Coupling Dynamics and Chemistry in Accreting Protoplanetary Disks

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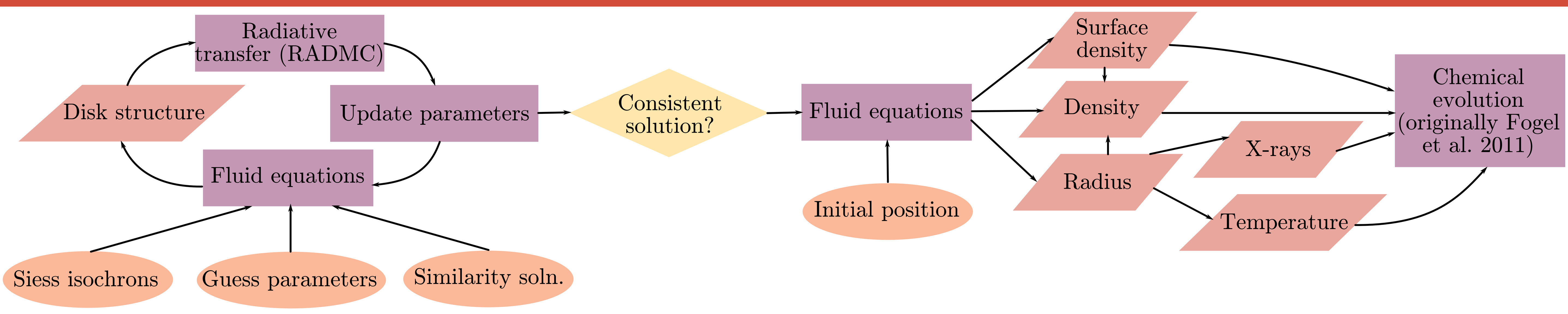
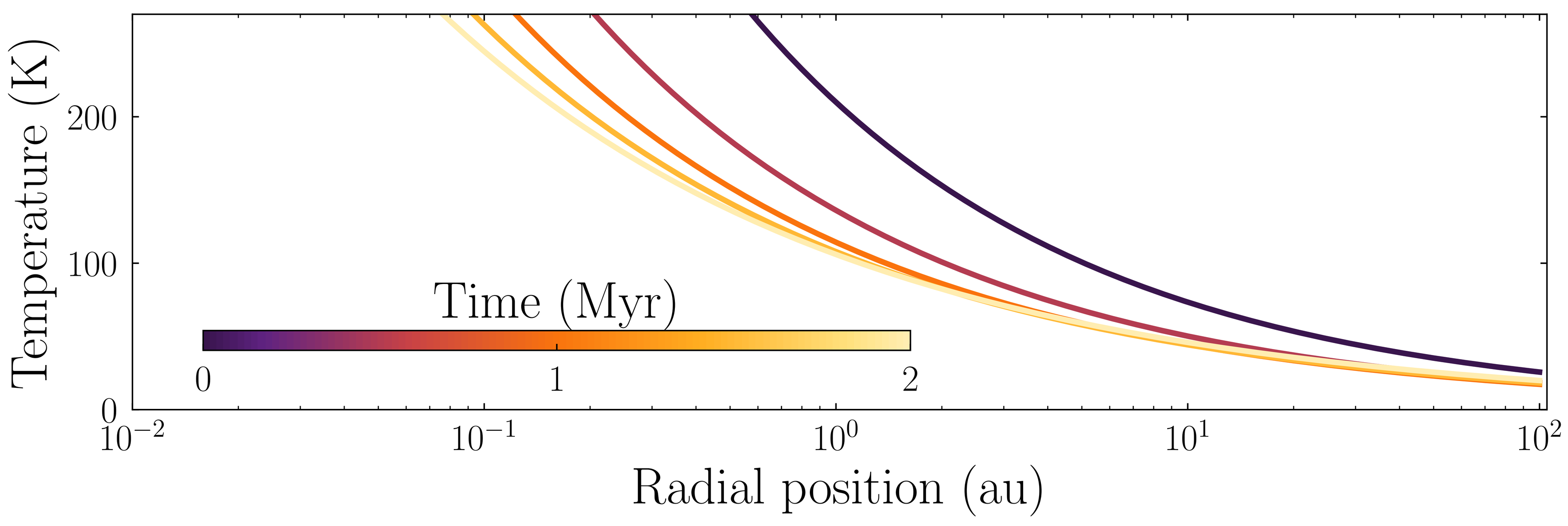
Background

