KMTNet Detection Algorithm

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Overview of the KMTNet (Kim et al. (2018))

The standard microlensing model is:

$$F(t) = f_s A[u(t; t_0, u_0, t_{\mathrm{E}})] + f_b; \qquad u(t) = \sqrt{\frac{(t-t_0)^2}{t_{\mathrm{E}}^2} + u_0^2}; \qquad A(u) = \frac{u^2+2}{u\sqrt{u^2+4}}.$$

- **5 parameters total**:
  - **Linear**: f_s (source flux), f_b (blend flux)
  - **Non-linear**: t_0 (time of peak), u_0 (impact parameter), t_E (Einstein timescale)

Overview of the KMTNet ([Kim et al. (2018)](#))

Instead of an expensive 3D grid search over (t_0, u_0, t_E), KMTNet applies two approximations to reduce complexity to 2D grids:

(based on Gould & Loeb 1992)

$$F(t) = f_1 A_j\left[Q(t; t_0, t_{eff})\right] + f_0;$$

$$Q(t; t_0, t_{eff}) = 1 + \left(\frac{t - t_0}{t_{eff}}\right)^2; \qquad (j = 1,2)$$

$$t_{eff} \rightarrow u_0 t_E$$

High magnification limit $(u_0 \rightarrow 0)$:

$$A_{j=1}(Q) = Q^{-1/2}$$

$$(f_1, f_0) \rightarrow (f_s/u_0, f_b)$$

Low magnification limit $(u_0 = 1)$:

$$A_{j=2}(Q) = \frac{Q+2}{\sqrt{Q(Q+4)}} = \left[1 - \left(\frac{Q}{2} + 1\right)^{-2}\right]^{-1/2}$$

$$(f_1, f_0) \rightarrow (f_s, f_b)$$

KMTNet Grid Strategy

- **Season duration:** ~250 days
- **Cadence:** about 1 hour

To efficiently search for microlensing events, KMTNet uses a **2D grid over t_0** and t_{eff}:

- $t_{\mathrm{eff},1} = 0.56$ days, increasing geometrically to ~99 days:

$$t_{\mathrm{eff},k+1} = (1+\delta)\, t_{\mathrm{eff},k}, \quad \delta = \frac{1}{3}$$

- For each $t_{\mathrm{eff},k}$, t_0 values follow:

$$t_{0,k,l+1} = t_{0,k,l} + \delta\, t_{\mathrm{eff},k}$$

- Each trial fit uses data within:

$$[t_0 - Z t_{\mathrm{eff}},\ t_0 + Z t_{\mathrm{eff}}], \quad Z = 5$$

  and requires at least **50 datapoints** in this window

Rubin Grid Strategy

We choose:

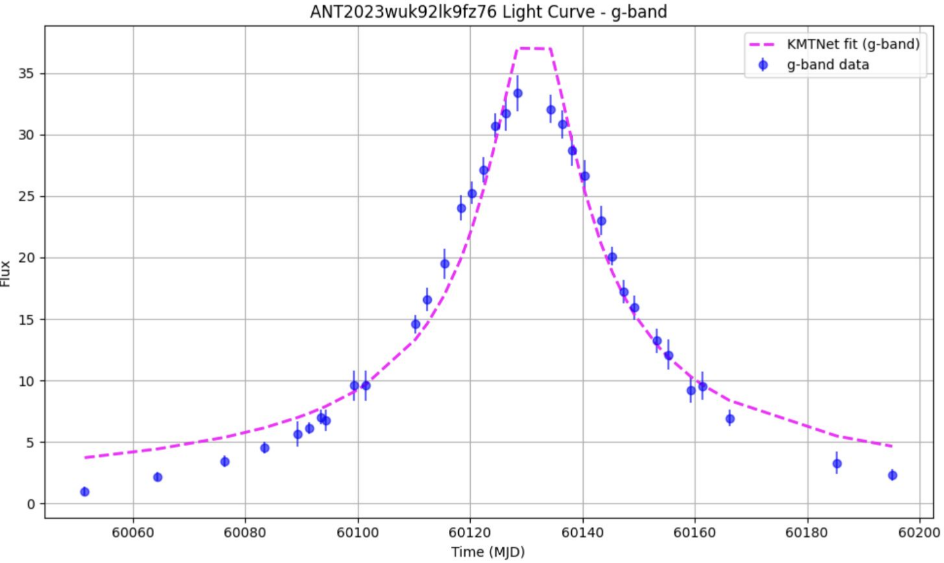
- $\delta = \frac{1}{3}$
- $t_{\text{eff}} = 1$ to **100 days**
- Fit window: $Z = 7$
- Minimum: **≥ 10 datapoints** in the window

