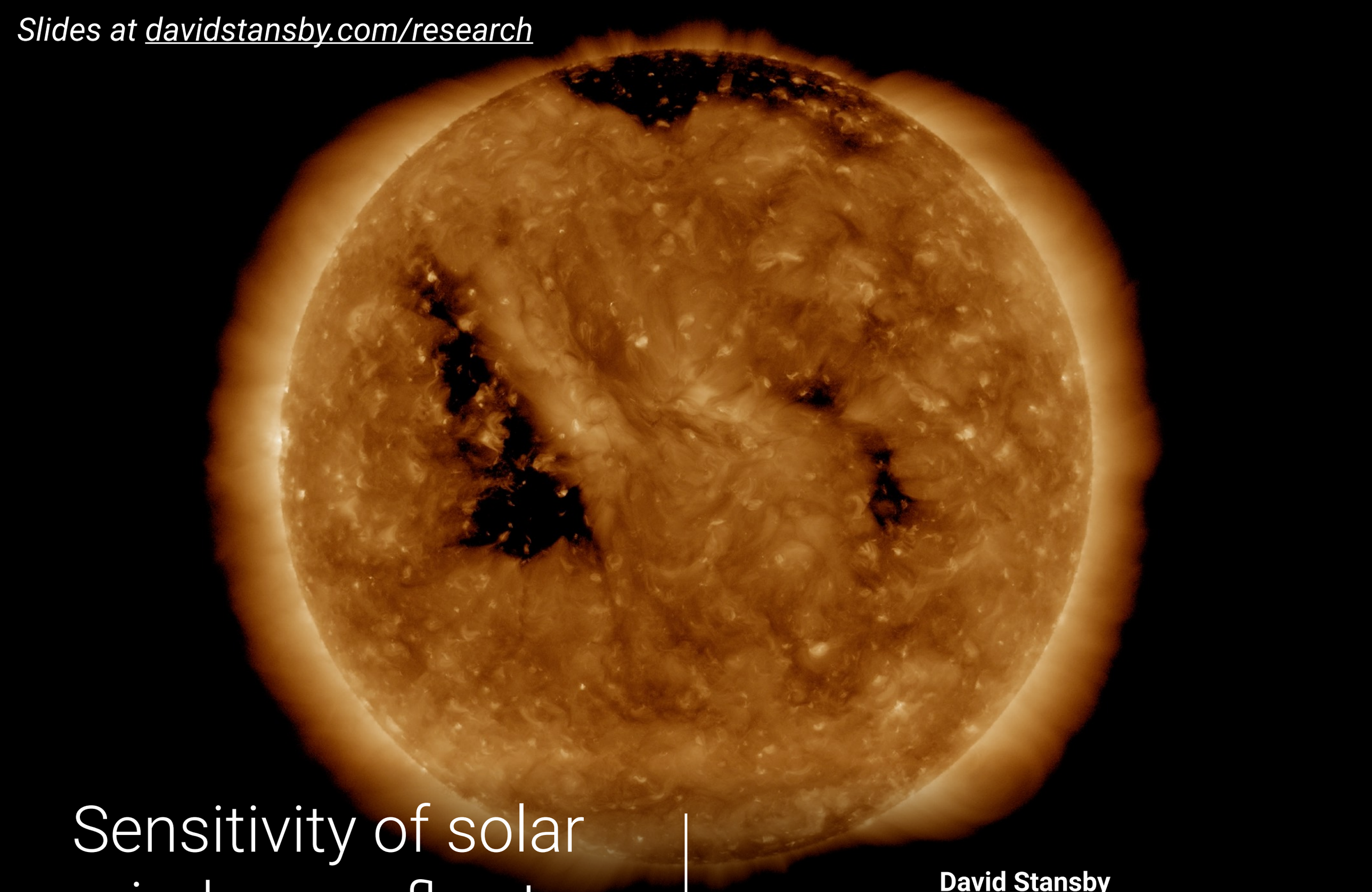
Slides at davidstansby.com/research



Sensitivity of solar wind mass flux to coronal temperature

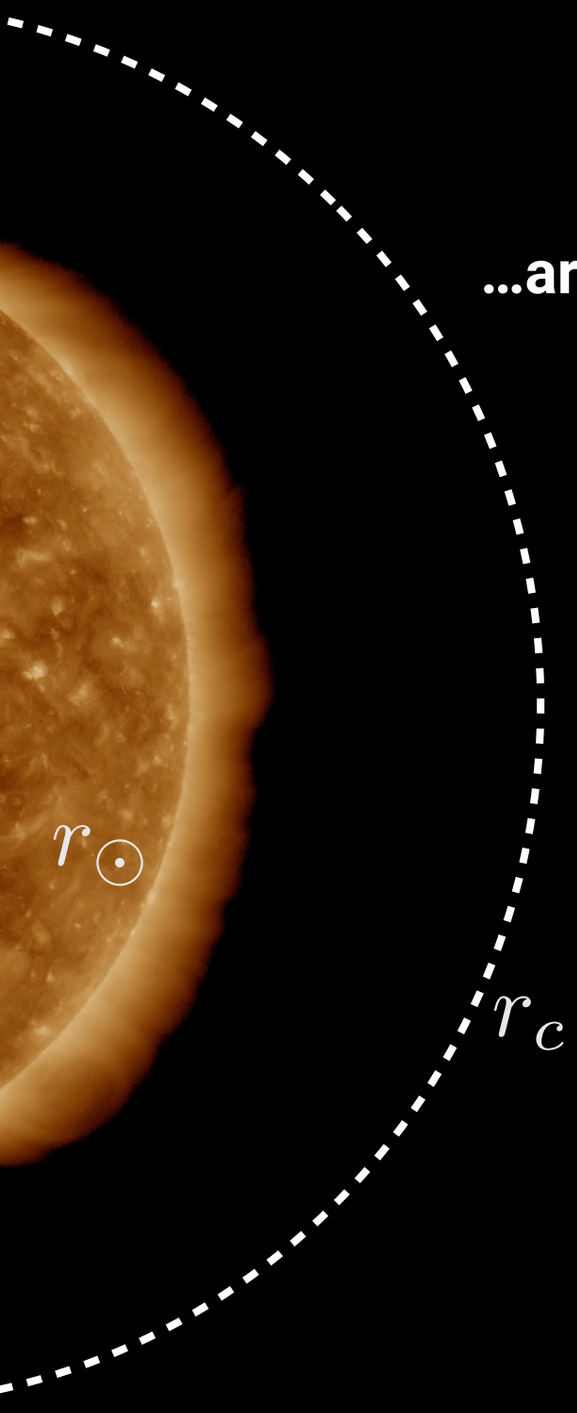
David Stansby
Laura Berčič, Lorenzo Matteini, Chris Owen,
Ryan French, Deb Baker, Sam Badman

