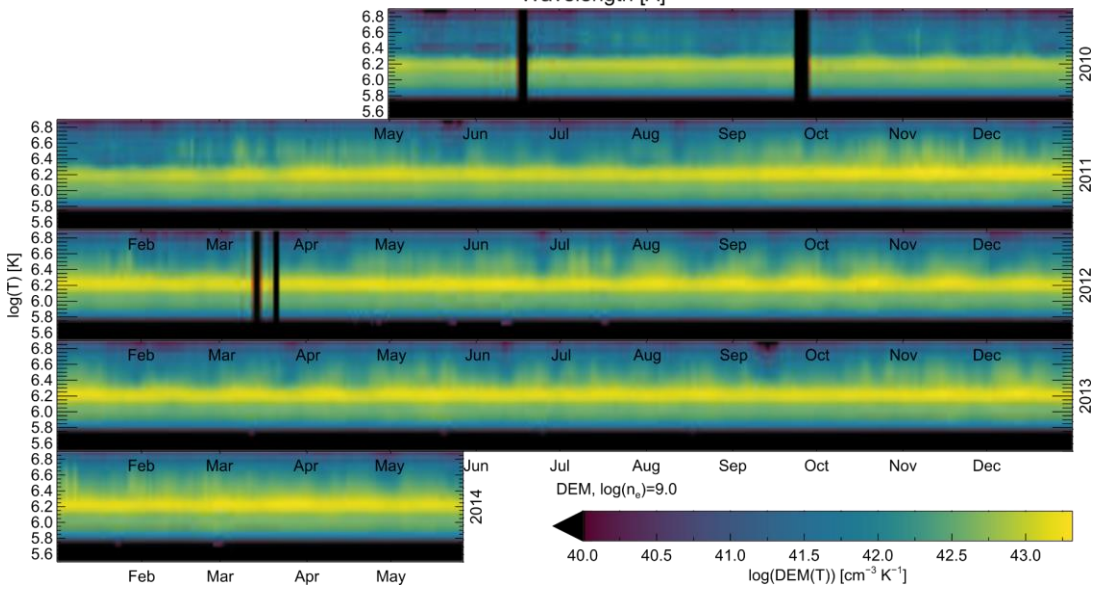
$$f_\nu \propto \int T^{-0.5} \boldsymbol{DEM}(\boldsymbol{T}) G(T, \nu)\, dT$$