We find the best-fit parameters by minimizing the chi-squared function in two magnification regimes (high and low) over the defined grid and fit window. The parameters yielding the lowest chi-squared are selected as the best microlensing fit.

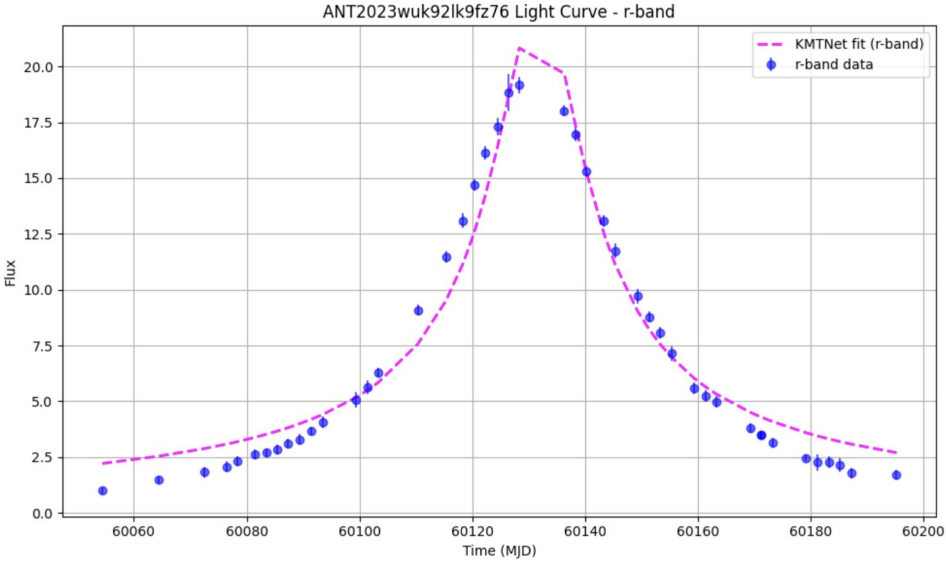
Next, using the same fit window defined by these best parameters, we fit a linear model to the data and compute its chi-squared. We then define the metric:

$$\Delta\chi^2 \equiv \left(\frac{\chi^2_{\mu lens}}{\chi^2_{flat}} - 1\right)$$

ANT2023wuk92lk9fz76_Microlensing

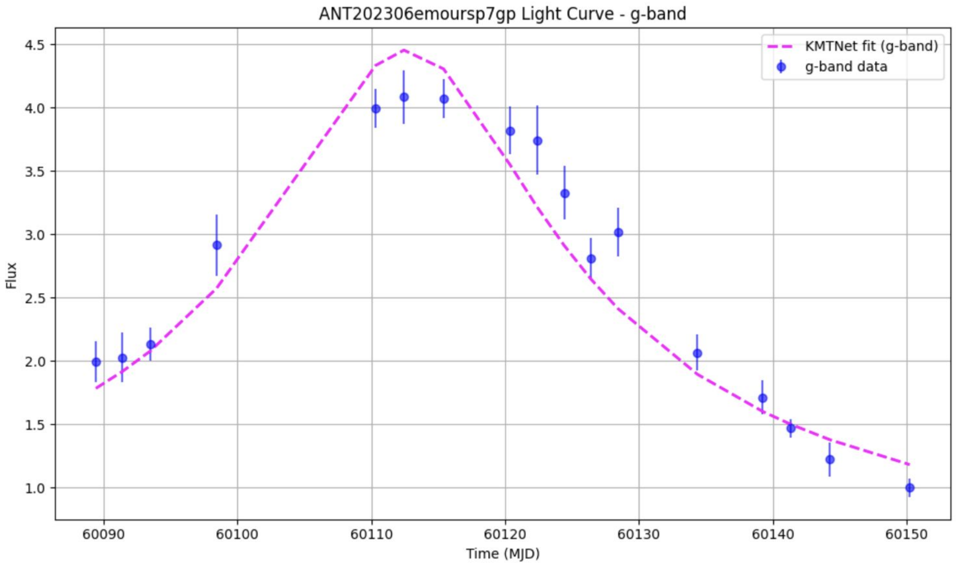


Delta Chi2=0.962

