Accretion Outbursts in Protoplanetary Disks

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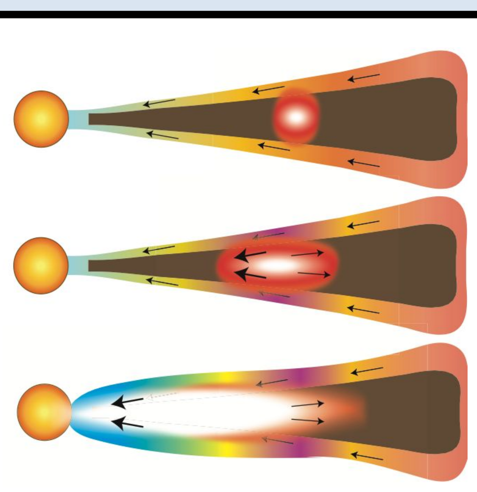
We compute model lightcurves and spectral energy distributions of accretion outburst events from protoplanetary disks. We input variable initial disk properties in order to make predictions on the amplitude and timescale of the outbursts. From previous simultaneous observations in the optical (Gaia) and infrared (NEOWISE), we anticipate an earlier observation of the outburst in the infrared than in the optical spectrum. Using this knowledge, our goal is to then constrain the location at which the outburst started in the disk and attempt to determine the level of mass and angular momentum transport that lead to the observed phenomena.

Background: Outbursts in Protoplanetary Disks



- Protoplanetary Disks are the disks of gas and dust around protostars and T Tauri stars.
- It is thought that matter infalling from the surrounding medium onto the disk adds more mass onto the disk than can accrete upon the star.
- This creates an instability in the system at which point a temperature spike begins in the disk. This causes the disk to accrete much more quickly, resulting in a wave of mass moving in; the release of gravitational potential energy causes the disk to become hotter and radiate more strongly.
- This outside-in accretion should result in an outburst that is cooler at large radii, first visible at long wavelengths, and then later visible at short wavelengths from the hot inner disk.

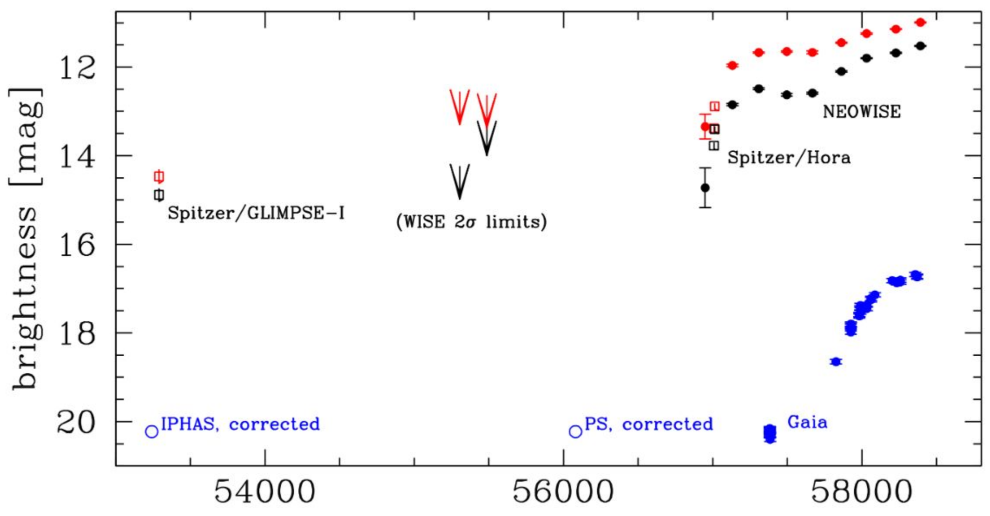


Fig: Top Right: visual representation of the process by which a low temperature spike in the outer disk, simultaneously moves inward while becoming hotter as it goes. Bottom Right: Data from (Hillenbrand et al, 2018) of an outburst with an infrared precursor. Displayed are 3 lightcurves at 0.67, 3.4,and 4.5 microns . The infrared data are mostly from NEOWISE with a few Spitzer points; and the optical data are from GAIA. The outburst is first seen at infrared wavelengths, as is expected for an outburst that starts at large radii and travels inwards.

