VEILS Observations of a Flat-Spectrum Radio Source: PKS 0027-426

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VEILS: VISTA Extragalactic Infrared Legacy Survey

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- VIRCAM on VISTA at Paranal Observatory
- Repeatedly images 9 deg^2 over 3 years
- 6 month observing seasons each year
- Aims for ~ 14 day cadences in Ks and J Bands

Image Credit:
https://www.eso.org/sci/facilities/paranal/telescopes/vista

DES: Dark Energy Survey

- DECAM on the Blanco 4-m telescope at CTIO
- Started Observing August 2013
- Optical Counterpart to VEILS from mid 2017 – early 2018
- Aimed for ~ 7 day cadences in griz bands

Image Credit: H. T. Diehl, Fermilab https://www.darkenergysurvey.org/the-des-project/instrument/

VOILETTE: VEILS OptIcal Light curves of Extragalactic TransienT Events

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- OmegaCAM on VLT at Paranal Observatory
- Optical Counterpart to VEILS from mid 2018 onwards
- Aims for ~ 10 day cadences in giz bands and ~ 6 day cadence in r band

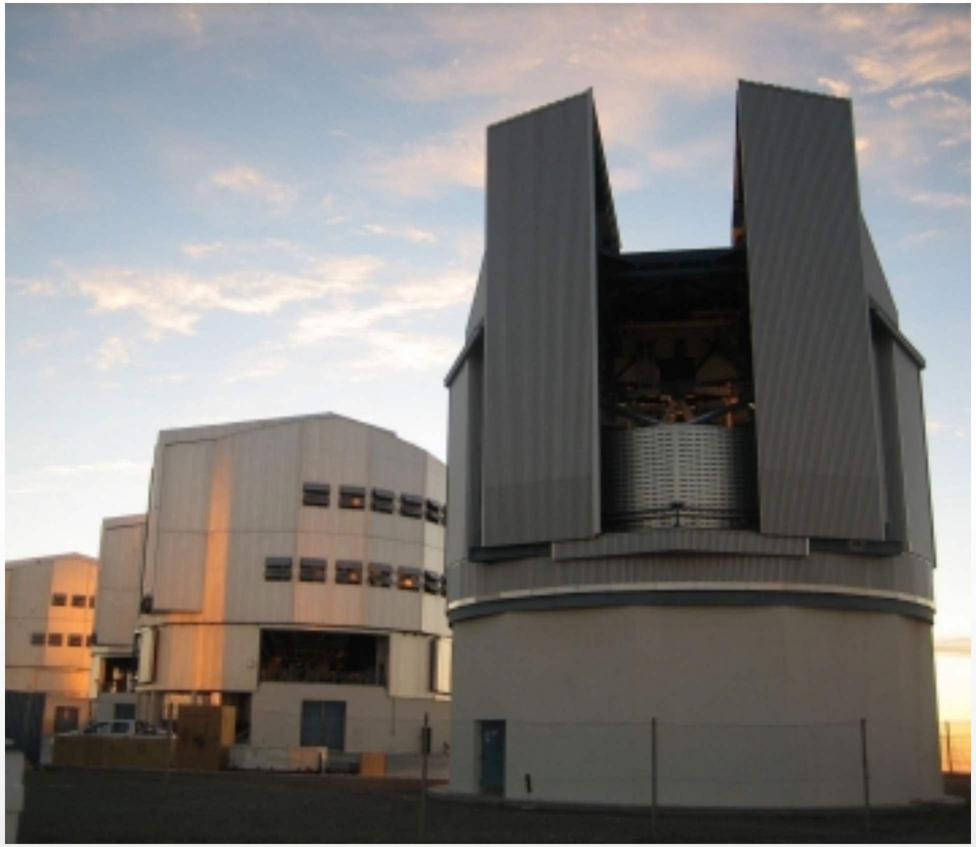

Image Credit:
https://www.eso.org/sci/facilities/paranal/telescopes/vst.html

Preliminary Quasar Detection

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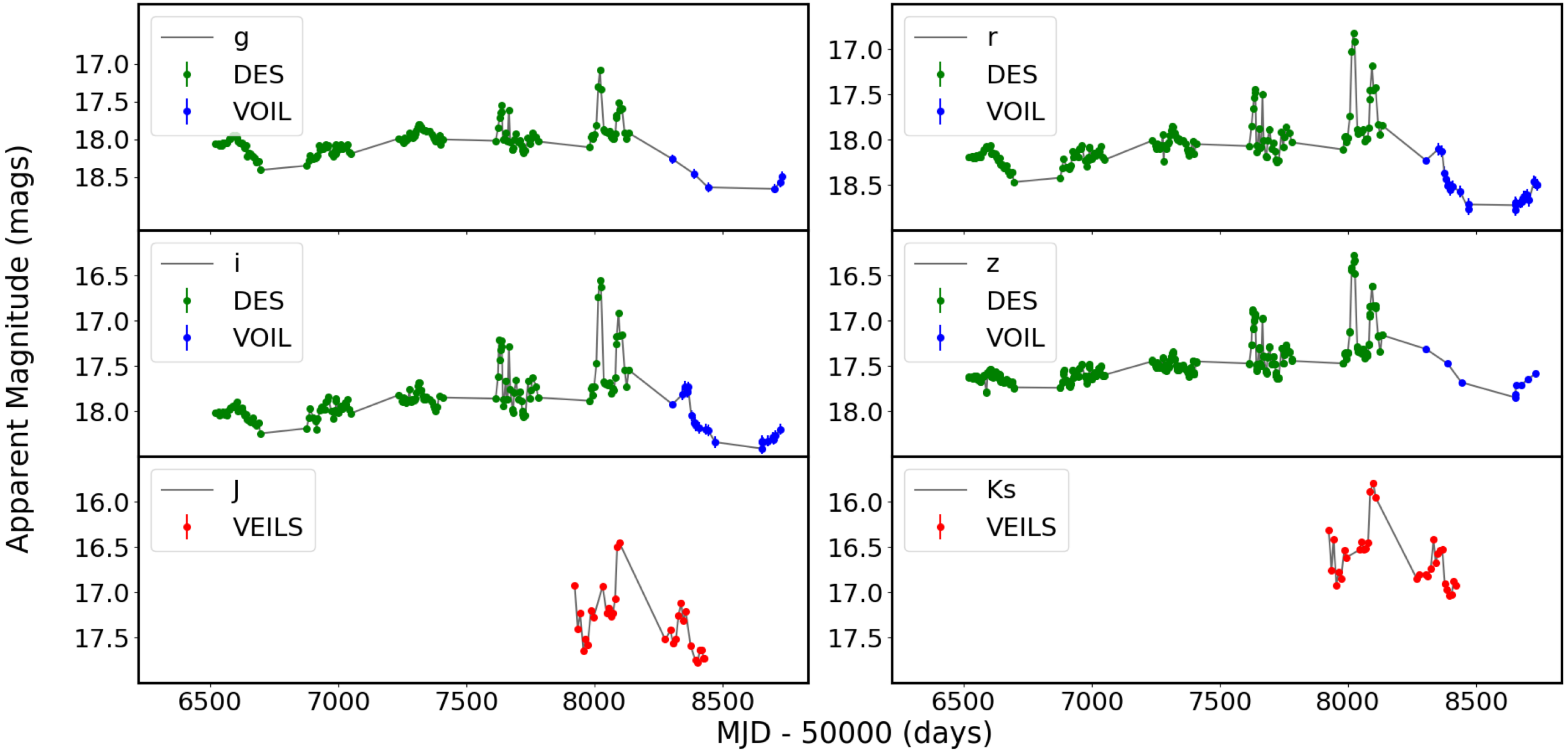
- Compared our catalogues to the OzDES Quasar Catalogue:
  - Spectroscopically confirmed Quasars
  - Redshift Range: $\sim 0.3 \leq z \leq 4$
- Currently constrained it to find only the highest possible cadenced light curves
- So far found ~ 300 AGN in VOILETTE, with ~ 100 also in VEILS

PKS 0027-426



g
DES
VOIL
r
DES
VOIL
i
DES
VOIL
z
DES
VOIL
J
VEILS
Ks
VEILS
17.0
17.5
18.0
18.5
16.5
16.0
Apparent Magnitude (mags)
6500
7000
7500
8000
8500
MJD - 50000 (days)

FSRQ Emission Processes

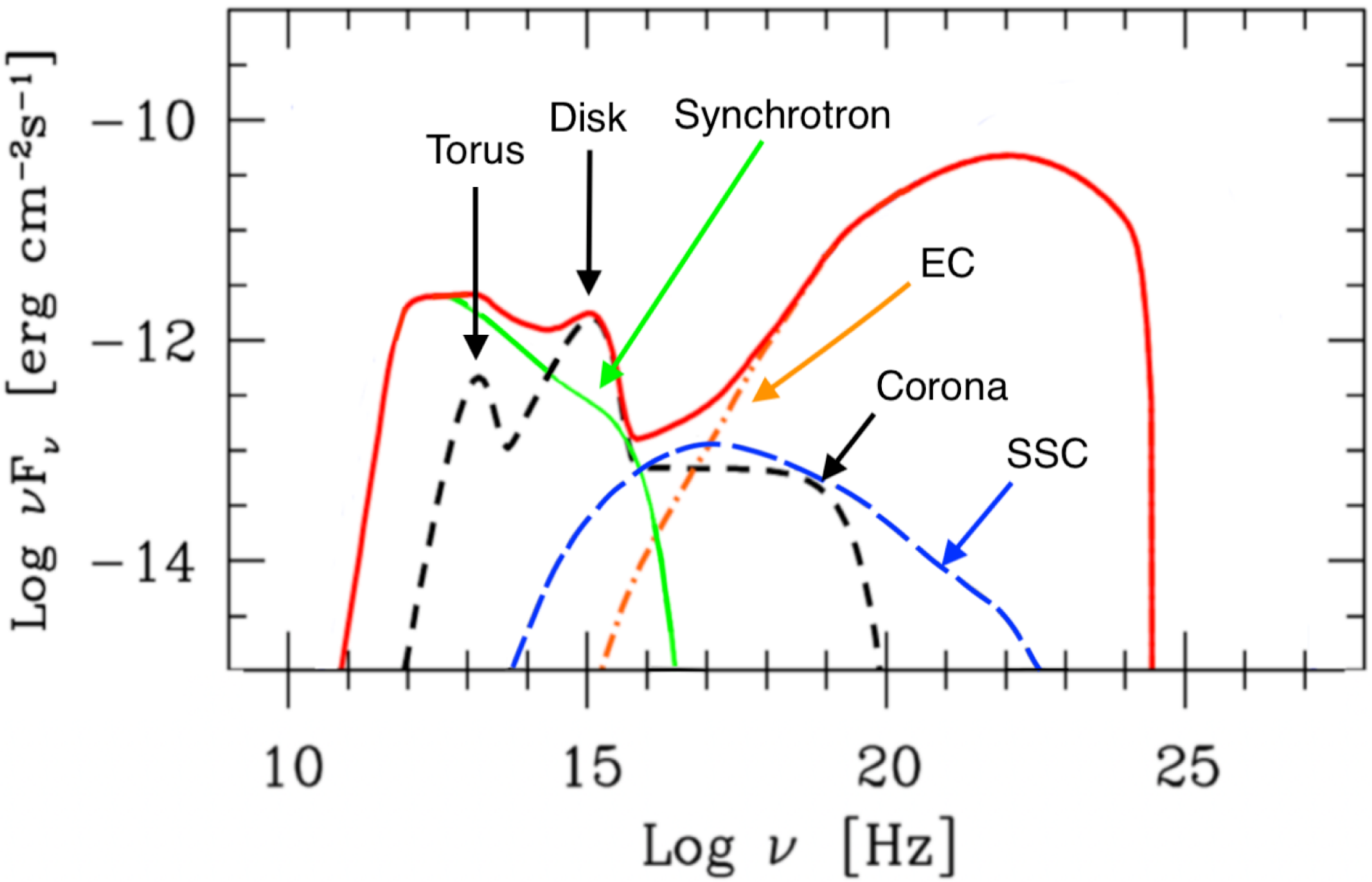


Image Credit: Adapted from G Ghisellini et al. General physical properties of bright Fermi blazars. Mon. Not.R. Astron. Soc, 402:497–518, 2010