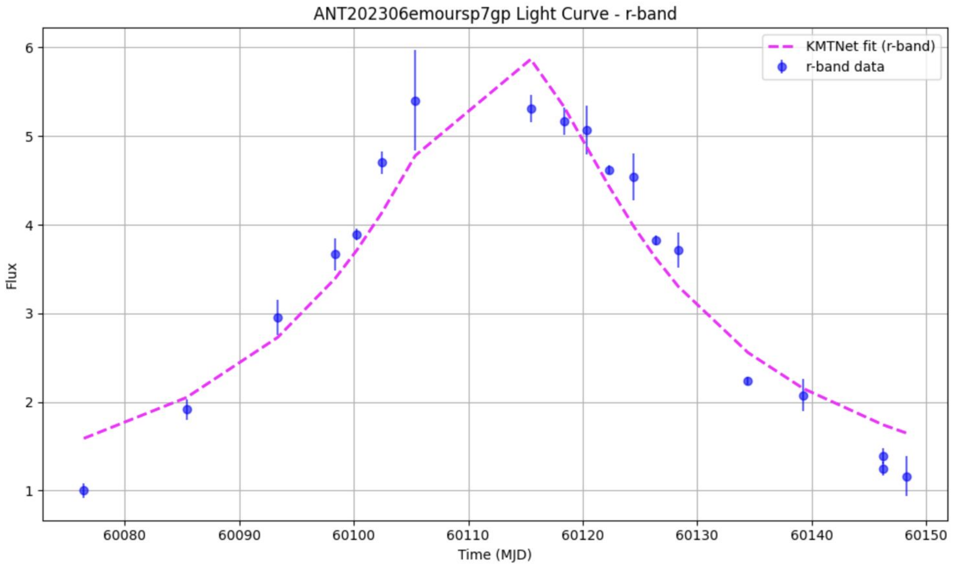


Delta Chi2=0.959

ANT202306emoursp7gp_Microlensing

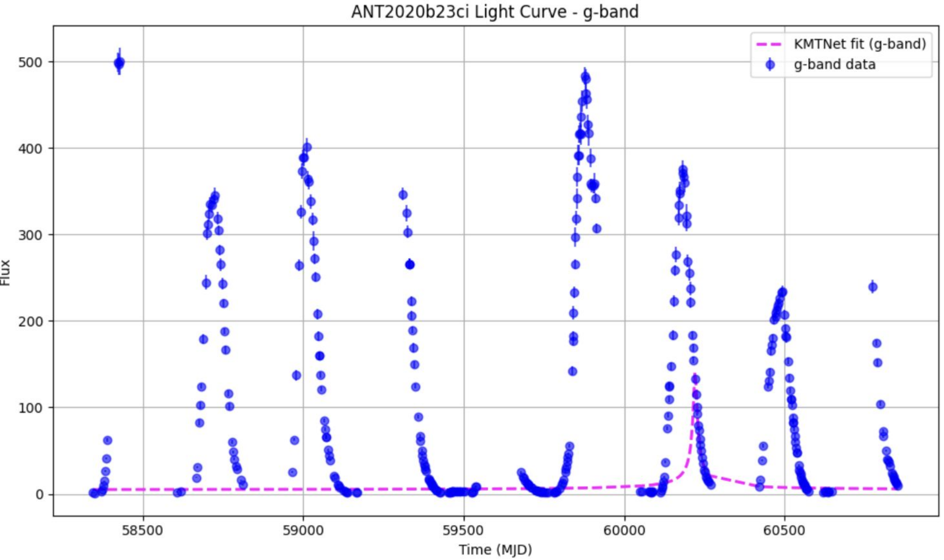


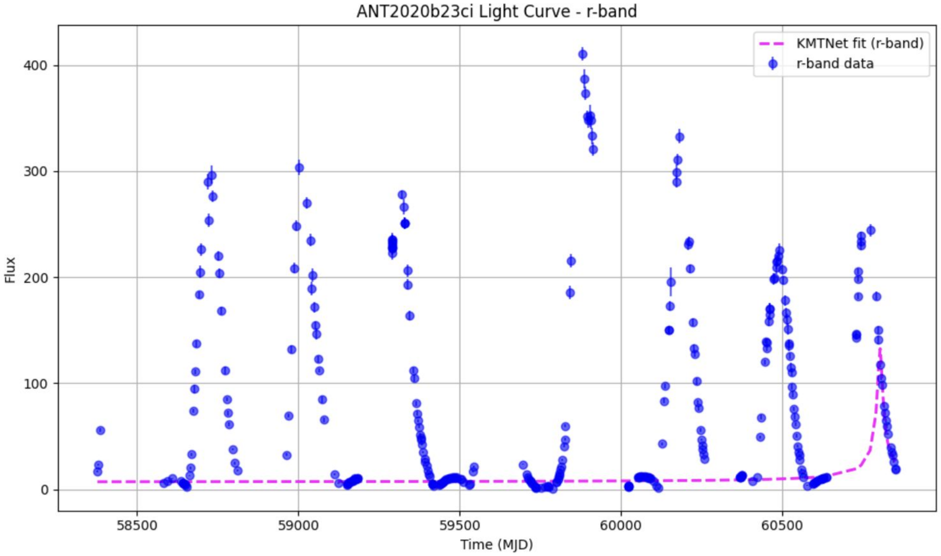
Delta Chi2=0.954



Delta Chi2=0.939

