1D semi-empirical model

Chromosphere above sunspot umbra

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Modelling of solar irradiance variability

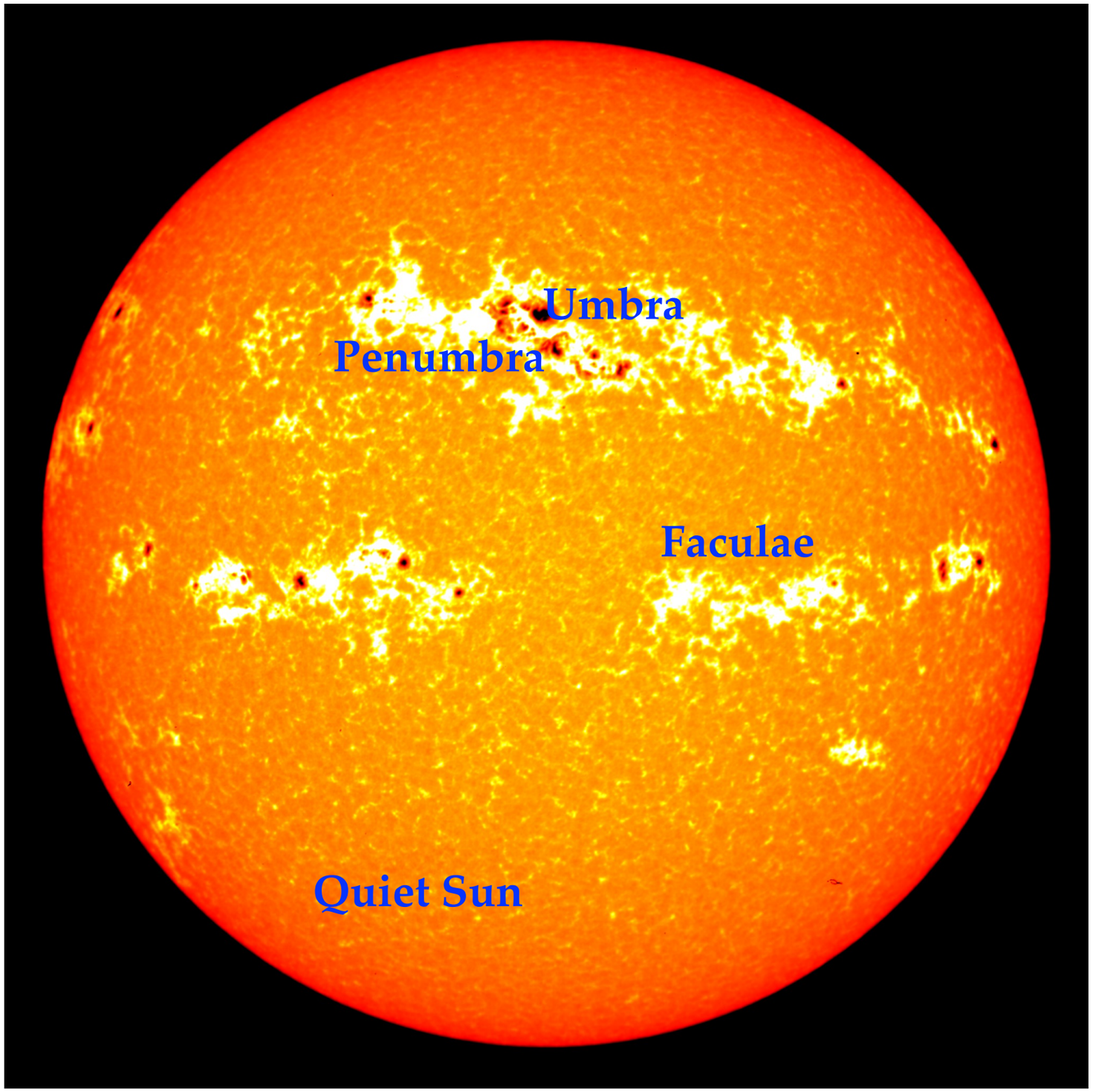


image credit: svs.gsfc.nasa.gov

Decompose the solar disk into different features

Compute spectra in non-LTE using 1D models

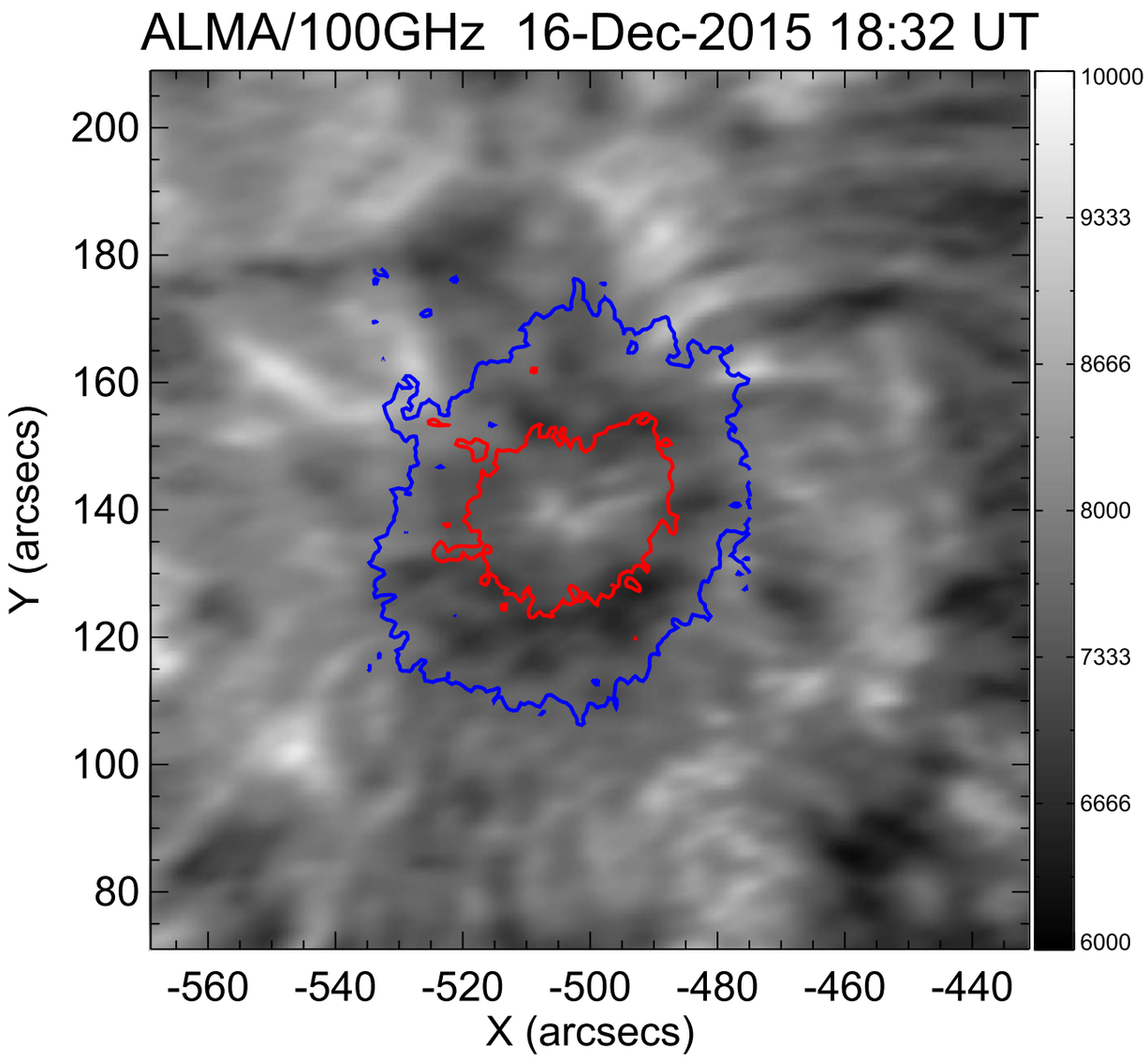
Umbral and penumbral models lack chromosphere

