# Magnolia

# Modeling AGN Optical Lightcurves via inference of AD-BLR lag

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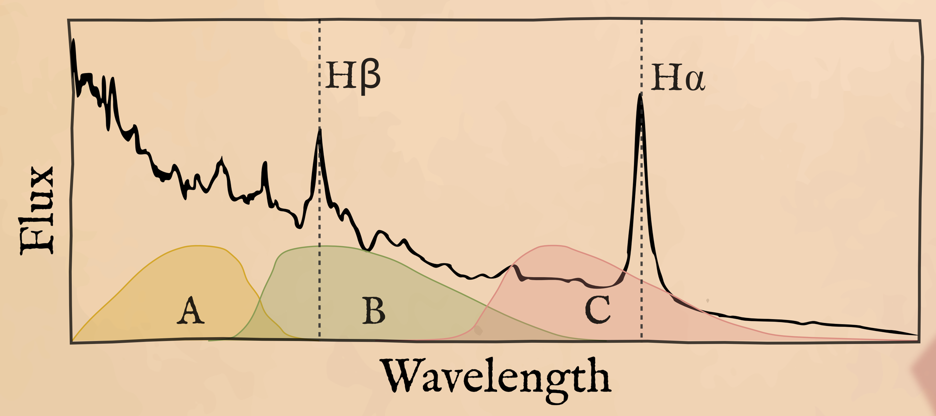
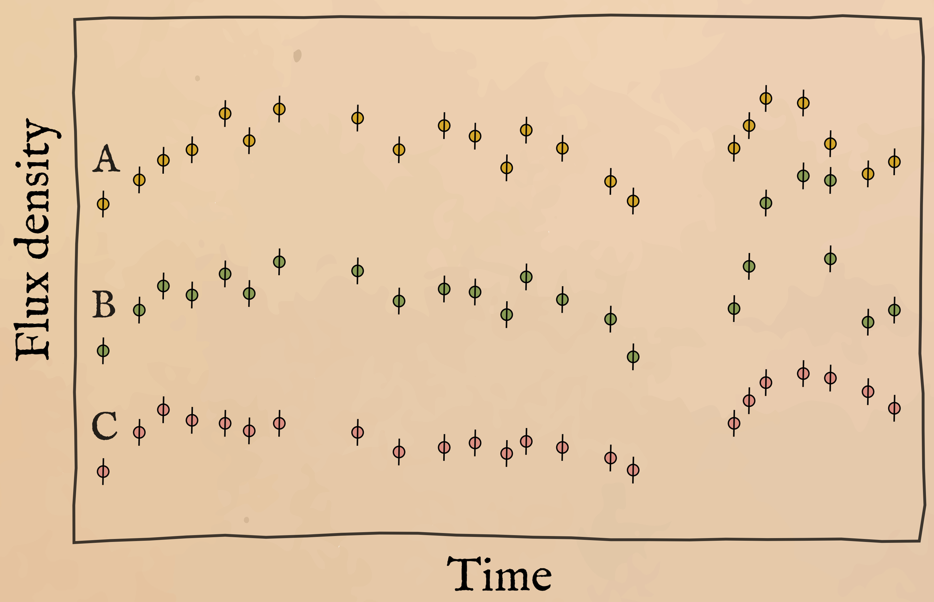
## *What is an AGN?*

