Coronal forbidden lines in the DKIST era

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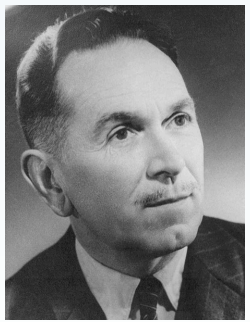

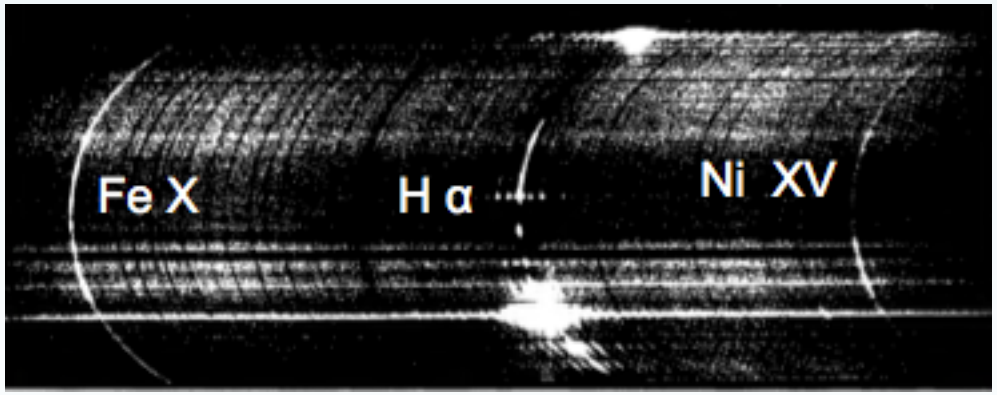

Lyot (1930's) observed 11 coronal lines regularly outside eclipses

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Pros and cons

Forbidden lines in the visible/IR are great to measure the (nearly unexplored) outer corona out to e.g. 2 R (due to strong photo-excitation), where important processes as interchange reconnection (Del Zanna+2011) is occurring.

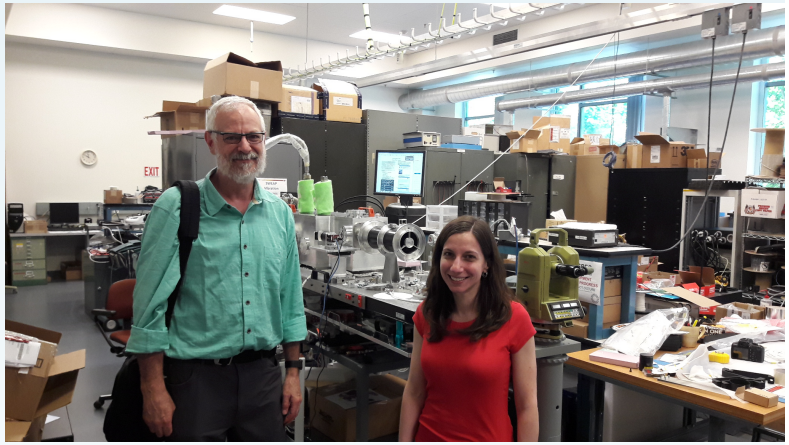
- Ne via line ratios
- T (ionisation T, but also Te in combination with EUV)
- Chemical abundances
- Non-Thermal effects (line widths, non-thermal electrons)
- Magnetic field

However:

- Visible/IR nearly unexplored ! (Del Zanna & DeLuca 2018)
- Atomic data not simple to calculate. Latest calculations (Del Zanna+ 2012, several A&A papers), made available to CHIANTI v.8 (Del Zanna+2015) showed increases of ~2 in the intensities (cf. Del Zanna & Mason, 2018)
- Modelling the signal is not trivial as photo-excitation is competing with electron collisional excitation (Del Zanna+2018)
- Significant atmospheric absorption for DKIST