Effective Temperature Distributions:

- One dimensional models of disk outbursts triggered by activation of the magnetorotational instability (Bae, 2015) provided the temperature-time data to synthesize the light curve.

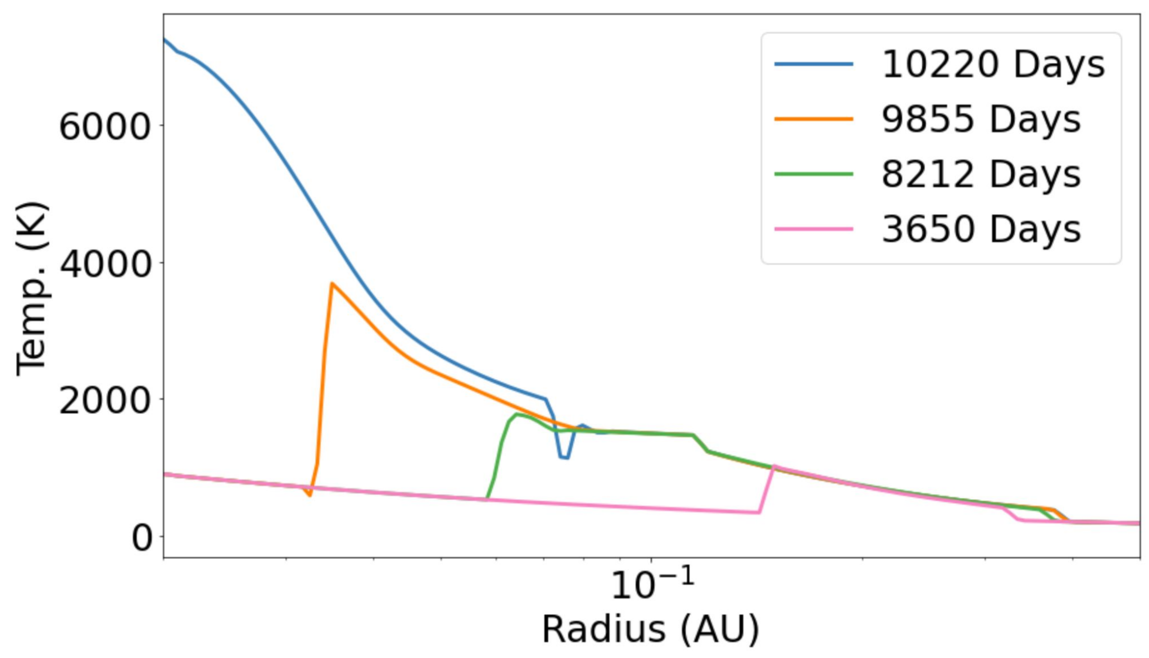


Fig: plot of Effective Temperature vs Radius for a range of times. As time increases, temp. increases and temp. spike moves inwards.

Numerical Methods: Synthetic light curves

- We begin by determining the λL_λ:

$$\lambda L_\lambda = \int_{R_1}^{R_2} 4\pi^2 R \lambda I_\lambda [T_{eff}(R)] dR$$

- The planck function (assumed blackbody radiation) was used for all temperatures outside our model temperature grid.
- In the grid, for all temperatures in between 2700 K and 15000 K we used a 2 Ångstrom resampled theoretical spectra model:

BT-NextGen (AGSS2009)

- This model provided a grid of flux (I_λ) and wavelength values for the above mentioned range of temperatures
- We also input a theoretical star in the model with assumed radius of 1 solar radius and effective temperature of 3800 K.
- We then place the star/disk at a distance of 1.27 Kpc, convert L_λ to flux and then subsequently to AB magnitude

Synthetic Photometry: Stellar Spectra Model

- Using our solar photometry model we were able to create synthetic spectra for a single point in time.

