The Origin of Wavelength-Dependent Continuum Delays in AGNs – a New Model

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Wavelength-dependent delays long expected in accretion-disc models

- Shorter-wavelength radiation comes from hotter inner disc regions. Expected delays on sound-crossing or dynamical (orbital) timescales.

FIRST SURPRISE:

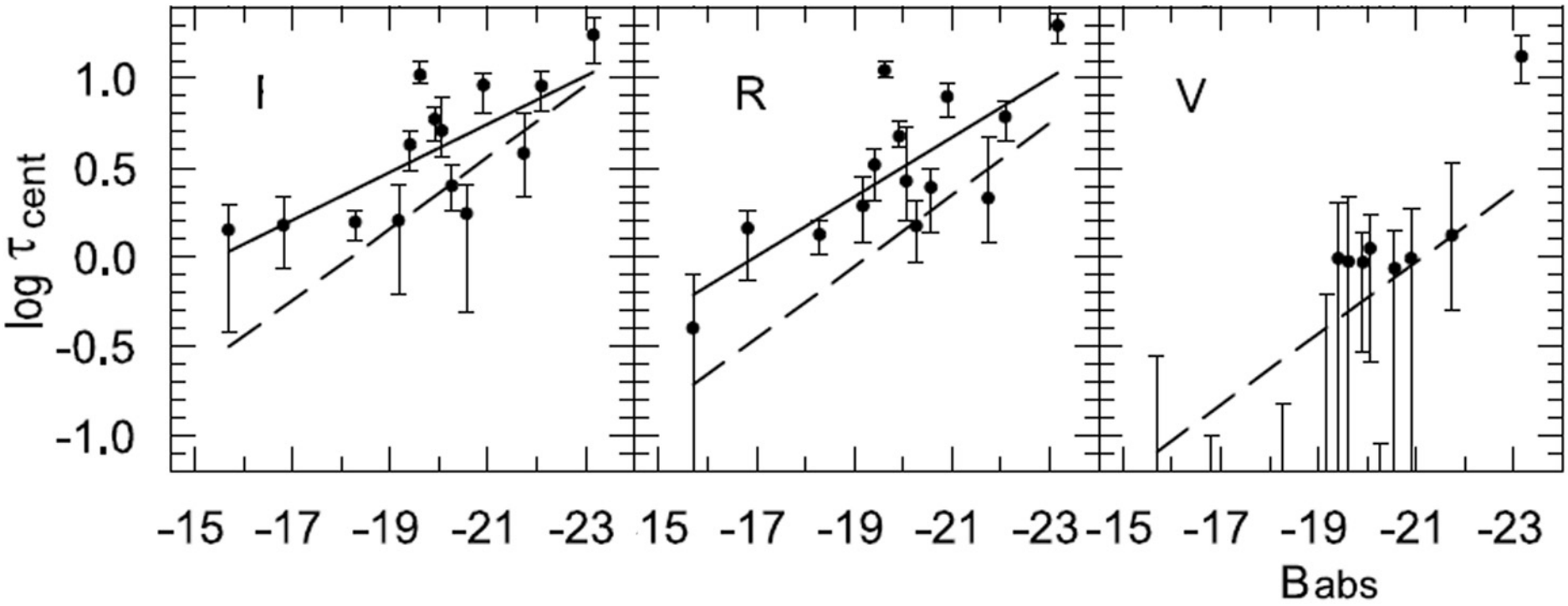
- Not seen at first (*e.g.,* NGC 5548, Korista *et al*. 1995; NGC 4151, Edelson *et al*. 1996) Upper limits ruled out long (dynamic) timescales $\Rightarrow$ light-crossing timescales.

Delays found on light-crossing timescales

- NGC 7469 – Wanders *et al*. (1997), Collier *et al*. (1998), Kriss *et al*. (2000)

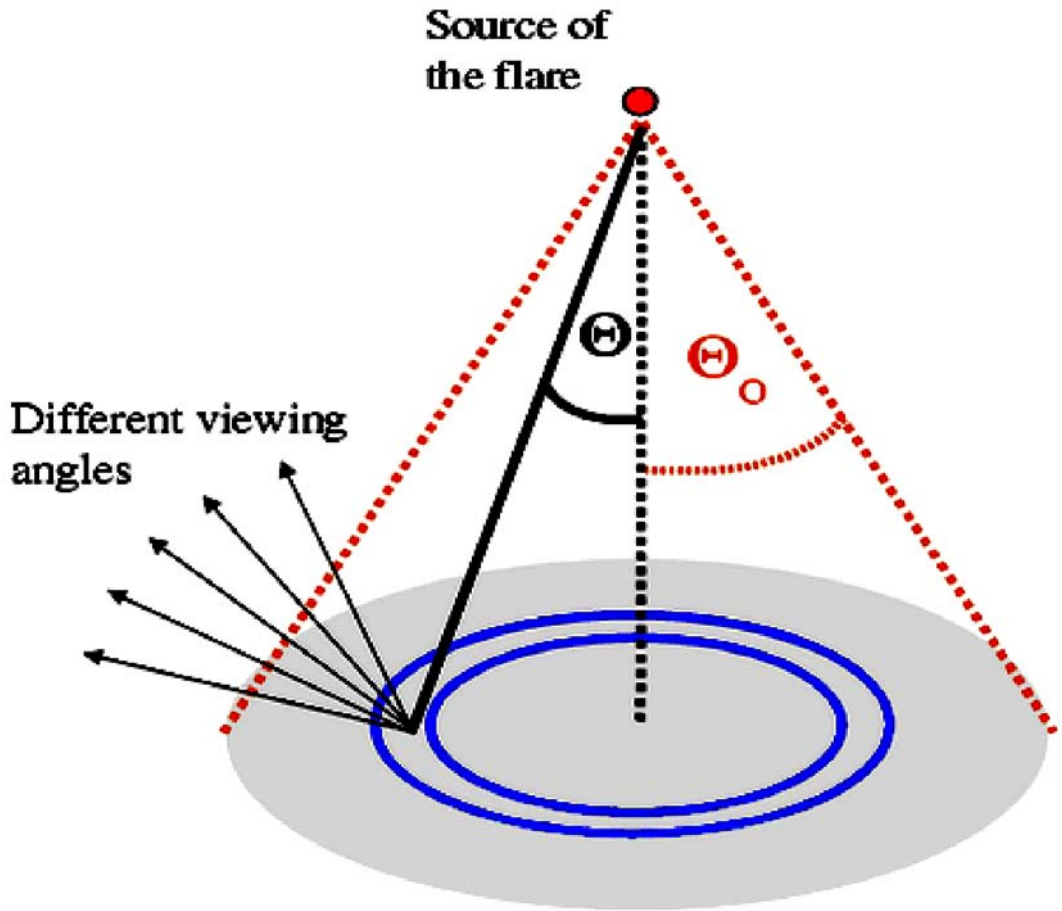
Important discovery (Sergeev *et al.* 2005) :

