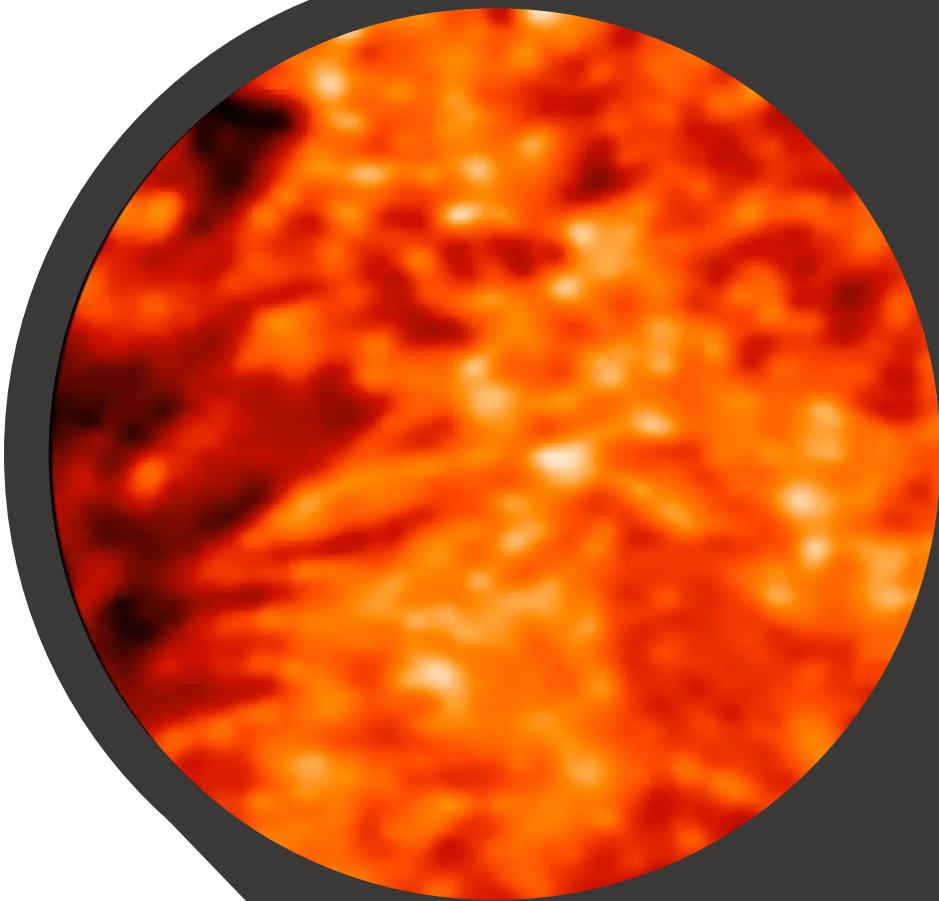


What do IRIS and ALMA tell us about plage: first inversion results

**João M. da Silva Santos¹, J. de la Cruz Rodríguez¹, J. Leenaarts¹,
G. Chintzoglou^{2,3}, B. de Pontieu^{2,4,5}, S. Wedemeyer^{4,5} & M. Szydlarski^{4,5}**



ALMA Band 6 | 1.25 mm

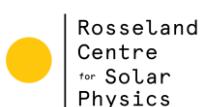
¹ Institute for Solar Physics, Stockholm University, Sweden
joao.dasilva@astro.su.se

² Lockheed Martin Solar & Astrophysics Laboratory, USA

³ University Corporation for Atmospheric Research, USA

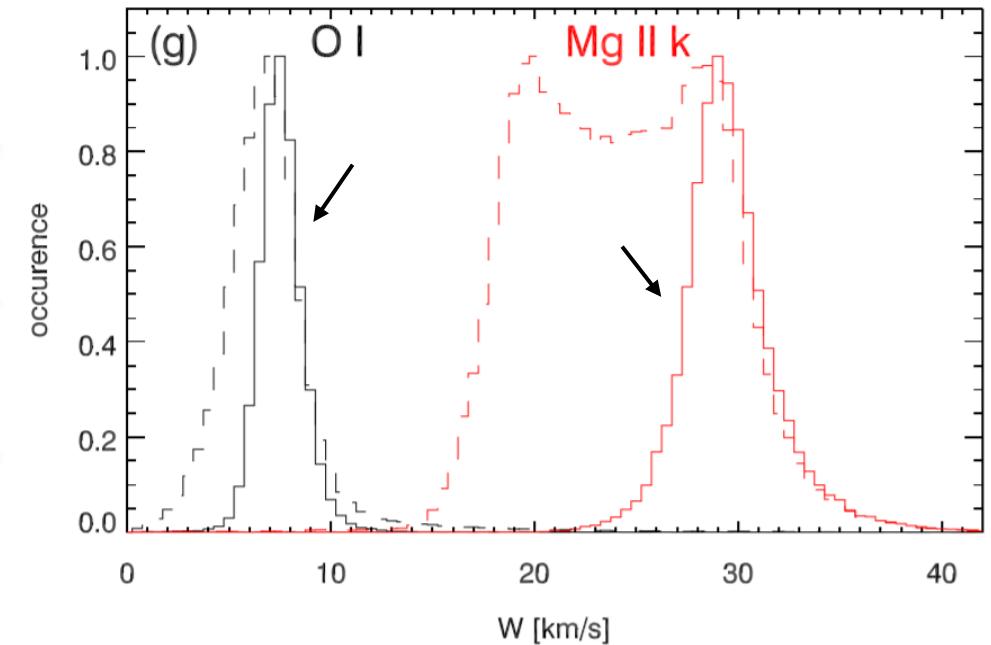
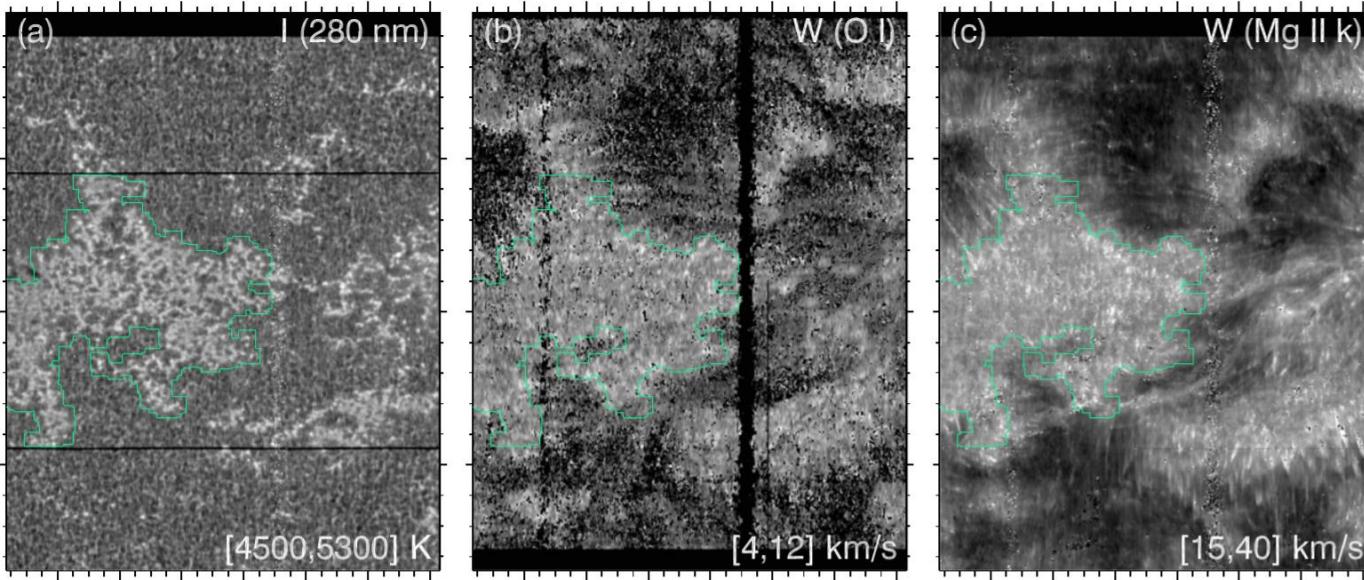
⁴ Rosseland Centre for Solar Physics, Norway