Concern for the far UV and strong spectral lines

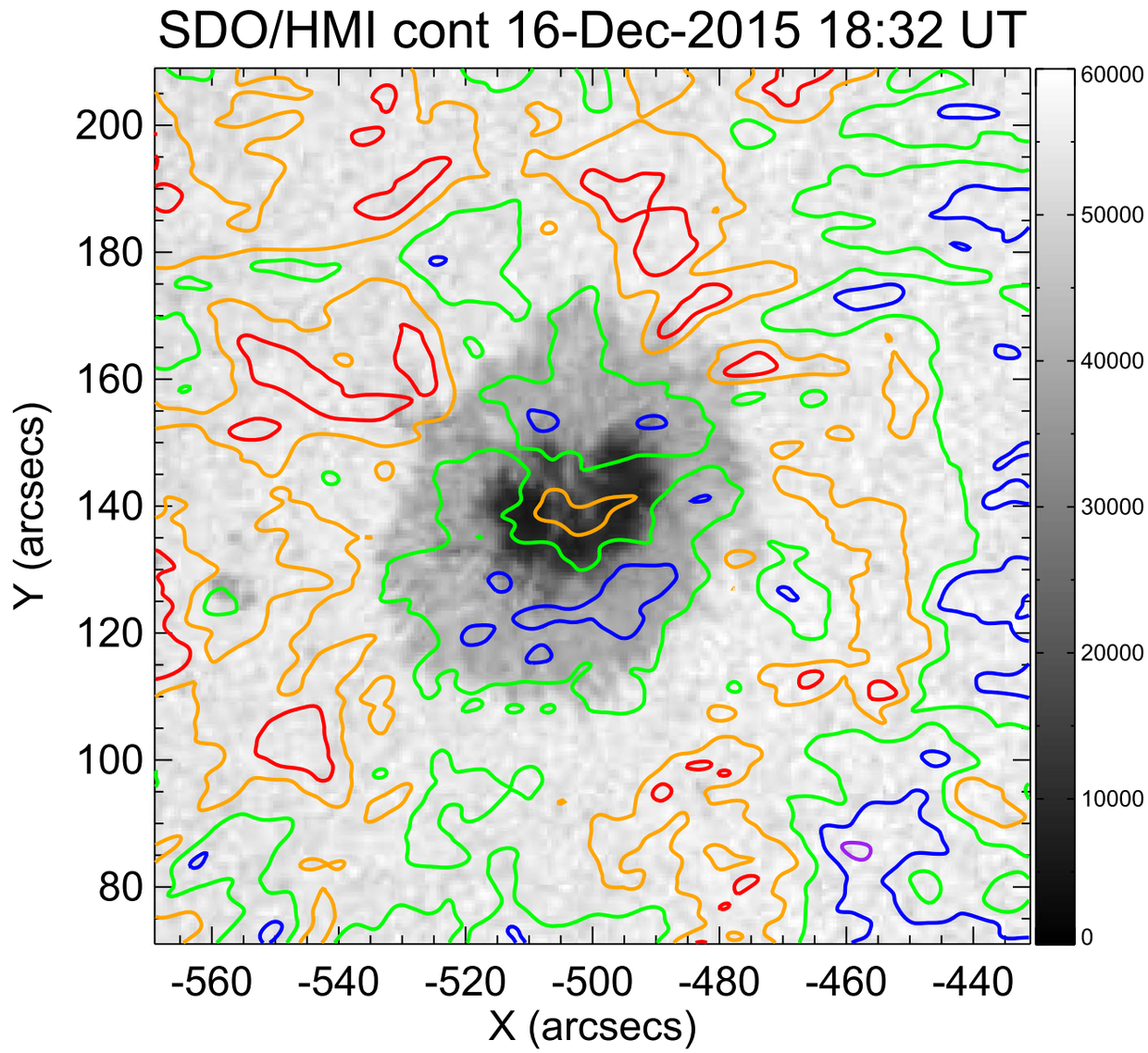
Tagirov et al. (2019)

From Atacama Large Millimeter/sub-millimeter Array (ALMA)

AR 12470



ALMA 3 mm

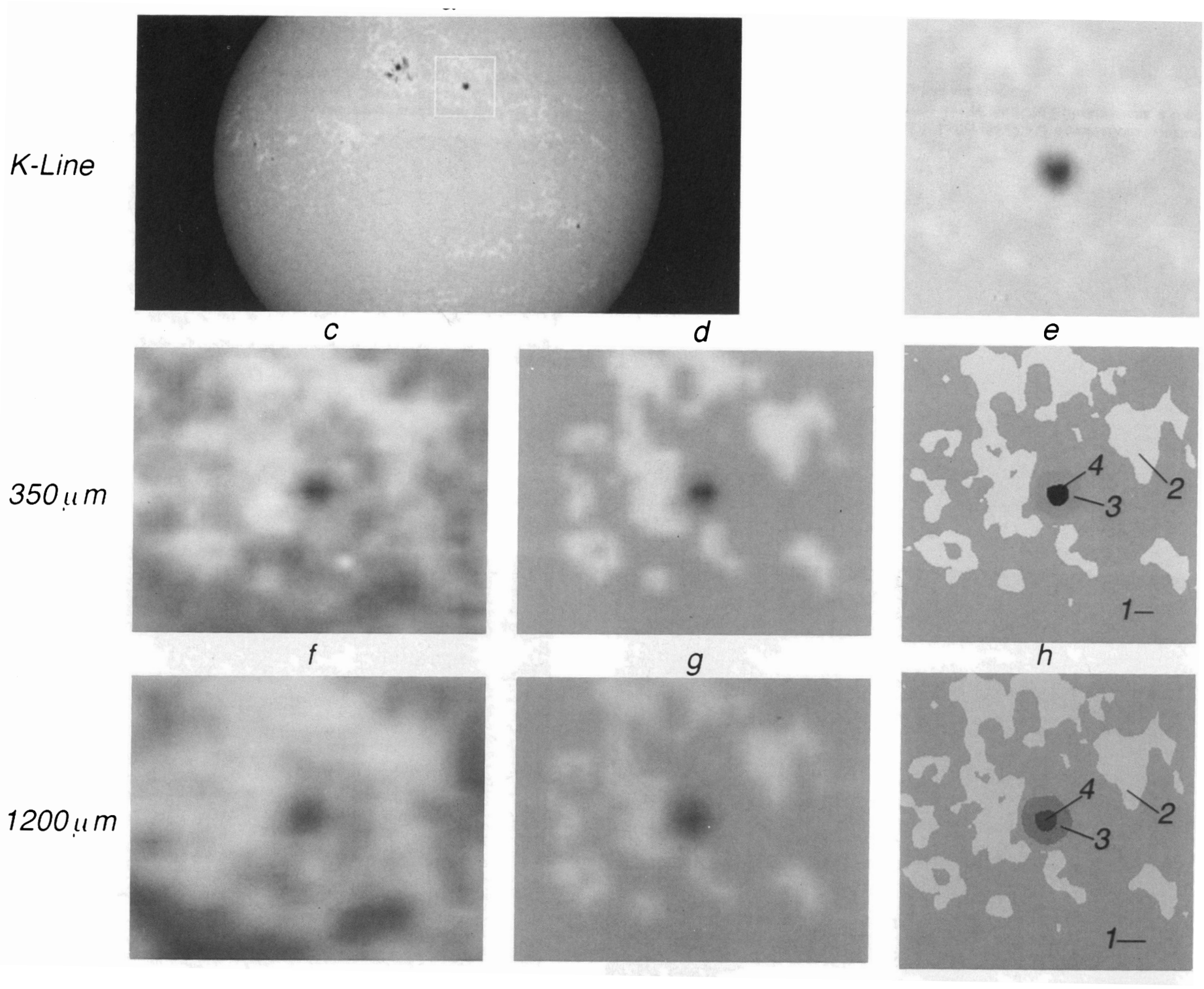


HMI continuum

Iwai et al. (2017)

From James Clerk Maxwell Telescope (JCMT)