Delay ∝ Luminosity



Current model: - “Lamp post” model

(*E.g.*, Goosmann *et al*. 2006)



Collier et al. (1998):

Steady-state disc has

$$T \propto R^{-3/4}$$

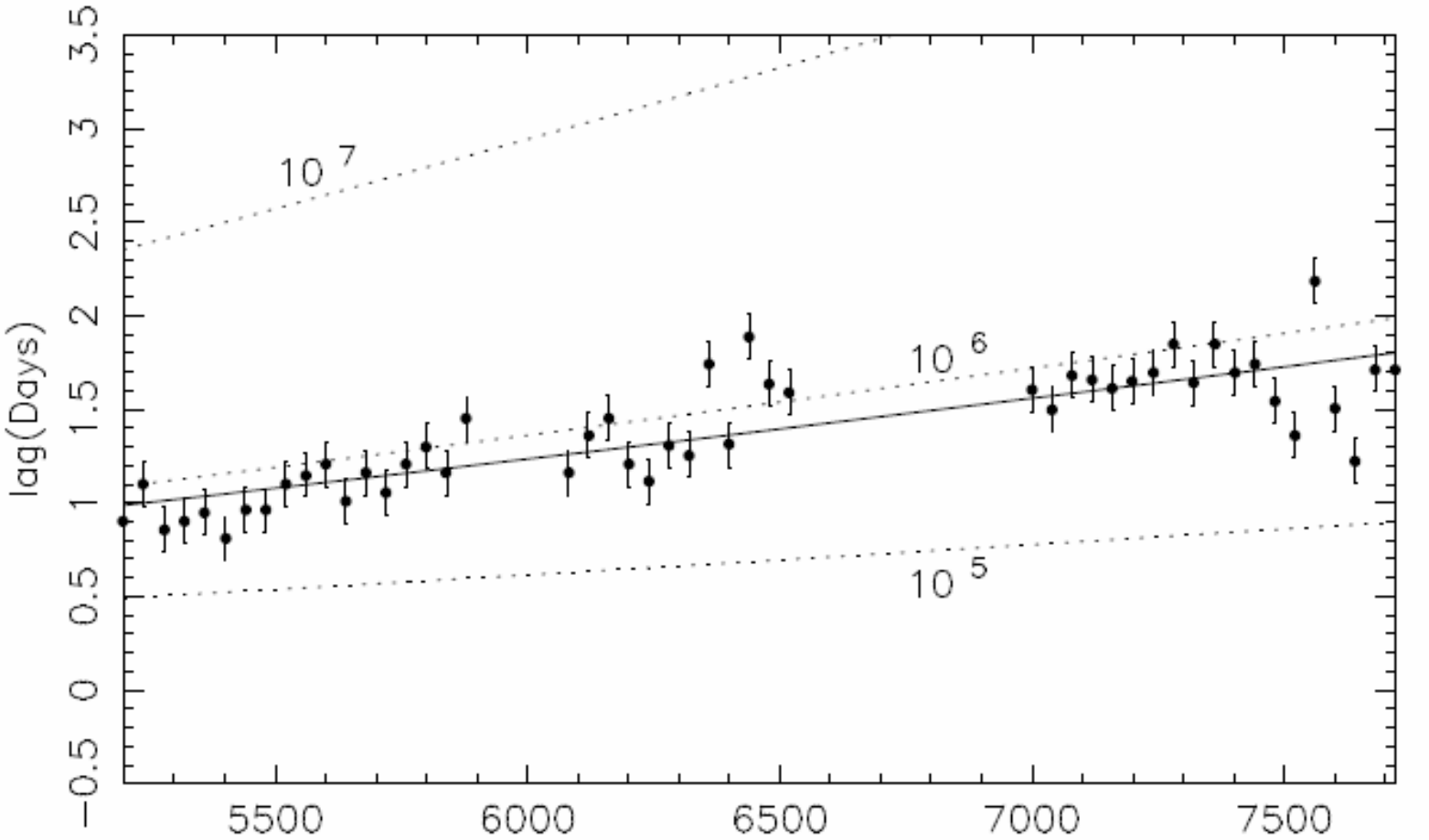
Quasi-central illumination heats disc at radius, *R,* after time $\tau = R/c$.