⁵ Institute of Theoretical Astrophysics, University of Oslo, Norway



UiO : University of Oslo

plage profiles are broader and brighter than those of the QS



^a Active region plage NOAA 12144, IRIS 2800 nm (raster scan)

^b Width of the OI 1356 Å line

^c Width of the MgII k 2796 Å line

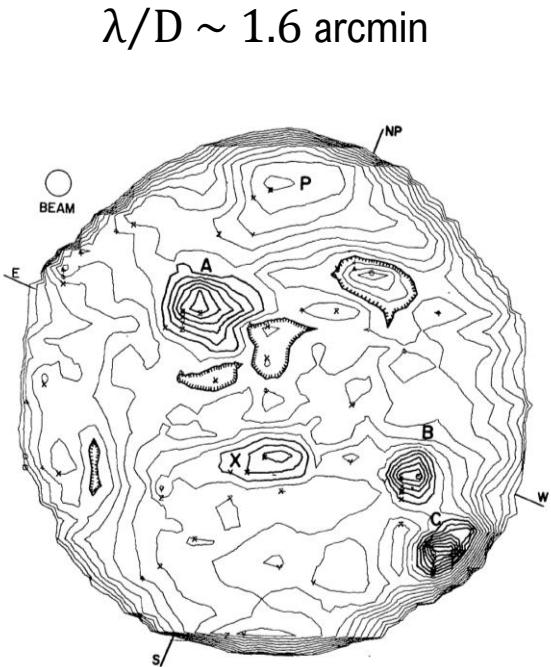
^g Histograms of line widths (solid for plage)

Carlsson et al (2015)

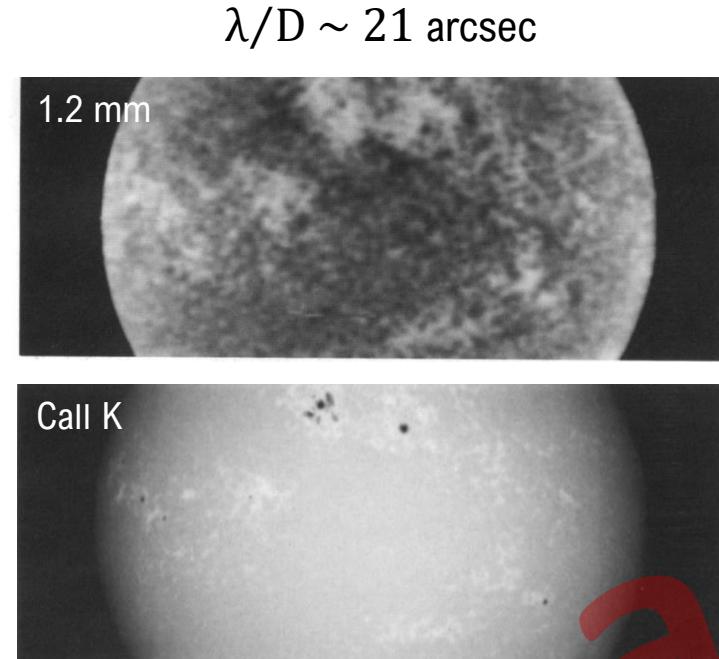
(see also review by Carlsson et al (2019))

Observations of plage in the millimeter

(see also review by [Wedemeyer et al \(2016\)](#))



Full-disk at 9.6 mm (**NRL** antenna)
[Kundu et al \(1972\)](#)
(see also [Beckman & Clark et al \(1971\)](#))



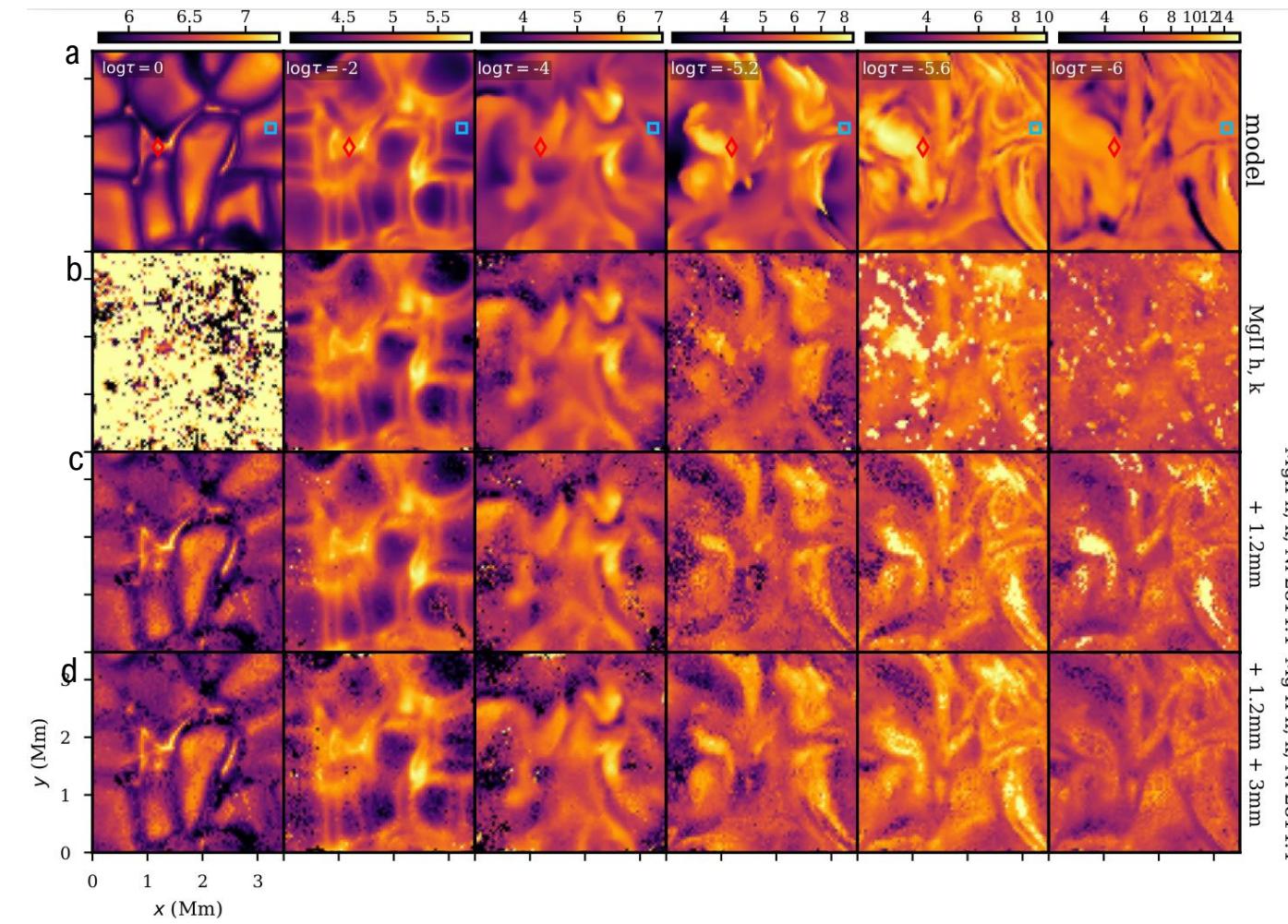
Full-disk at 1.2 mm (**JCMT**)
compared to Call K (San Fernando
Solar Observatory)
[Lindsey et al \(1995\)](#)

