UV Continuous Opacities for Cool Stars

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Why care about continuous opacity?

- Affects broadband colors
- Affects abundance measurements
- Boundary condition for photochemistry

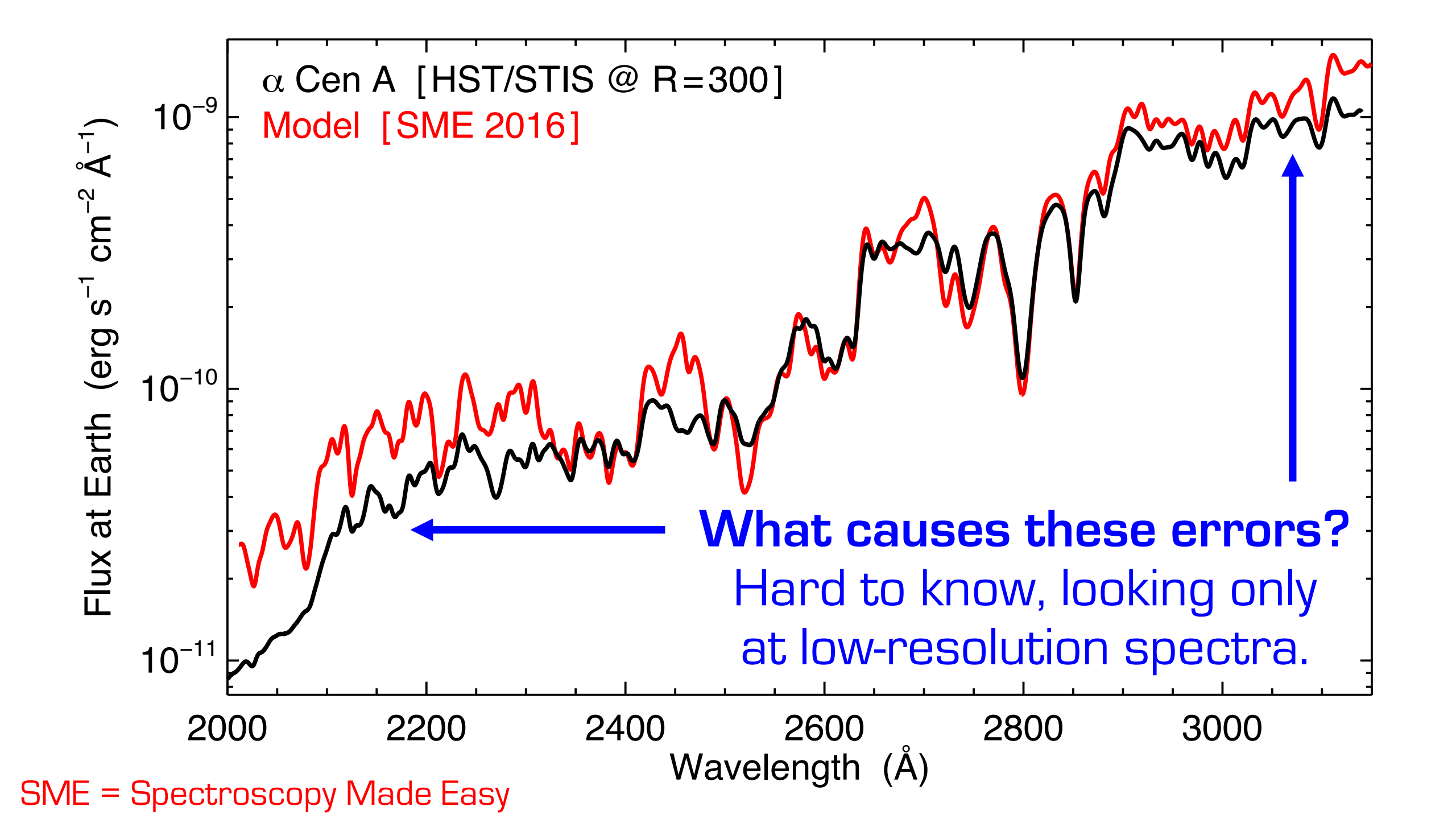
High-resolution flux-calibrated spectra can reveal continuous opacity errors