Re-radiation is at effective temp of disc at radius, R. Hence, by Wien's law:

$$\Rightarrow \quad \tau = R/c \propto T^{-4/3} \propto \lambda^{4/3}$$

(Easy two parameter fit).

Collier et al. (1998)



PROBLEMS!

1. Optical-band delays on surprisingly large timescales. 5 light-day radius disk of same temperature as the sun has

$$L > 10^{10} L_{\odot}.$$

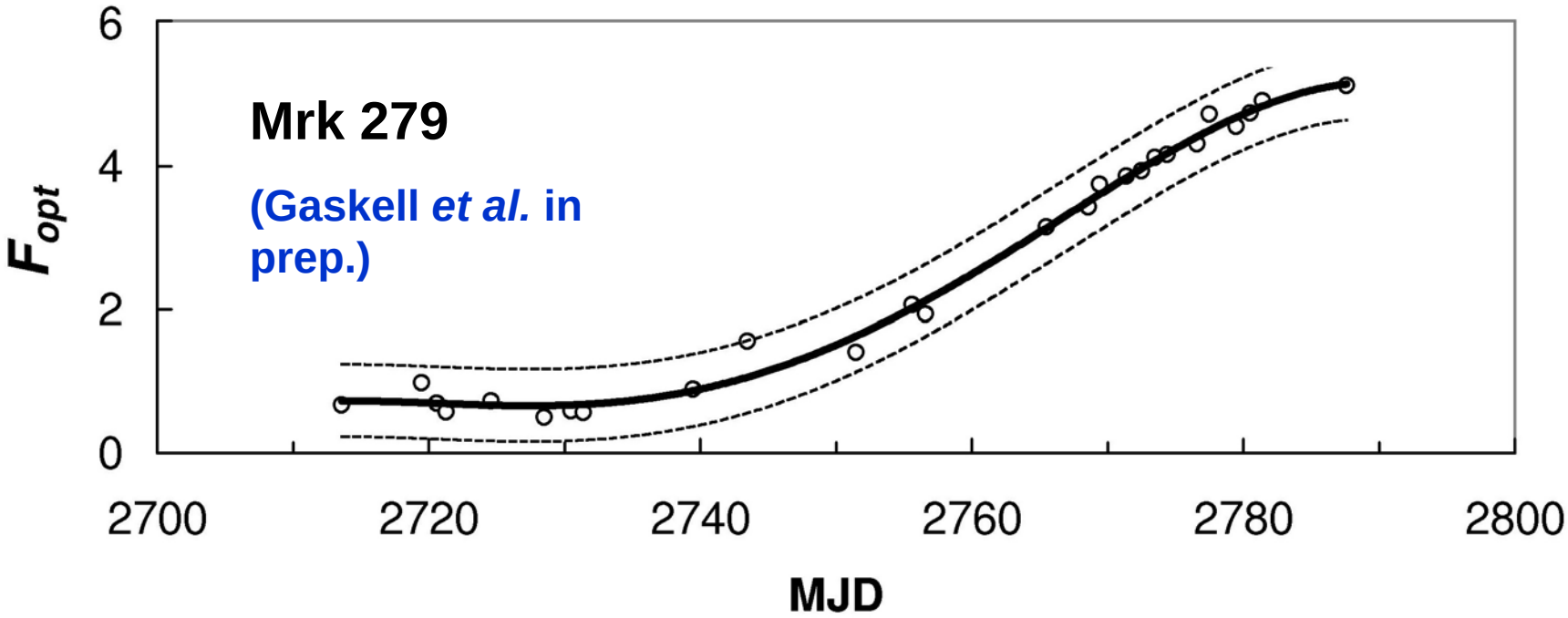
Expect optical/UV continuum emission region to be ~100x smaller.

2. L_{opt} can vary by an order of magnitude.

$\Rightarrow$ Irradiance would dominate over viscous energy production in the disc!!

$\Rightarrow$ Main energy source would not be the disc!!

(*i.e.*, our old model is totally inconsistent!)