animation



Blinking Mg II h core and 1.25 mm continuum
(ALMA science verification data)
(see also [Bastian et al \(2017\)](#); [Jafarzadeh et al \(2019\)](#))

constraining temperatures in inversions using the mm continuum



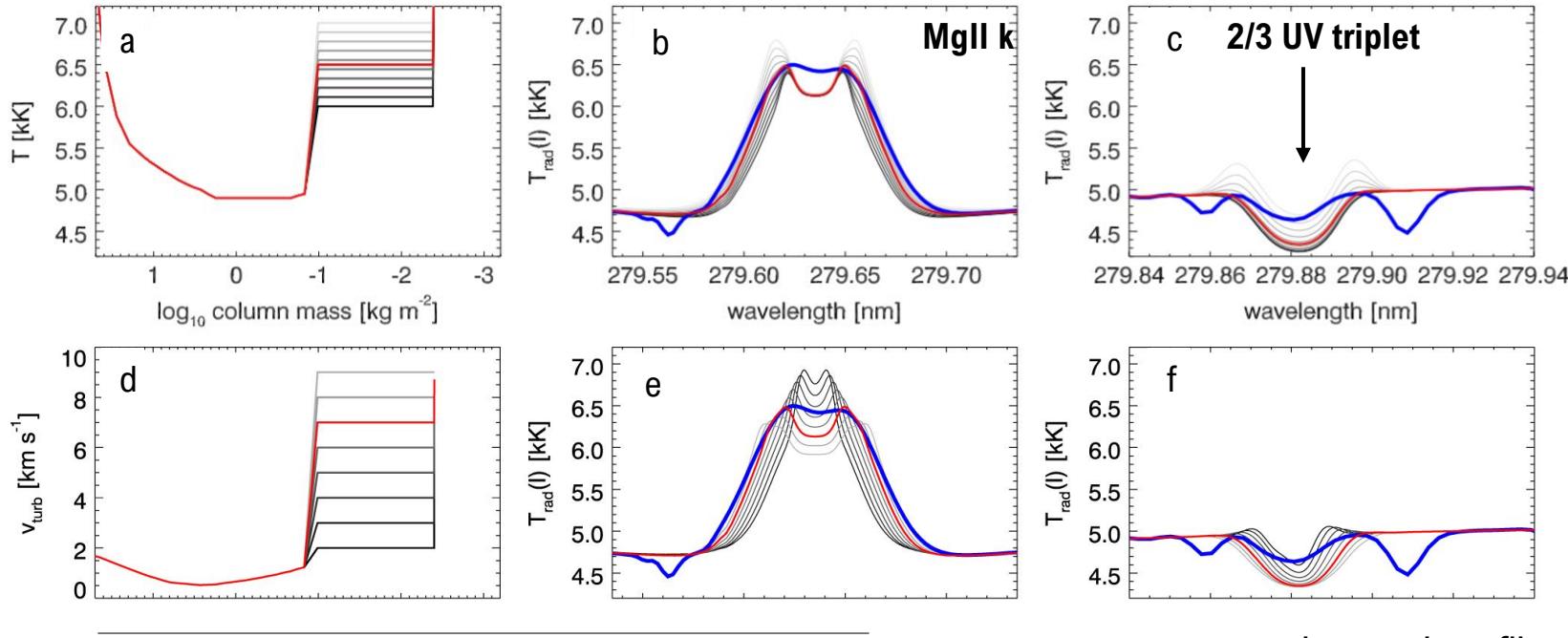
a Temperature [kK] at different log optical depths in a **Bifrost** simulation (public snapshot [Carlsson et al \(2016\)](#))

b Inverted temperatures fitting the IRIS MgII h and k window

c,d (...) MgII h and k window + NiI + **mm continuum**

[da Silva Santos et al \(2018\)](#)

temperature and microturbulence have an imprint on the line shape



- a Temperature profile vs column mass
- b,e Mg II k 2796 Å line core
- c,f Mg II 2798.8 Å triplet
- d Microturbulence profile vs column mass