$$F_{\oplus} = \left(\frac{R_*}{D}\right)^2 F_*$$

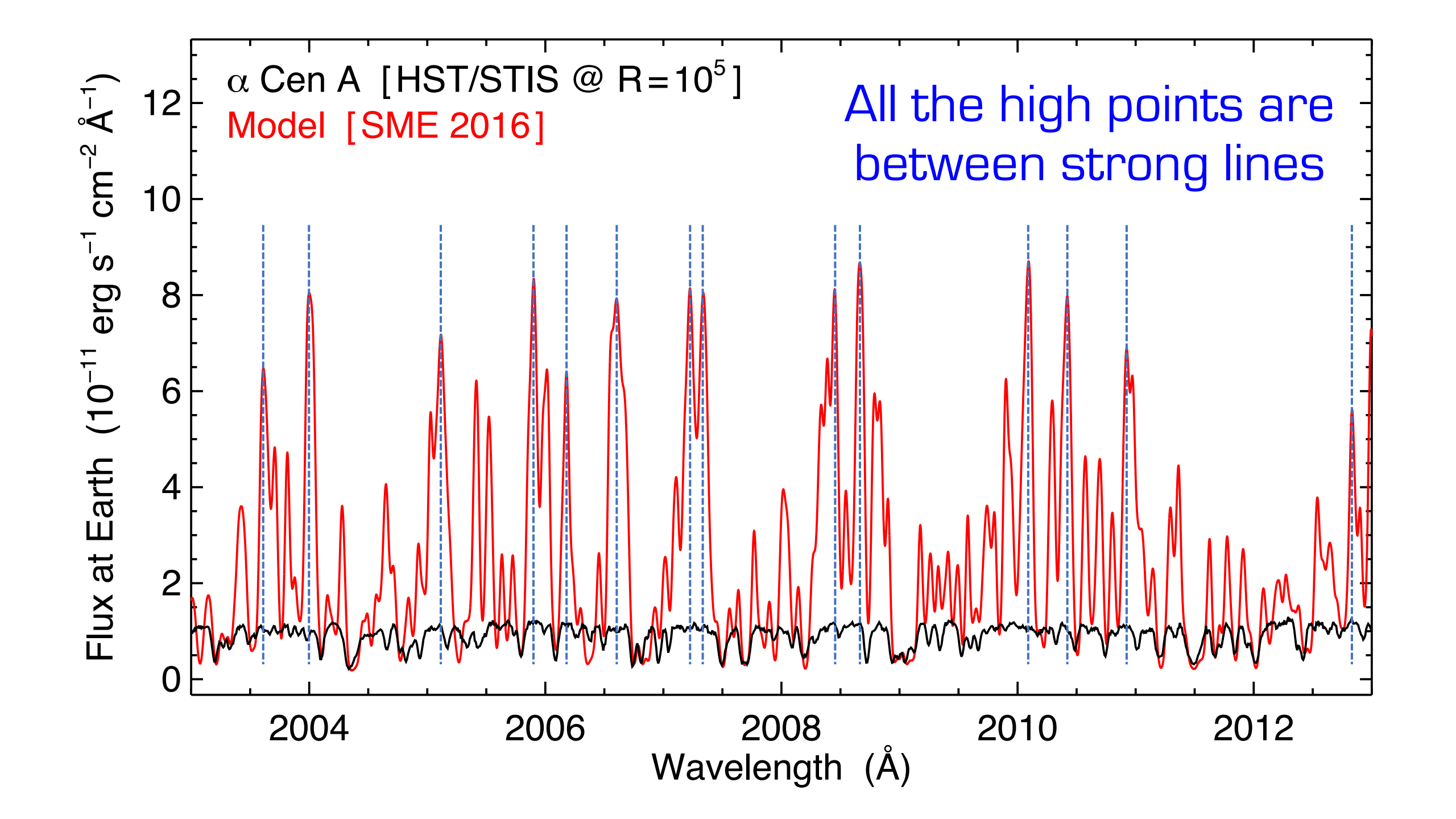
Observed (HST)