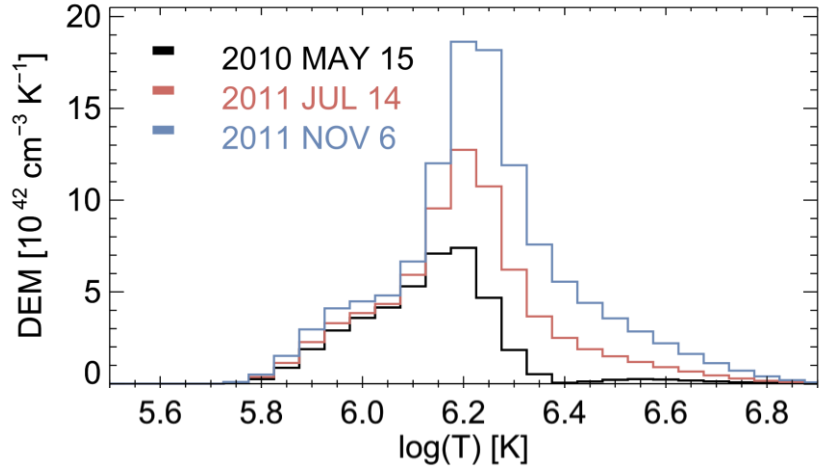


EVE MEGS-A Irradiance and DEMs



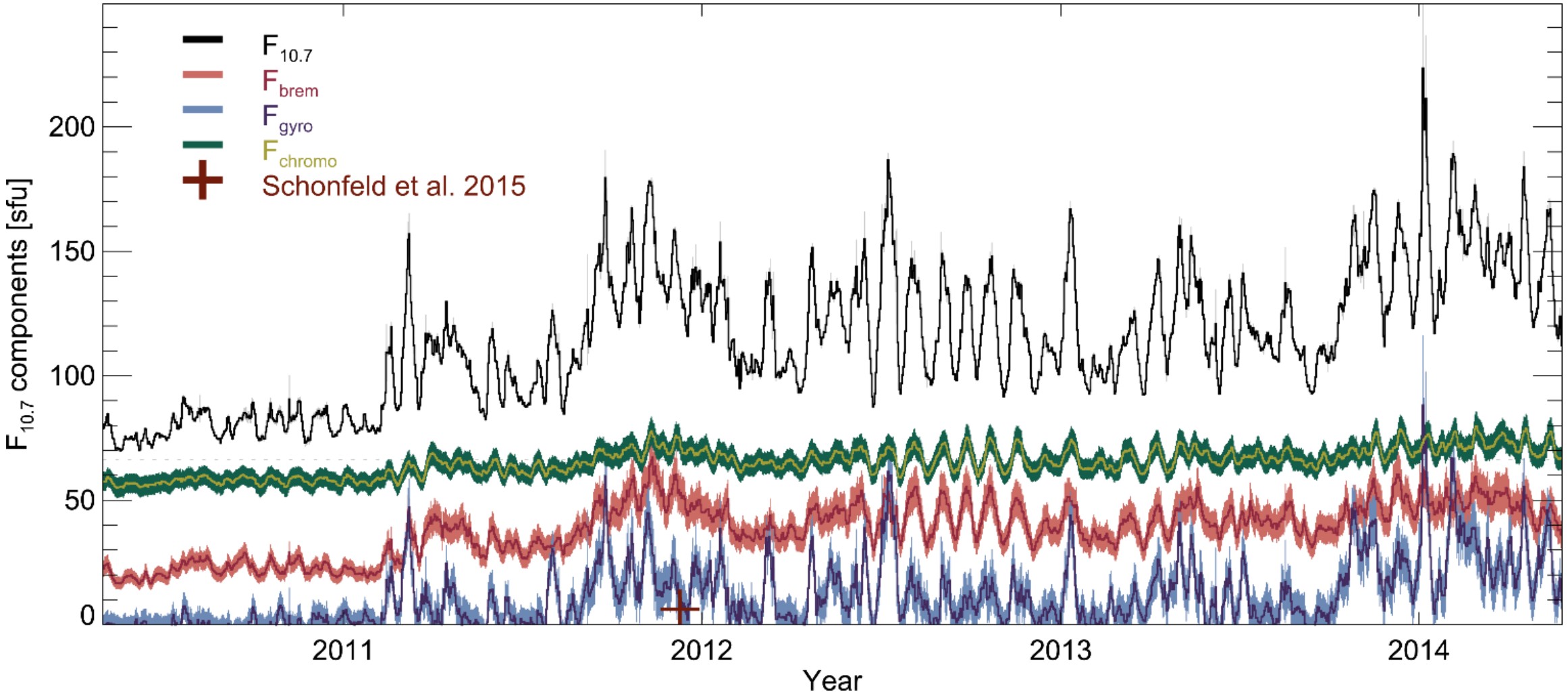


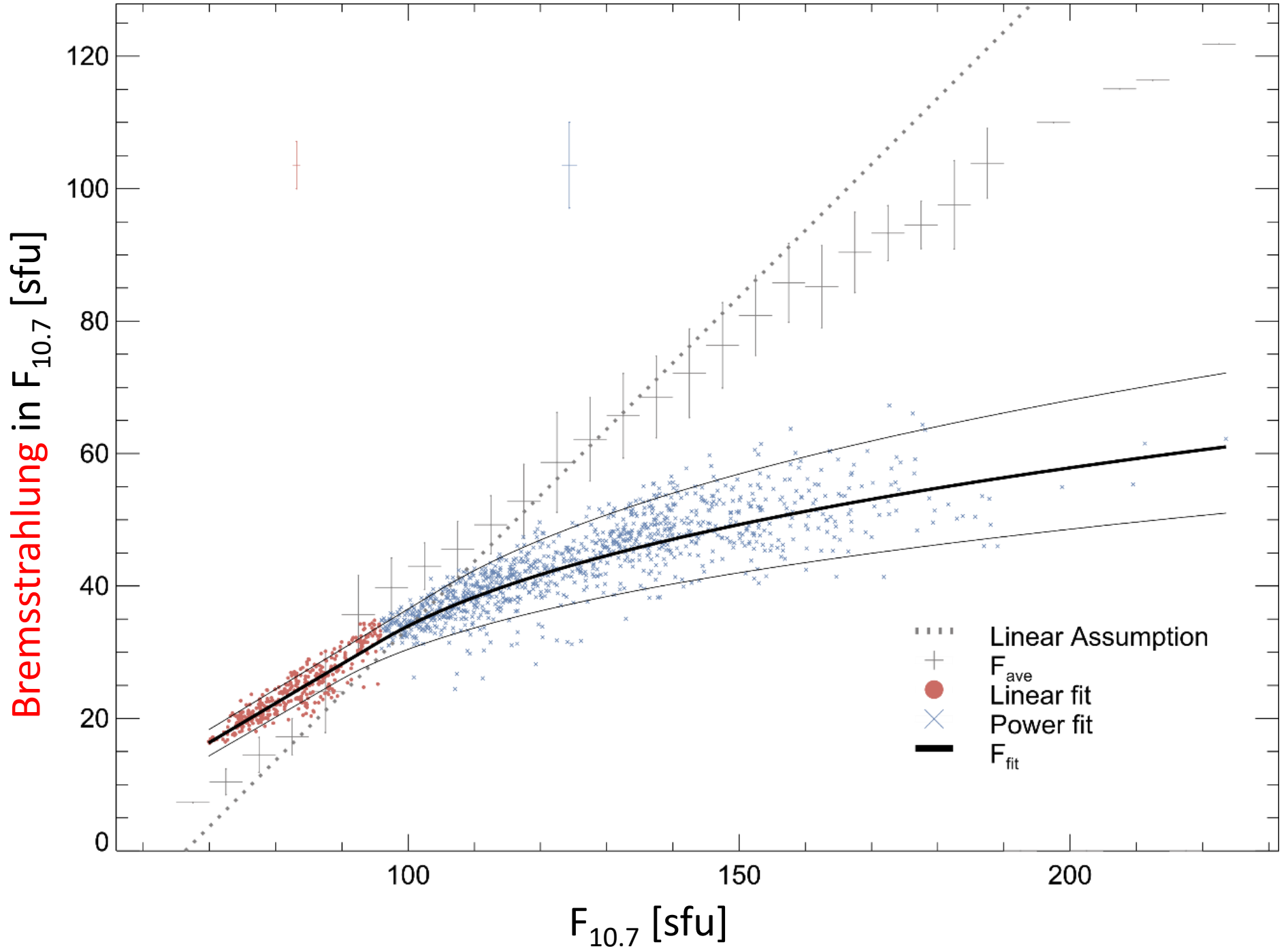




