Once in a blue moon: detection of "bluing" during debris transits in WD 1145+017

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Haifa, March 9th, 2017

Tel-Aviv University / ESO

with

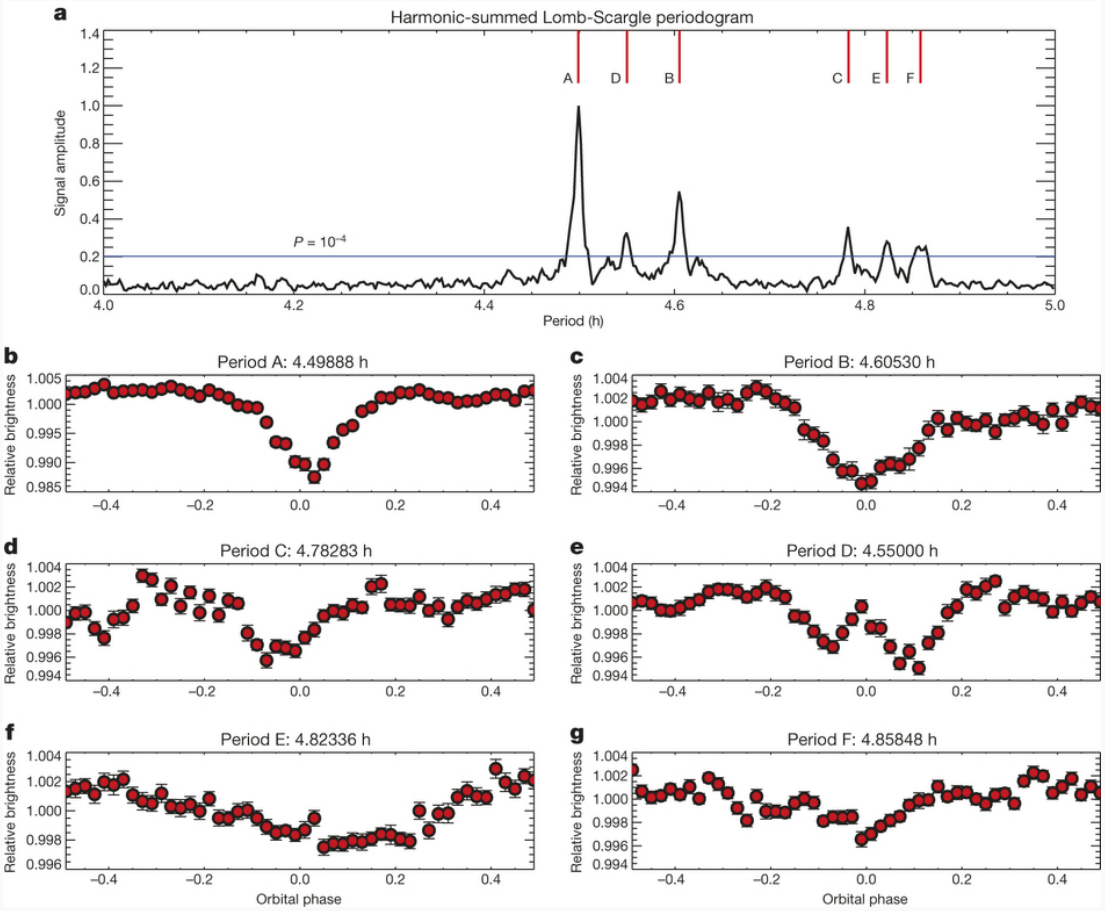
S. Xu, D. Maoz, T. R. Marsh, V. D. Ivanov, V. S. Dhillon, M. C. P. Bours, S. G. Parsons, P. Kerry, S. Sharma, K. Su, S. Rengaswamy, P. Pravec, P. Kušnirák, H. Kučáková, J. D. Armstrong, C. Arnold, N. Gerard, and L. Vanzi

Introduction: meet WD 1145+017

CfA/Mark A. Garlick

Introduction: meet WD 1145+017

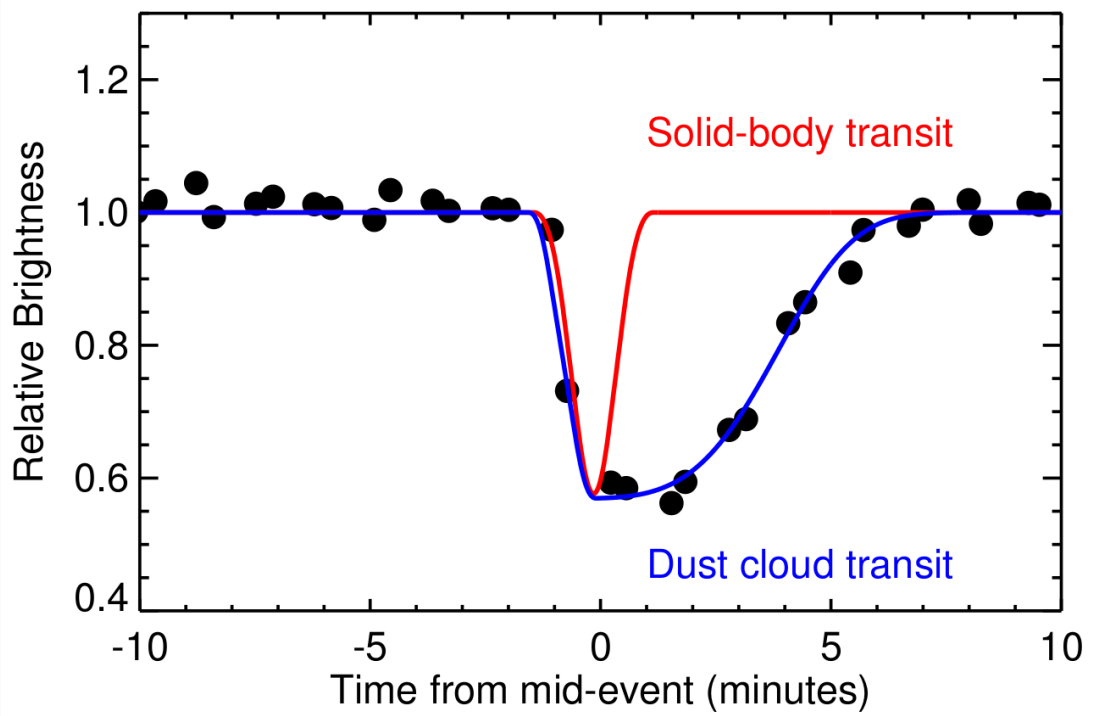
- Multiple transiting objects
- Orbital period $\sim 4.5 - 5\,\mathrm{h}$