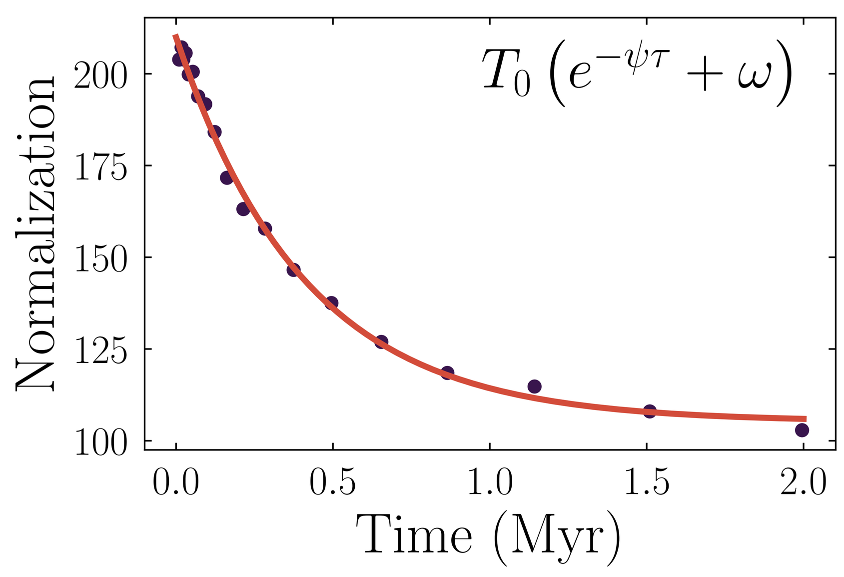
Protoplanetary disks are complex systems of dust and gas orbiting young stars. Chemical reactions determine which species become abundant and, therefore, which species will contribute to the initial compositions of forming planetesimals. Changes in physical conditions affect which chemical reactions can take place and how the disk evolves at a given radius. Many existing disk chemistry codes compute time-varying chemistry as a function of radius in the disk but do not take into account the changing physical conditions. Codes which do couple chemistry and dynamics are frequently computationally expensive, preventing thorough exploration of parameter space. **We take a different approach by following local physical conditions in accretion streams of gas and small grains in the midplane,** which allows us to determine how disk parameters affect the underlying disk chemistry.

