Z119a Differentiable mapping of stellar surface for solar-type stars

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Starspot is an apparent indicator of stellar magnetic activity on the stellar surface and ubiquitously observed on young and cool stars (G-, K-, and M-dwarfs). It is essential to explore starspots and magnetic fields on both stellar and exoplanetary aspects: (i) stellar internal dynamo, (ii) origin of stellar flares and plasma eruptions, (iii) heating stellar atmosphere and XUV radiations, and (iv) contamination in the radial velocity and transmission of planetary atmosphere. Starspots have been investigated from the photometric brightness modulation and distortion of absorption lines in high-dispersion spectroscopy along with the stellar rotation.

In this study, for the purpose of delving into the relation between starspots and stellar flares, we have been developing codes with a (sub-)differentiable probabilistic programming to decipher the stellar surface as inversion problems (GitHub: KaiIkuta/StarspotMapping and /jaxsmap). First, we deduce spot properties, such as locations and temporal size variations, from quasi-periodic brightness modulation of monochromatic photometry by the Kepler space telescope and Transiting Exoplanet Survey Satellite (TESS) with the sampling-based Bayesian inference (Ikuta et al. 2020, 2023, & submitted). Second, we map the stellar surface jointly from multichromatic photometry and high-dispersion spectroscopy (Doppler imaging), mainly by the space and ground-based telescopes such as the 3.8m Seimei telescope, with gradient-based continuous optimizations. We present a series of the studies for the stellar activity and techniques inherent in the inversion problems and propose future prospects to implement physics-informed inferences in the differentiable astronomy.