Fe charge states in coronal hole wind observed with ACE/SWICS

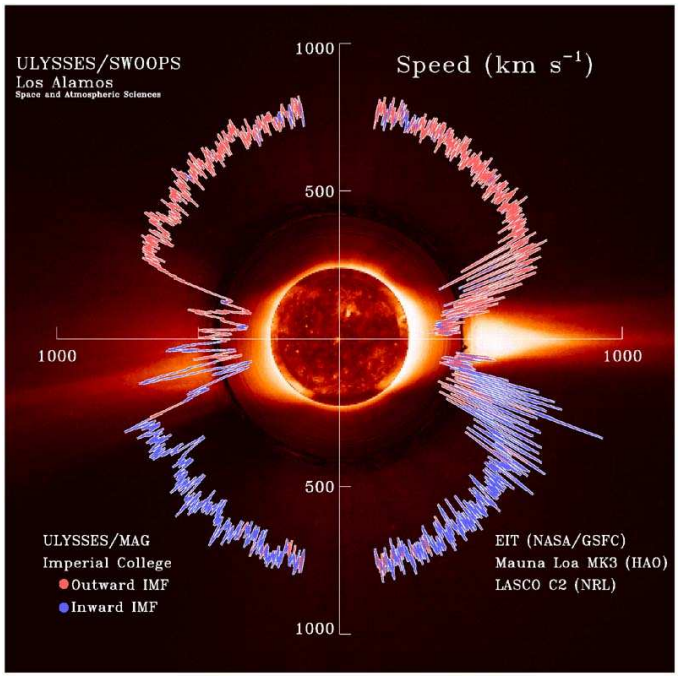
Verena Heidrich-Meisner, Thies Peleikis, Lars Berger, Robert F. Wimmer Schweingruber

June, 3rd, 2016

Outline

1. Solar wind types
   - Fe charge states in coronal hole wind
2. Origin of Fe-hot and Fe-cool coronal wind
3. Temperature profile
4. Summary

Solar wind



typical solar wind properties:

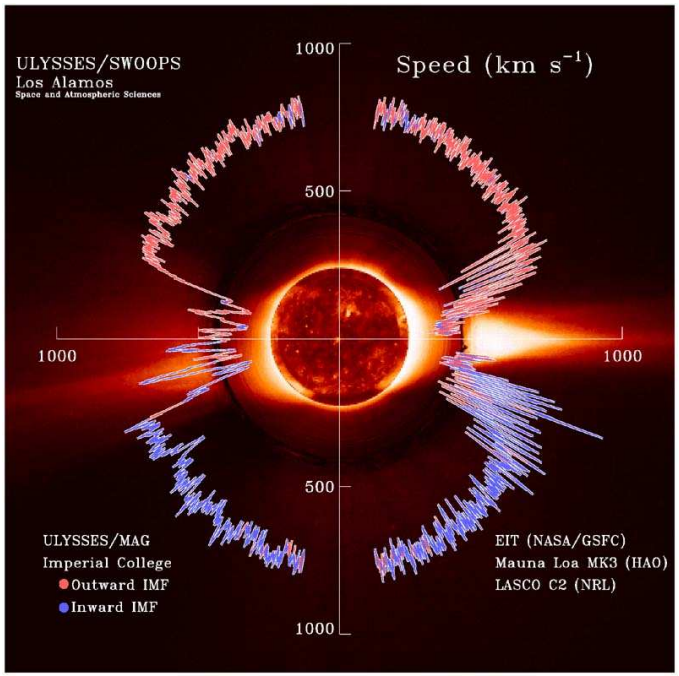
	v_p	n_p	T_p	q
slow	low	high	high	high
fast	high	low	low	low

with:

- proton speed v_p,
- proton density n_p,
- temperature T_p,
- charge states q

Solar wind

fast wind: coronal holes



slow wind: active regions? coronal hole boundaries? S-web?

typical solar wind properties:

	v_p	n_p	T_p	q
slow	low	high	high	high
coronal hole	high	low	low	low

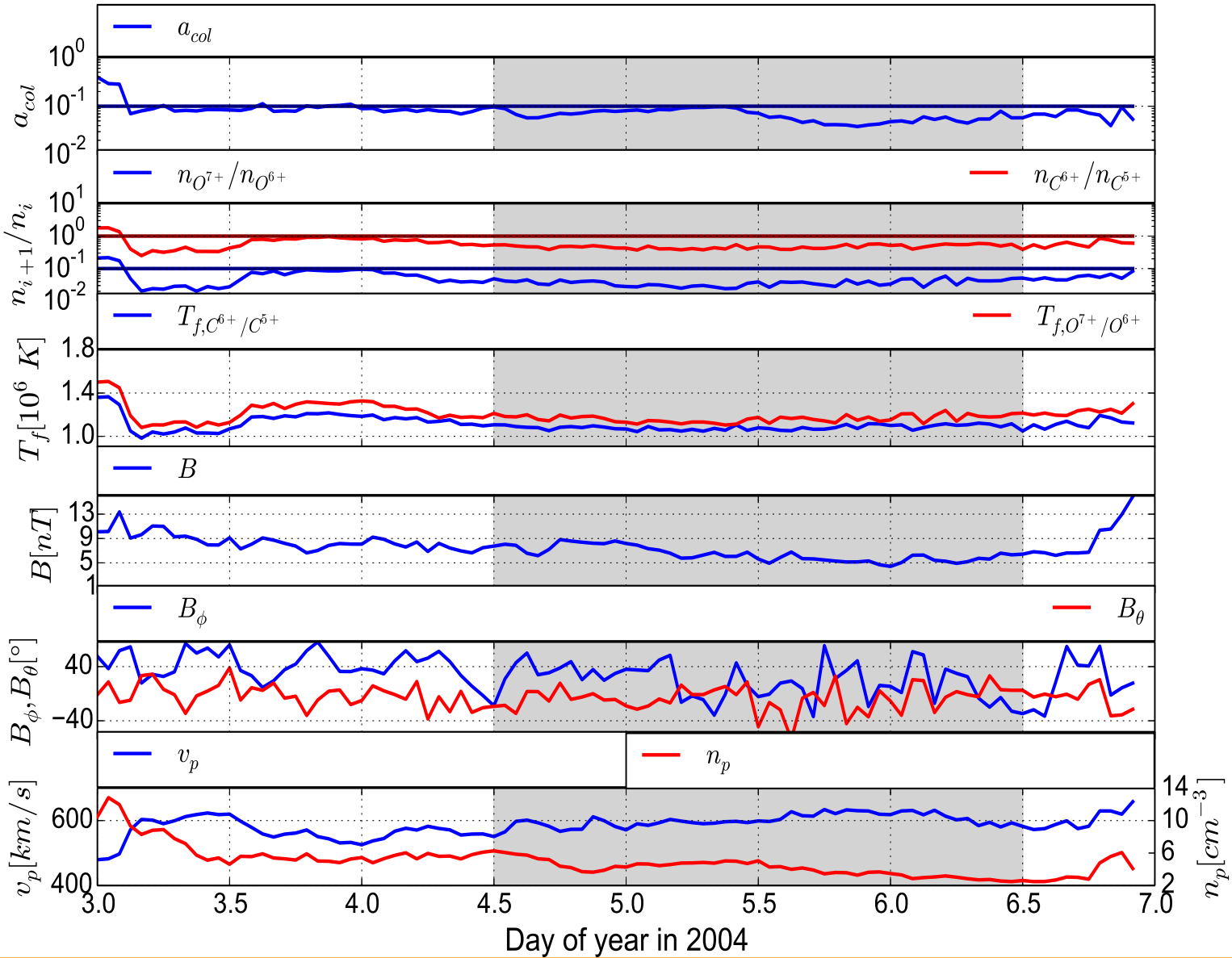
with:

- proton speed v_p,
- proton density n_p,
- temperature T_p,
- charge states q

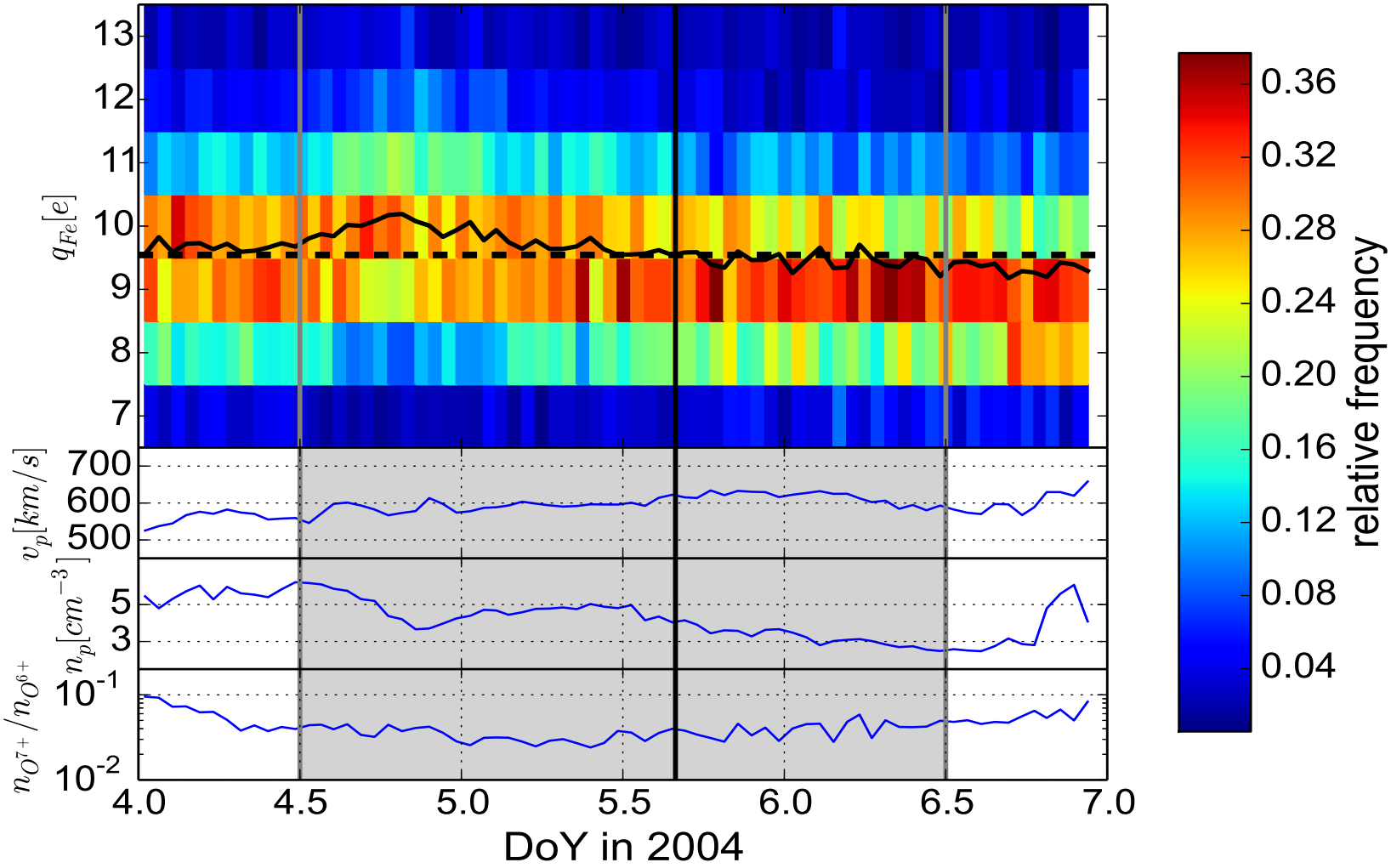
Coronal hole-type solar wind in the following:

- $n_{O^{7+}}/n_{O^{6+}} < 0.1$,
  $n_{C^{6+}}/n_{C^{5+}} < 1$,
  $a_{\text{col. age}} \sim \frac{n_P}{v_p T_P^{1.5}} < 0.1$