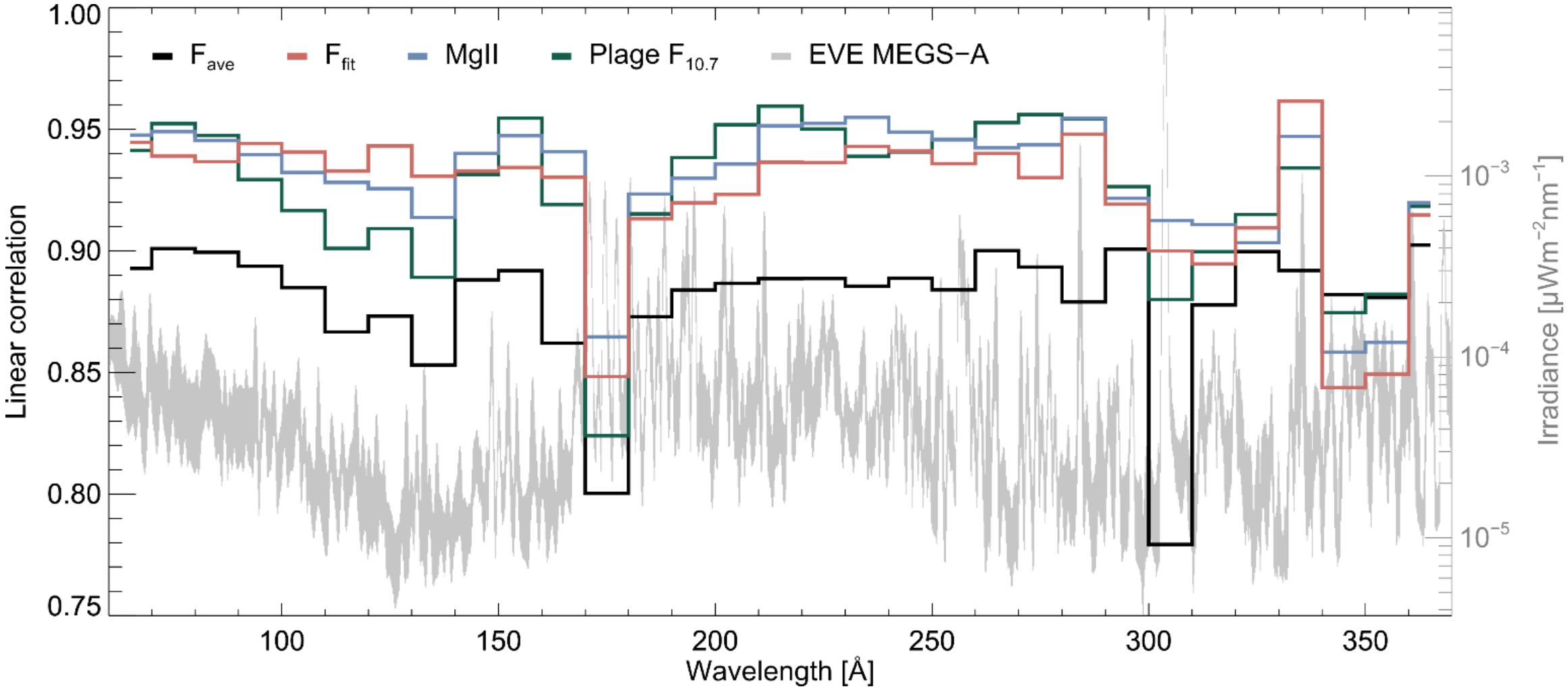
Schonfeld et al. 2017 ApJ 844 163

Emission components of $F_{10.7}$



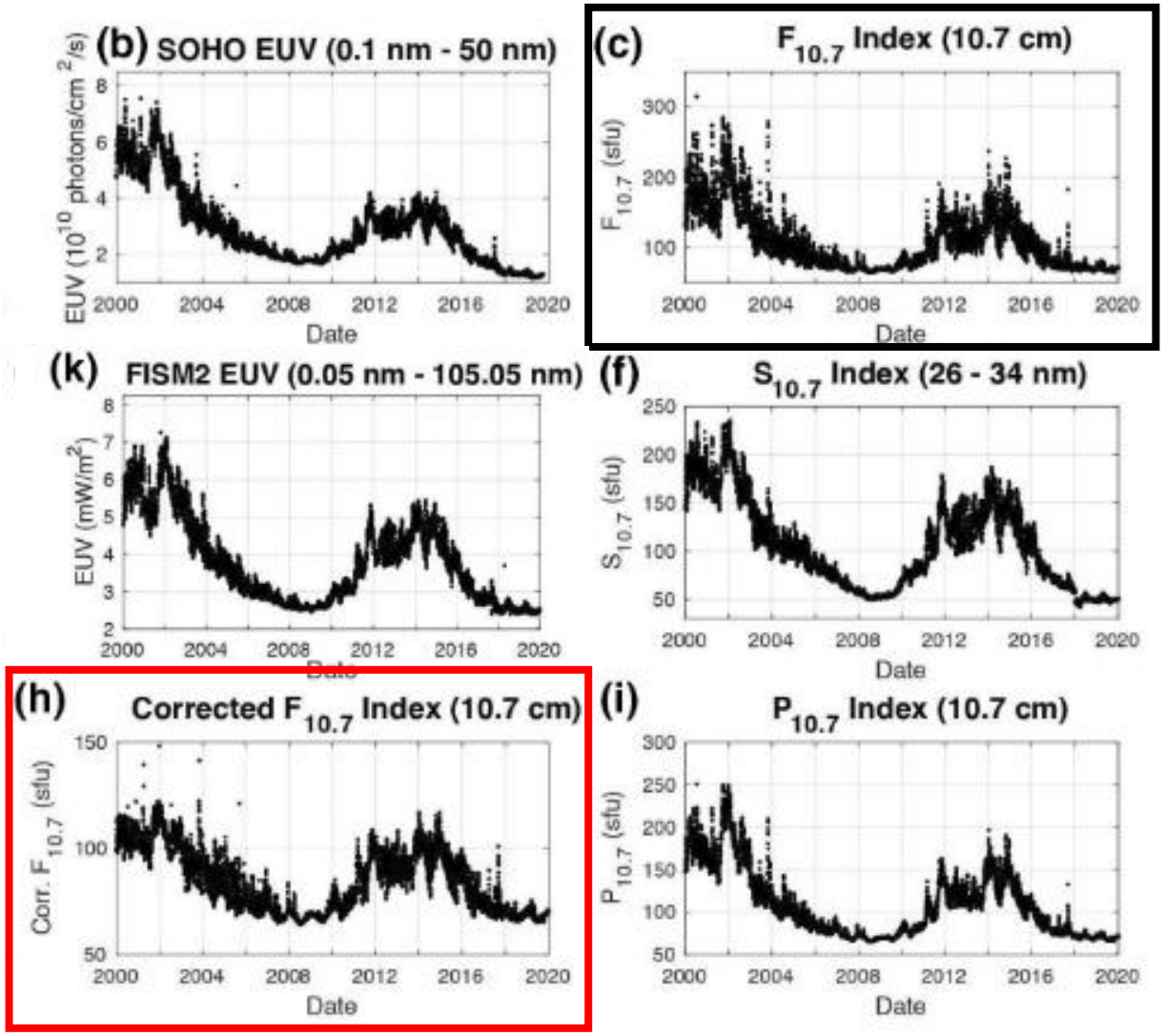

Bremsstrahlung in $F_{10.7}$ [sfu]
$F_{10.7}$ [sfu]
