Blinking Lights in Taurus

Long-Term Variability of Young Low Mass Stars

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Introduction

Young stellar and substellar objects are known to change their apparent brightness in an irregular way. By studying this variability from the optical to mid infrared it is possible to uncover information on the underlying physics. The Taurus cloud complex is one of the closest star forming regions to the solar system (~140 pc), containing newly formed, sparsely distributed, stellar and substellar sources (Luhman 2018).

By matching a catalog of confirmed young stars (Esplin & Luhman, 2019) in Taurus to archival multi-epoch photometric data from both the Zwicky Transient Facility, ZTF, (optical) and a allWISE (mid-infrared) surveys we aim at uncovering the population of visual and infrared variables in the Taurus Clouds and study their properties.

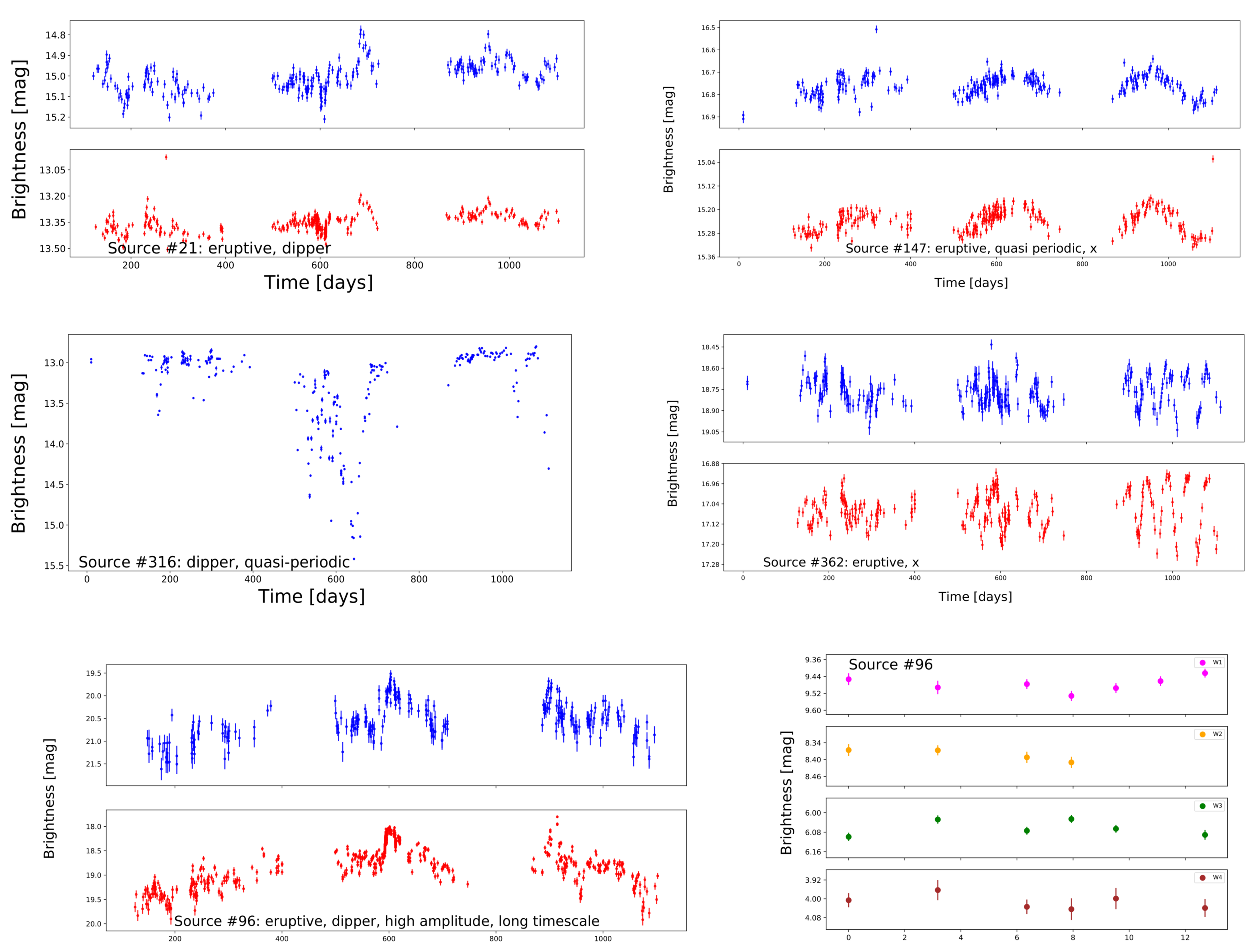

Figure 2. Light Curves of Taurus YSOs. ZTF g-band in blue, r-band in red; W1 in magenta, W2 in orange,W3 in green and W4 in brown. ZTF light curves include the associated visual classification. Time equals zero is the start of each campaign for the light curves of both surveys.