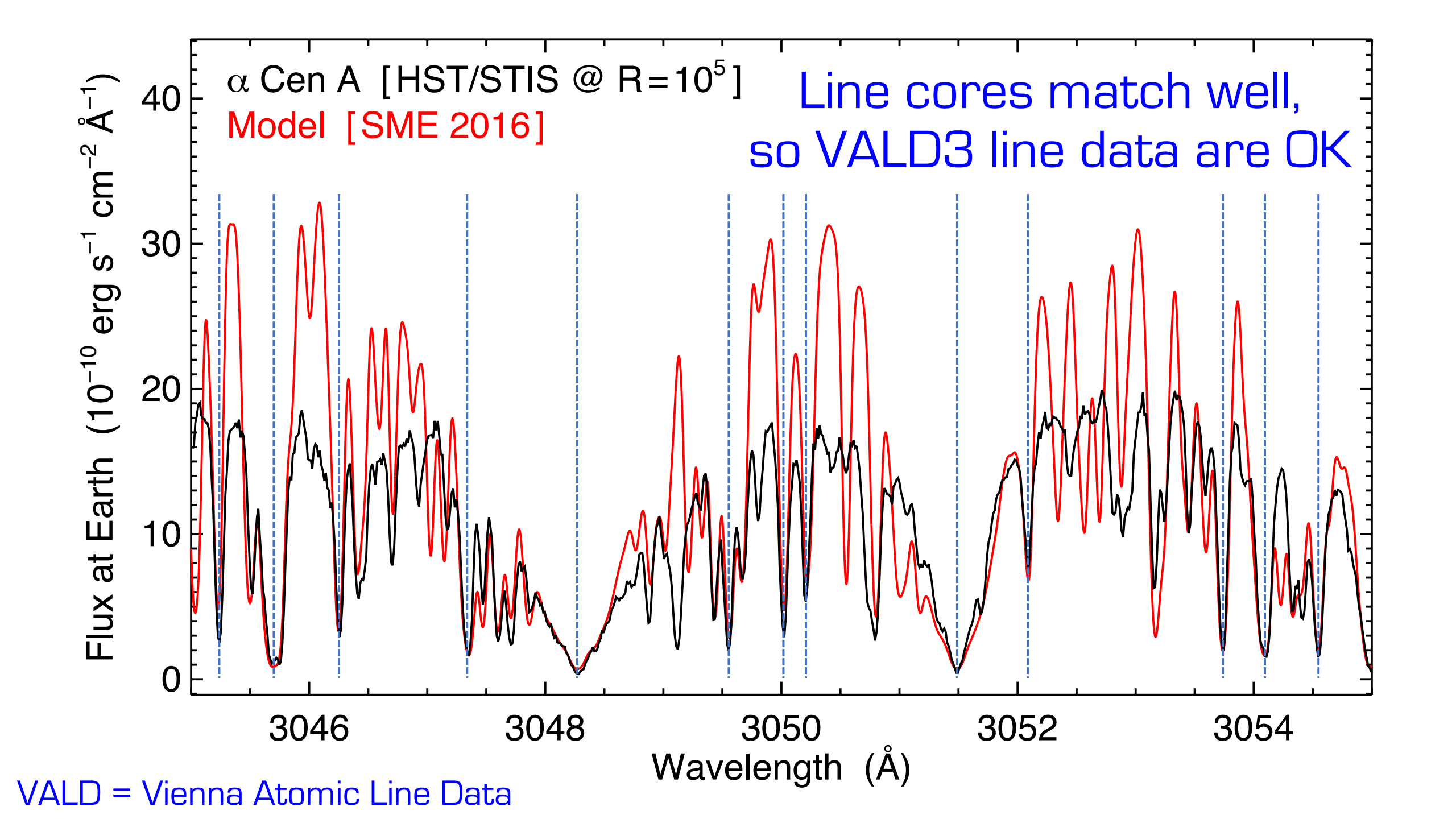
Angular radius

From RT code (SME)



