THE REFLECTION EFFECT IN BINARY SYSTEMS

DIPLOMA THESIS

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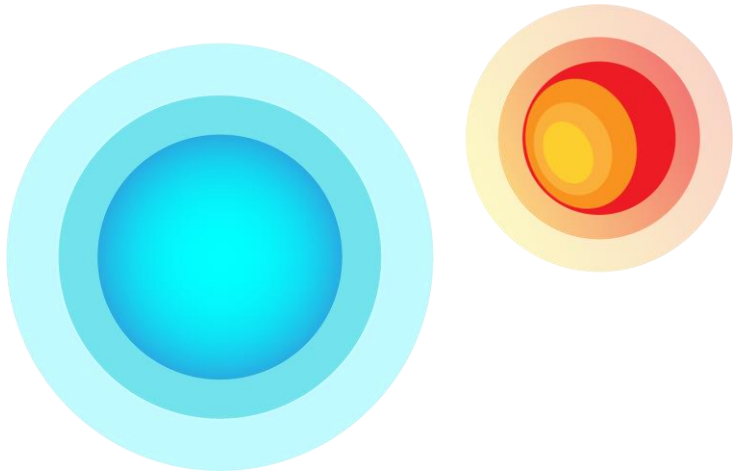
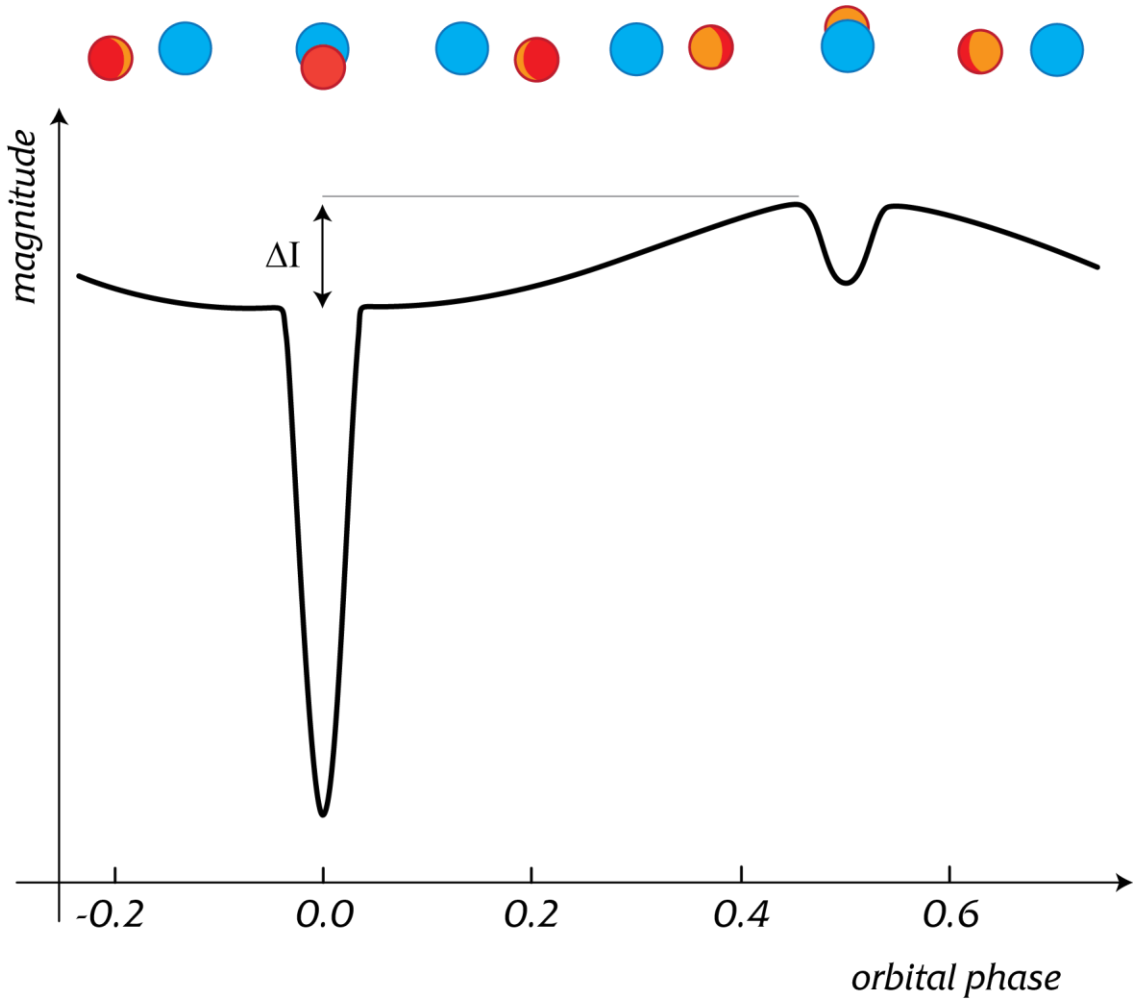
THE REFLECTION EFFECT

WHAT IT IS?

- mutual irradiation in close binaries
  - close binaries – P ~ hours/days, circular orbits, synchronous rotation, eclipsing
  - heated hemisphere
  - amplitude ~ components temperature difference