Color-Magnitude Analysis

The change of color as a function of the brightness change can provide important clues for the nature of the variability, helping to disentangle the extinction effects from those happening close to the surface. It is possible to look for common trends between consecutive light curves such as the color becoming redder/bluer or the source getting brighter/fainter. Fig. 4 shows that the source varies in color between 1.2 - 2.2 for all epochs but is consistently brighter between time 600-650 than after or before.

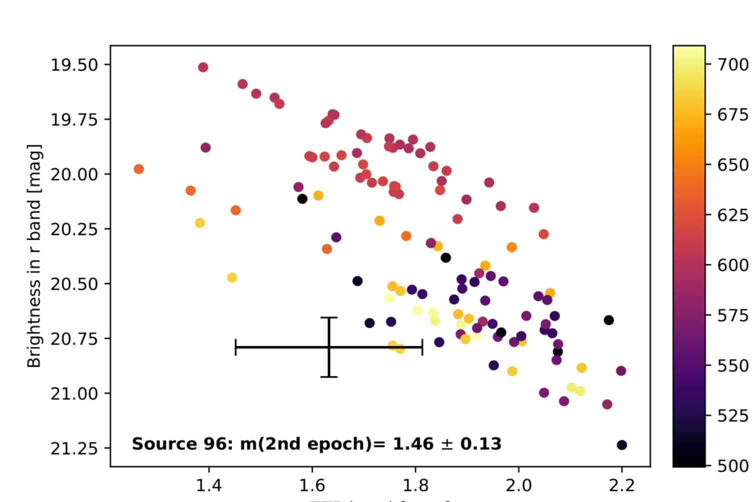

Figure 3. CMD of 2nd epoch in ZTF light curve. Cross symbol refers to the mean errors and color bar refers to the time in days. Results from a linear fit on the data are shown in the plot.

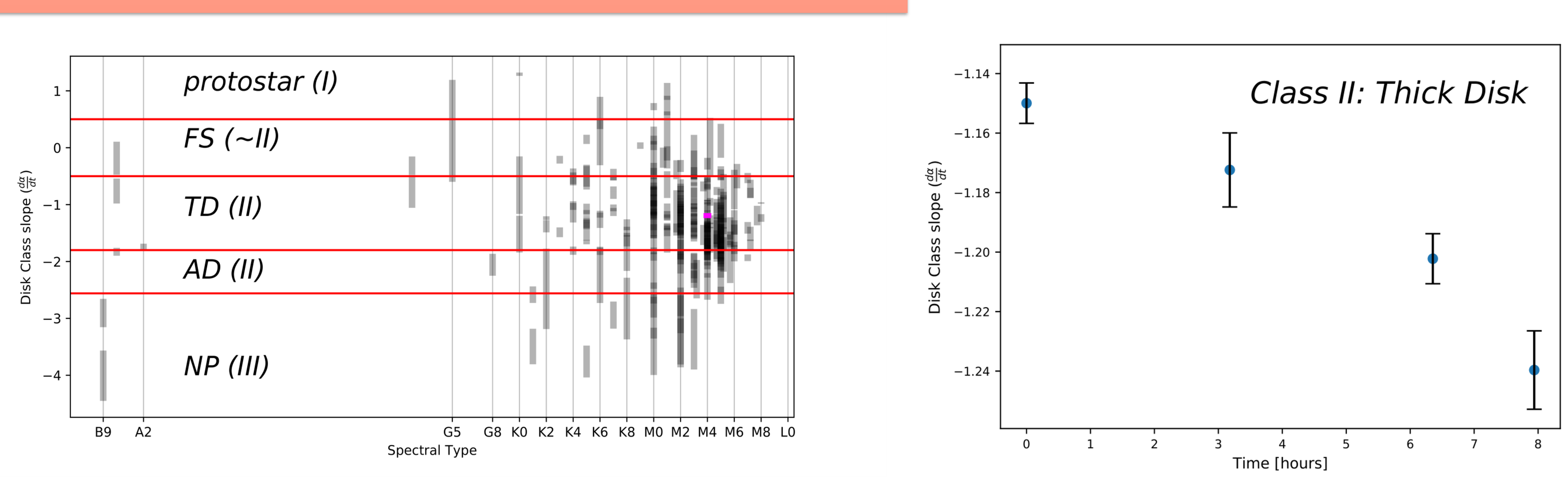

Figure 5. Amplitude of the change in the alpha disk class slope as a function of spectral type, on the left. For each source, for each epoch in which all WISE bands are available and have associated uncertainties, we employ a monte carlo simulation to find the average fit for that epoch and its uncertainty. On the right, plot of disk class slope as a function of time for source #96 from which the amplitude plotted in pink on the left is determined.