Vanderburg+2015

Introduction: meet WD 1145+017

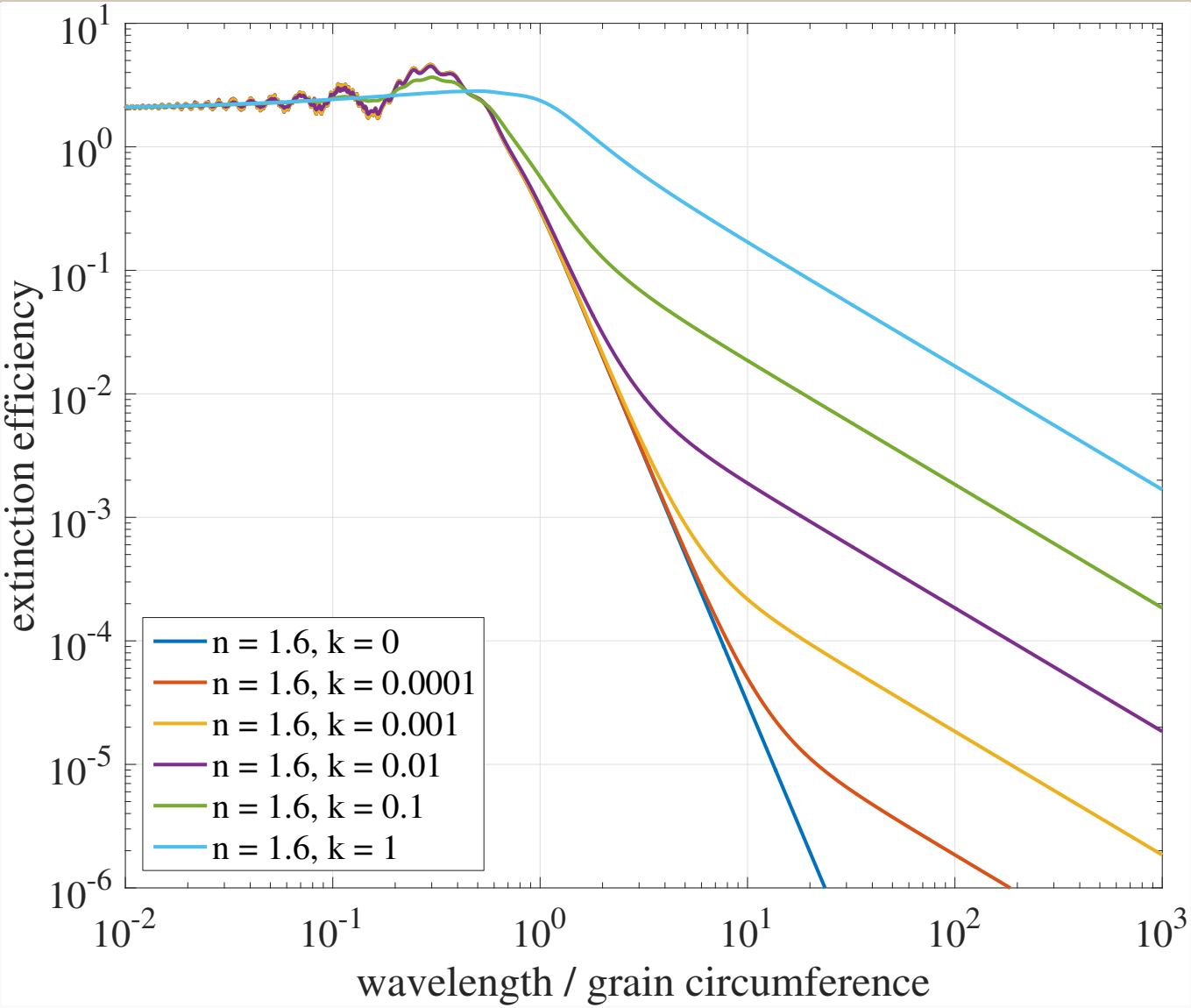
- Multiple transiting objects
- Orbital period $\sim 4.5 - 5\,\mathrm{h}$
- Long asymmetric transits
- Rapidly evolving



Vanderburg+2015

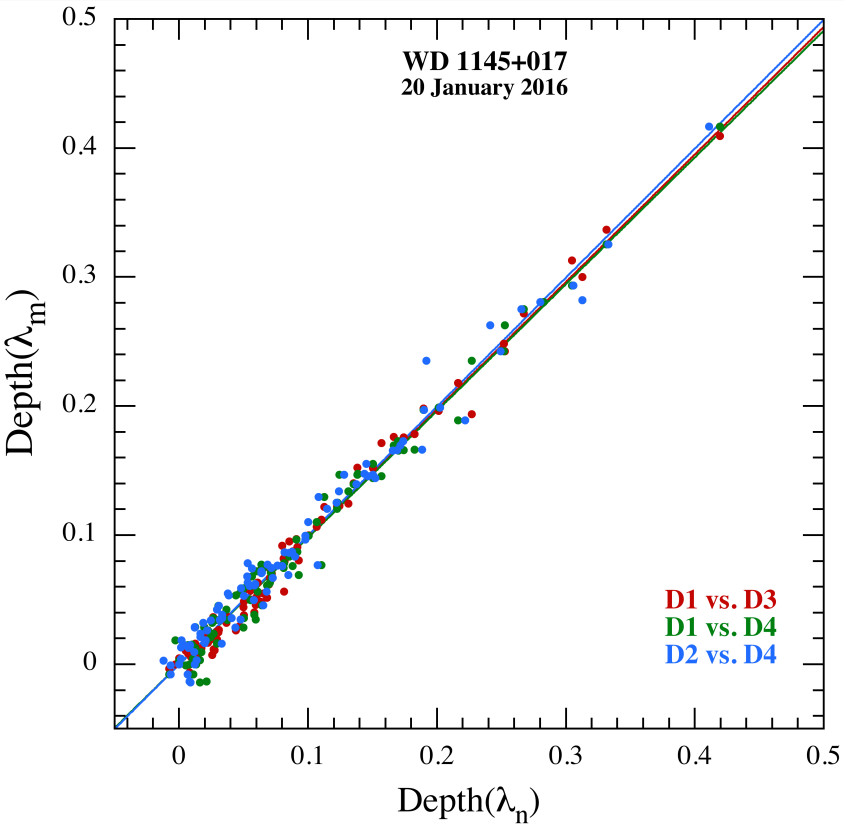
If dust clouds are causing transits, what are their properties?

Extinction depends on grain-size to wavelength ratio and on grain com-position:



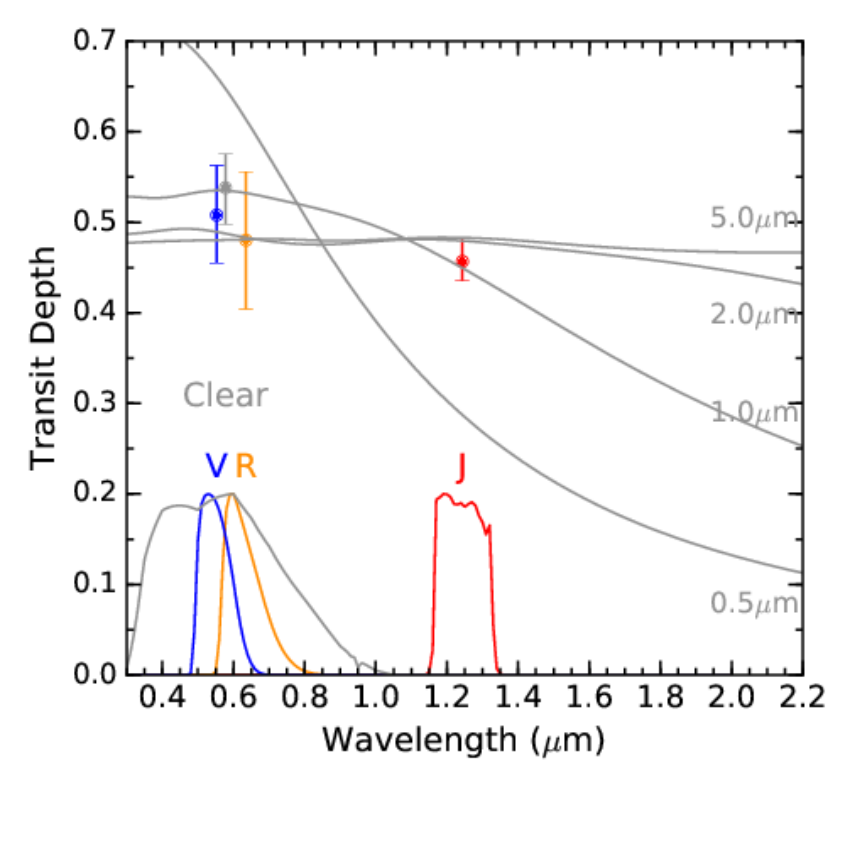
Previous studies: grey transits (Croll+2015, Alonso+2016, Zhou+2016)