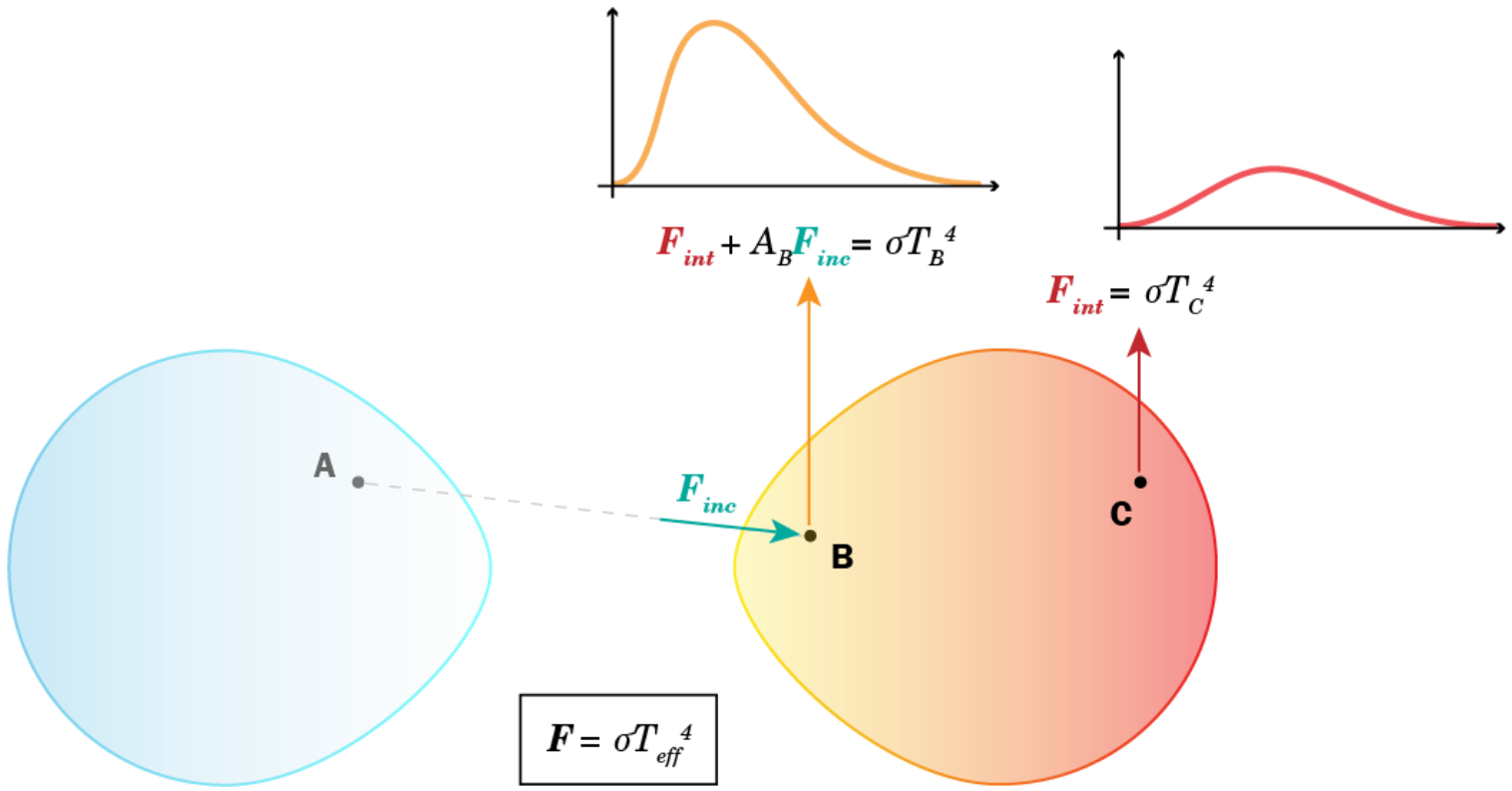




THE REFLECTION EFFECT

STANDARD TREATMENT (WILSON 1990)

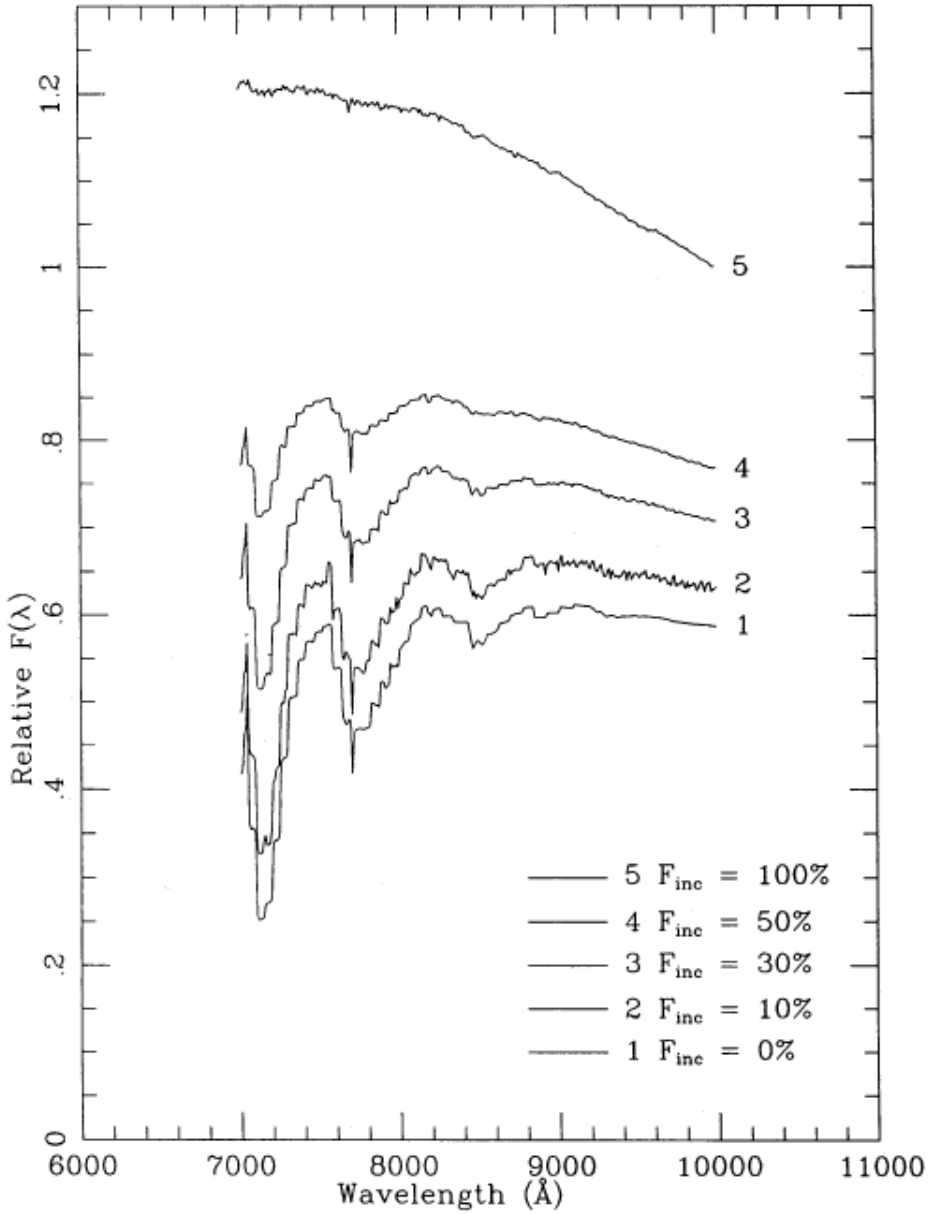
- reflected light = absorbed and re-emitted
  - local heating → different surface temperature
- amount of reflection → bolometric (heat) albedo (A)
  - A = 1 → all incident flux is converted into heat and give rise to additional outgoing flux
  - radiative envelopes: A = 1
  - convective envelopes: A = 0.5
- problem: $A_2 > 1$