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4. Even if it does exist,

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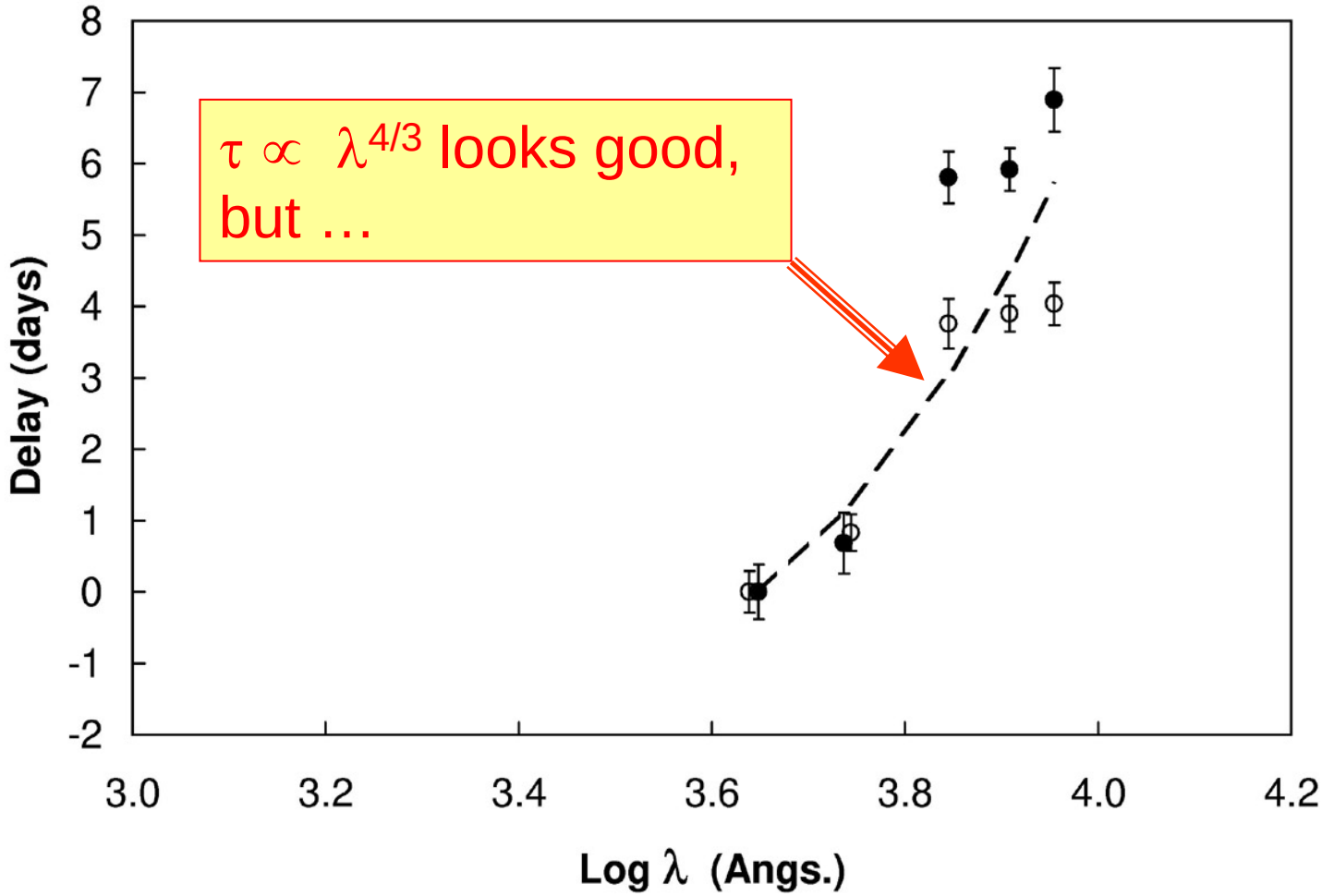
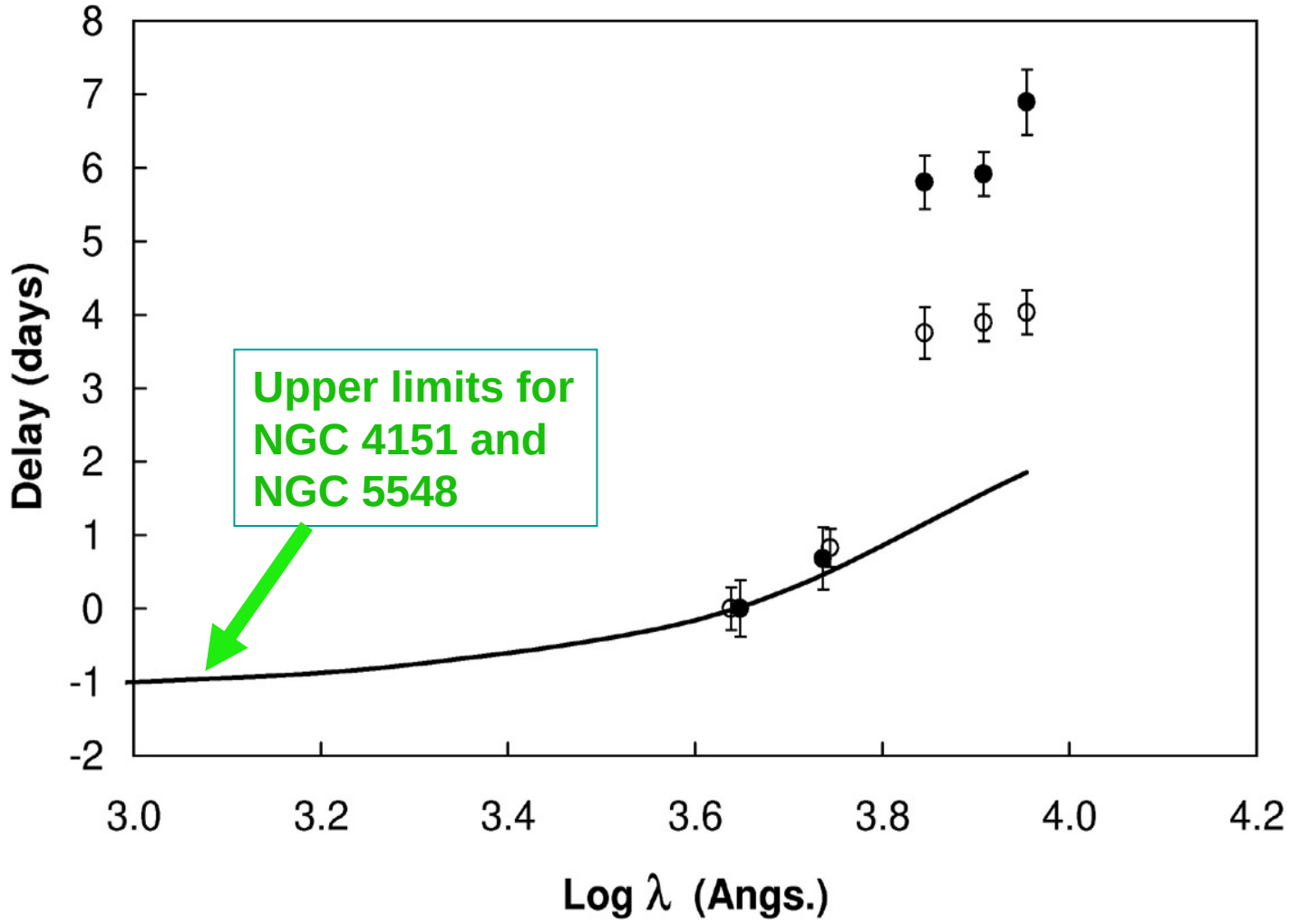
3. **What <u>is</u> this amazing light bulb?!**
4. Even if it <u>does</u> exist, **WHY DON'T WE SEE IT?!**

Have to have "full-cutoff" fixtures! (*International Dark Sky Association* approved!)