$4800 - 9200$ Å



Alonso+2016

$5000 - 12000$ Å



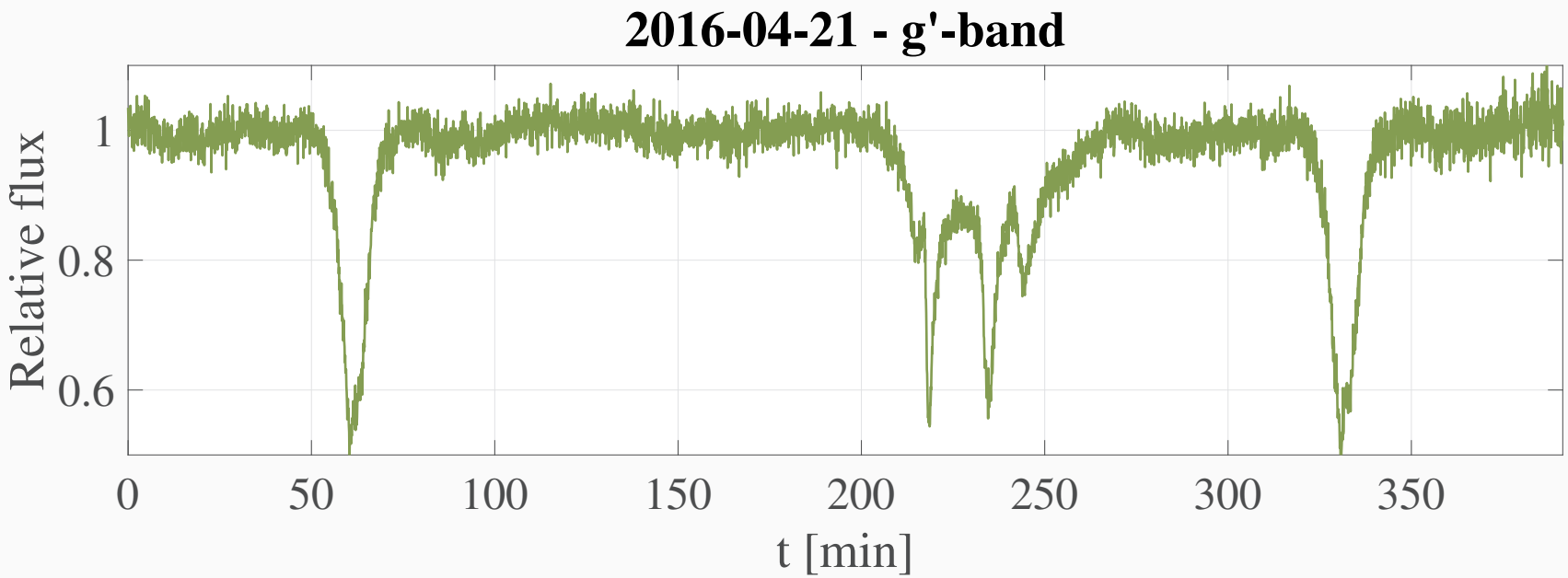
Zhou+2016

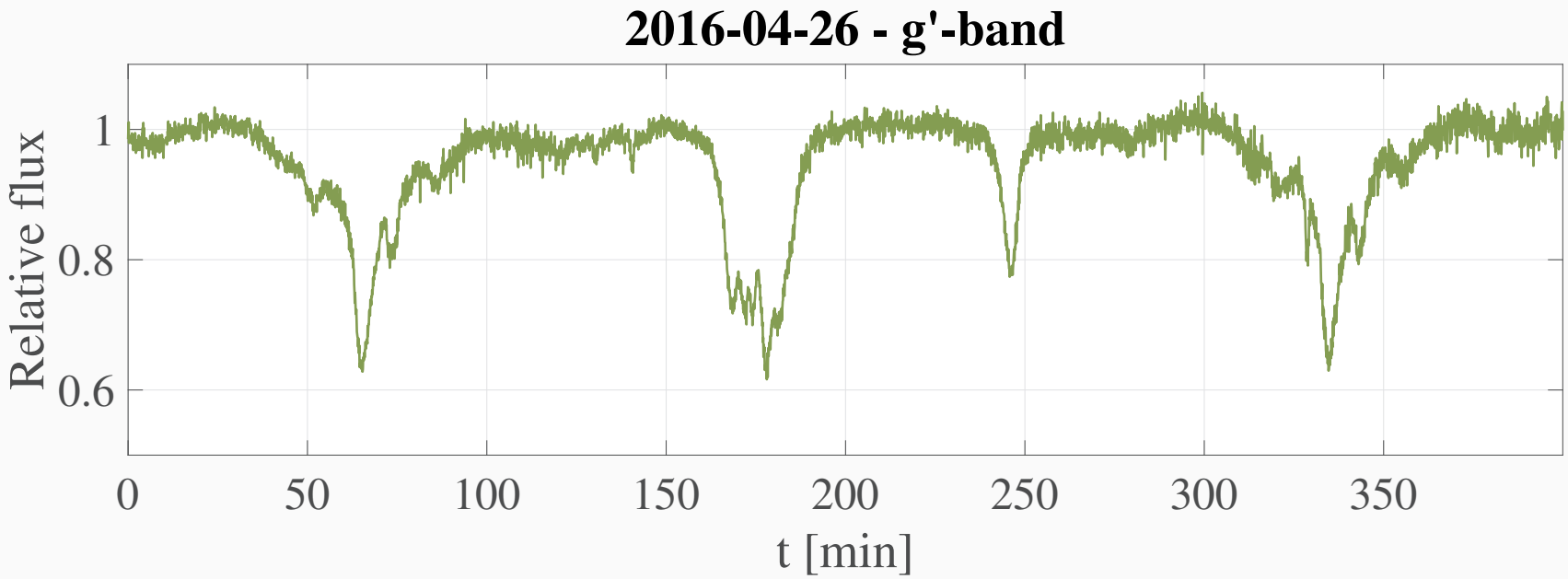
ULTRACAM@NTT: Multiband fast photometry

Observatory	Location	Tele.	Size [m]	Filter	Exposure [s]
ESO La Silla	Chile	NTT	3.58	*u'g'r'i'*	5, 10
Mauna Kea	Hawaii	UKIRT	3.8	*JK*	10, 30
ARIES	India	DFOT	1.3	*r'*	60, 120, 180
Vainu Bappu	India	JCBT	1.3	*R*	600, 900
LCO	South Africa		1	Clear	60
Wise	Israel	C28	0.71	*ExoP*	60
Ondřejov	Czech Republic	D65	0.65	*R*	180
LCO	Hawaii		0.4	Clear	270
LCO	Australia		0.4	Clear	270
UC	Chile		0.4	*i'*	120, 180

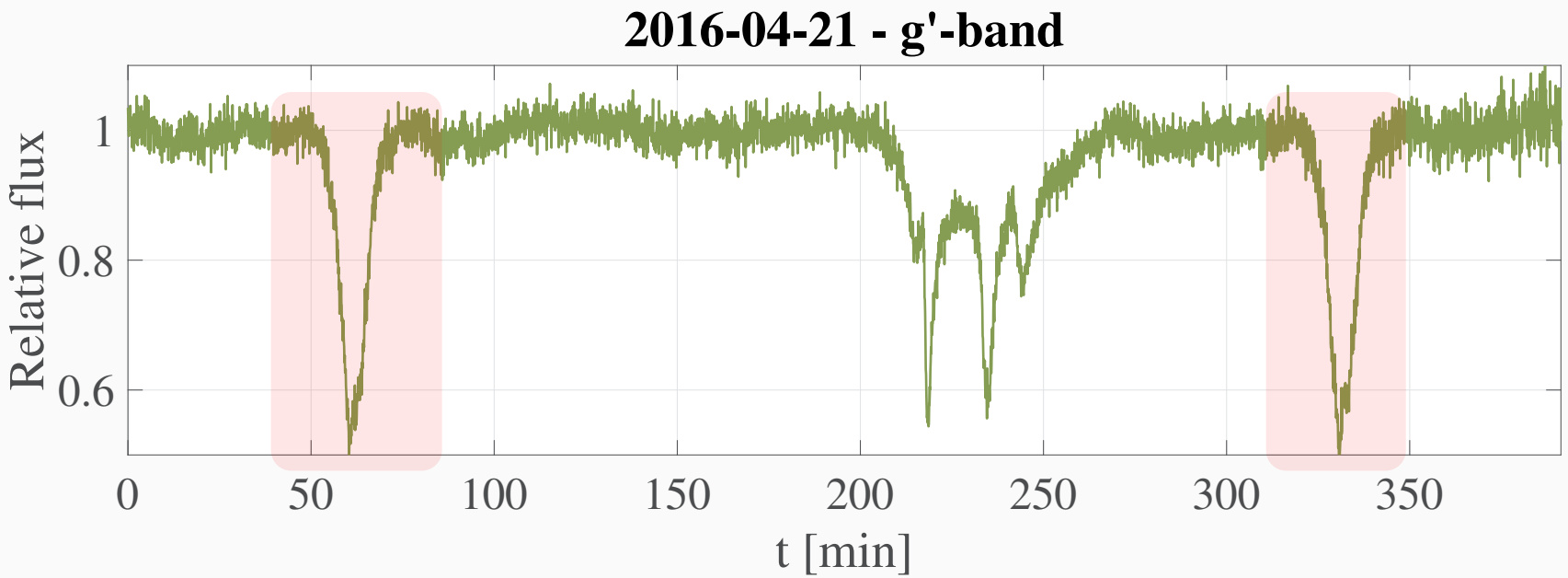
+ half a year-long light curve from Gary+2017

