Spectropolarimetry Probes Stellar Mass Loss at Cosmological Distances

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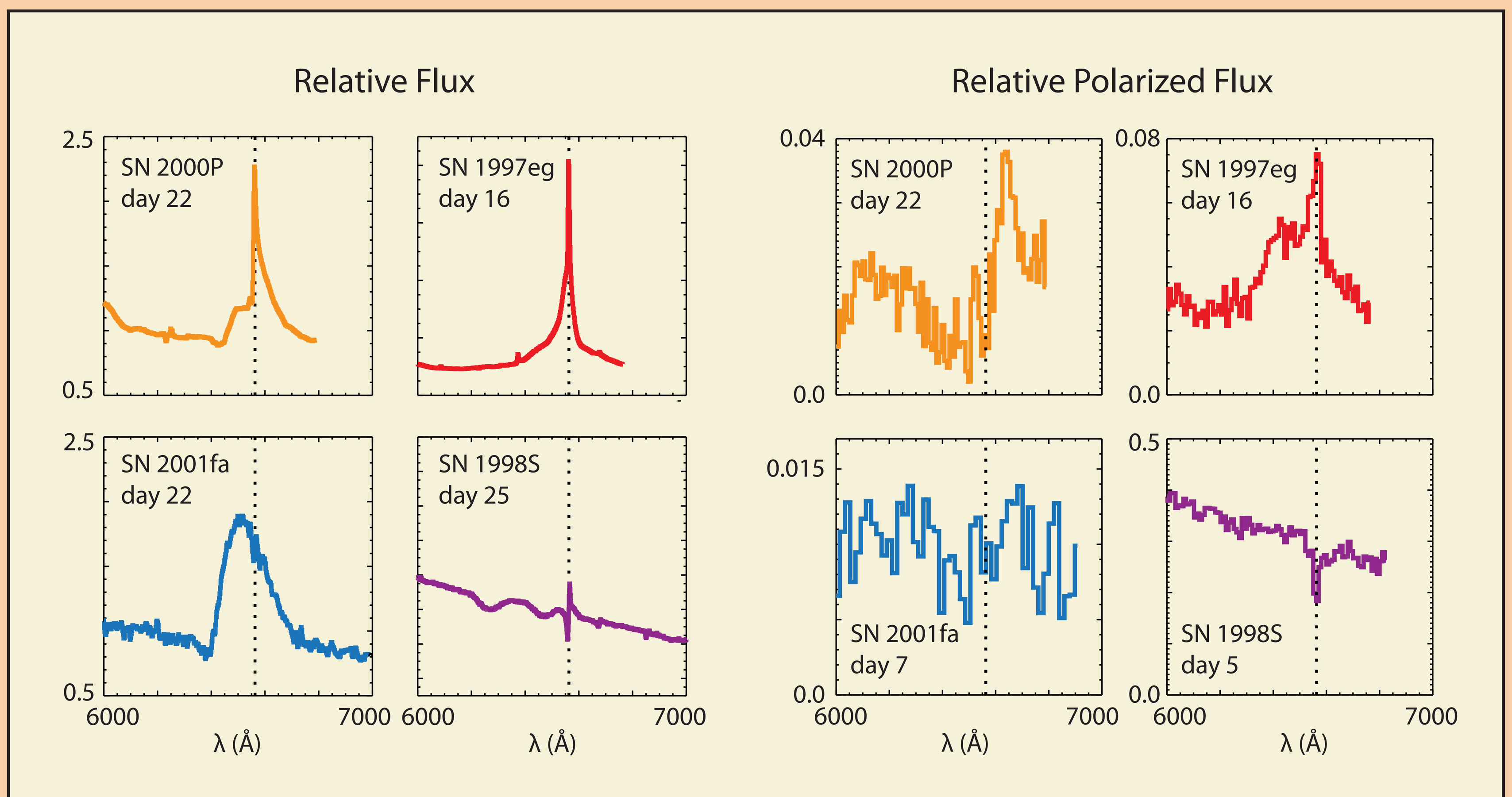