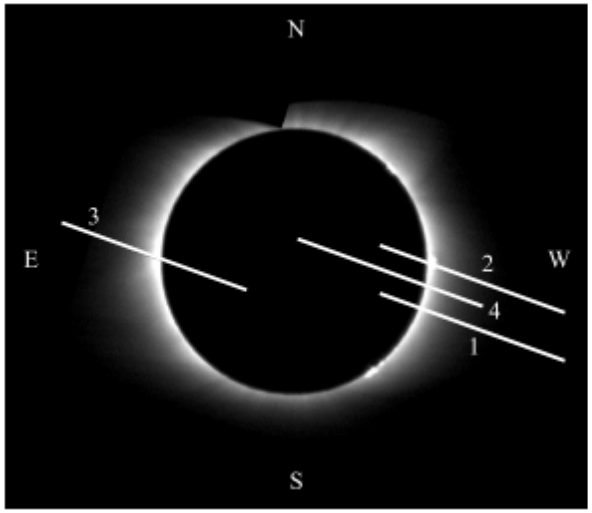
Air-Spec as a pathway to DKIST

First near-infrared spectrometer (after 1970: Olsen+1971) to observe during an eclipse from a high-altitude airplane, where lines not accessible to DKIST can be observed.
Obtained data on 2017 Aug 21 and 2nd July 2019 (Chile). Built at CfA, SAO (Samra et al.)



(a)

*NSF/NCAR **G**ulfstream-**V***
***H**igh-performance*
***I**nstrumented **A**irborne*
***P**latform for **E**nvironmental*
***R**esearch (GV HIAPER)*