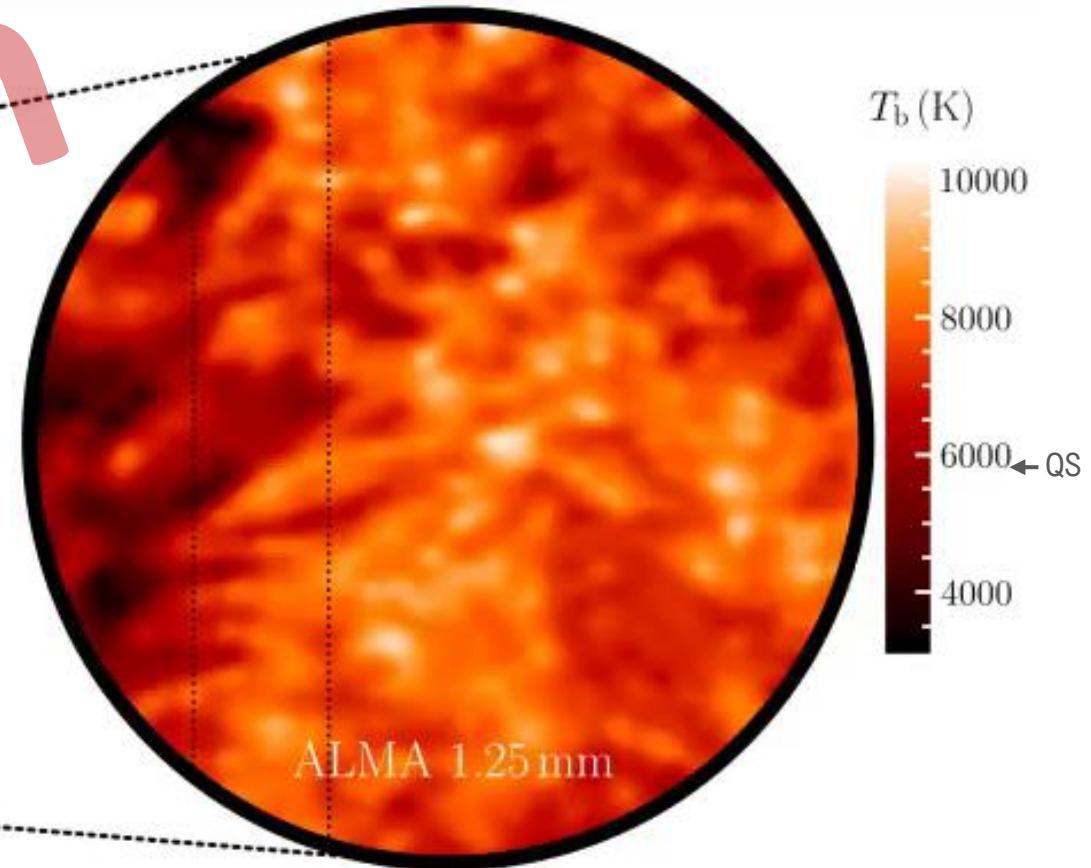
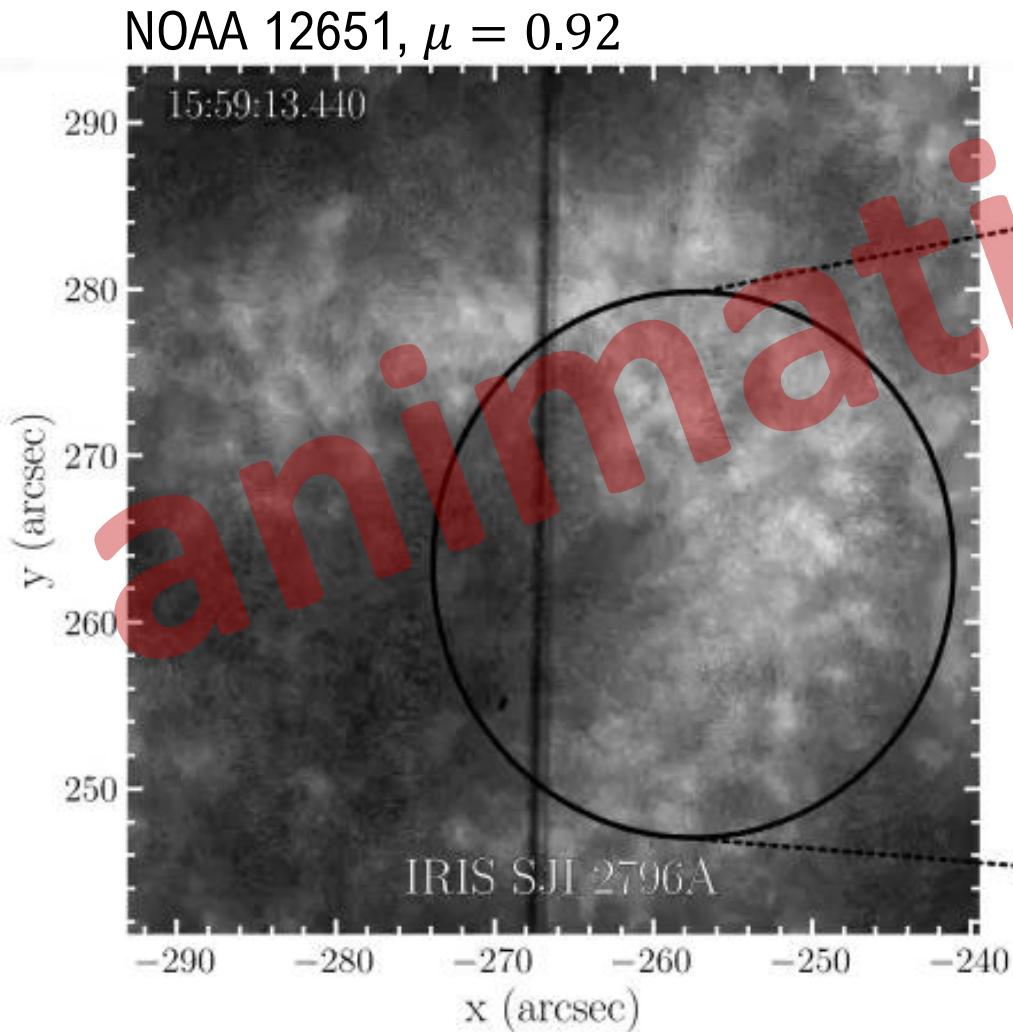
— average observed profile

Carlsson et al (2015)

