Modelling X-ray Bright Points on the Quiet Sun.

Parameter fitting to a Coronal Heating solution.

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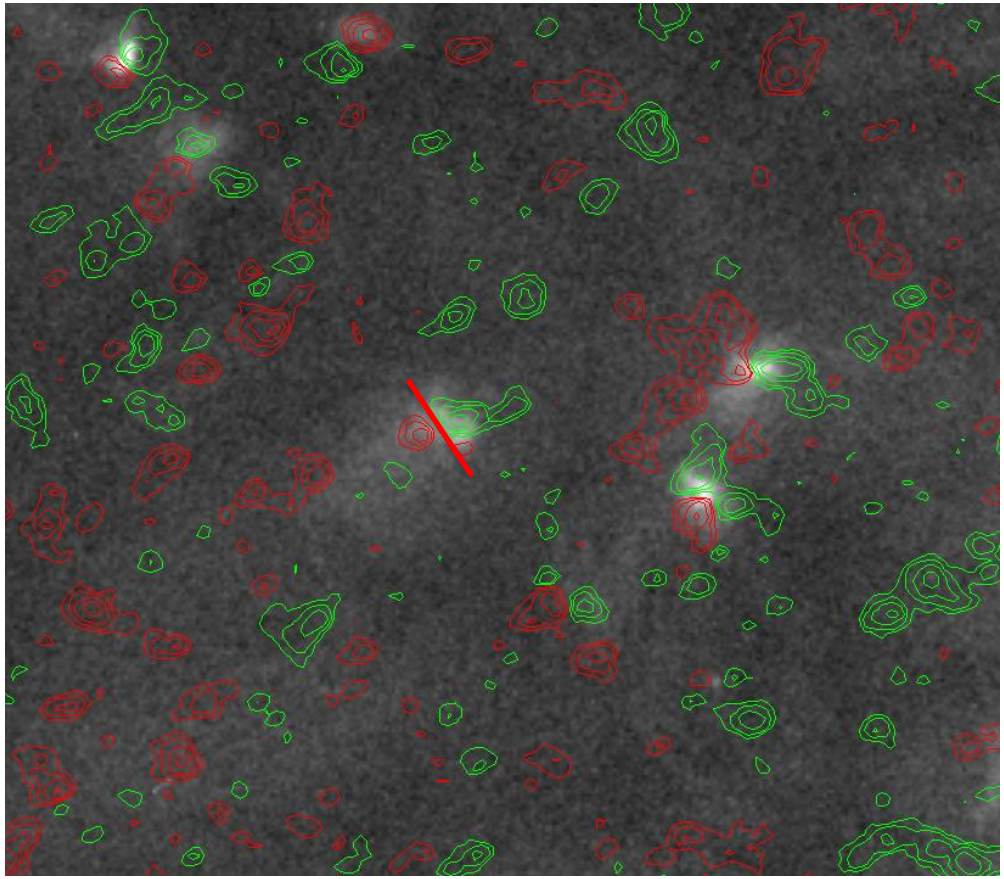
What is an X-ray Bright point?

- X-ray bright points are small dynamic loop structures that are observed all over the solar corona.
- They have a correspondence with small bipolar magnetic regions (Krieger et al. 1971, Tousey et al. 1973).