EFFECTS OF IRRADIATION

DIFFERENT SPECTRA

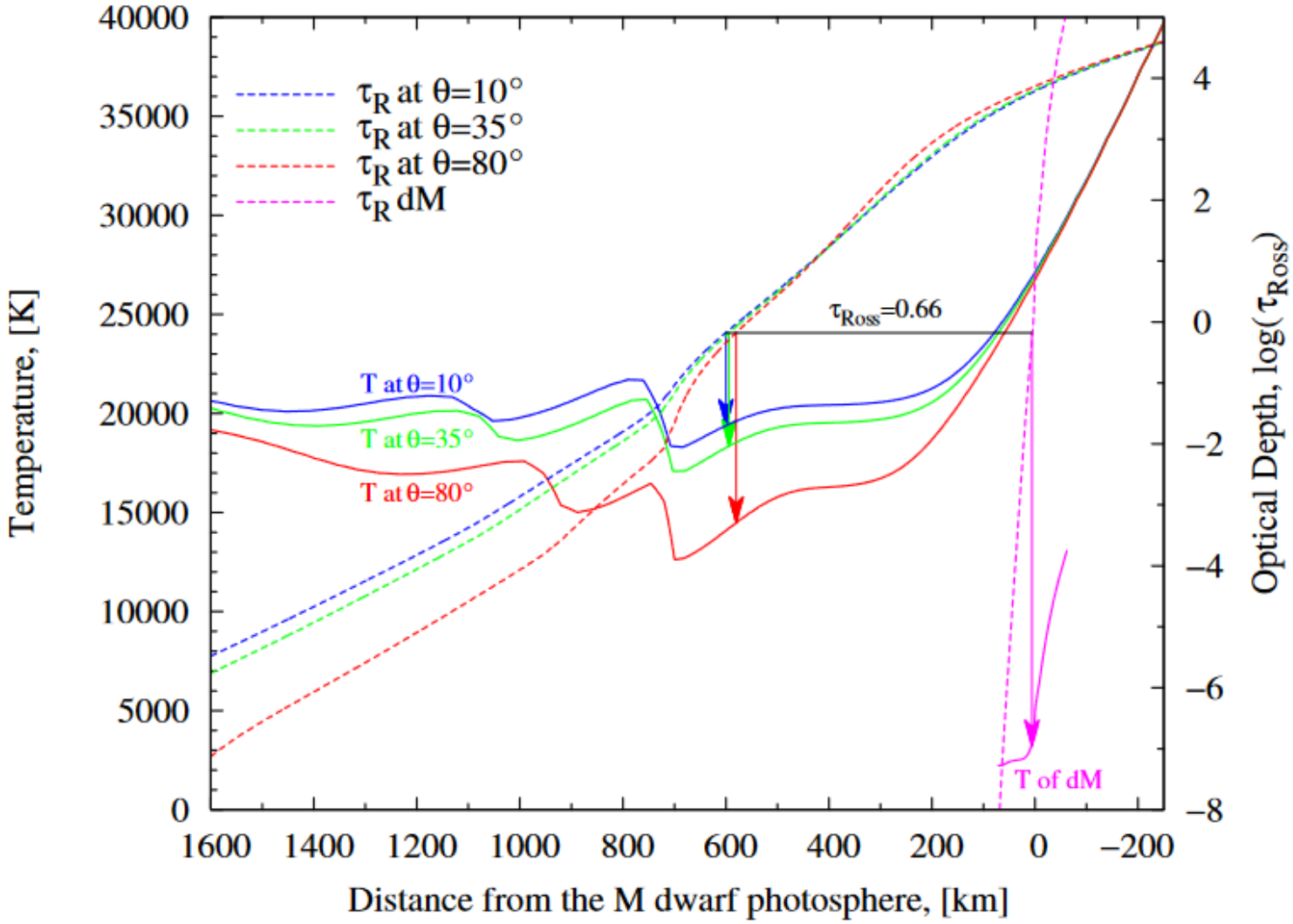
- Brett et al. (1993)
- irradiation ⟶ convection shuts down
  - decreased temperature gradient



AA DOR SECONDARY

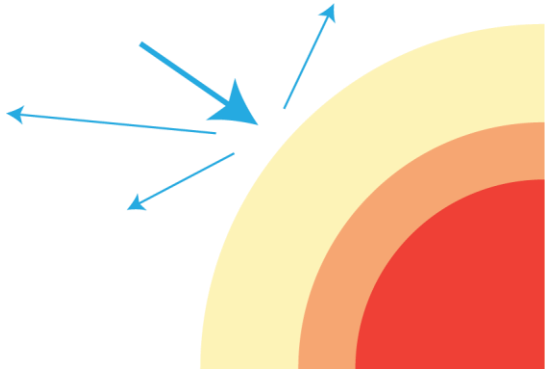
SYNTHETIC SPECTRUM

- **Vučković et al. (2015)**
- model of irradiated atmosphere
- emission lines (Balmer, C, O, He, ...)
- several temperature inversion regions + extended atmospehere



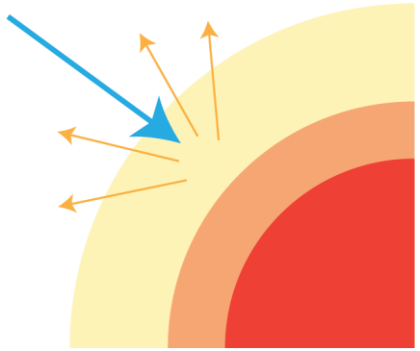
THE REFLECTION EFFECT

ALTERNATIVE TREATMENT (BUDAJ 2011)



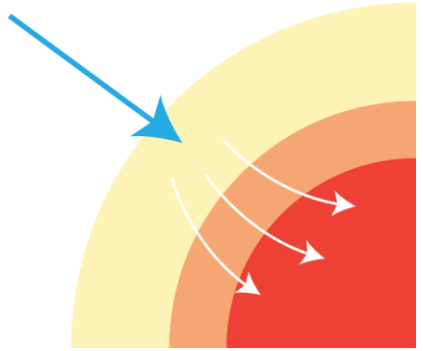
REFLECTED FLUX

- scattered photons
- causes no heating
- Rayleigh / Thomson
- Bond albedo A_{Bond}



ABSORBED FLUX

- converted into heat
- causes heating



REDISTRIBUTION

- heat flow
- causes heating on the non-illuminated side
- parameter of redistribution P_r

