Solar Cycle Dependence of Mass Density and Ion Composition at Geosynchronous Orbit

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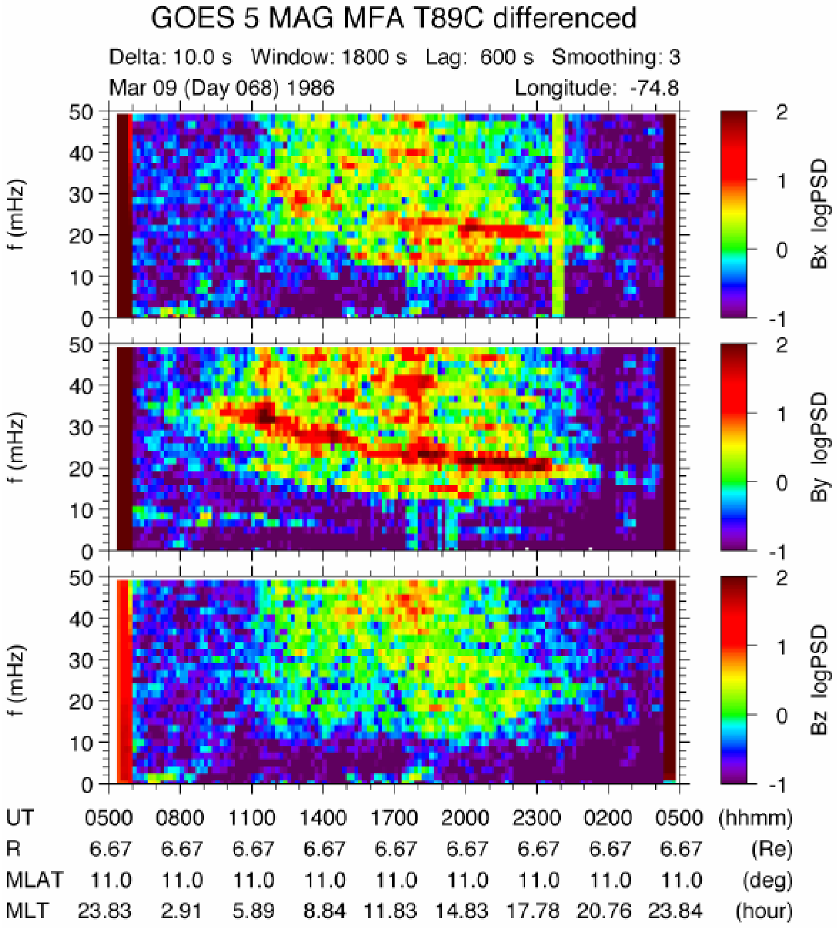
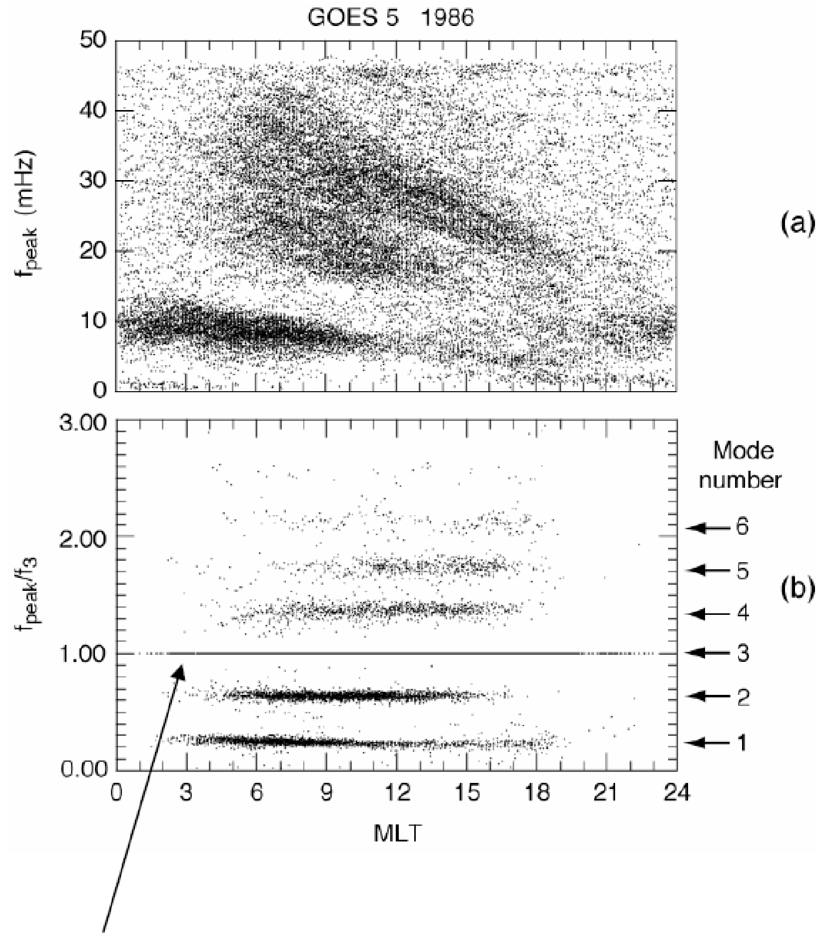
Toroidal waves at geosynchronous orbit