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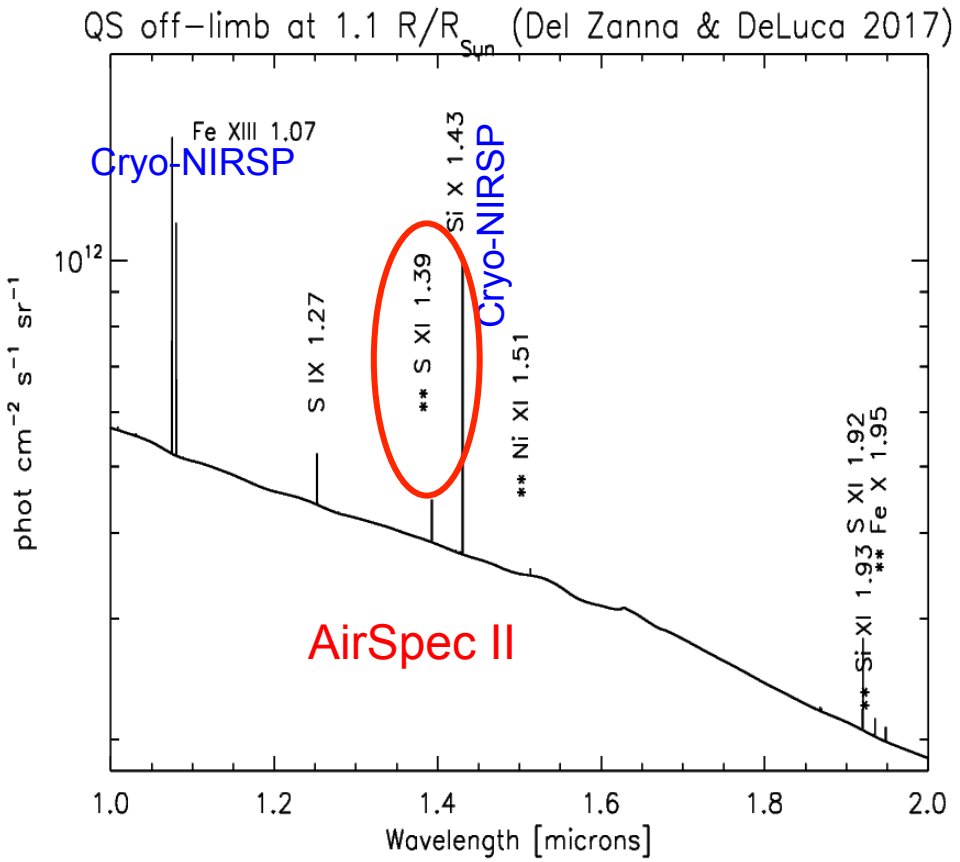
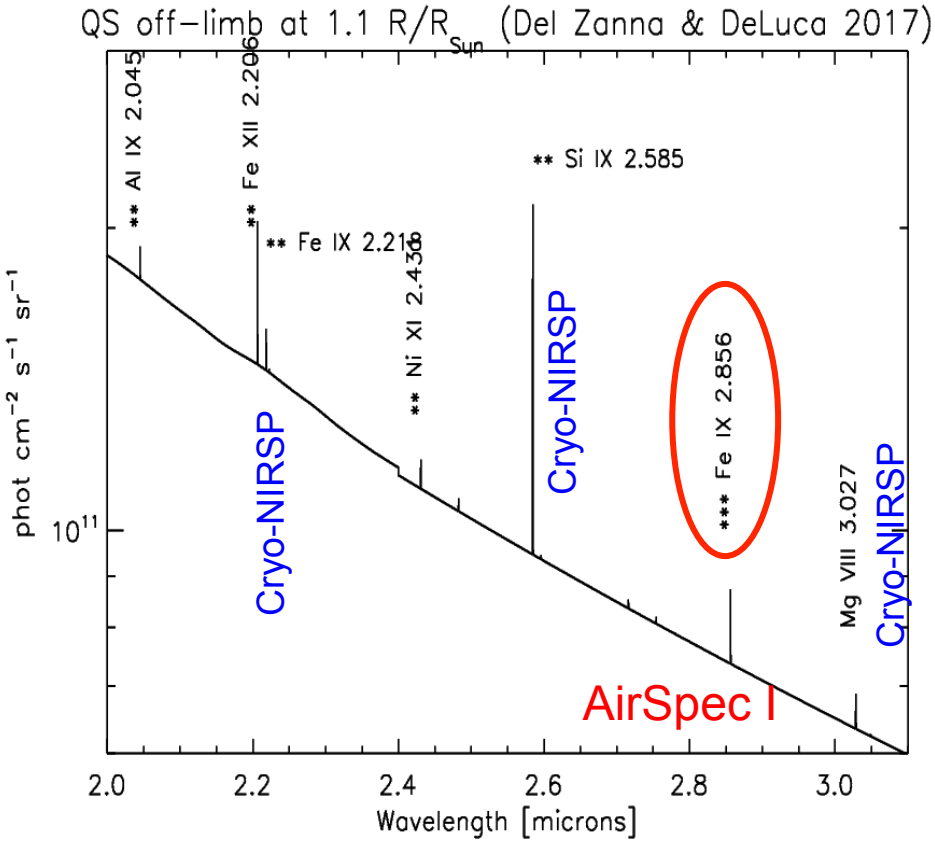
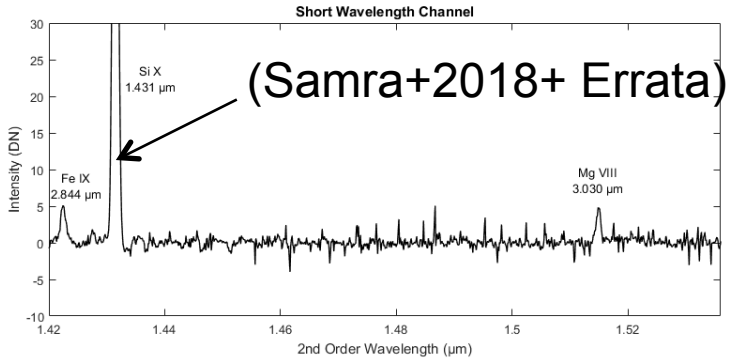
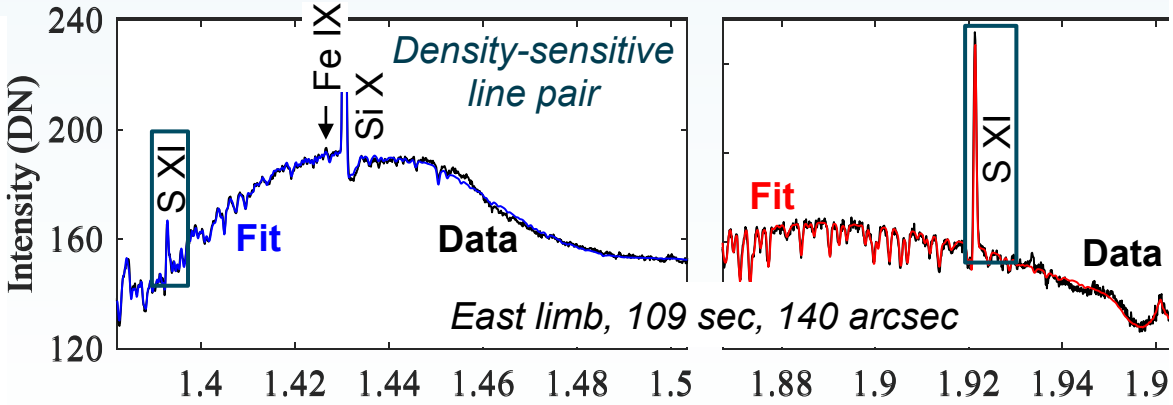