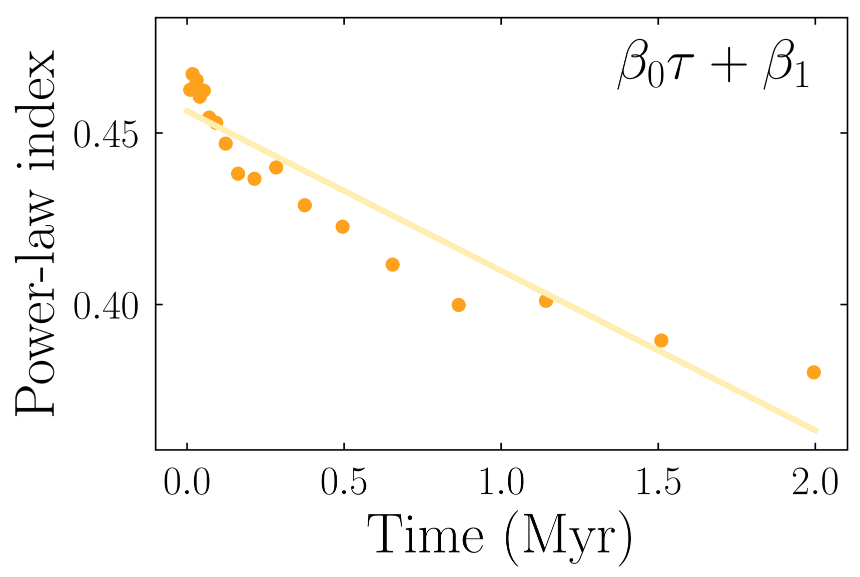
Methods



Disk Temperature Evolution

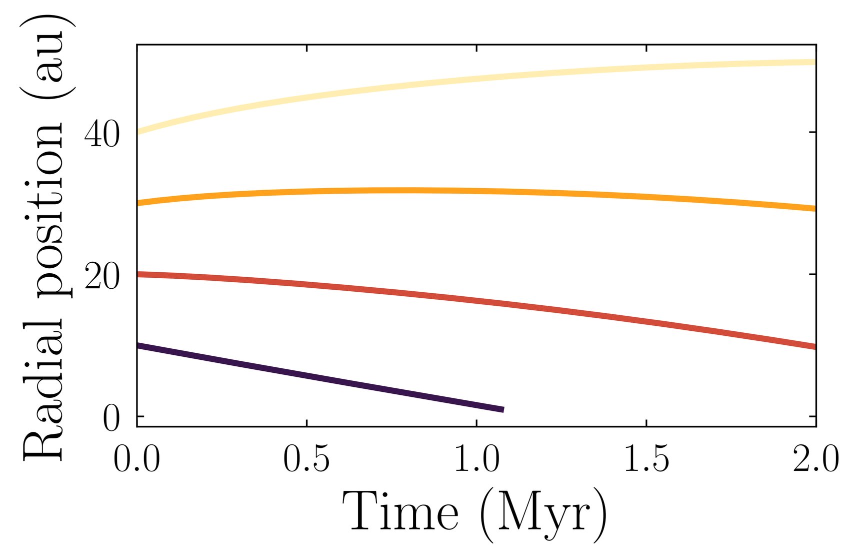


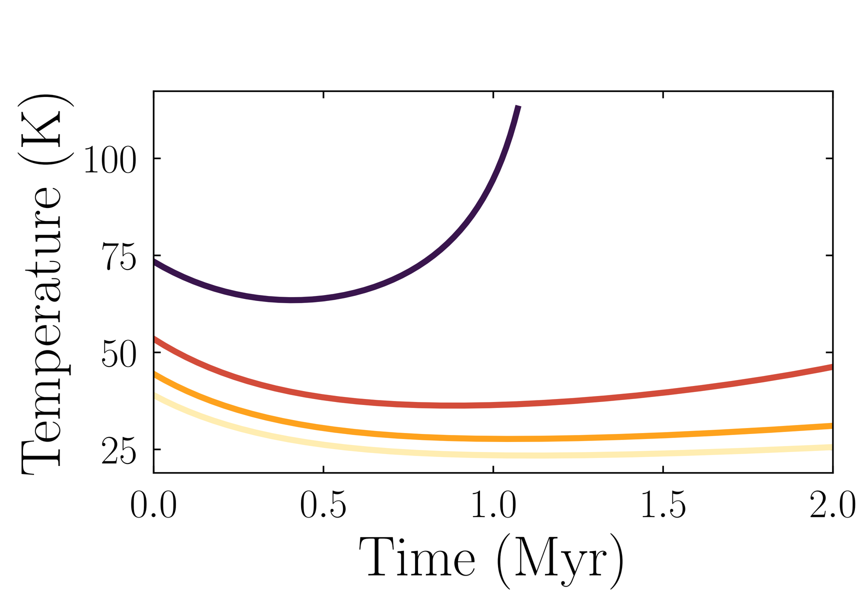


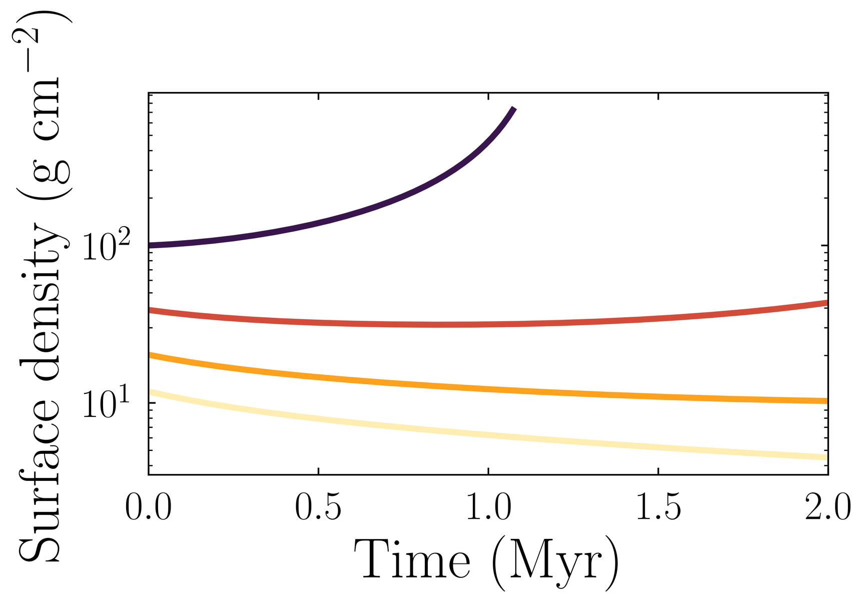


Accreting Gas Parcel Trajectories

For tracks with various initial radii, we show the evolution of the local physical parameters in the midplane as the parcel of gas follows the bulk motion of the gas and the star evolves. Even a track that moves monotonically inward (towards the star) can experience non-monotonic temperature changes due to the stellar evolution.