0
20
40
60
80
100
120
100
150
200
Linear Assumption
F_{ave}
Linear fit
Power fit
F_{fit}

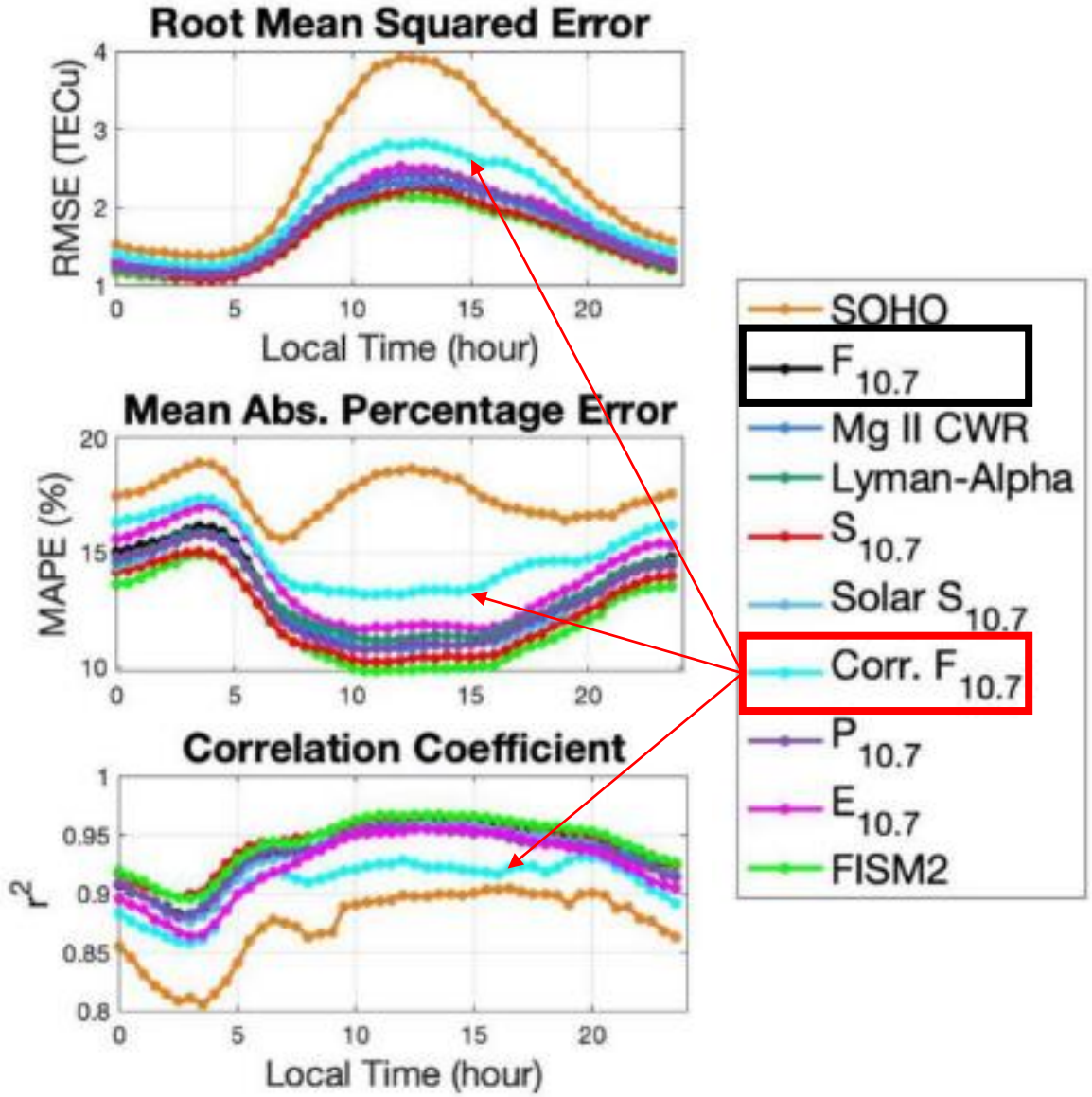
Bremsstrahlung component as an EUV proxy