ANT2020b23ci_nonMicrolensing

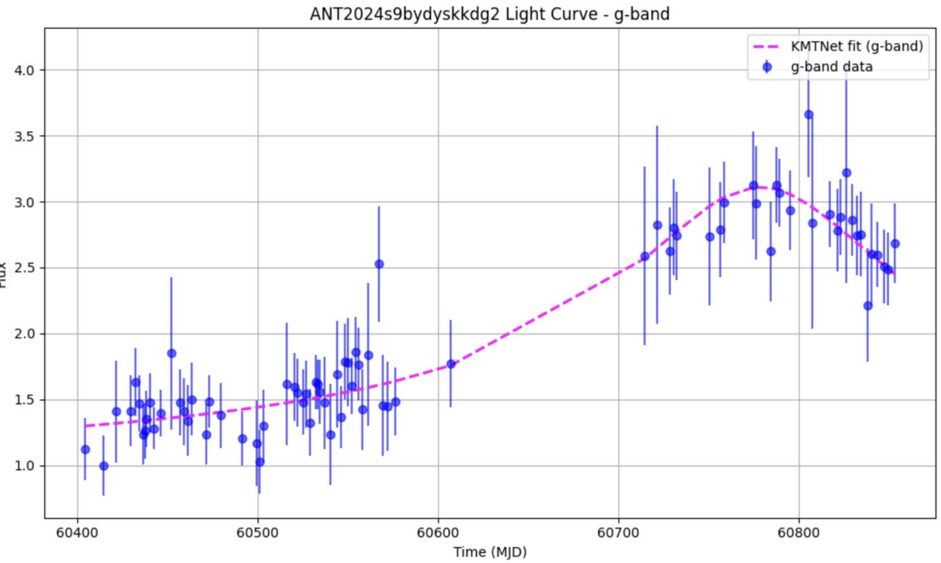


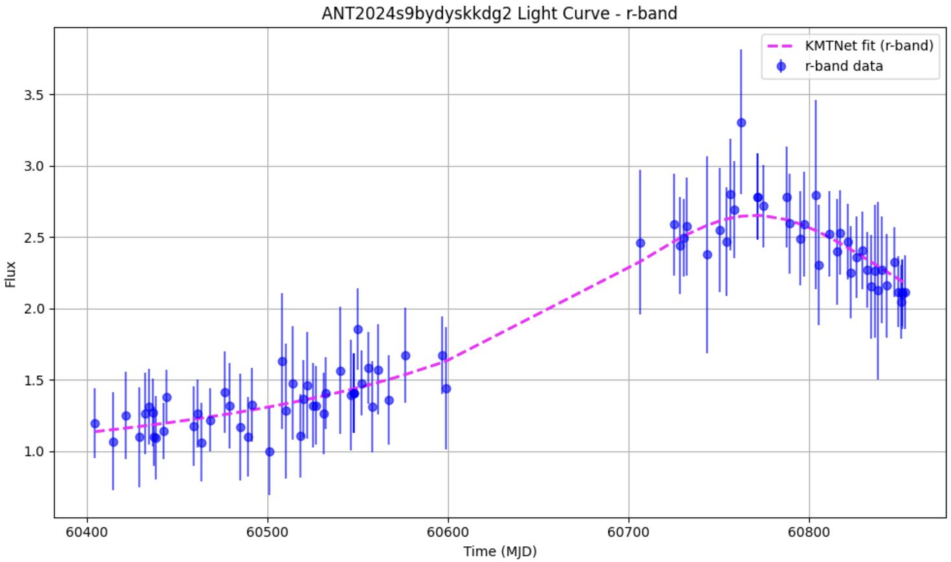


Delta Chi2=0.863

Delta Chi2=0.882

ANT2024s9bydyskkdg2_nonMicrolensing (Supernova)