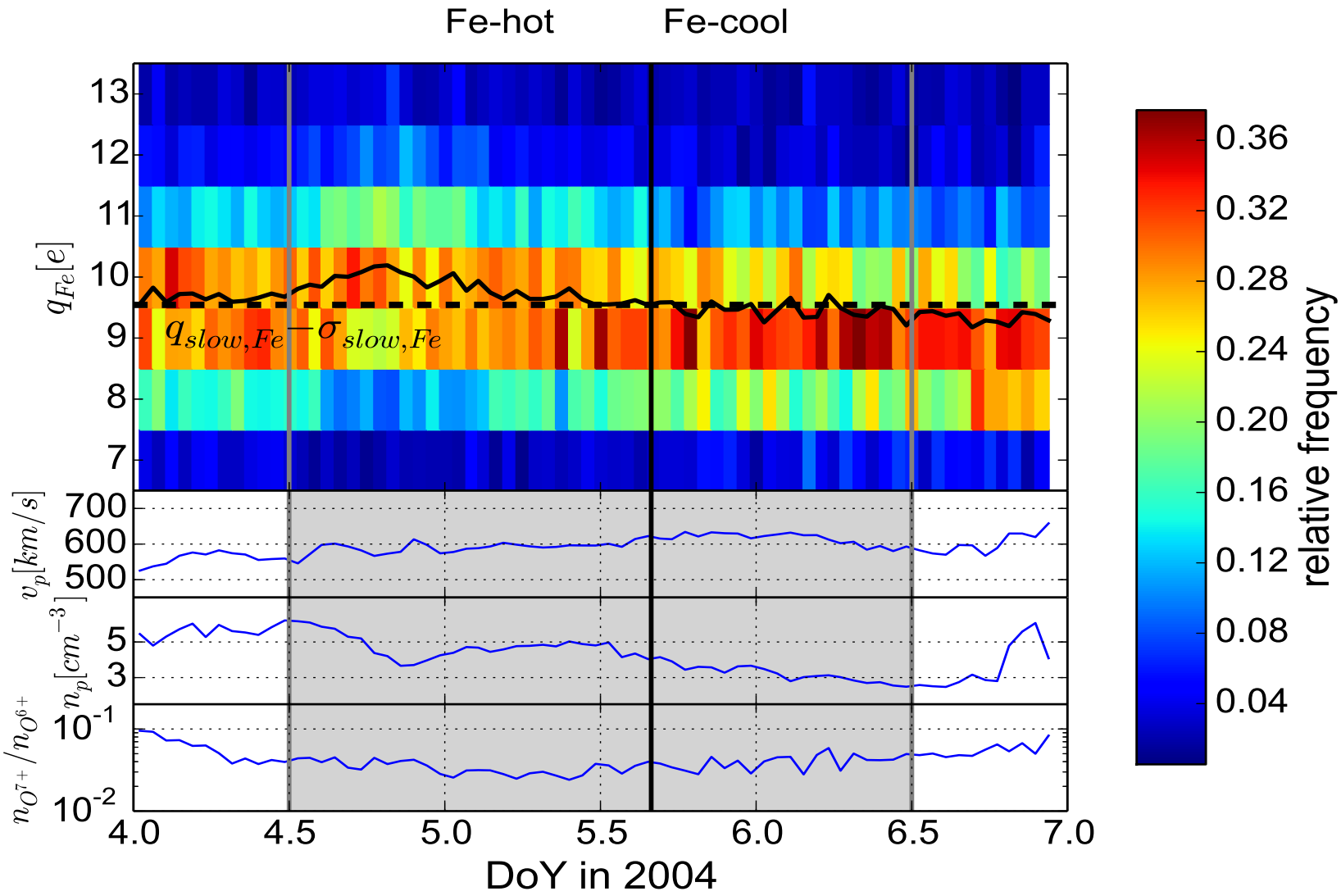
Typical coronal hole-type wind



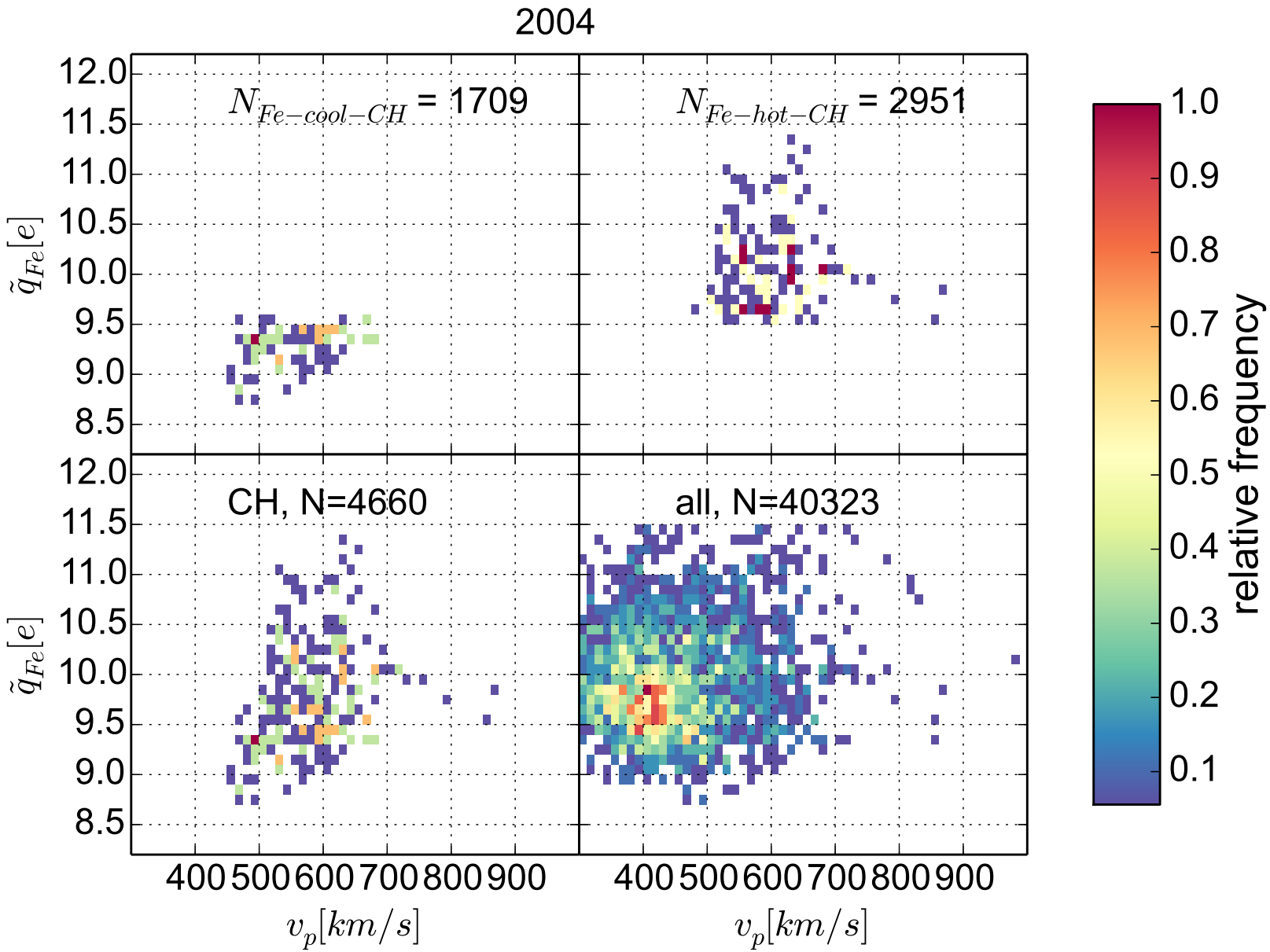
Typical coronal hole-type wind?



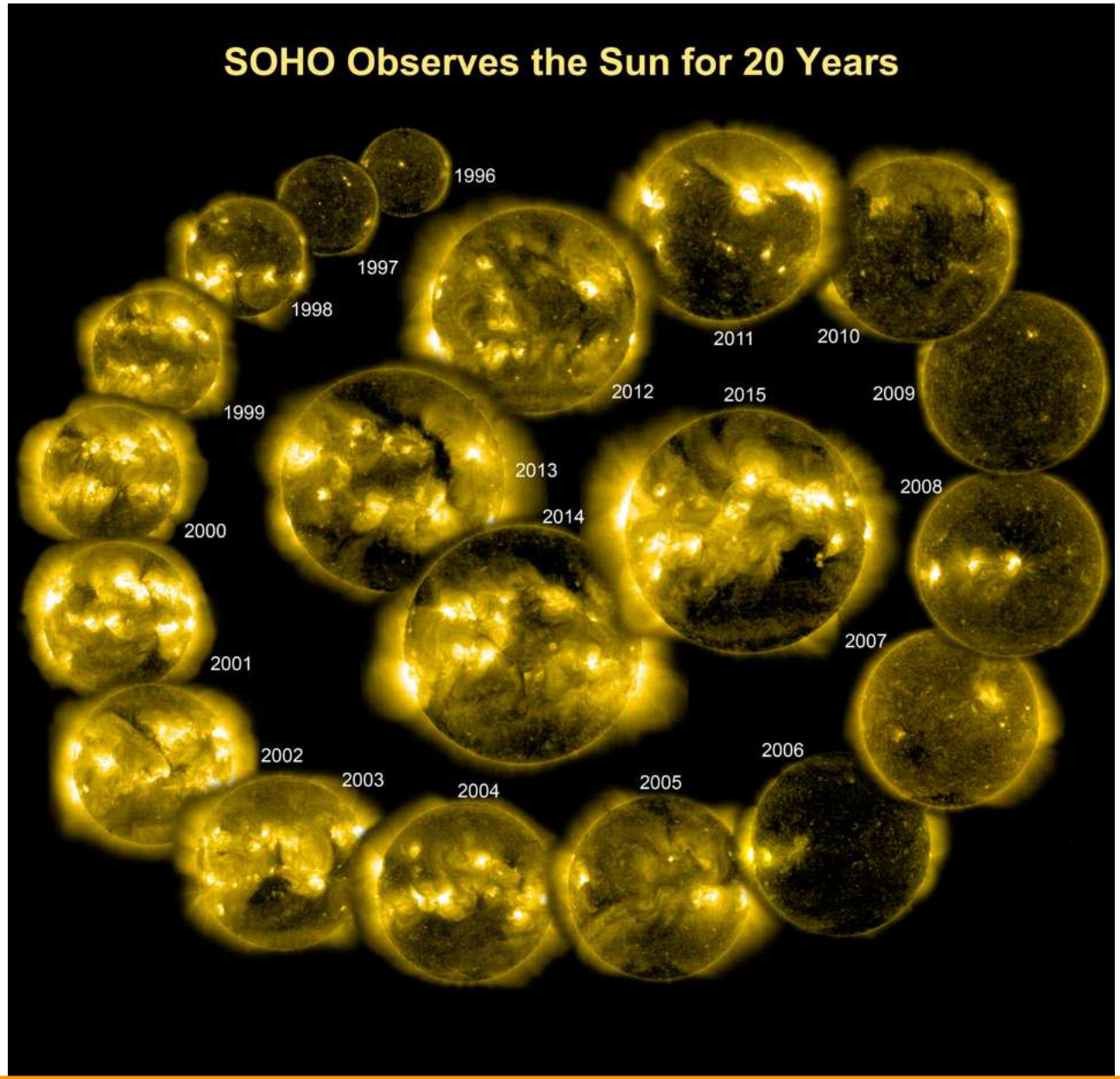
Typical coronal hole-type wind?



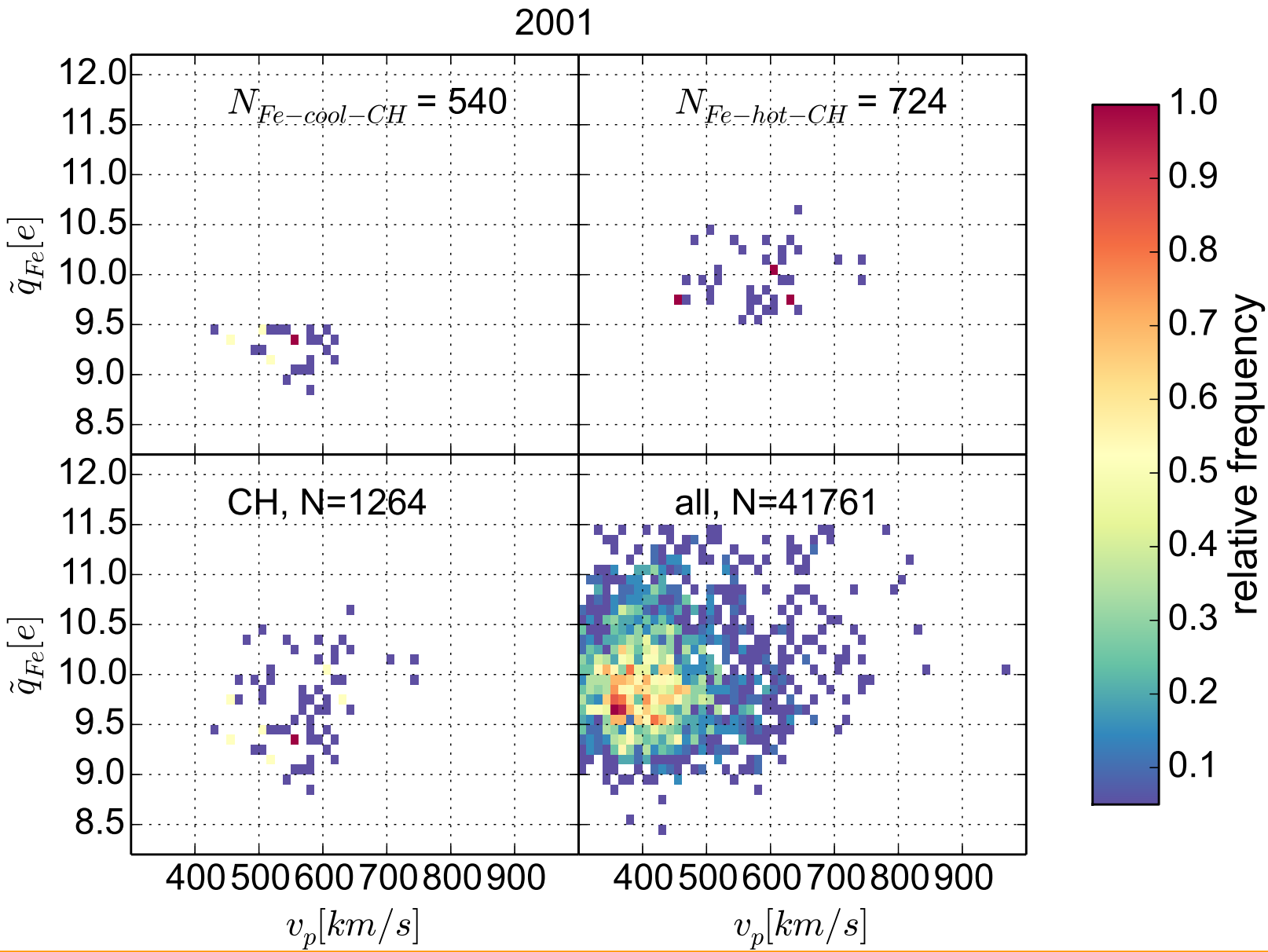
Is this an exception? Distribution in 2004