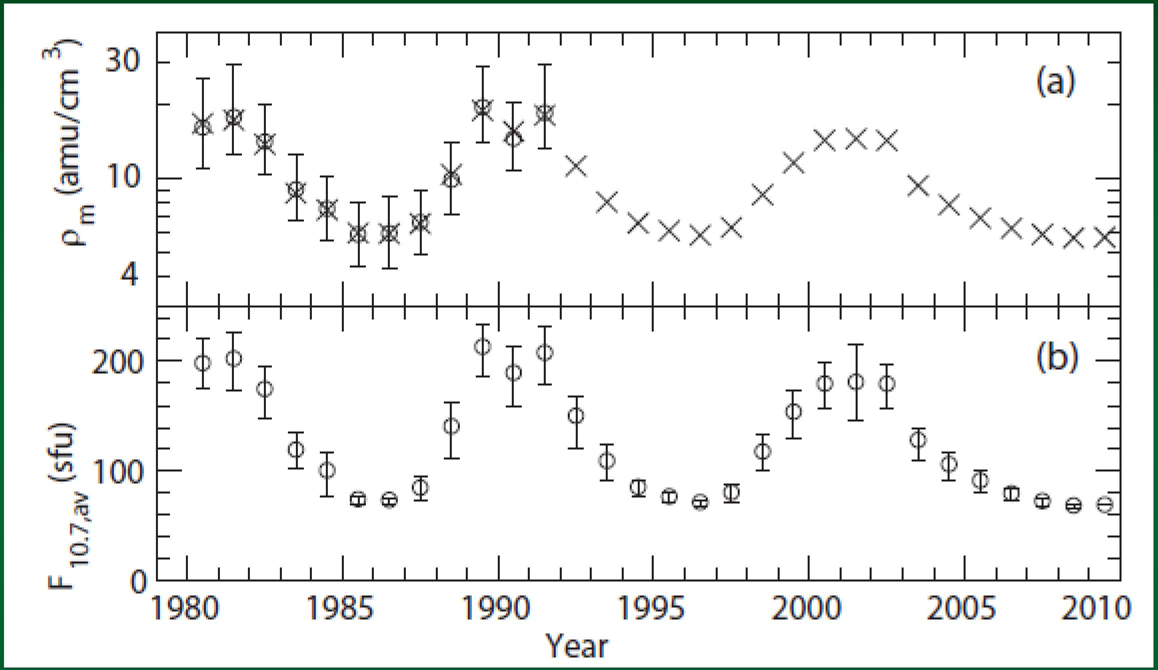
Takahashi and Denton [2006a]

Frequencies normalized to the frequency of the third harmonic, the most common harmonic observed by GOES 5 and 7

Solve for Mass Density

- We use the TS05 magnetic field model with the Qin et al. [2007] database of model parameters
- We assume a R^{-1} field line dependence
- And a perfectly conducting ionosphere
- We then solve for the mass density using the Alfven wave equation of Singer et al. [1981] and the third harmonic (n = 3) Alfven frequencies