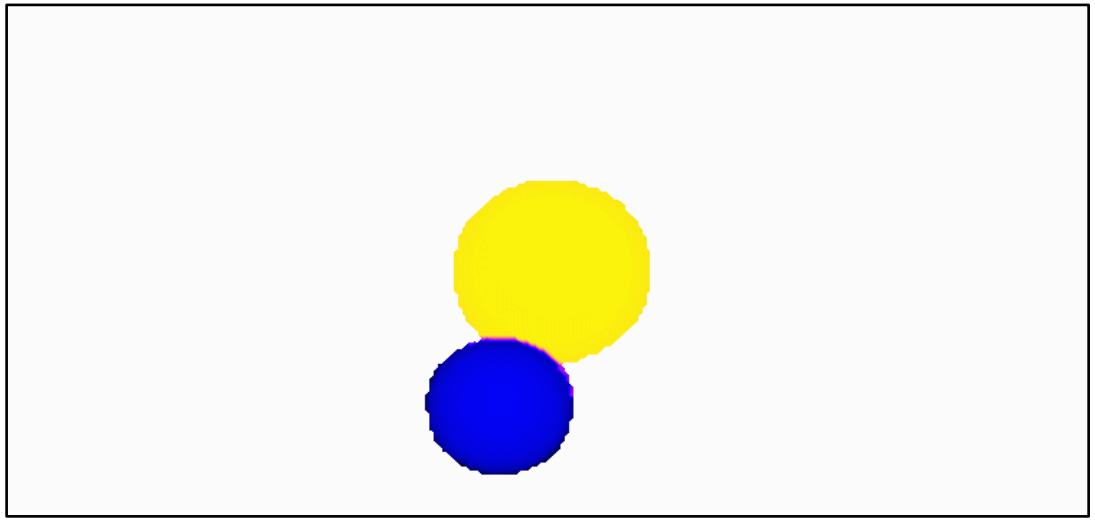
INCIDENT FLUX

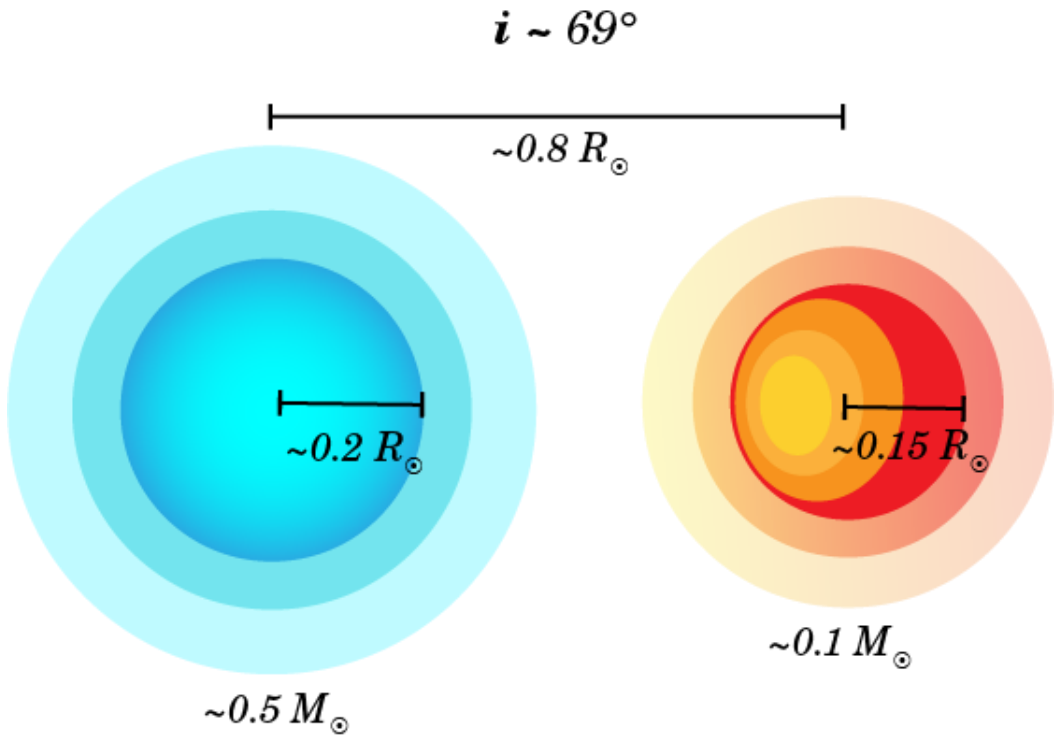
SHELLSPEC

- SHELLSPEC – **Budaj et al.** (2004-2019)
  - multi-purpose (CM, non-transparent objects)
  - Fortran90
- Roche geometry
- **extended model for reflection effect**
- doesn‘t solve inverse problem
  - PYSHELLSPEC – Brož & Nemravova
- **light curves** and spectra

2M 1938+4603

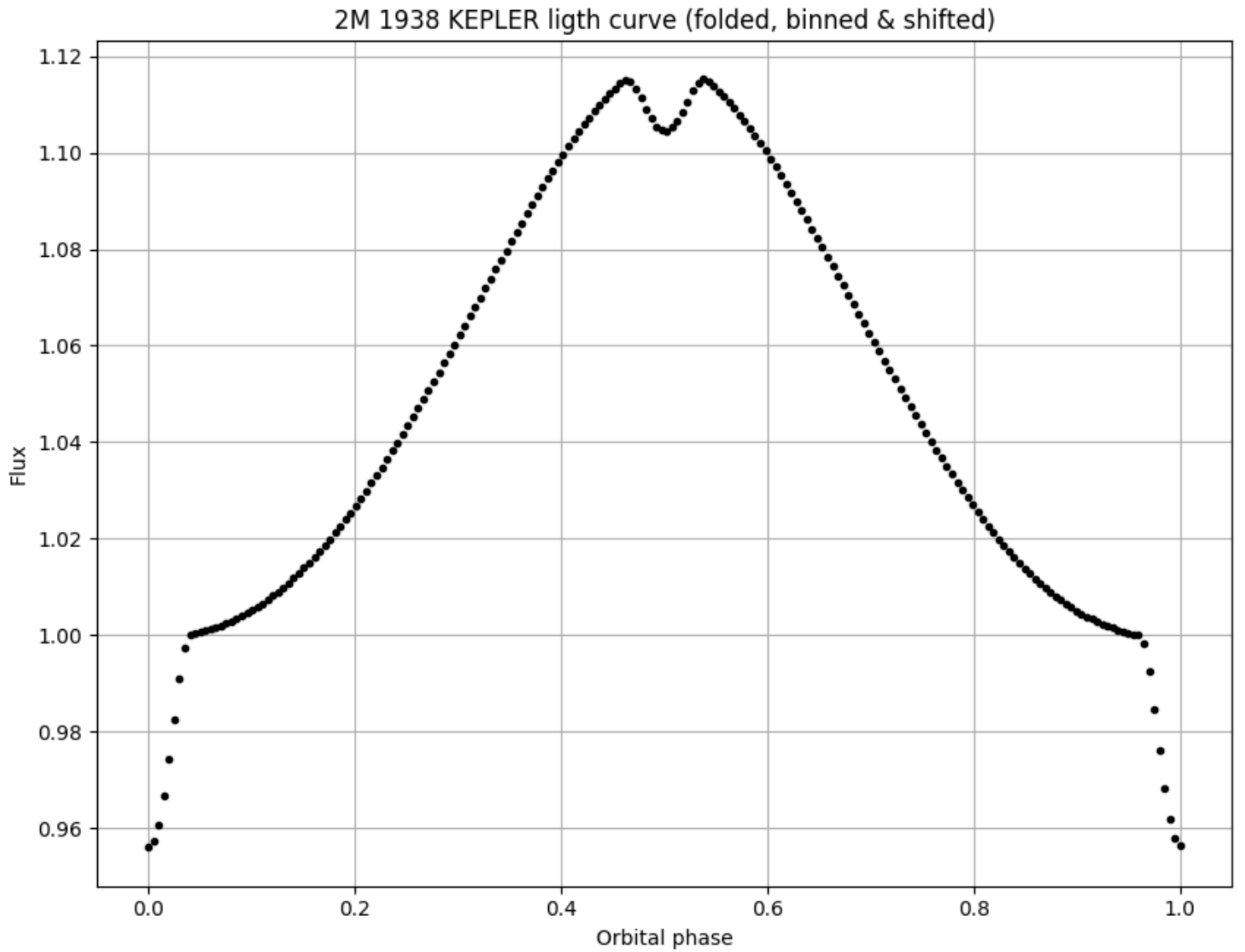
- sdB + dM
- eclipsing
- orbital period ~ 3 hours
- light curve – strong irradiation
- pulsations – evolution scenario ?