The Sun over the solar cycle (EIT 284Å)



Long-term behavior average charge state: 2001



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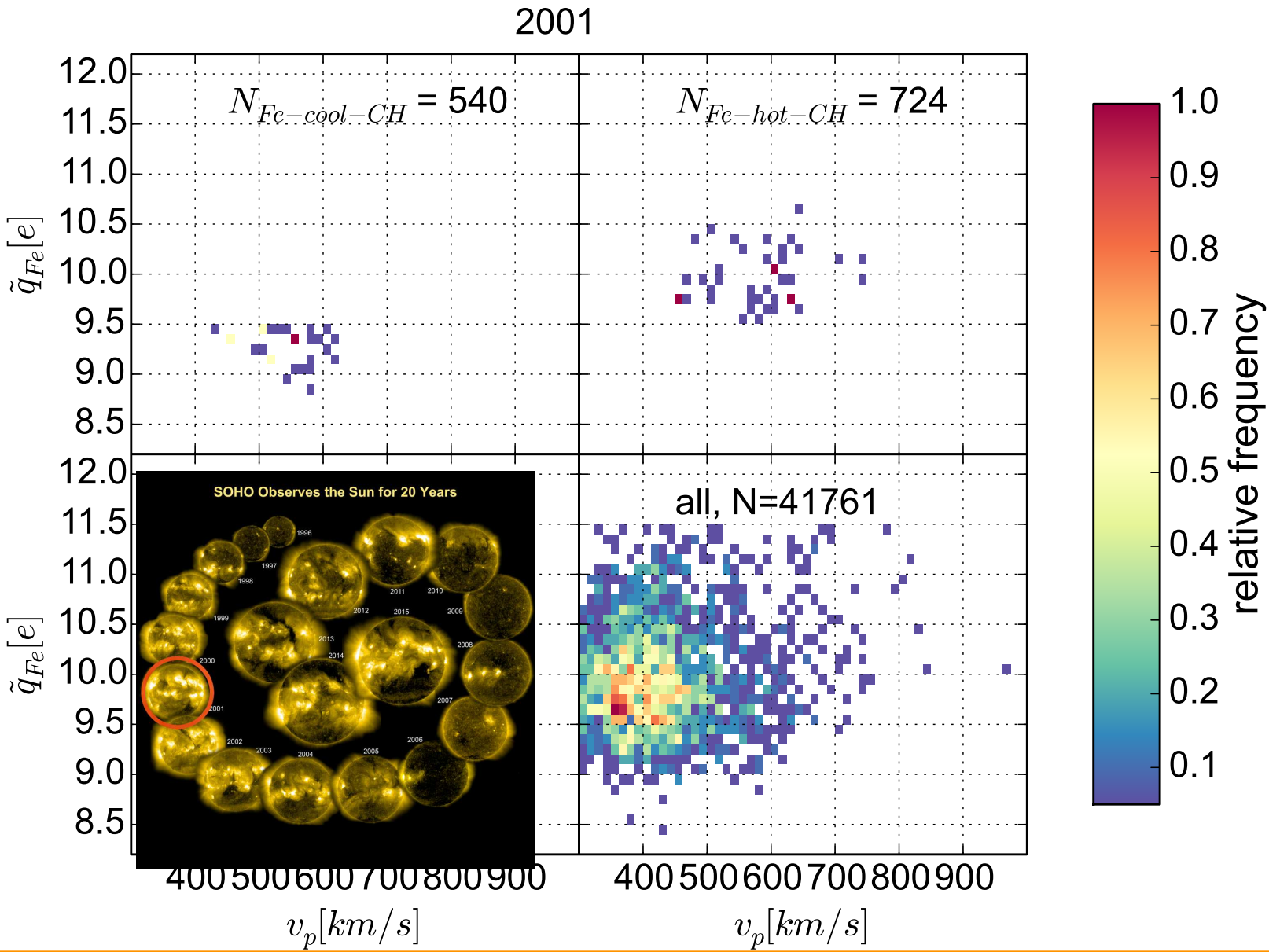
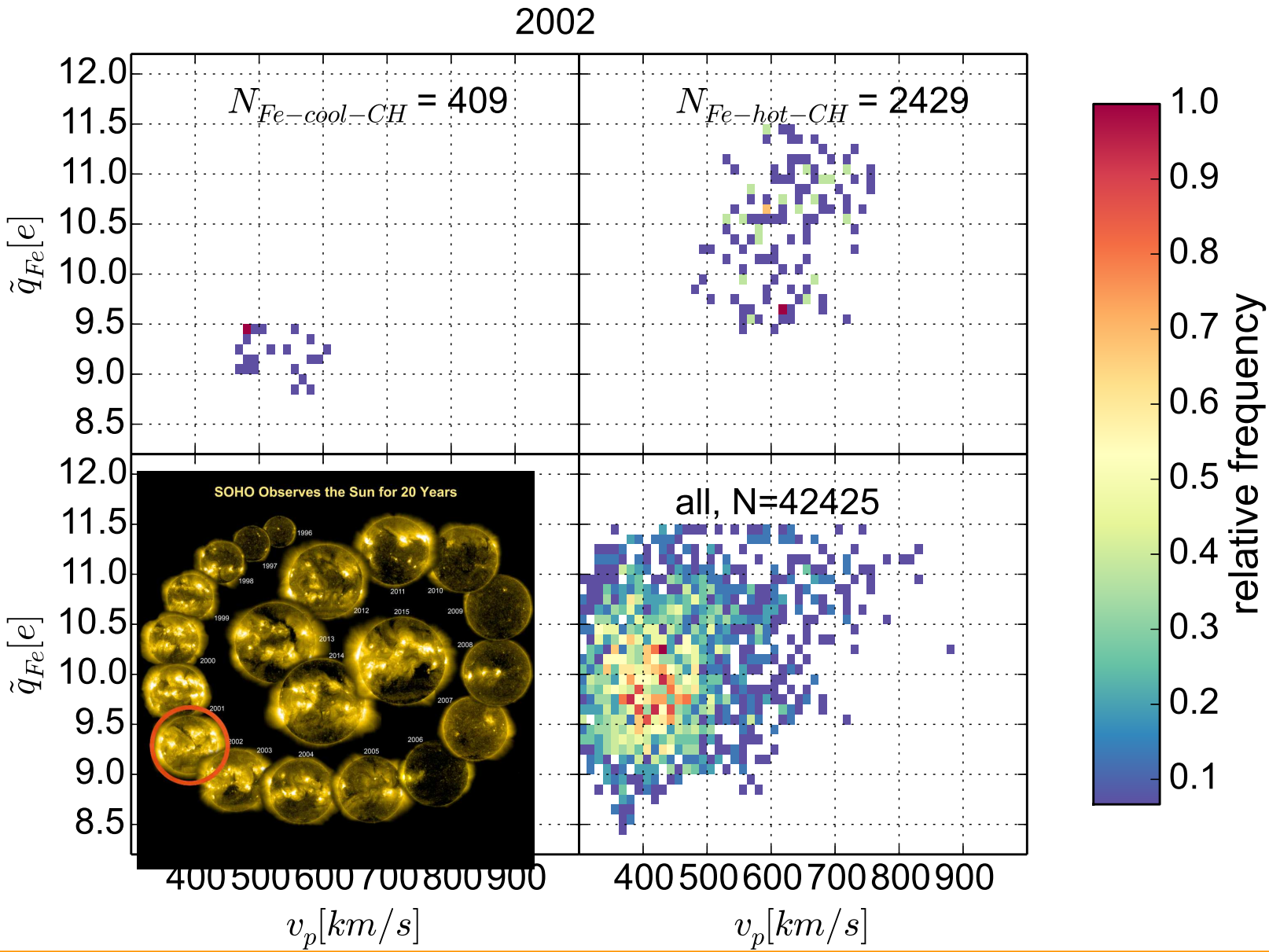
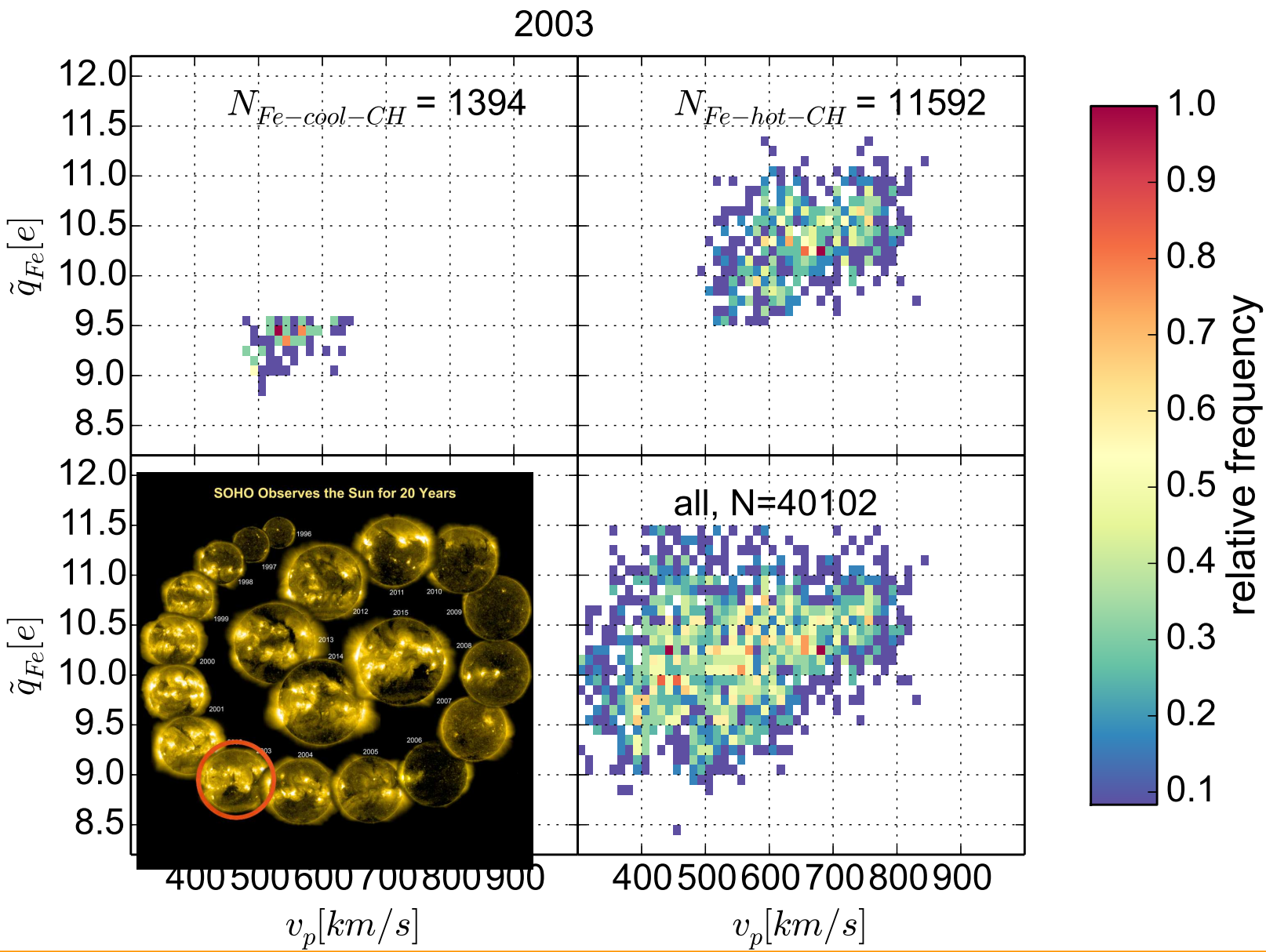