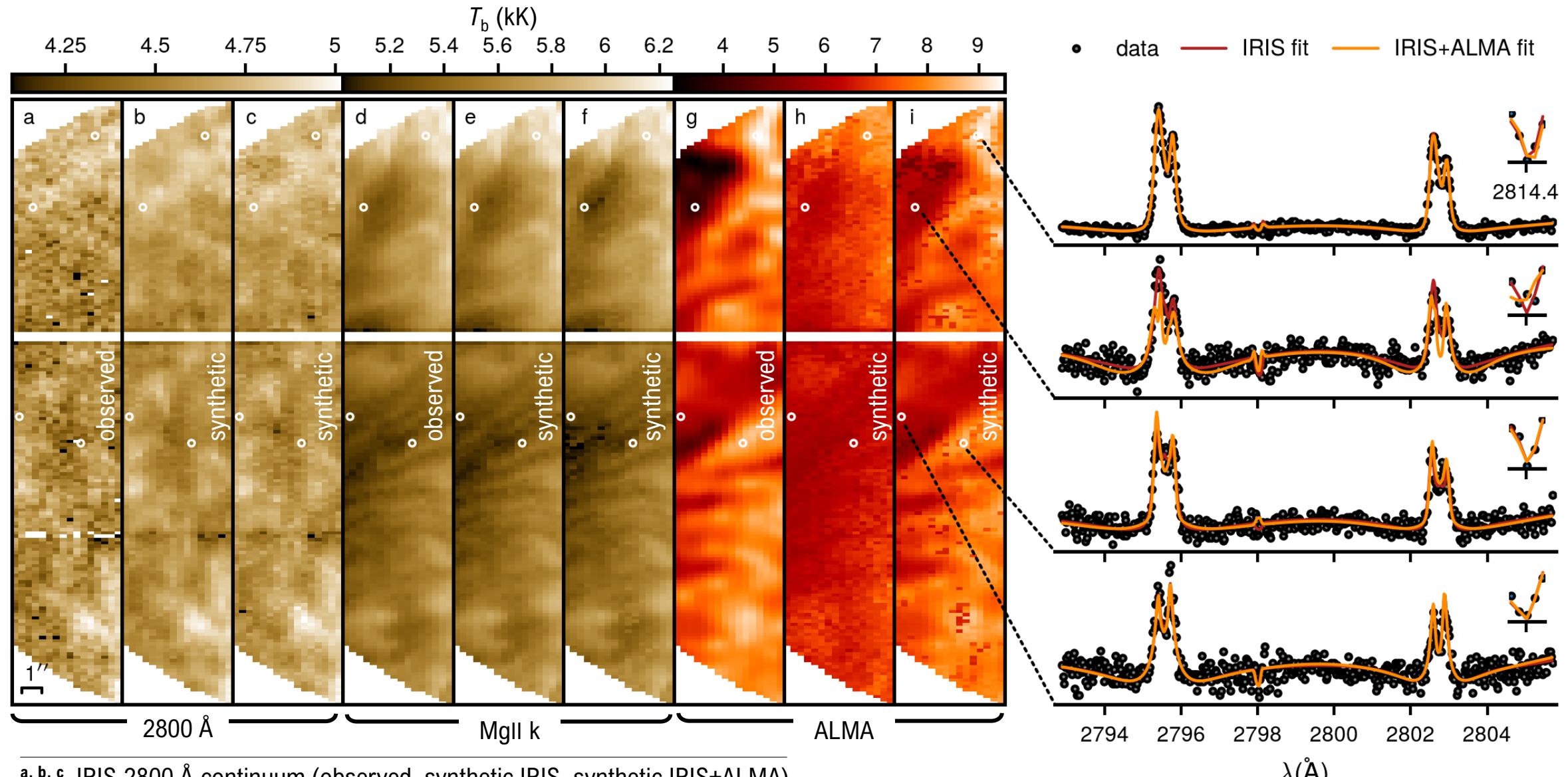
(see also de la Cruz Rodríguez et al (2016, 2019); Sainz Dalda et al (2019))

non-LTE inversions of plage with IRIS and ALMA

da Silva Santos et al (in prep)



2016.1.00050.S B. de Pontieu et al.
reduction pipeline Szydlarski et al (in prep)

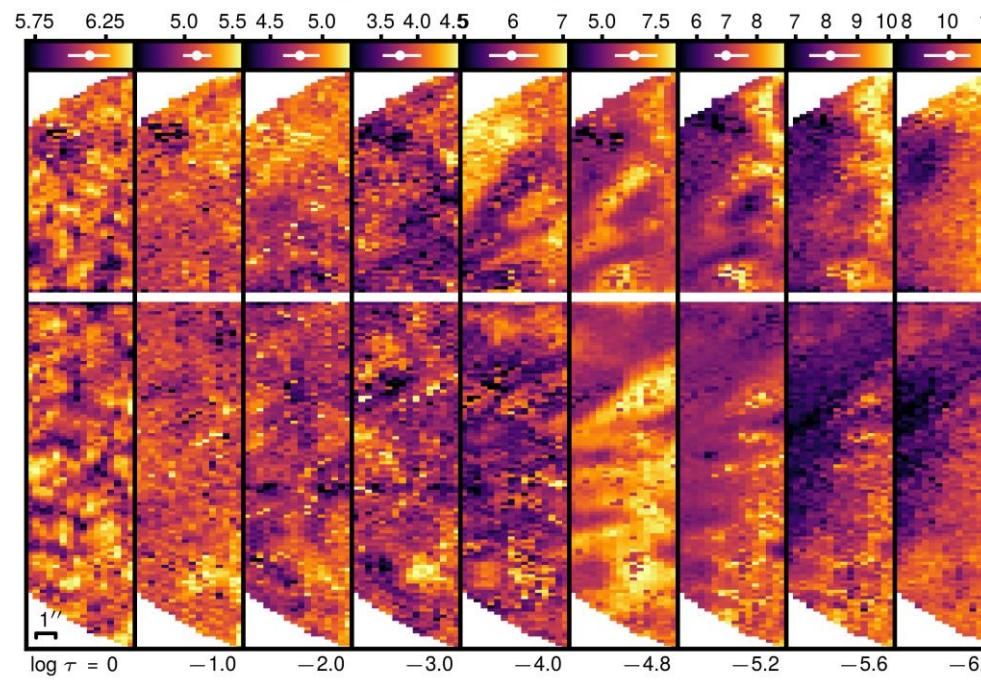
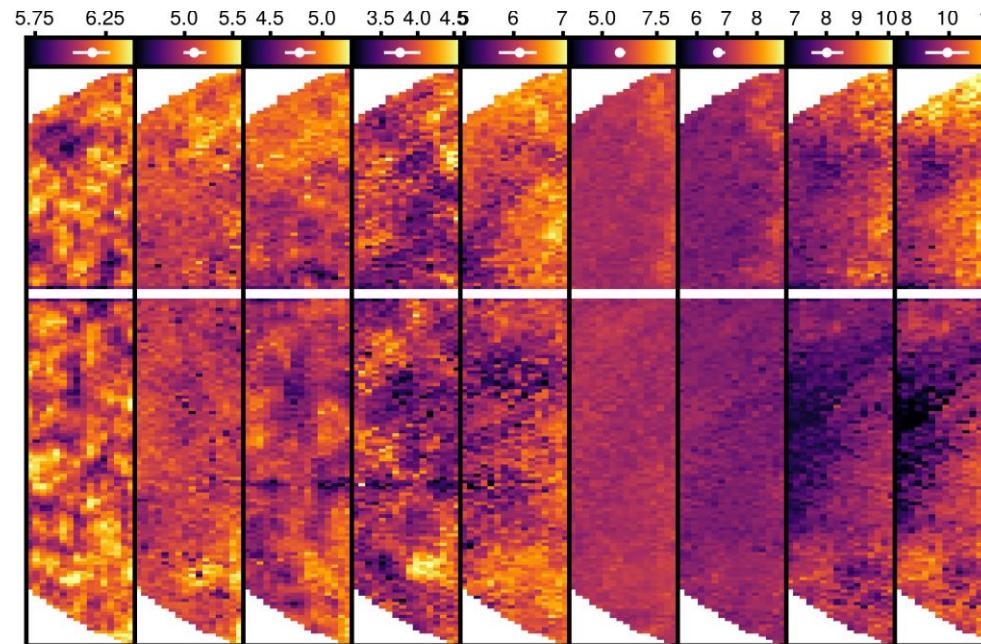


a, b, c IRIS 2800 Å continuum (observed, synthetic IRIS, synthetic IRIS+ALMA)

d, e, f IRIS Mg II k core (observed, synthetic IRIS, synthetic IRIS+ALMA)

g, h, i ALMA 1.25 mm (observed, synthetic IRIS, synthetic IRIS+ALMA)