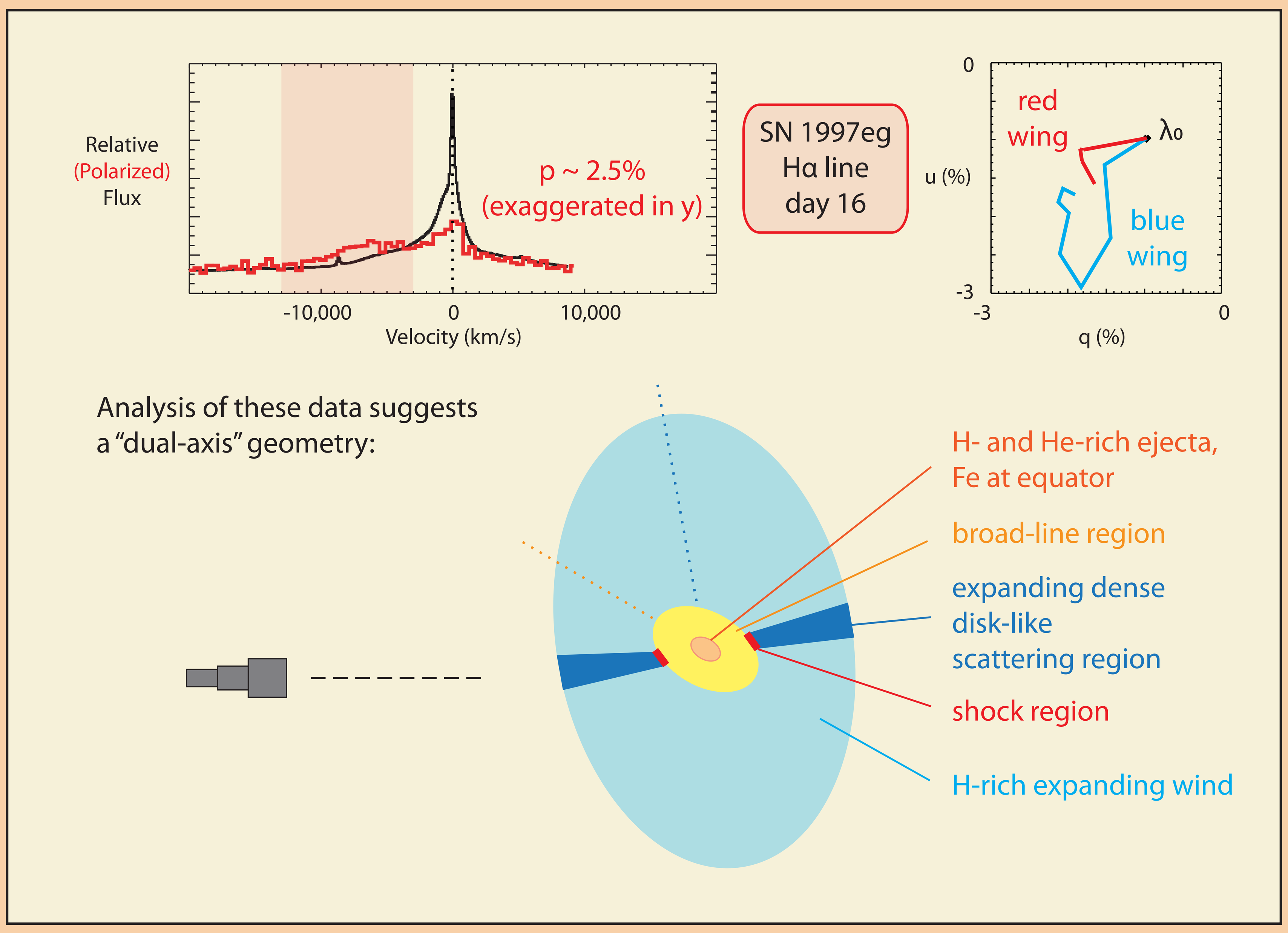
1. Some core-collapse supernovae are surrounded by dense pre-existing circumstellar material.