AR 6484

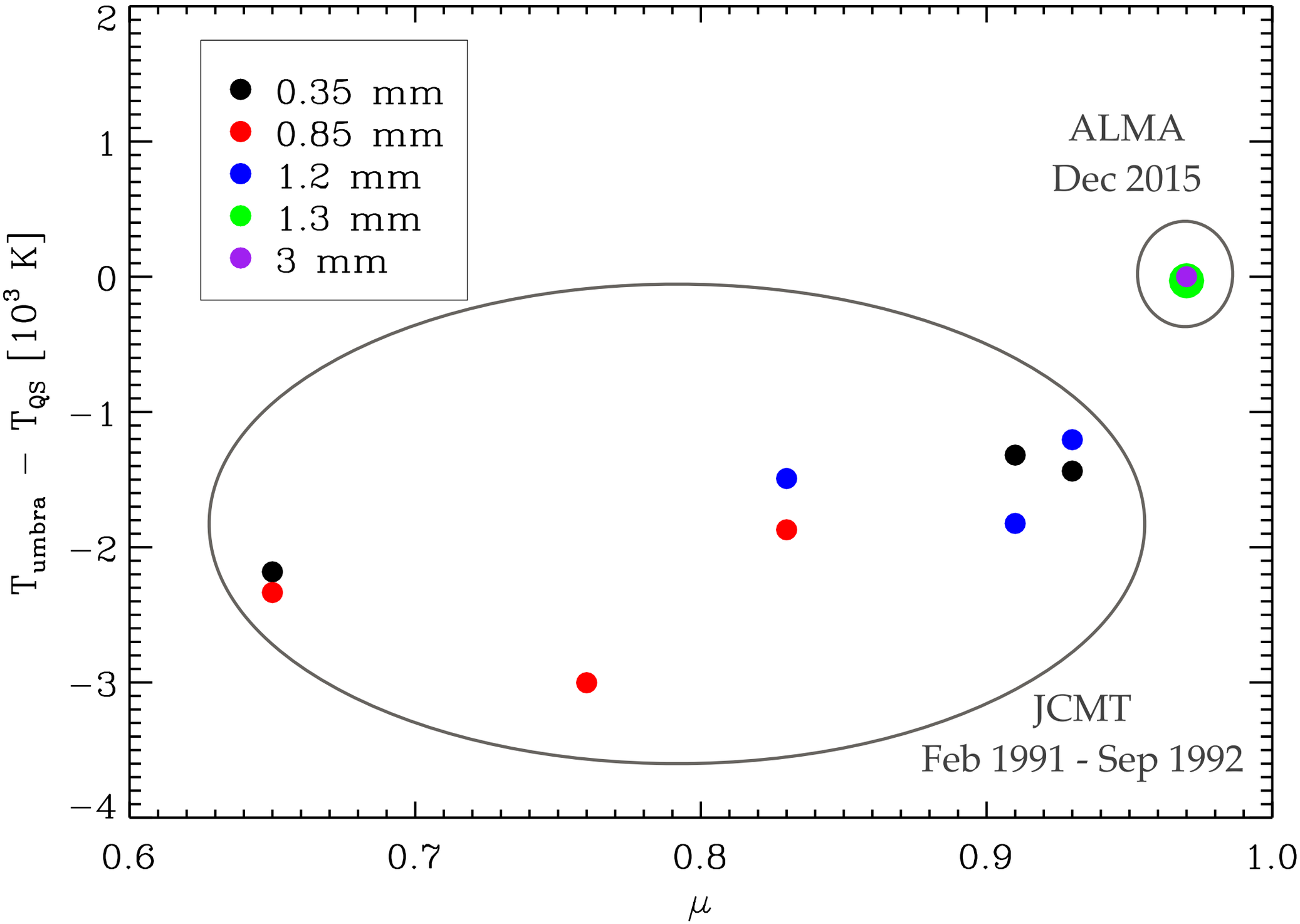


0.35 mm →

1.2 mm →

Lindsey & Kopp (1995)

Observations in mm/sub-mm



Radiative transfer code

Non-LTE Spectral SYnthesis (NESSY)

- Solves the 1D spherically symmetric non-LTE radiative transfer equation for a given temperature and density stratification
- Population equations are solved simultaneously with the radiative transfer equation for elements from hydrogen to zinc
- Performs spectral synthesis taking into account millions of spectral lines

Tagirov et al. (2017)