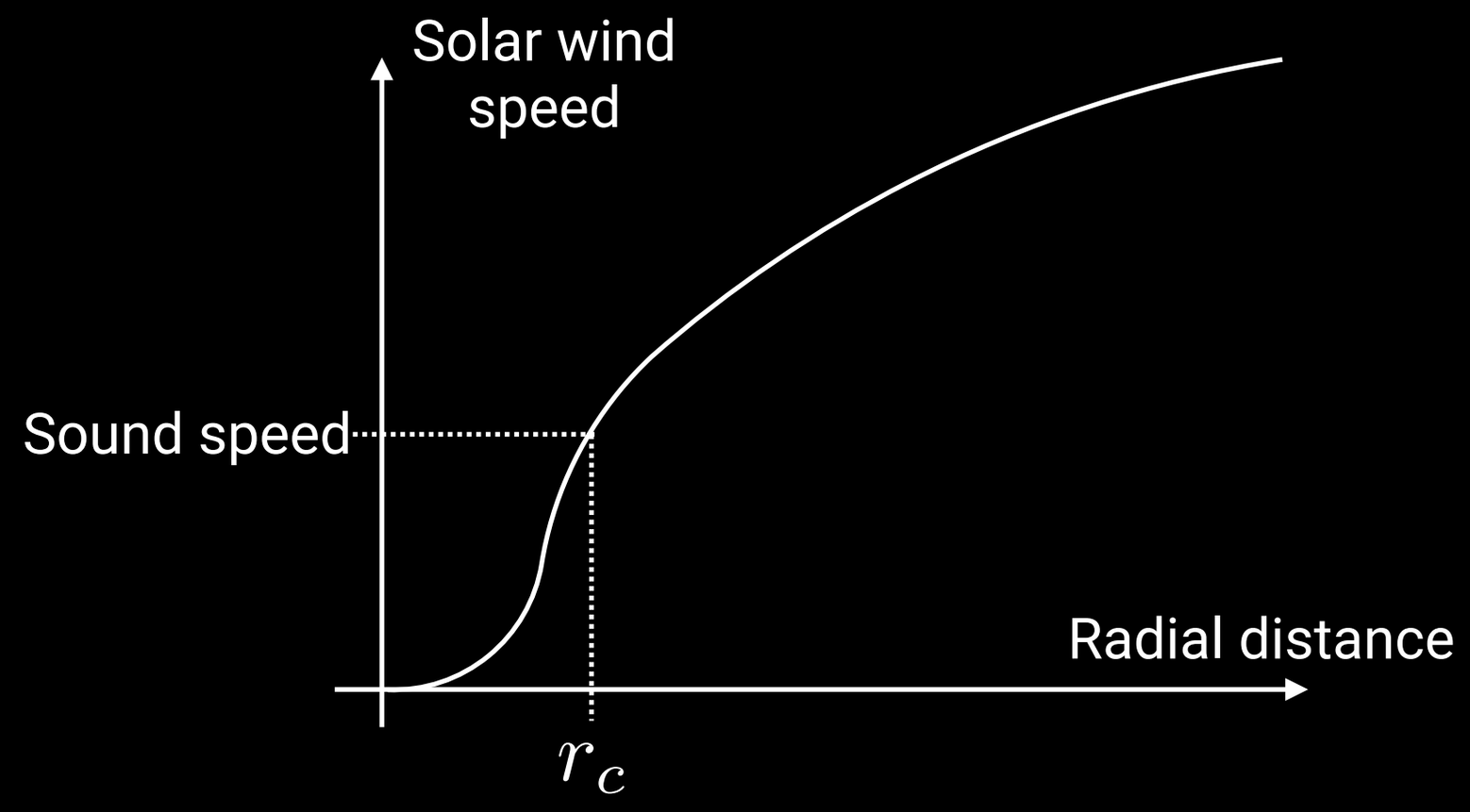
The solar wind event horizon

UCL

Solar wind properties here…

…are set by plasma properties here





The sonic critical point is an “inverse event horizon”

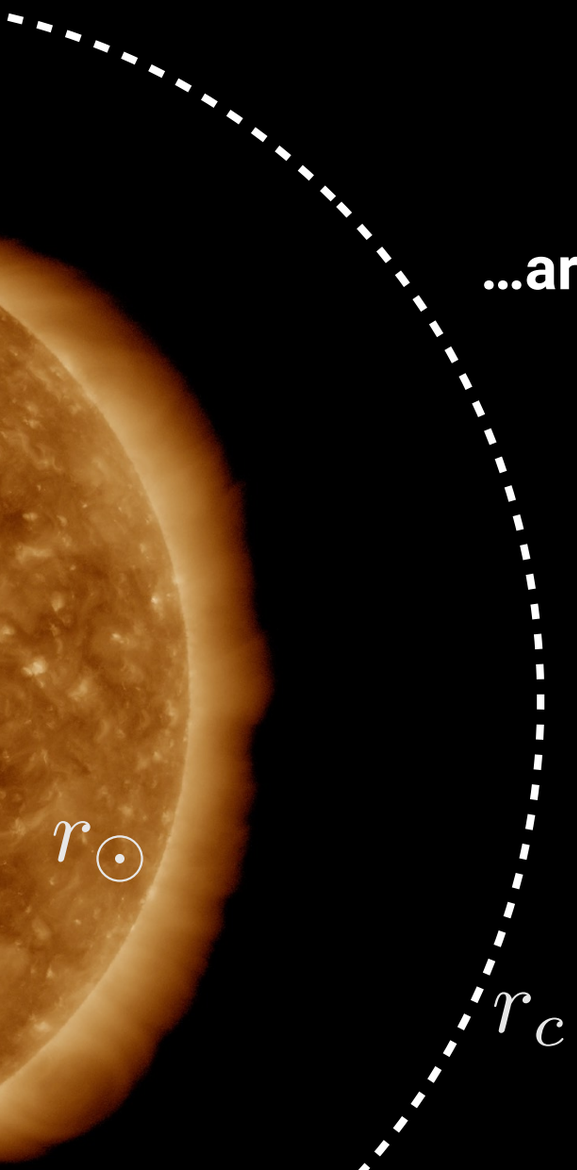
[Parker 1960]

The solar wind event horizon

UCL

Solar wind properties here…

…are set by plasma properties here



$r_\odot$

r_c

$$n_\odot v_\odot = n_\odot c_\odot \frac{c_\odot}{c_c} \frac{r_c^2}{r_\odot^2} \exp\left[- \int_{r_\odot}^{r_c} \frac{r_\odot dr}{r^2} \frac{w^2}{c(r)^2} \right]$$

Mass flux

Constants

Integrate from surface to critical point

Temperature profile; $c^2 \sim T$

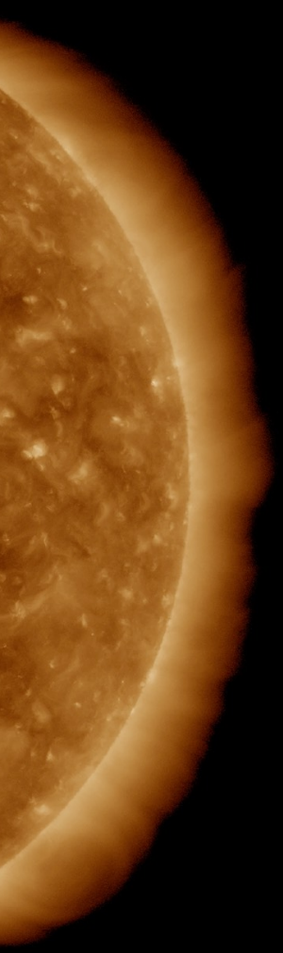
[Parker 1964]

The mass flux problem

$$n_\odot v_\odot \sim \frac{n_\odot}{T^{3/2}} \exp\left[-\frac{(11.5\ \mathrm{MK})}{T}\right]$$

Coronal mass flux

Coronal temperature



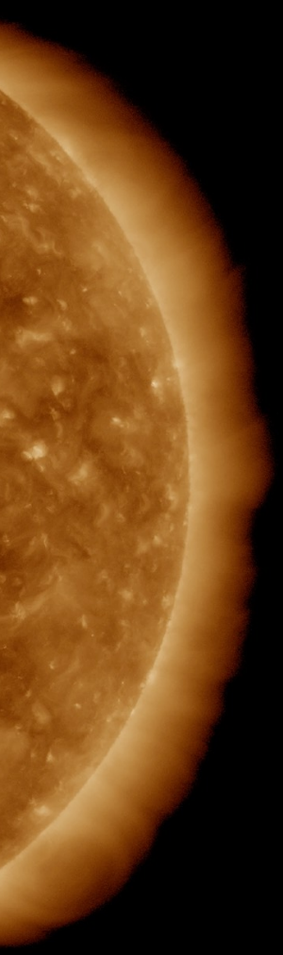
Small variations in coronal temperature should result in large variations in mass flux