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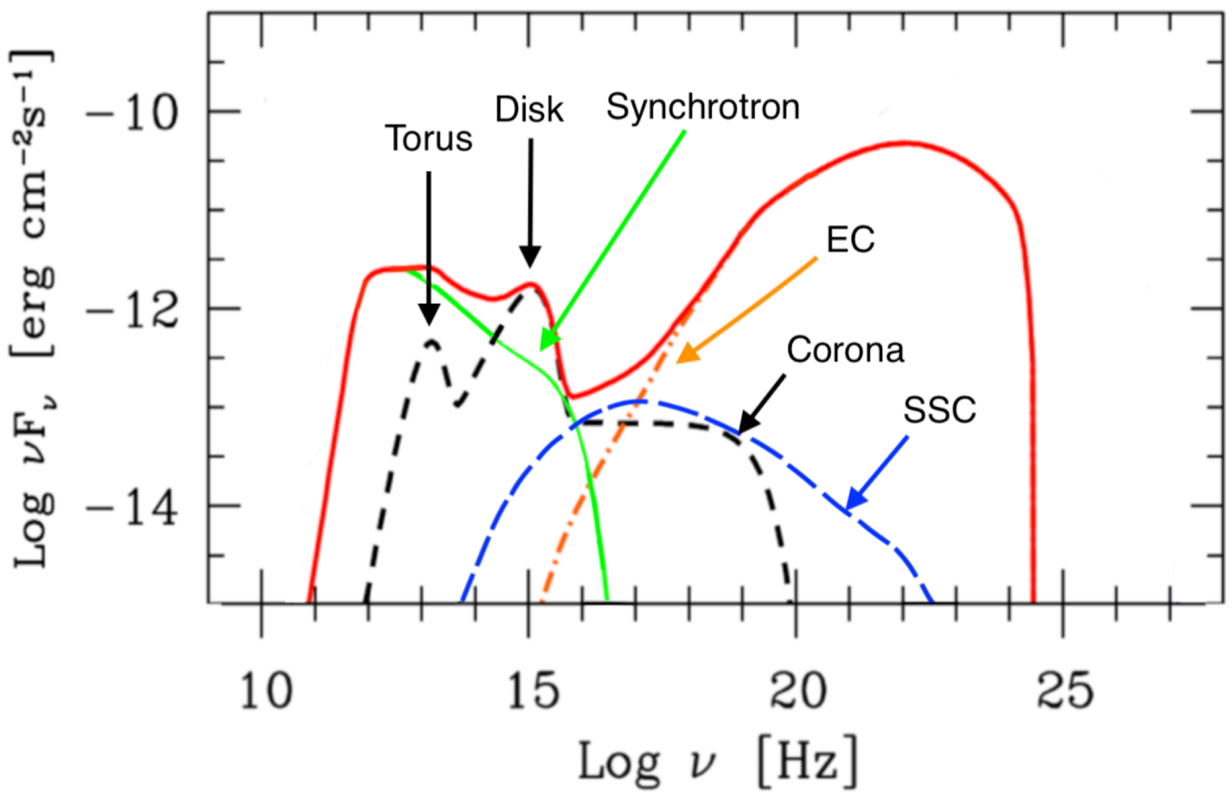


Image Credit: Adapted from G Ghisellini et al. General physical properties of bright Fermi blazars. Mon. Not.R. Astron. Soc, 402:497–518, 2010

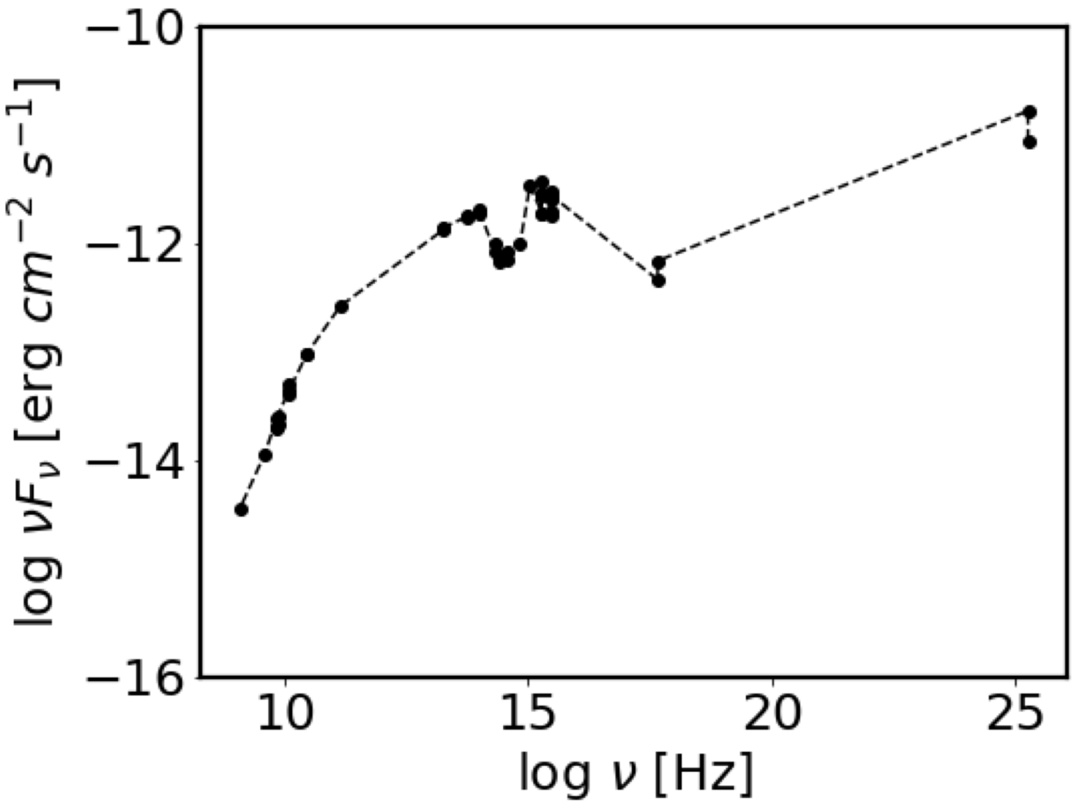


Image Credit: Adapted from NED

Multi-Wavelength Variability of FSRQs

- Important for understanding the emission processes in the relativistic jets and central engines

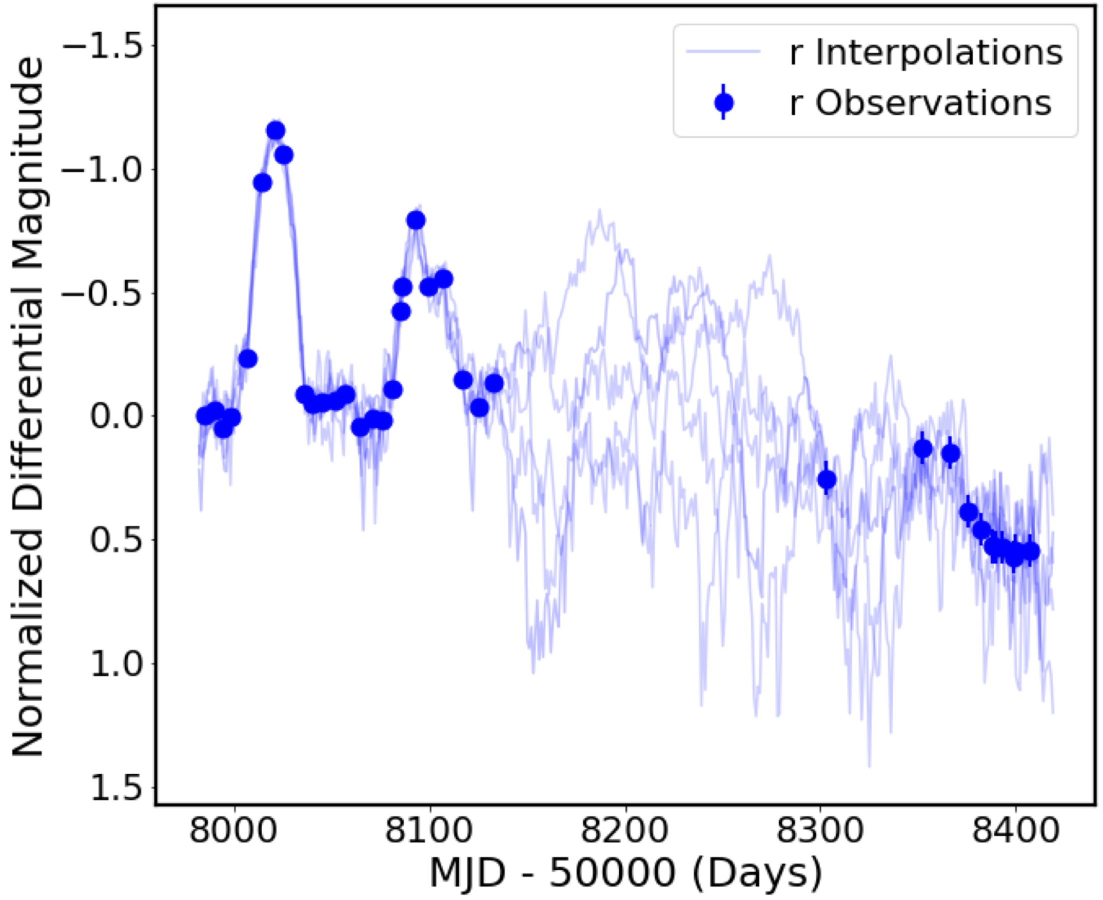
- Time Variability
  – Cross Correlations