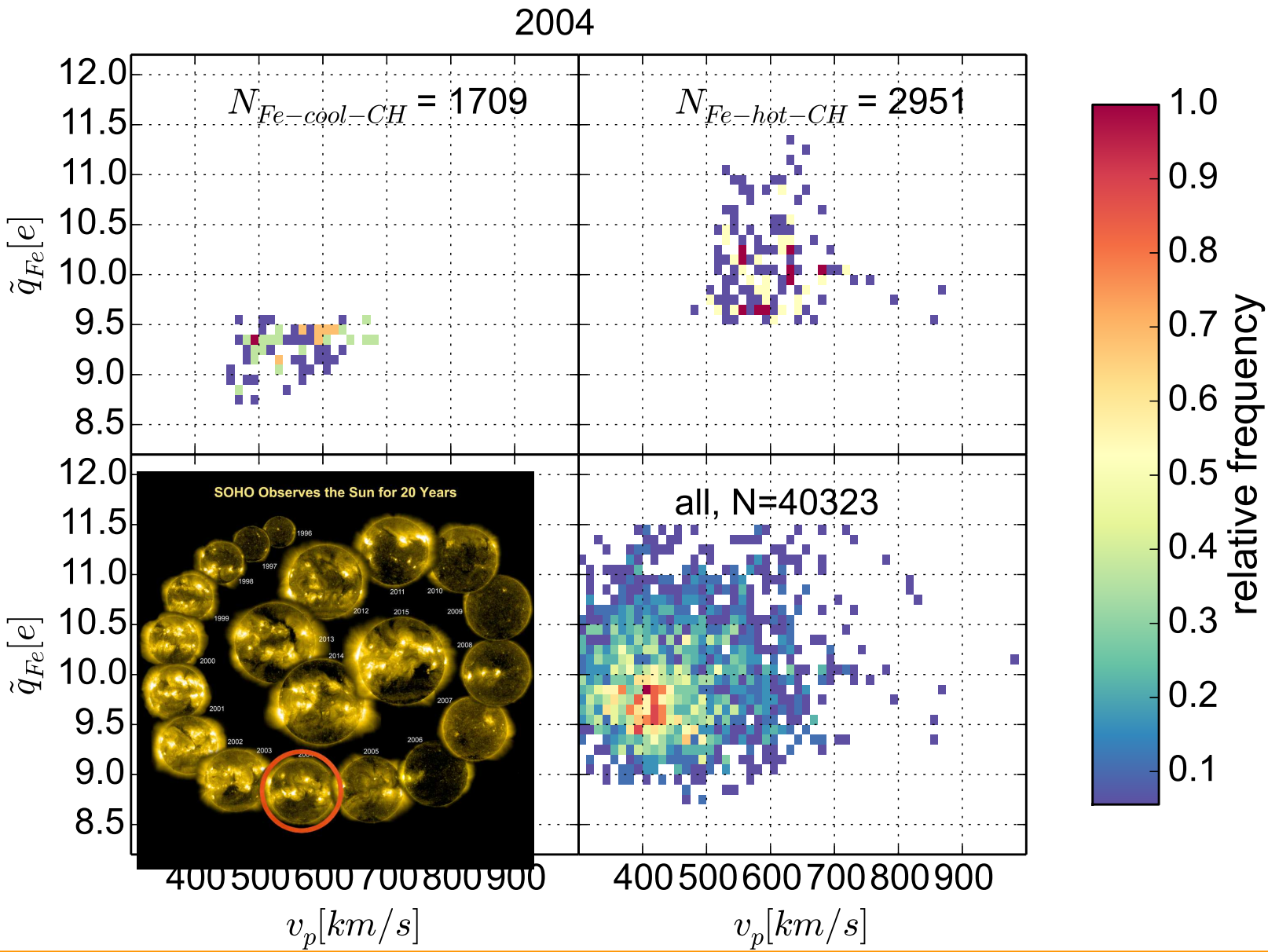
Long-term behavior average charge state: 2002



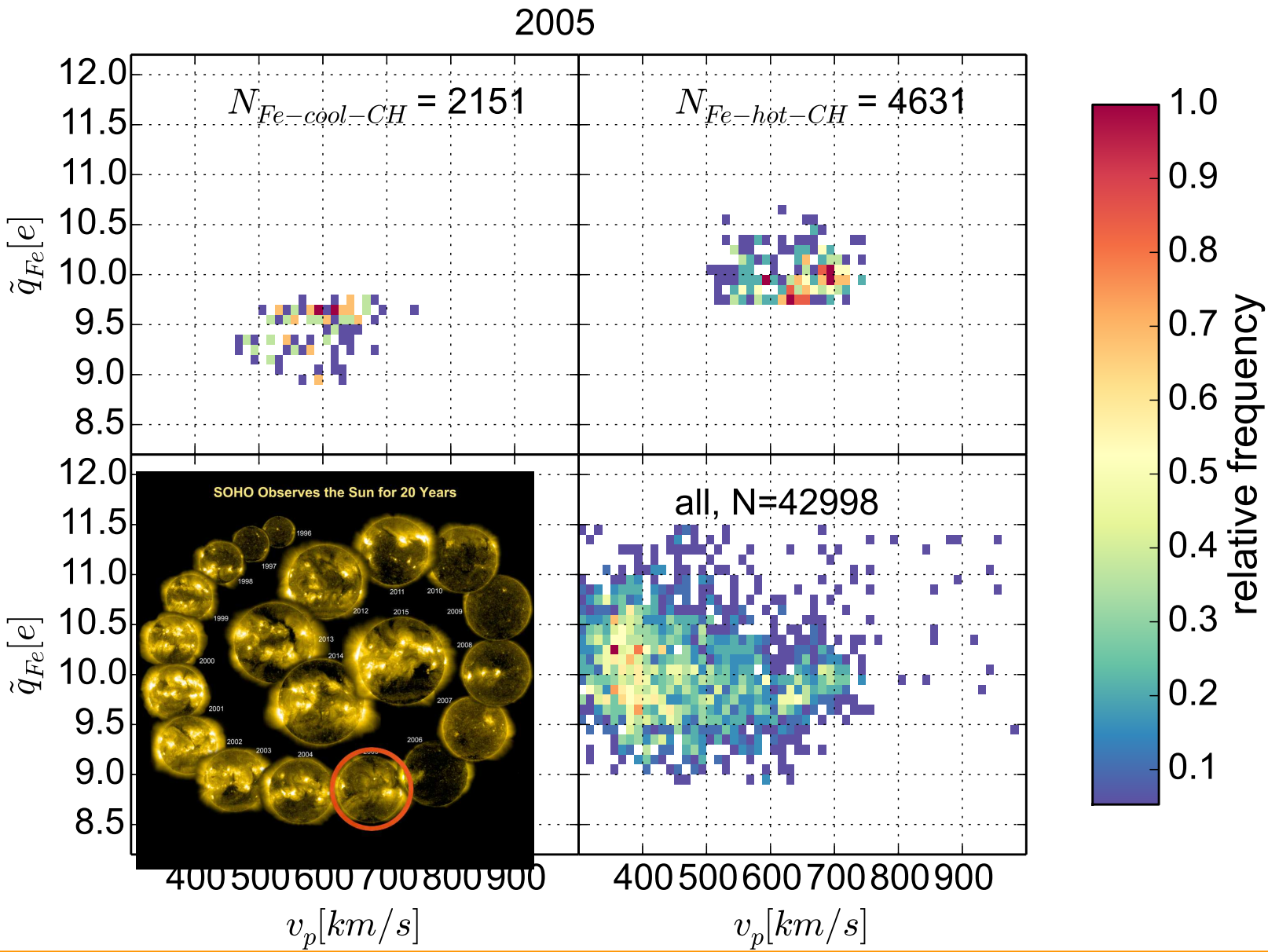
Long-term behavior average charge state: 2003



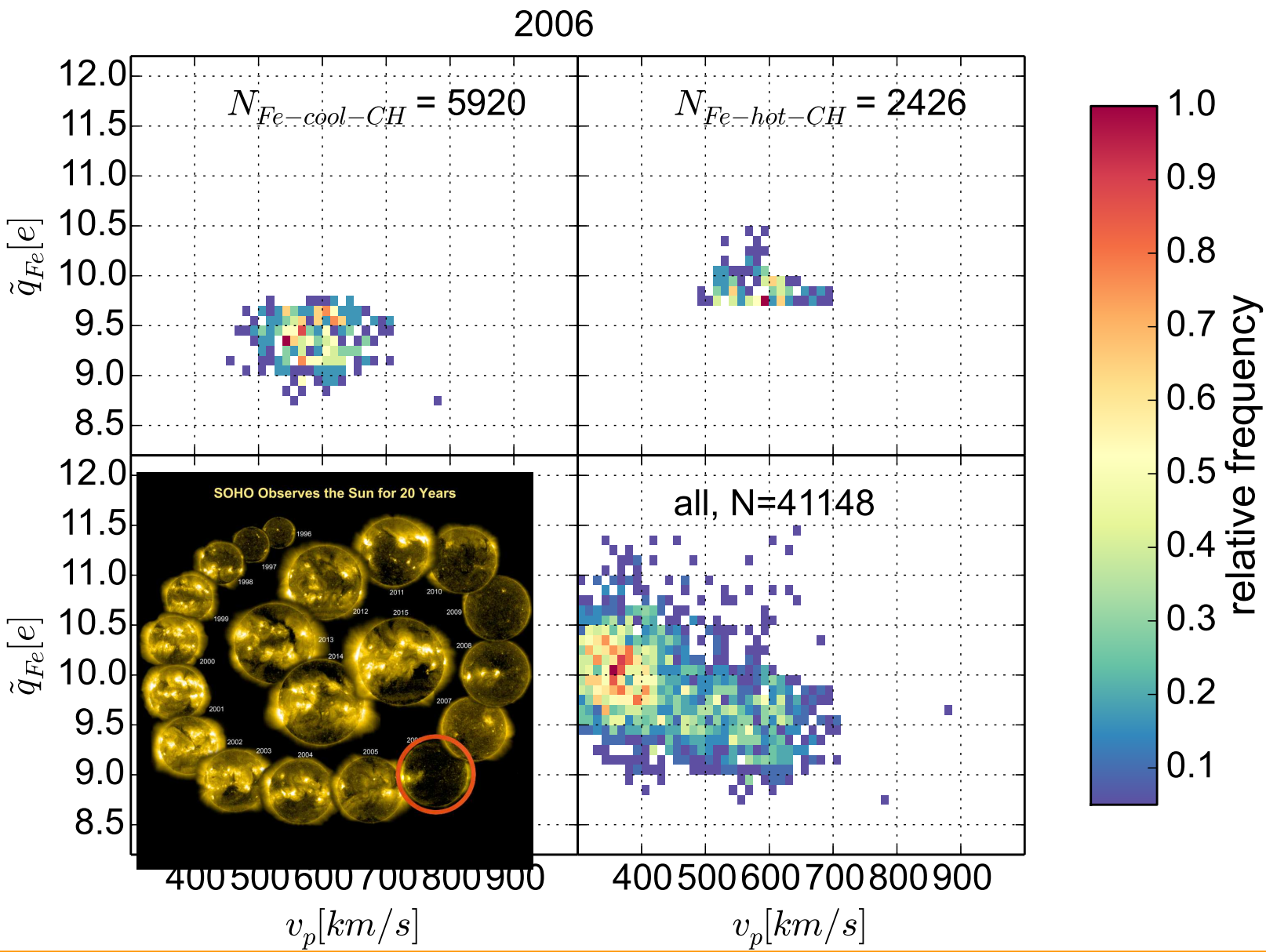
Long-term behavior average charge state: 2004



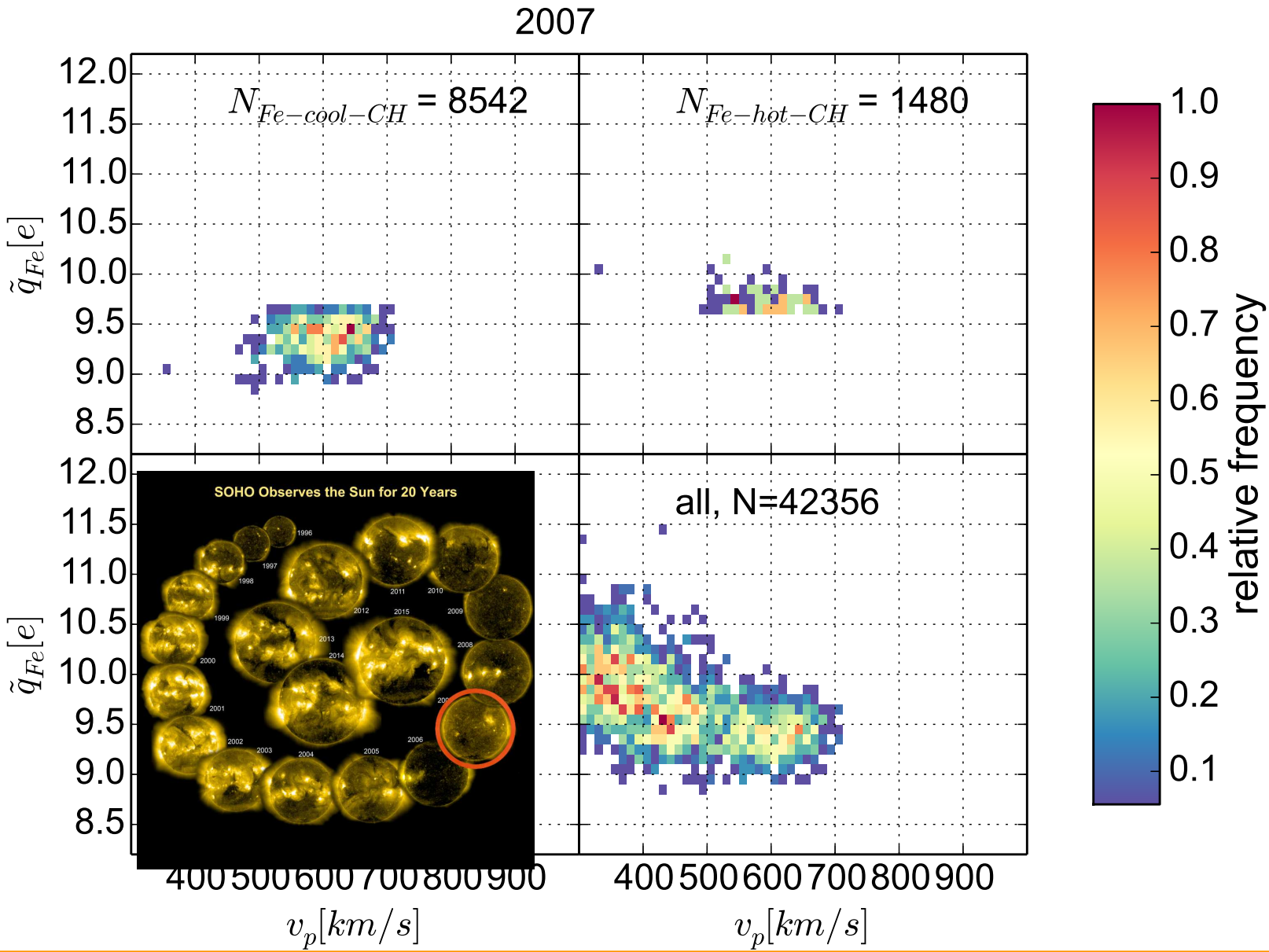
Long-term behavior average charge state: 2005