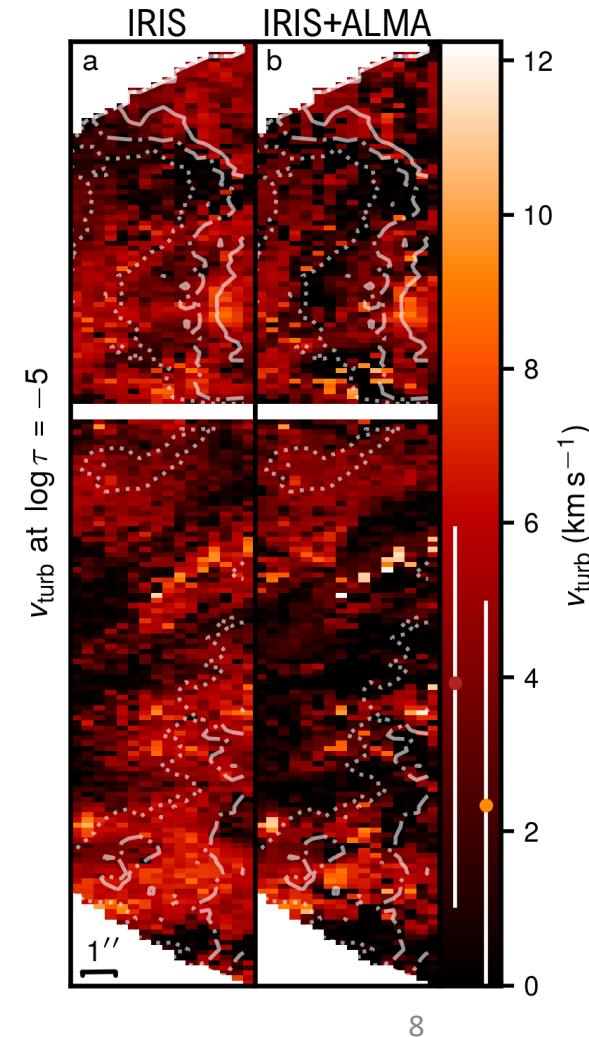
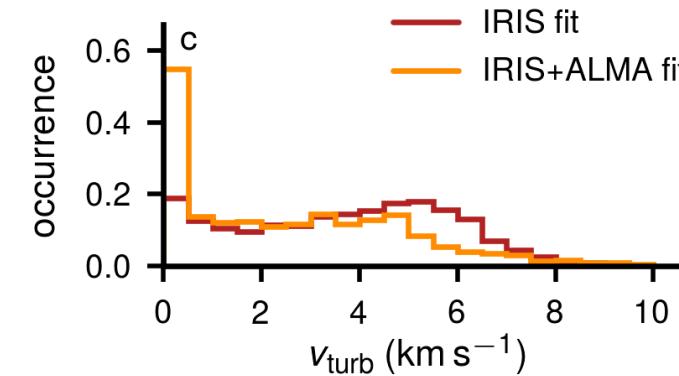
da Silva Santos et al (in prep)



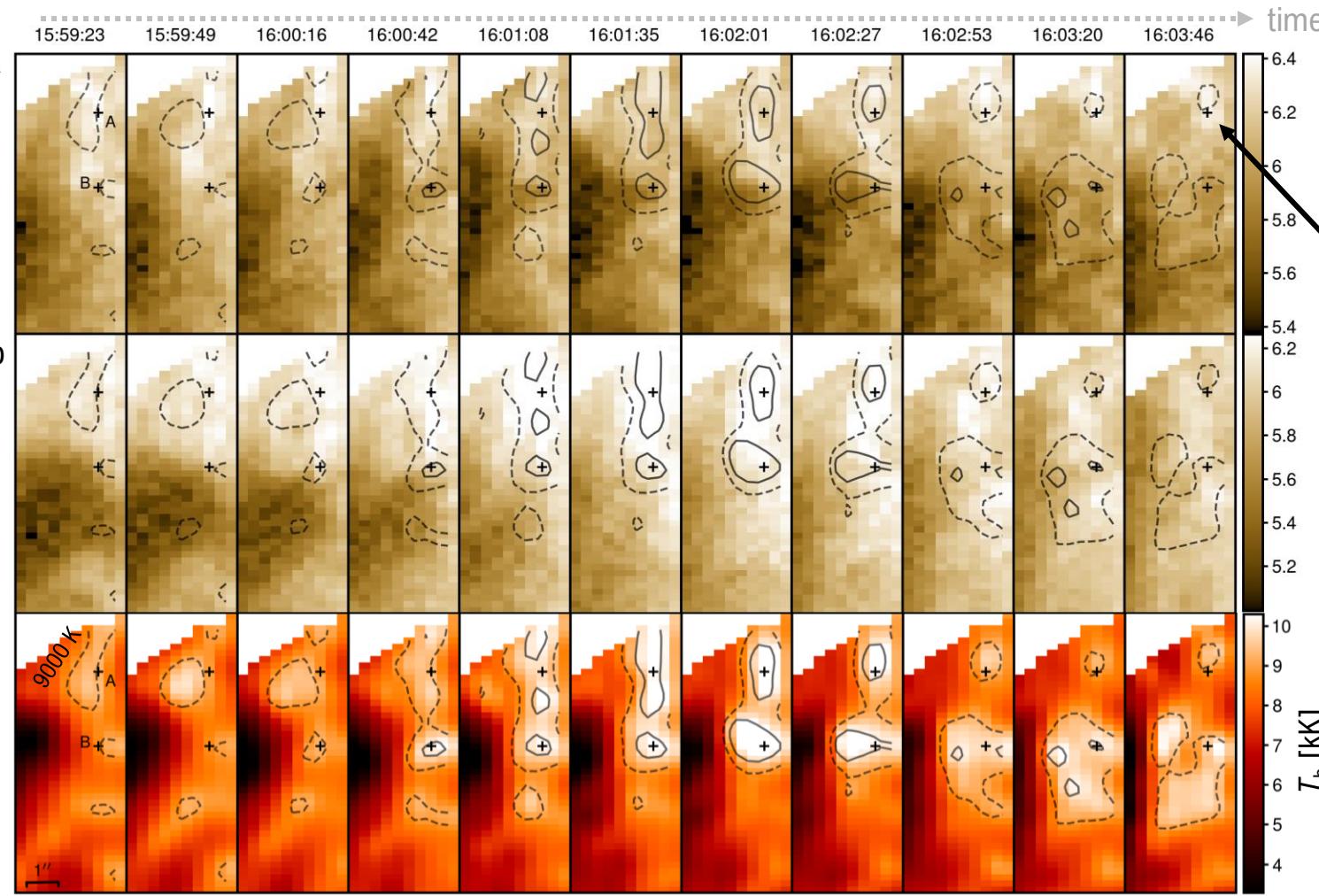
da Silva Santos et al (in prep)