Solar Cycle Dependence of Mass Density

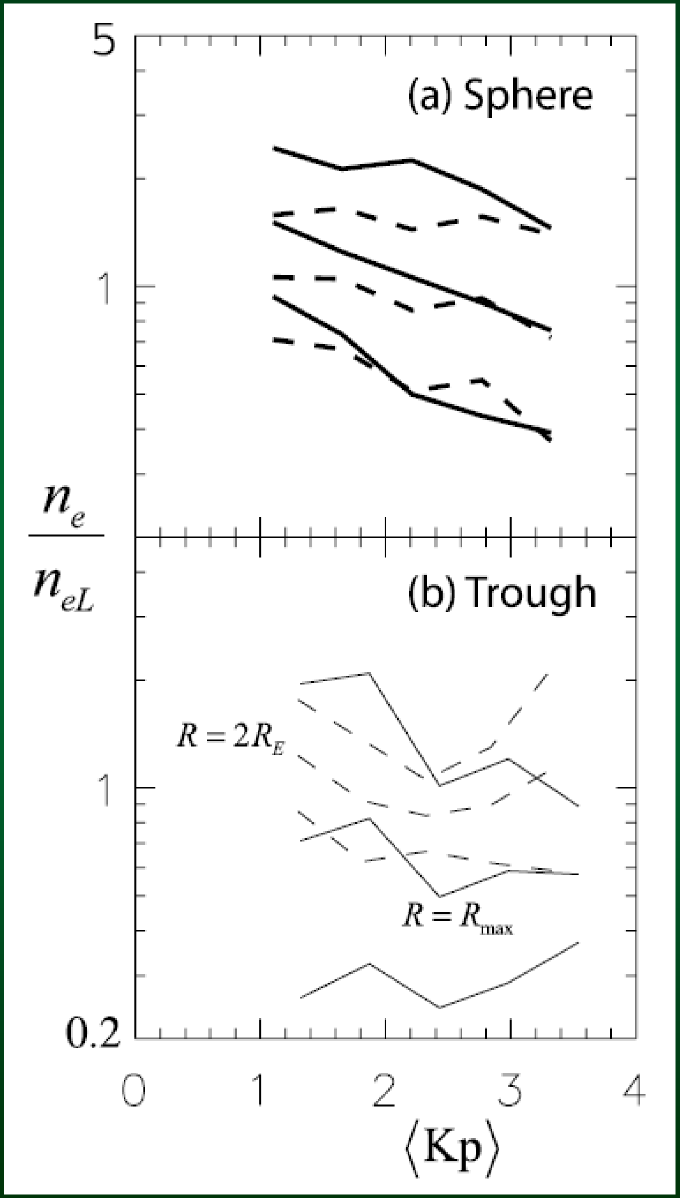


→ Model for yearly median mass density

$$\log_{10}\left(\rho_{\mathrm{m,yr-med},8^\circ}\right) \simeq 0.5089 + 0.003607 F_{10.7,\mathrm{yr-av}},$$

Defies our expectations for electron density

- There is at least a small trend to have lower electron density for large Kp (which occurs at solar maximum) – see Polar data at right [Denton et al., 2004]
- But the major reason why electron density is lower on average at solar maximum, is because geosynchronous orbit is more likely to be outside the plasmapause



Ion Measurements at Geosynchronous Orbit

- While we don't have good electron density measurements at geosynchronous orbit, we do have good ion density measurements from the MPA instrument on LANL spacecraft
- The MPA instrument is less sensitive to heavy ions than to light ions

$$\frac{n_{\mathrm{MPA-th}}}{n_e} = \eta_{\mathrm{H+}} + \frac{\eta_{\mathrm{He+}}}{2} + \frac{\eta_{\mathrm{O+}}}{4},$$

