Search for Collisions and Planet-Disk Interactions in the Beta Pictoris Disk with Long Baseline, High Precision HST/STIS Imaging

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Goals & Motivations

- Measure surface brightness variations in the Beta Pictoris disk between three epochs of data (2012, 2021, 2023)
- Constrain the level of planet-disk interactions between epochs
- Search for signals of planetesimal collisions in the disk and quantify sensitivity

Midplane Surface Brightness Measurements

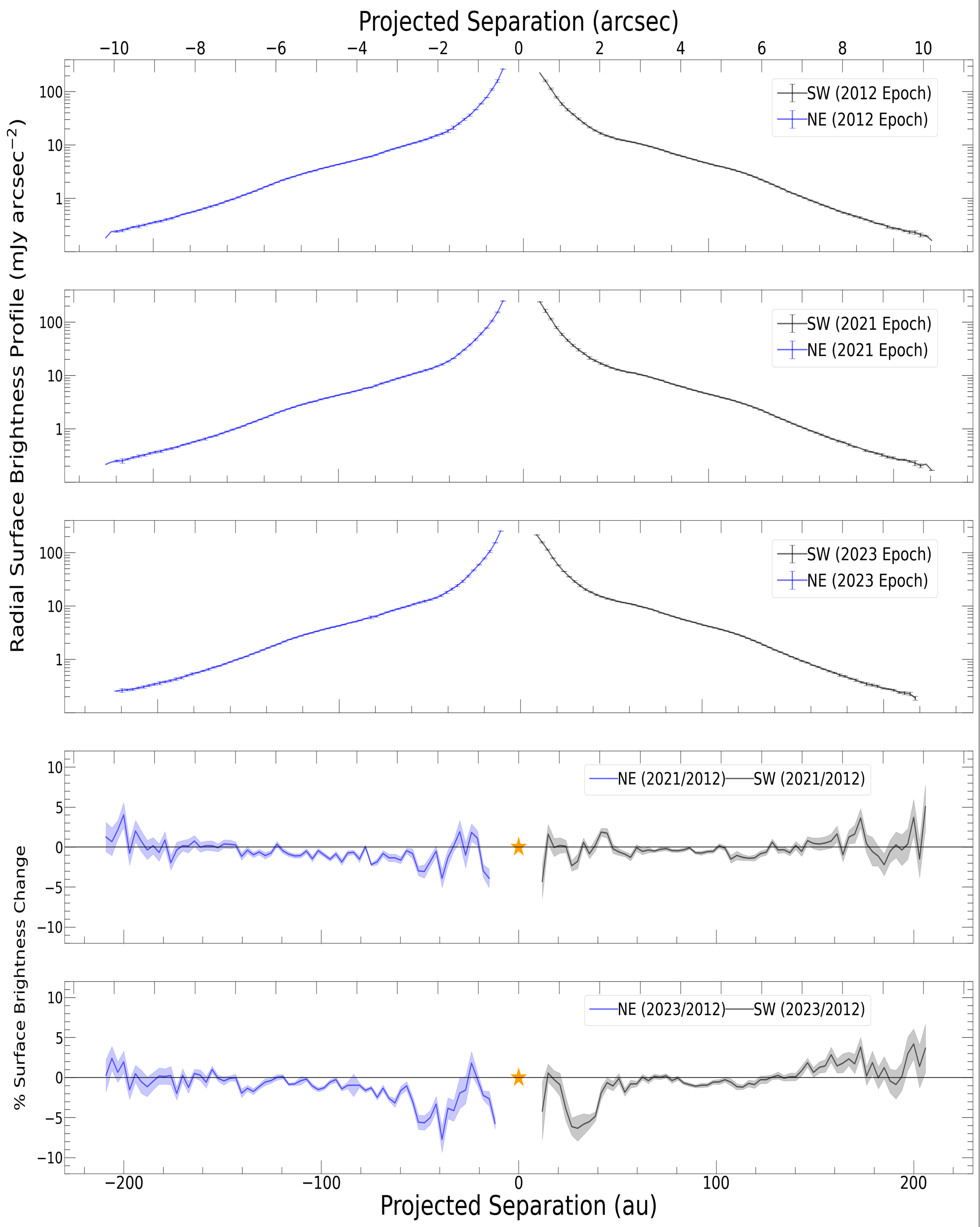

Figure 1 - Top three panels: Midplane radial surface brightness profiles of the three epochs of Beta Pic's debris disk. Bottom two panels: Midplane radial surface brightness ratio measurements between epochs. Shaded regions indicate 1-sigma uncertainties. In our highest SNR regions of the disk (50-150 au), we obtain sub-percent precision of the surface brightness changes from epoch to epoch.