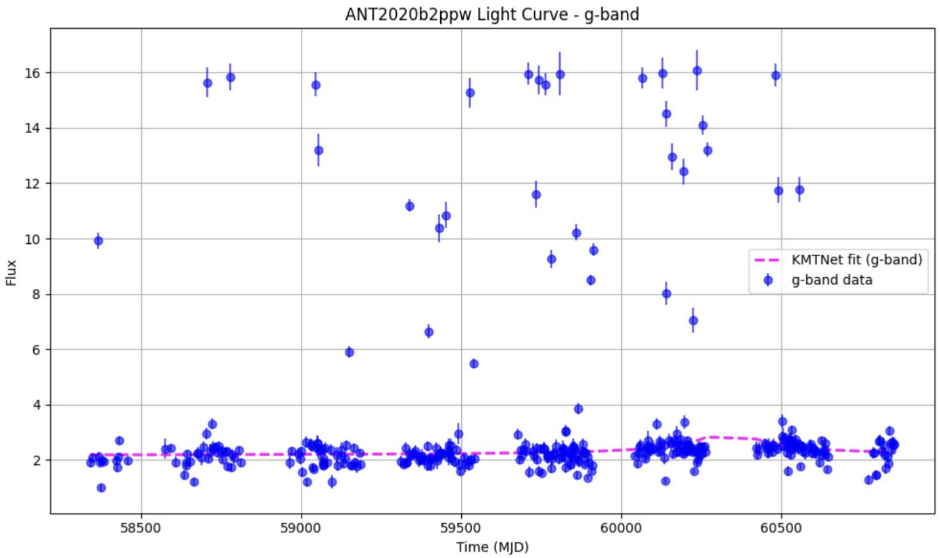




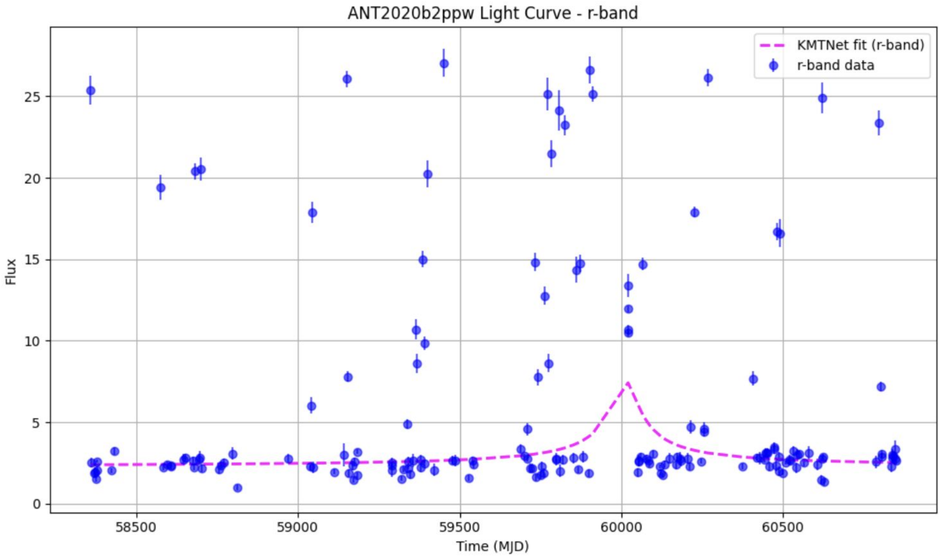
Delta Chi2=0.923

Delta Chi2=0.952

ANT2020b2ppw_nonMicrolensing

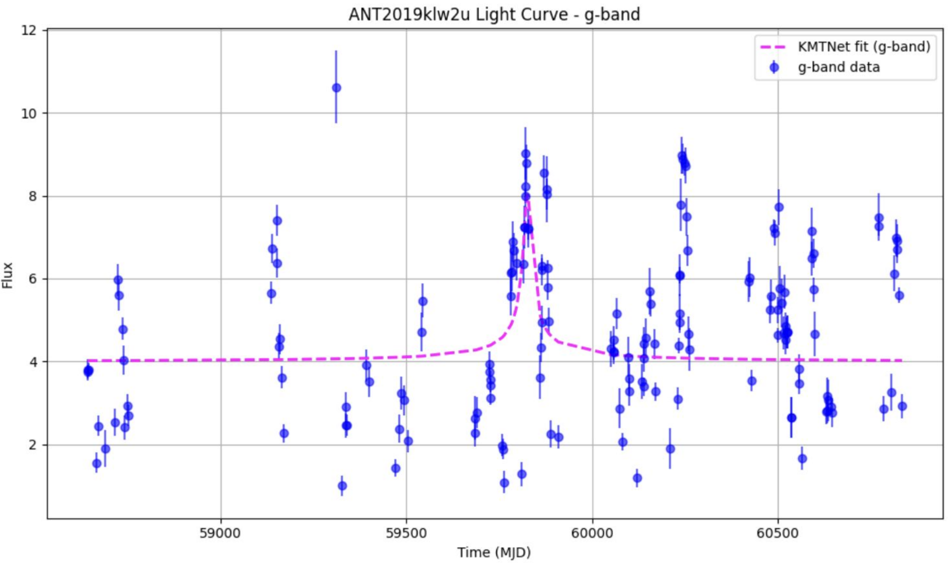


Delta Chi2=0.025

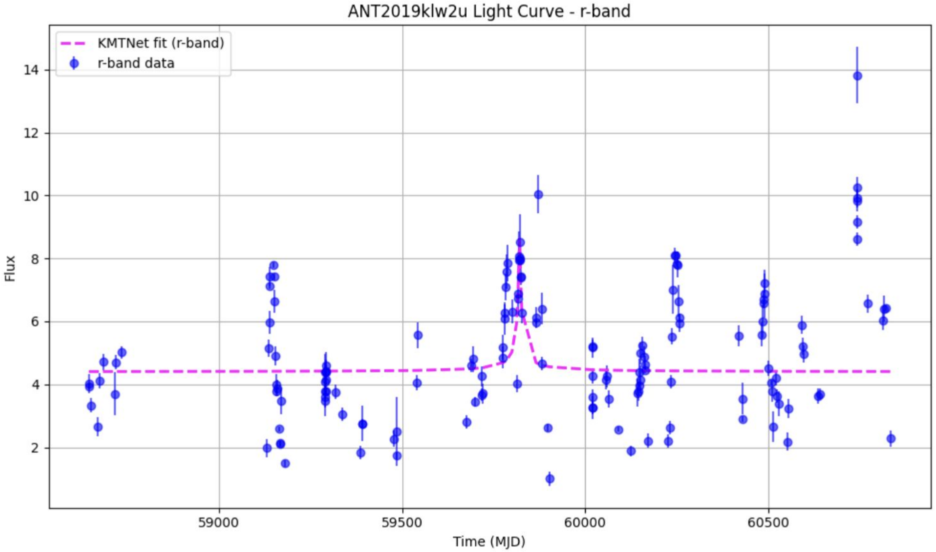