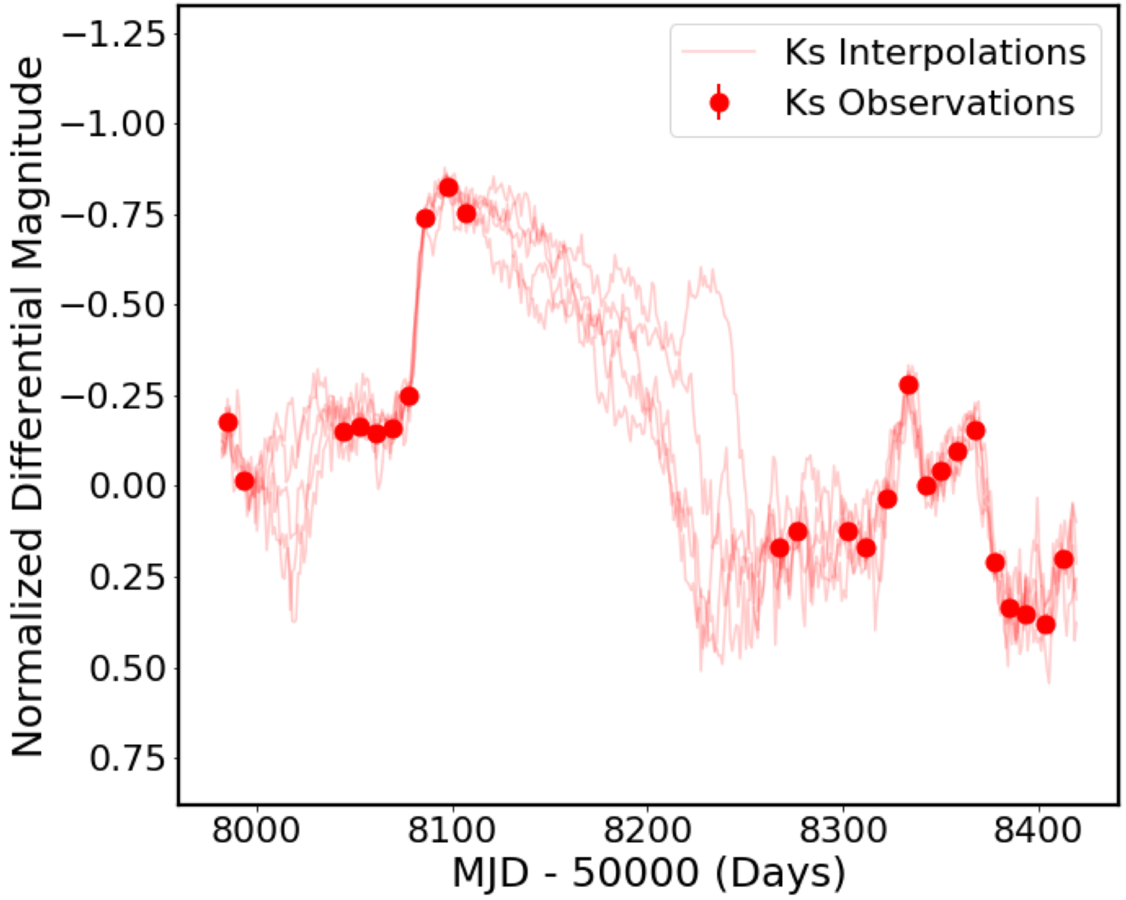
- Spectral Variability
  – Colour-Magnitude Plots

Time Variability Analysis of PKS 0027-426

First Method of Interpolation – r and Ks

Interpolating both light curves using the structure function





Cross Correlation Results – r and Ks

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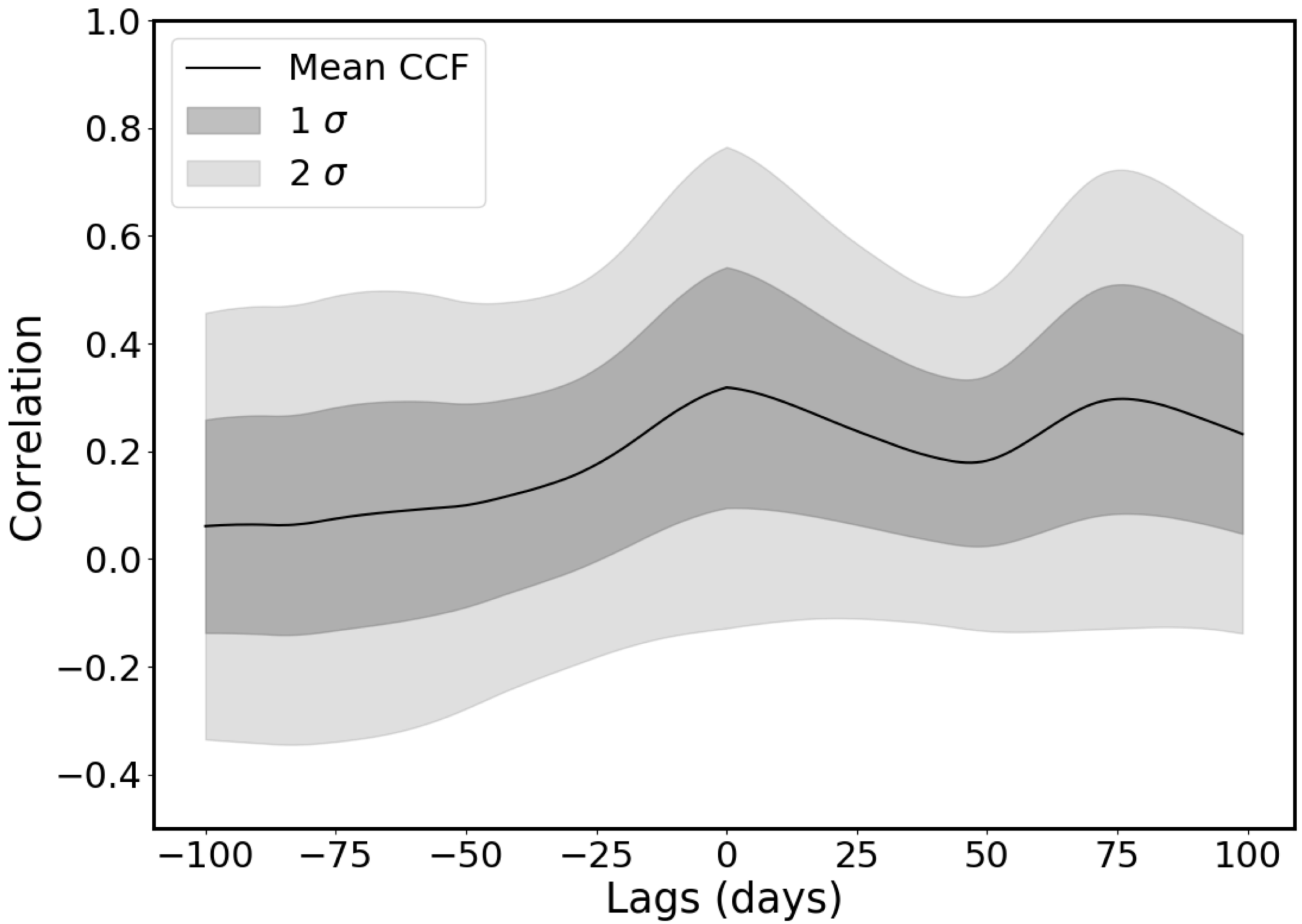
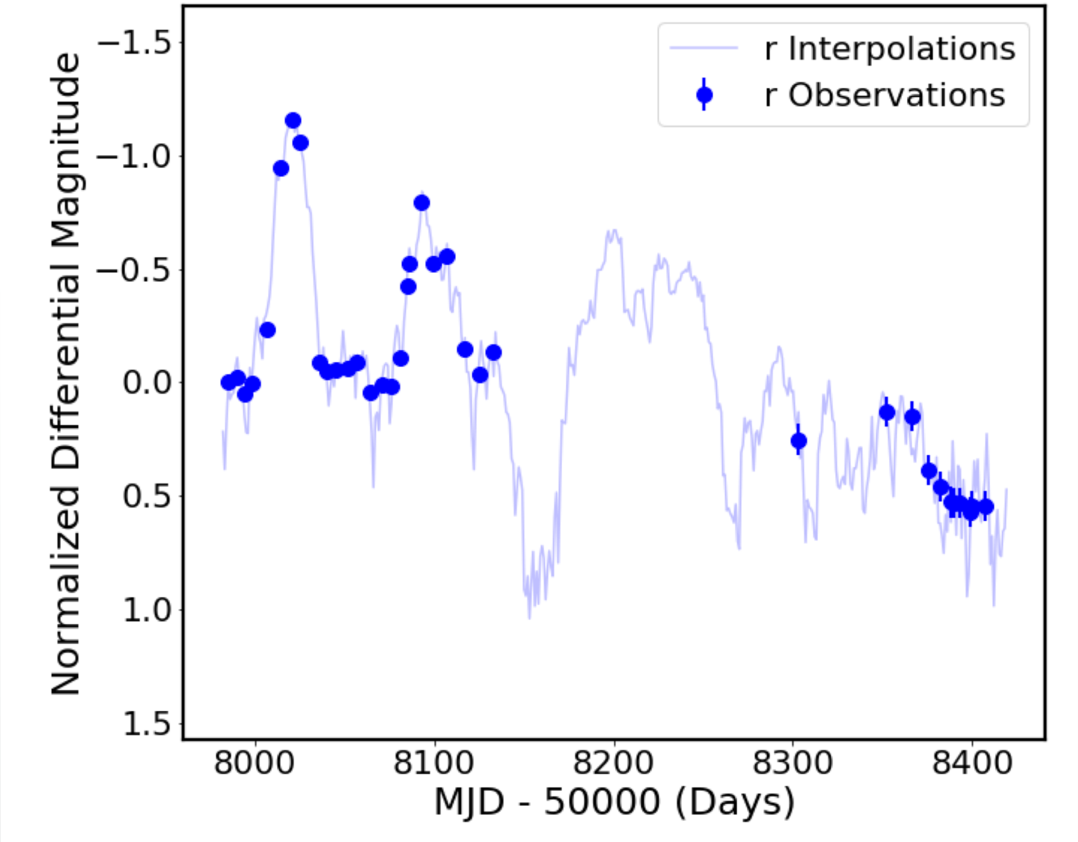