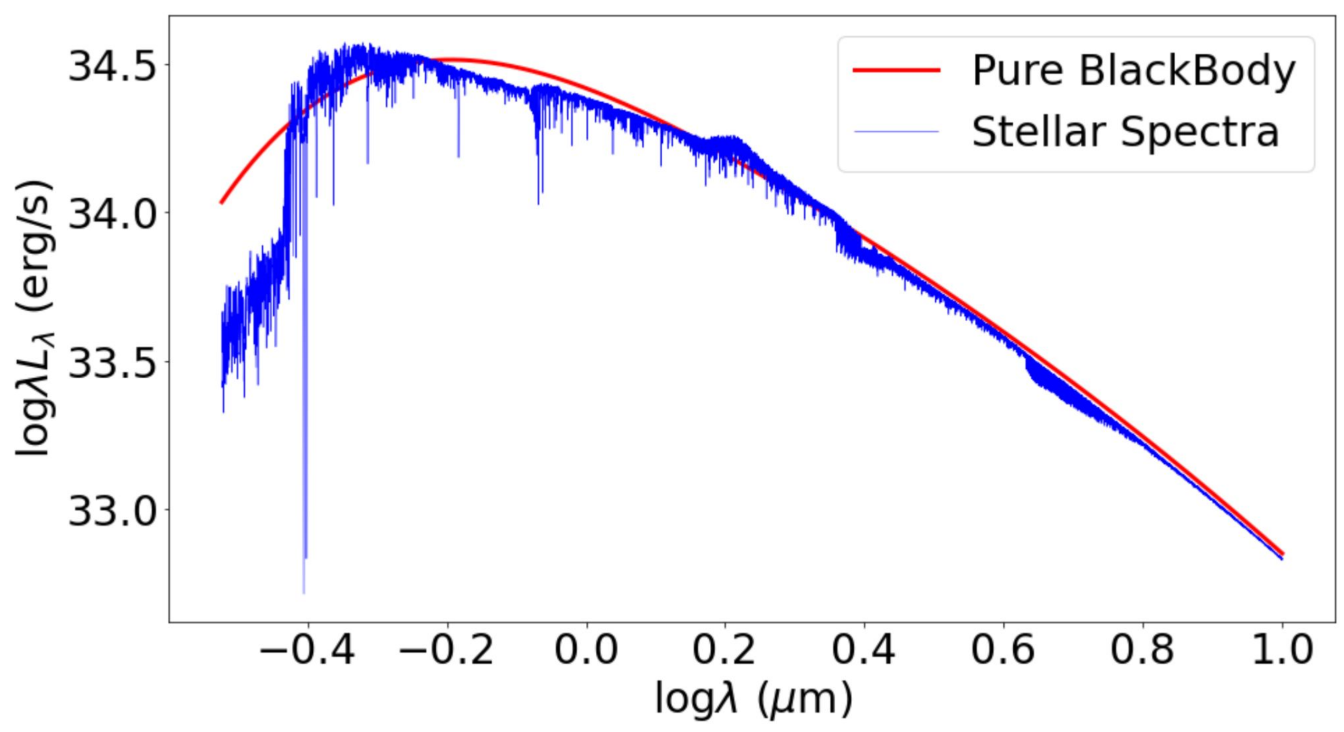
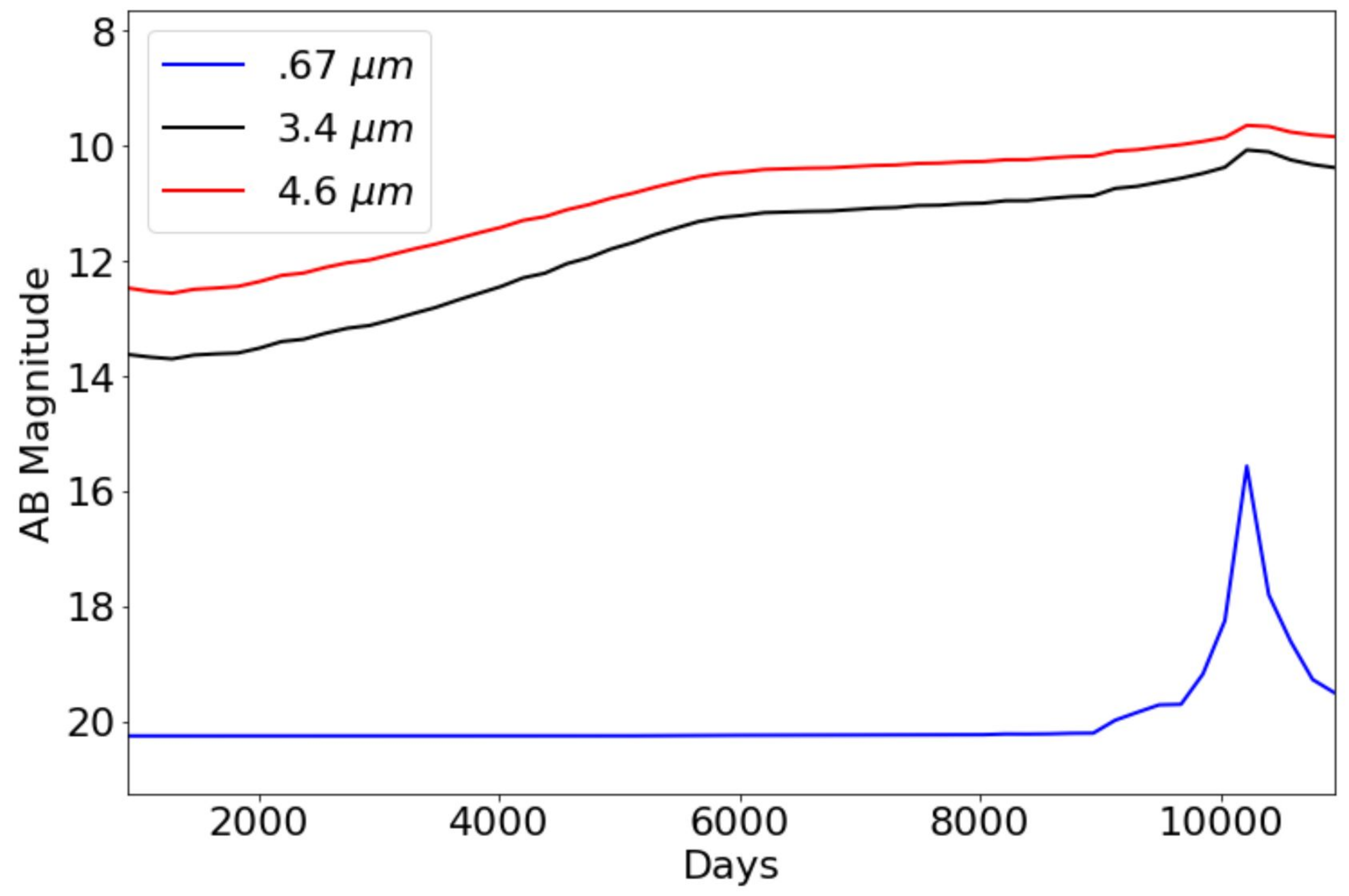