Delta Chi2=0.167

ANT2019klw2u_nonMicrolensing

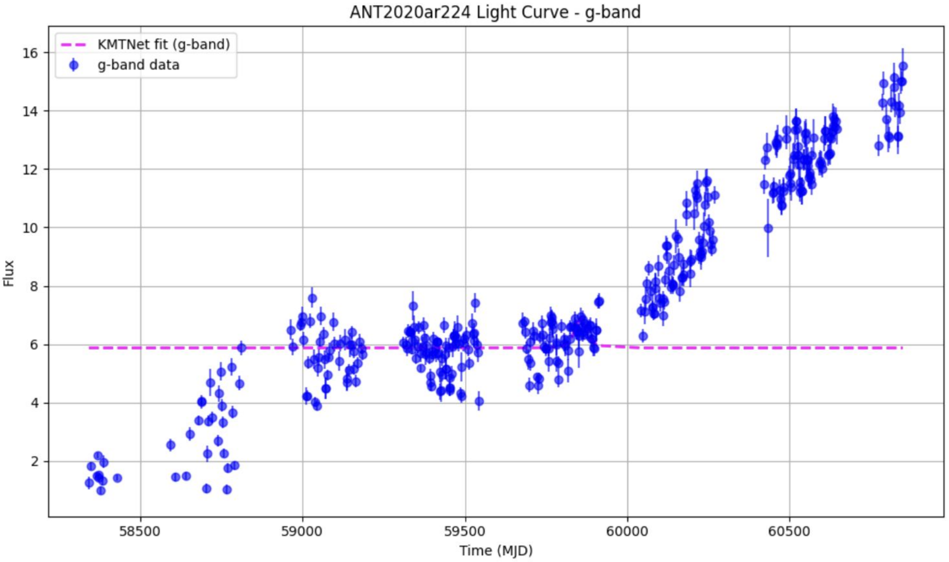


Delta Chi2=0.432

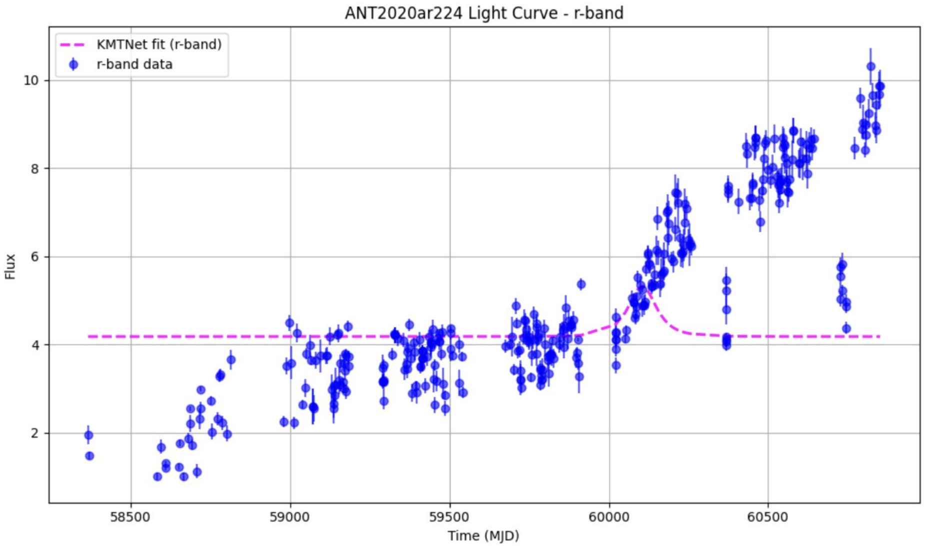


Delta Chi2=0.698

ANT2020ar224_nonMicrolensing



Delta Chi2=0.010



Delta Chi2=0.158