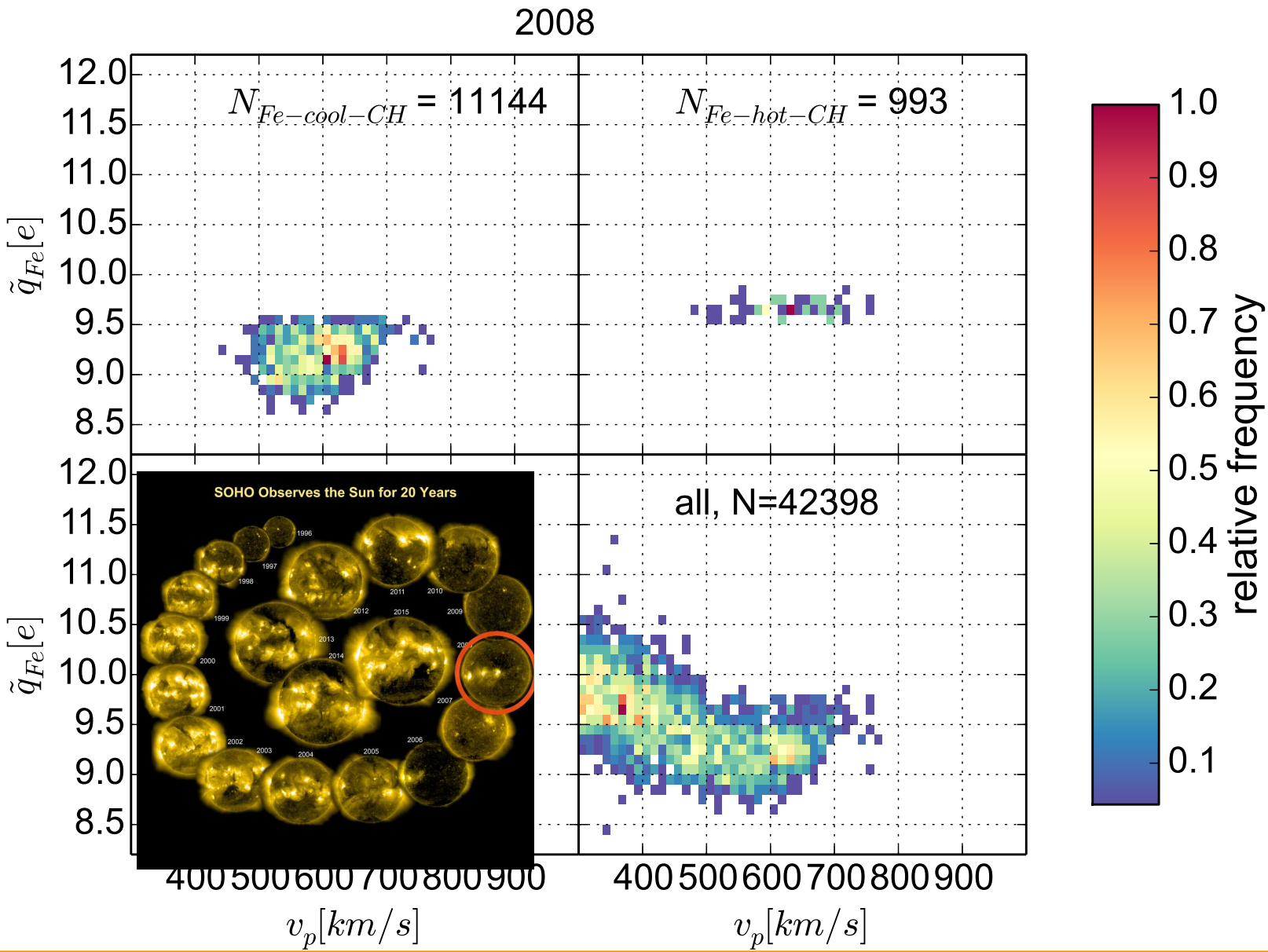
Long-term behavior average charge state: 2006



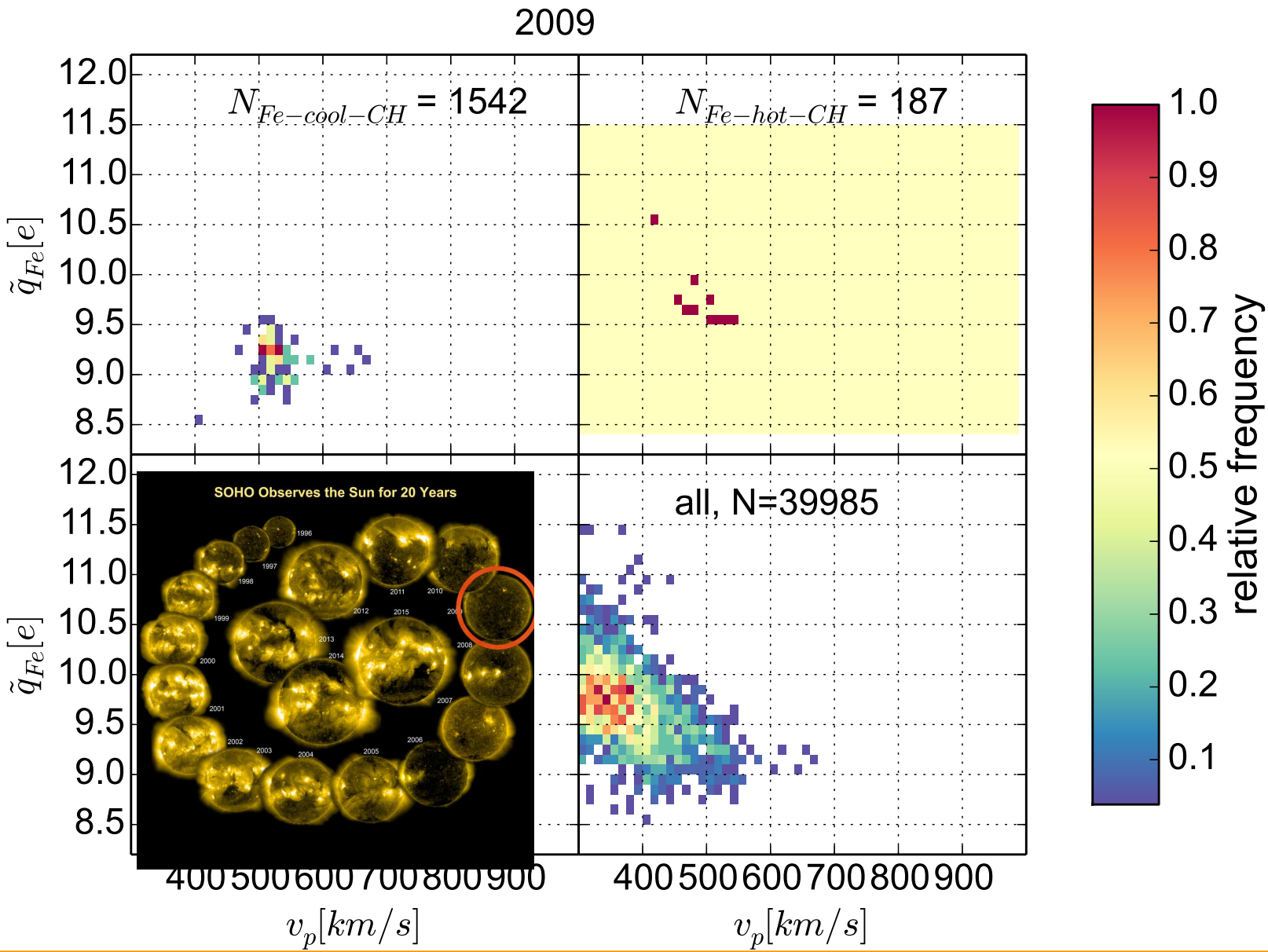
Long-term behavior average charge state: 2007



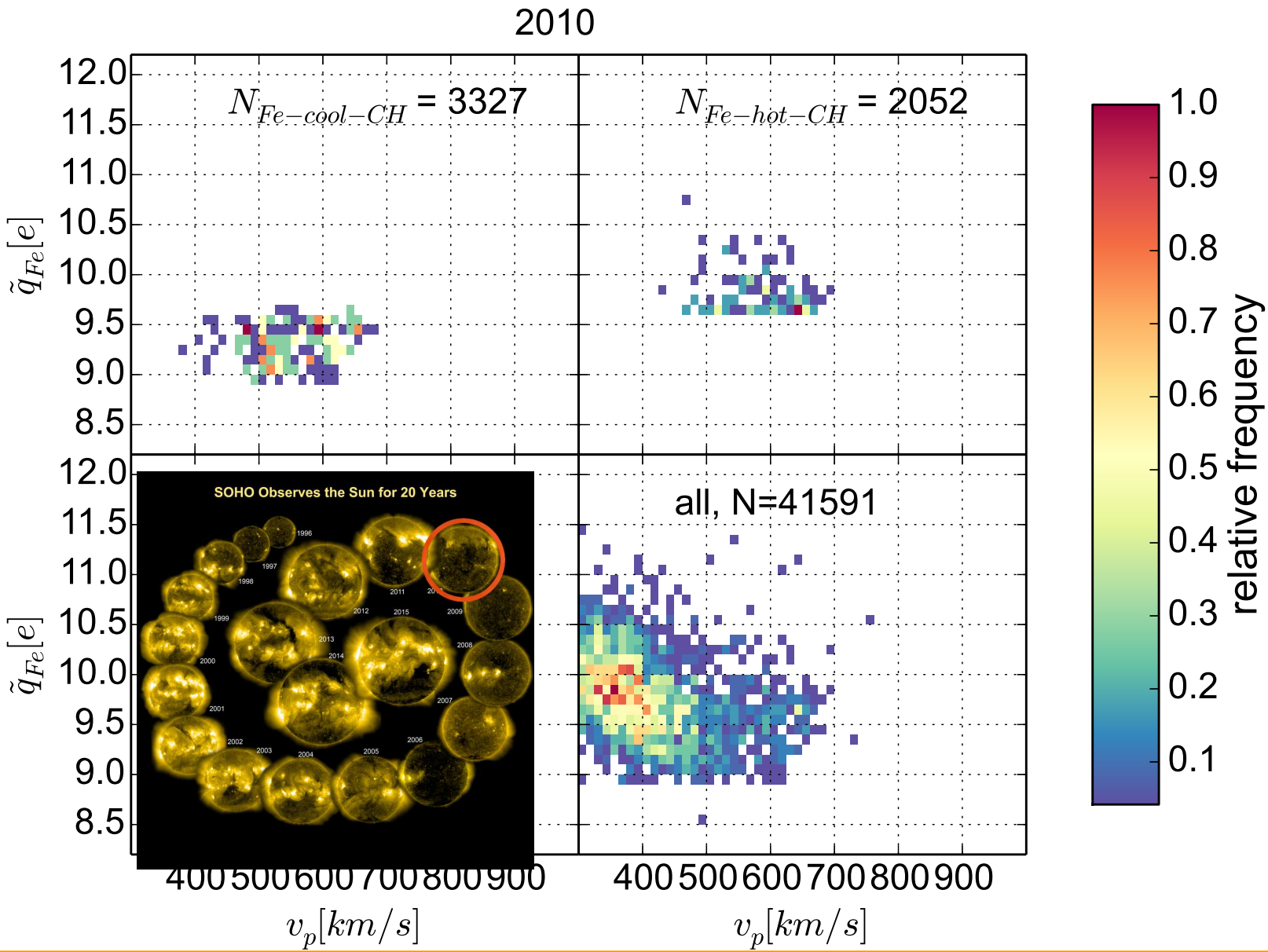
Long-term behavior average charge state: 2008



Long-term behavior average charge state: 2009



Long-term behavior average charge state: 2010



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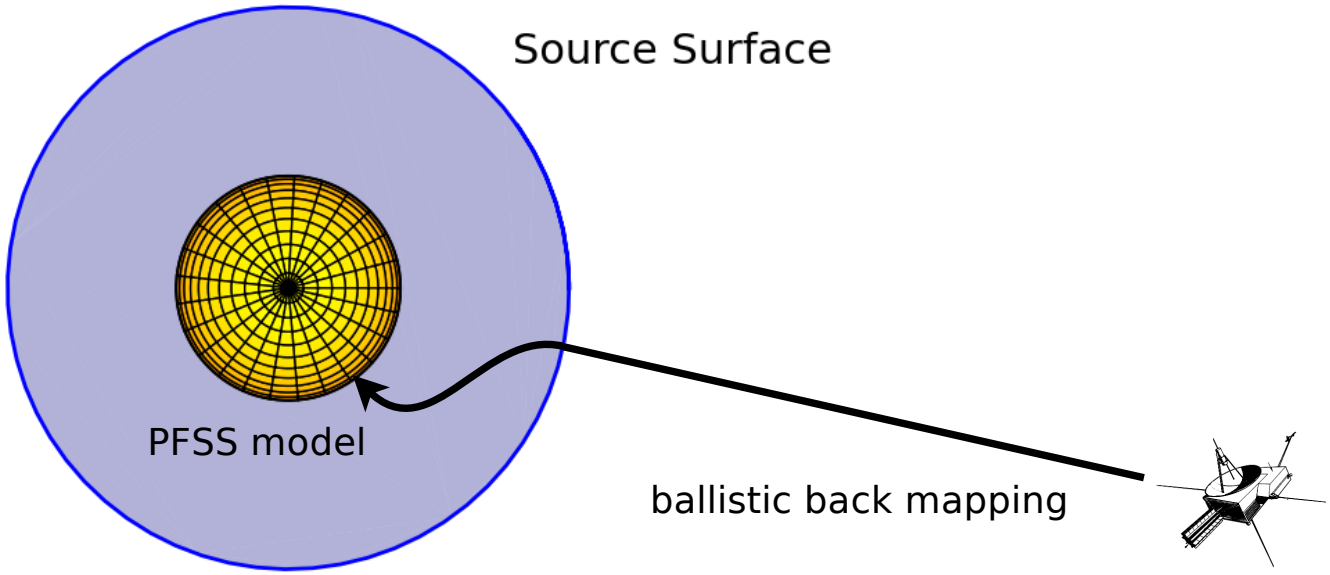
Backmapping: ballistic + PFSS (potential field source surface) based on SOHO/MDI magnetrograms