AirSpec - total eclipse 2017 and 2019



Samra+2021; Del Zanna+2021



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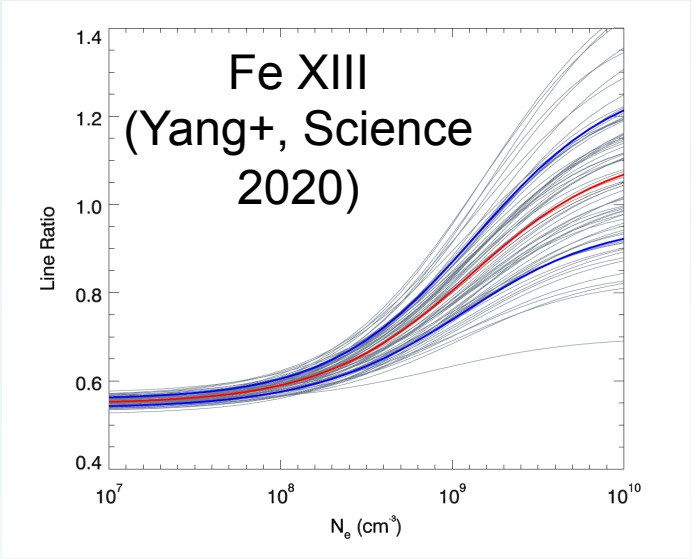
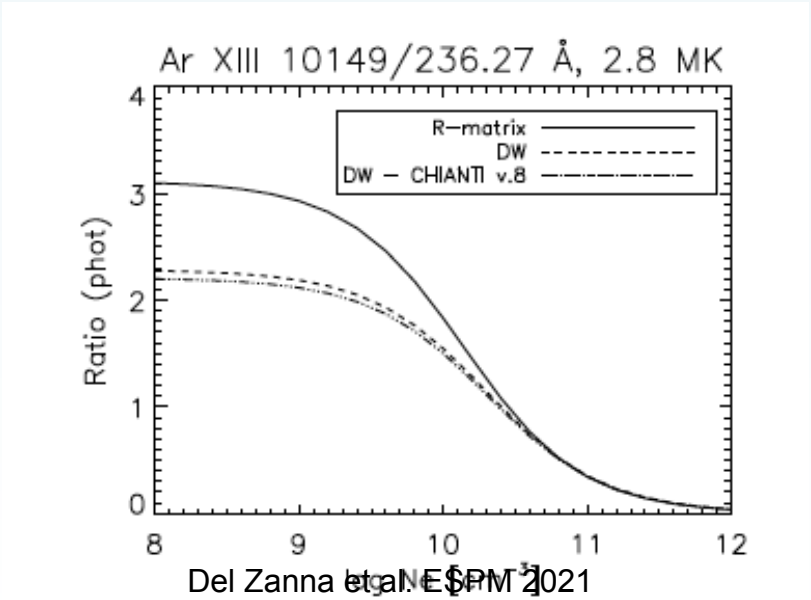
Atomic data for forbidden lines