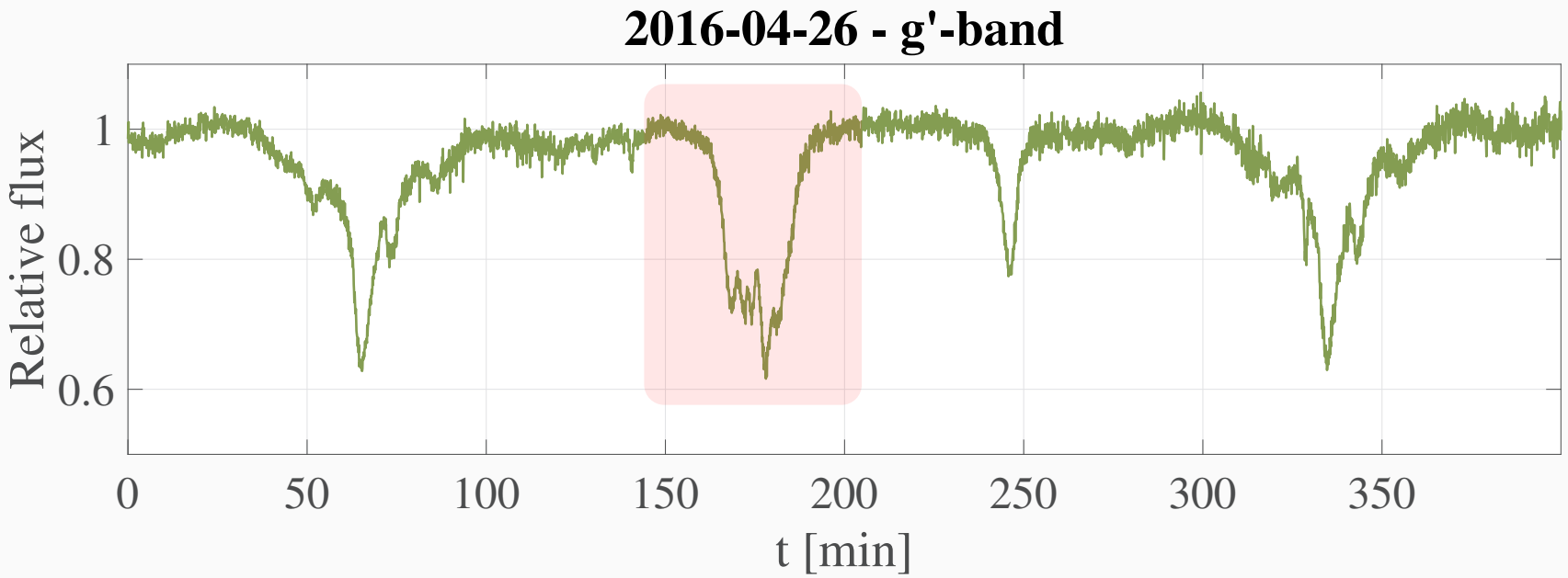
Light curve evolution



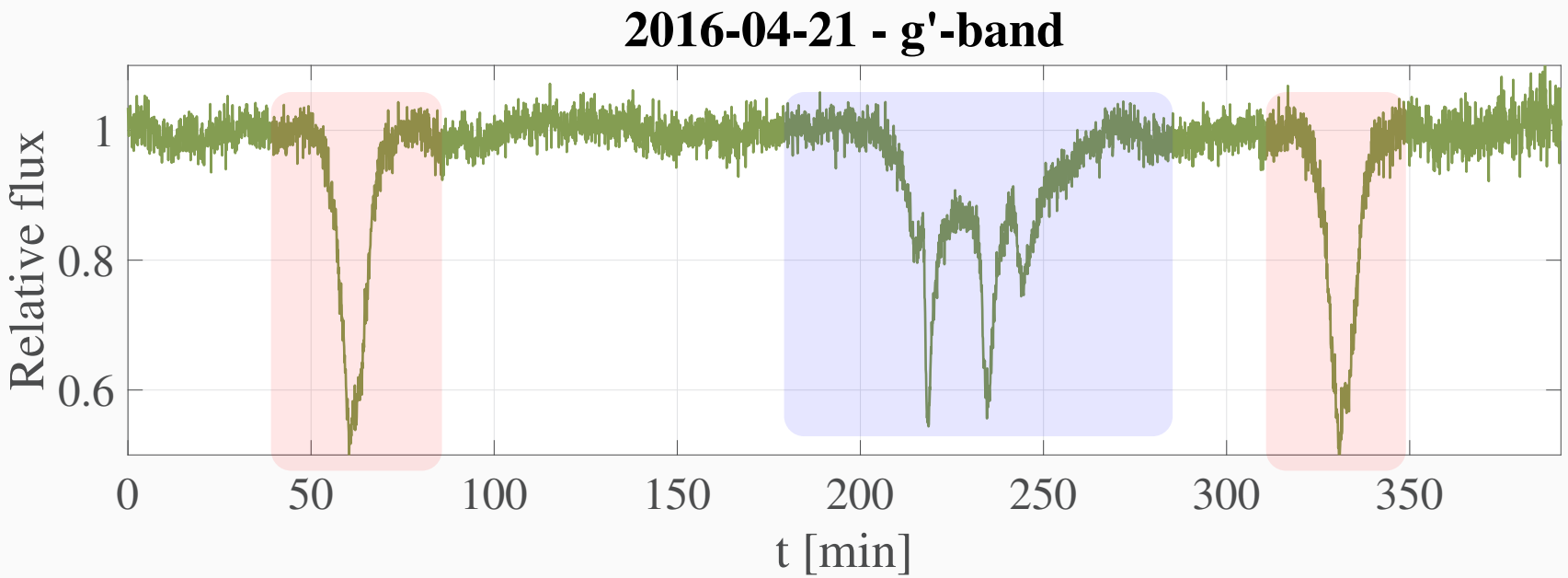


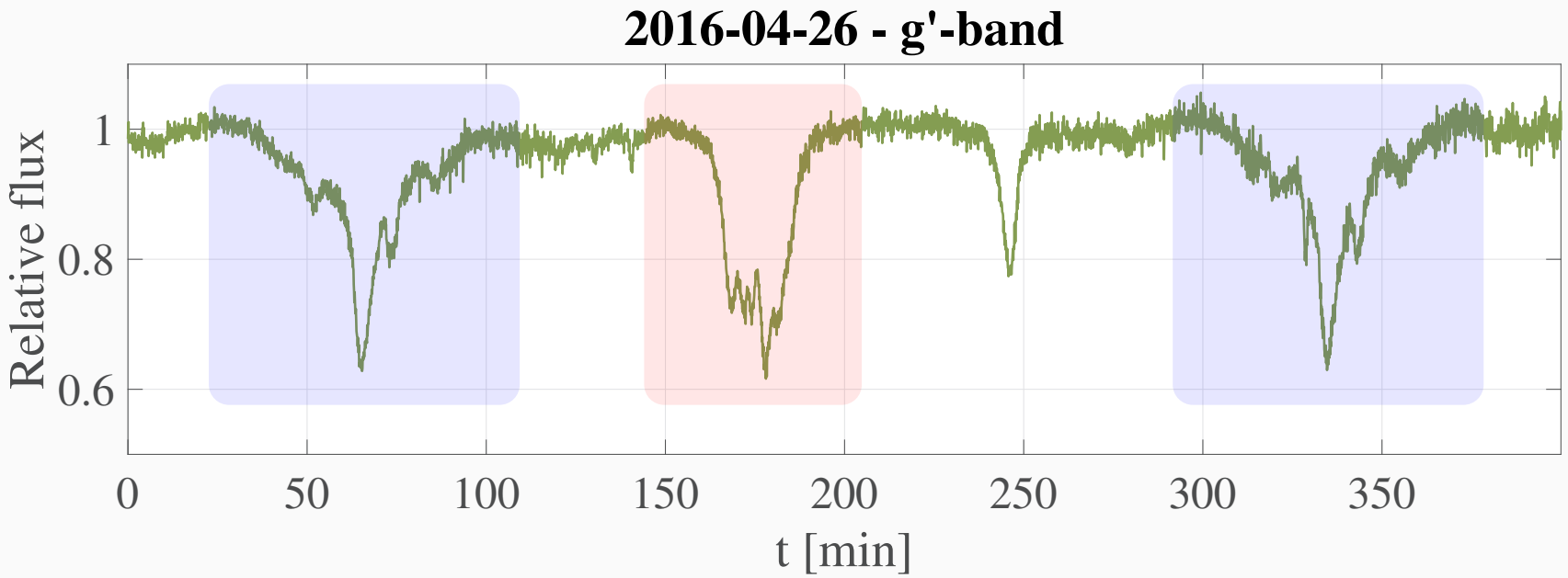
Light curve evolution



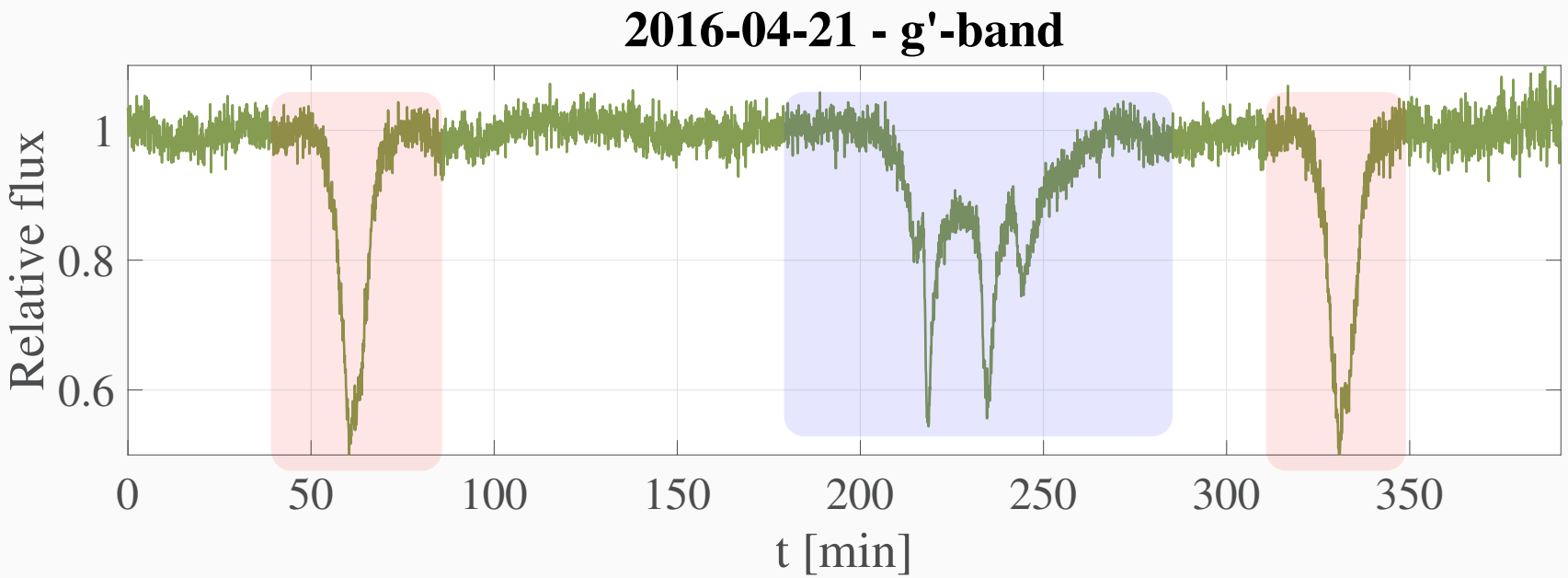


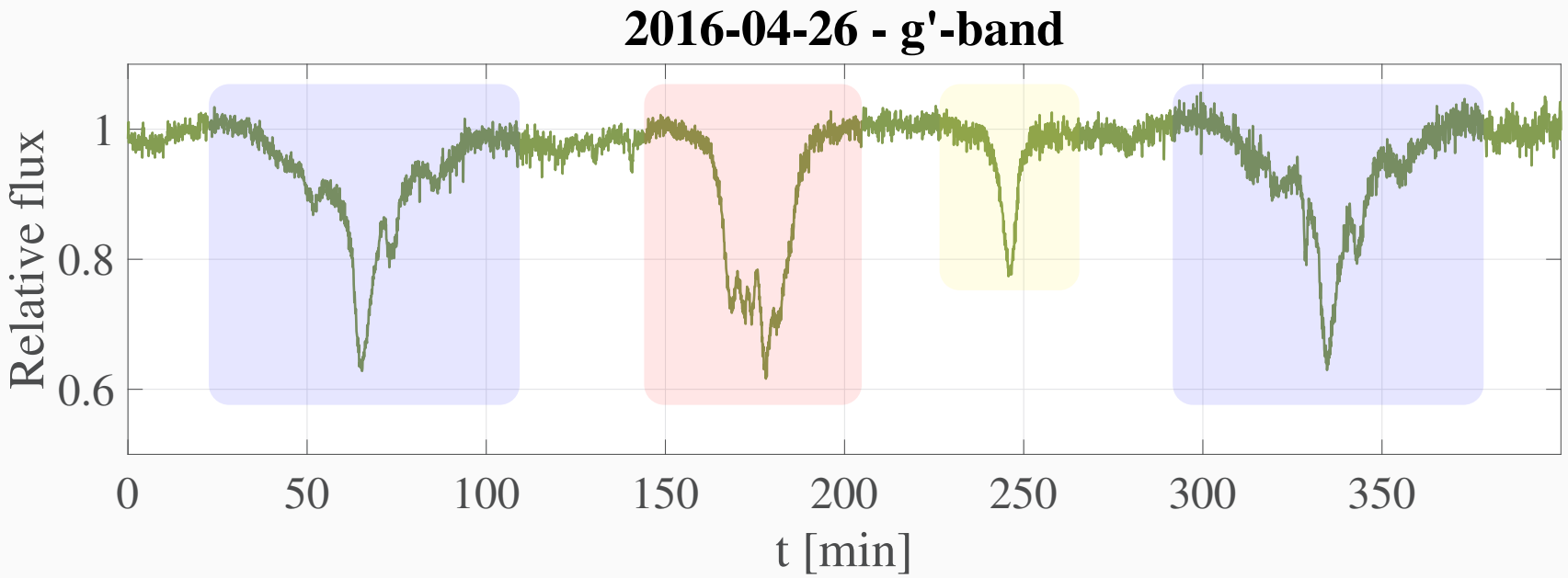