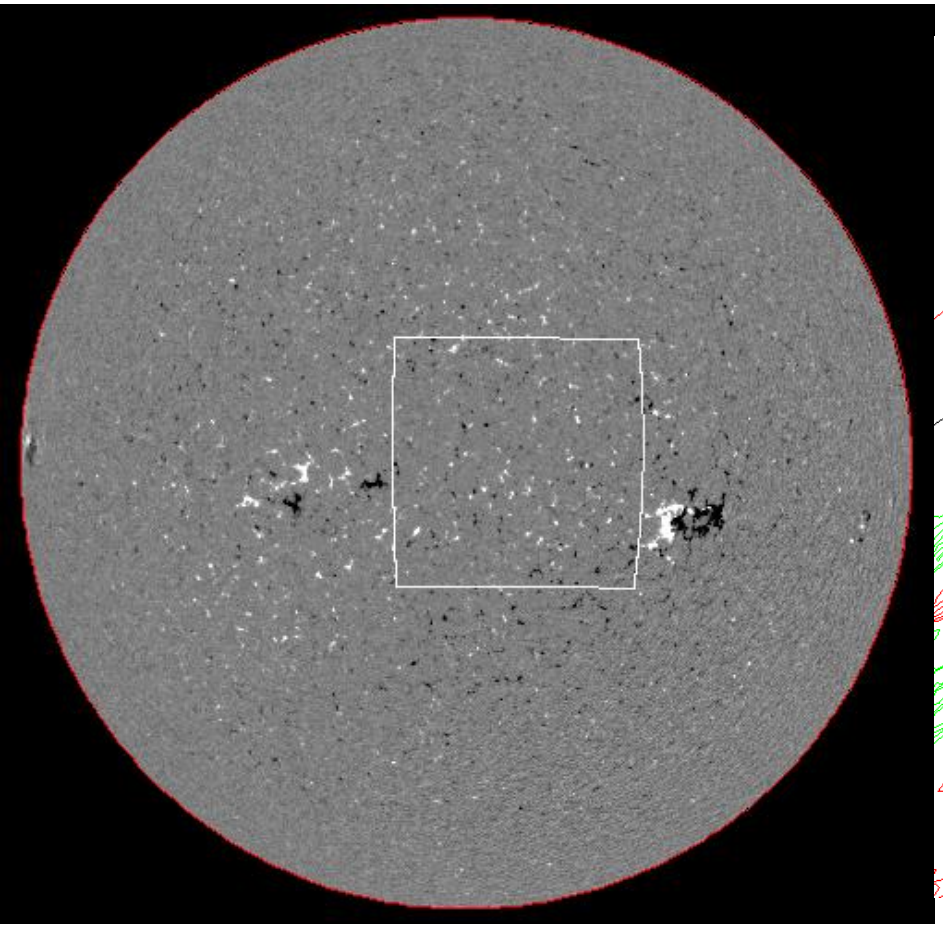
Aim

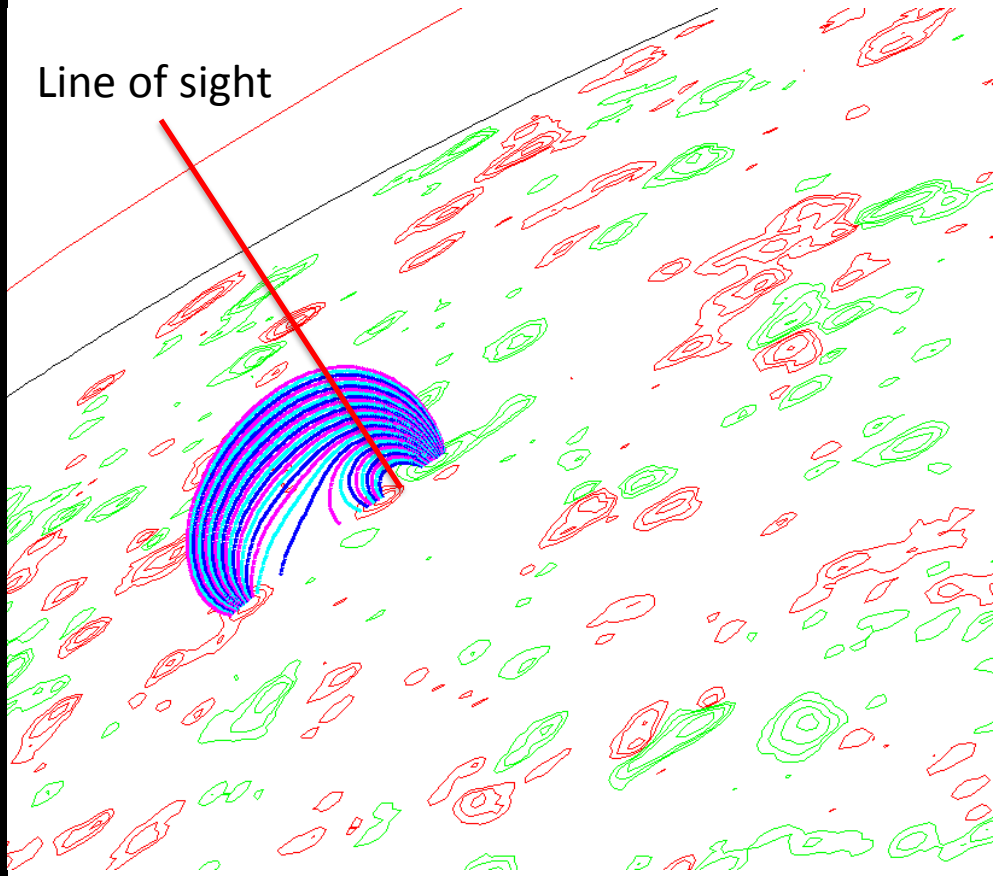
- To find coronal heating parameters that enable modelling of XRT intensities in multiple filters.

Method

- Construct a potential field from a magnetogram.
- Solve the energy equation for each field line.
- Compute XRT intensities.
- Compare to XRT data.

Construct Potential field





Coronal Heating rate per unit volume

$$\varepsilon_H = \frac{B_{photo} \cdot B_{mag}}{4\pi \cdot f \cdot L_T^{\,2}} \cdot \frac{L_p^{\,2}}{\tau}$$

(van Ballegooijen 1986)

B_{photo} – 1500G, field strength in the photospheric network (Stenflo 1984).

B_{mag} – the magnetic field strength at each point along the field line.

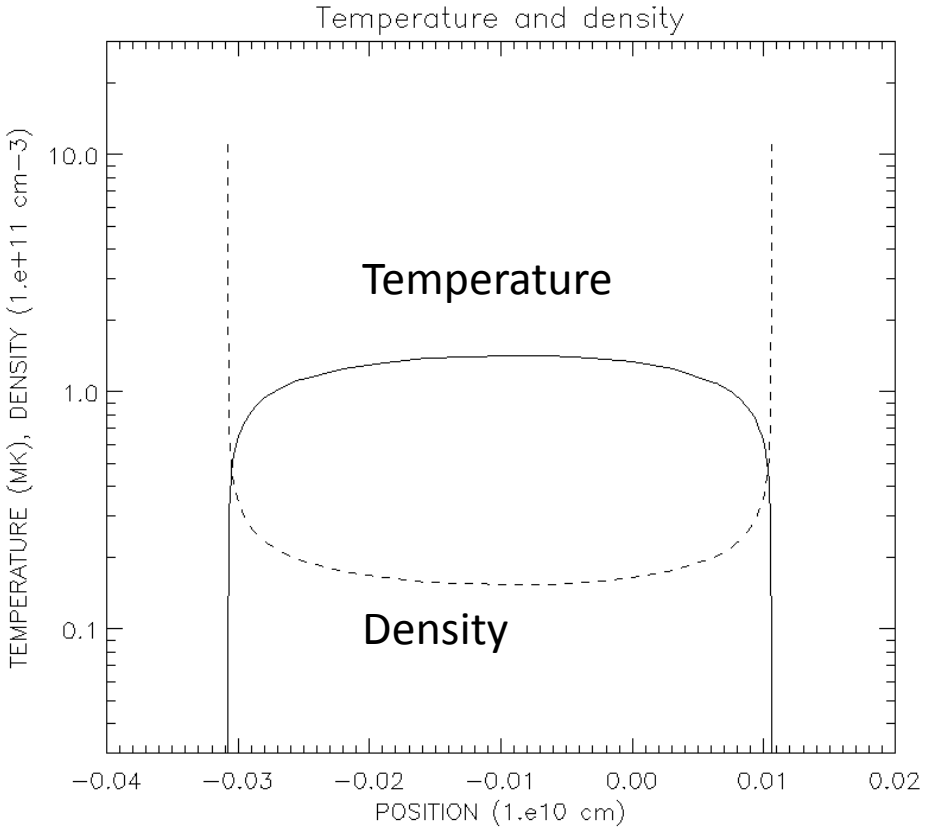
f – filling factor, the heat is not applied evenly along the LOS, but is applied to a proportion of each part of the LOS.