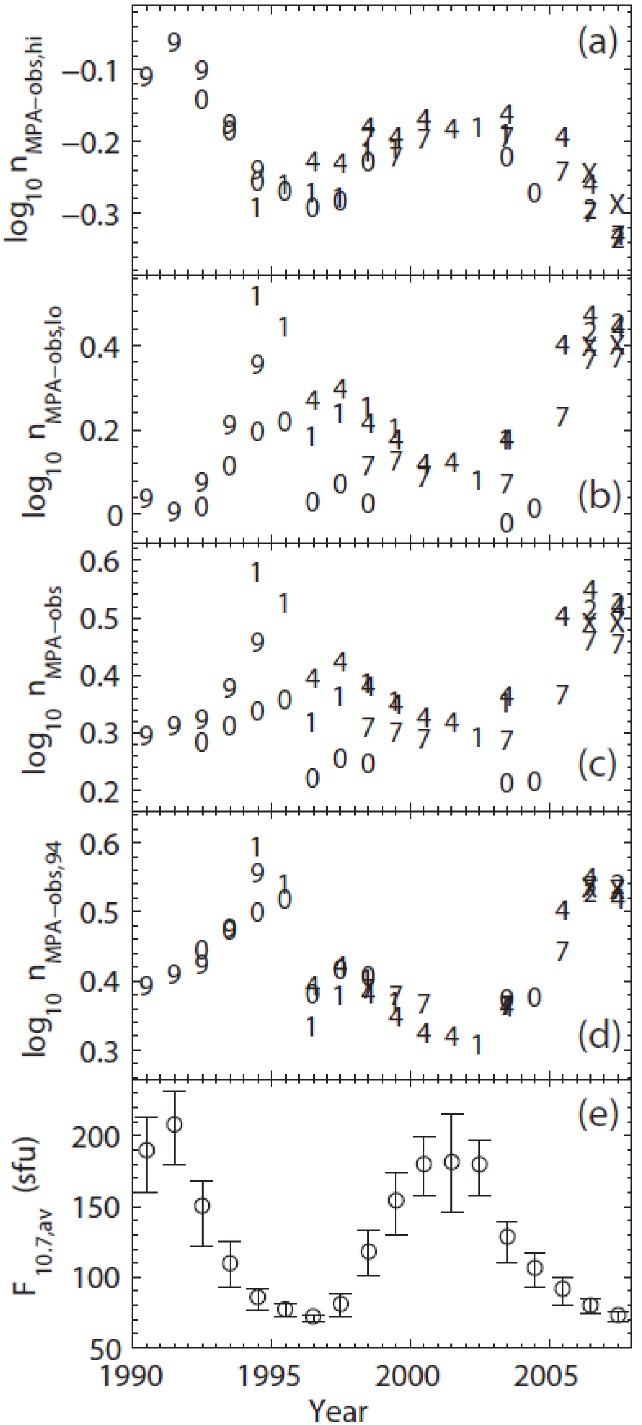
- In a sense, the MPA instrument measures an "inverse mass density" (more precisely, inverse square root mass density)

