Using advanced regularised inversion methods for mapping stellar surfaces

Doppler Imaging (DI) is a powerful astronomical remote sensing technique that converts time series of stellar spectral variations into two-dimensional maps of structures on the surfaces of distant stars. DI, initially introduced about 40 years ago, is currently used to derive maps of chemical inhomogeneities, temperature spots, magnetic fields and pulsational disturbances using principles of regularised image reconstruction, akin to medical imaging. The maps of stellar surfaces delivered by DI have effective spatial resolution surpassing conventional direct imaging methods by orders of magnitude, even comparing with the capabilities of the largest telescopes on Earth. Consequently, this method provides unique information about several important phenomena and physical processes that are highly relevant for stellar astrophysics in general and for understanding our Sun in particular.

Despite its repeated successful applications, the key mathematical foundations of the DI inverse problem methodology remained unchanged over several decades. Potentially, DI can be made much more efficient and reliable by introducing a number of modern mathematical methods and data analysis techniques, including (but not limited to) image reconstruction using Principal Component Analysis and sparsity principles, Bayesian statistical inferences, modern optimisation strategies and inverse problem approaches. The task of exploring these methods and testing them in the context of practical astronomical applications of DI comprises an excellent opportunity for an interdisciplinary astronomical/mathematical PhD thesis project.

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