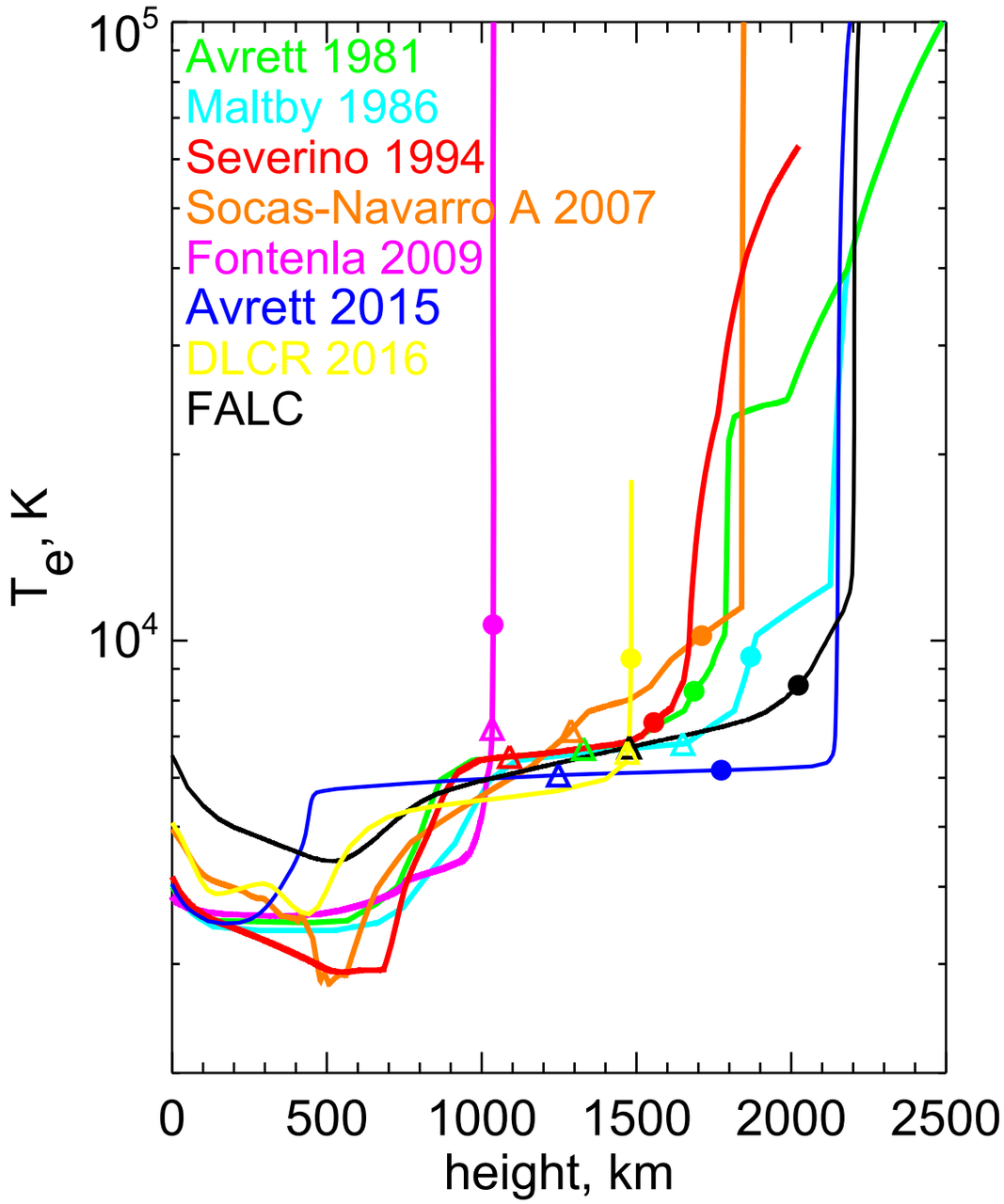
Model atmospheres

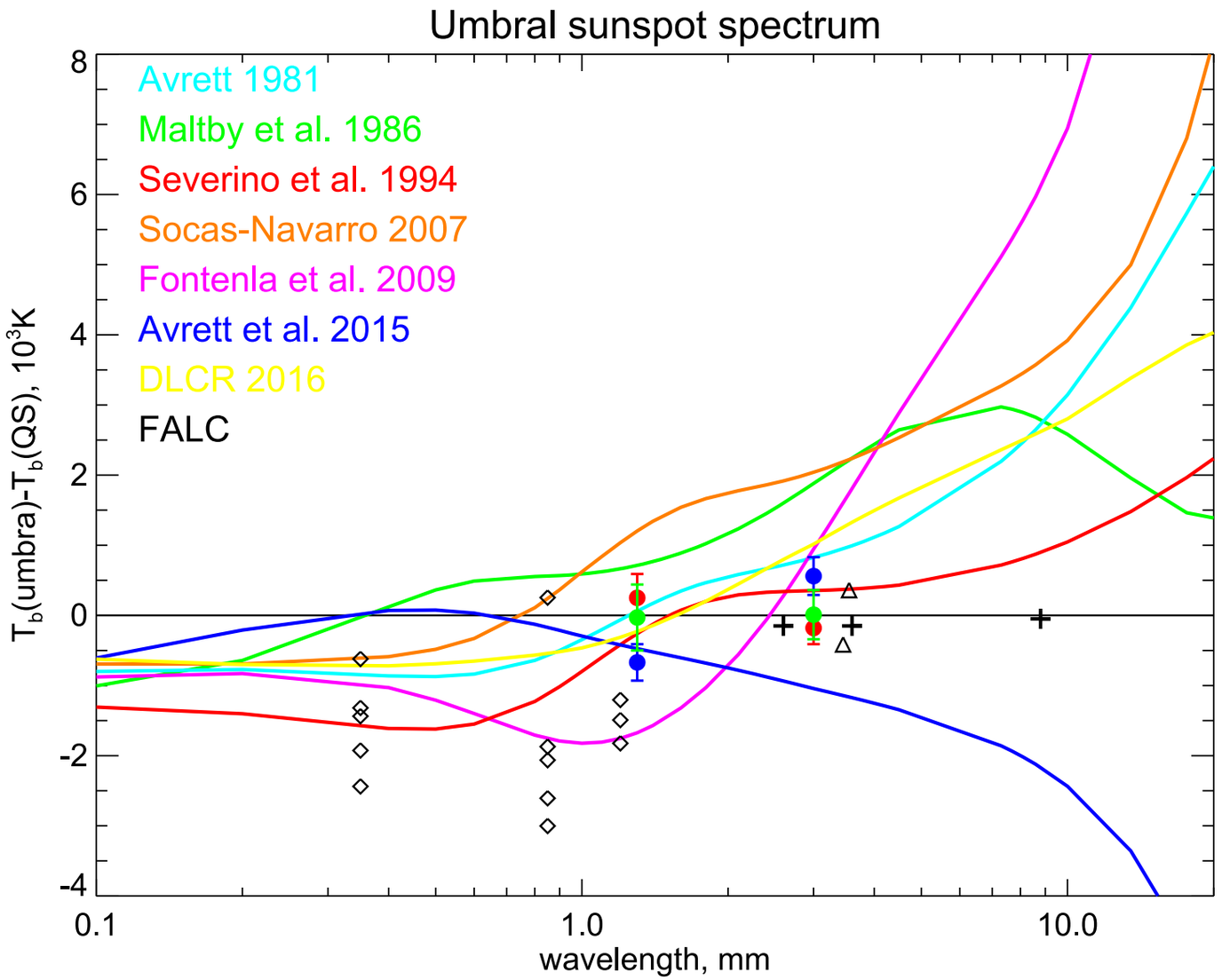
Quiet Sun spectrum: FAL99-C

Umbral spectrum: Severino

Fontenla et al. (1999), Severino et al. (1994)

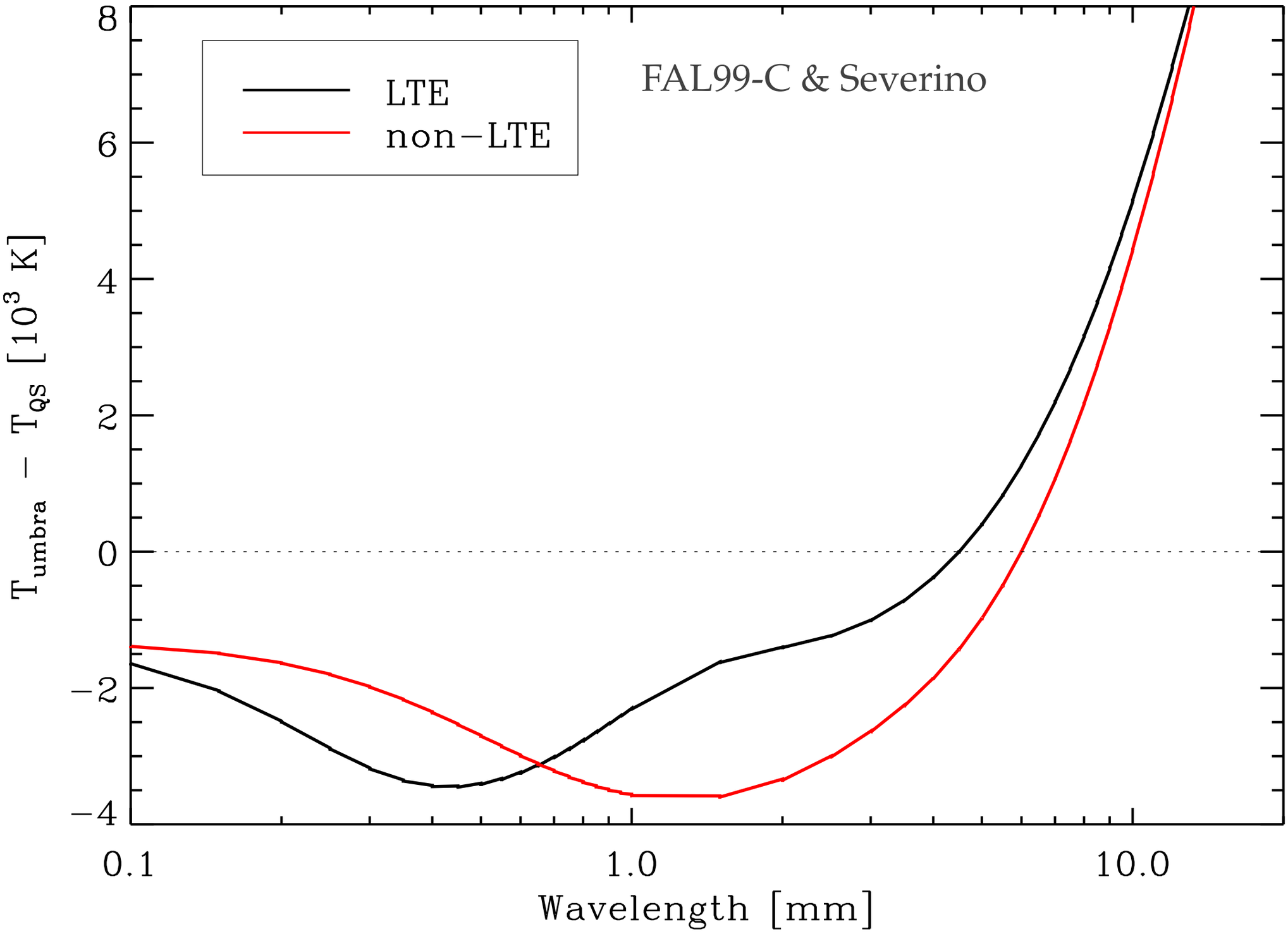
Umbral models - an overview





Loukitcheva et al. (2017)