Inverted temperatures and microturbulence

using non-LTE electron densities



signatures of shock waves

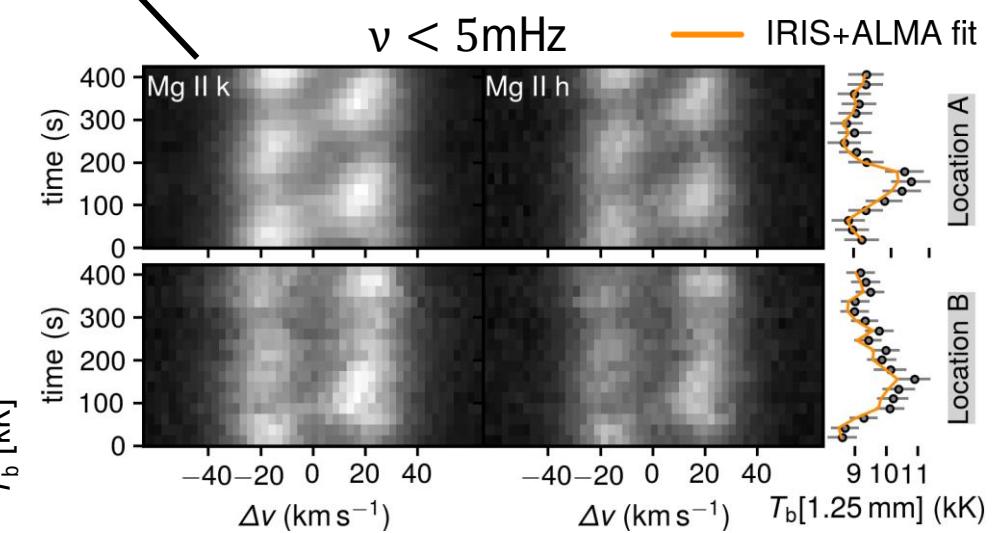


^a k2v brightness temperature T_b [kK]

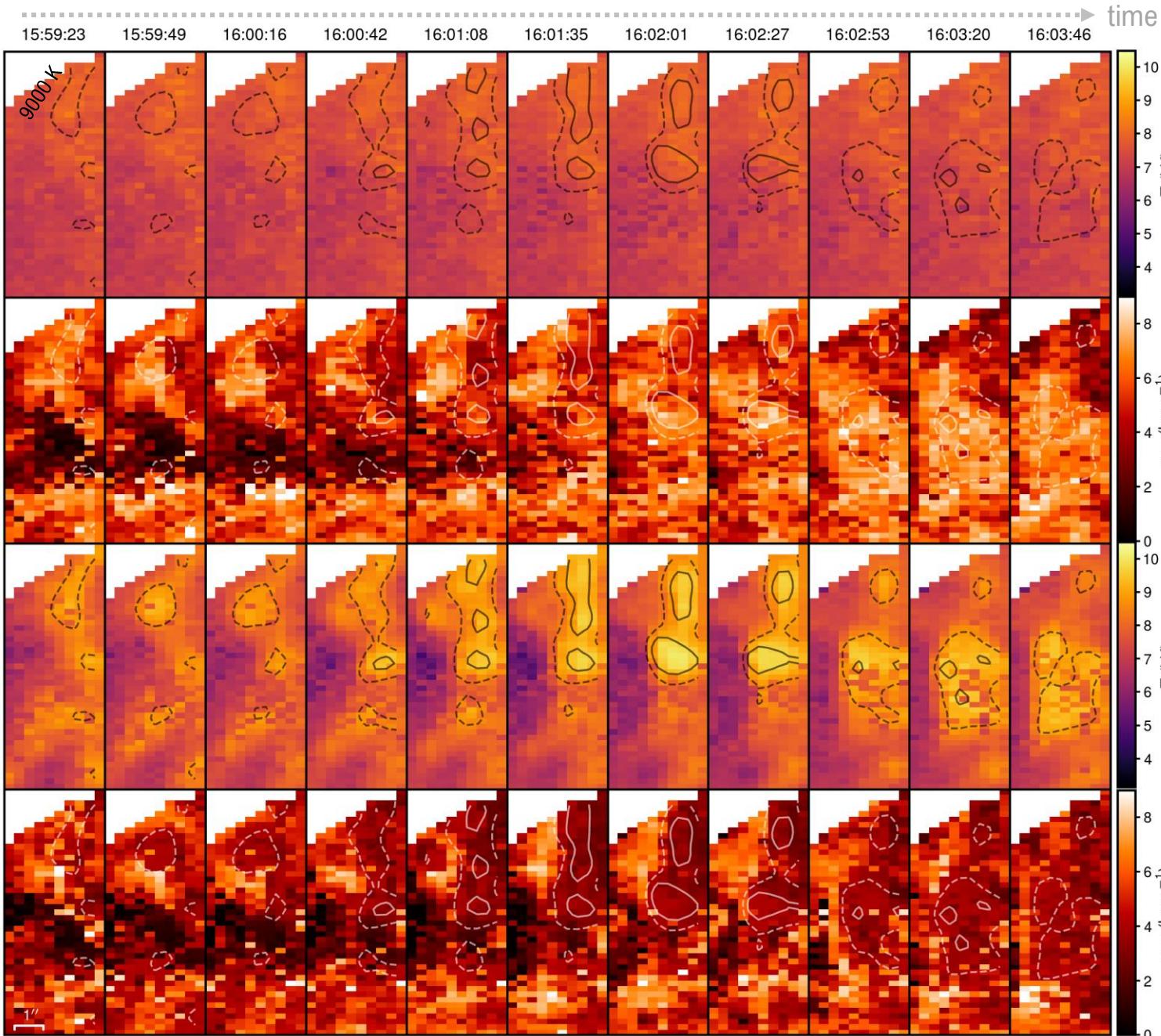
^b k2r T_b

^c ALMA 1.25 mm T_b

da Silva Santos et al (in prep)



(and more in Chintzoglou et al. (in prep))