2D Collisional Sensitivity Map

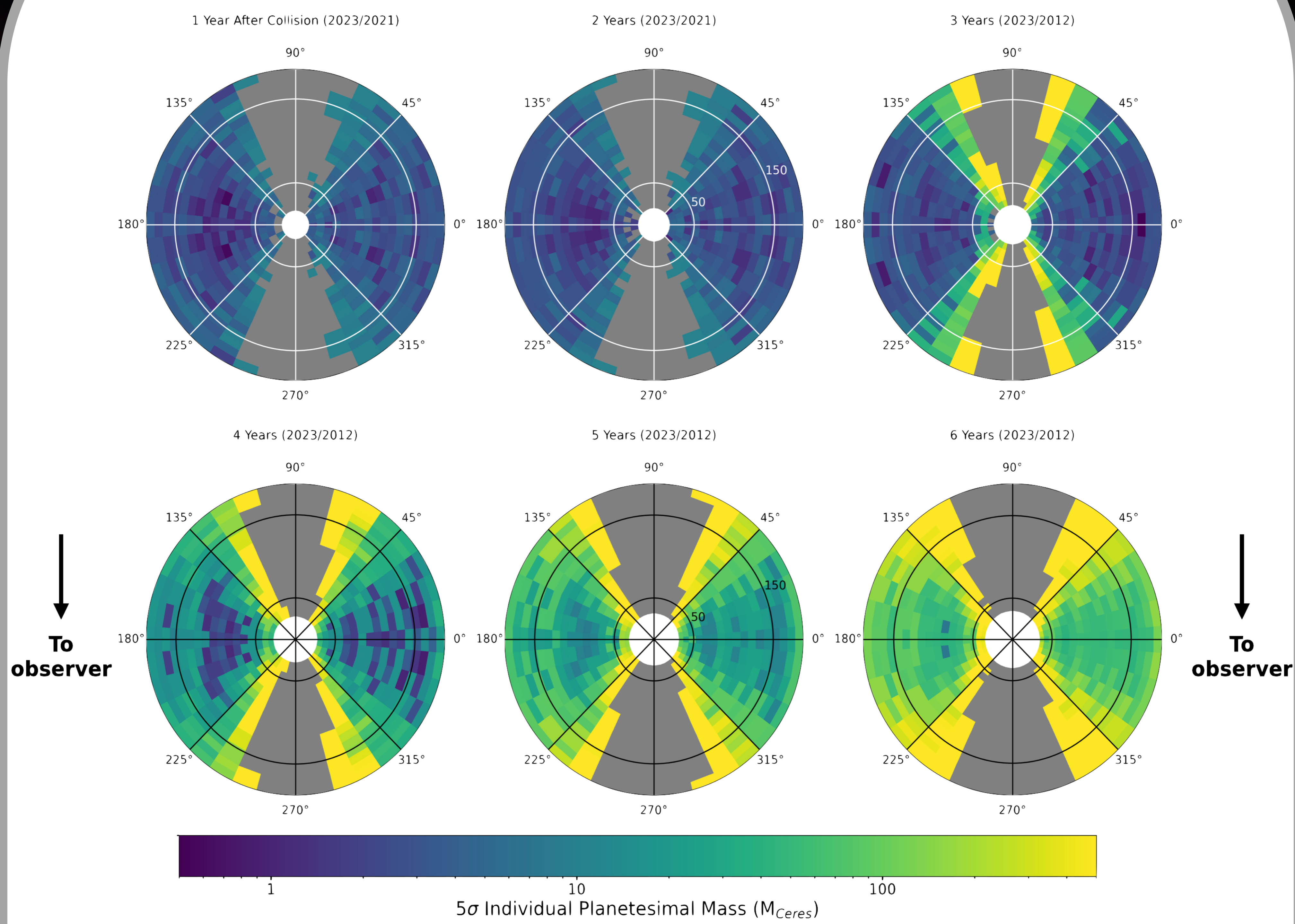

Figure 2 - 5σ 2D collisional sensitivity maps for the Beta Pic disk. Each map shows the mass of a single collisional progenitor (assuming both progenitors are equal mass) needed to have a 5σ detection in our ratio maps. The radial labels are shown in units of au. The maps are shown from a face-on perspective of the disk, and the black arrows indicate the direction to the observer. We can see an order-of-magnitude increase in progenitor mass required for a detection over the 6 years modeled, pointing to continual monitoring being essential to finding collisional remnants in scattered light observations and observing multi-wavelength evolution of the remnants.