Outline of Research

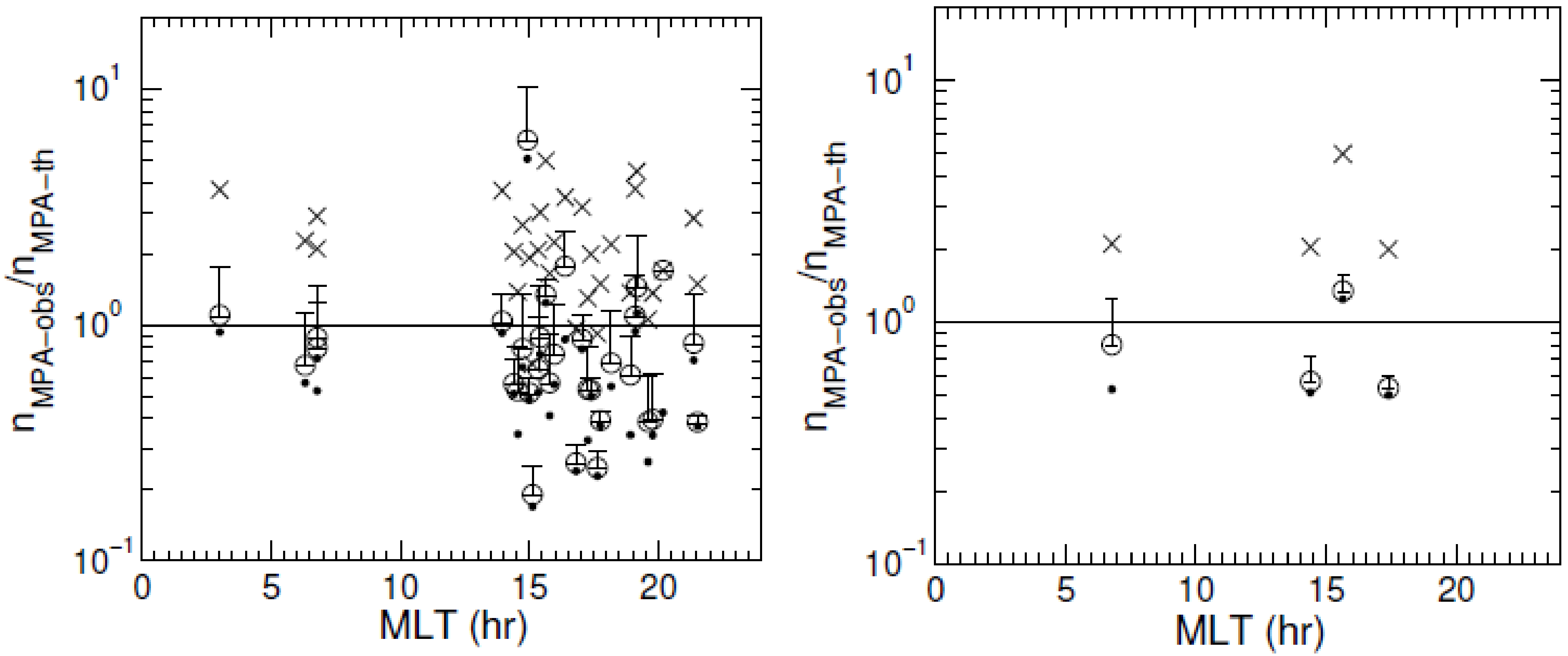
- First, we calibrate MPA measurements from one spacecraft relative to that of another
- Secondly, we calibrate the observed MPA densities to the theoretical values (the values that MPA would observe if it measured all the particles) using conjunctions between LANL spacecraft and CRRES (at which we know both the electron and mass density)
- Then we assume a small density of He+, 3% at solar maximum and 1% at solar minimum [Craven et al., 1997]
- Finally, we combine yearly median mass density from the model that we developed with yearly median ion density from MPA to derive the typical ion composition over the solar cycle

MPA Measurements From Different Spacecraft

Spacecraft[a]	$\frac{n_{MPA-obs,i}}{n_{MPA-obs,94}}$
1989	0.80
1990	0.69
1991	0.96
1997	0.84
2001	0.91
2002	0.97



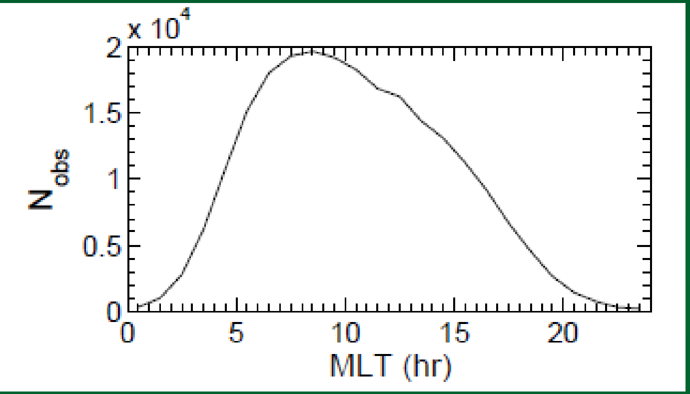
Observed to Theoretical MPA Density



Conclude that MPA observed densities (LANL 1994 levels) are low by a factor of about 1.5 *on average*