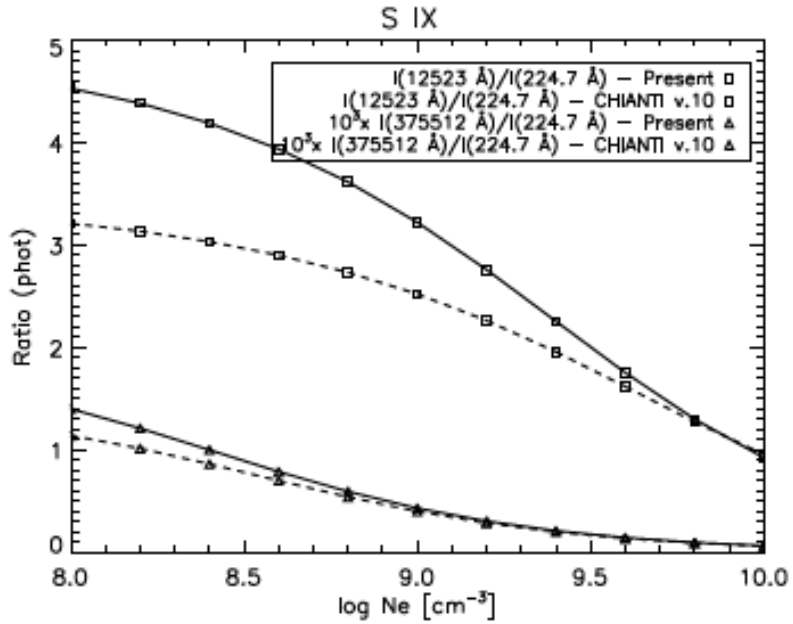
- To model the Fe XIII forbidden lines, large atomic models (e.g. Del Zanna & Storey 2012) are needed as cascading populates the lower states.
- Fe XIII NIR lines can be used to measure Ne and infer the coronal magnetic field.
- Improvements in CE rates for forbidden lines are still needed for some ions, although we have improved many (UK-APAP funded by STFC, UK)