LTE vs non-LTE contrasts



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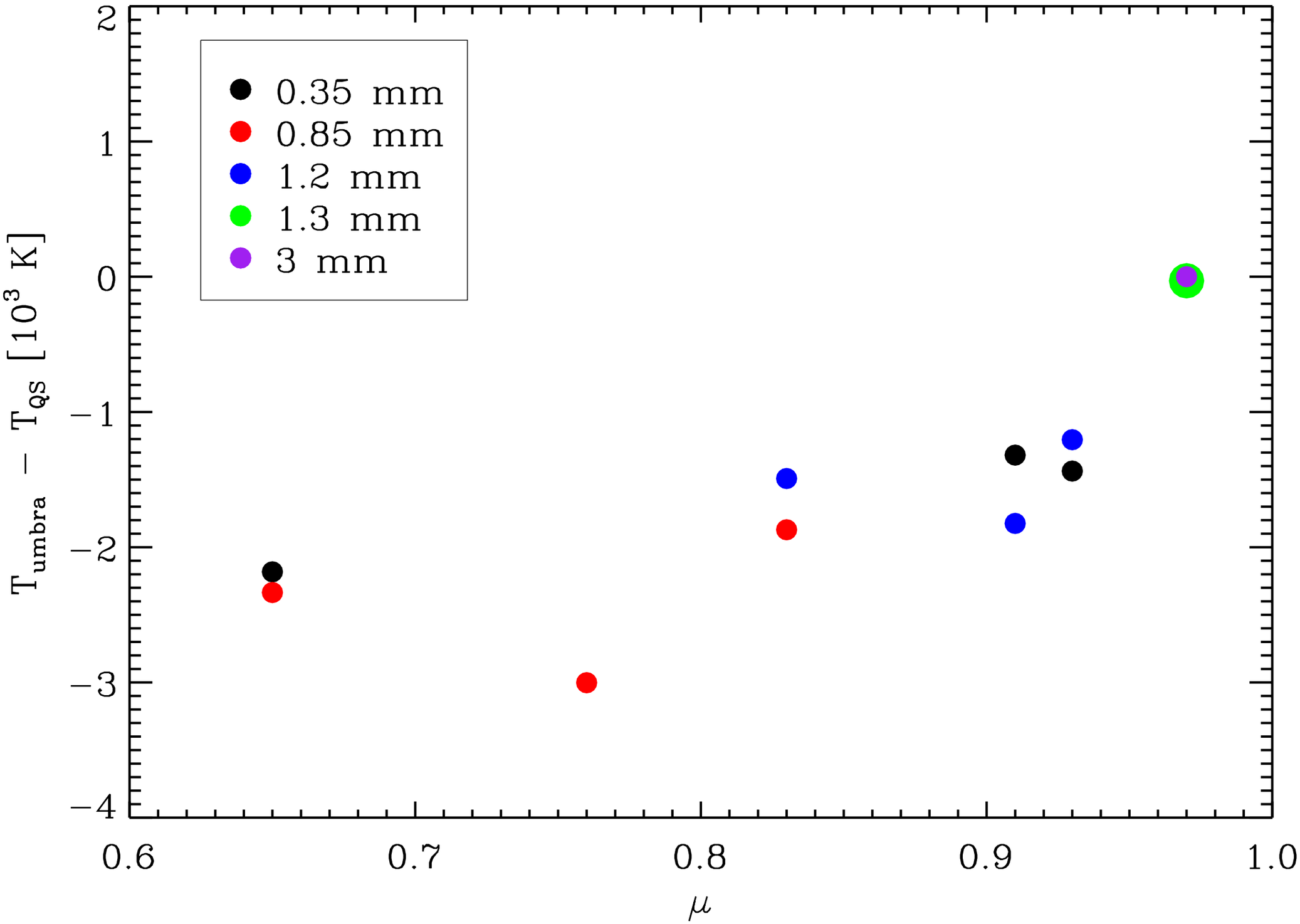
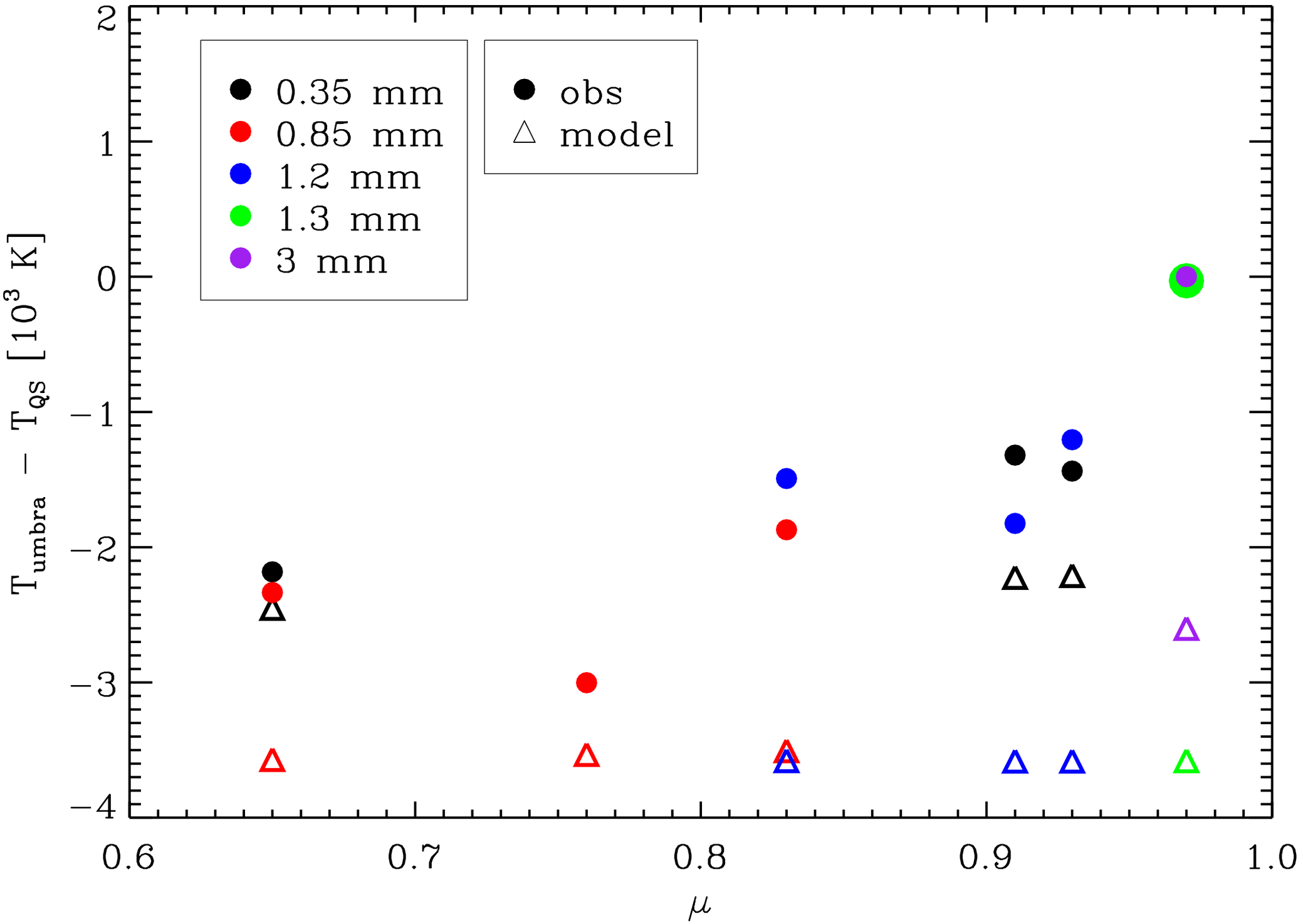
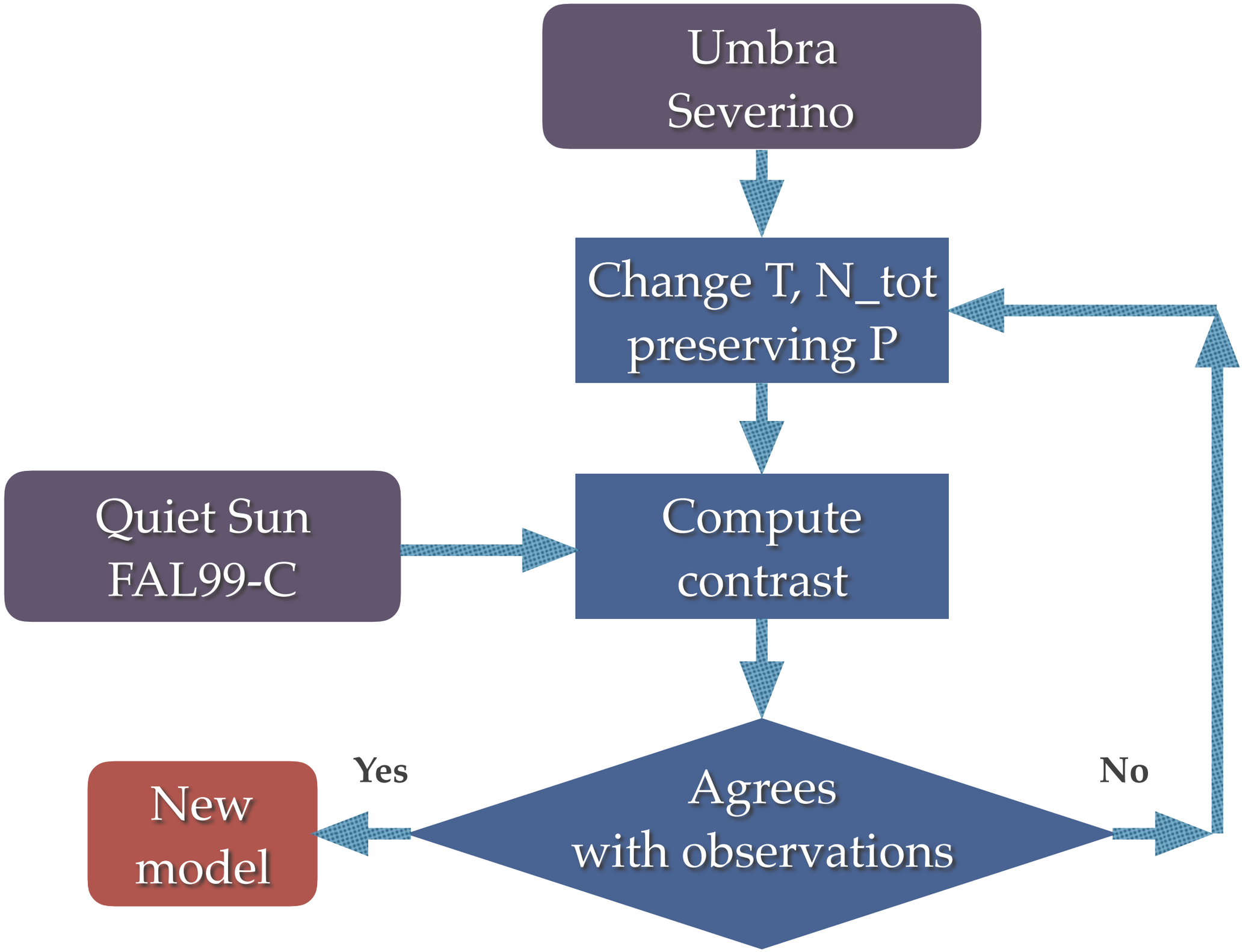


