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Doppler Imaging Fun

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1. INTRODUCTION

Check out Luger et al. (2019) and Bedell et al. (2019) and stuff.

2. THE EQUATION

In the most general form, the Doppler-shifted intensity observed at wavelength λ at position x, y on the surface of the star at time t is

$$\begin{aligned} I(\lambda, \beta, x, y, t) = I\big(\lambda, 0, x, y, t\big) \\ + \frac{\mathrm{d}I(\lambda, \beta, x, y, t)}{\mathrm{d}\beta}\bigg|_{\beta=0} \Delta\beta(x, y) \\ + \frac{\mathrm{d}^2 I(\lambda, \beta, x, y, t)}{\mathrm{d}\beta^2}\bigg|_{\beta=0} \Delta\beta^2(x, y) \\ + \dots \end{aligned} \tag{1}$$

where $\beta \equiv \frac{v}{c}$ is the relativistic parameter for a radial velocity v on the surface.

3. DIFFERENTIATING THE SPECTRUM

The derivatives of the spectrum $I(\lambda)$ with respect to the relativistic parameter β are found by application of Faà di Bruno's formula for taking high order derivatives of the chain rule:

$$\frac{\mathrm{d}^n I(\lambda, \beta)}{\mathrm{d}\beta^n}\bigg|_{\beta=0} = \sum_{k=1}^{n} \frac{\mathrm{d}^k I(\lambda_0)}{\mathrm{d}\lambda_0^k}\bigg|_{\lambda_0=\lambda} \lambda^k P_{nk} \tag{2}$$

where

$$P_{nk} \equiv B_{n,k}\left(\left\{(-1)^j j!\right\}_{j=1}^{n-k+1}\right) \tag{3}$$

and $B_{n,k}$ is the incomplete Bell polynomial. The quantity $\frac{\mathrm{d}^k I(\lambda_0)}{\mathrm{d}\lambda_0^k}\Big|_{\lambda_0=\lambda}$ is just the k^{th} derivative of the spectrum with respect to wavelength in the rest frame, and must either be inferred from the data or computed numerically from the spectrum.

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REFERENCES

Bedell, M., et al. 2019, arXiv e-prints, arXiv:1901.00503

Luger, R., et al. 2019, AJ, 157, 64