Hα line profiles of several SNe IIn at comparable epochs.
Both the flux and the polarized flux profiles vary widely between objects.

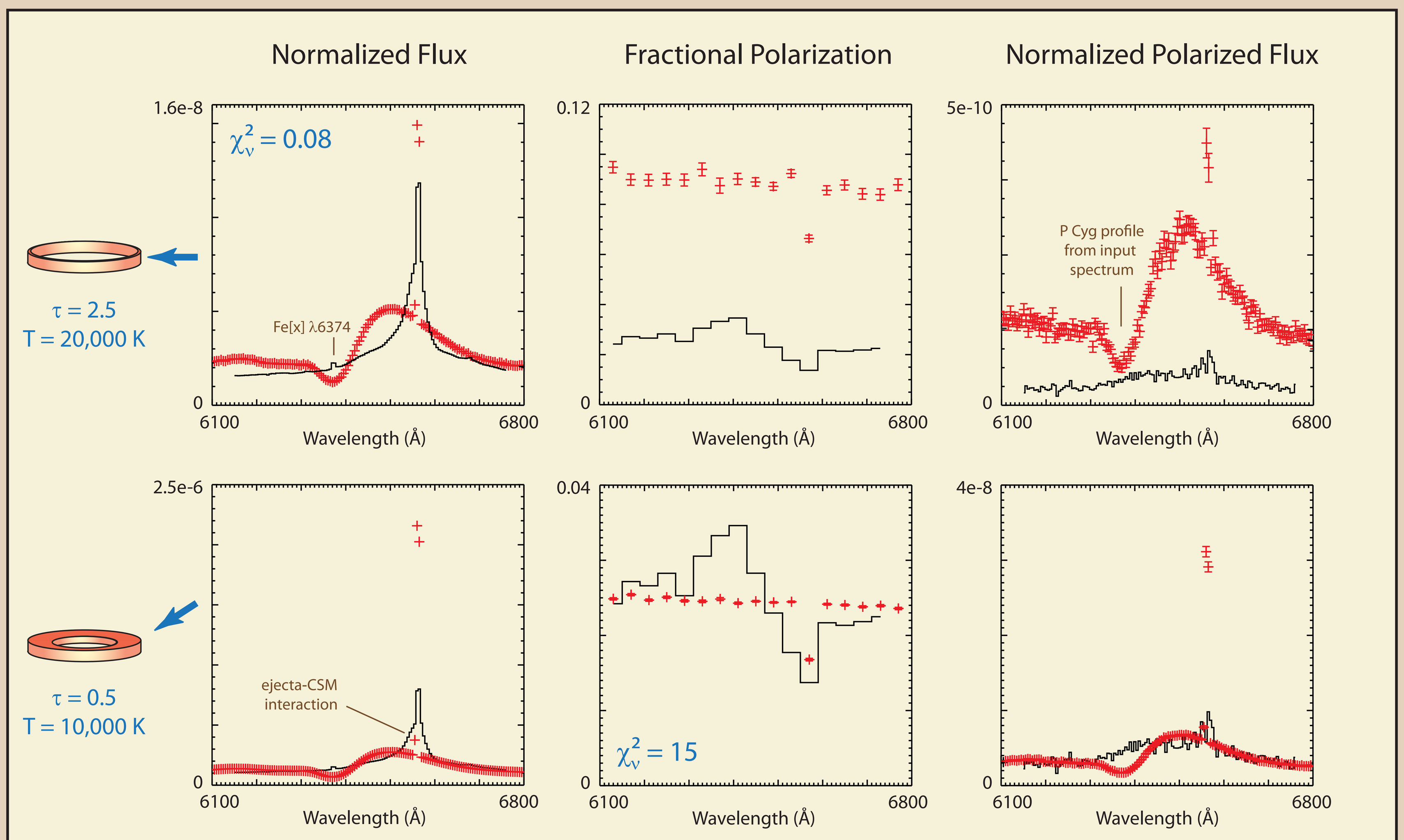
These "interacting supernovae," also called Type IIn supernovae, show strong, narrow hydrogen Balmer emission lines in their spectra. However, the category is heterogeneous, with wide variation in flux and polarization spectra, light curves, and radio/X-ray brightness among these objects. Such variations may reflect differing characteristics of their circumstellar material. Because this CSM is formed by pre-supernova stellar winds, studying interacting supernovae can probe the mass-loss history of the most massive stars.

2. Analysis of polarized line profiles gives clues to the circumstellar geometry of these objects.



Spectropolarimetry constrains the shape, orientation, and composition of circumstellar scattering regions. In the Type IIn SN 1997eg, enhanced blue wings in the polarized Balmer lines suggested that the receding side of the expanding disk-like scattering region was obscured. Loop-like shapes across emission line profiles in the Stokes *q-u* plane implied that the emission and scattering regions were misaligned to one another. Analysis of other polarized lines revealed that the ejecta contained H, He, and Fe, while the wind was composed mainly of hydrogen with a mass of ~10 solar masses (consistent with an LBV eruption).