F_{brem} driving TEC model

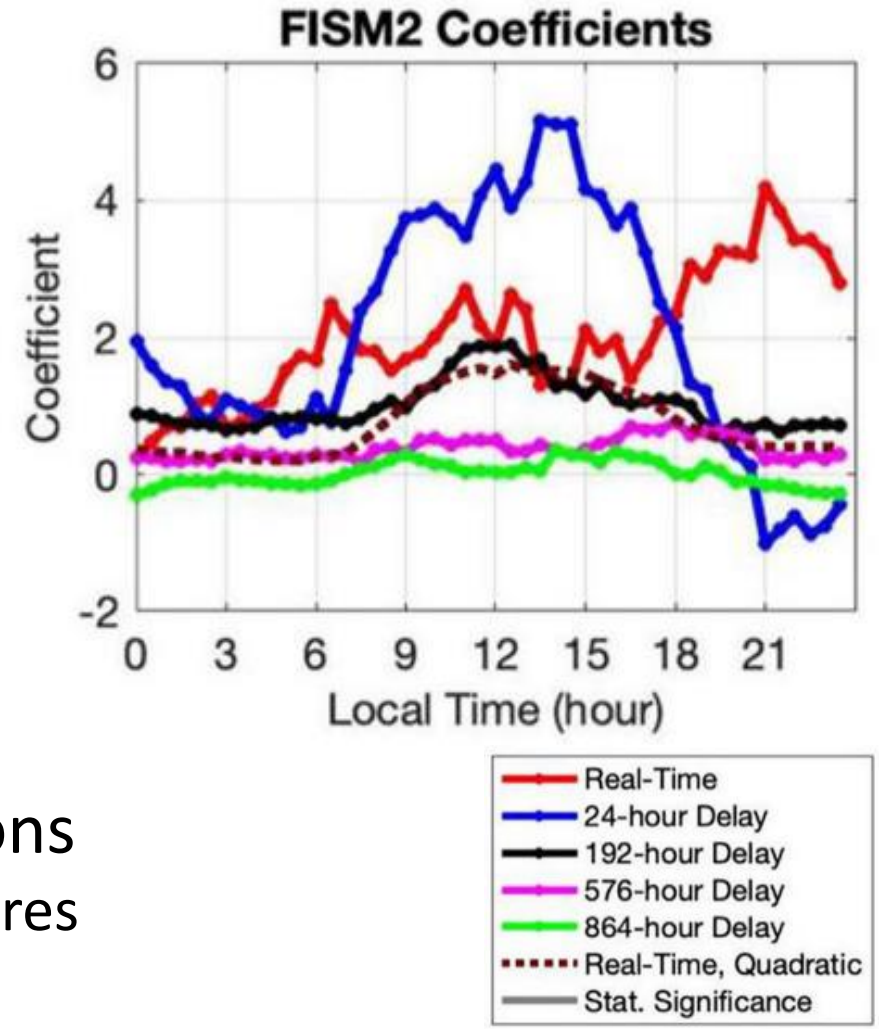
Goncharenko, et al. 2021
JGR Space Physics 126 e28466