NORMALIZED DELAYS FOR 14 AGNS



. . . IT PREDICTS WRONG UV-OPTICAL DELAY BY ALMOST AN ORDER OF MAGNITUDE.



THE NEW MODEL

1. Intrinsic continuum variability has essentially no wavelength-dependent lag.
2. LAGS PRODUCED BY CONTAMINATION BY A SMALL AMOUNT OF LIGHT WITH A LARGE DELAY FROM THE DUSTY TORUS.

IR emission comes from hottest dust = dust at sublimation temperature

THE NEW MODEL

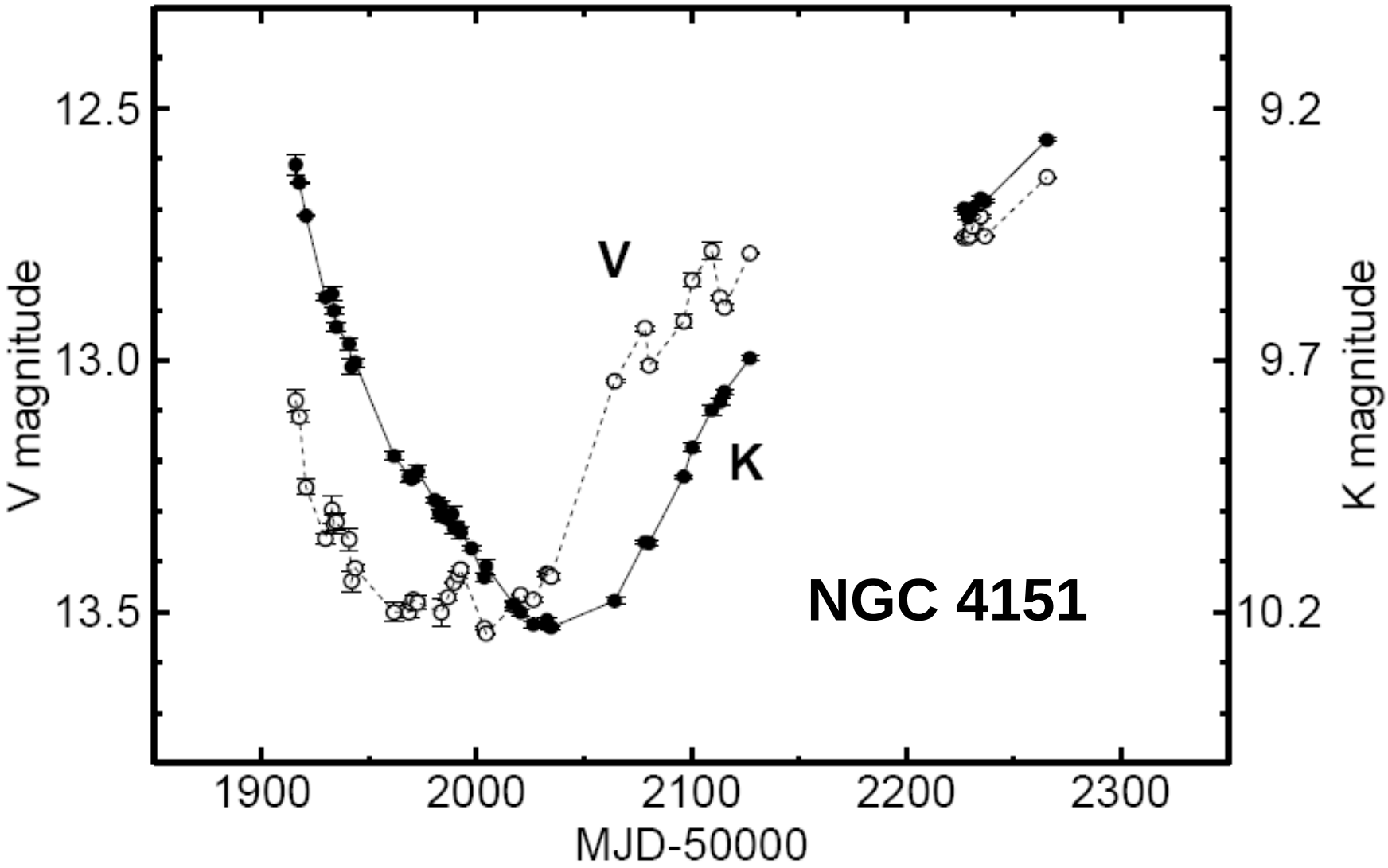
A candle flame is at sublimation temperature and a candle shines in the optical!

So hot AGN dust shines in the optical too!