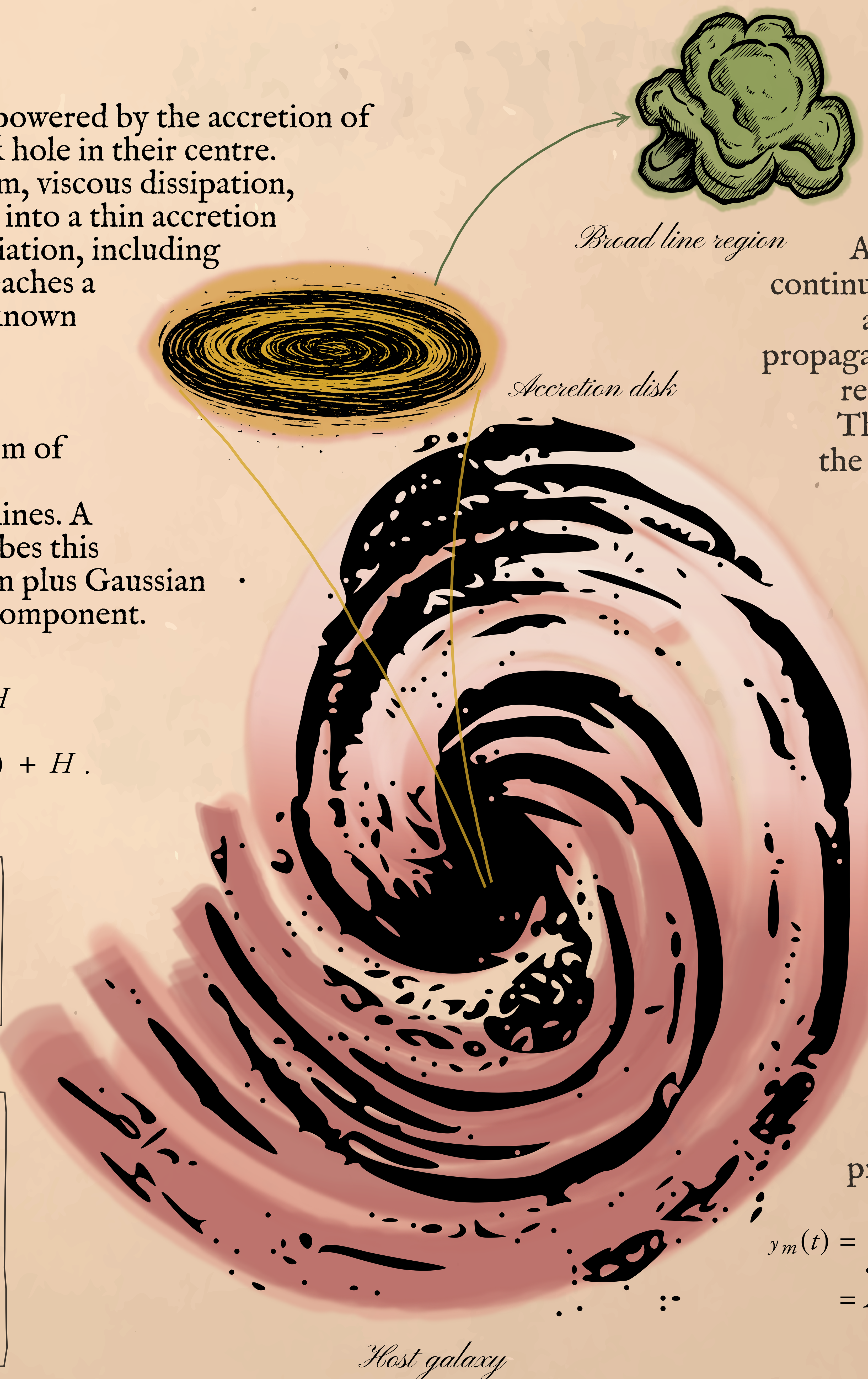
Active Galactic Nuclei (AGN) are powered by the accretion of matter onto the supermassive black hole in their centre. Conservation of angular momentum, viscous dissipation, and cooling shape the infalling gas into a thin accretion disk (AD), which emits thermal radiation, including ionizing photons. This radiation reaches a dense, dust-free region of clouds known as the broad line region (BLR), photoionizing the gas.

As a result, the UV-optical spectrum of an AGN is dominated by the AD continuum and the BLR emission lines. A widely used empirical model describes this spectrum as a power-law continuum plus Gaussian emission lines, plus a host-galaxy component.

$$\xi(\lambda) = AD(\lambda) + BLR(\lambda) + H$$
$$= b \cdot \lambda^{-\gamma} + \sum_{n=1}^{N} w_i \cdot \phi_i(\lambda) + H .$$




## *Optical variability*

AGN are variable sources. The AD continuum flux variability is triggered by accretion changes. This variability propagates outward, producing a delayed response in the BLR emission lines. This time delay, $\Delta\tau$, corresponds to the light-travel time between the AD and the BLR.