L_T – the total length of the field line

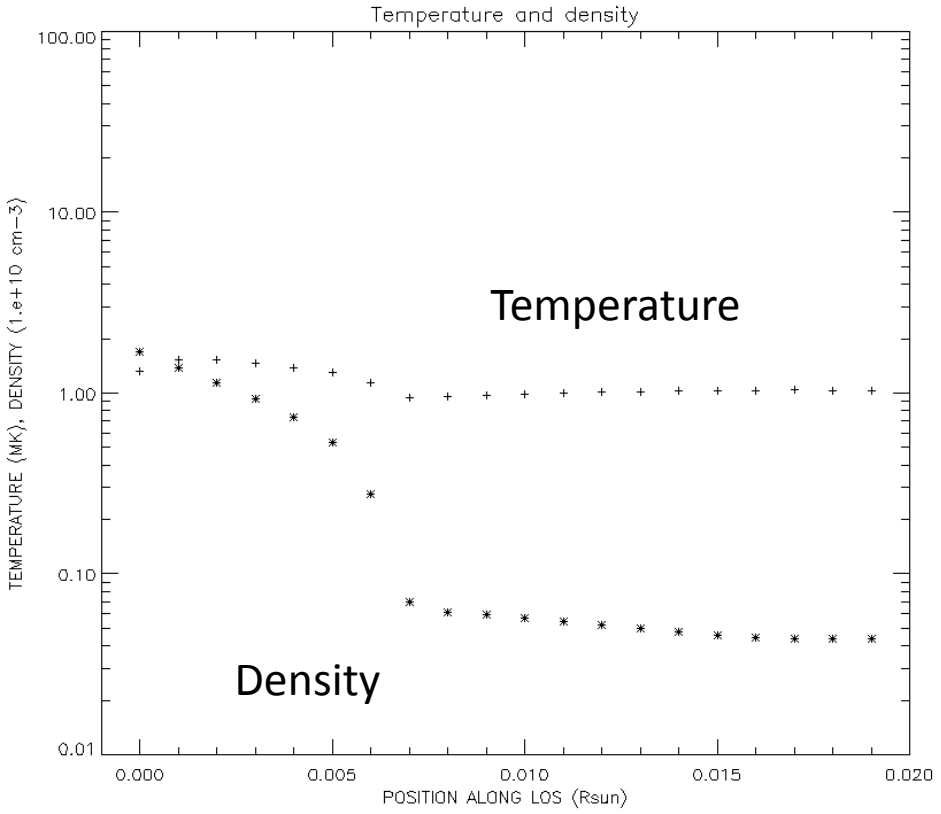
L_p & τ – variables which describe the length and time scales of the granulations which input the energy into the system.

f & L_p are the unknown variables which make up our parameter space.