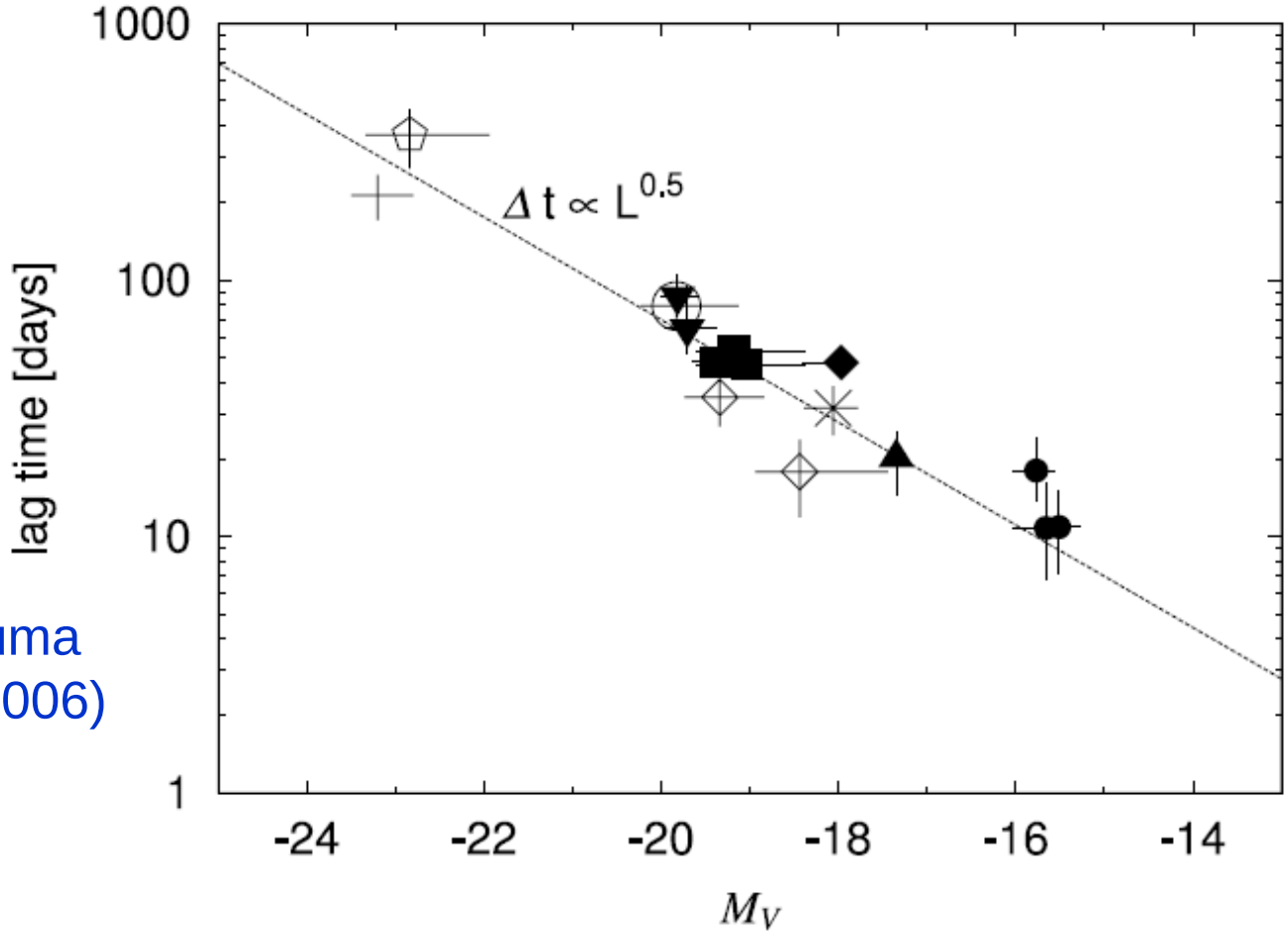
3. Delay depends linearly on the relative strengths of the simultaneous component and delayed one.

Example: NGC 4151 – 2.2 μm lags 0.55 μm by ~ 50 days

Minezaki et al. (2006)