Light curve evolution



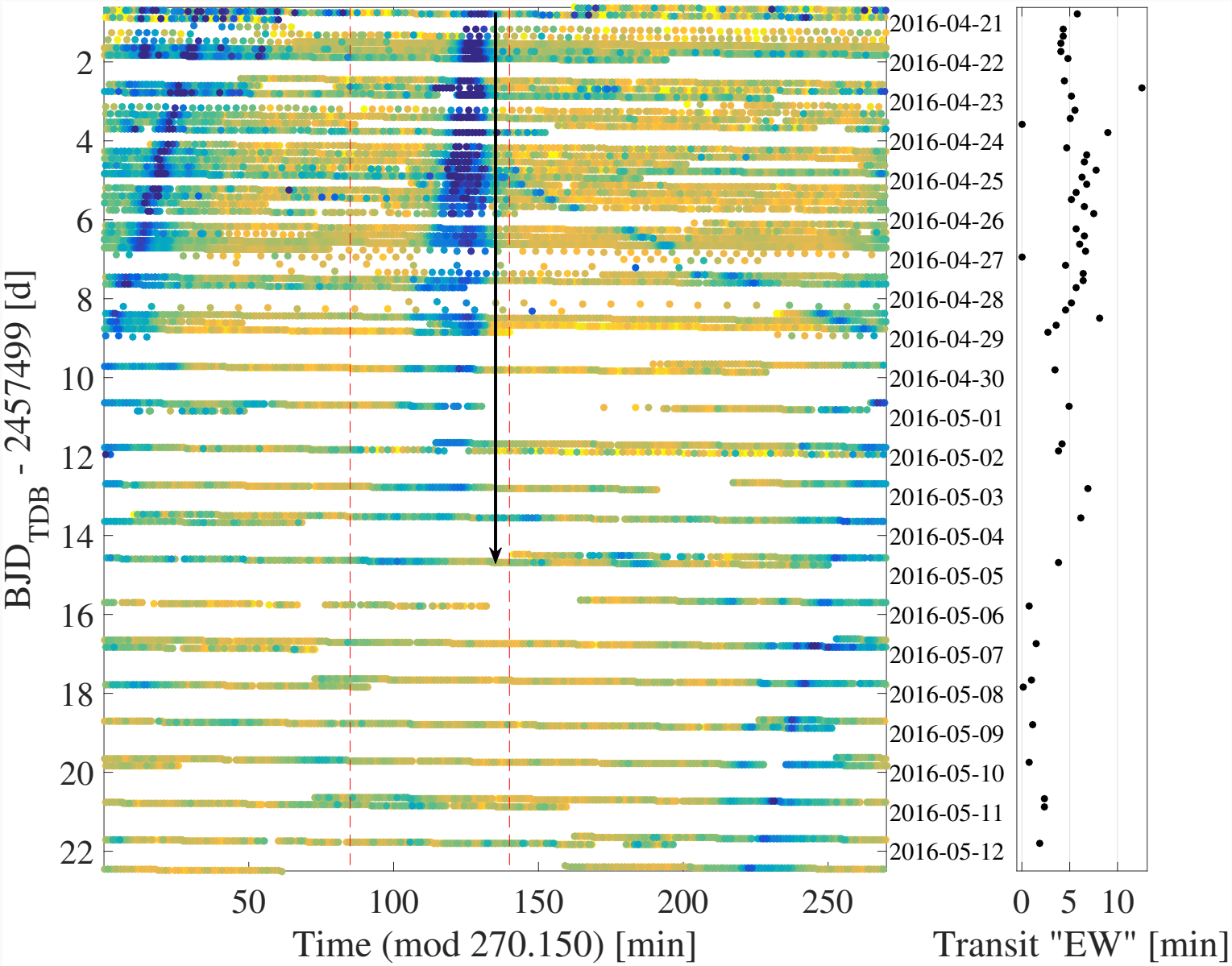


Light curve evolution

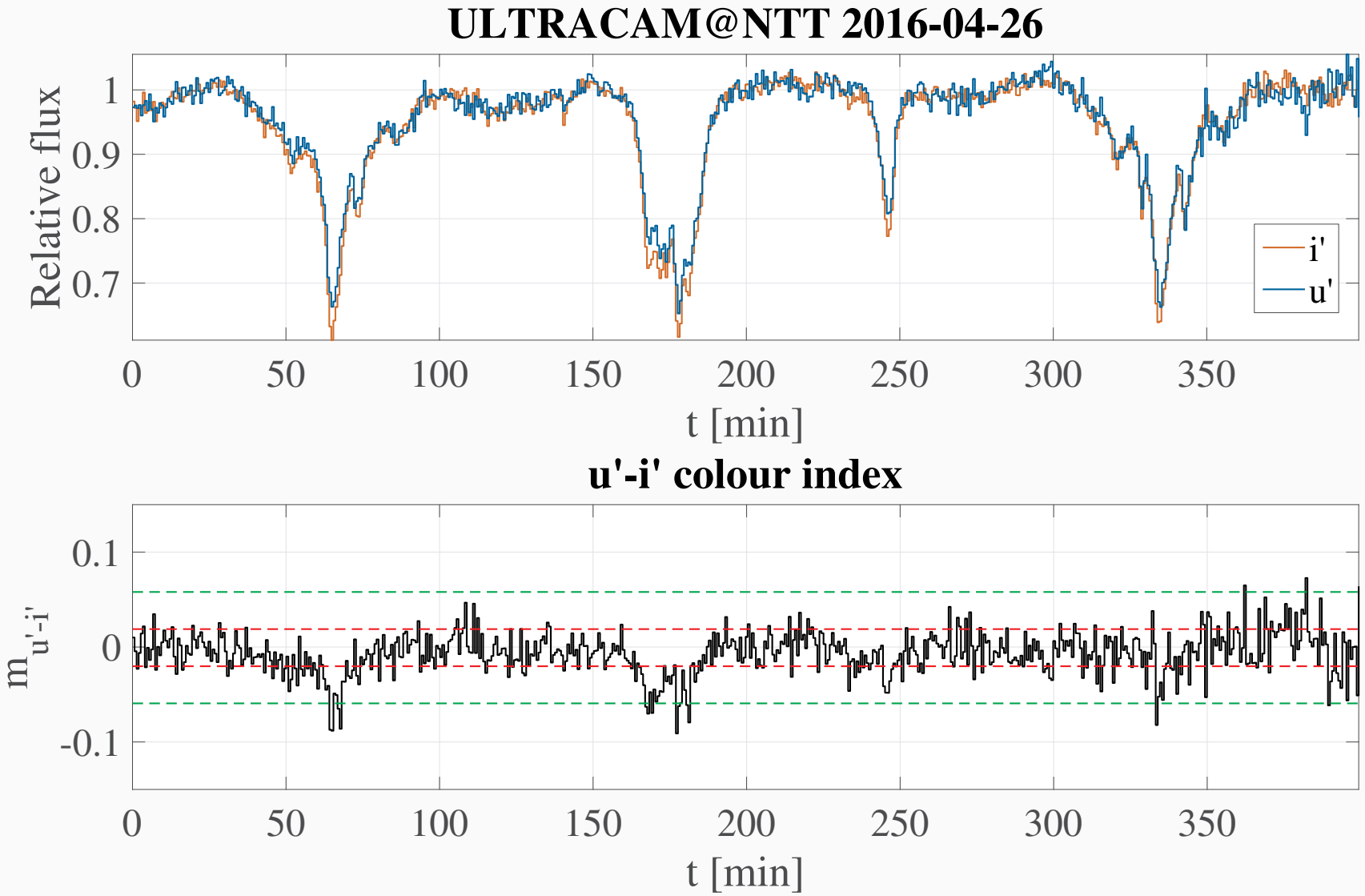




Light curve evolution: a cloud breaking up



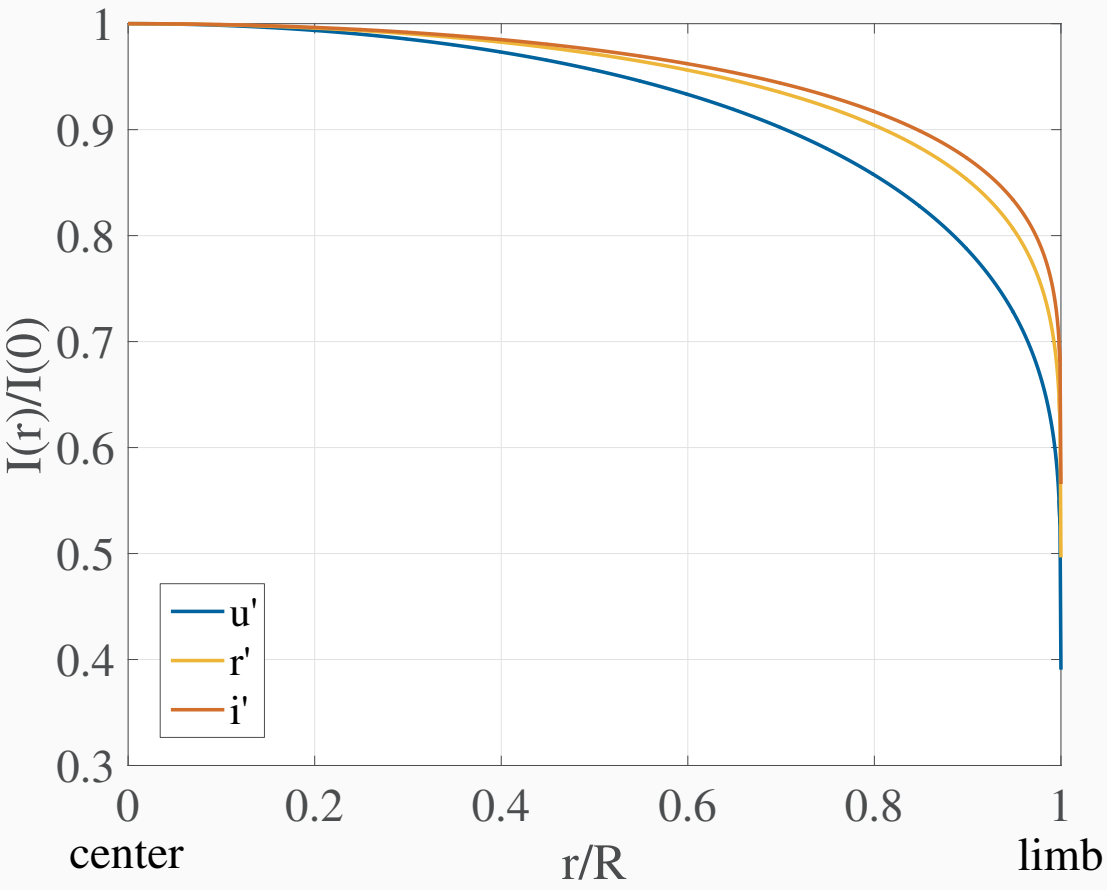