Solving the Energy Equation

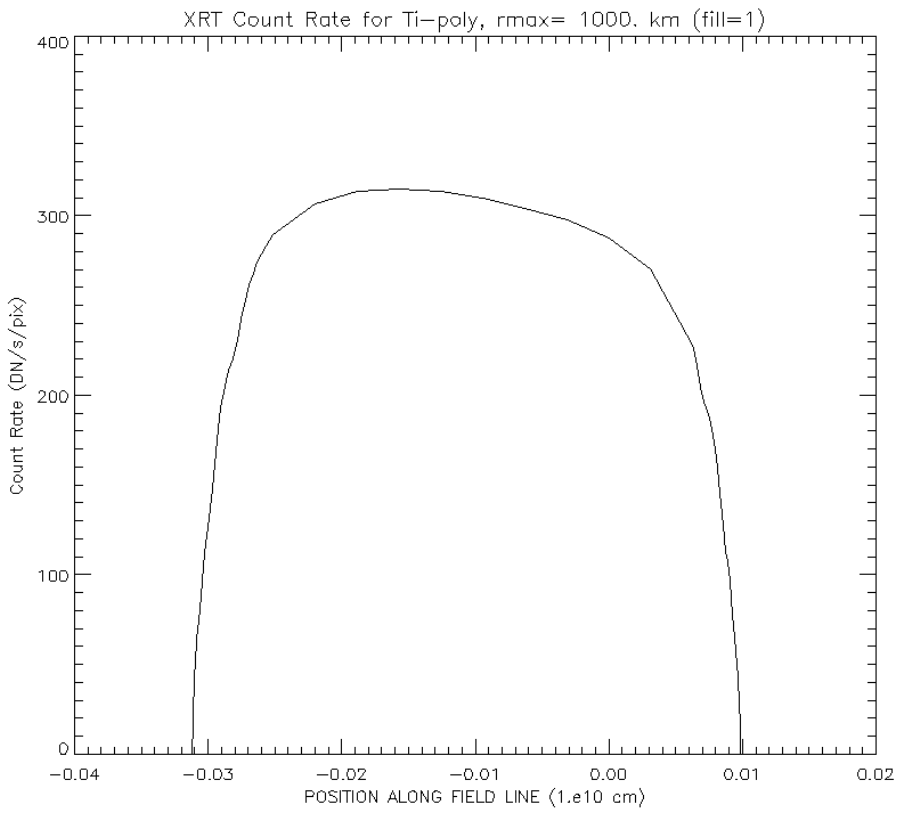


Field line

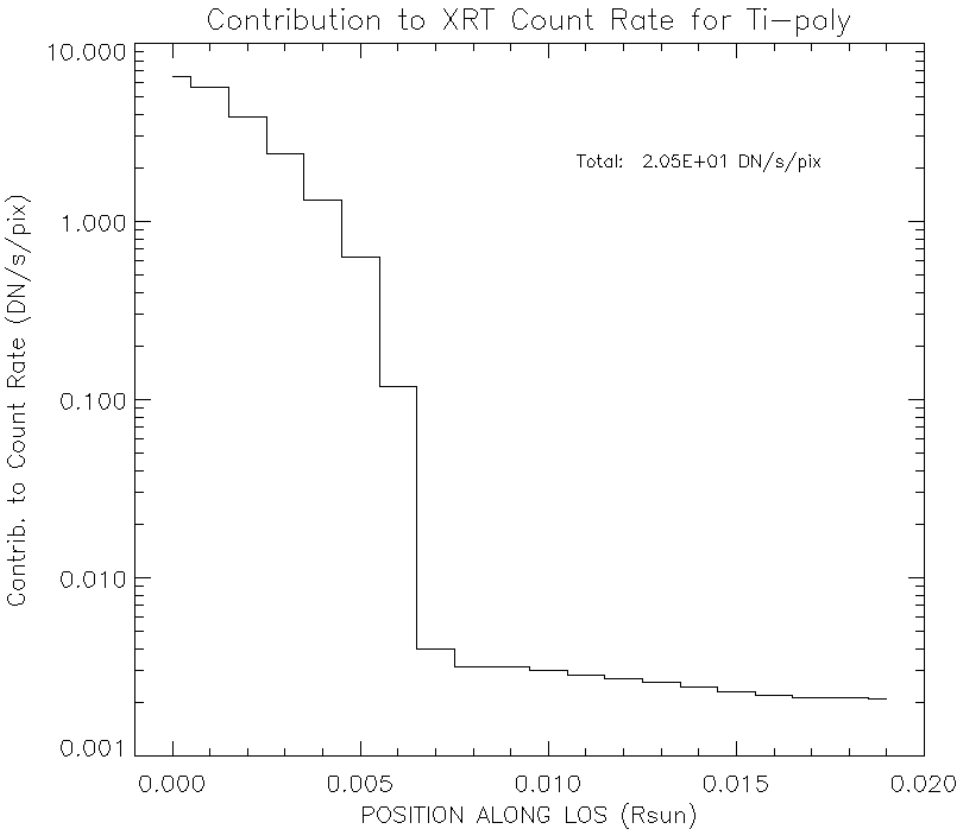


Line of sight

Computing XRT Intensities

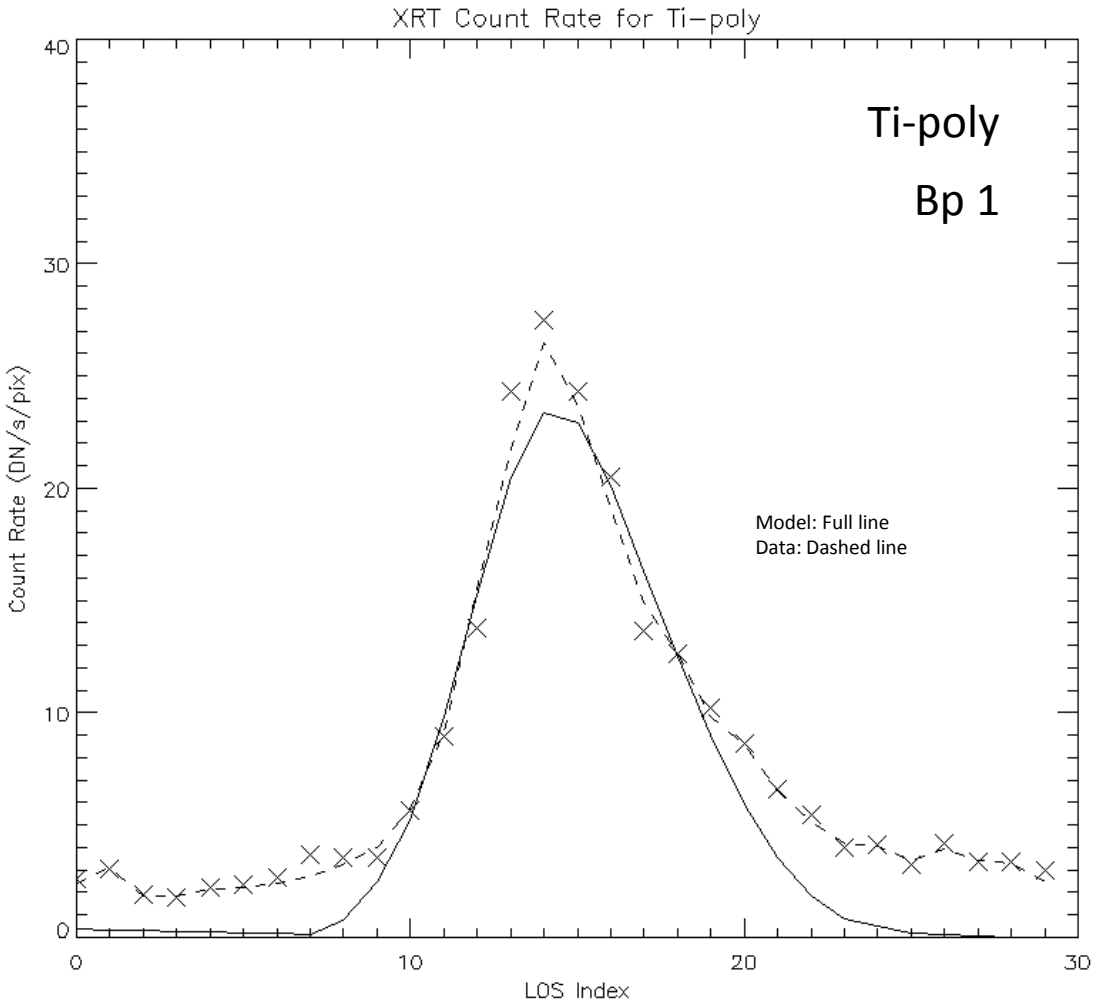


Field line



Line of sight

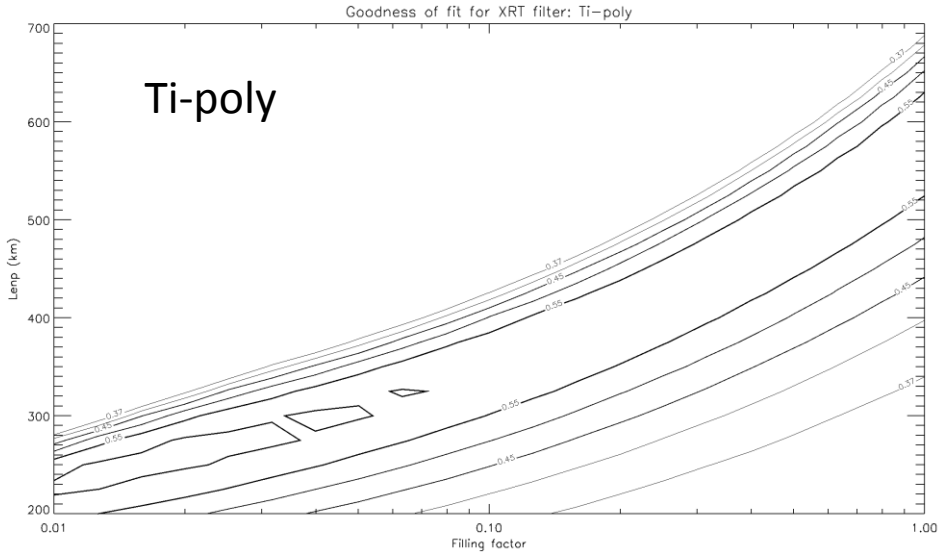