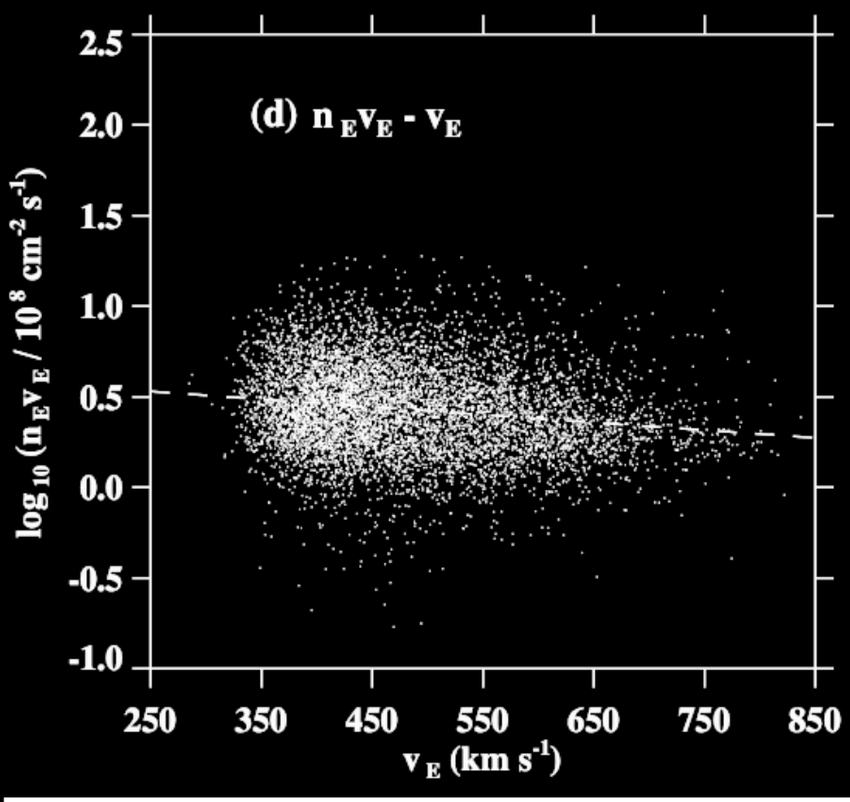
$$\frac{n_\odot v_\odot\,(T = 2\ \mathrm{MK})}{n_\odot v_\odot\,(T = 1\ \mathrm{MK})} \approx 100$$

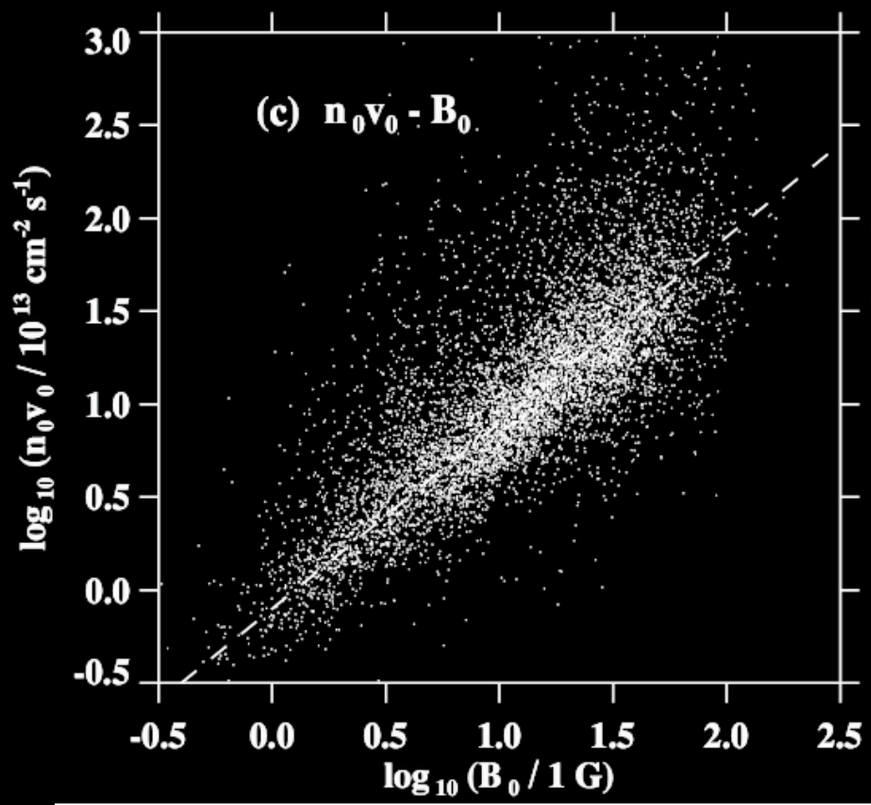
[Withbroe 1989]

The mass flux problem

Small variations in coronal temperature should result in large variations in mass flux







Solar wind mass flux ~constant at 1AU

But highly variable in the corona (as expected)

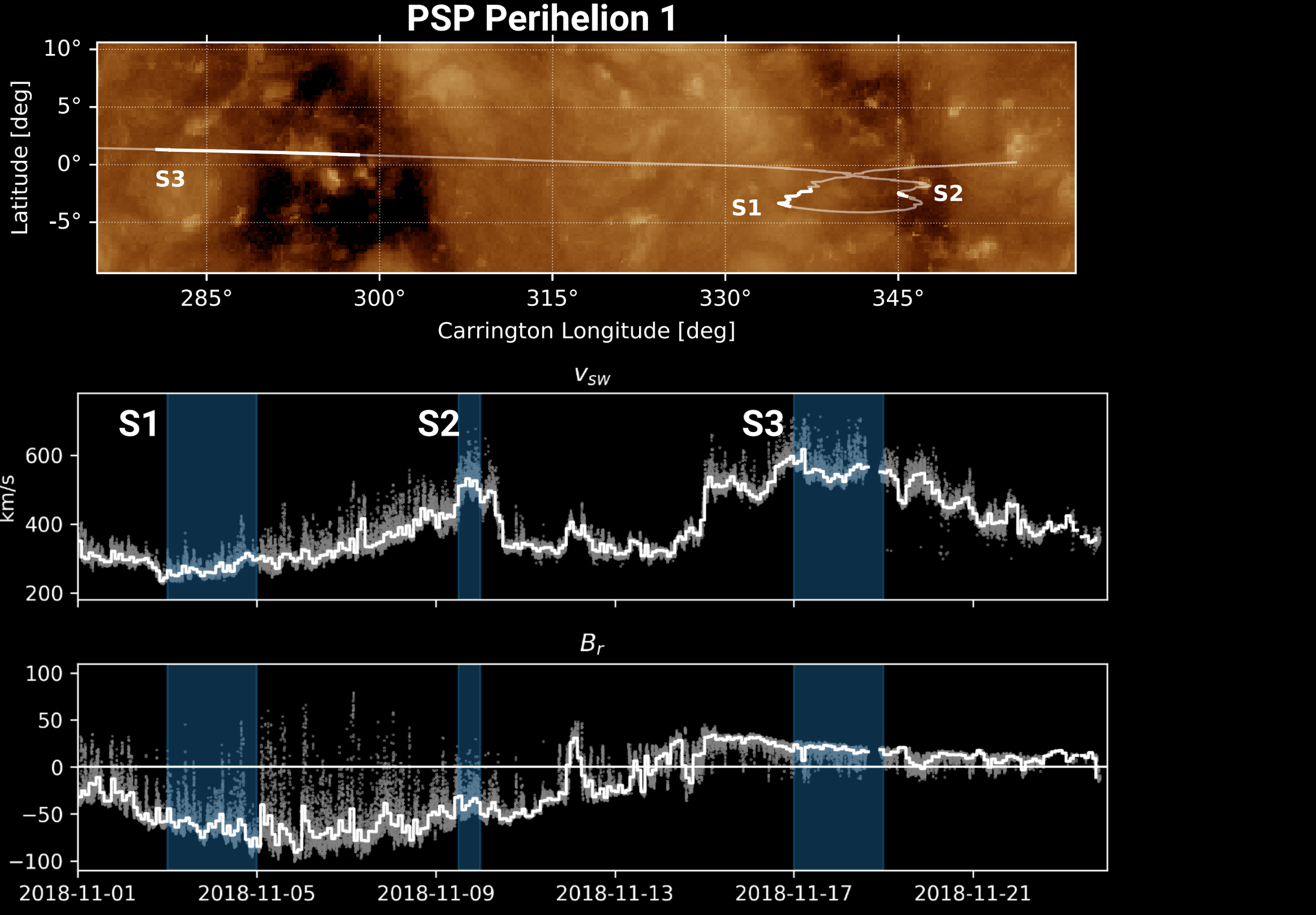
Is mass flux variation driven by coronal temperature?