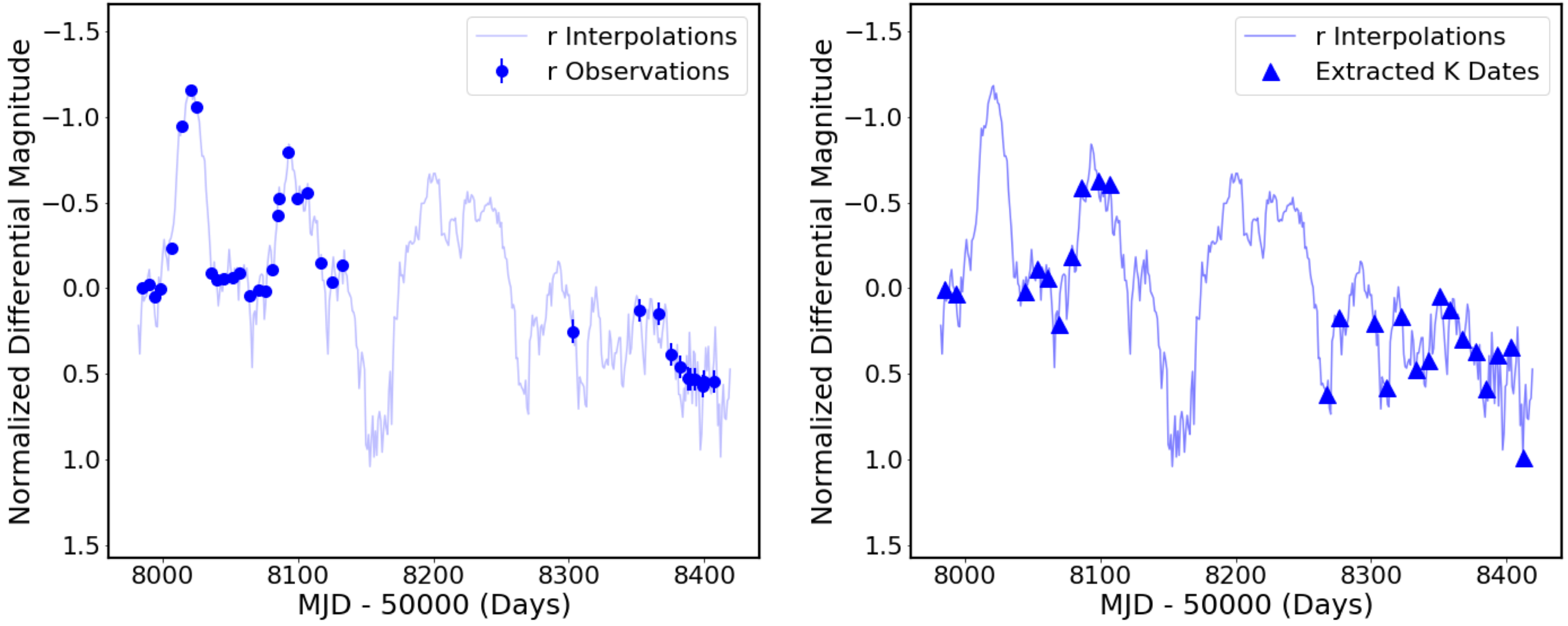
Alternate Method of Interpolations

1. Interpolate 1 Light Curve using the Structure Function



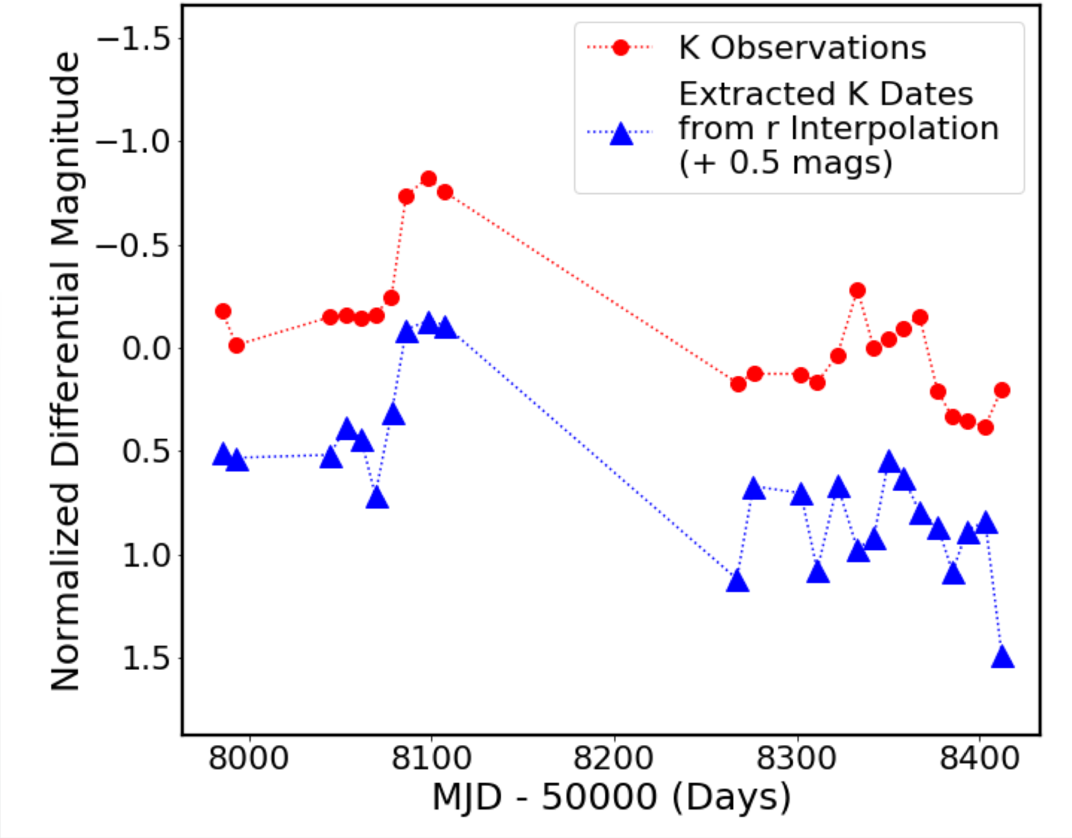
Alternate Method of Interpolations

2. Extract the matching dates from the interpolated light curve and Light Curve 2



Alternate Method of Interpolations

3. Cross Correlate only these matching dates with 0 lag



Alternate Method of Interpolations

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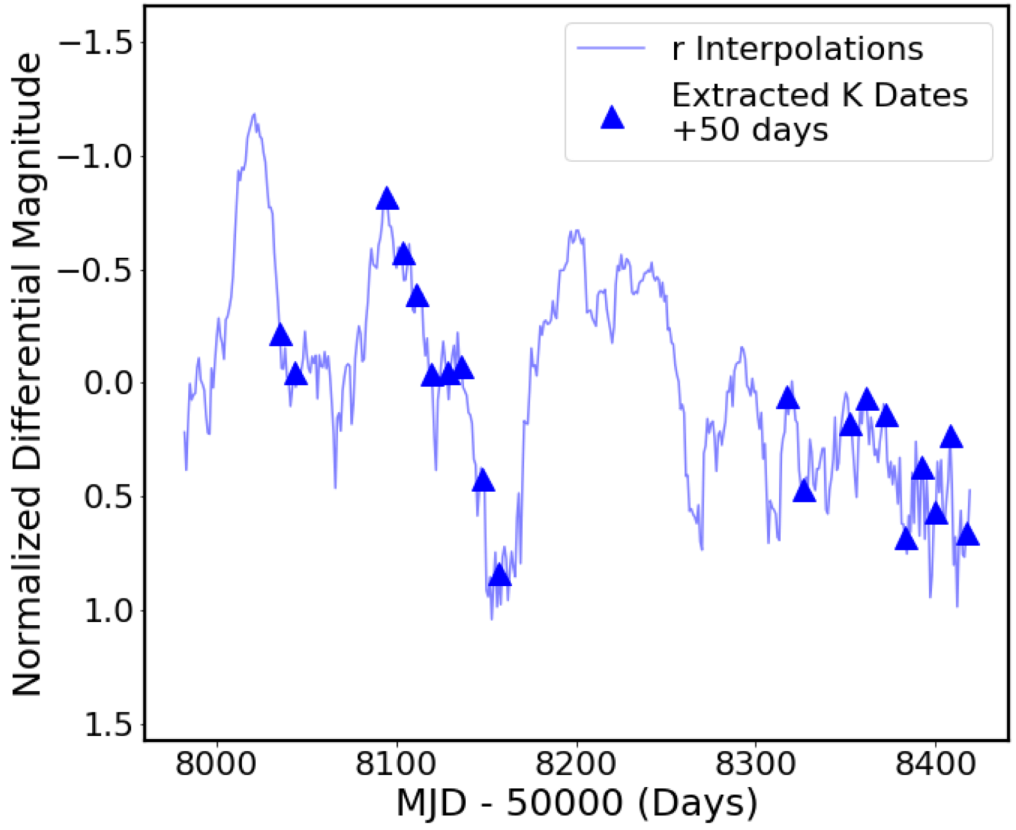
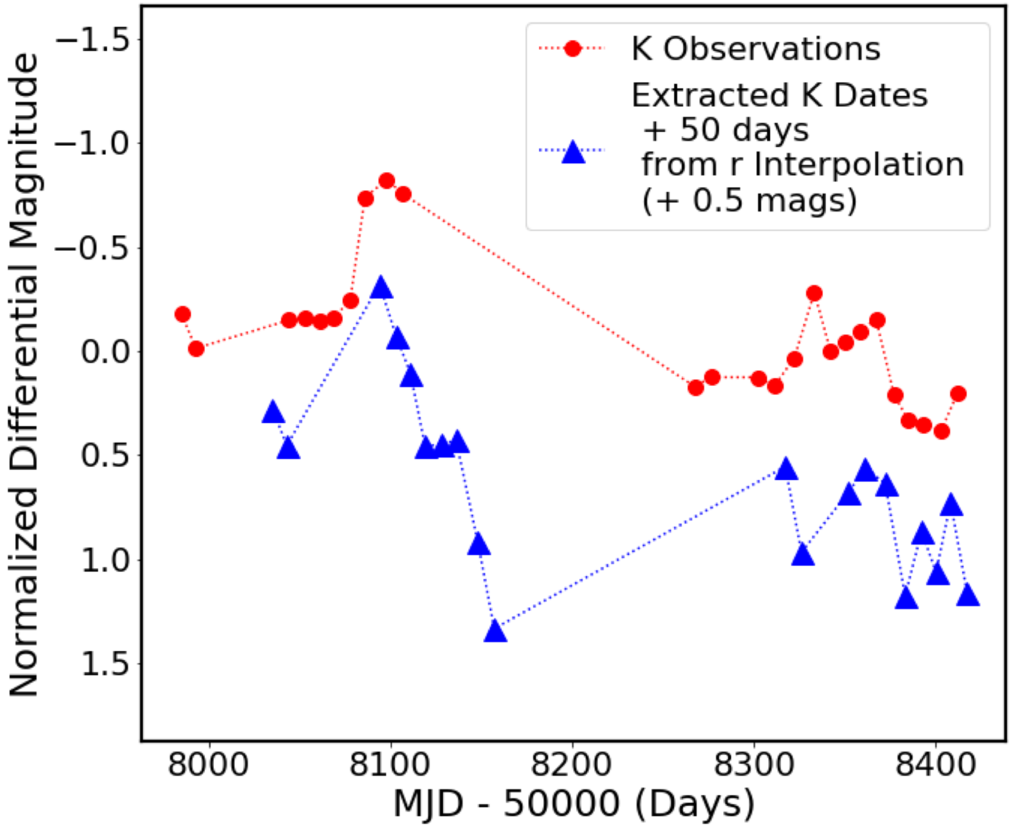
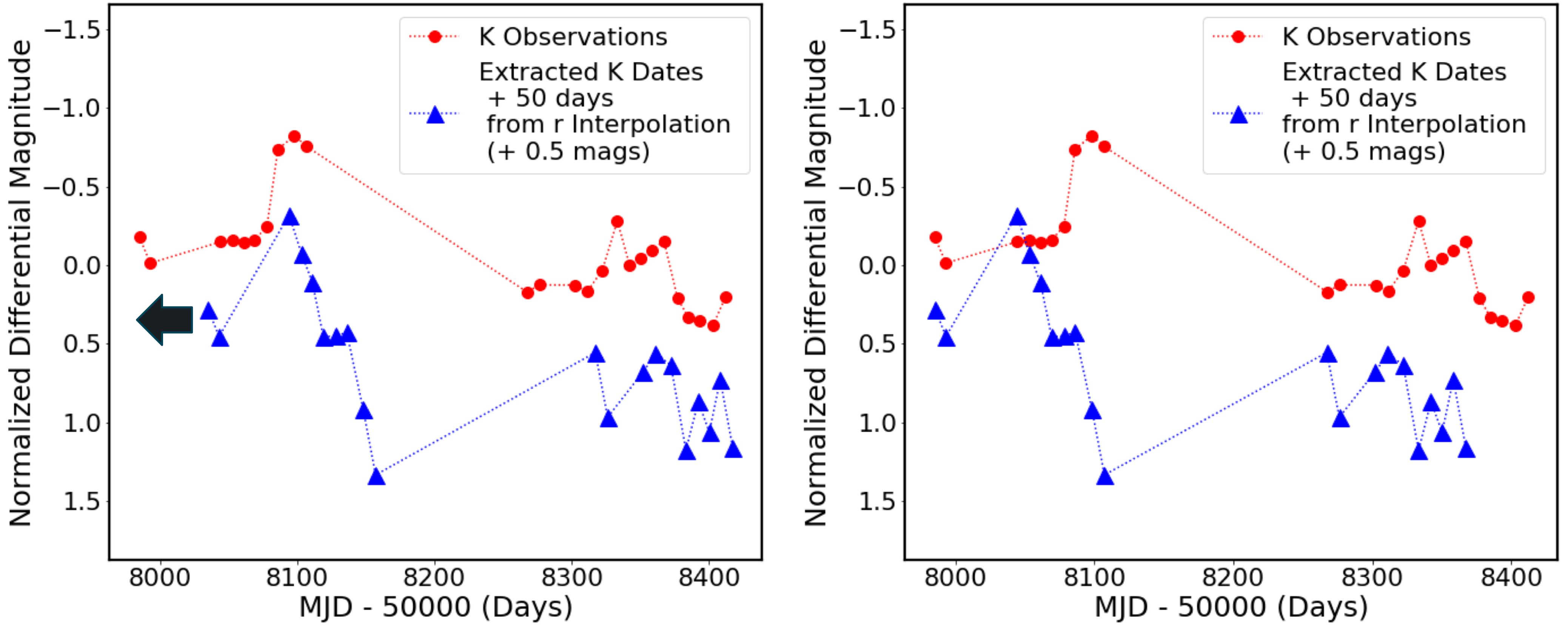
4. Extract the dates from the interpolated light curve which match Light Curve 2 + *lag*, $\boldsymbol{\tau}$, e.g. -100 ≤ $\boldsymbol{\tau}$ ≤ 100