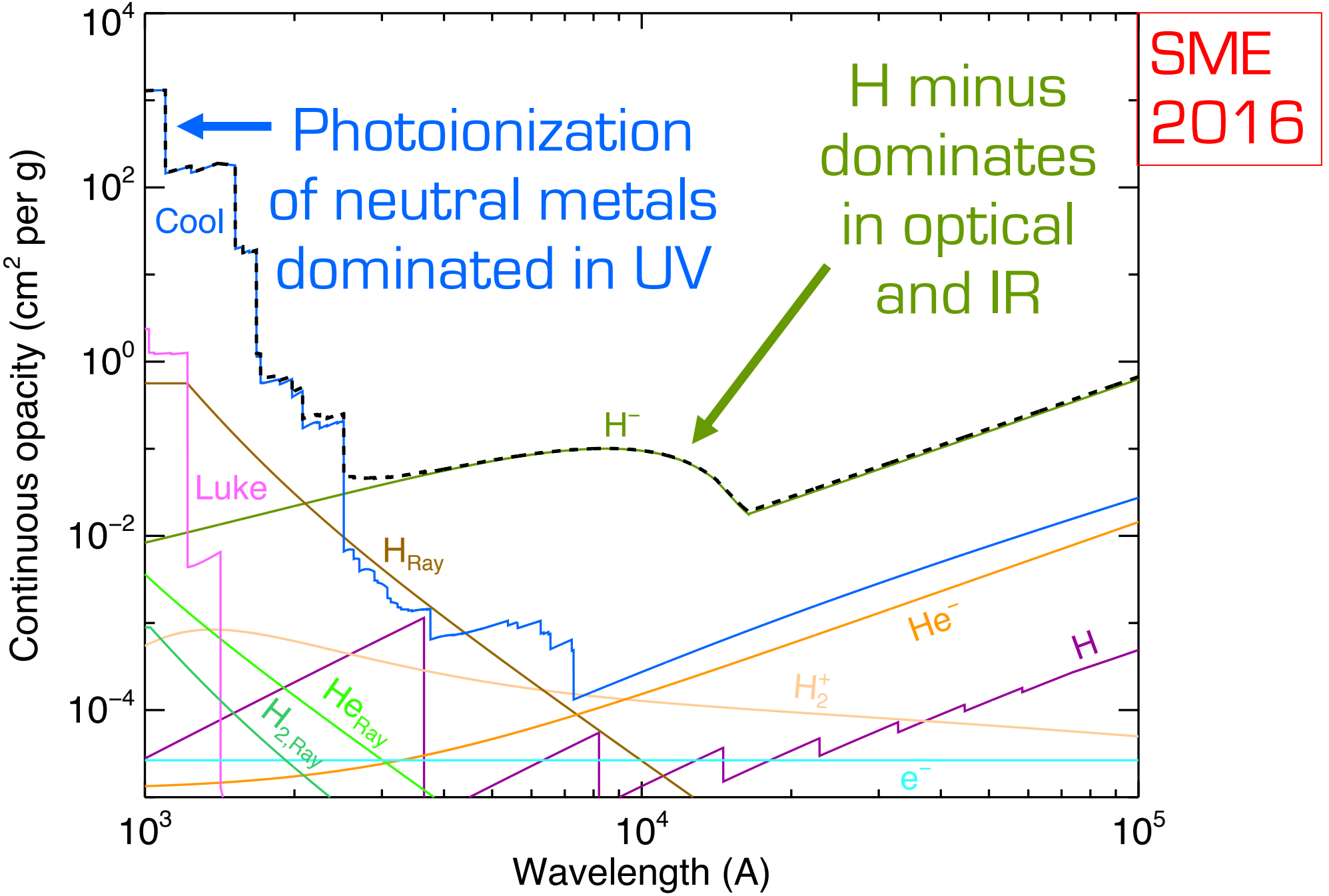
SME = Spectroscopy Made Easy

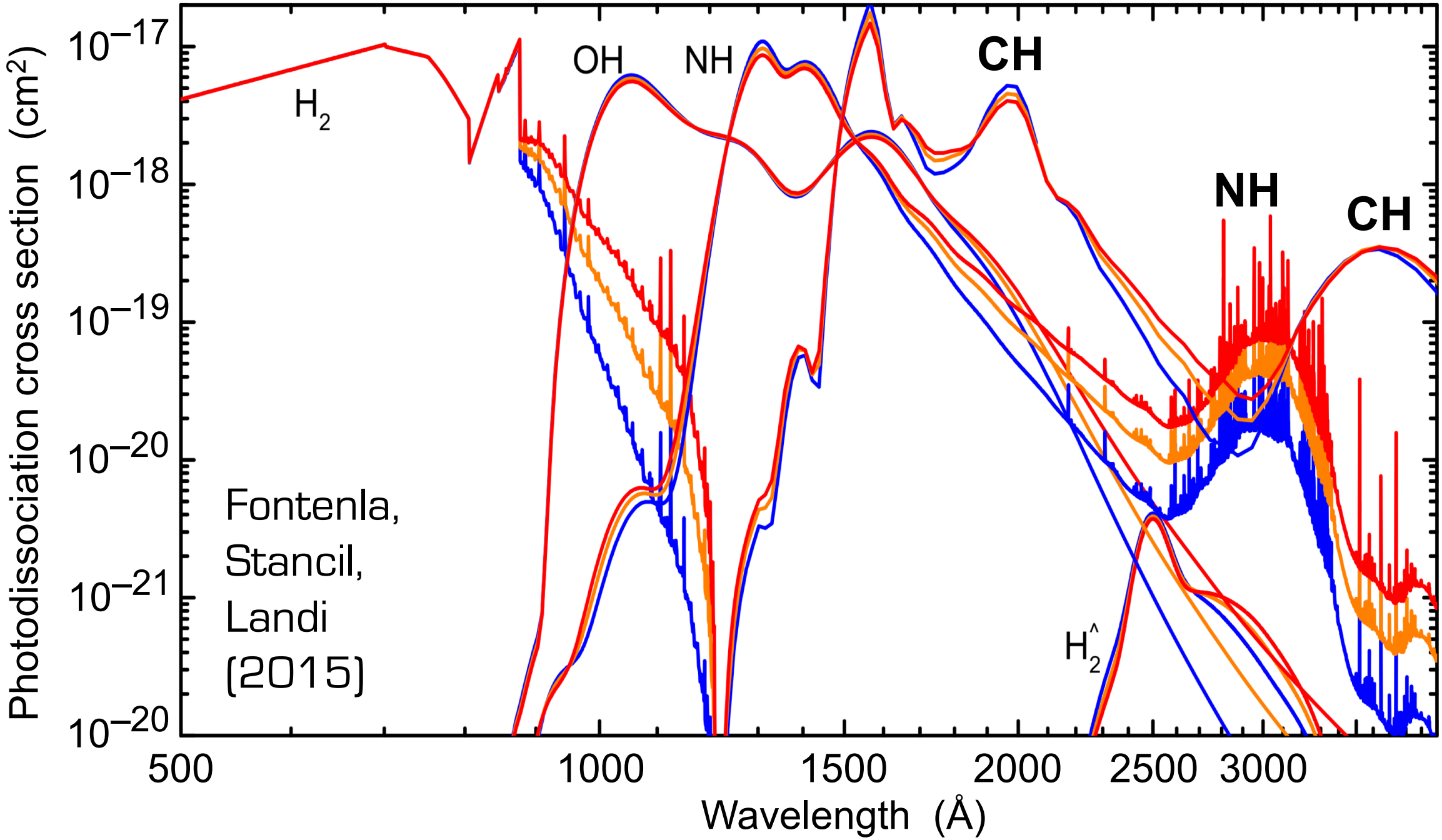

α Cen A [HST/STIS @ R=10^5]
Model [SME 2016]
All the high points are between strong lines
Flux at Earth (10^-11 erg s^-1 cm^-2 Å^-1)
0
2
4
6
8
10
12
2004
2006
2008
2010
2012
Wavelength (Å)