[Wang 2010]

Measuring mass flux

- Using frozen-in flux theorem, $n_{\odot} v_{\odot} = n_{sw} v_{sw} \frac{B_{\odot}}{B_{sw}}$
- Need to measure:
  - Solar wind mass flux + **B** → in-situ measurement
  - Coronal **B** → remote measurement (magnetograms)
- Compare to coronal T → in-situ or remote measurement

Coronal hole observations



[see Badman et al. 2020 for detailed modelling]

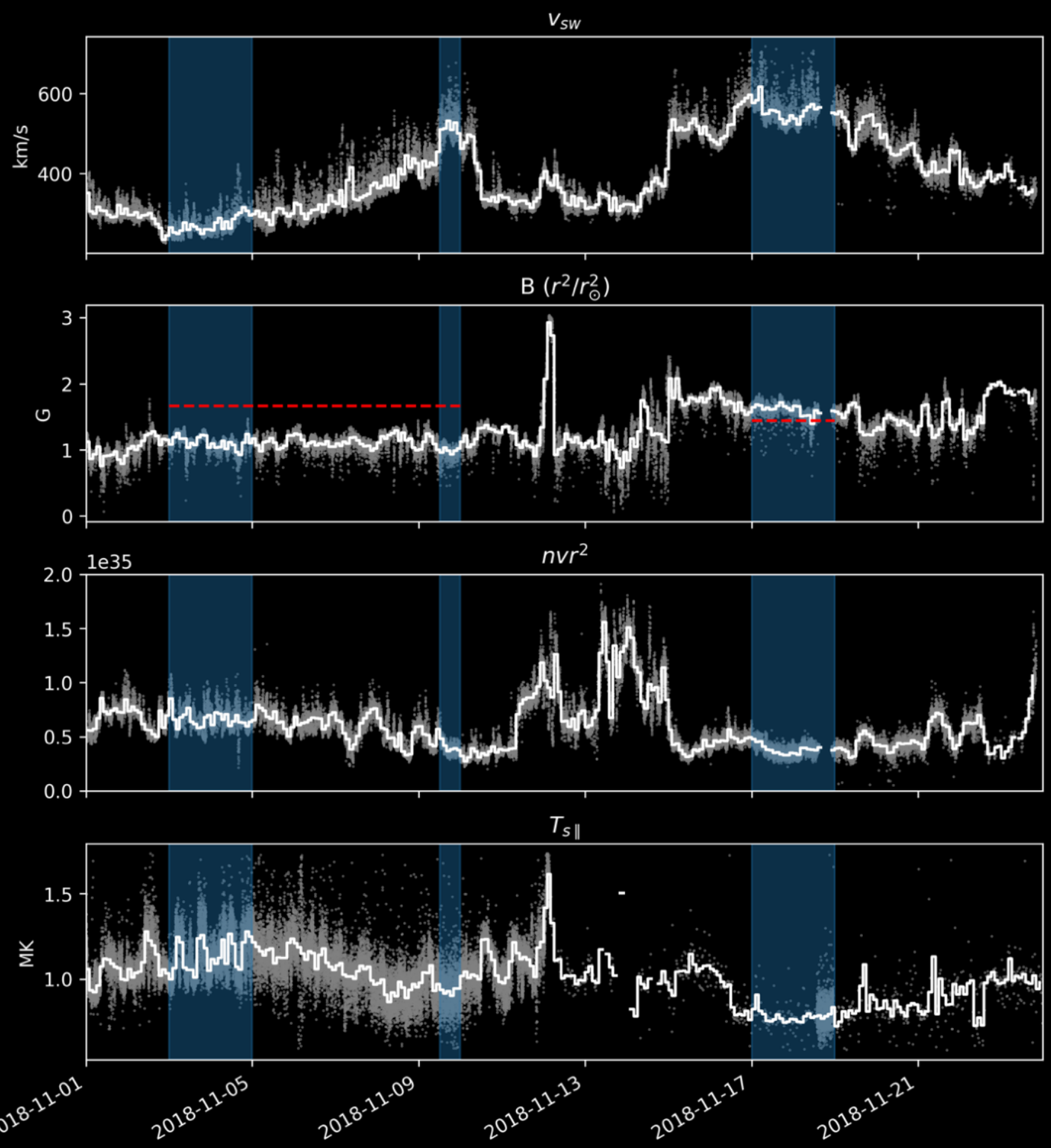
Coronal hole observations

Speed

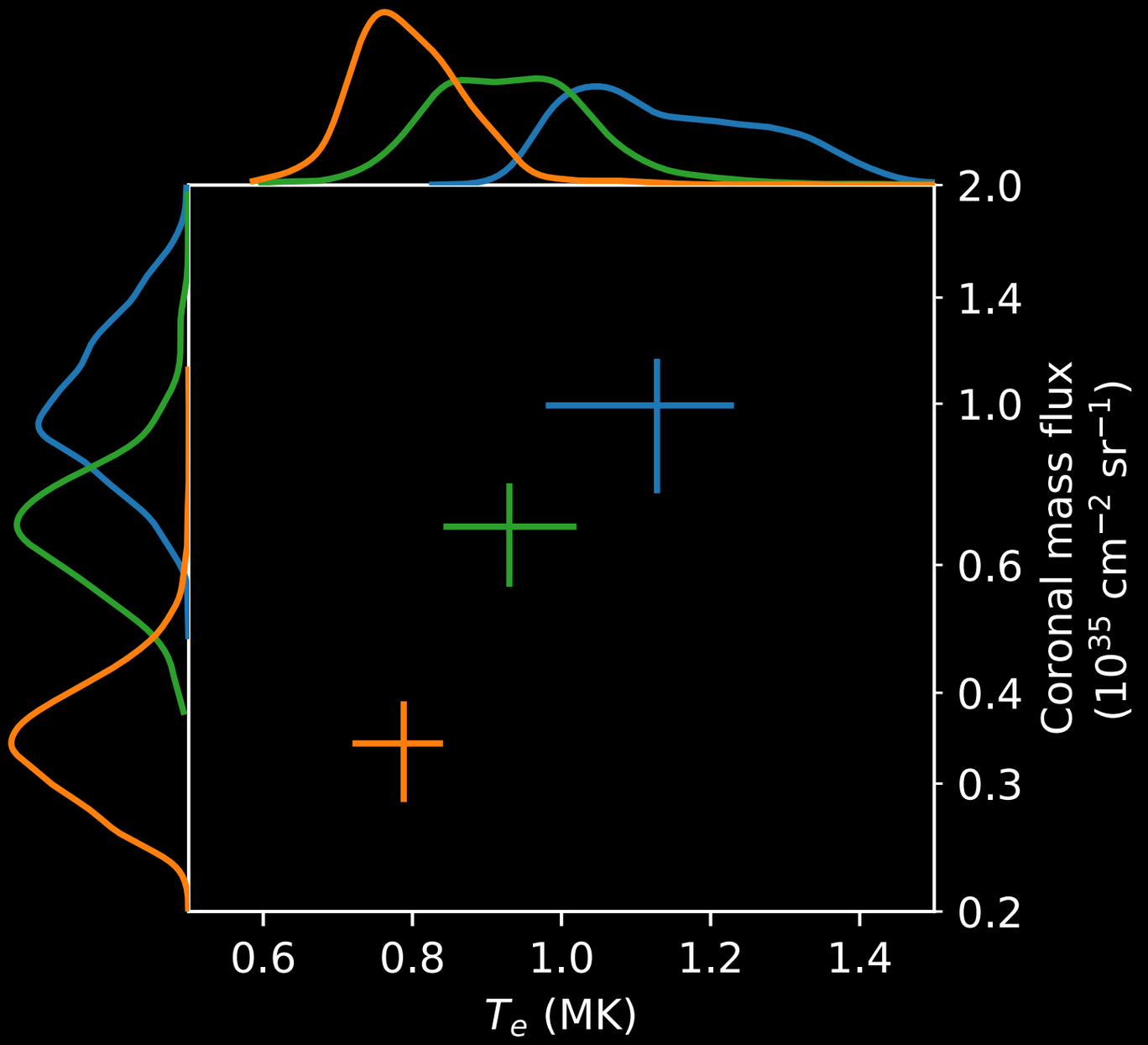
r^2 scaled B

r^2 scaled mass flux

Strahl || temp,
~ coronal temp
(Berčič et al. 2020)



Results

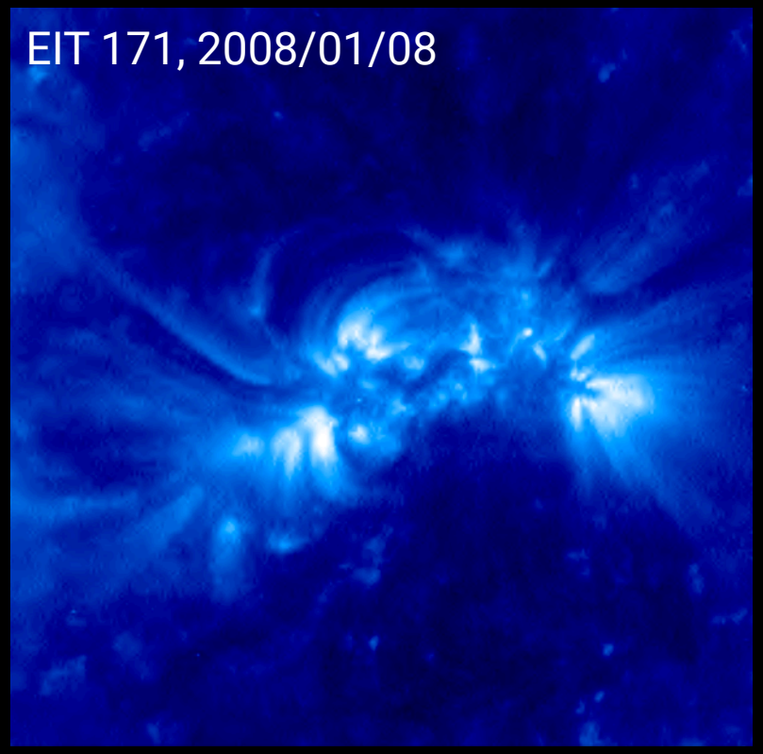


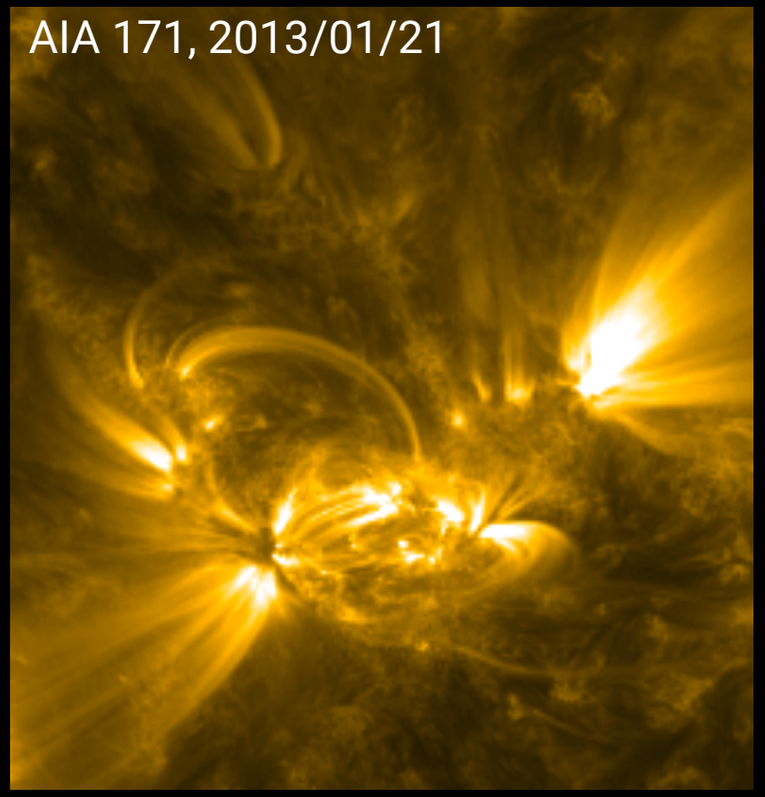
50% increase in Te results in ~ 200% increase in mass flux