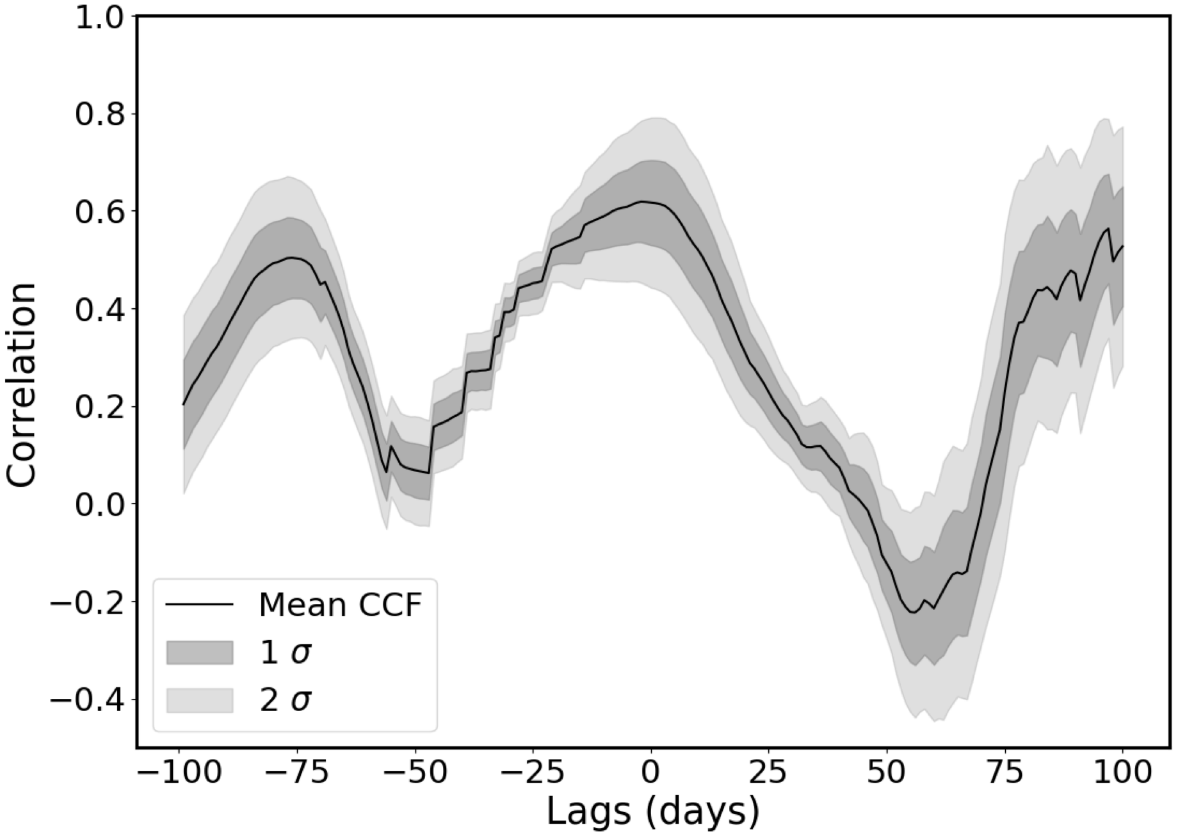
Alternate Method of Interpolations

5. Cross Correlate with 0 lag

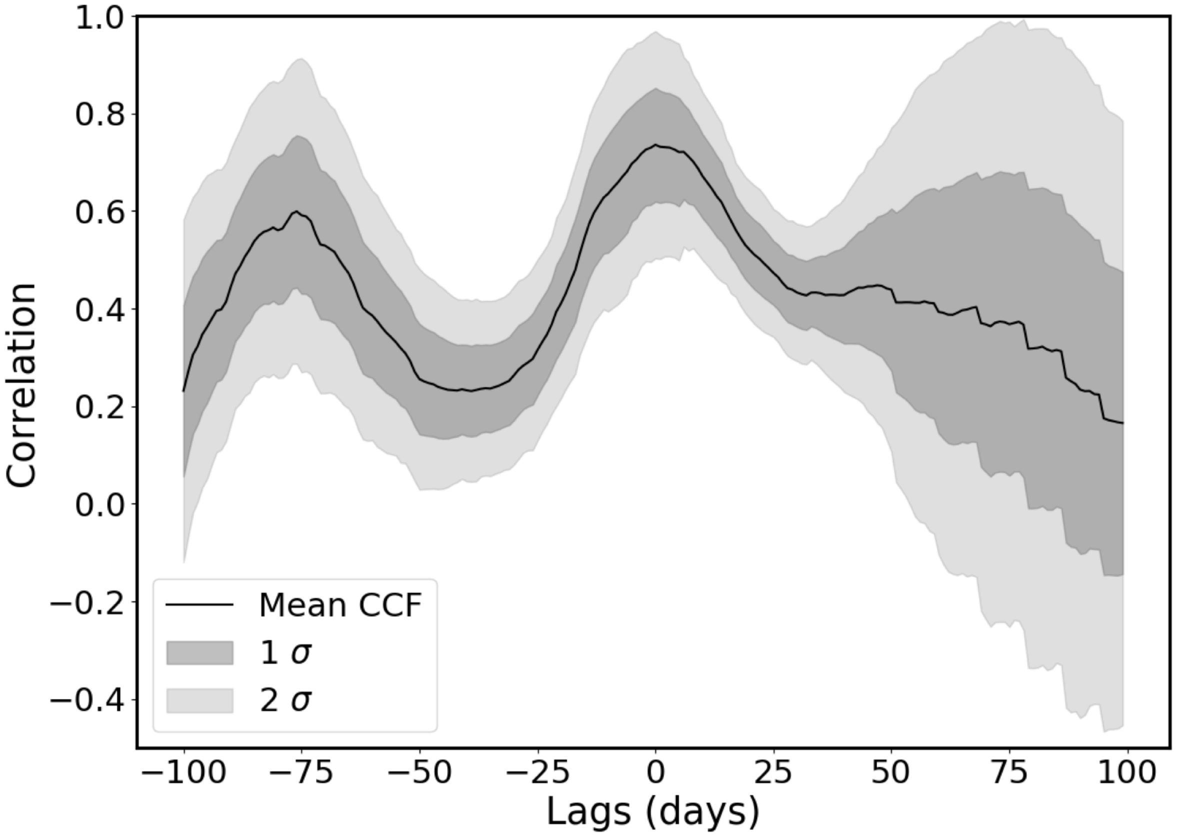


Cross Correlation – Results

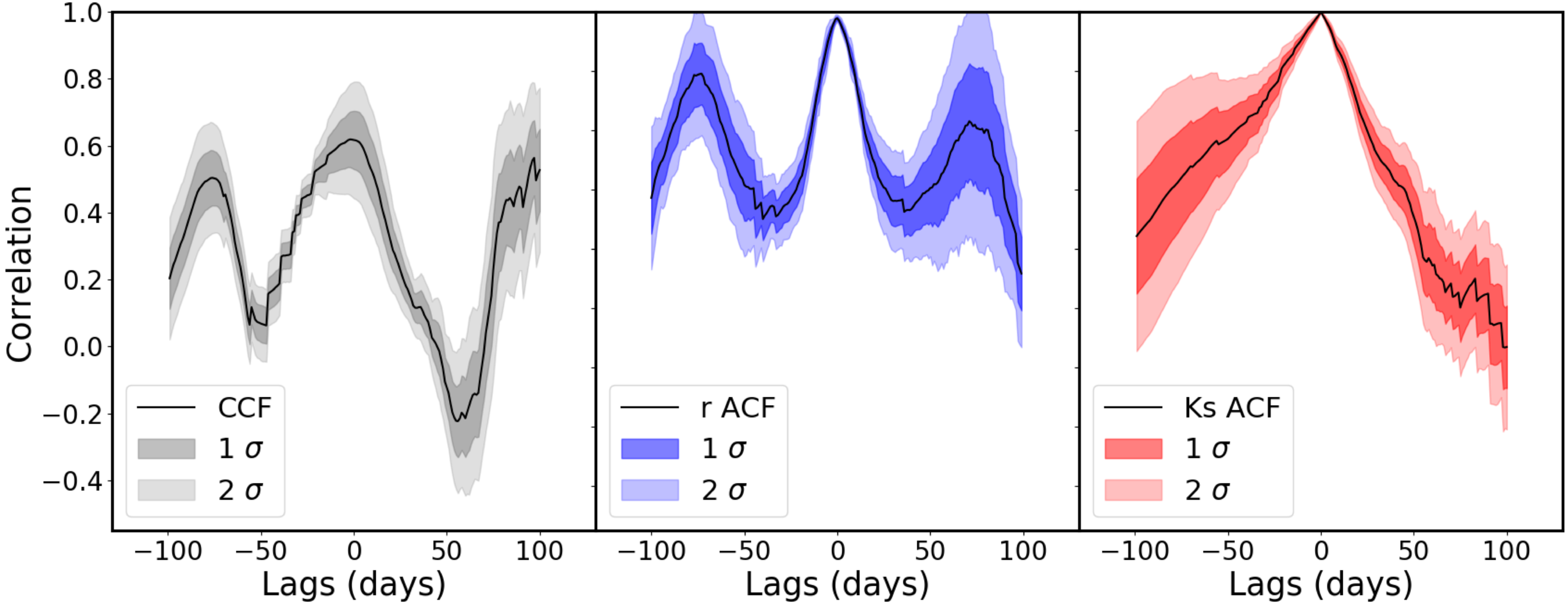
Interpolated Ks band
(extracted r dates)



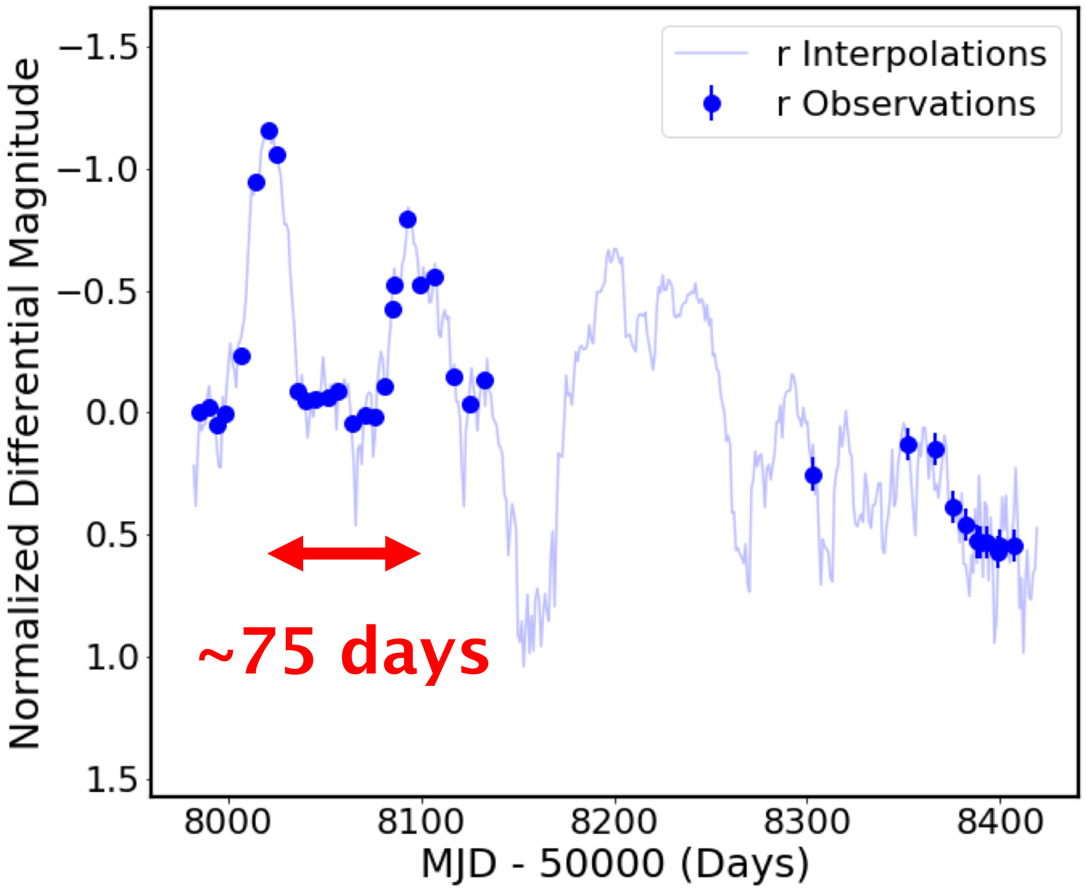
Interpolated r band
(extracted Ks dates)