Comparing to XRT data

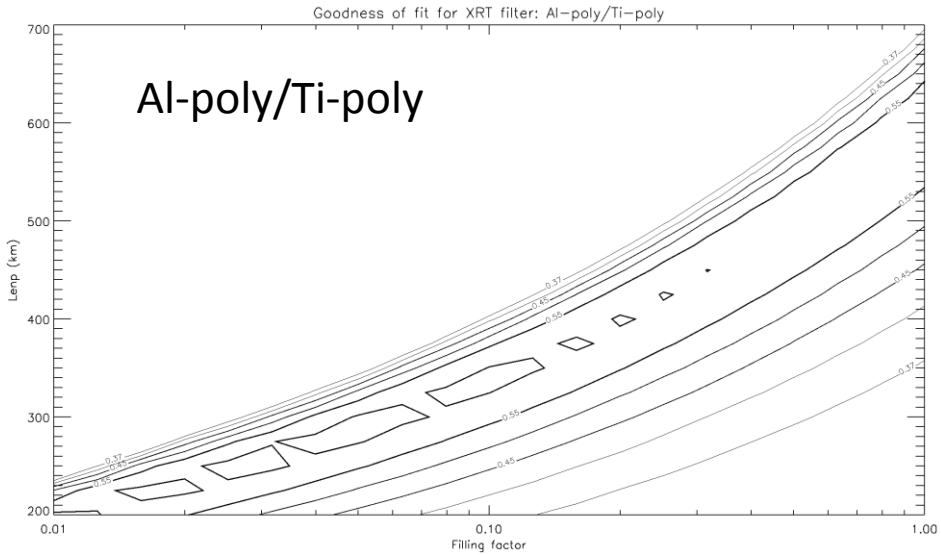


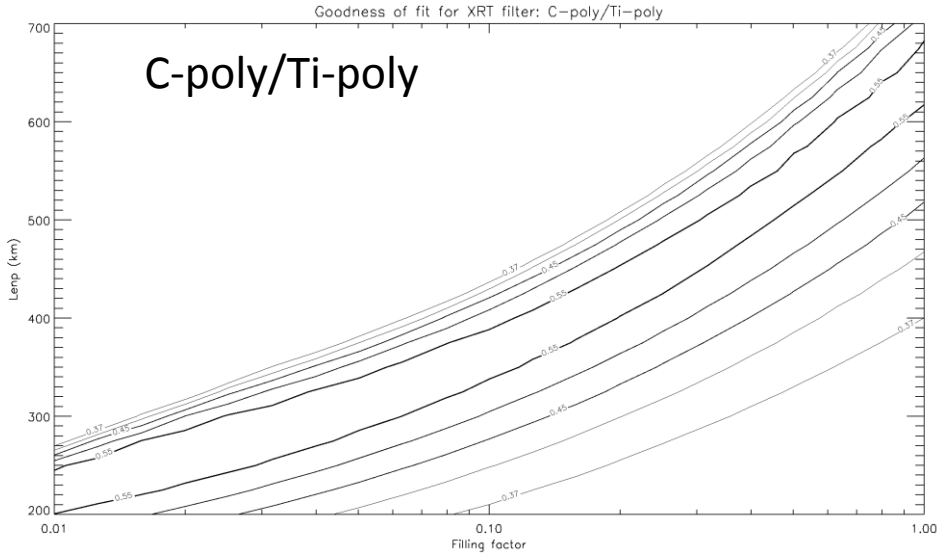
Measuring the fit

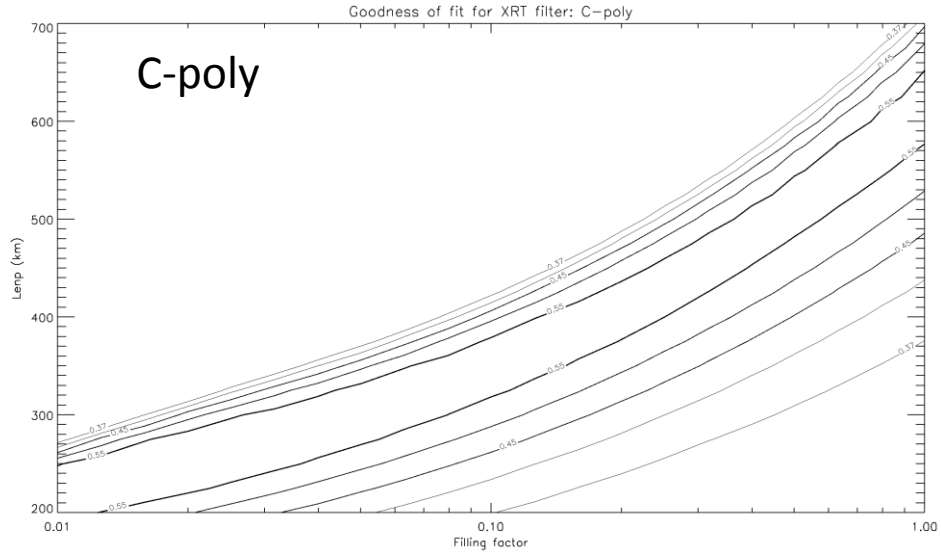
$$\exp\left(-\frac{1}{\nu}\sum_{LOS}\left(\frac{O_i - E_i(f, L_p)}{O_i}\right)^2\right)$$