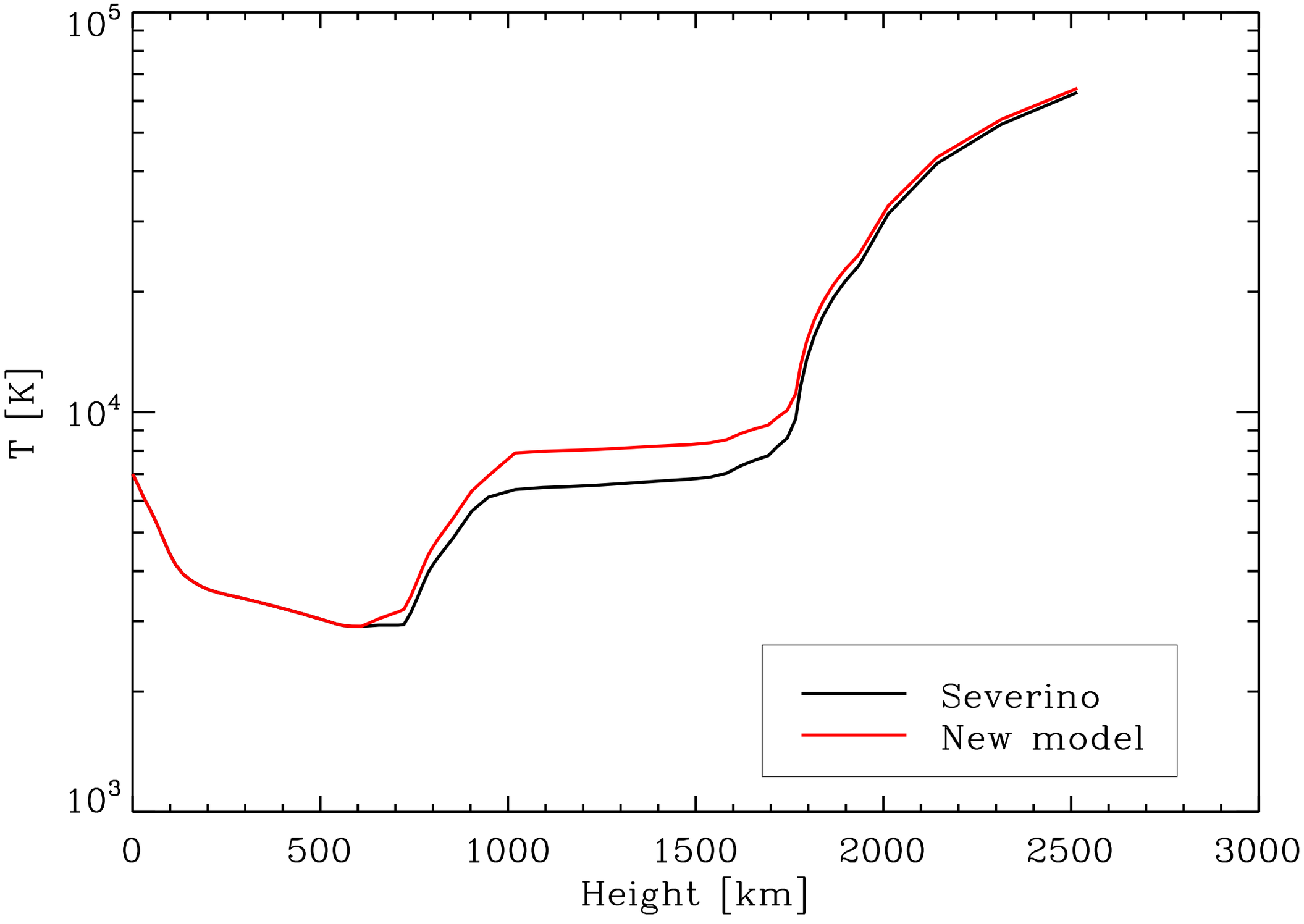
Contrasts from FAL99-C and Severino models



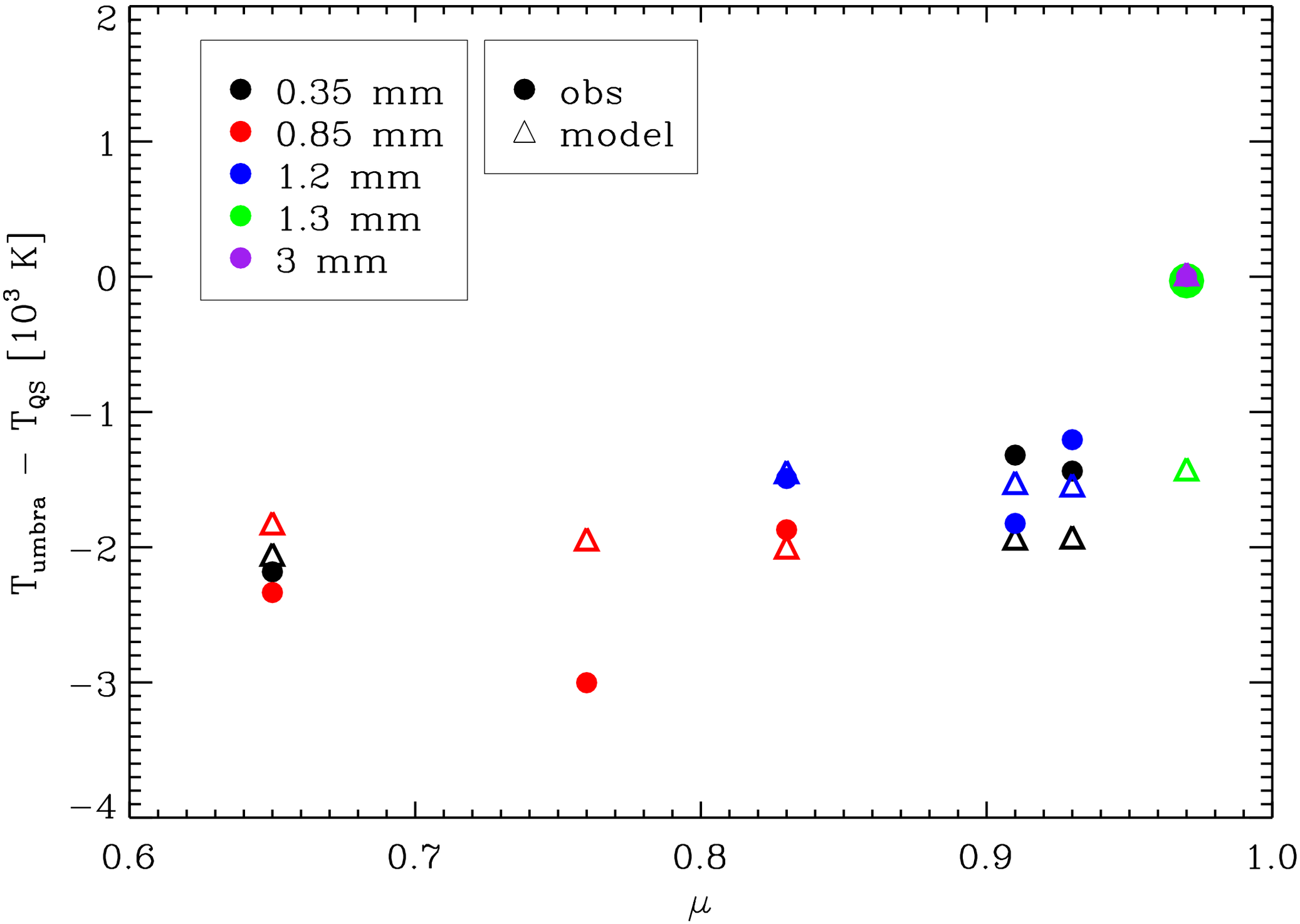
How do we construct the model?