Fig: plot of synthetic spectra and pure blackbody spectra for range of .3 to 10 micrometers. Synthetic photometry was created with BT-NextGen model.

Results

- Results in general follow the expected trend: observation of the outburst in the infrared (3 and 4.5 micron) before a later observation in the optical (.67 micron).
- While the overall trend is good, there is still much room for improvement in terms of the length and magnitude increase of the outburst in the infrared wavelengths.
- An extinction of roughly A_V = 3 was factored in for the optical wavelength in order to account for interstellar reddening.

Fig: Synthetic lightcurves created using methods and temperature dist. as mentioned in Numerical Methods. Plotted is AB magnitude over a period of 10000 days. An initial slow outburst is seen in the infrared with a in increase in magnitude of ~3 magnitudes. A later outburst in the optical is seen but with an outburst rise of ~1000 days and an increase in magnitude of ~4.



Conclusion/Where Next:

- We were able to use synthetic spectra in order to create a model able to reproduce synthetic lightcurves. Given files of radii vs temperature for varying times, our model is able to reproduce not only spectra but also lightcurves.
- As can be seen from our results, our model was able to qualitatively replicate the behavior of an outburst that is consistent with an outside-in outburst.
- Our next goal is to begin to modify the parameters of the highly simplified one dimensional time-dependent disk simulations to see if we can achieve a better match to the observed data.

References

Hillenbrand *et al* 2018 *ApJ* 869 146

Bae, J., Hartmann, L., & Zhu, Z. *2015, ApJ*, 805, 15