We model this variability with a Gaussian Process (GP), $g$, assuming the AD and BLR share the same temporal behaviour except for the lag $\Delta\tau$. The GP has zero mean and an Ornstein-Uhlenbeck kernel, capturing the AGN stochastic nature.

$$\xi(\lambda, t) = AD(\lambda) \cdot g(t) + BLR(\lambda) \cdot g(t - \Delta\tau) + H .$$

Integrating the spectral model against the transmission curves of each photometric band, $m$, predicts the observed light curves:

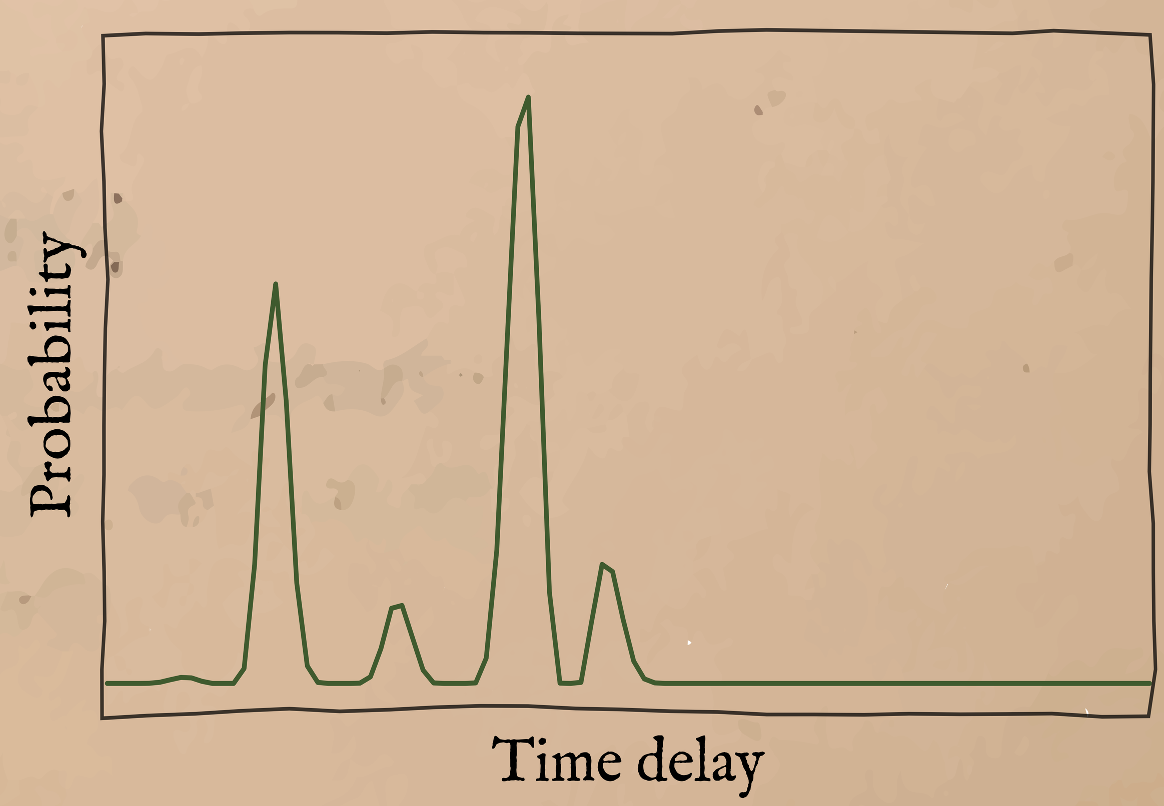
$$y_m(t) = \int \mathcal{T}_m(\lambda) \cdot \xi(\lambda, t) \cdot \lambda \, d\lambda + \sigma_m$$
$$= AD'_m \cdot g(t) + BLR'_m \cdot g(t - \Delta\tau) + H'_m + \sigma_m .$$

## *A probabilistic approach*

Comparing the predictions to observational data yields a model likelihood with a closed-form solution.

$$\prod_{t=1}^{T} \prod_{m=1}^{L} \mathcal{N}\left(y_m(t) \mid AD'_m \cdot g(t) + BLR'_m \cdot g(t - \Delta\tau) + H'_m, \sigma_m^2\right) .$$

Evaluating this likelihood over a grid of trial delays yields a full posterior probability for $\Delta\tau$, rather than a single point estimate.




*References:*
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*Acknowledgments:*
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