Bp 1

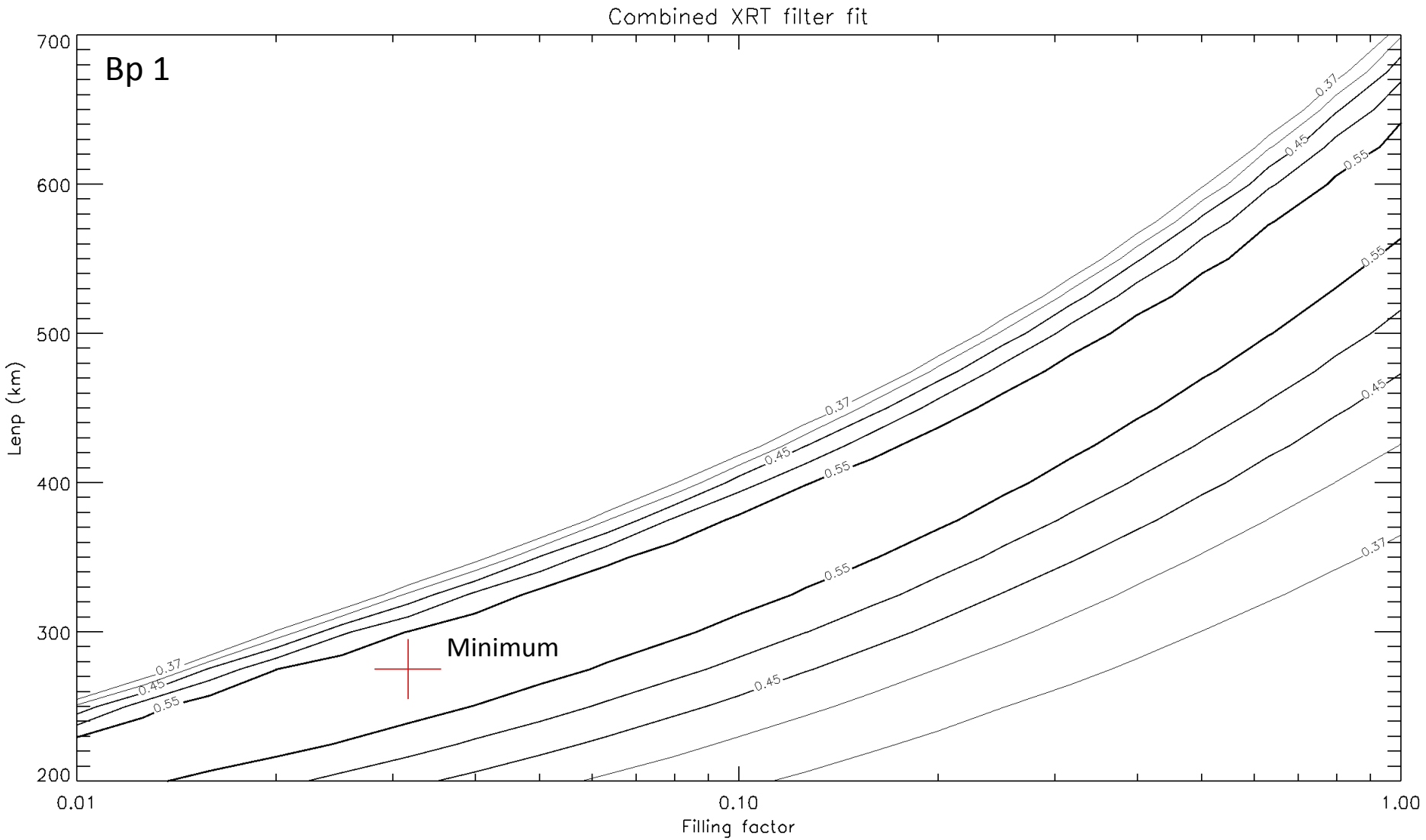




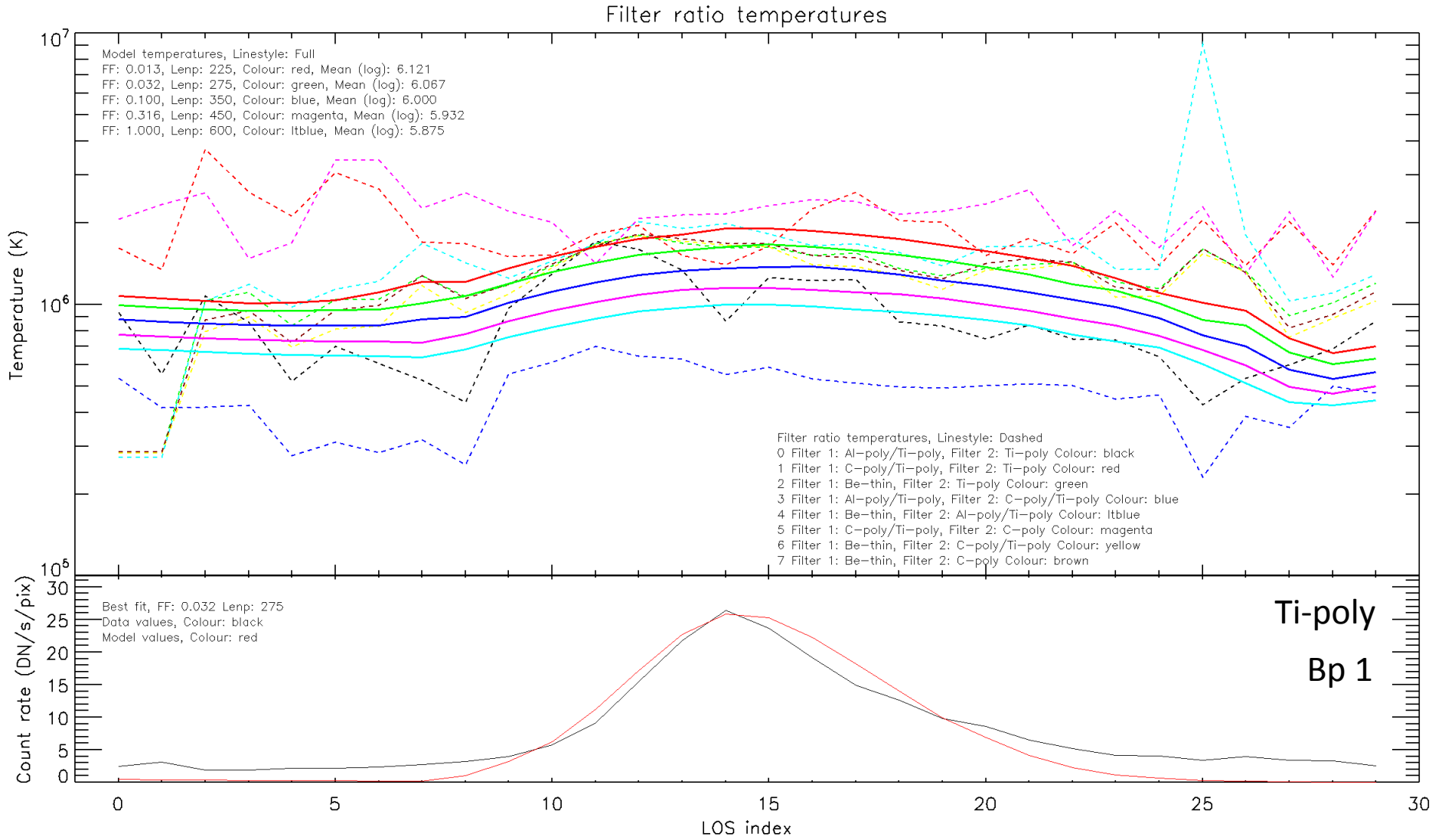




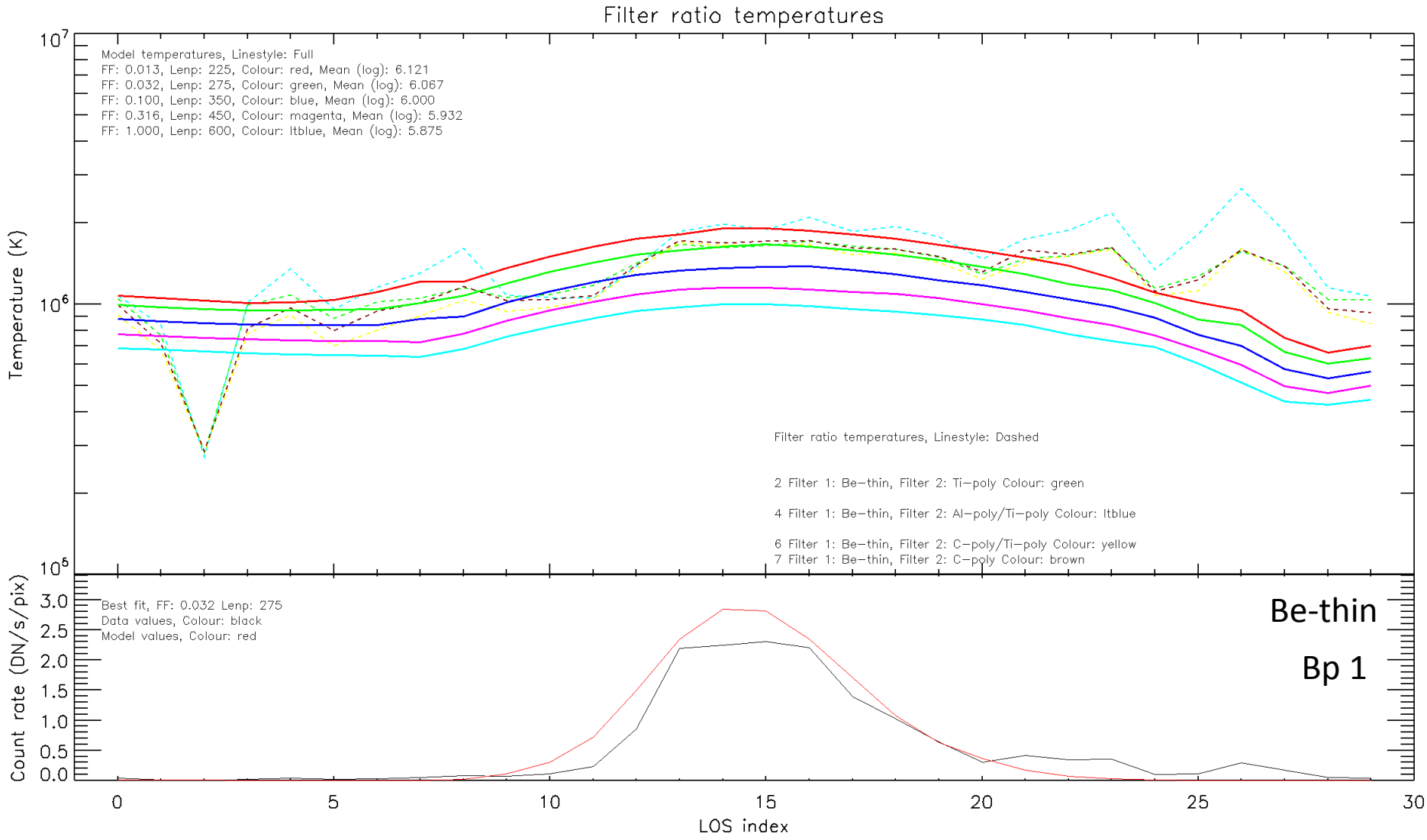
Combined fit



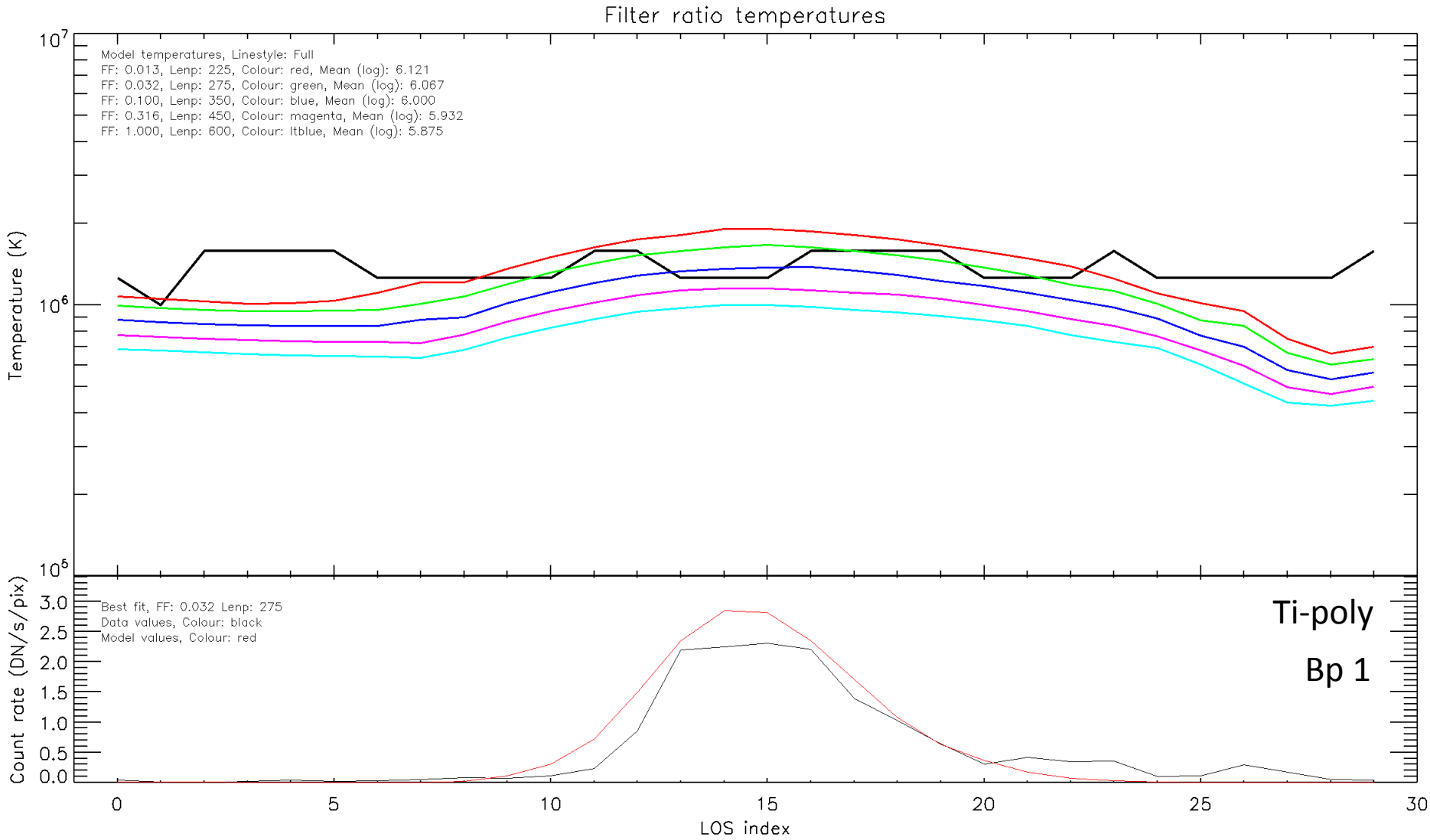
Fitting the Temperature



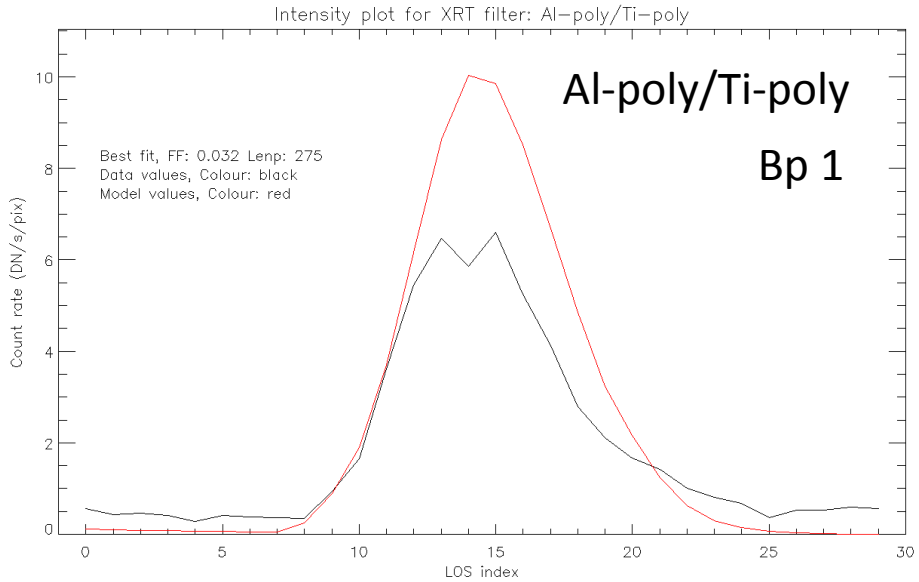
Fitting the Temperature

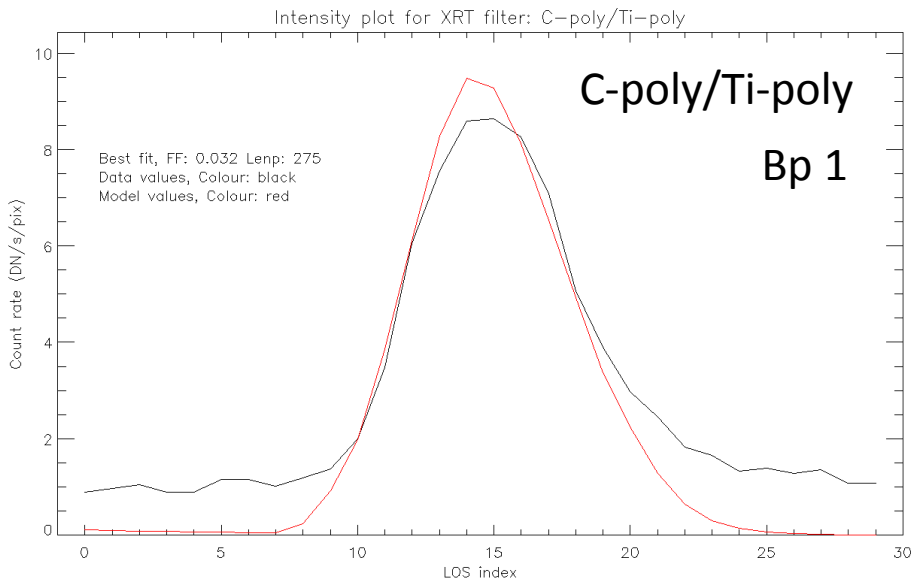


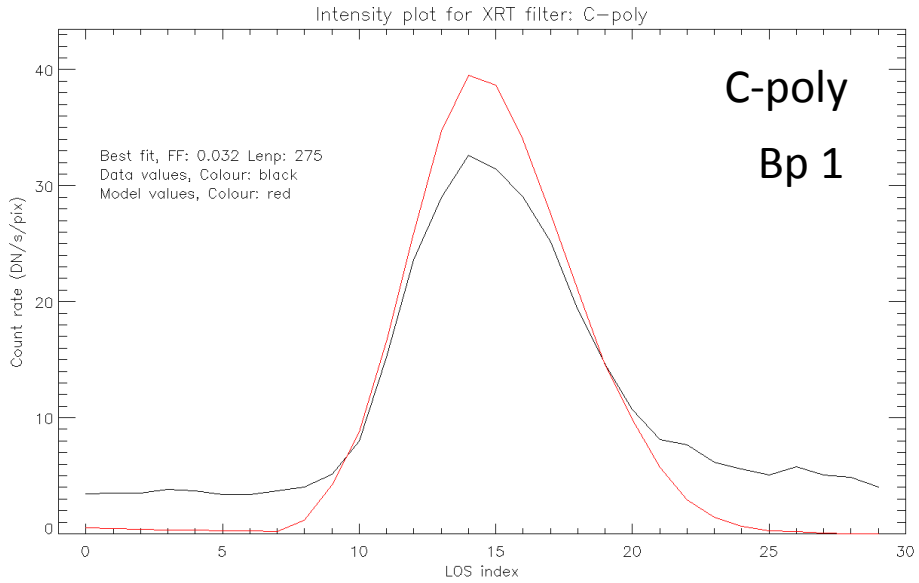
Fitting the Temperature

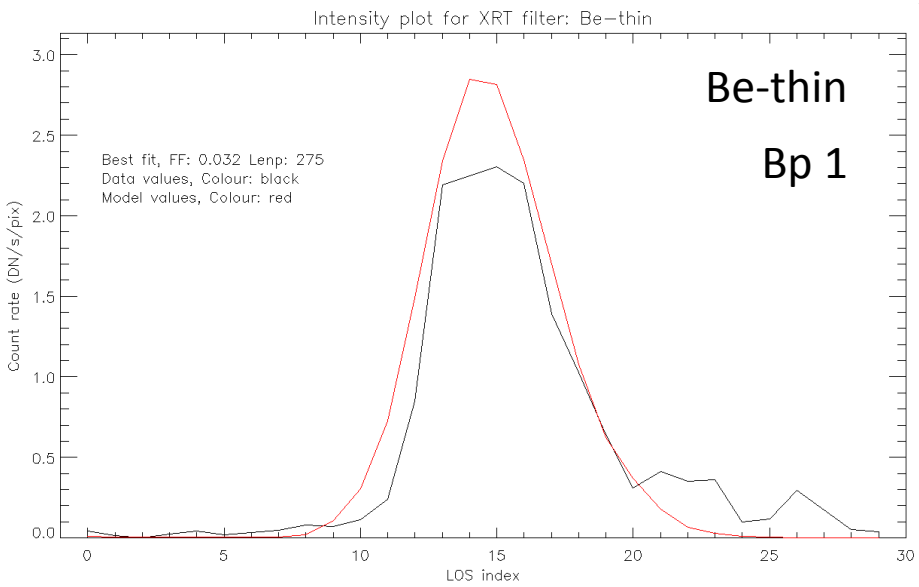


Intensities in other filters









Errors

Using this XRT data, we cannot uniquely determine the filling factor. Need longer exposures in thicker filters?

Other sources of error/uncertainty:

- Alignment of XRT images to the magnetogram.
- Calibration of XRT intensities.
- Unclear what the statistical errors are.
- XRT response rates.
- Heating model is time averaged, but bright point intensities oscillate (Kariyappa & Varghese 2008).
- Plasma beta > 1 for low filling factors.

Conclusions

- For this bright point a good fit can be achieved for all 5 filters.
- This method has also been successfully applied to other bright points (in this and other data-sets).
- Fits are not always found for more complicated magnetic structures.
- Systematic difference found at the sides of the features.
- Work with density sensitive line ratios has found bright point filling factors < 0.1 (Dere 2008 & 2009).

Thanks to Aad van Ballegooijen, Steve Saar, Henry (Trae) Winter III, Kelly Koreck and everyone else!