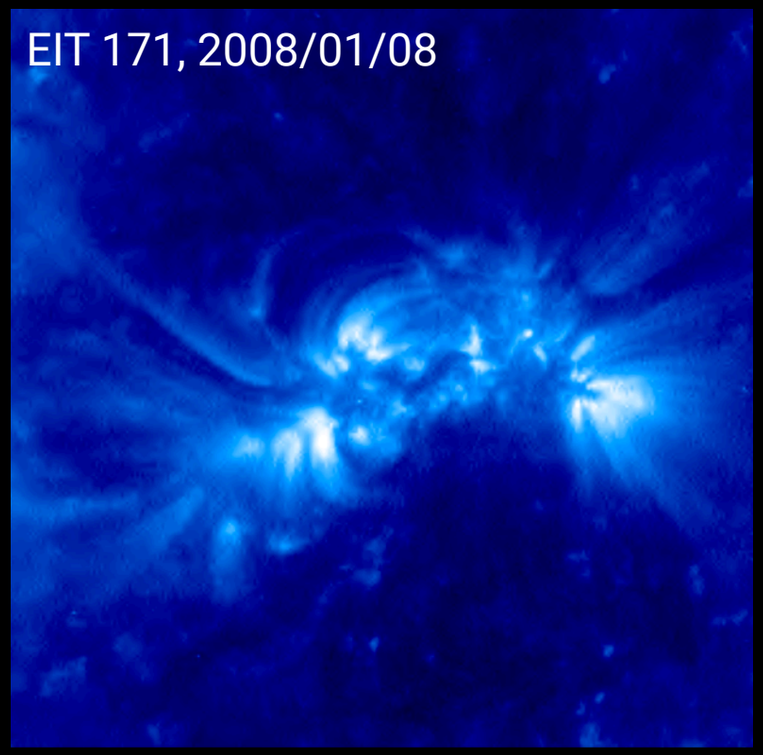
Measuring active region T

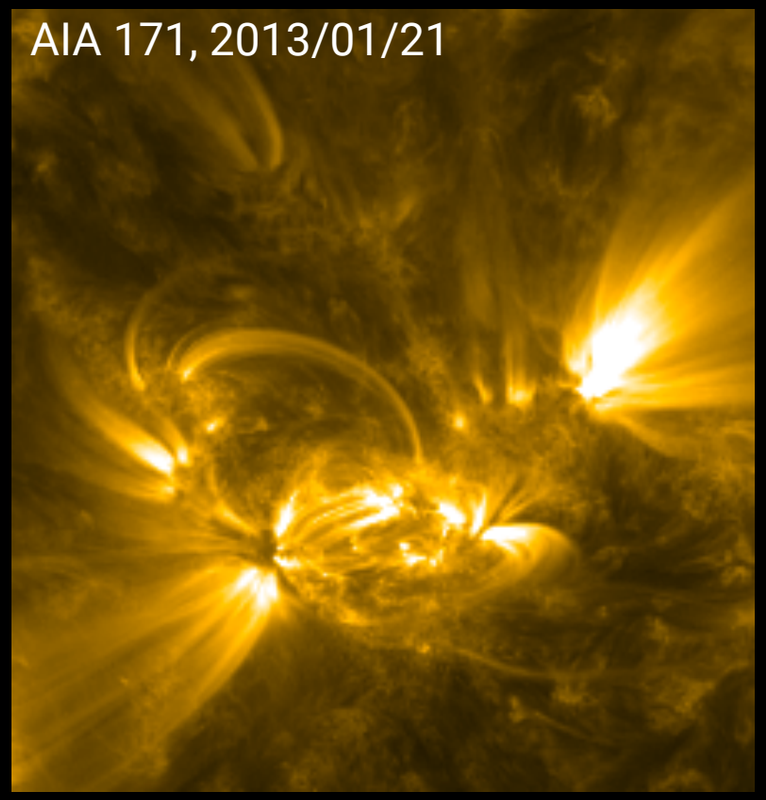
- Could use same method, but no Active Region solar wind measured by PSP (at time of work)
- Active regions are dense + hot, emit lots of photons
- Use two AR outflows tracked to L1 in literature

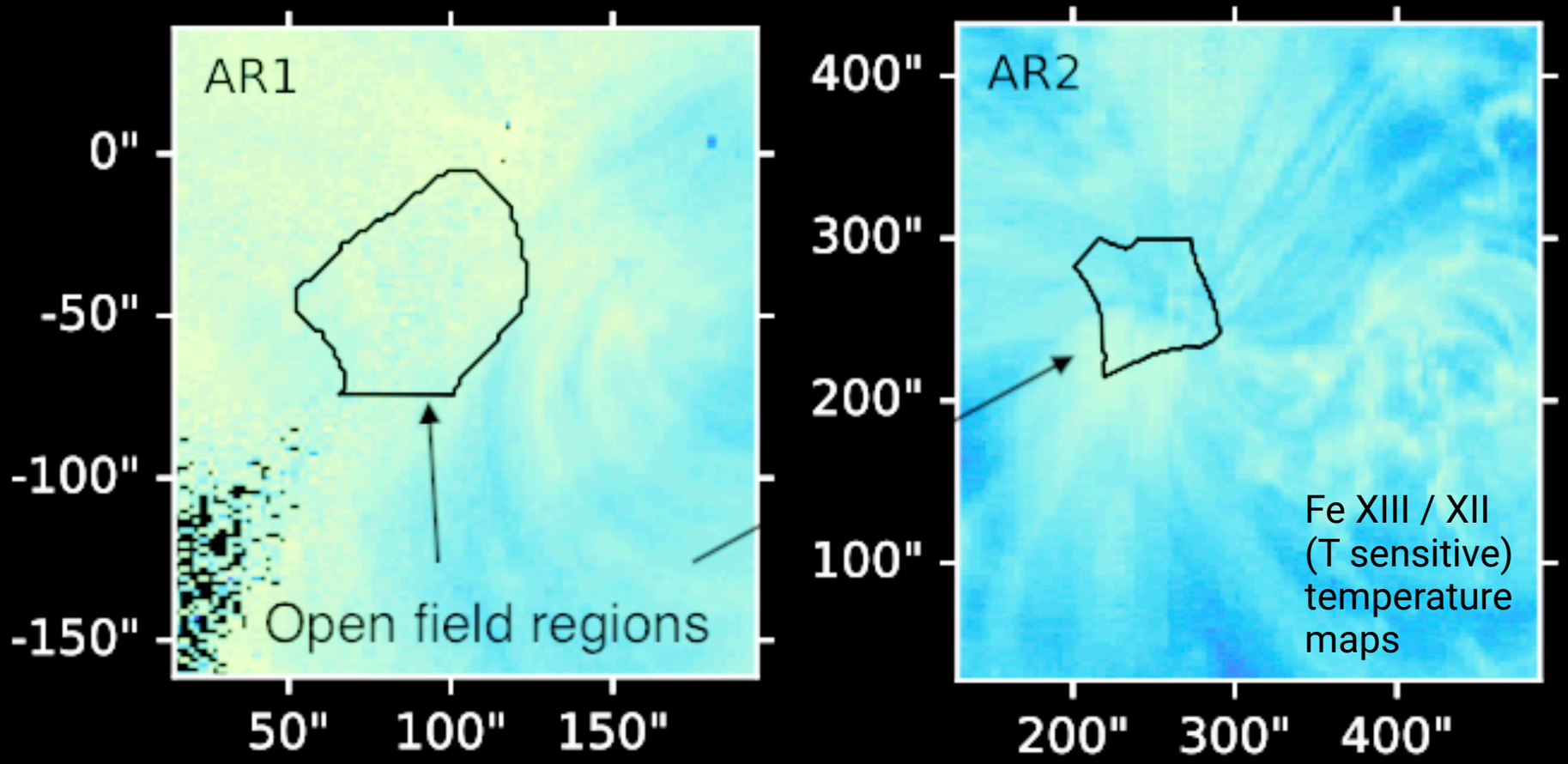
[van Driel-Gesztelyi 2012, Stansby 2020]