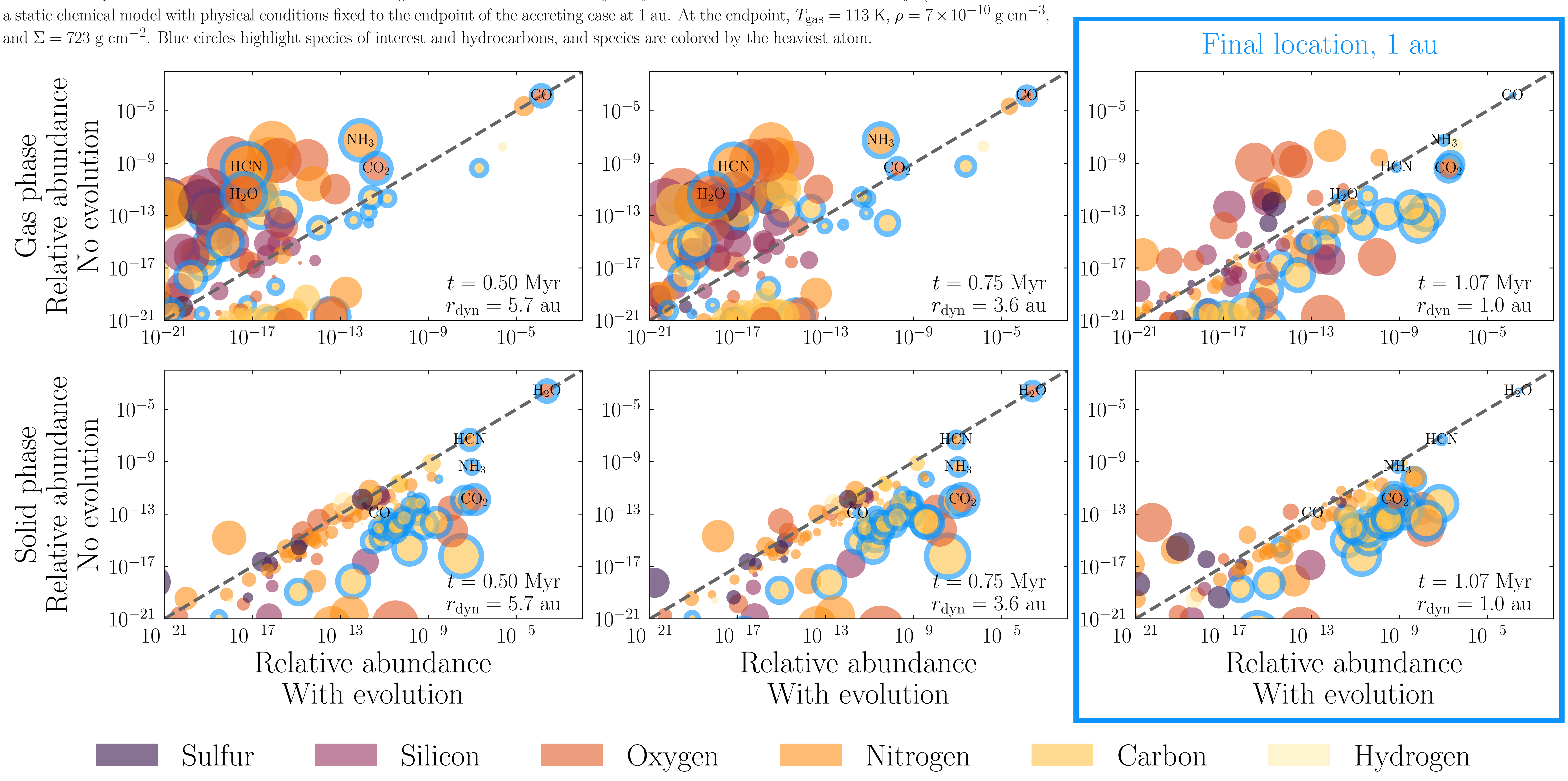






Dynamic vs. Static Abundances for the Inner Disk

Below, we compare the chemical abundances of an accreting disk chemical model for a trajectory that travels from 10 au to 1 au in 1 Myr (with evolution) to a static chemical model with physical conditions fixed to the endpoint of the accreting case at 1 au. At the endpoint, $T_{\rm gas} = 113$ K, $\rho = 7\times10^{-10}$ g cm^{-3}, and $\Sigma = 723$ g cm^{-2}. Blue circles highlight species of interest and hydrocarbons, and species are colored by the heaviest atom.



Results

In the inner disk, the accretion history of the gas parcel enhances the abundances of hydrocarbons — both on the grains and in the gas phase — by orders of magnitude. Nitrogen-bearing species are also mildly enhanced. Water, on the other hand, does not appear to be affected. The outer disk (radii > 10 au) is much less affected over the lifetime of the disk by viscous accretion.

References and Acknowledgements

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