2M 1938+4603

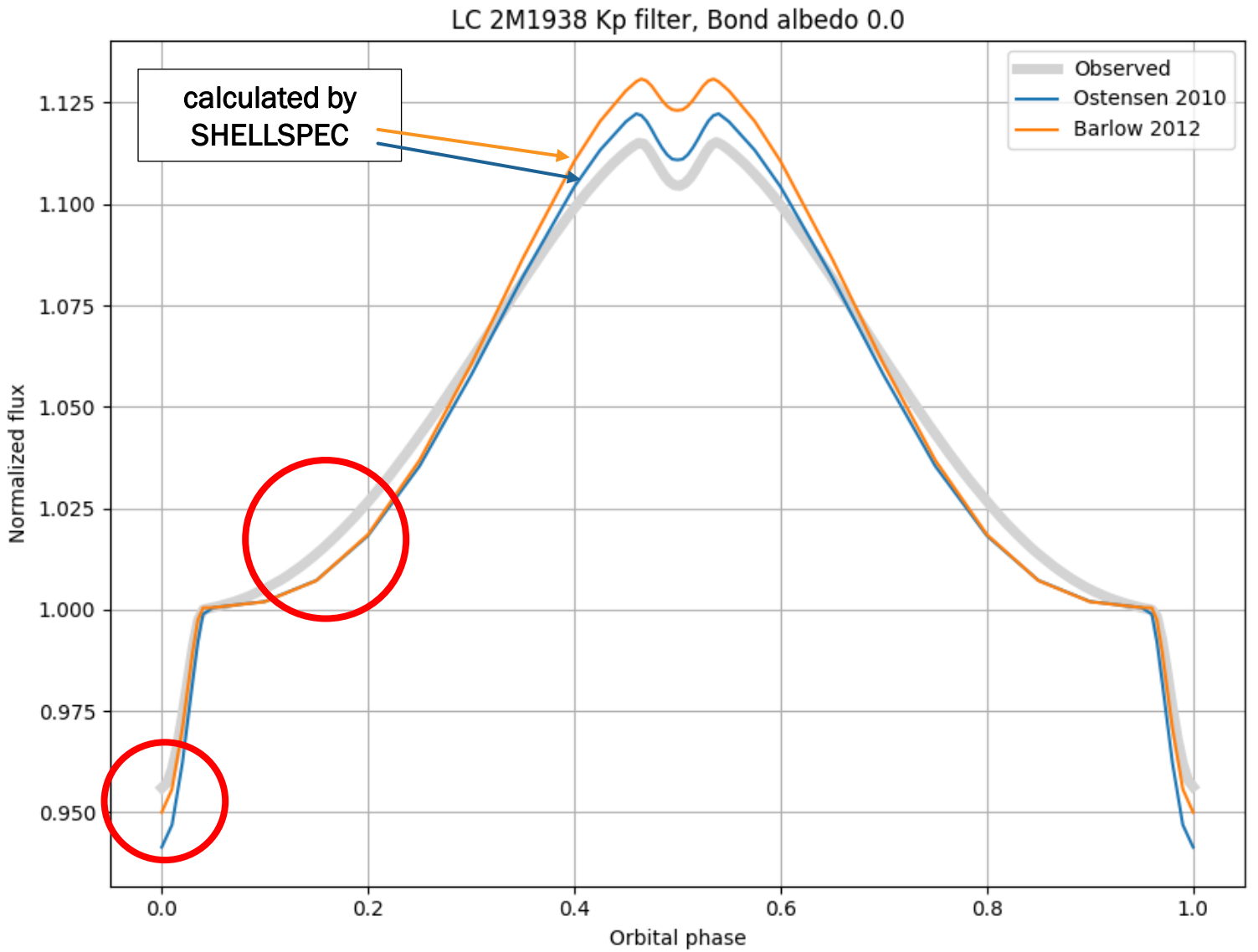
- KEPLER data (MAST archive)



LIGHT CURVE

2M 1938+4603

- **2 different sets of parameters** (masses, radii, separation, ...)
- Østensen et al. (2010)
  - spectroscopy → T_1 = 29 564 K
- Barlow et al. (2012)
  - Rømer delay (2.06 s)
  - Binary Maker → A_2 = 1.2
- different parameters → different curves
- poor fit