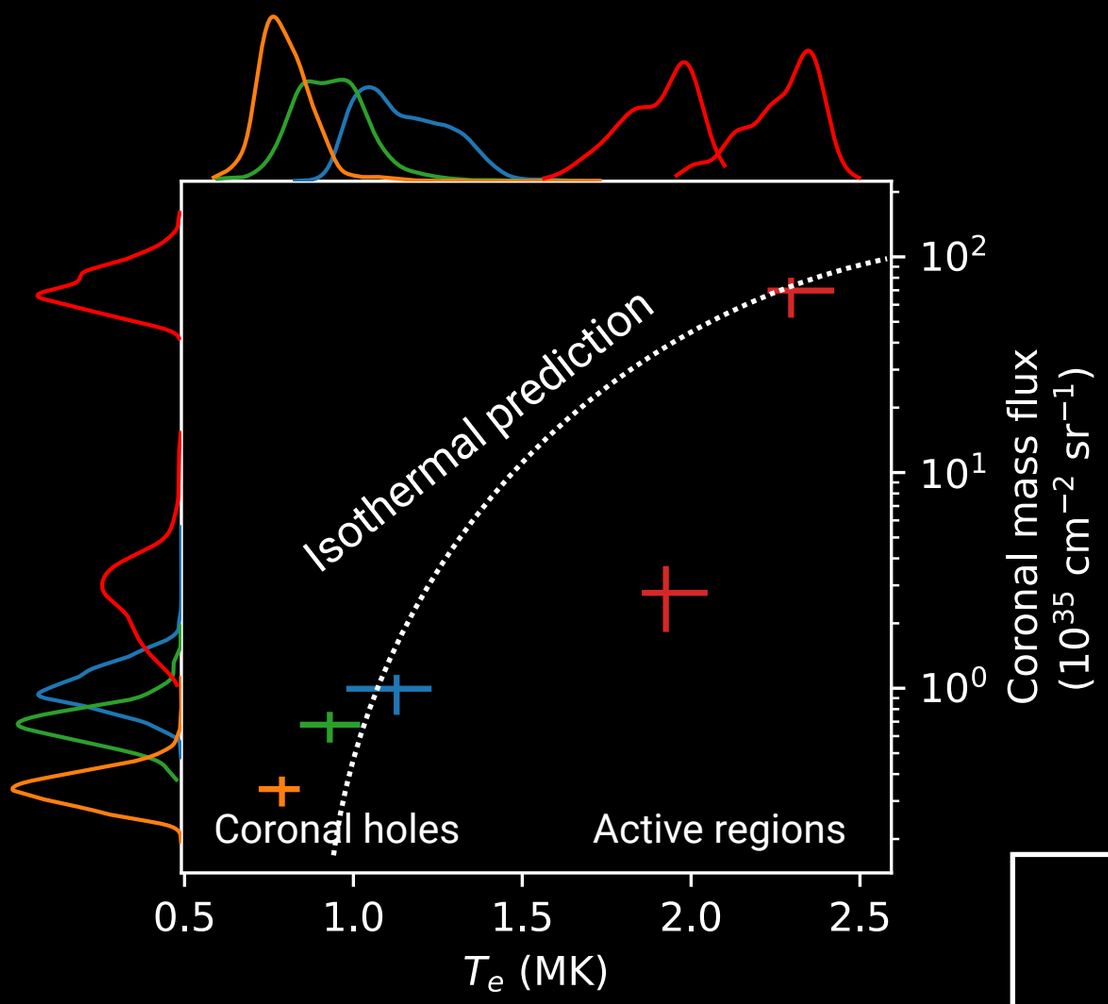



EIT 171, 2008/01/08


AIA 171, 2013/01/21


AR1
0"
-50"
-100"
-150"
50"
100"
150"
Open field regions
AR2
400"
300"
200"
100"
200"
300"
400"
Fe XIII / XII
(T sensitive)
temperature
maps
2.75
2.50
2.25
2.00
1.75
1.50
T (MK)