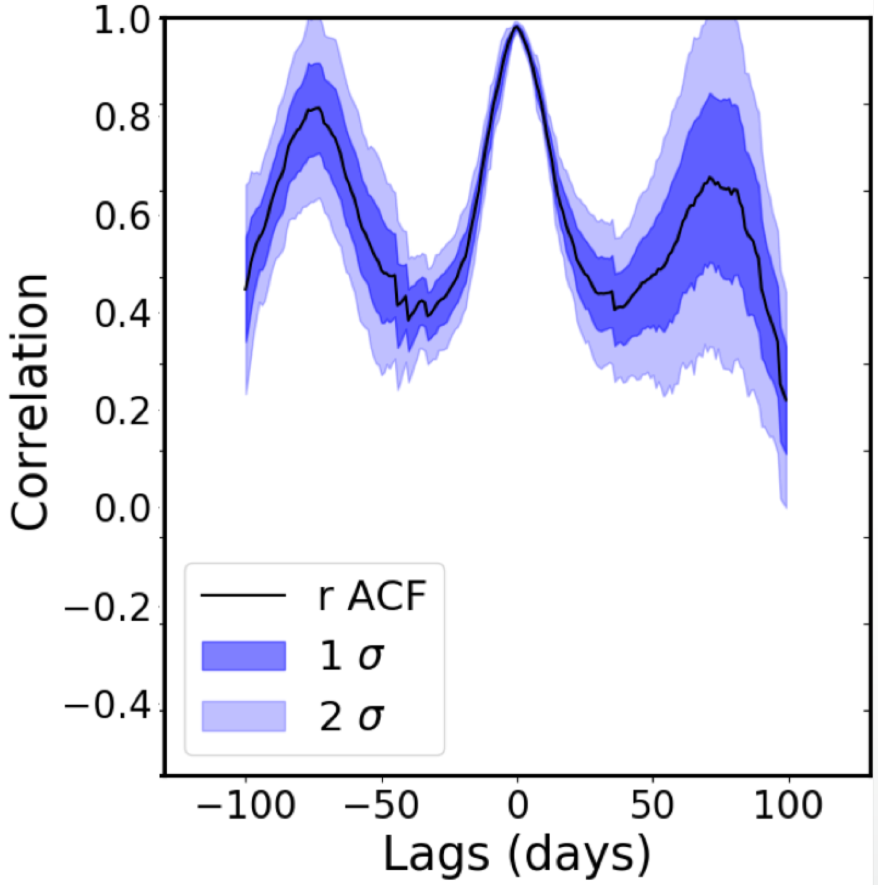


Auto Correlations- Interpolated Ks

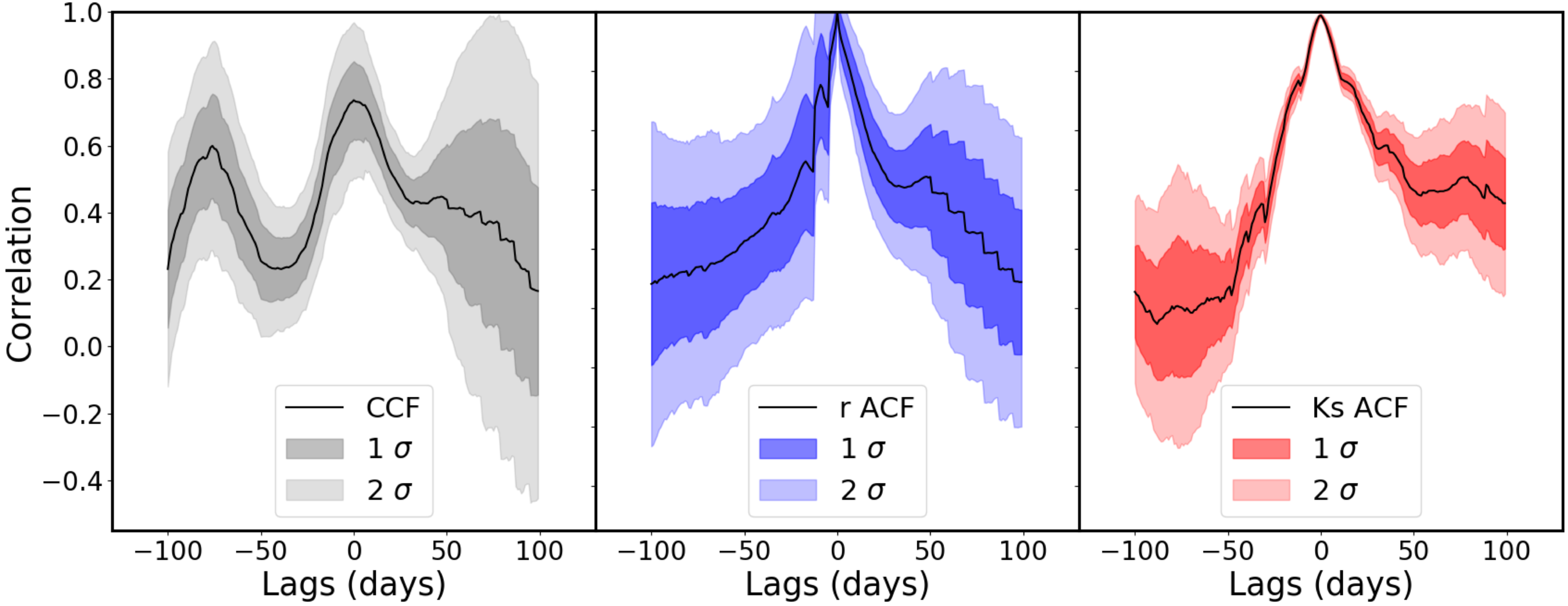


Auto Correlations- Interpolated Ks

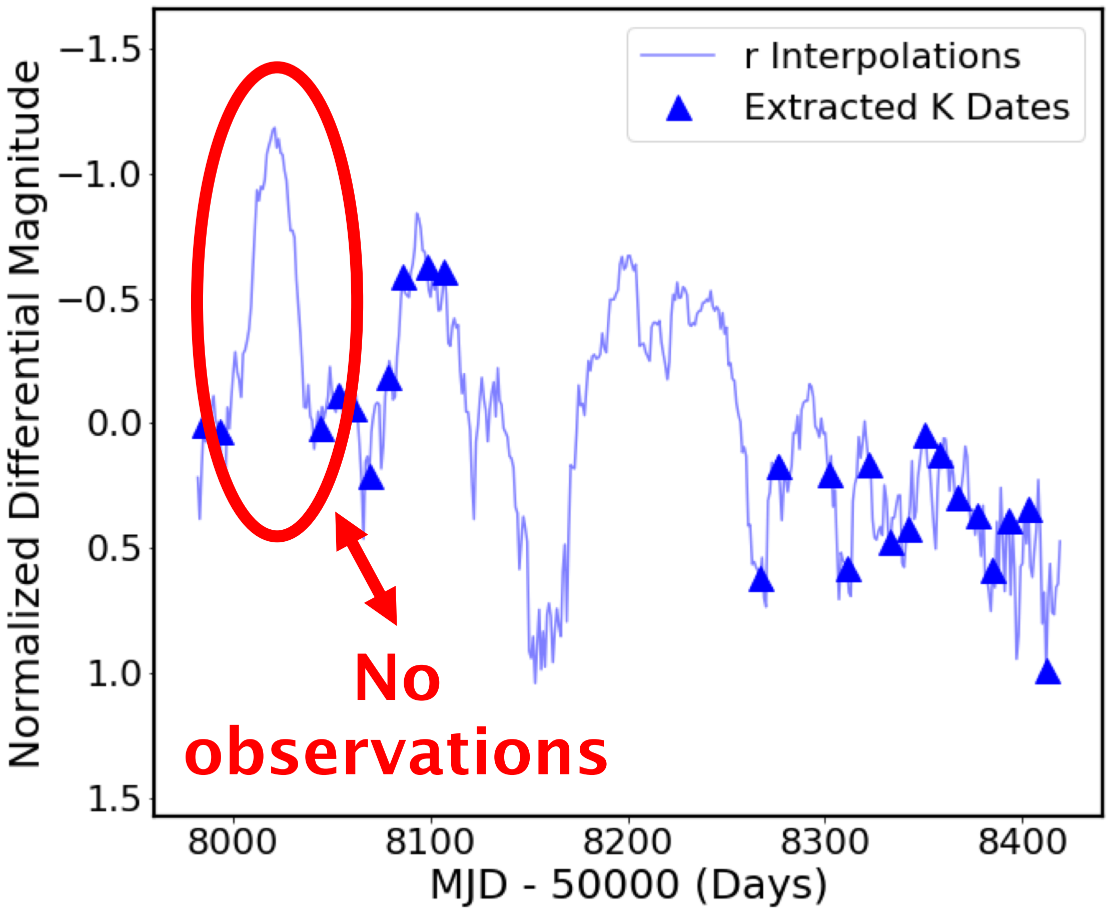


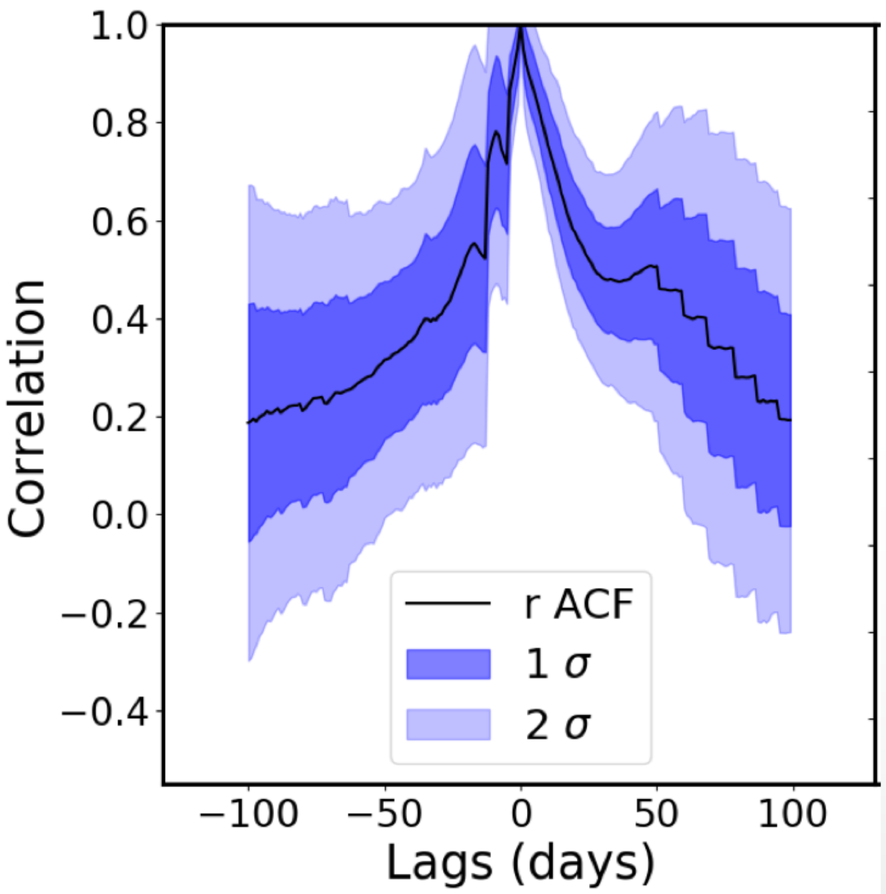


Auto Correlations - Interpolated r

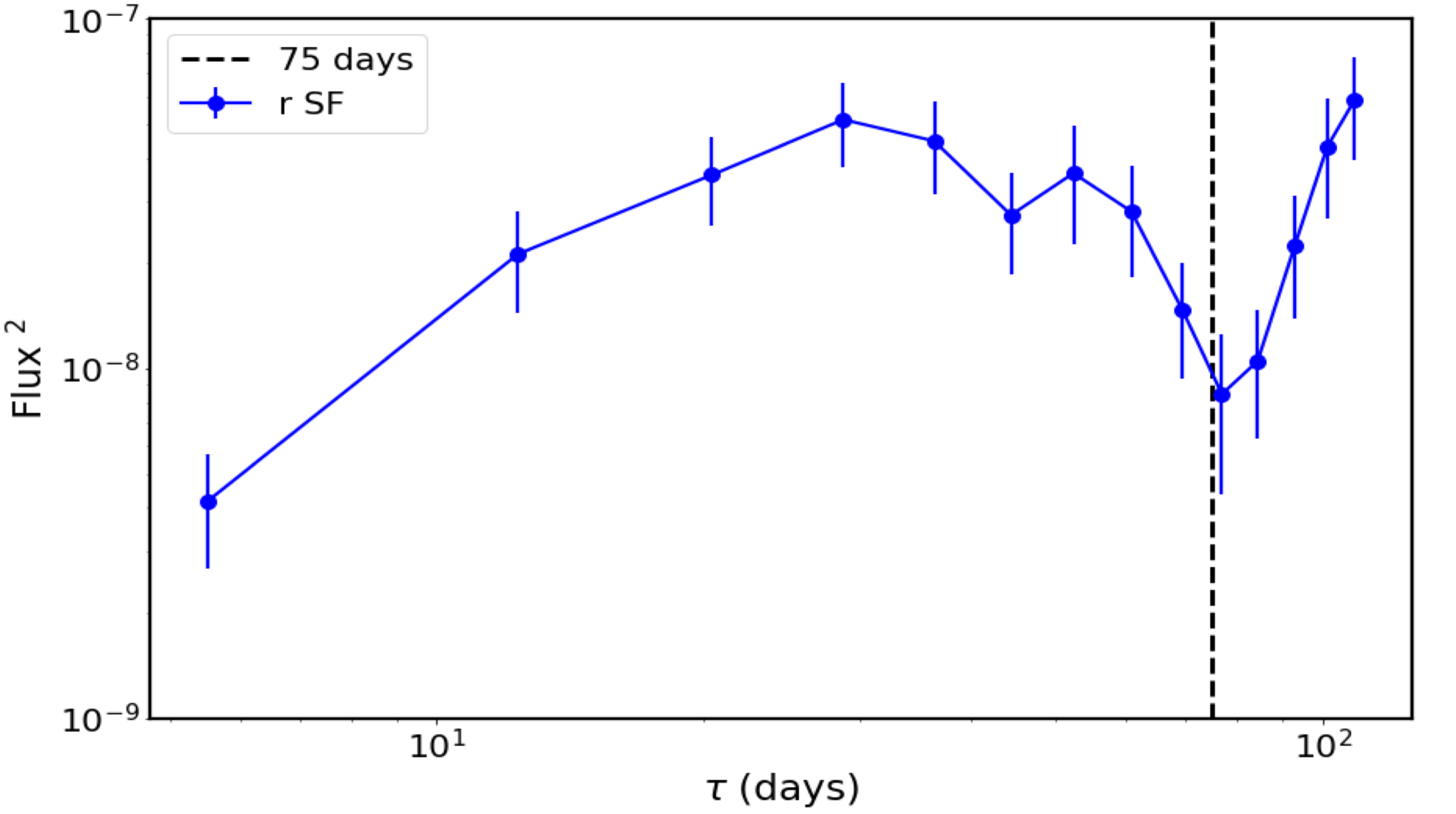


Auto Correlations- Interpolated r





Structure Function in r



Structure Function Simulation

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- Timmer and Koenig 1995 Method
  - Calculate the power spectrum from observed light curve
  - Use the power spectrum to simulate 100,000 random light curves whilst varying input parameters
  - Calculate the structure function for each light curve
- Results: ~10% of simulations had a dip at 75 days, with no obvious connection between input parameters

Time Variability of PKS 0027-426

- -75 and 75 days lags between r and Ks bands cannot be confirmed at this time
- 0 day correlation is present in all cross correlation functions
  - Need to study further using smaller timescales