Change of colour during transits



$\Rightarrow$ Bluing!

Bluing I: Limb darkening?

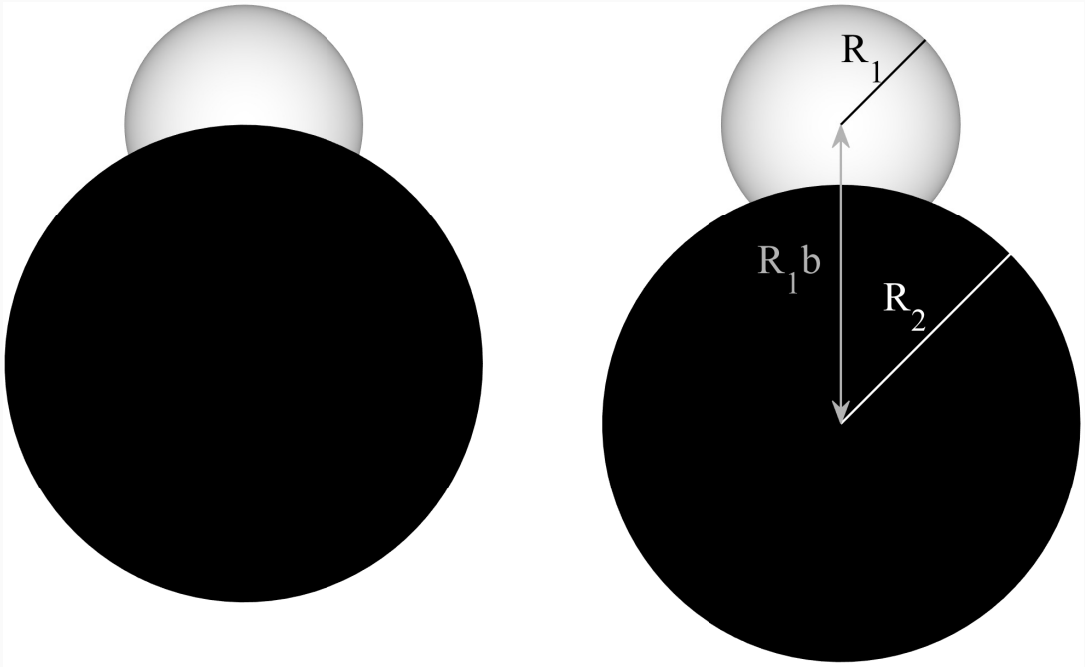
- The limb is redder
- Obscuring mostly the limb might cause the bluing



$T_{eff} = 15900\,\mathrm{K}$, $\log g = 8$ (Gianninas+2013)