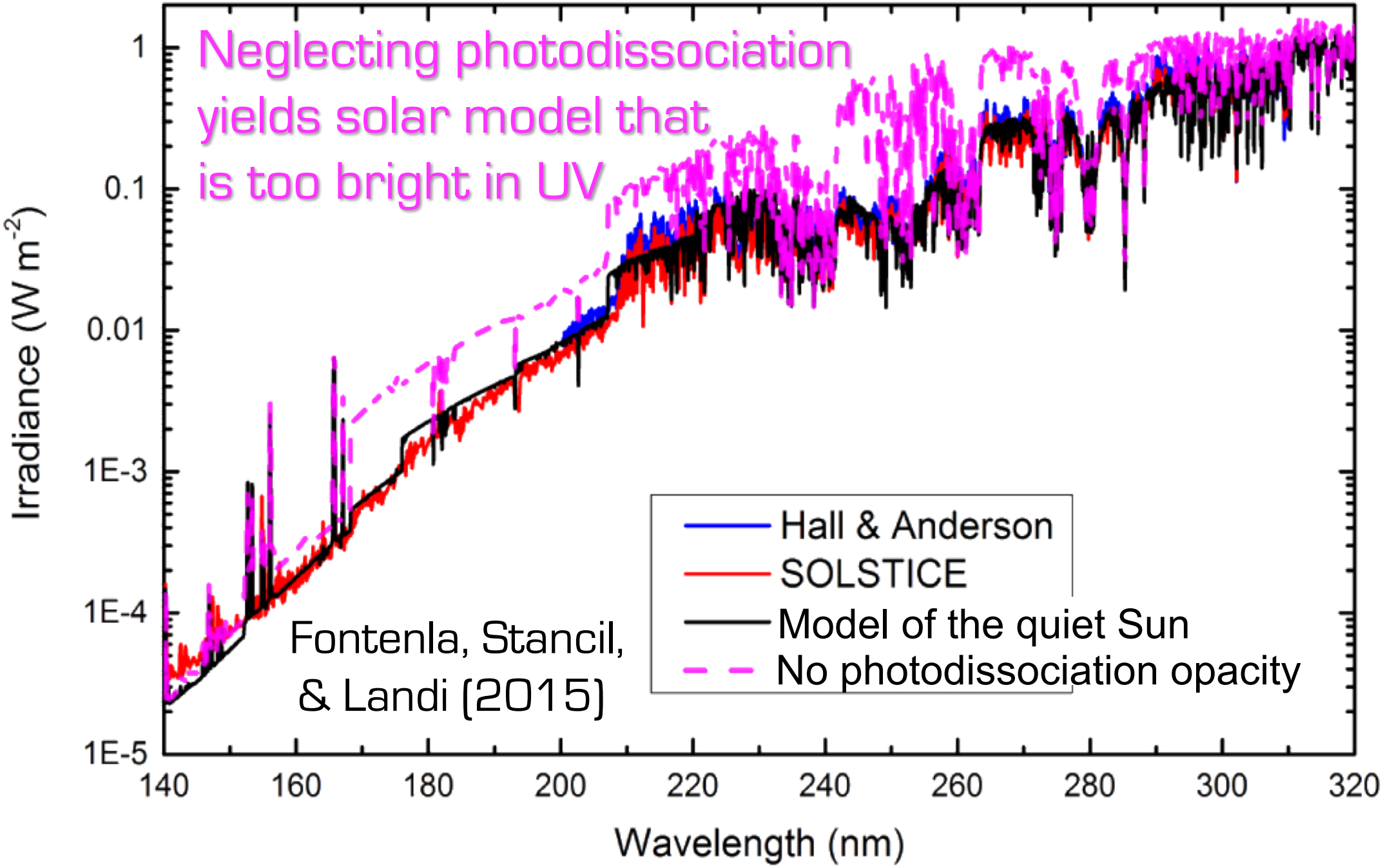


VALD = Vienna Atomic Line Data

Need more continuous opacity in NUV.


SME 2016
Photoionization of neutral metals dominated in UV
H minus dominates in optical and IR
Cool
Luke
H^-
H_{Ray}
He_{Ray}
$H_{2,Ray}$
He^-
H_2^+
H
e^-
Continuous opacity (cm^2 per g)
Wavelength (A)
10^4
10^2
10^0
10^{-2}
10^{-4}
10^3
10^4
10^5


Photodissociation cross section (cm²)
10⁻¹⁷
10⁻¹⁸
10⁻¹⁹
10⁻²⁰
10⁻²¹
10⁻²⁰
500
1000
1500
2000
2500
3000
Wavelength (Å)
H2
OH
NH
CH
NH
CH
H2^
Fontenla,
Stancil,
Landi
(2015)


Neglecting photodissociation
yields solar model that
is too bright in UV
Irradiance (W m-2)
1
0.1
0.01
1E-3
1E-4
1E-5
140
160
180
200
220
240
260
280
300
320
Wavelength (nm)
Fontenla, Stancil,
& Landi (2015)
Hall & Anderson
SOLSTICE
Model of the quiet Sun
No photodissociation opacity