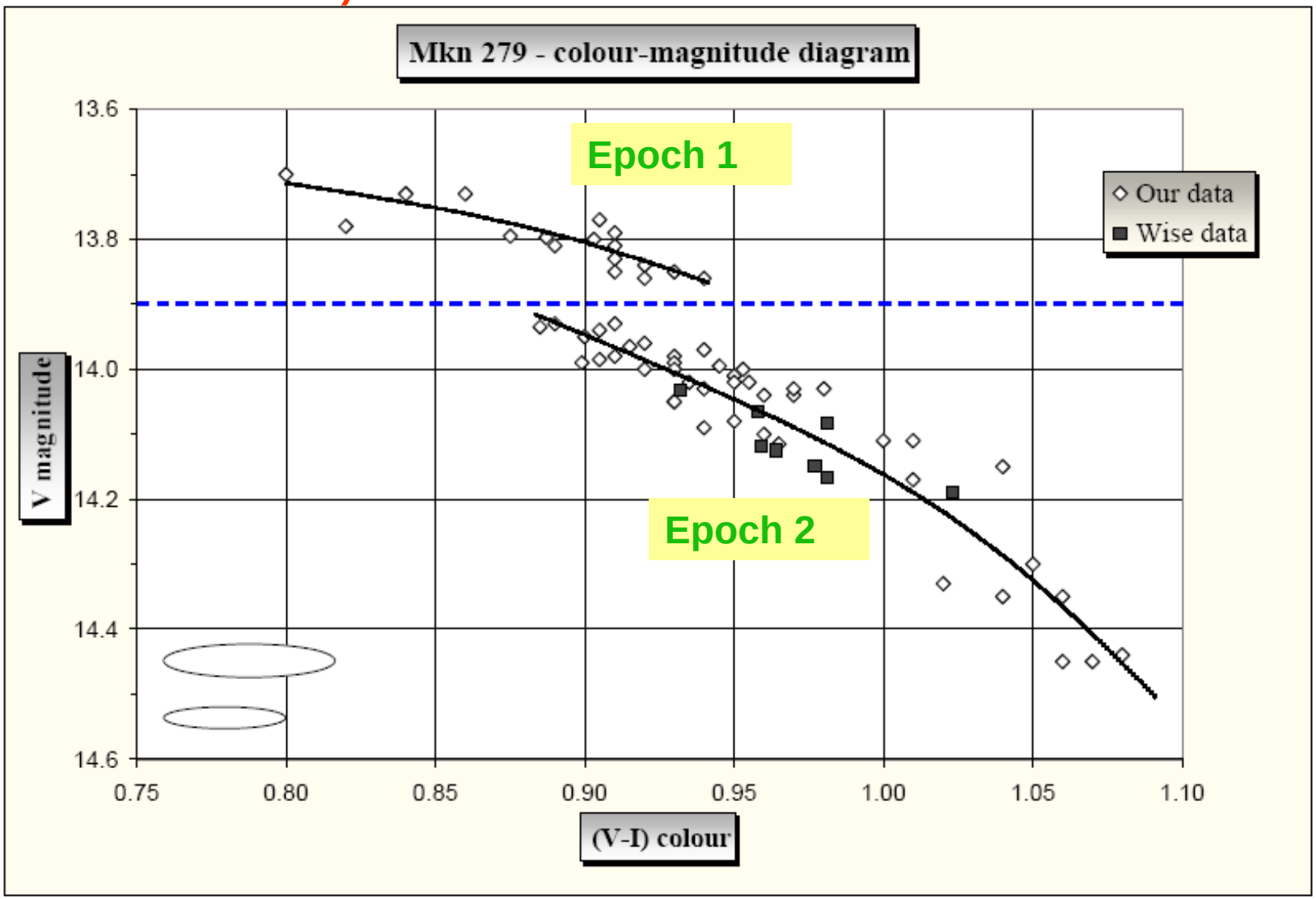
2.2 μm delay ⇒ gives inner radius of torus (= dust sublimation radius) ∝ $L^{1/2}$.



Suganuma *et al.* (2006)

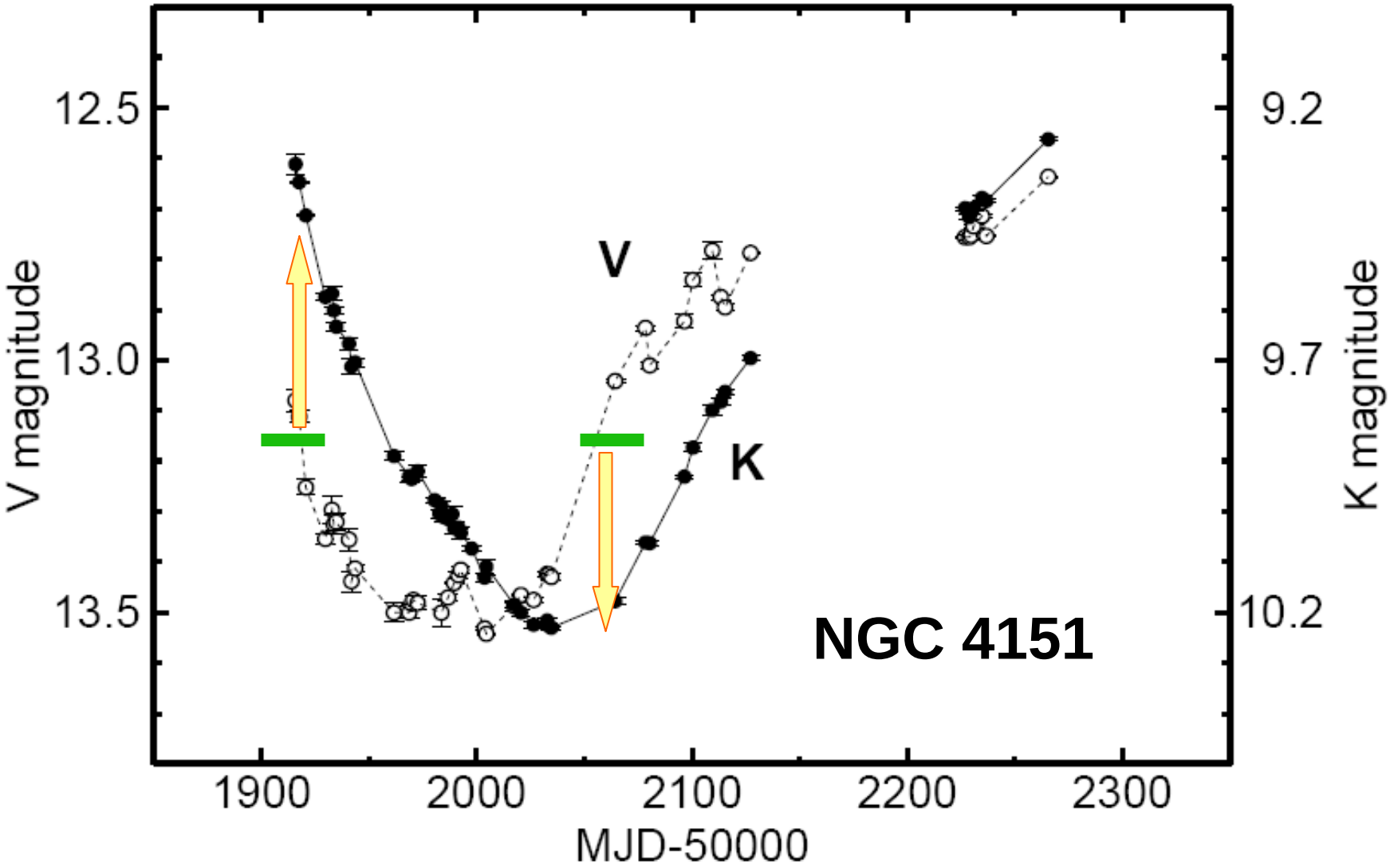
Thus new model quantitatively explains Sergeev *et al*. (2005) luminosity dependence of optical lags.