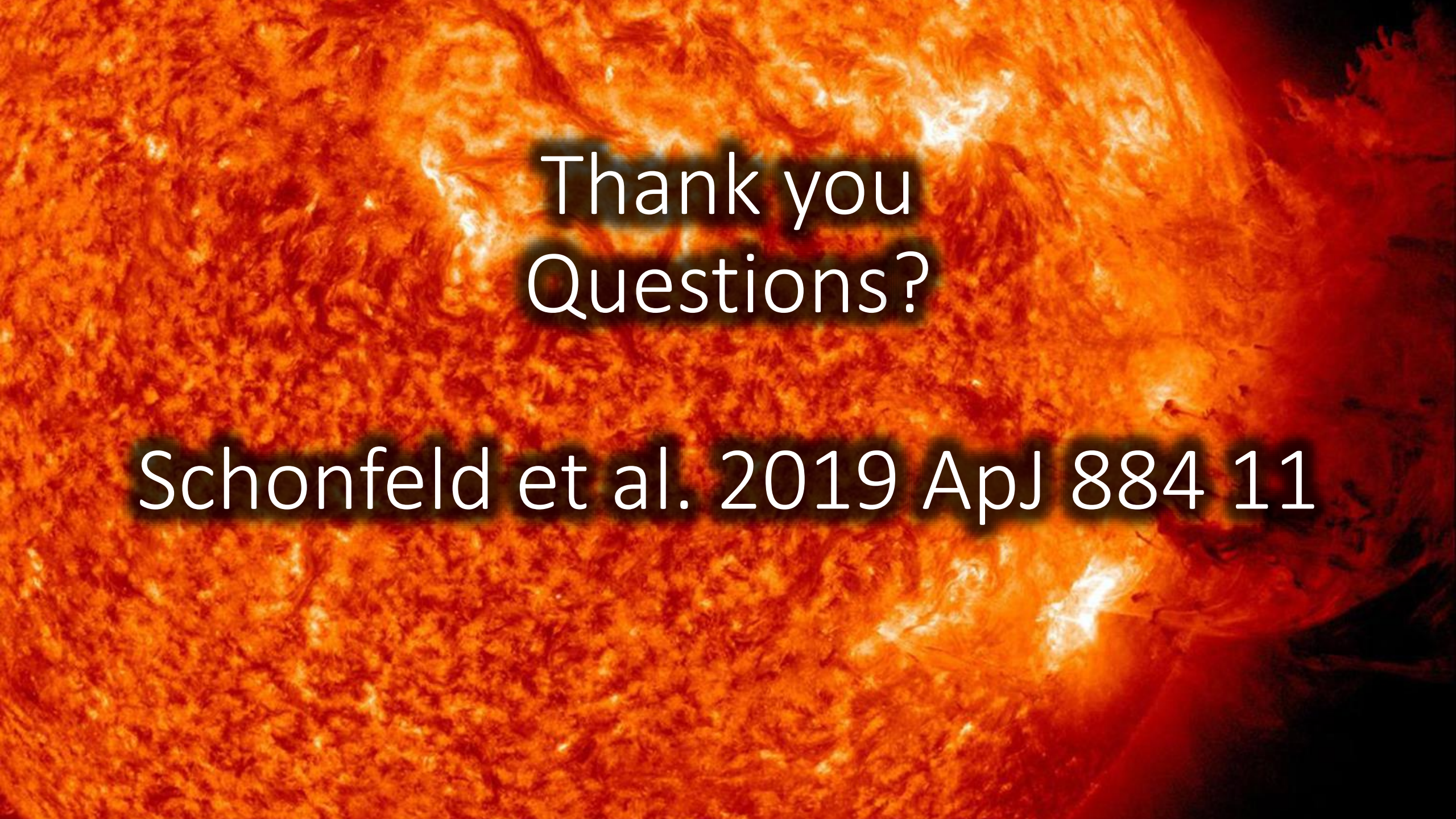
Why doesn't F_{brem} improve the TEC model?

- TEC response to solar input complex
  - Models include delay terms
  - Naturally filters gyroresonance
- Characteristic bremsstrahlung fit
  - Daily scatter around best-fit
  - Derived using only weak Cycle 24
  - Does not include chromospheric variability
- Gyroresonance produced in large active regions
  - Might contain valuable information about e.g. flares



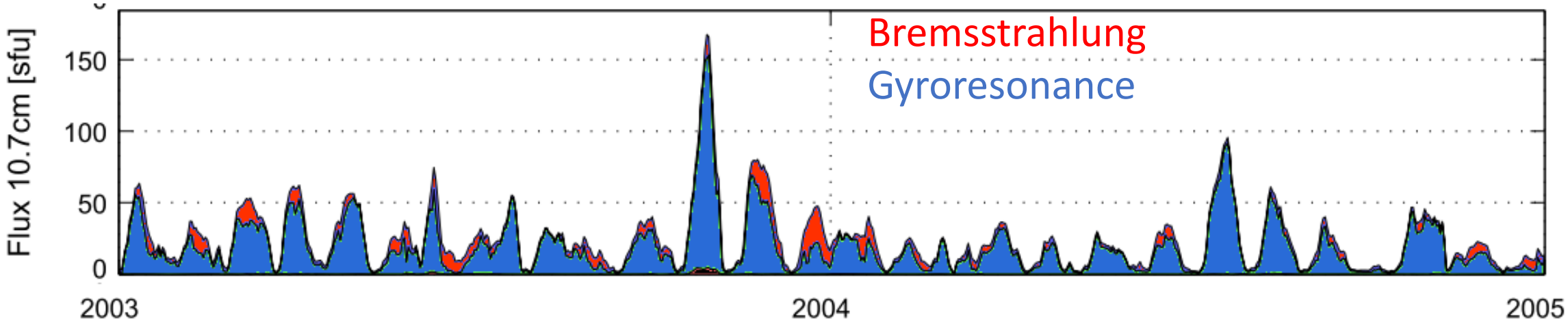
Conclusions

- Nonlinearity between $F_{10.7}$ and EUV at high activity due to gyroresonance emission
- Bremsstrahlung component fit from observed $F_{10.7}$
  - Improved correlation with observed EUV
  - Does not improve TEC model
- $F_{10.7}$ provides value, even with modern EUV observations
- Spatially and spectrally resolved $F_{10.7}$ (polarization) measurements can unambiguously isolate the emission components
  - e.g. EOVSA