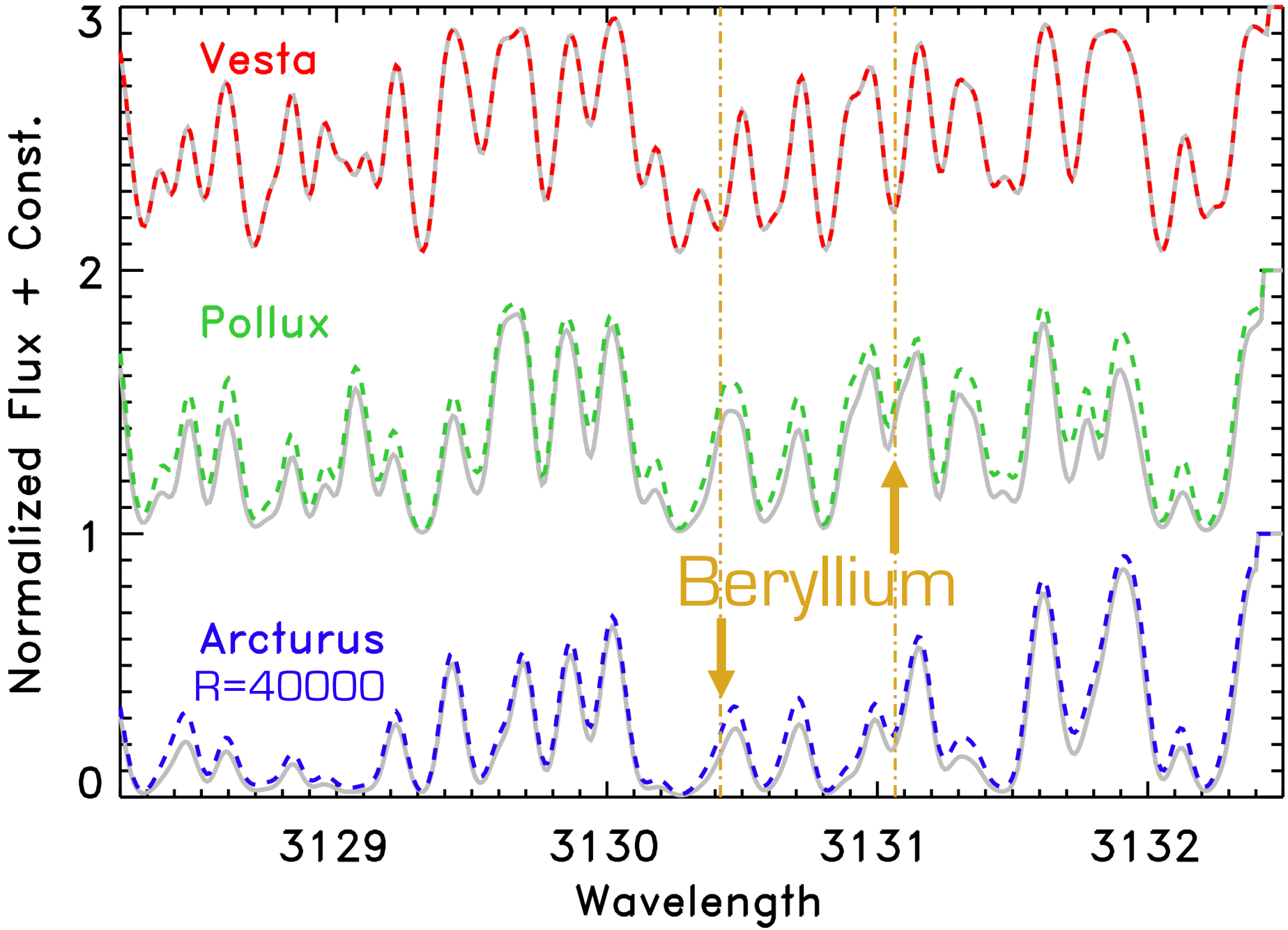


Figure courtesy of Joleen Carlberg (see Poster #41)

Dashed curves include CH and NH photodissociation

CH and NH continuous opacity has larger effect for giants

Molecular photodissociation is an important continuous opacity source in the UV.

OH AND CH CONTINUOUS OPACITY IN SOLAR AND STELLAR ATMOSPHERES

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ABSTRACT

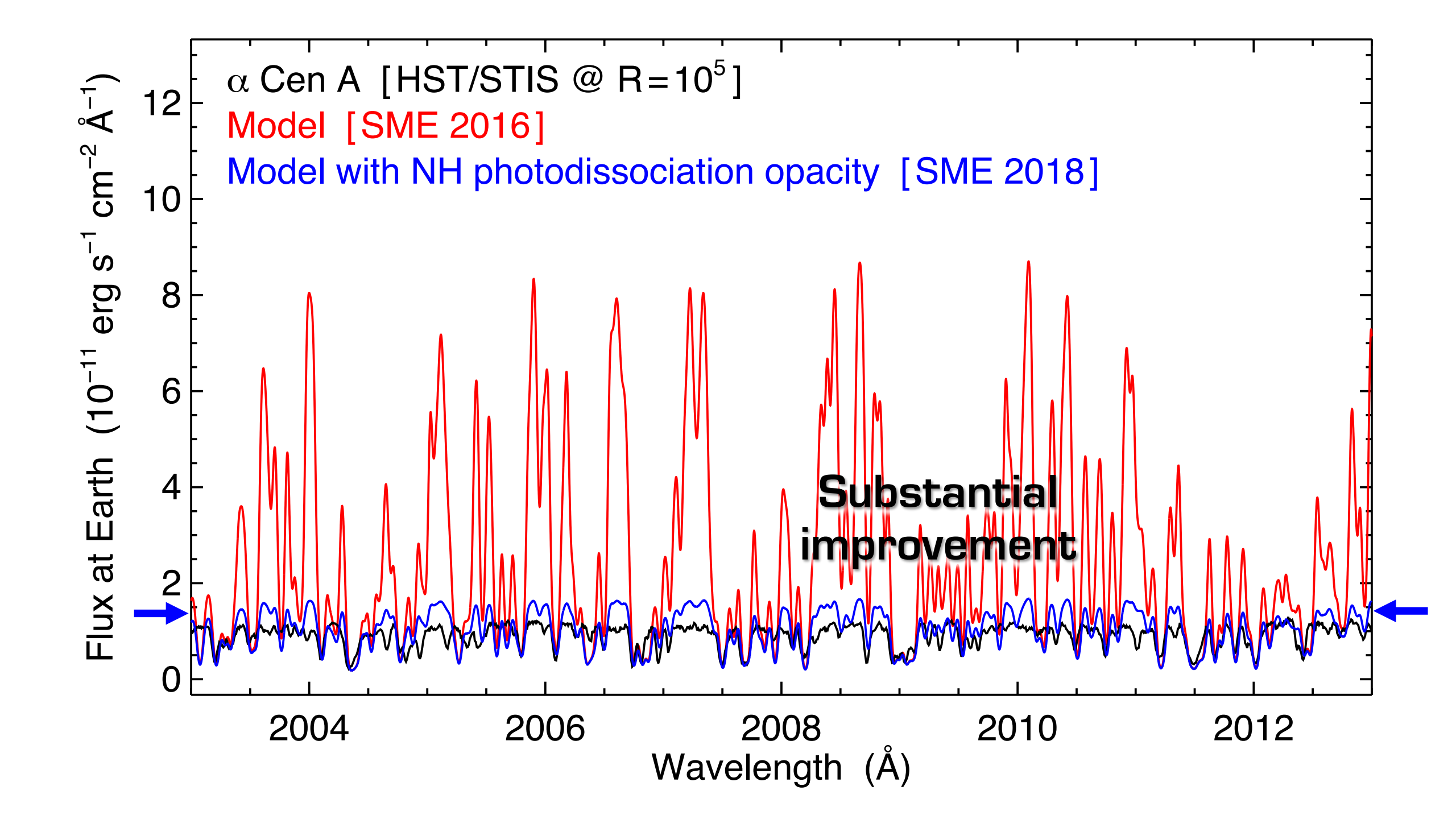
Continuous absorption cross sections of OH and CH have been computed for the temperature range 1000 K to 9000 K. Both OH and CH produce significant ultraviolet opacity in the Sun and cool stars. CH is also significant in the visible at 400 nm.