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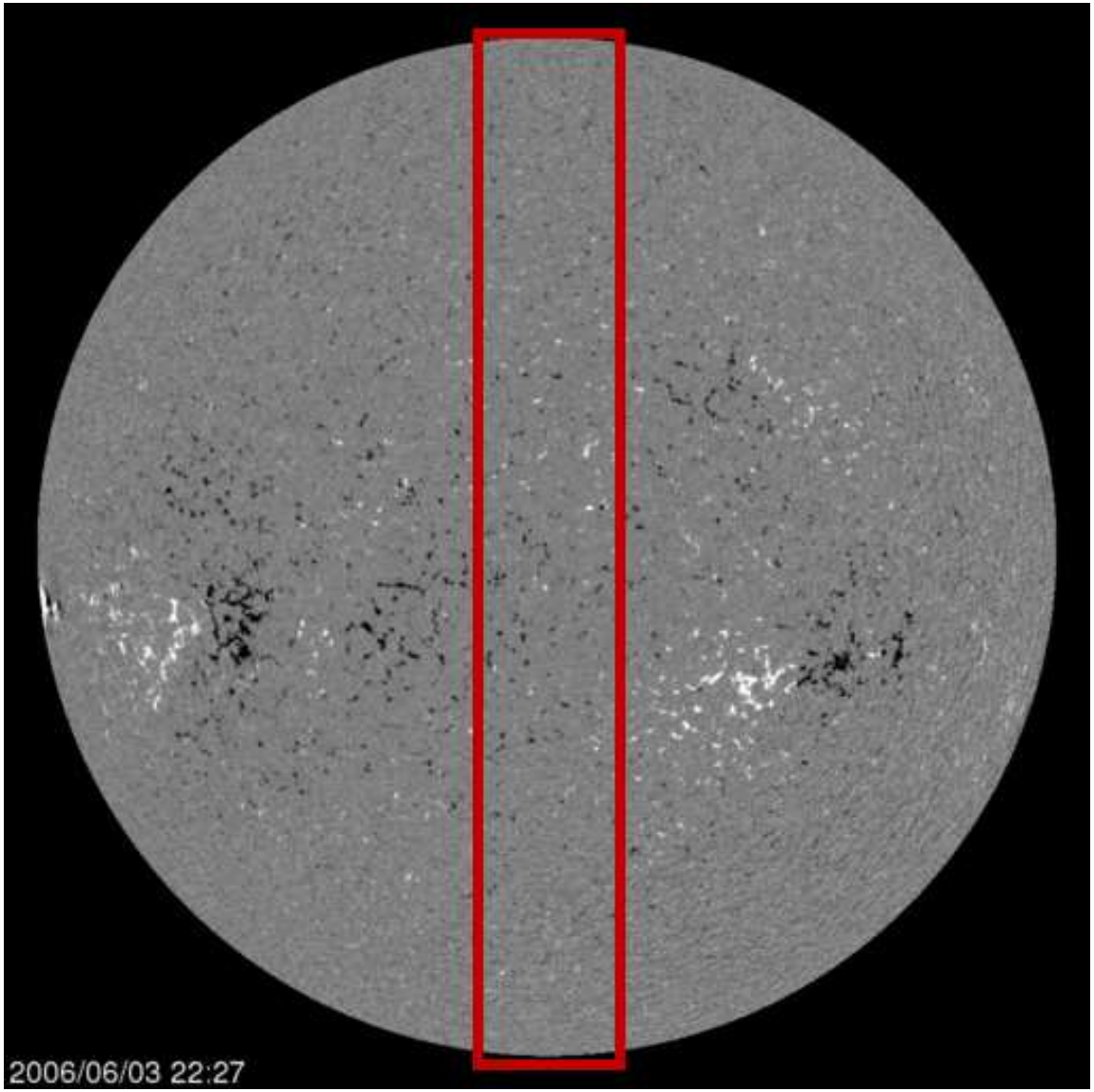

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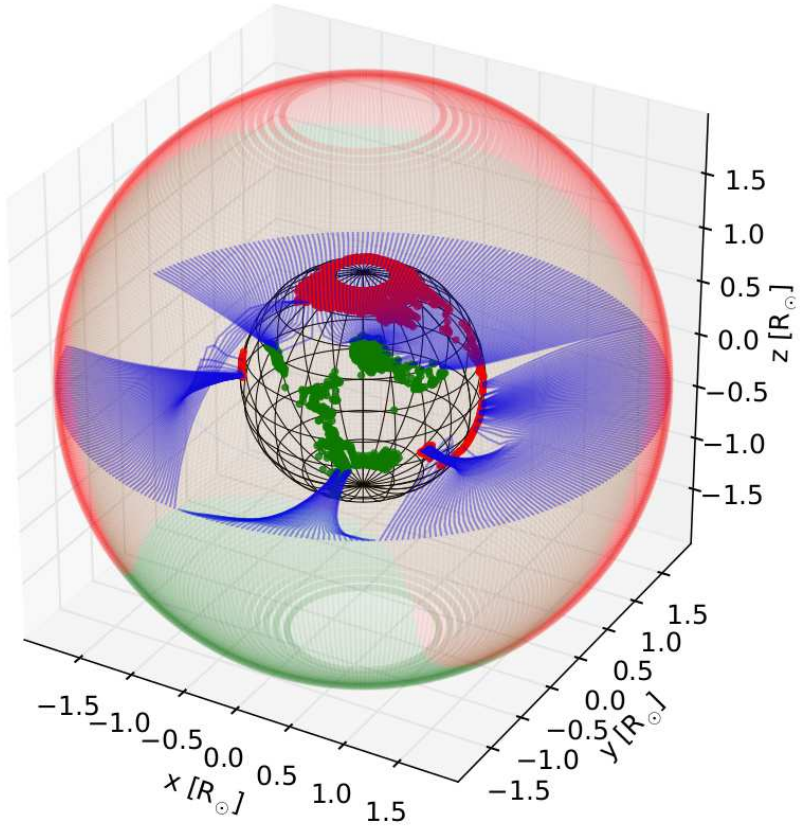
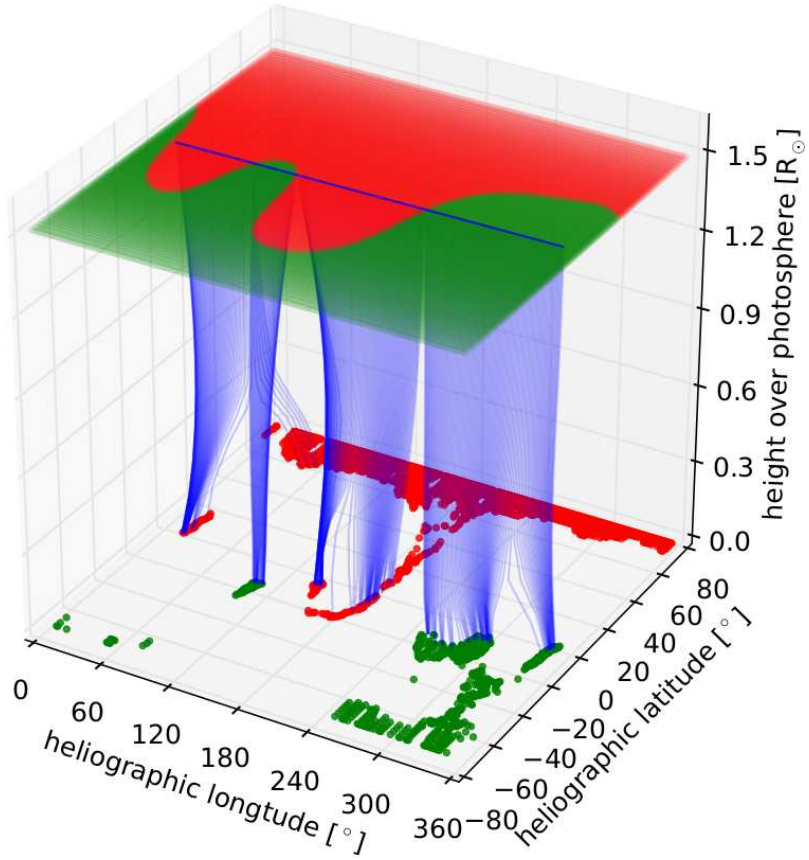
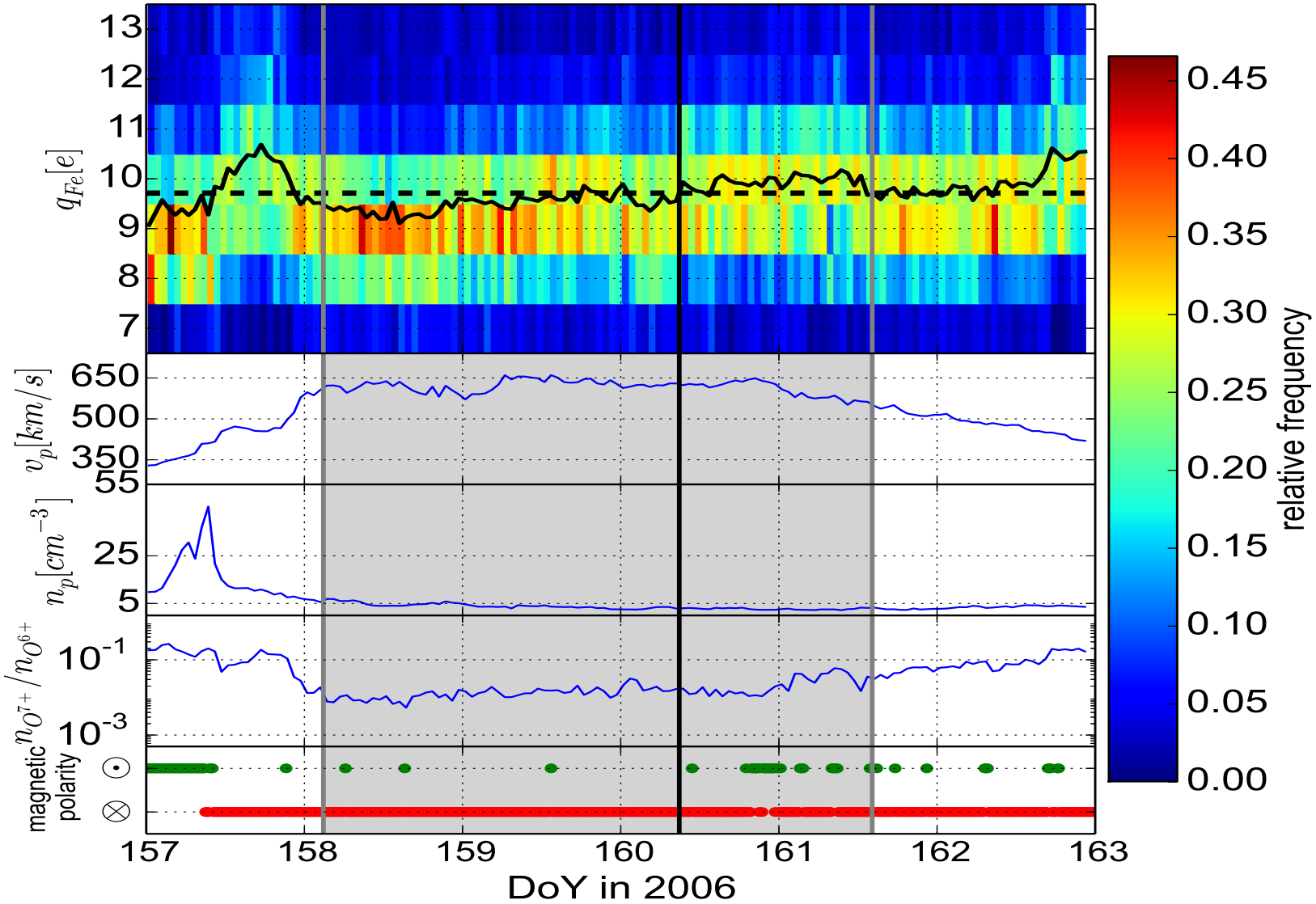