Bluing I: Limb darkening?

Impossible to simultaneously get observed bluing and depth:



$$u' - i' \gtrsim -0.006$$

But we need $u' - i' \sim -0.05$!

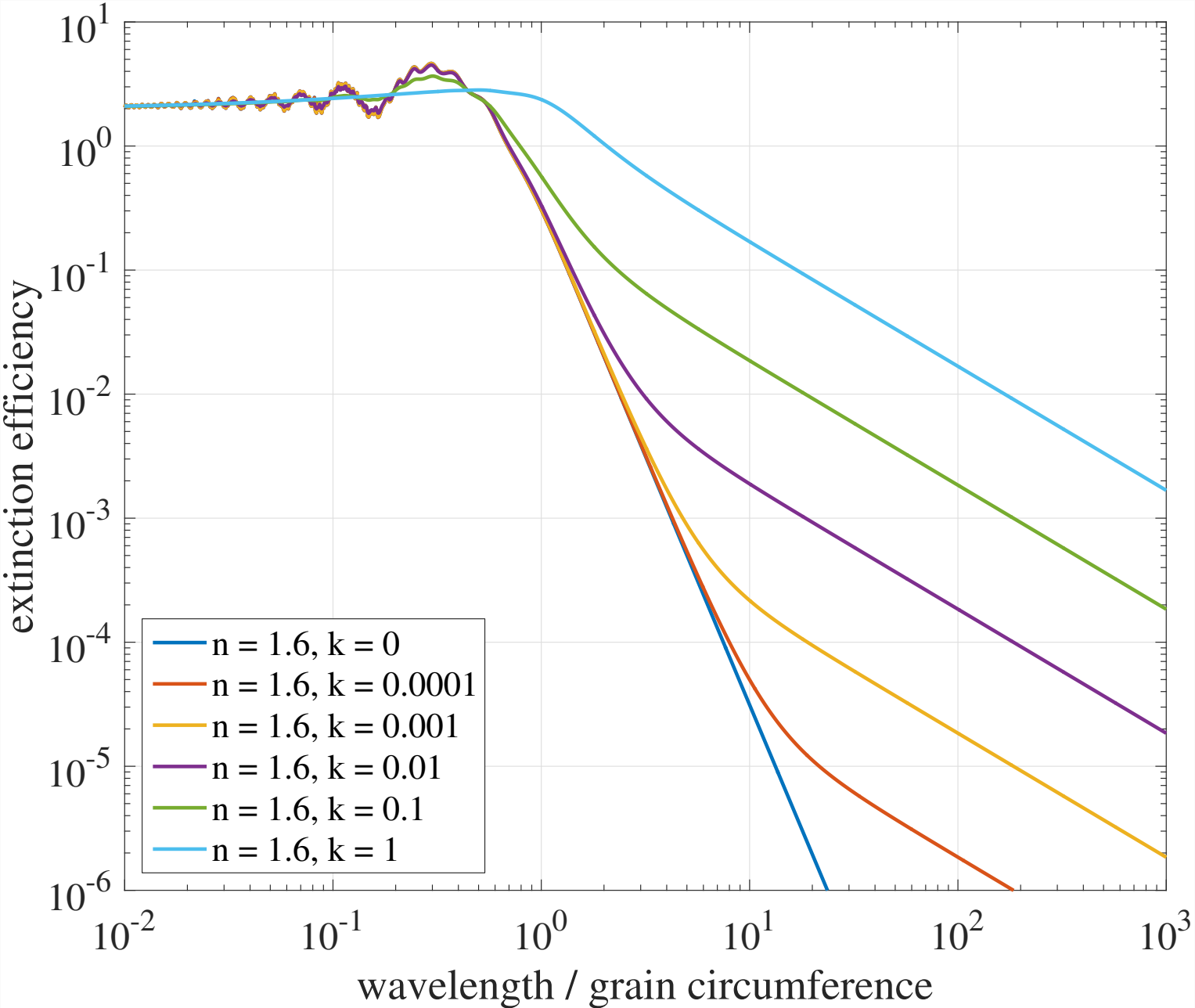
Bluing II: Peculiar dust properties; once in a blue moon?