Results

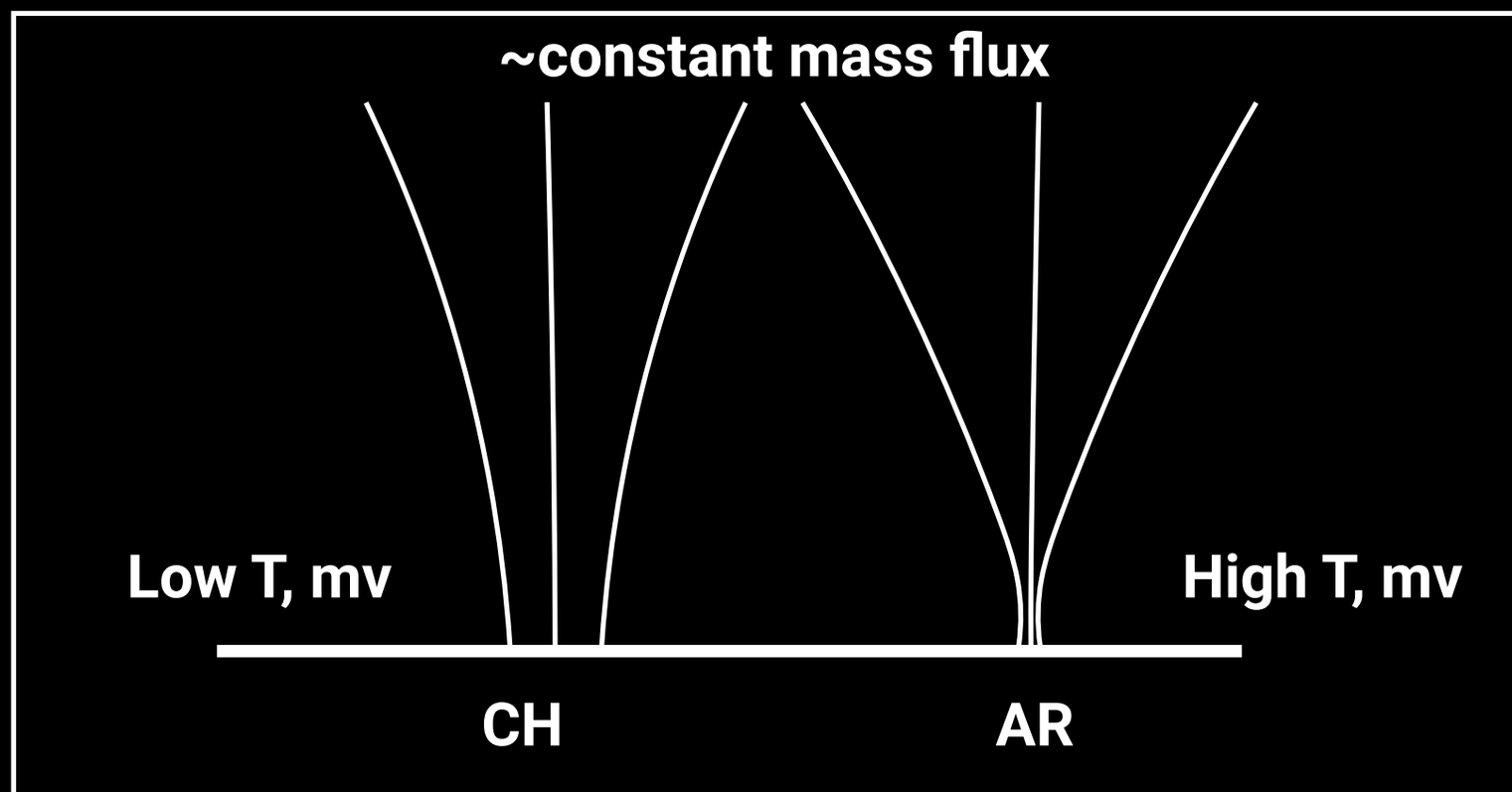


GONG
SDO/AIA
SDO/HMI

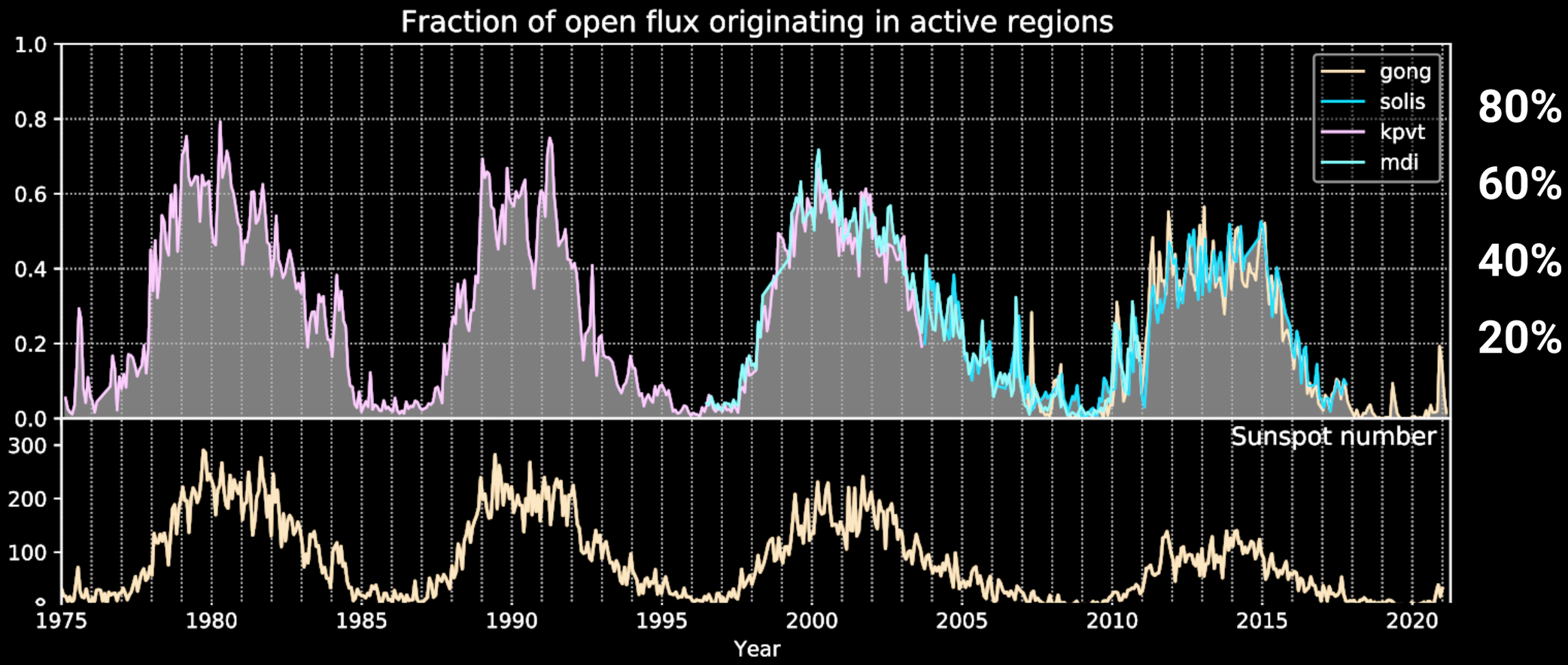
SOHO/MDI
Hinode/EIS
WIND/MFI
WIND/SWEPAM

PSP/FIELDS
PSP/SWEAP

3x increase in T
↓
200x increase in mass flux
(hotter plasma evaporates quicker)



Context and further work



Stansby et al., arXiv:2104.04417

- Example of multi-instrument comparison of wind sources
- Active regions are > 40% of solar wind at solar max
- PSP & Orbiter will increasingly measure active region solar wind

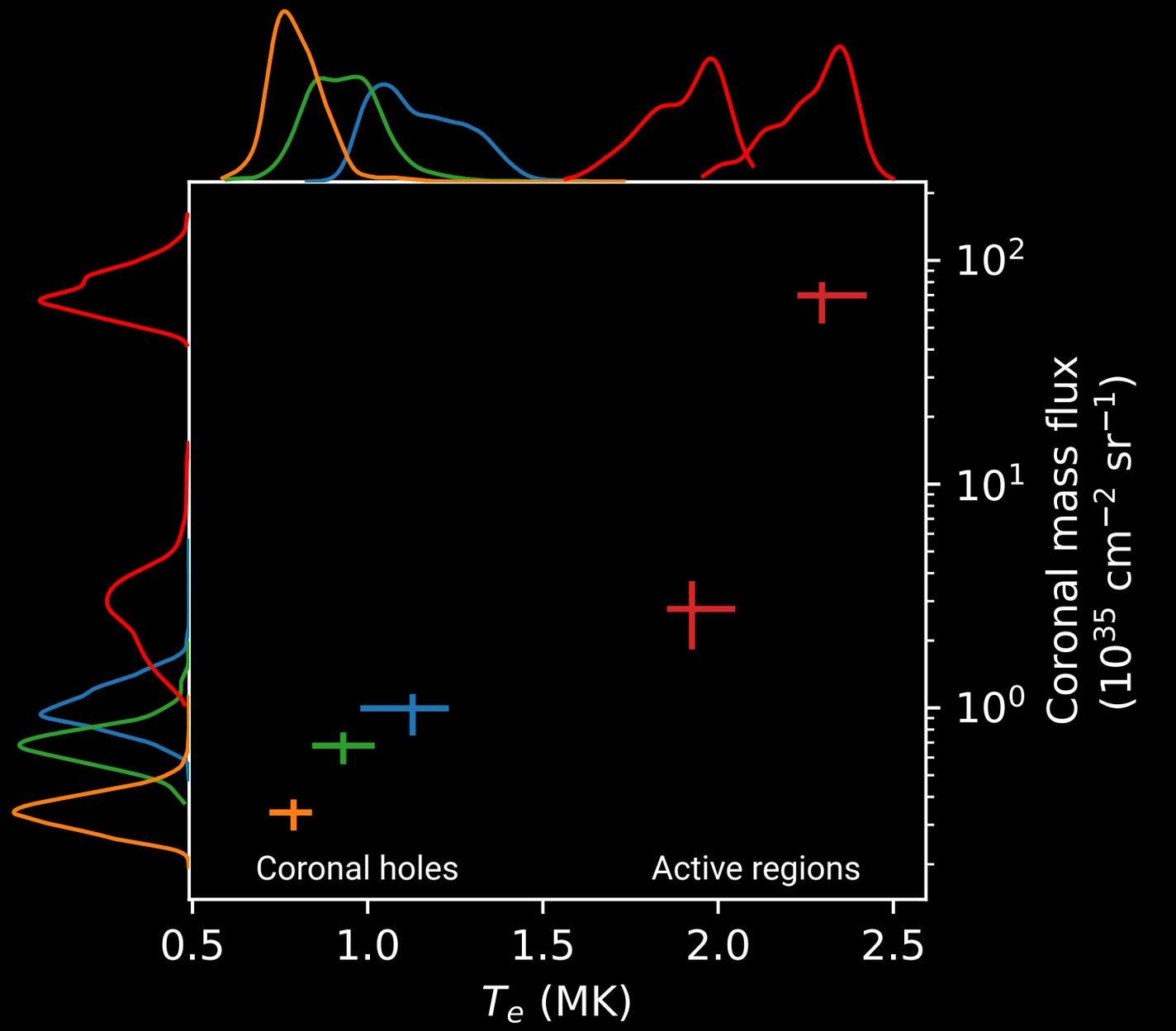
Conclusions

Hotter regions of the corona have higher mass fluxes

Example of what multi-instrument studies can do

New insights into active region solar wind sources

Stansby et al. 2021, A&A



Sensitivity of solar wind mass flux to coronal temperature

D. Stansby[1]*, L. Berčič[2,3], L. Matteini[4], C. J. Owen[1], R. J. French[1], D. Baker[1], and S. T. Badman[5,6]

Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Surrey RH5 6NT, UK
LESIA, Observatoire de Paris, PSL Research University, CNRS, UPMC University Paris 6, University Paris-Diderot, Meudon, France
Physics and Astronomy Department, University of Florence, Sesto Fiorentino, Italy
Department of Physics, Imperial College London, London, SW7 2AZ, UK
Physics Department, University of California, Berkeley, CA 94720-7300, USA
Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA

d.stansby@ucl.ac.uk

Slides at davidstansby.com/research