3. Numerical models provide diagnostics connecting line profiles to CSM characteristics.

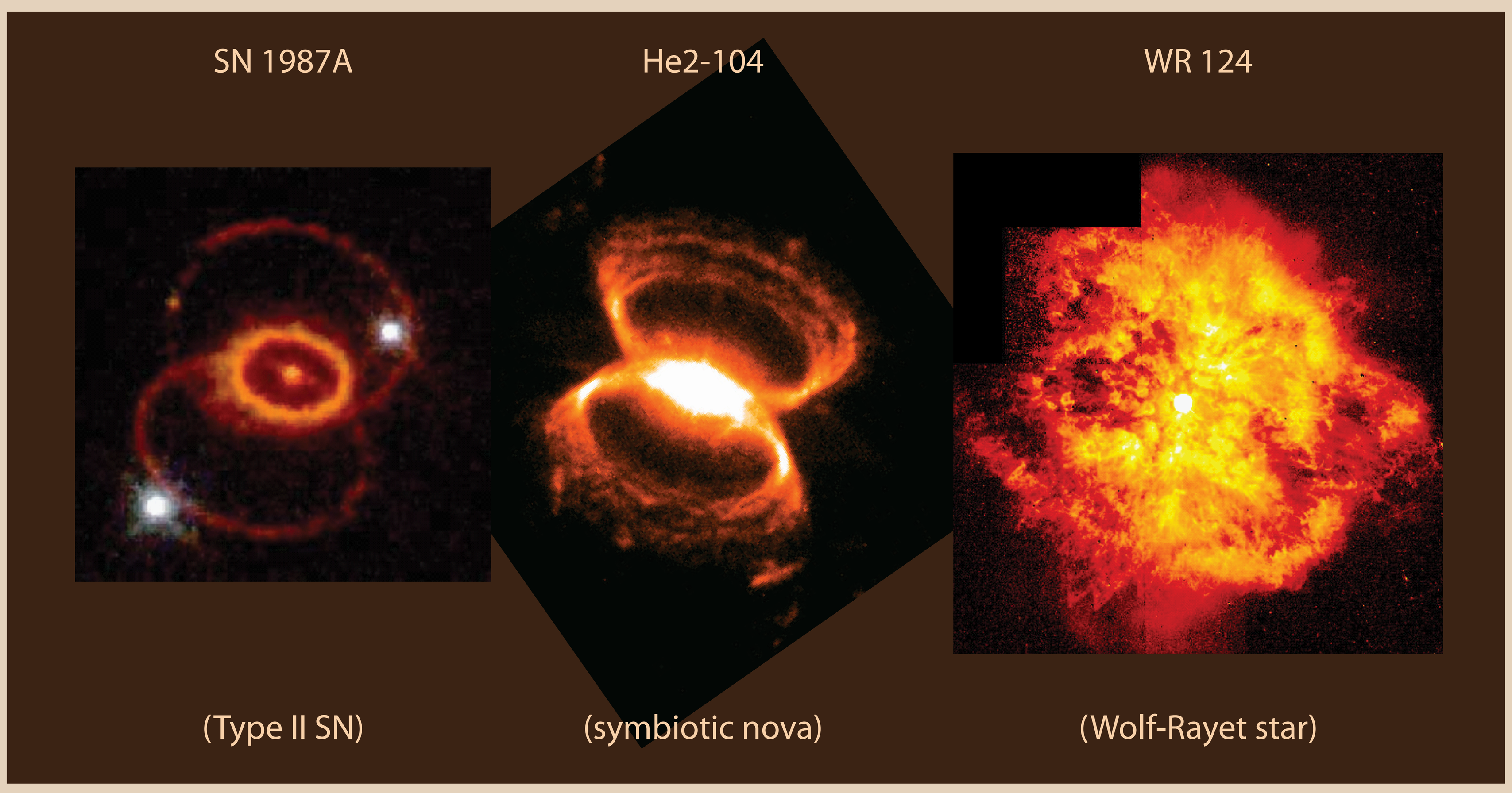


Profiles of the Hα line in SN 1997eg at day 16 (black lines) compared with two Monte Carlo models (red points). The upper model yields the best fit to the flux profile of all the models in our grid, but produces too little polarization. The lower model yields the best fit to the polarization profile and also fits the flux fairly well, but does not match the central "spike". Models do not yet include interaction between the ejecta and CSM, which likely gives rise to the intermediate-width "shoulder" in the observed data.

Monte Carlo radiative transfer models predict the total and polarized flux profiles arising from different CSM geometries. In the example above, the broad base of the Hα line profile of SN 1997eg in total light is well fitted by a model with a toroidal shell, but this model does not fit the polarized line profile. Another model with a more disk-like CSM reproduces the line's polarization behavior but not its profile in total light. The difference in viewing angle between these two "partial best fit" models supports the picture of multiple axes in SN 1997eg.

Ongoing analysis of a large model grid will allow identification of the best *simultaneous* fit(s) for both total and polarized light. From these fits, we can constrain the geometry, density, and temperature of the components of the circumstellar shell at varying times during the SN's evolution.

4. Comparing CSM geometries with those of massive stars can link SNe with progenitors.



A better understanding of the wind structures surrounding potential SN progenitors in our own galaxy will allow us to draw connections with the CSM geometries inferred at large distances. For example, misaligned components like those in SN 1997eg may imply a progenitor with unstable, convection-driven mass loss. Developing spectropolarimetric diagnostics by matching data with models will help create a CSM "distance ladder" with the potential to illuminate the nature of stellar mass loss at cosmological distances and in a variety of galactic environments.

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