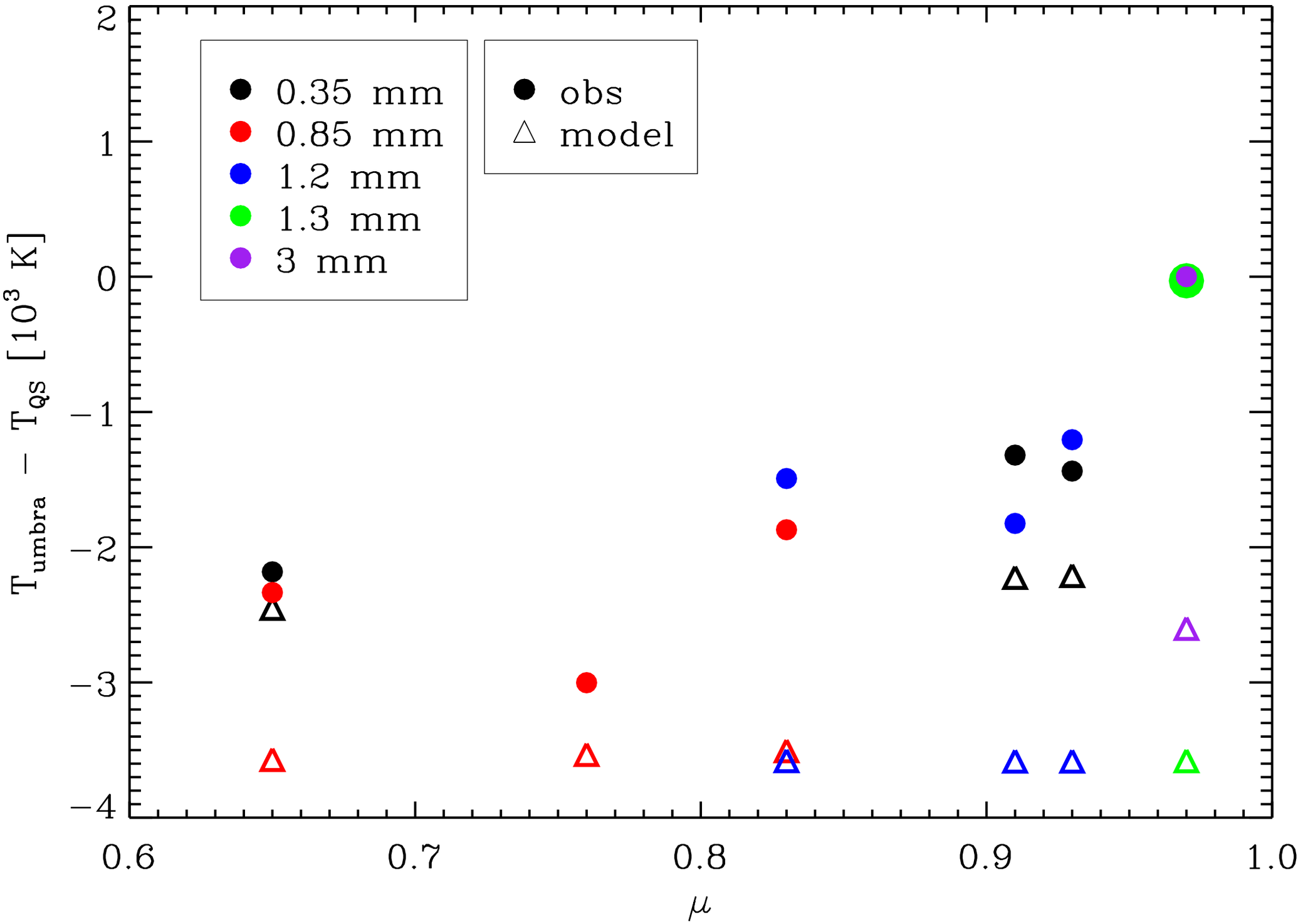
Temperature structure



New model


0.35 mm
0.85 mm
1.2 mm
1.3 mm
3 mm
obs
model
$T_{umbra} - T_{QS}$ [10^3 K]
2
1
0
−1
−2
−3
−4
0.6
0.7
0.8
0.9
1.0
μ