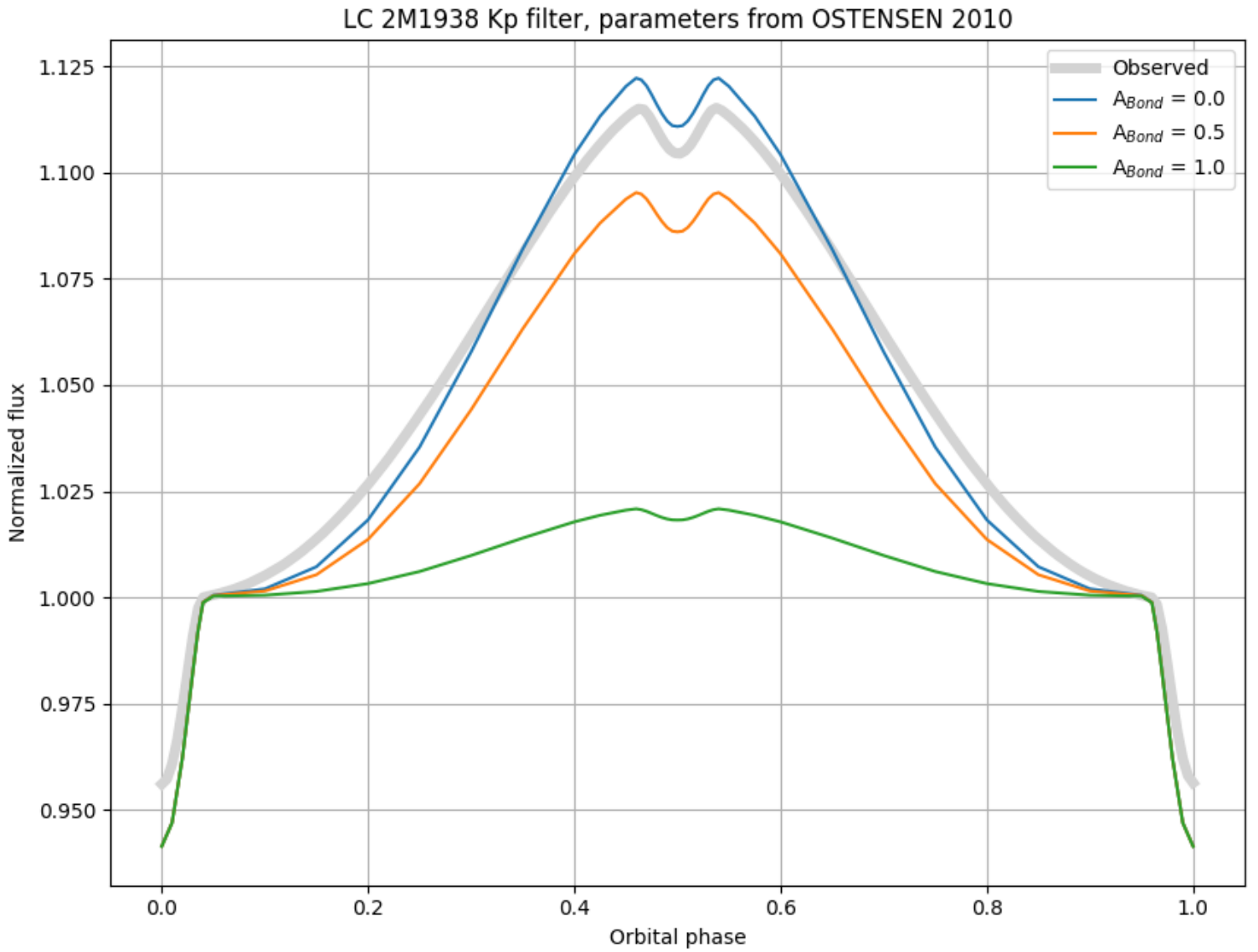
BOND ALBEDO

$A_{bond} = 0$

- **nothing** scattered
- ⟶ **maximal** heating
- ⟶ high amplitude

$A_{bond} = 1$

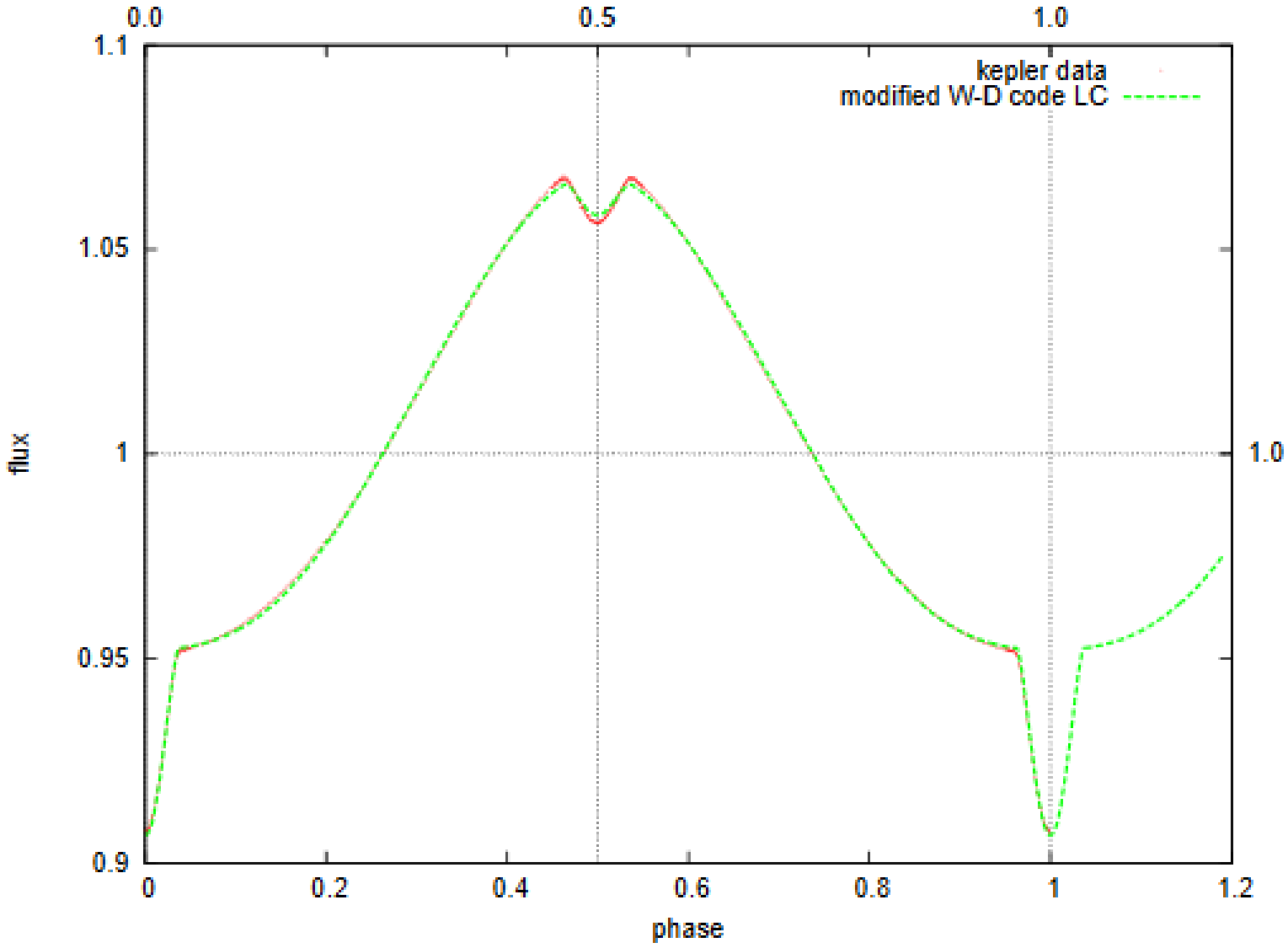
- **everything** scattered
- ⟶ **no** heating
- ⟶ low amplitude (low thermal radiation)
- ⟶ higher amplitude, if scattered light dominates (maybe FUV)