Inverted temperature and microturbulence

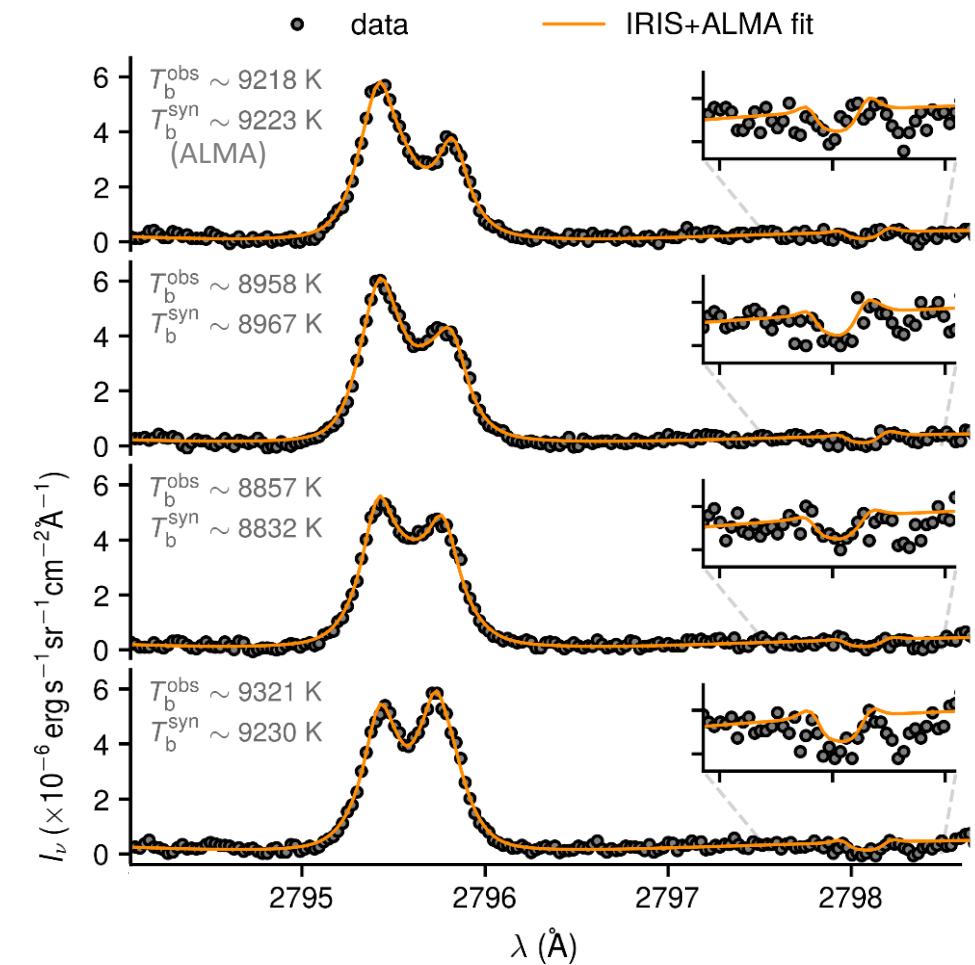
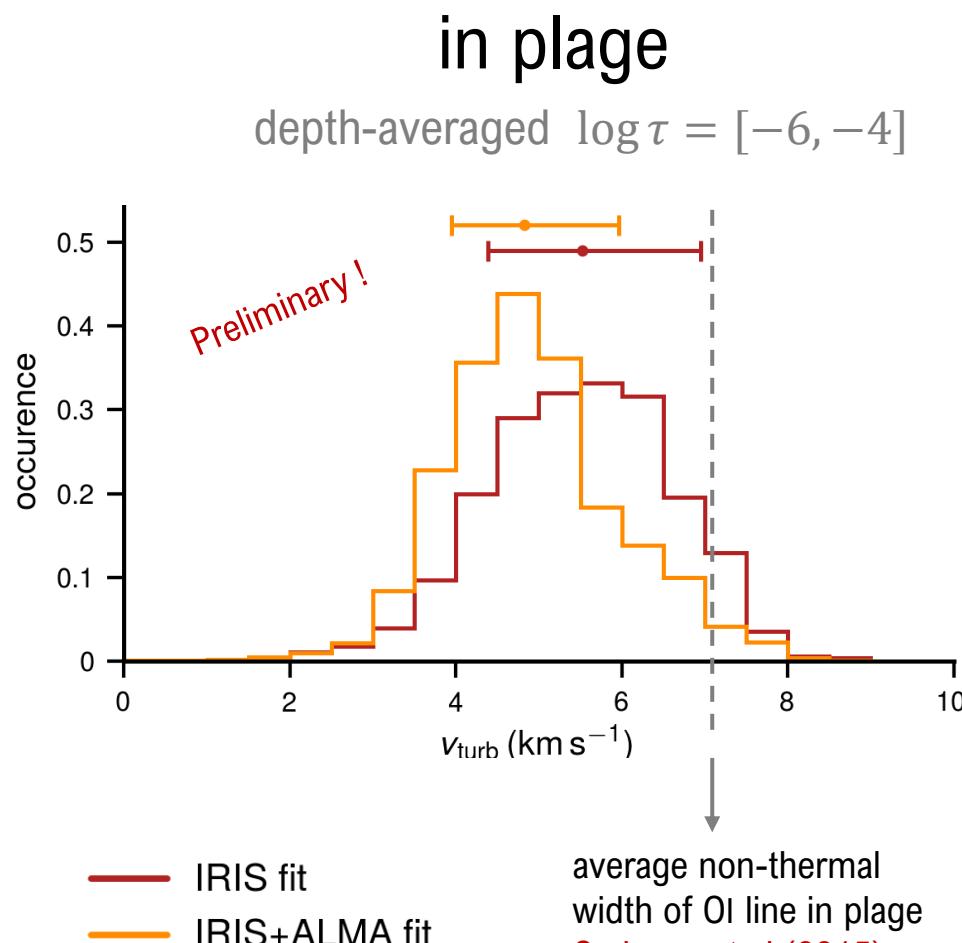
from IRIS

depth-averaged $\log \tau \sim [-6, -4]$

from IRIS+ALMA

depth-averaged $\log \tau \sim [-6, -4]$

the plage spectra are
well reproduced



Example data and fits in plage
da Silva Santos et al (in prep)

Conclusions

da Silva Santos et al (in prep)

- **IRIS and ALMA are complementary diagnostics:** ALMA complements the diagnostic potential for temperatures, velocities and microturbulence of the MgII lines with a tighter **constraint on the temperature gradient** in the chromosphere.
- Inversions of the MgII lines cannot accurately predict the observed mm continuum.
- Inversions with **ALMA B6** imply a **hotter chromosphere in plage**, and the temp. range and **contrast are increased** ($\log \tau \sim [-5.8, -4.8]$ (700-1500 km in Bifrost sim)).
- **Depth-averaged microturbulence** in plage is in the lower limits of non-thermal widths of the OI 1356 Å line (in the literature).
- We find evidence for **heating** due to magnetoacoustic **shocks**.