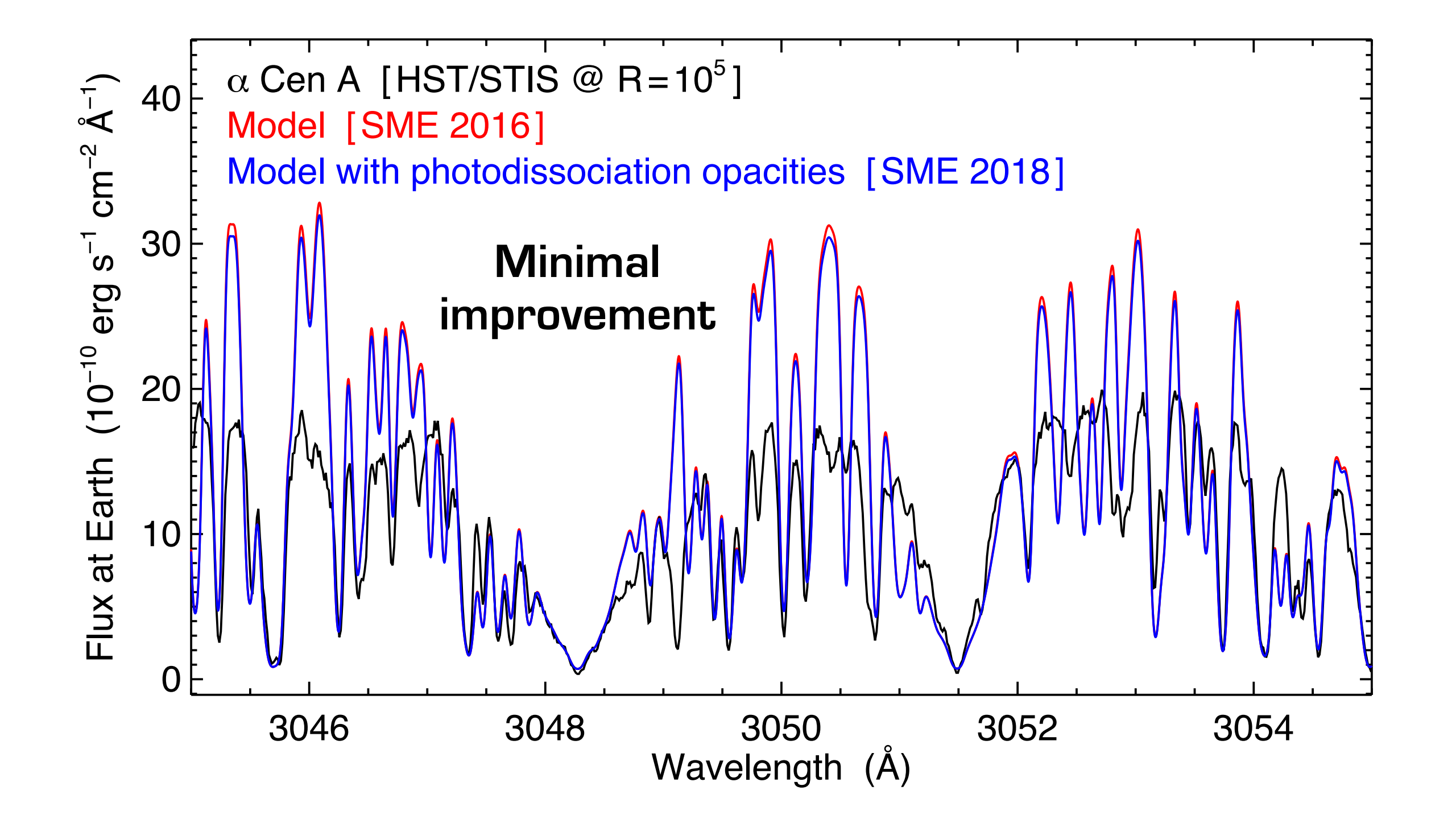
Subject headings: molecular processes — opacities — stars: atmospheres