Origin of transition region in CR2043-CR2044



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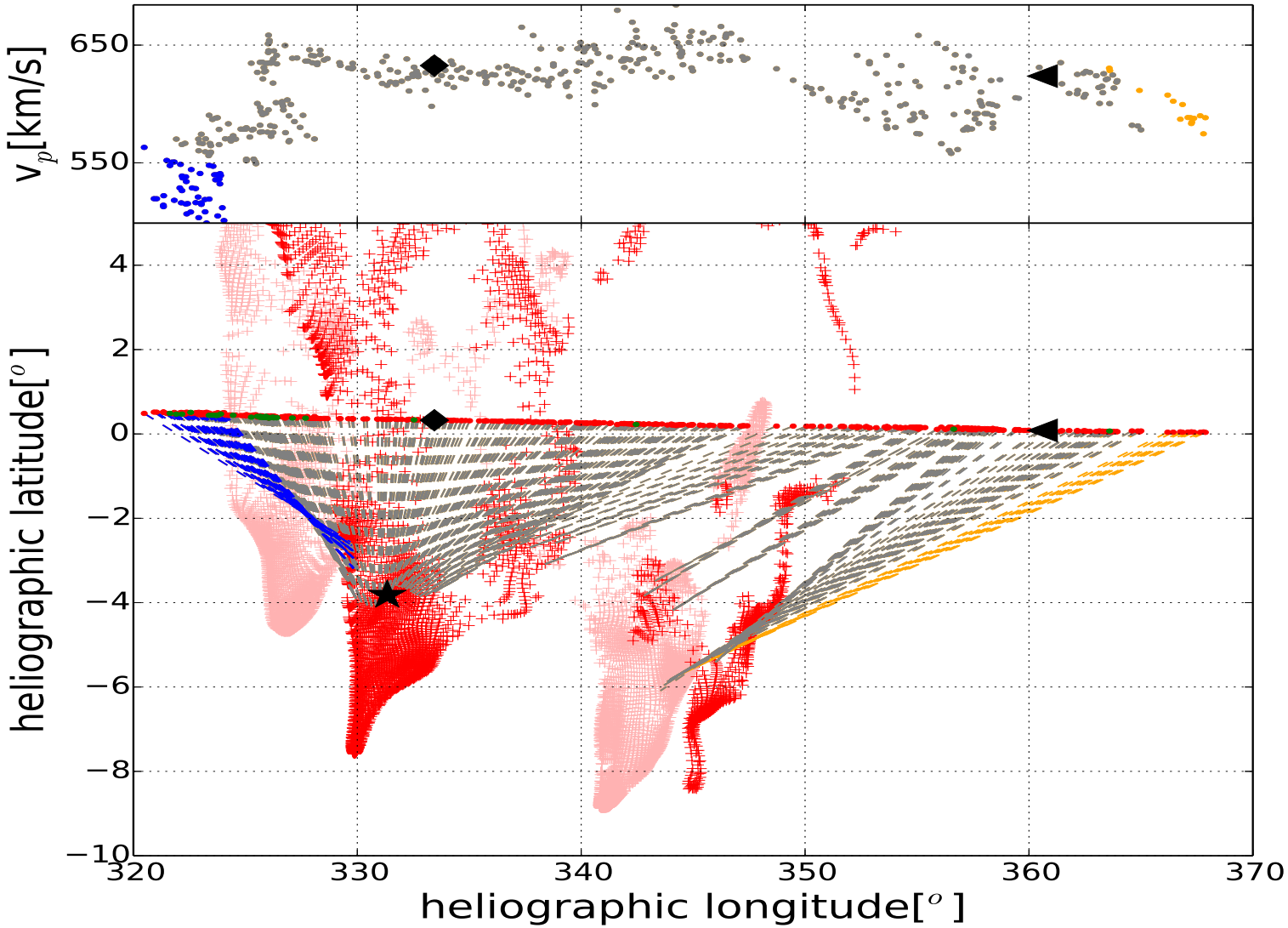

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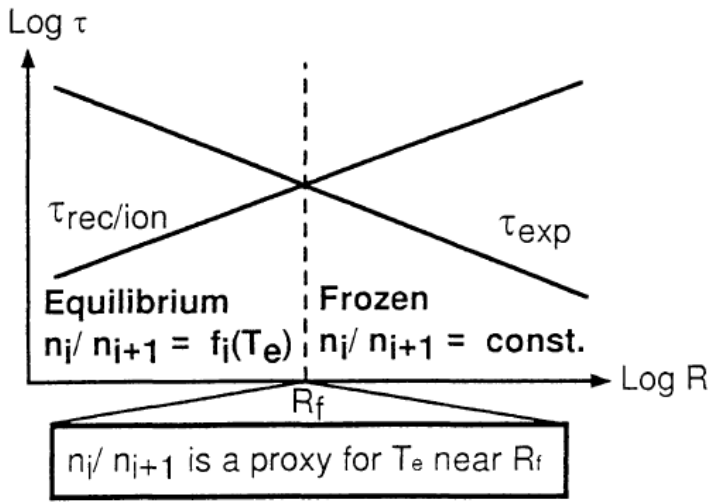
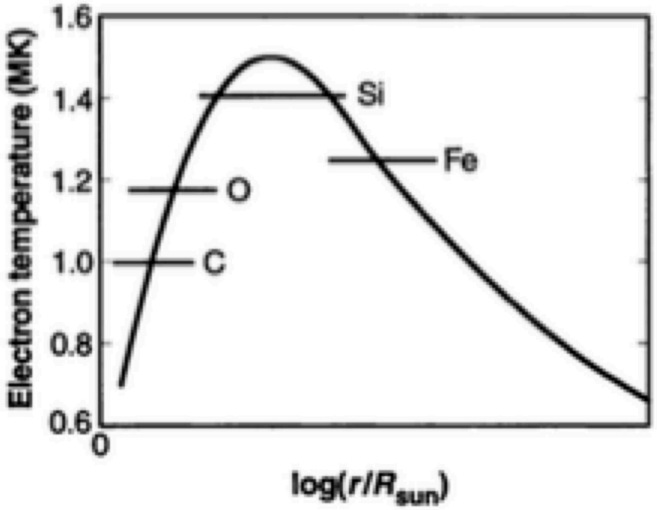
Freeze-in temperature: concept

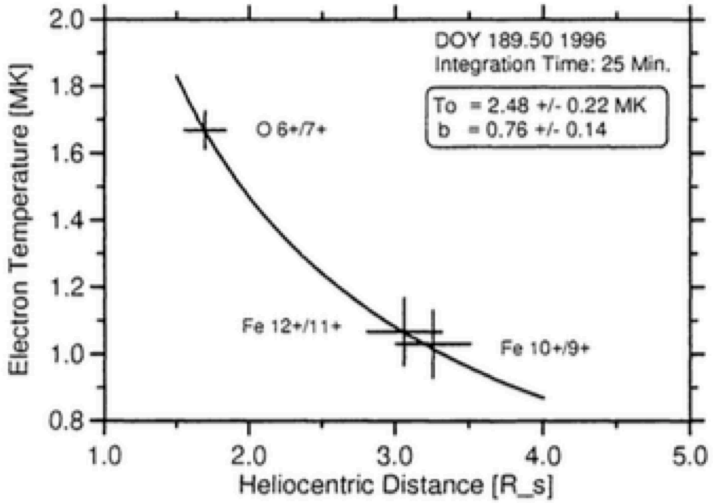


- expansion timescale: $\tau_{\text{exp}} = \frac{H}{u}$, H: scale height, u: solar wind bulk speed
- charge modification timescale: $\tau_{\text{rec/ion},i}(T) = \frac{1}{n_e(C_i+R_{i+1})}$, C_i: ionization rate, R_i: recombination rate, n_e: electron density
- assuming equilibrium: $n_i/n_{i+1} = R_{i+1}(T_f)/C_i(T_f)$

Freeze-in temperatures: previous observations



Ulysses, Geiss, 1995 [3]
fast, i.e. coronal hole, wind



CTOF, Aellig, 1997 [1]
interaction region between (probably) slow wind streams

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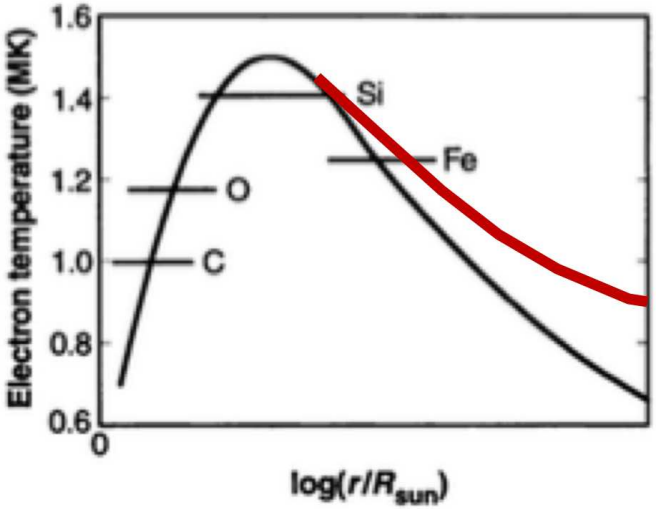

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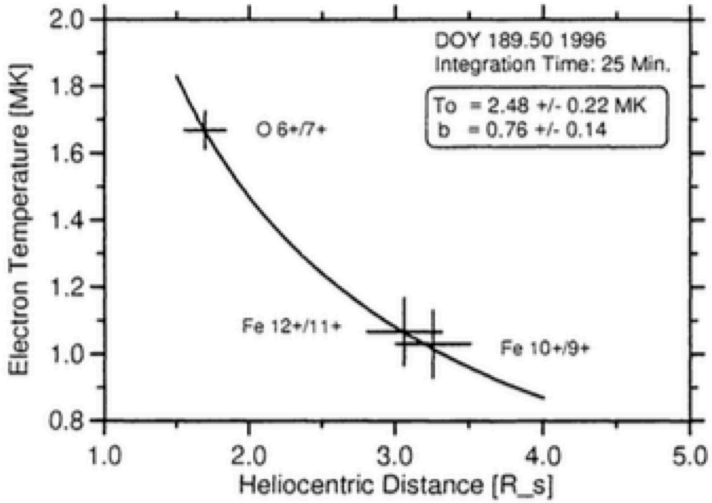

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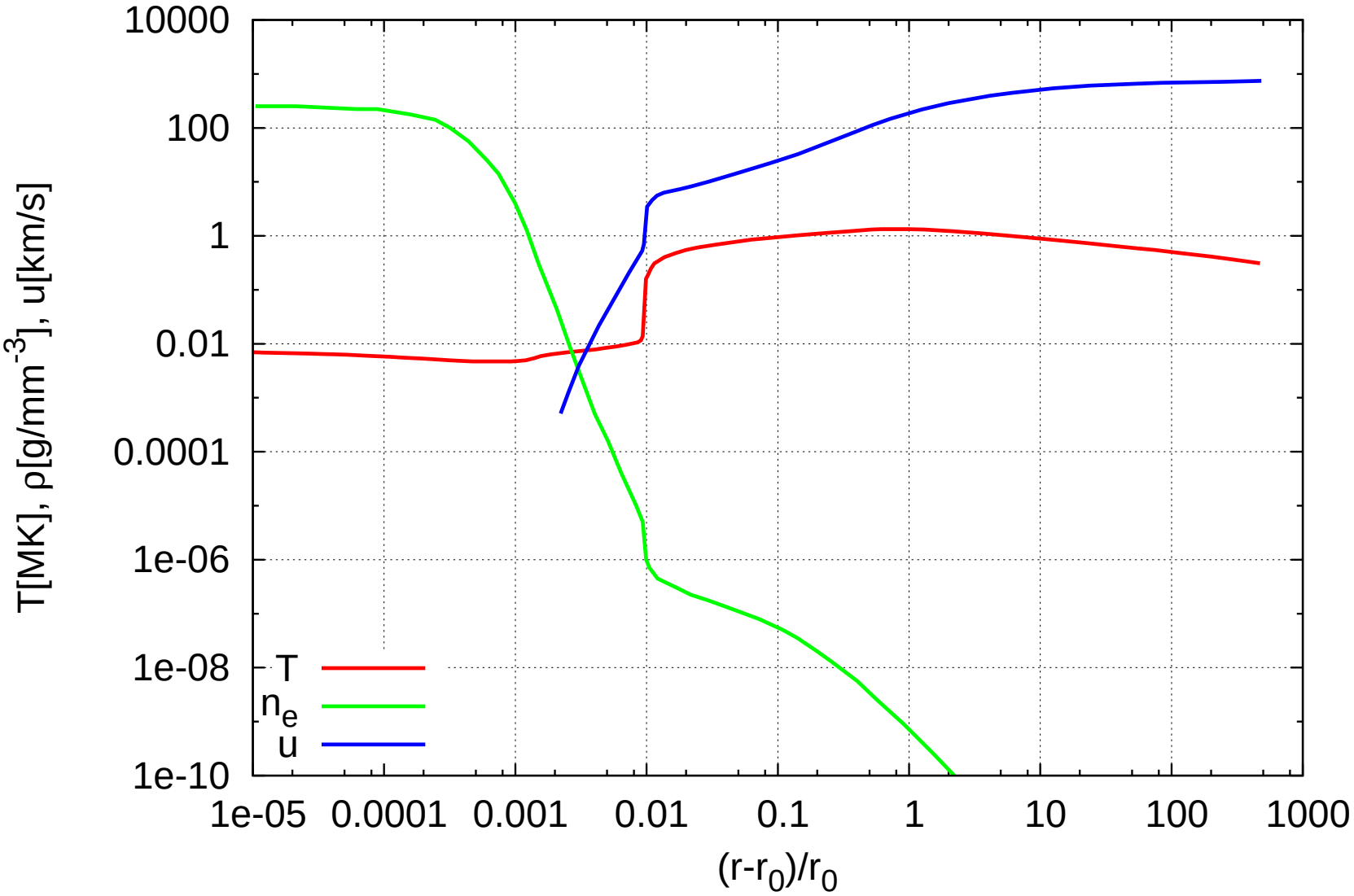
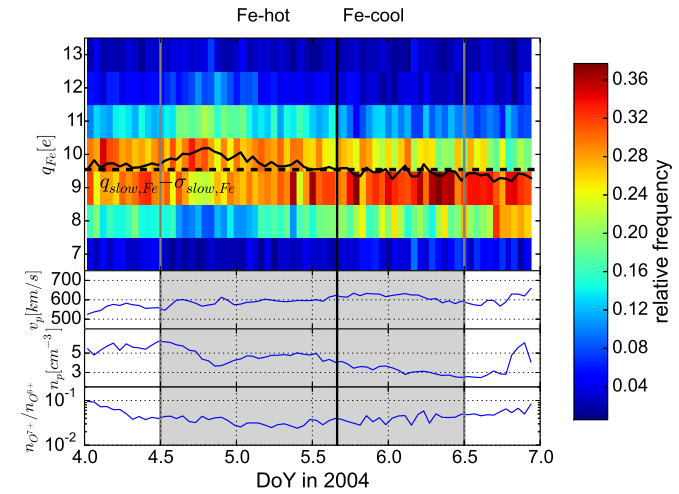
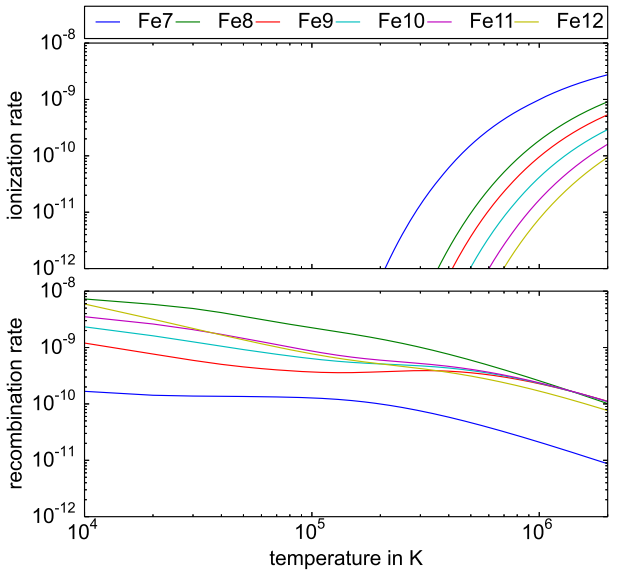
Cranmer 2007 model [2]: Temperature profile