Contrasts from FAL99-C and Severino models



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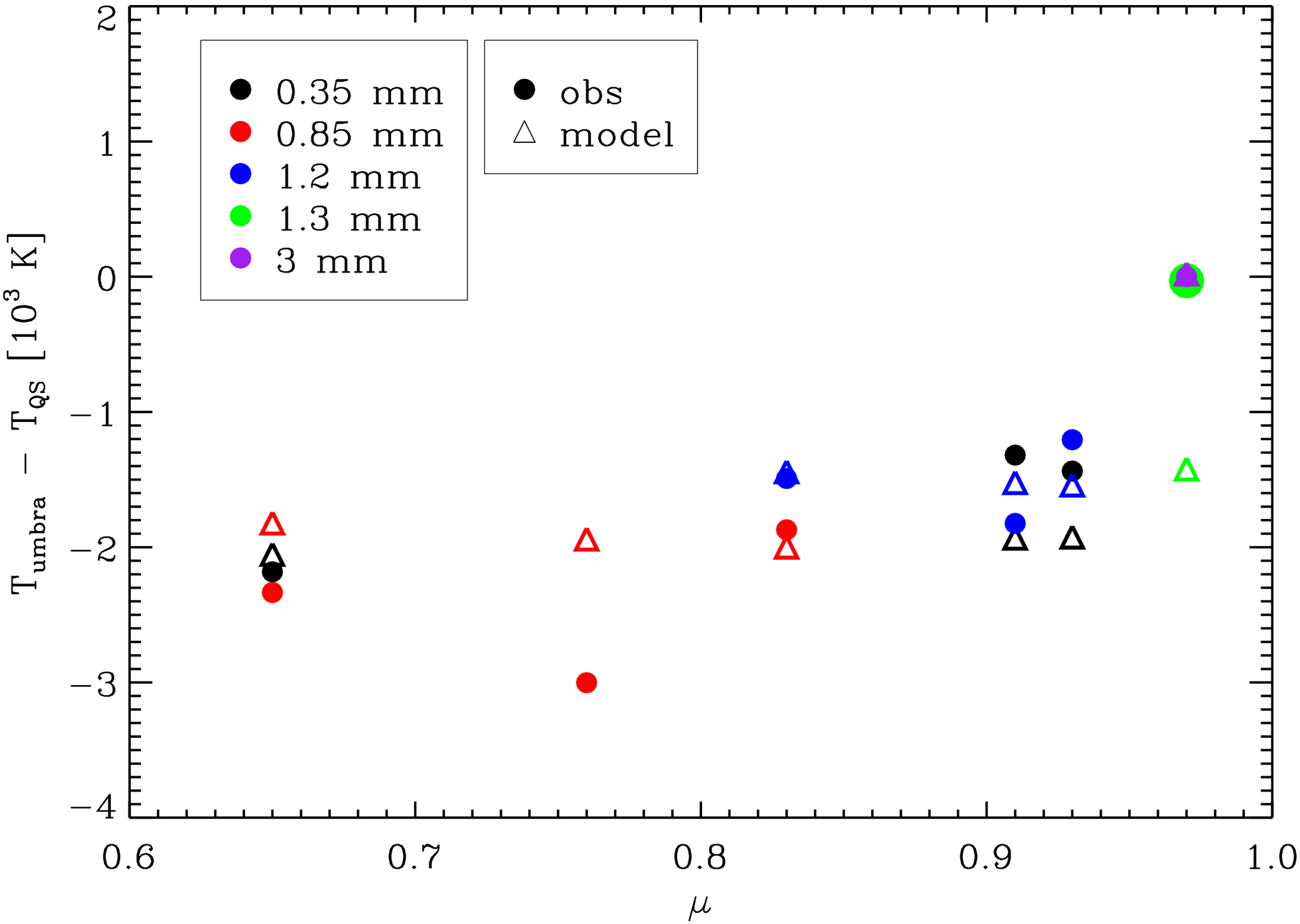
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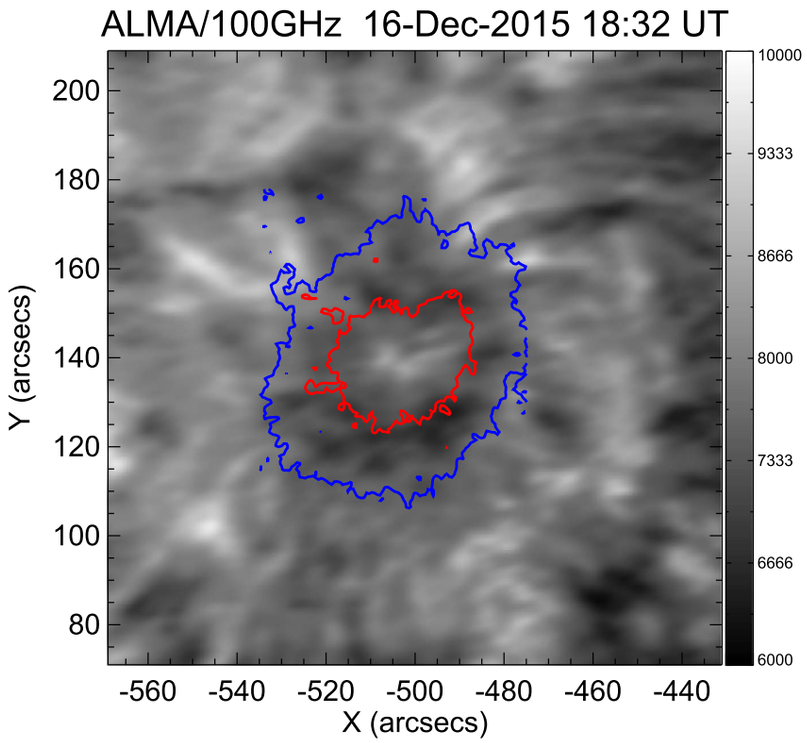
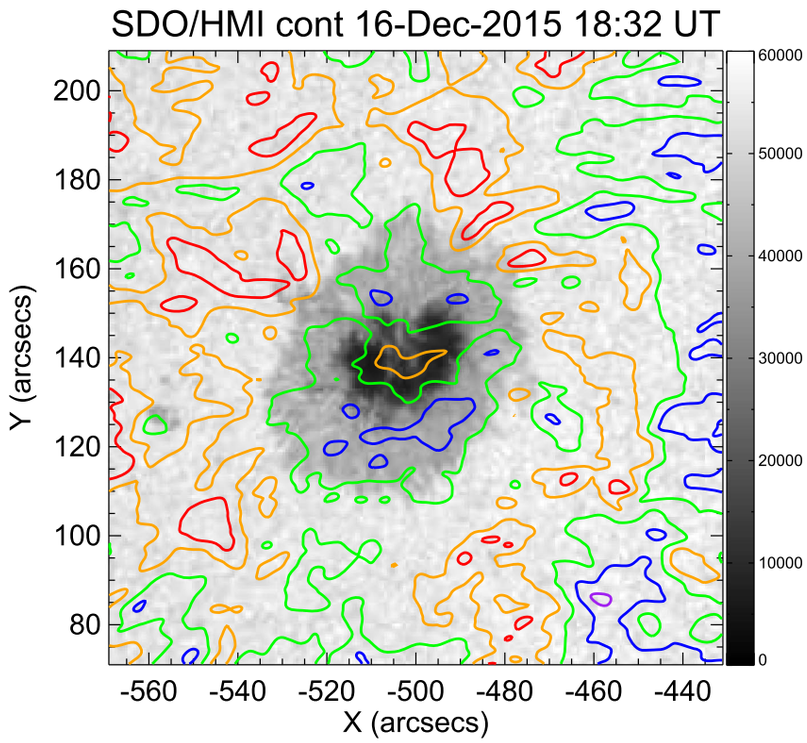
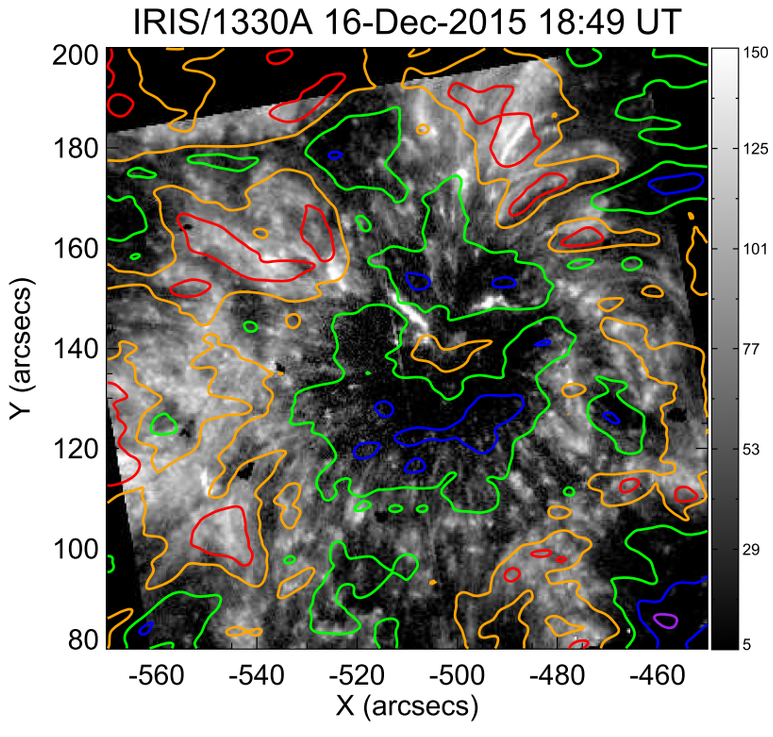
Summary

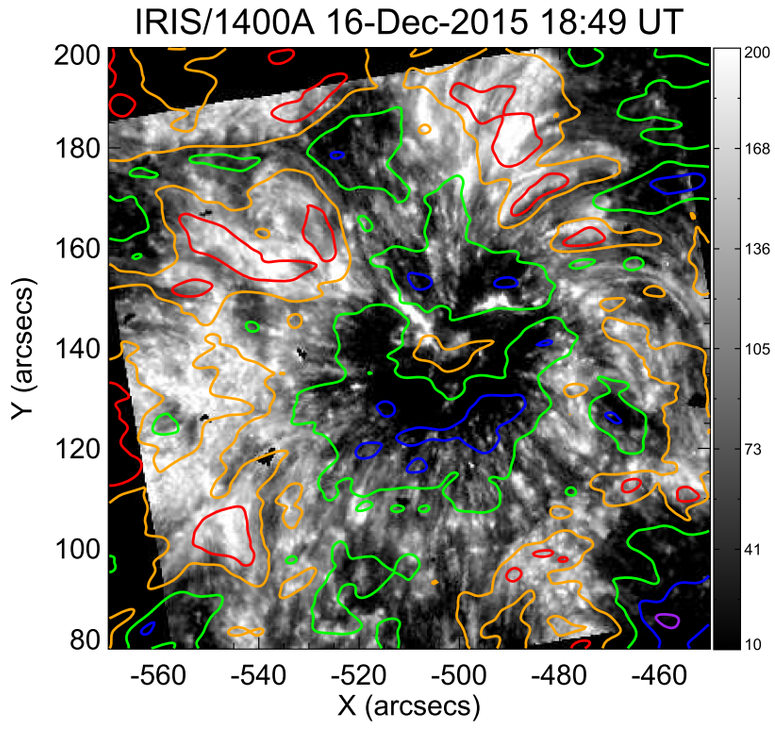
- The existing models for the sunspot umbra and penumbra either lack chromosphere or have a poor representation of it
- Using the recent observations from ALMA along with the ones from JCMT, we construct a model for the umbra with a better constrained chromosphere

ALMA and IRIS









Iwai et al. (2017)

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- Using the recent observations from ALMA along with the ones from JCMT, we construct a model for the umbra with a better constrained chromosphere
- Potential additional constraints from IRIS data
- Next step is to improve the chromosphere in penumbral models
- Implement these updated models in SATIRE to reconstruct the irradiance variability in the UV
- Use the models to interpret the observations from future missions such as Aditya-L1 and Sunrise-3

Thank you for your attention!