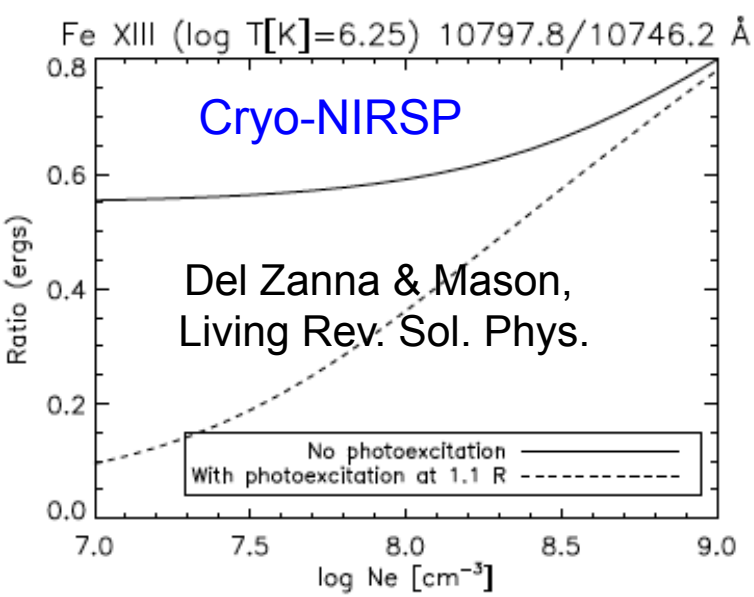
Mao,Badnell,Del Zanna 2020



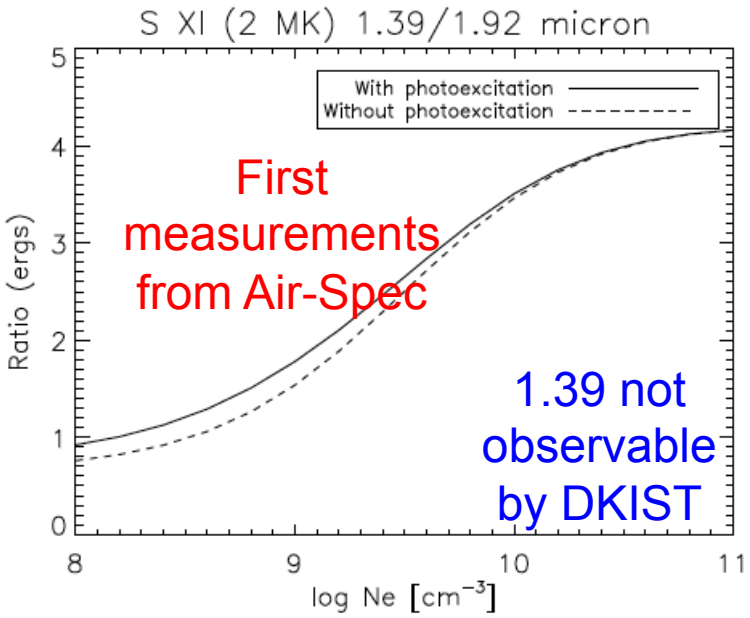
Mao,Badnell,Del Zanna 2021

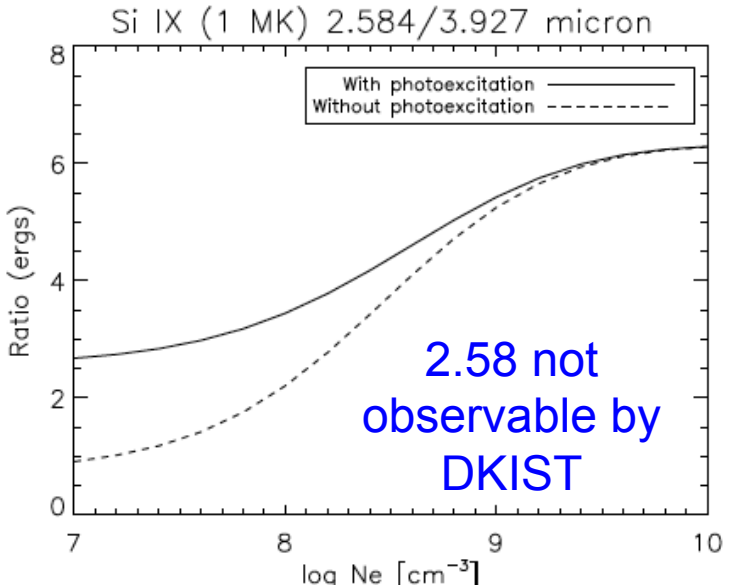


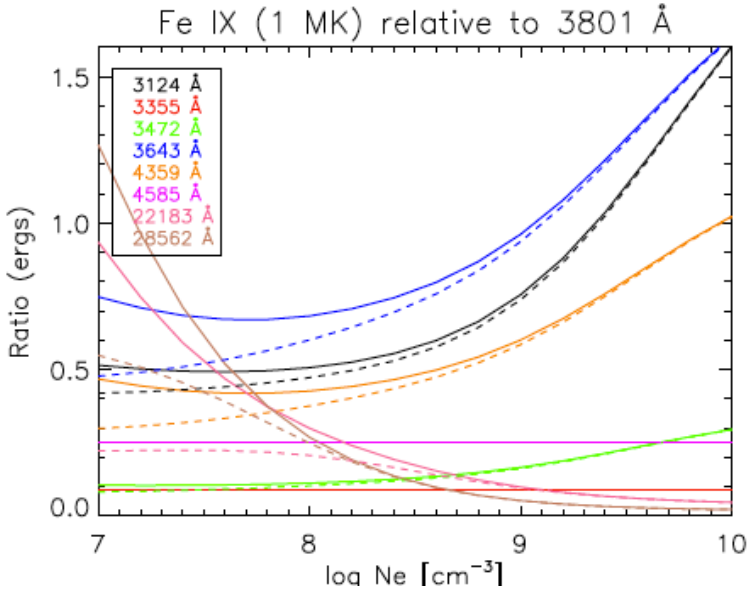
Measurements of Ne



Del Zanna & DeLuca (2018)