ANOTHER ANALYSIS

ZOLA & BARAN (2013)

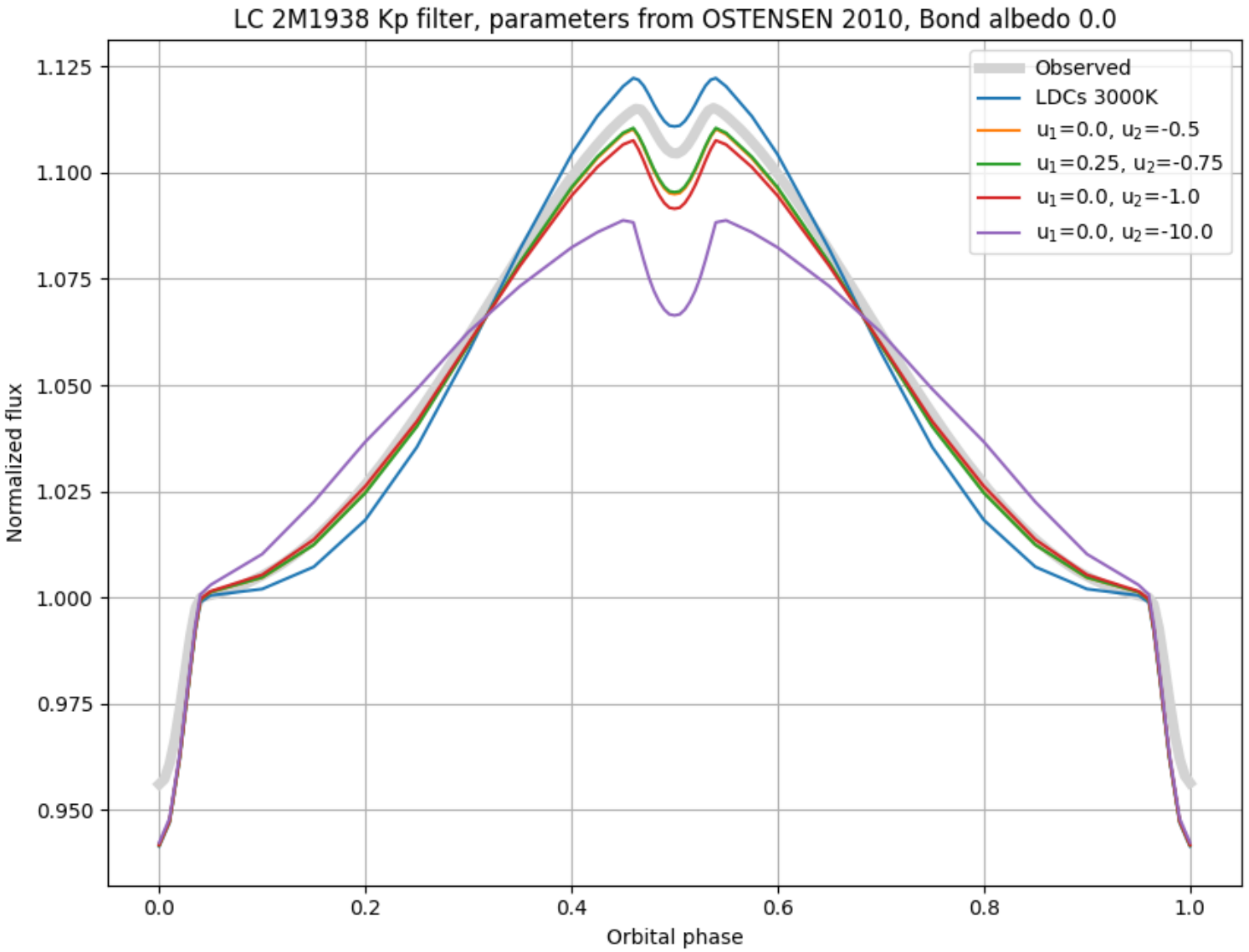
- Wilson-Devinney code
- **limb darkening**, **gravity darkening** and **albedo** according to local temperature
- new values of some parameters
  - SHELLSPEC – poor fit