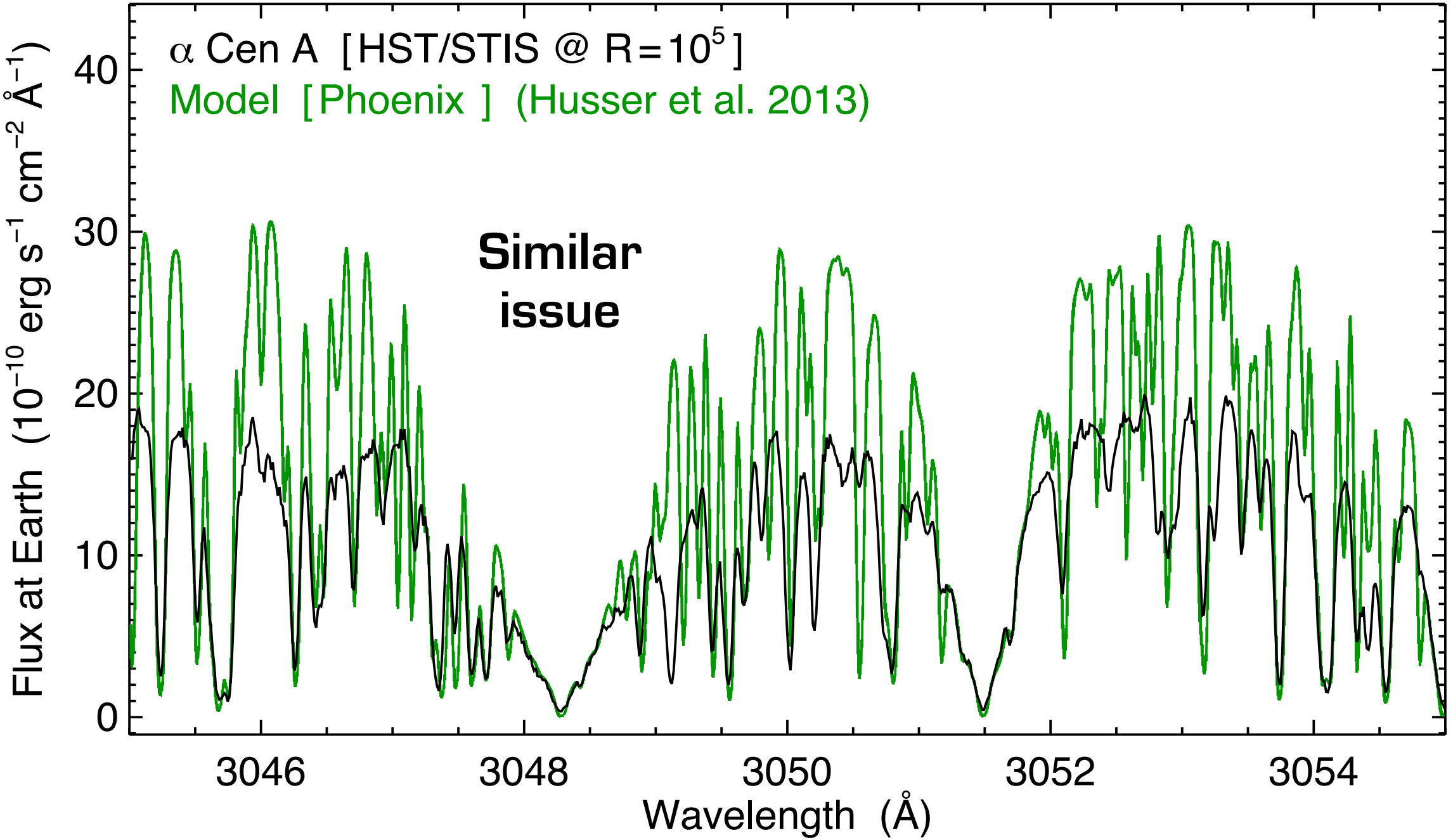
SME 2018:

Photodissociation: OH and CH from Kurucz, NH from Stancil

Photoionization: Fe 1 from Bautista, Other atoms from Kurucz


α Cen A [HST/STIS @ R=10^5]
Model [SME 2016]
Model with NH photodissociation opacity [SME 2018]
Substantial improvement
Flux at Earth (10^-11 erg s^-1 cm^-2 Å^-1)
Wavelength (Å)
0
2
4
6
8
10
12
2004
2006
2008
2010
2012


α Cen A [HST/STIS @ R=10^5]
Model [SME 2016]
Model with photodissociation opacities [SME 2018]
Minimal improvement
Flux at Earth (10^-10 erg s^-1 cm^-2 Å^-1)
Wavelength (Å)
0
10
20
30
40
3046
3048
3050
3052
3054


α Cen A [HST/STIS @ R=10^5]
Model [Phoenix] (Husser et al. 2013)
Similar issue
Flux at Earth (10^-10 erg s^-1 cm^-2 Å^-1)
Wavelength (Å)
0
10
20
30
40
3046
3048
3050
3052
3054

We are still missing continuous opacity sources in the UV.

Acknowledgements:

▷ Bob Kurucz for CH and OH photodissociation opacity routines and updated photoionization opacity routines for C I, Mg I, Al I, Si I, and Fe I

▷ Juan Fontenla for highlighting the importance of photodissociation

▷ Phillip Stancil for NH photodissociation cross sections

▷ Manuel Bautista for new Fe I photoionization cross sections

▷ Sultana Nahar and Anil Pradhan for photoionization expertise

▷ VALD3 for curated spectral line data [http://vald.astro.uu.se]

▷ Bengt Edvardsson for comparisons with MARCS spectra and opacities

▷ Tim-Oliver Husser for publishing a library of Phoenix spectra [290 citations]

▷ Tom Ayres for the ASTRAL spectral library

Key points:

▷ High-resolution flux-calibrated spectra can reveal continuous opacity errors.

▷ Molecular photodissociation is an important continuous opacity source.

▷ We are still missing continuous opacity sources in the UV.