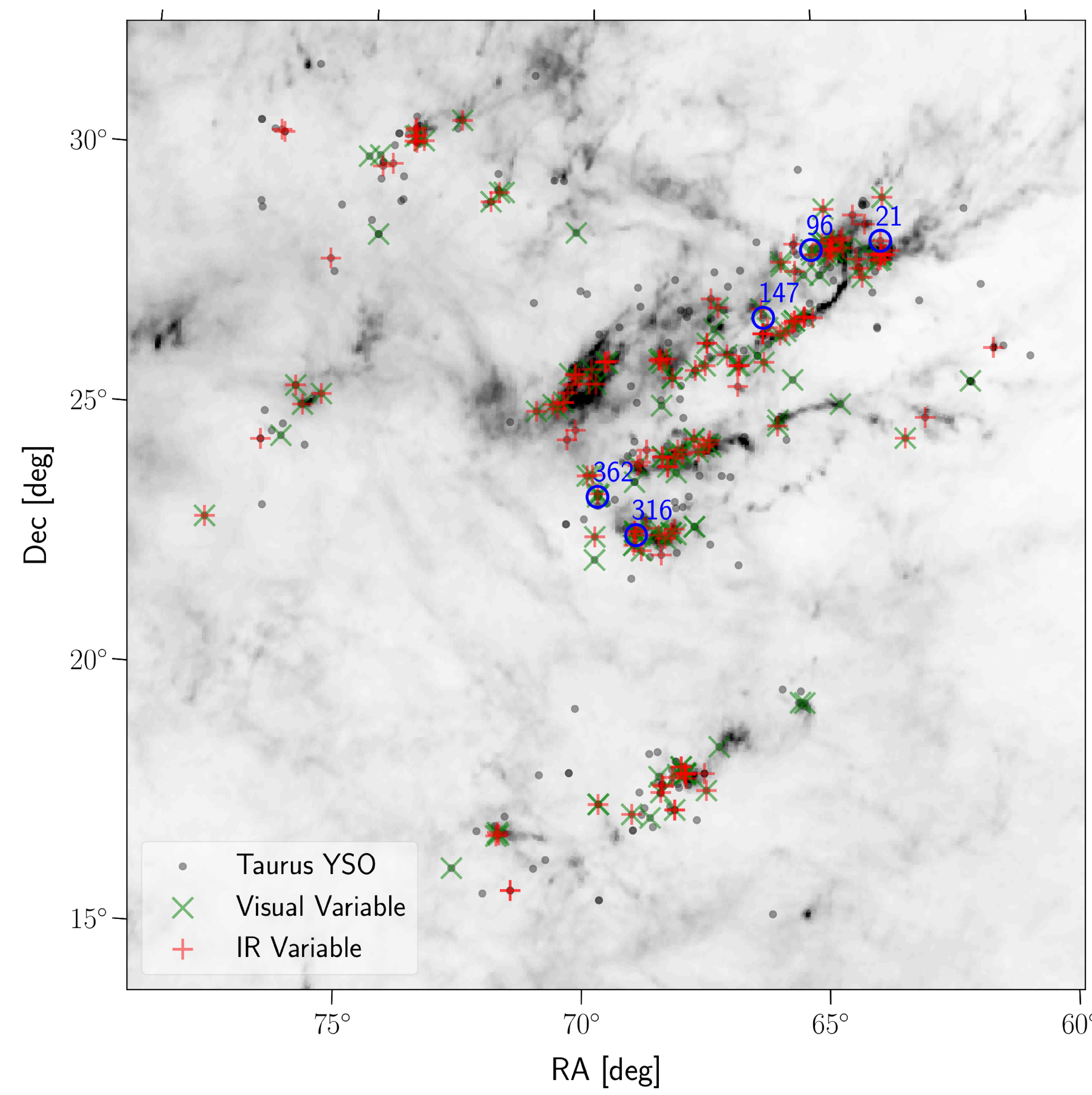

Figure 1. Planck HFI 857 GHz dust map of the Taurus star forming region with the variable stellar population overplotted. Numbered sources are featured in the light curves in Fig 2.