Spectral Variability Analysis of PKS 0027-426

Spectral Variability of Blazars

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- Flux variations in Blazars are usually accompanied by changes in the spectral shape
- Spectral changes can be represented by changes in colour
- Typical Colour behaviours include:
  - Bluer When Brighter (BWB) trends
  - Redder When Brighter (RWB) trends

Spectral Variability – RWB trends

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- Most Common in FSRQs
- Possible Explanation:
  - 2 Component Model:
    - Redder component (e.g. synchrotron emission from the jet) varies more than the bluer component (e.g. thermal emission from the accretion disk)

Spectral Variability – BWB trends

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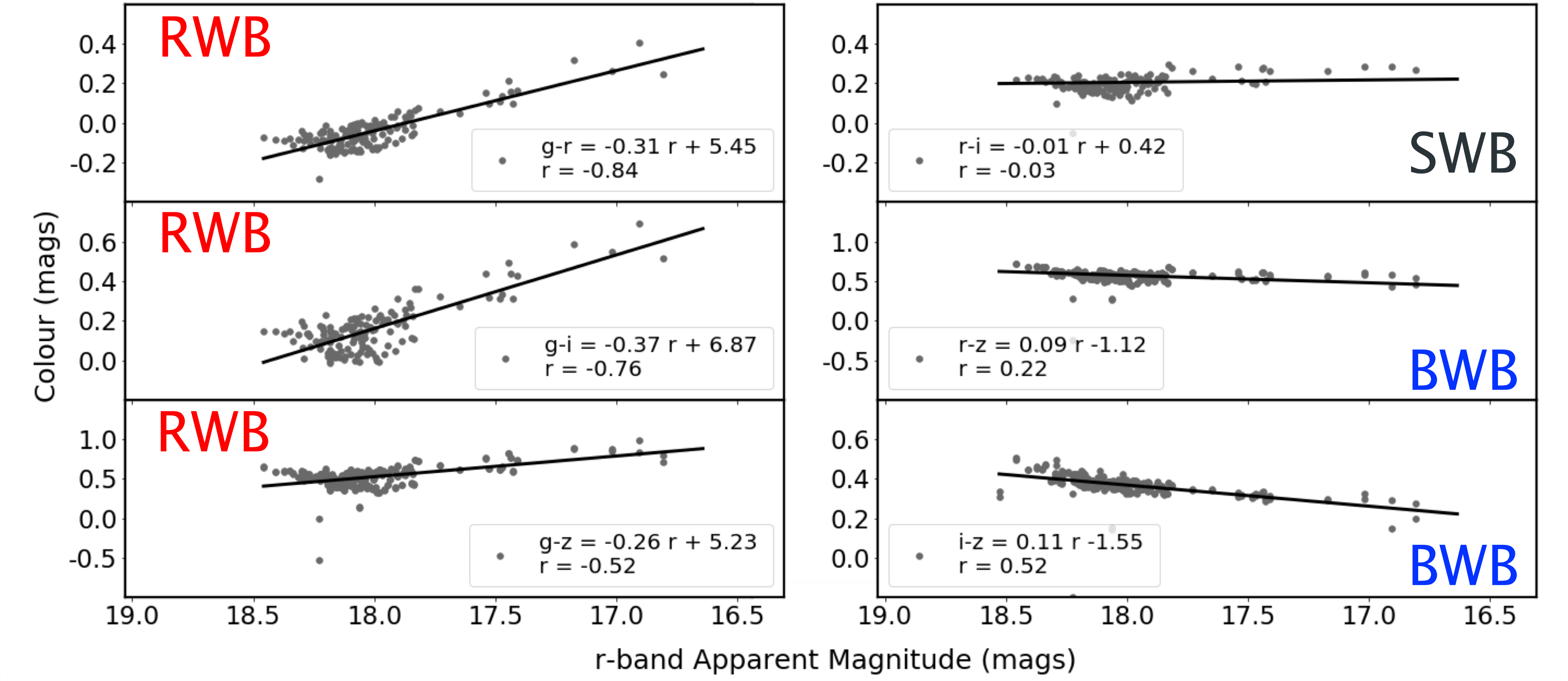
- Most Common in BL Lacs
- Possible Explanations:
  - 1 Component Synchrotron Model:
    - Increase in energy release boosts the emission to higher frequencies
  - 2 Component Model:
    - Bluer component varies more than the redder component