Collisions Modeling + Injection/Retrieval

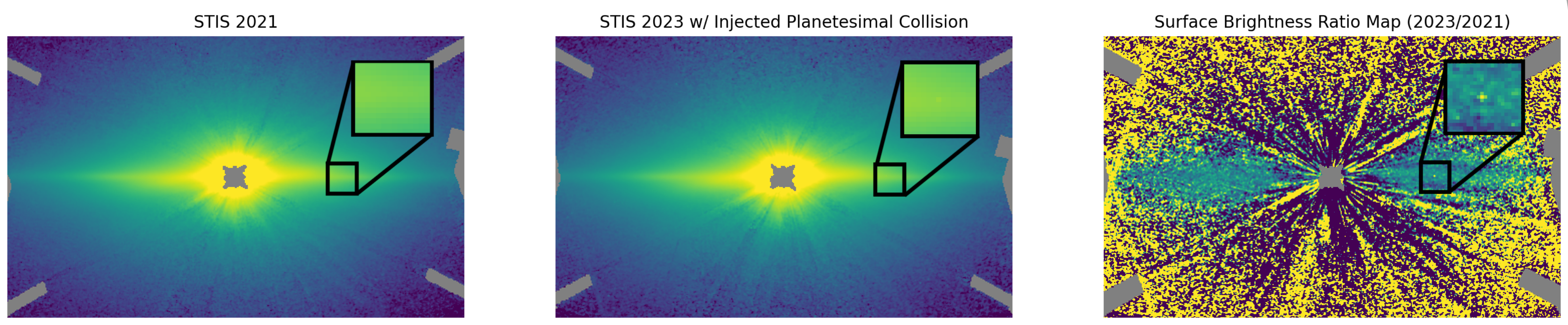

Figure 3 - We created an order-of-magnitude planetesimal collisional model to understand how a collision would appear in our data. We can see a simulated collision between two progenitors (8 Ceres masses each) is barely visible in the 2023 data and can easily be missed in single epochs. Creating a ratio map (2023/2021) clearly reveals the collision, which has an SNR of ~14. No point source-like signals (which are expected for recent collisions) with an SNR greater than 2 have been thus far detected, and monitoring is ongoing.

Constraints on Planet-Disk Interactions

- Migration of massive planets over multiple au can capture surrounding planetesimals and dust into a resonance, similar to Jupiter's Trojans
- Modeling of Beta Pic b's migration has shown that we would expect surface brightness changes *as large as 300%* as the planet and the cloud orbit the central star (Wyatt 2006)
- We find the inner disk surface brightness to change by ≤5% from 2012 to 2023

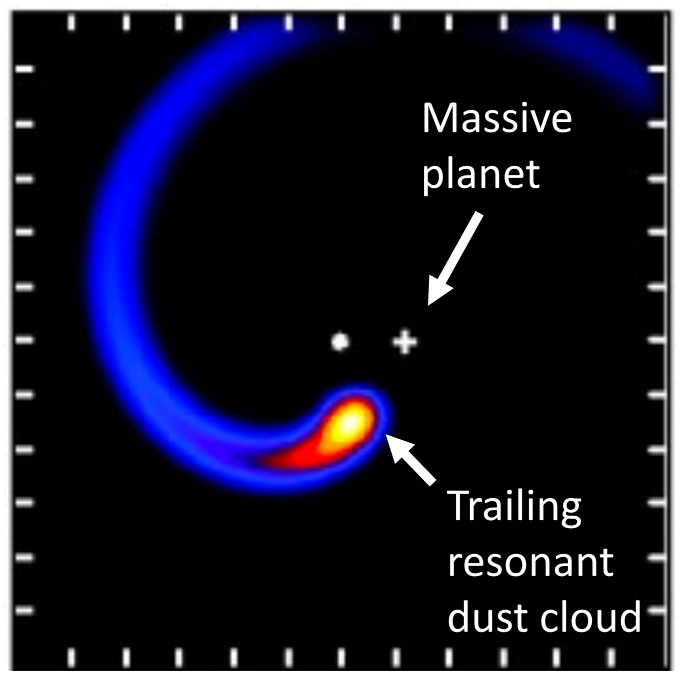

Figure 4 –Model of a resonant dust cloud trailing a massive planet seen from a face-on perspective from Wyatt 2006

Key Results

- We constrain the level of surface brightness variations between 10-200 au, informing our understanding of planet-disk interaction models
- We create a planetesimal collision model, which we use to constrain our sensitivity limit down to 1 Ceres mass per progenitor up to 3 years after collision. Monitoring of the disk in search of collisional remnants is ongoing
- Paper reporting results of this work has been submitted to ApJ (Avsar et al.)