Thank you
Questions?
Schonfeld et al. 2019 ApJ 884 11

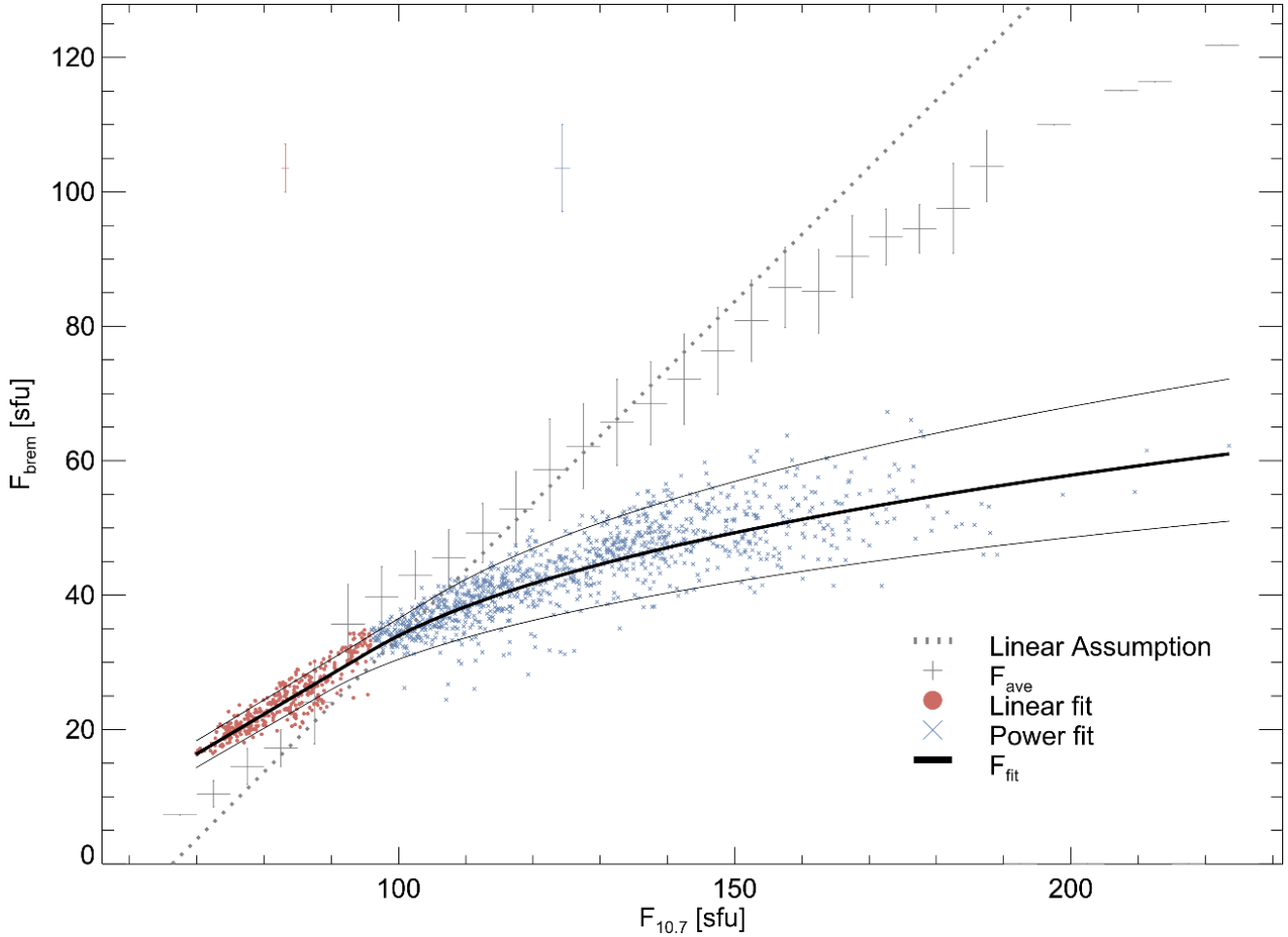
Recent $F_{10.7}$ Times Series Analysis

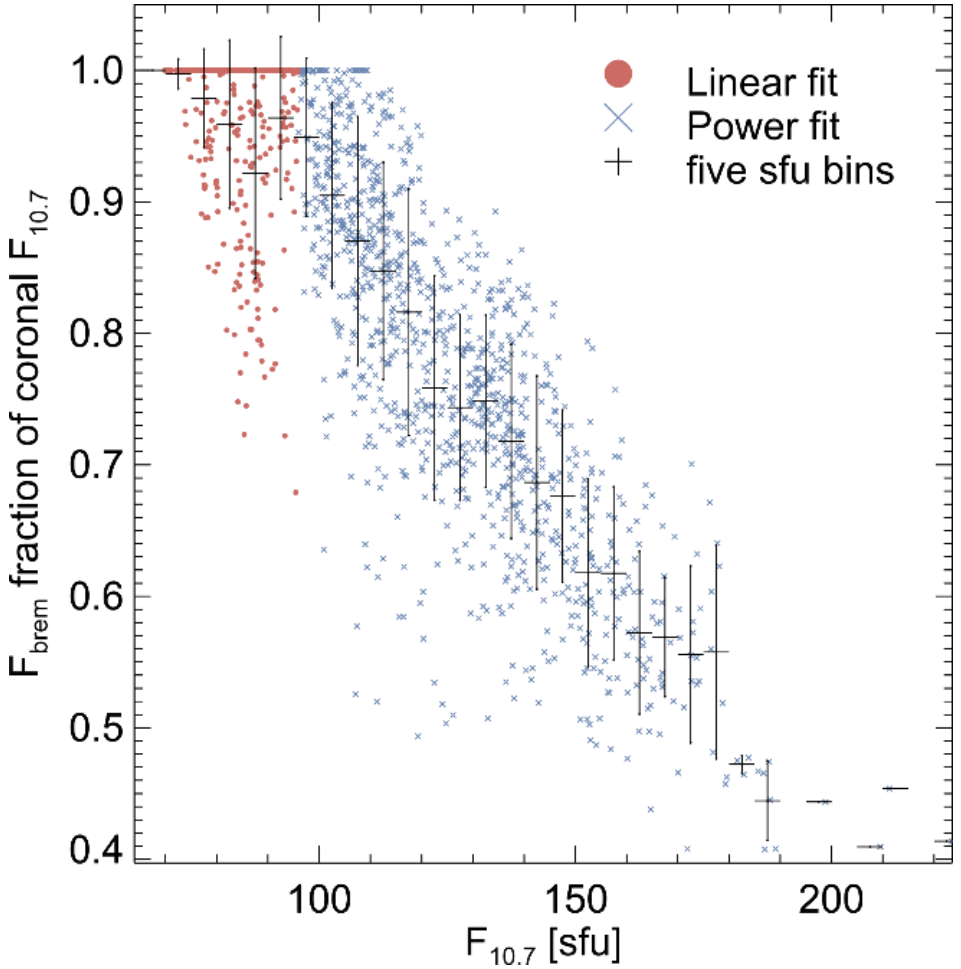
- $F_{10.7}$ plus 1.0, 2.0, 3.75, and 9.4 GHz
  - Blind Source Separation, correlation with solar activity proxies
- 90% of rotational variability due to gyroresonance emission
  - Identified by spectral and temporal characteristics and relationship to sunspots