NEW MODEL ALSO QUANTITATIVELY EXPLAINS HYSTERESIS IN COLOR-MAGNITUDE (OR COLOUR-COLOUR) DIAGRAMS



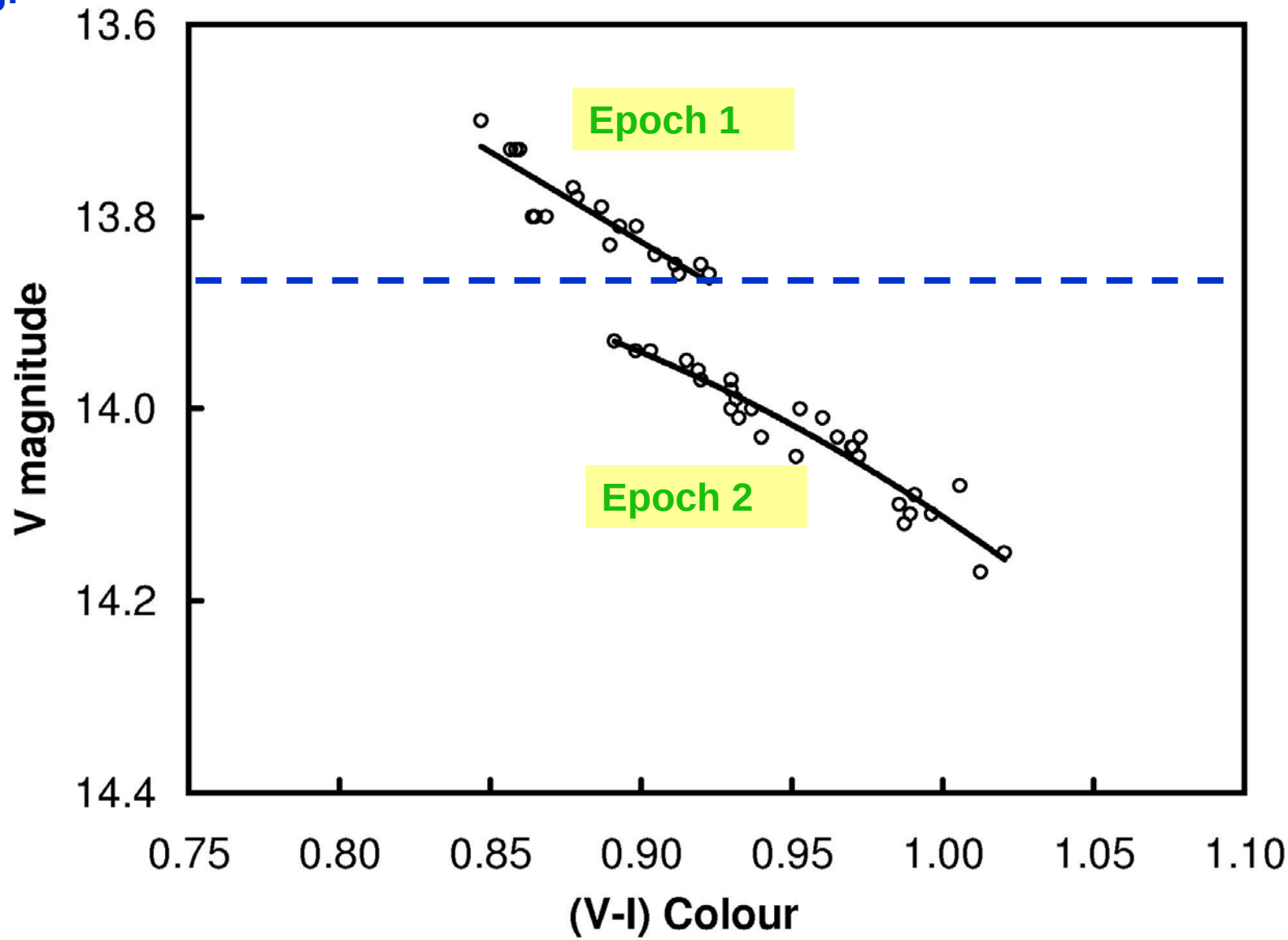
Bachev & Strigachev (2003)

Similar V fluxes; different K fluxes because of history.



Minezaki et al. (2006)

Model prediction based on observed V-band light curve of Bachev & Strigachev (2003) and a simulated I-band light curve using an 80-day K-band lag.



Additional Results

Torus has significant albebo $\Rightarrow$ reflected light contaminates all λ's. This explains:

a) Smoothing of UV/optical light curves.

b) Polarization reverberation (Gaskell, Shoji, & Goosmann 2005 - see also *STOKES* poster by René Goosmann).

CONCLUSIONS

- Wavelength-dependent delays in the optical are not real delays due to the reprocessing at ~ 10,000 Schwarzschild radii of radiation from a hypothetical, highly-energetic, invisible “mystery source.”
- They are **artifacts of contamination by delayed light from the much more distant torus.**