Colour Variability of Optical – Method

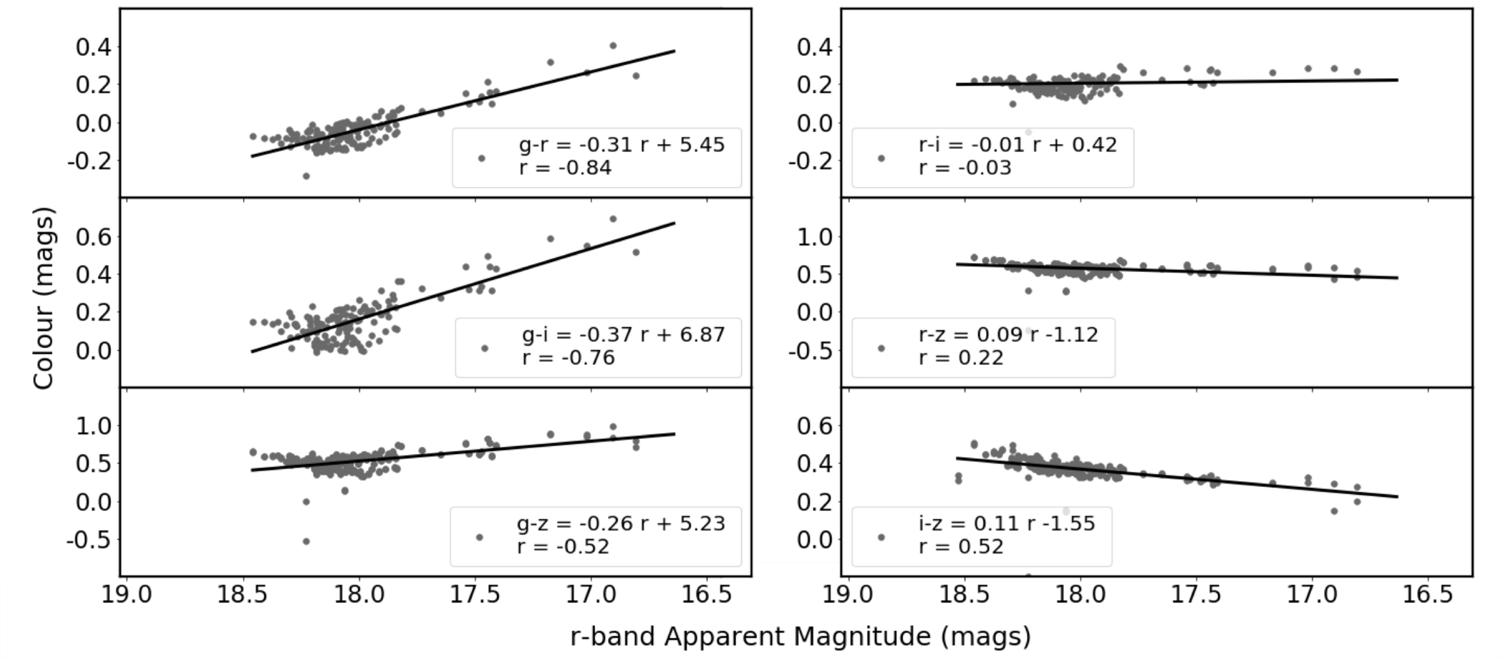
- Calculated colour from quasi-Simultaneous optical observations with DES
- Average time between observations is 6.5 minutes, with a maximum of 18.5 minutes
- Plot colour against the r band magnitude and determine correlation between colour and brightness

Colour Variability of Optical – Results



Colour Variability of Optical – Results

- Shows both BWB and RWB trends for different filters



Colour Variability of Optical and NIR– Method

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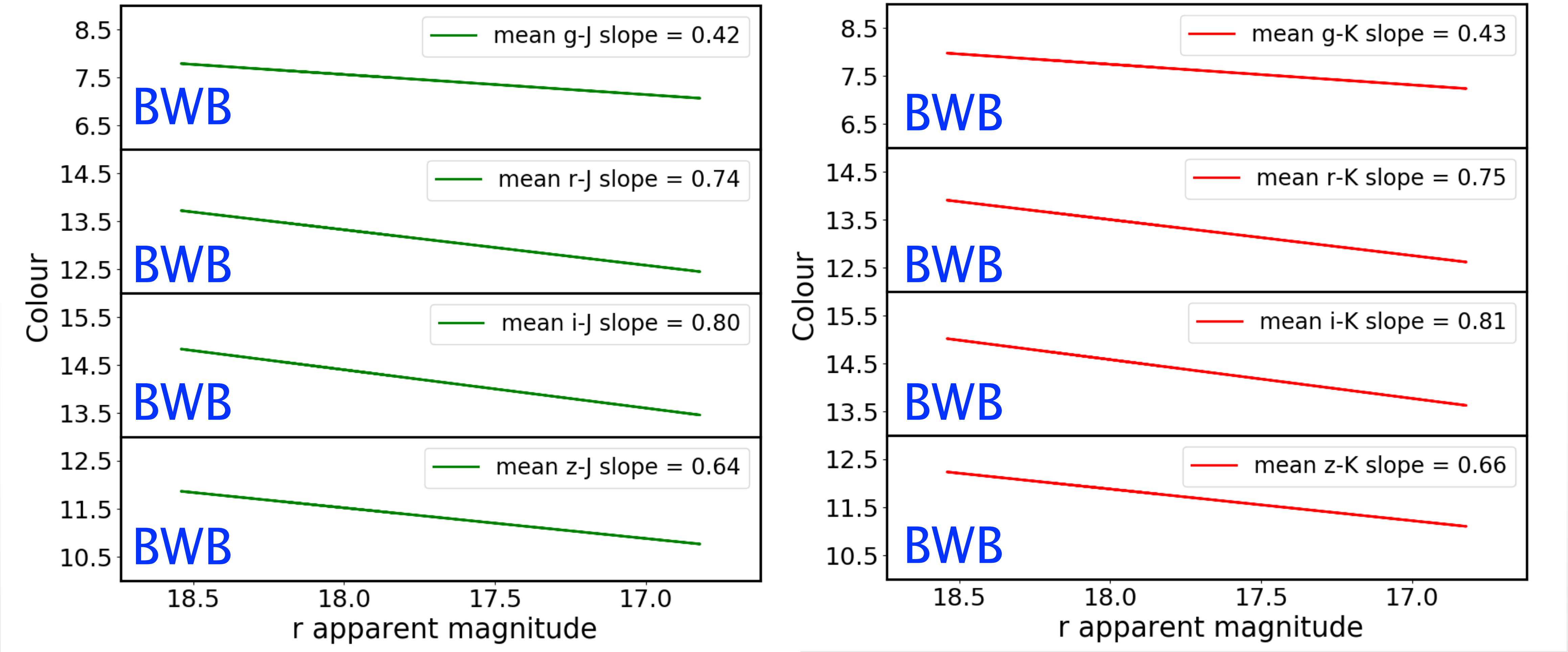
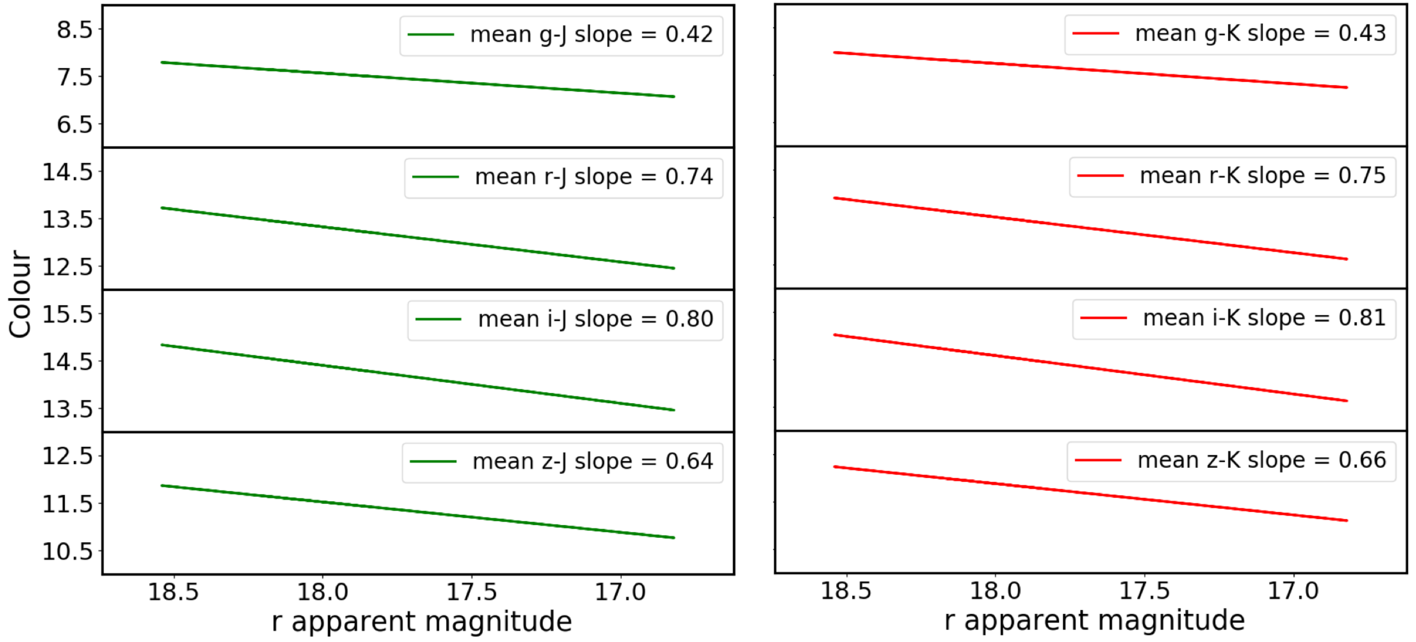
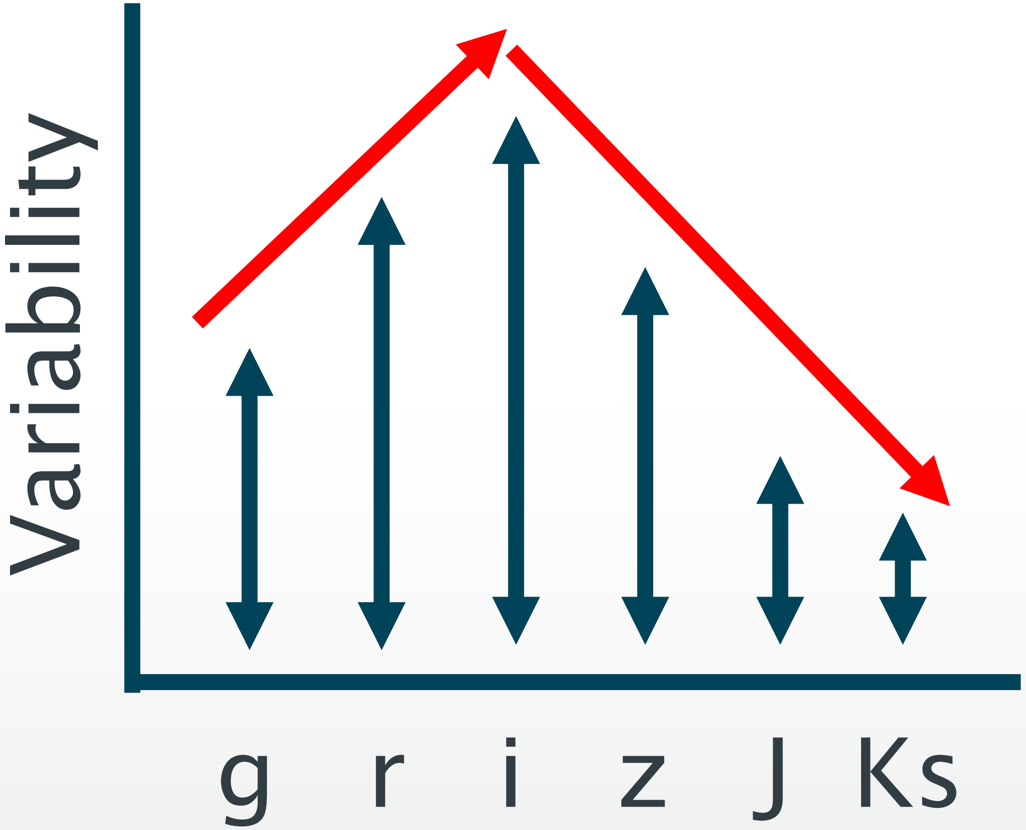
- No quasi-simultaneous observations between optical and NIR
- Instead:
  - interpolate the light curves 10,000 times and extract the matching dates
  - Calculate the mean slope of the colour vs r band magnitude plot

Colour Variability of Optical and NIR– Results



Colour Variability of Optical and IR – Results





Colour Variability of PKS 0027-426

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- Possible Explanation:
  - Higher frequency emission has a thermal contribution from emission lines which are less variable
    - would need multiple spectra to confirm the role of emission lines

Summary

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- Time Variability of PKS 0027-426:
  - Correlation between light curves at 0 days
  - **Future:** Include final year of VEILS in time analysis
  - **Future:** Intra-day light curves for further 0 day correlation analysis
- Spectral Variability of PKS 0027-426:
  - PKS 0027-426 demonstrates both RWB and BWB behaviour depending on filters
  - **Future:** Multiple spectra needed to compare emission lines to filters