LIMB-DARKENING

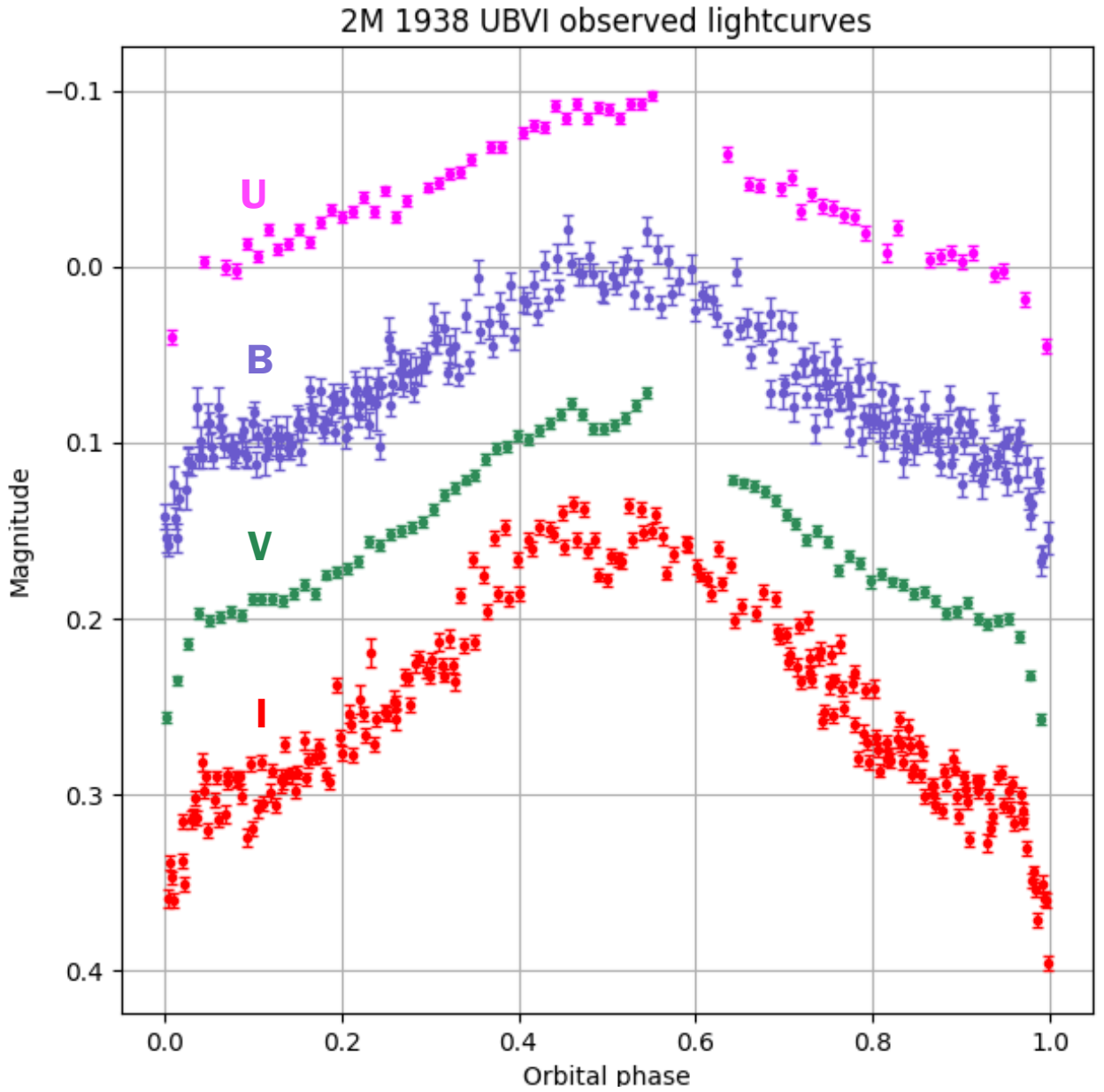
OR BRIGHTENING

- temperature inversion ⟶ **emission in the upper layers** of the secondary
- **negative values** of limb-darkening coefficients (**quadratic** limb darkening law)
- ⟶ more flux after the primary eclipse
- ⟶ lower amplitude
- ⟶ changed profile of the secondary eclipse



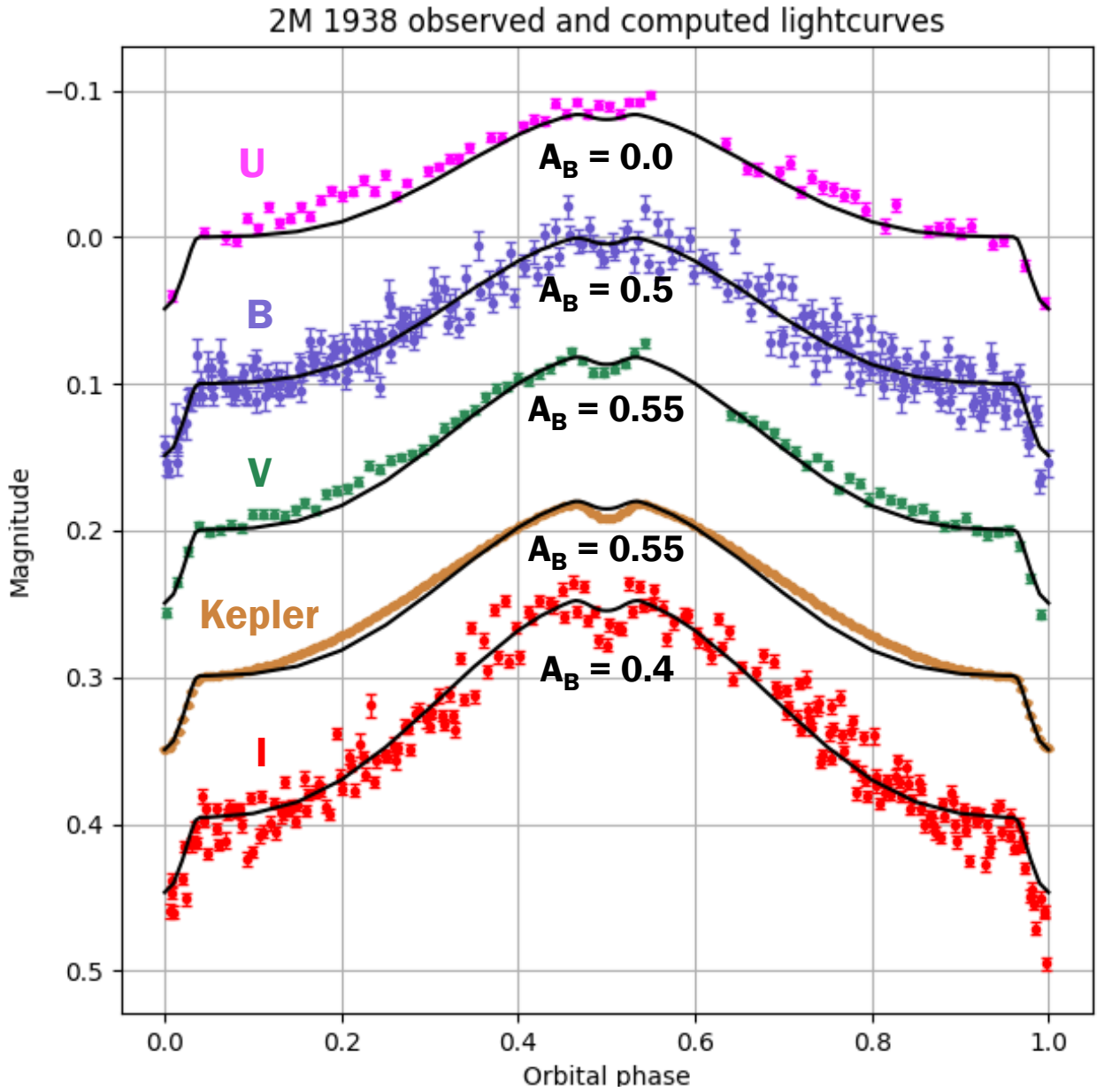
UBVI DATA

- 60 cm telescope in Stará Lesná
- RNDr. Zoltán Garai, PhD.,
  RNDr. Ján Budaj, CSc.



NEW SET OF PARAMETERS

- **PyWD2015** (Güzel & Özdarcan 2020)
  - Wilson-Devinney code
  - **only Kepler LC used**
  - differential correction ⟶ **parameters adjusted**
- used in SHELLSPEC with different values of Bond albedo for each filter to fit observed amplitudes
  - convoluted Kurucz fluxes used
- **goal:** one value of Bond albedo for each filter (bolometric quantity!)
  - monochromatic albedo – profile?
- **problem:** missing light in U



PROBLEM & SOLUTION

- higher amplitude needed
- *More scattered light? … No.*
- *More UV light? … Probably.*
- ⟶ spectra of irradiated atmosphere
- ⟶ lower intrinsic temperature of the secondary
- limb-brightening should be included

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THANK YOU FOR ATTENTION!

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