What I know about the temperature profile

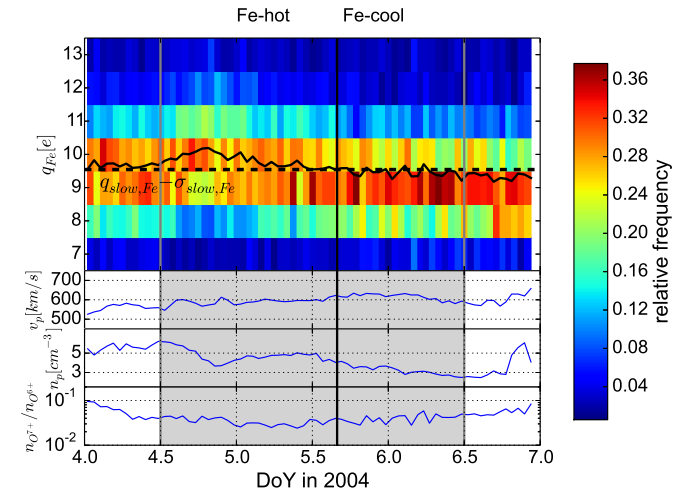
- timeseries of (equilibrium) freeze-in temperatures for ion pairs of C, O, Mg, Si, S, Fe
- temperature dependent recombination (and ionization) rates from CHIANTI

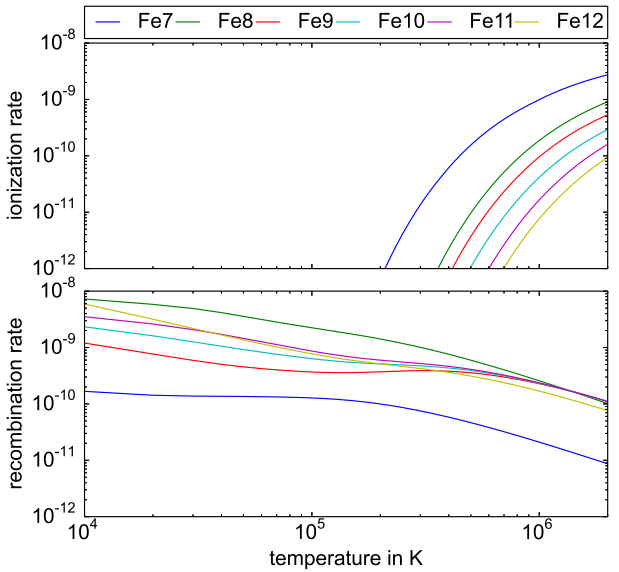




What I know about the temperature profile

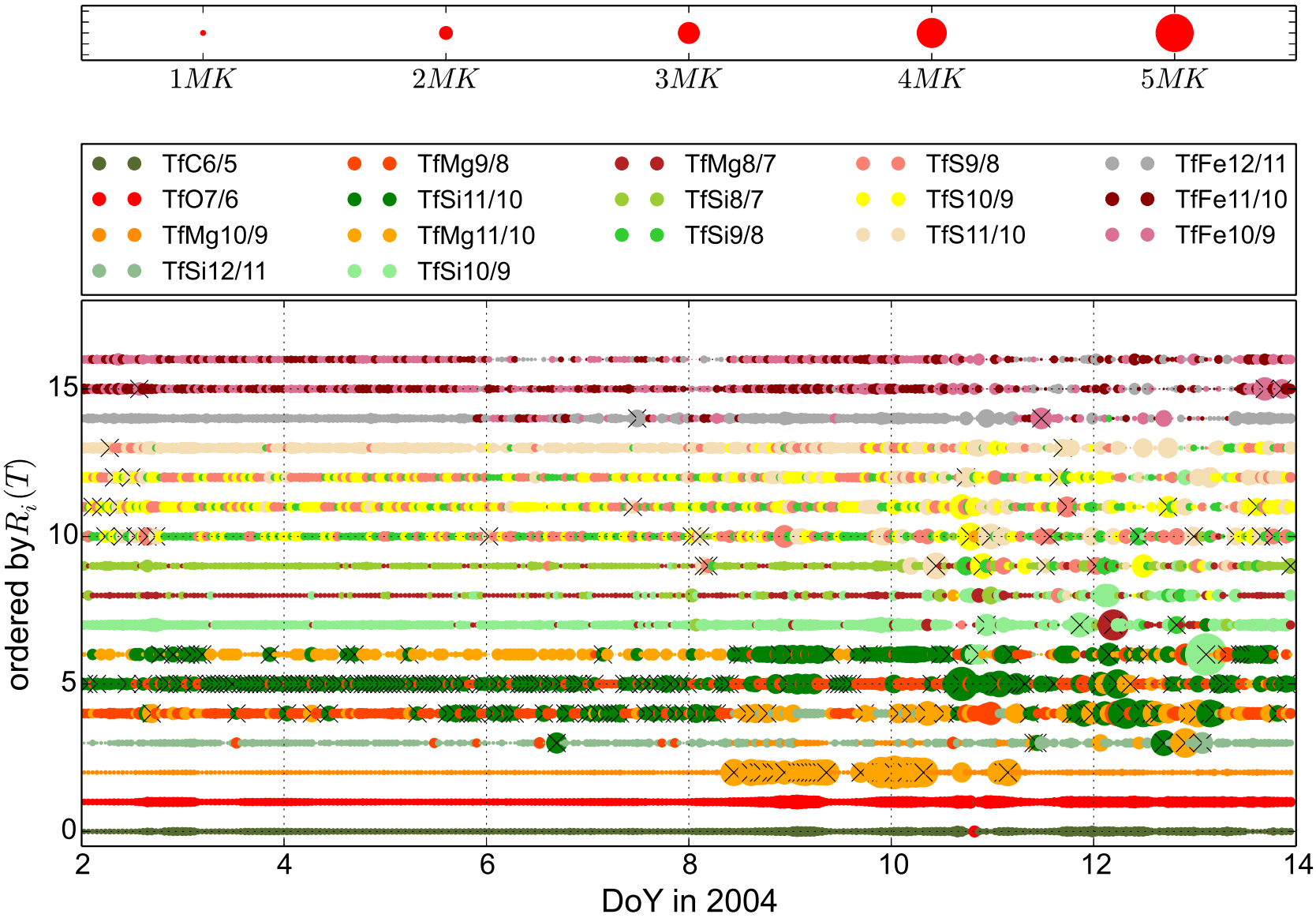
- timeseries of (equilibrium) freeze-in temperatures for ion pairs of C, O, Mg, Si, S, Fe
- temperature dependent recombination (and ionization) rates from CHIANTI $\longrightarrow$ order in which ion pairs probably froze in.





What I know about the temperature profile

different wind types



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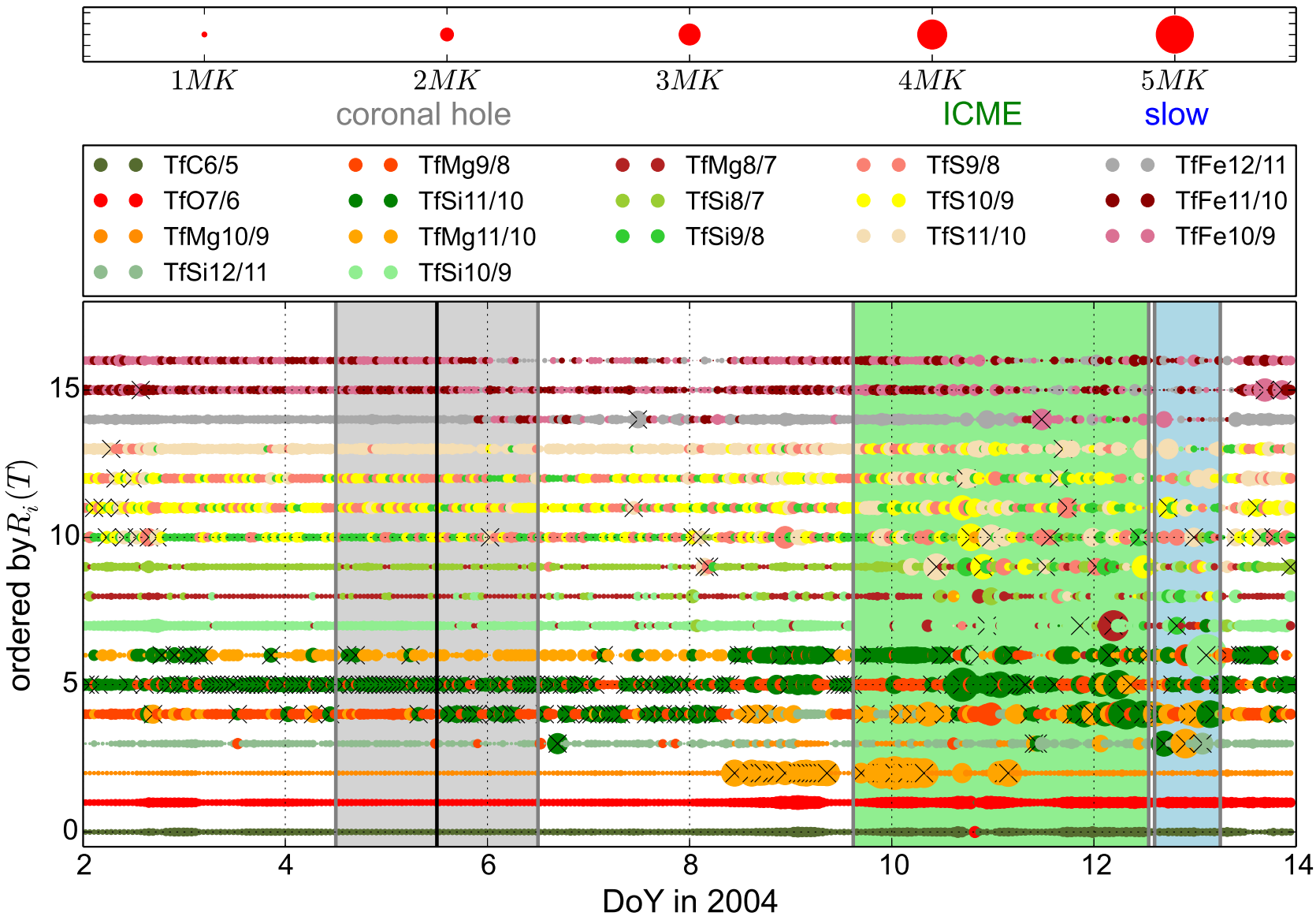

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Summary

- The steady coronal hole wind can be either Fe-cool or Fe-hot.
- Both Fe-hot and Fe-cool coronal hole wind occur frequently. Probably solar cycle dependence.
- Unlike for H, O, and C, Fe charge states are as high in the coronal hole wind as in the slow solar wind.
- Transitions between Fe-hot and Fe-cool streams appear to be within coronal holes. Possibly close to the border of a fine structure.
- Different temperature profiles in the corona for Fe-hot and Fe-cool coronal hole wind.

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Thank you for your attention!

M. Aellig, H. Grünwaldt, P. Bochsler, S. Hefti, P. Wurz, R. Kallenbach, F. Ipavich, D. Hovestadt, M. Hilchenbach, C. Team, et al.
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