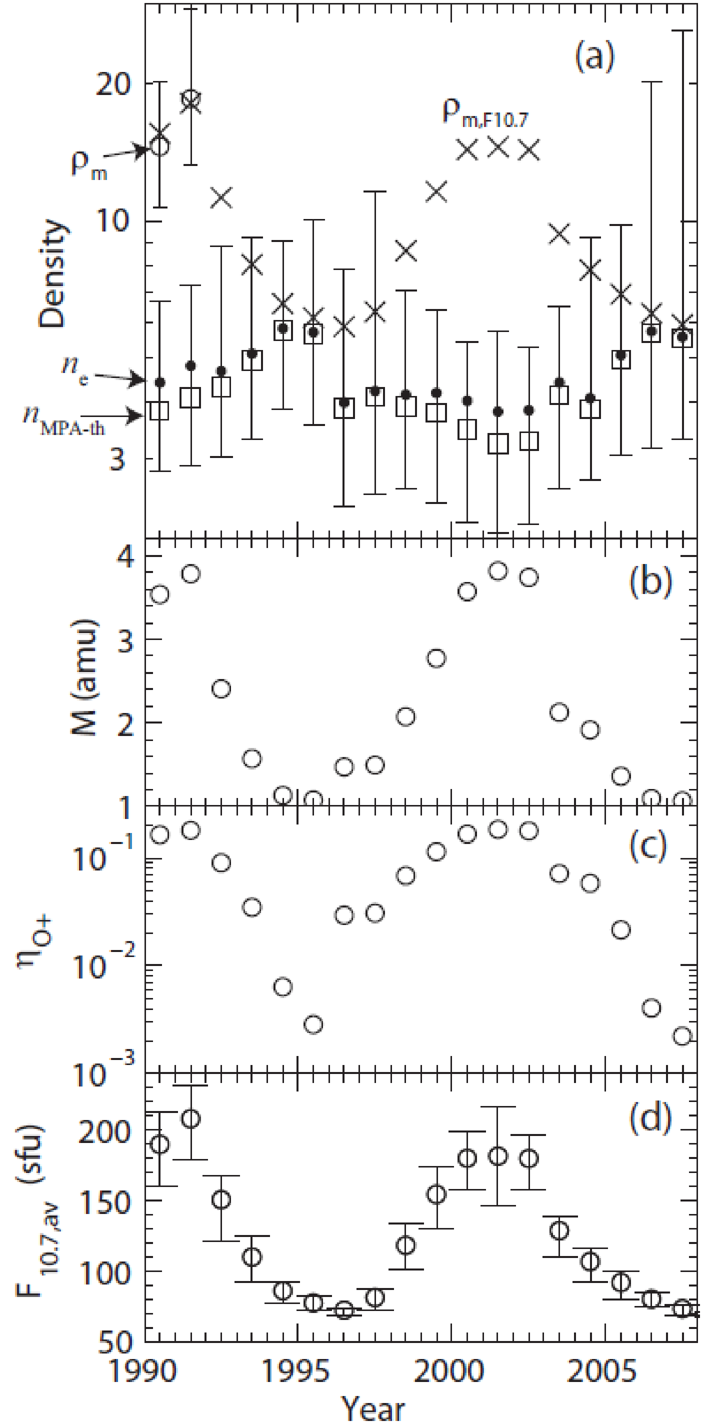
More on Procedure

- Weight the MPA measurements using the probability distribution of mass density measurements versus MLT



- Calculate median MPA measurements
- Assuming the He+ concentration, can solve for the H+ and O+ density from the mass density and MPA ion density

Solar Cycle Dependence of Ion Composition



Conclusions

- At geosynchronous orbit, the mass density peaks at solar maximum while the MPA ion density peaks at solar minimum (what we'd expect for electron density)
- This implies a much higher concentration of O+ at solar maximum.
- Combining all the data, and assuming a low concentration of He+, we find a two order of magnitude variation in the concentration of O+ over the solar cycle, with typically $n_{O+}/n_e \cong 0.2$ and average ion mass $M \cong 3.8$ at solar max, and $n_{O+}/n_e \sim 0.002$ and $M \sim 1$ at solar min.