Dudok de Wit, Bruinsma, Shibasaki 2014

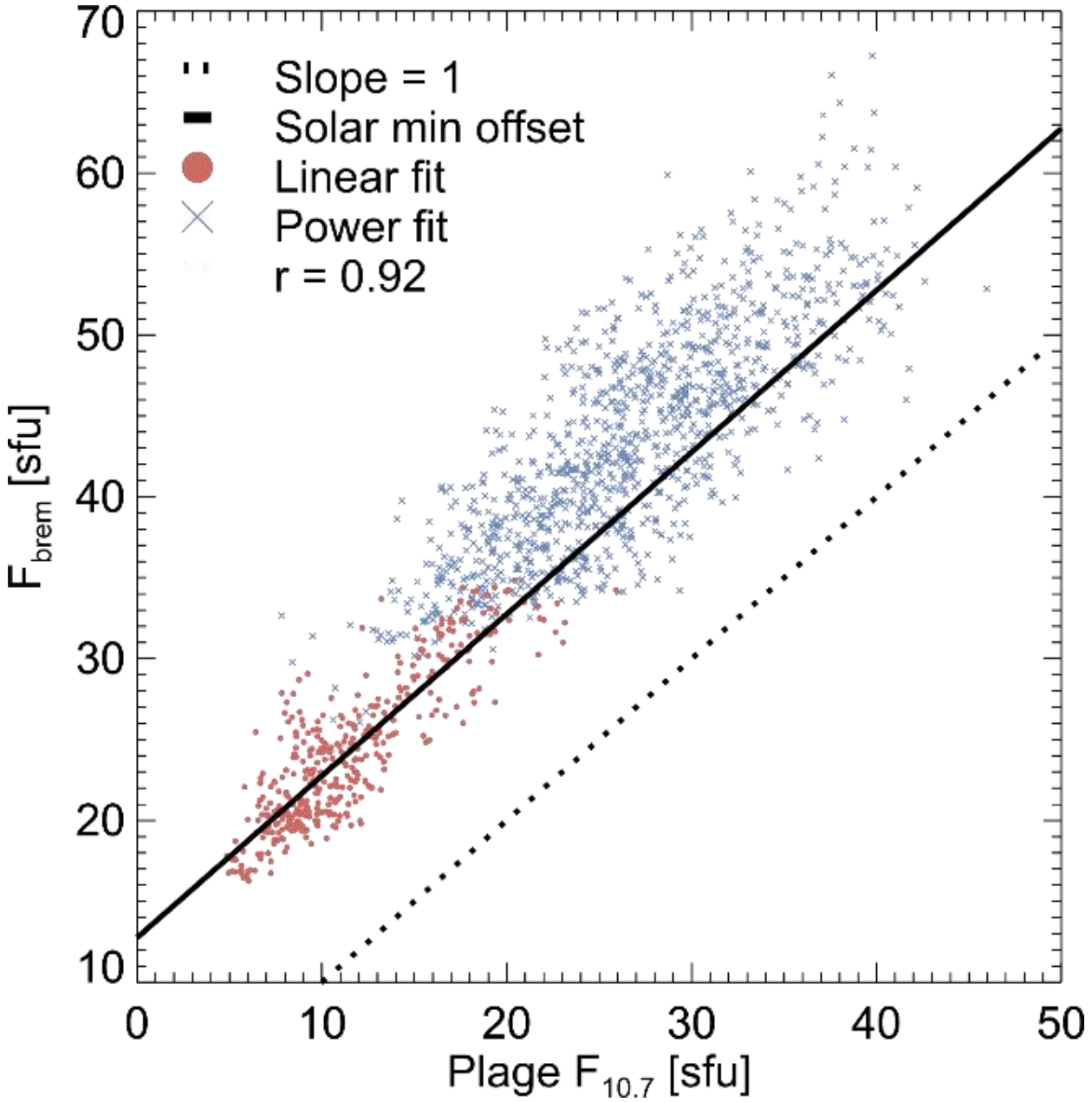
Bremsstrahlung component of $F_{10.7}$





$F_{10.7}$ and **B**-field

- Henney et al 2012 used photospheric **B**-field (plage and active region) to forecast $F_{10.7}$
- Bremsstrahlung compared with same **B**-field observations
  - Correlates best with the plage field strengths



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