Finding the Variables

To determine if a source is variable from its light curve we employ a statistical approach. A set of variability indices are calculated for each light curve and *cut-off* points are determined from an analysis of the histograms. These *cut-off* points separate the variables from the non-variables. To compile a rigorous catalog, variables must obey the following criteria:

- Present either a Dip or a Burst with an amplitude larger than the *cut-off;*
- Be variable in the reduced χ^2, weighted σ and single Stetson index J tests;
- Be variable in the Welch-Stetson test when there is data in two bands bands for that source and survey.

We find that 37% of sources in Taurus are visible variables and 36% are infrared variables.

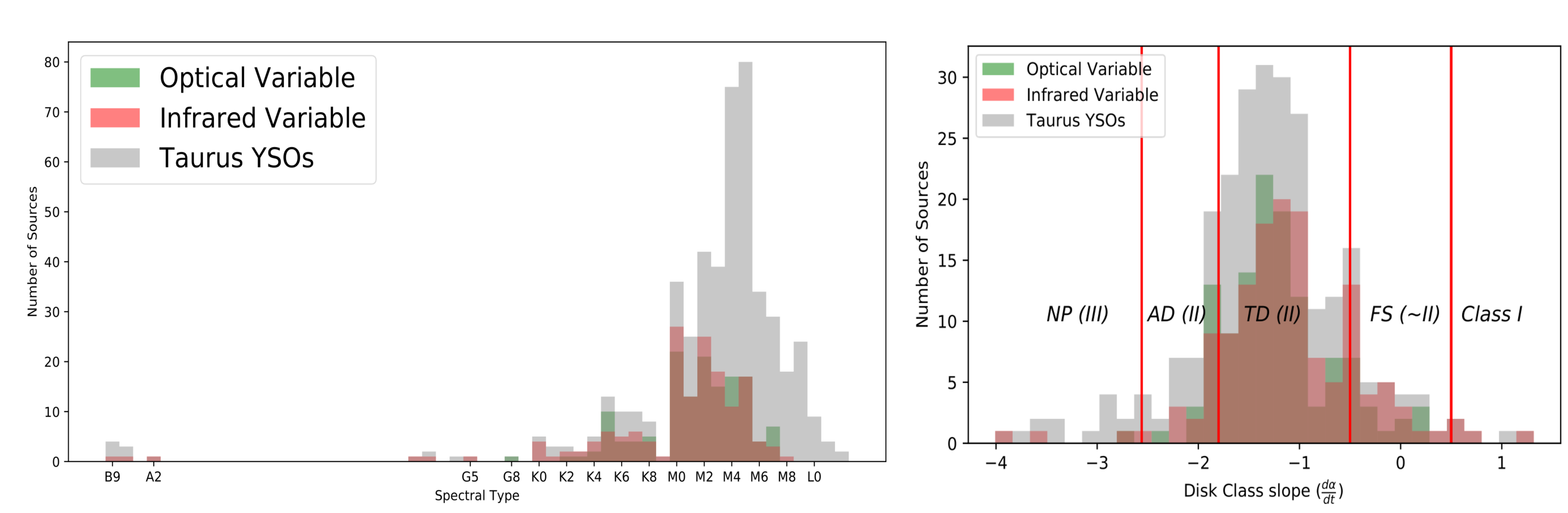

Figure 4. Histogram of spectral types of Taurus YSOs from Esplin et al (2019), on the left, and histogram of average disk class slope derived from the WISE 4 bands over the available epochs, on the right. The vertical lines in the right plot refer to the adopted disk classes: Naked Photosphere (NP), Aneamic Disk (AD), Thick Disk (TD) and Class I.

Changes in disk class

Stellar variability will undoubtely influence any parameters which are derived from photometric measurements such as stellar mass and disk classification. The latter is an important parameter because it affects the rate of star formation and our understanding of early stellar evolution. Using allWISE data we can study how the slope of the spectrum over the 4 bands changes through the duration of the light curve. This slope defines the disk classes, for which we adopt the values defined by Lada et al (2006) and expanded by Teixeira et al (2012).

We find that brightness variations in young stars can significantly influence the subtype of Class II disk but can also cause changes from Class I to Class II or from Class III to Class II, as can be seen in Fig. 5

Esplin, T. L. and Luhman, K. L., AJ, 158, 54. (2019)
Bellm E. C. et al., PASP, 131, (2019)
Cutri R. M. et al., yCat, II/328 (2021)
Lada, C. J. et al., AJ, 131, 1574 (2006)
Teixeira, P. S. et al., A&A, 540, A83 (2012)

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