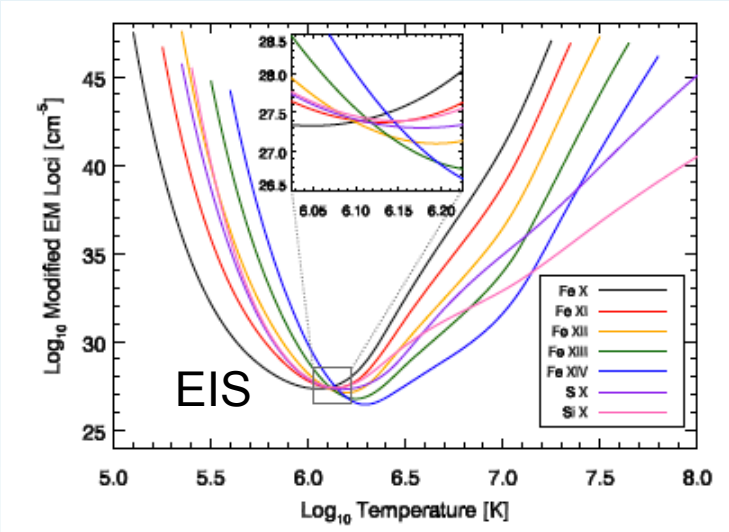


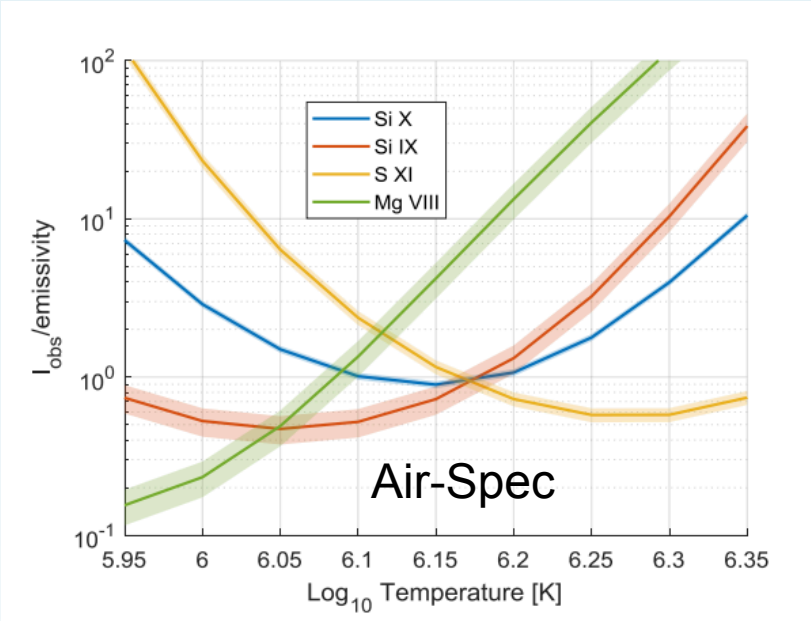




Results

$$EMLoci = \frac{Iobs}{Ab(X)\ Gji(Te)}$$





Combined NIR (Air-Spec) and EUV (Hinode EIS) measurements confirm previous findings (Del Zanna & DeLuca 2018): nearly isothermal plasma and photospheric S/Si abundances (Asplund+2009) in the quiet corona.
Ne from S XI (NIR), Fe XII (EUV) line ratios, and WL pB in broad agreement.
Air-Spec I (Madsen+2019), Air-Spec II (Del Zanna+2021).

Near Future: further Air-Spec flights, DKIST, UCOMP, Aditya VELC,etc.

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