- Bluing is possible but very rare
- Possible only with very specific and narrow distribution of grain sizes

71-1250, Houghton Library, Harvard University

NASA/JPL-Caltech/MSSS/Texas A&M Univ.

Bluing II: Peculiar dust properties; once in a blue moon?



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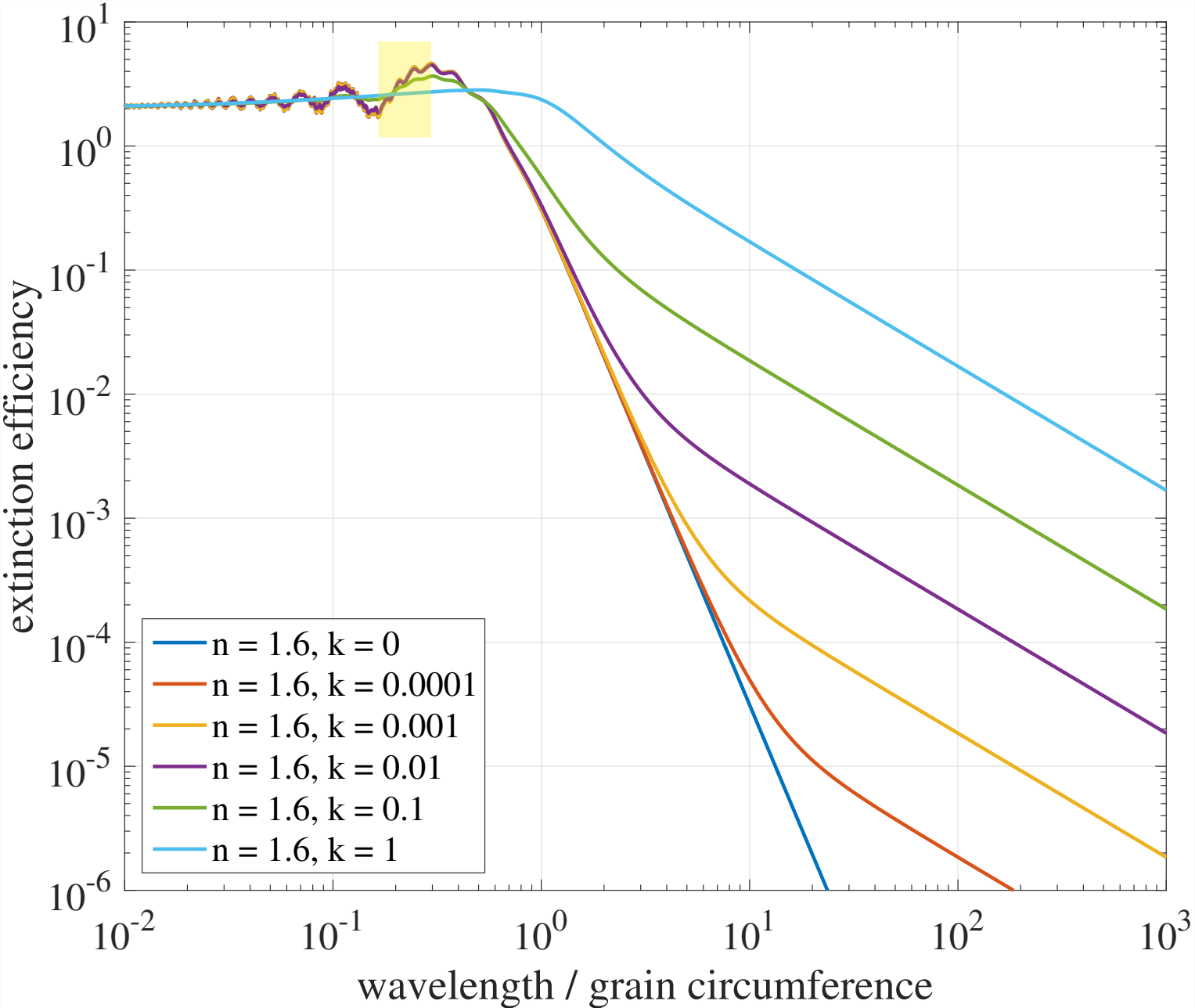

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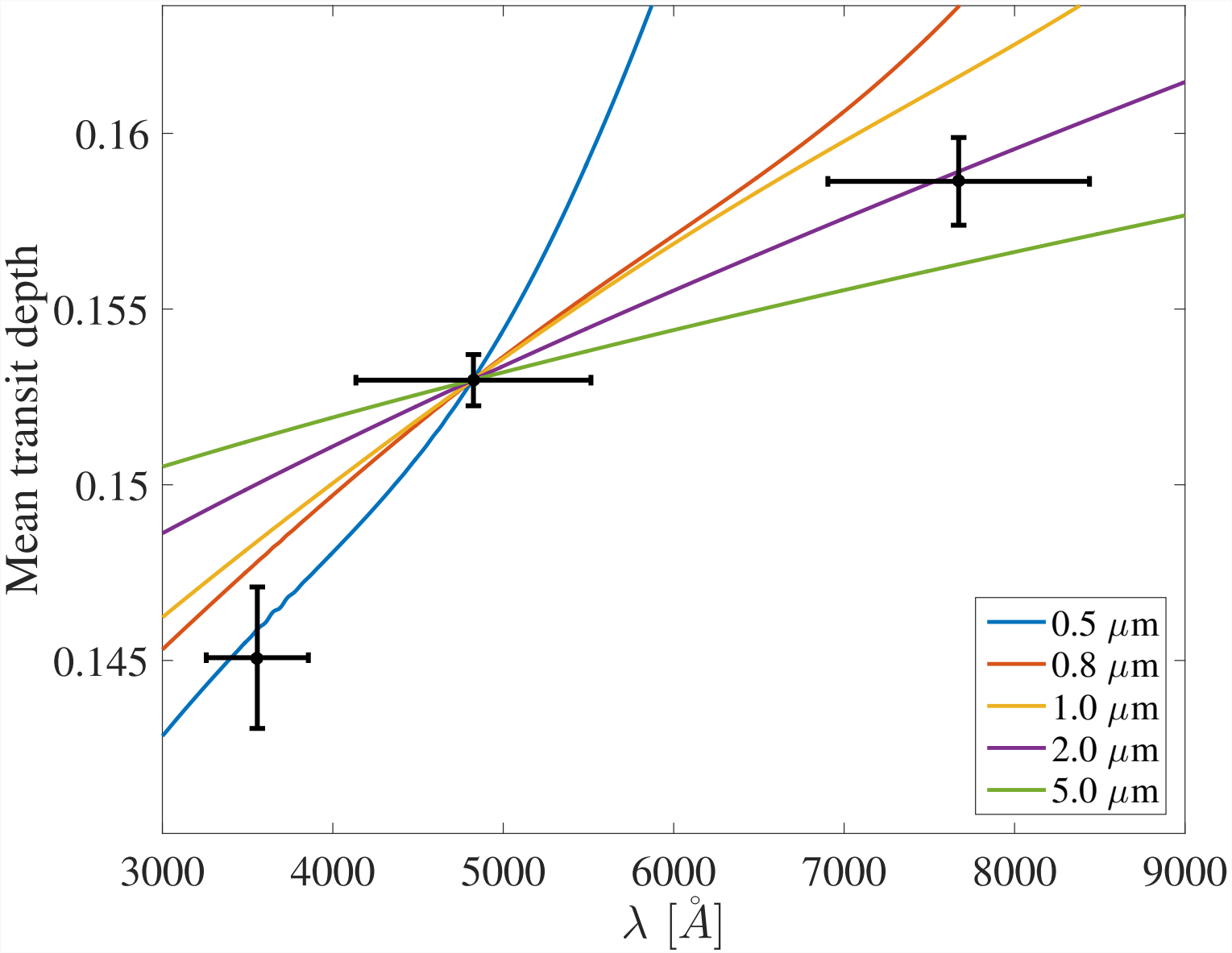
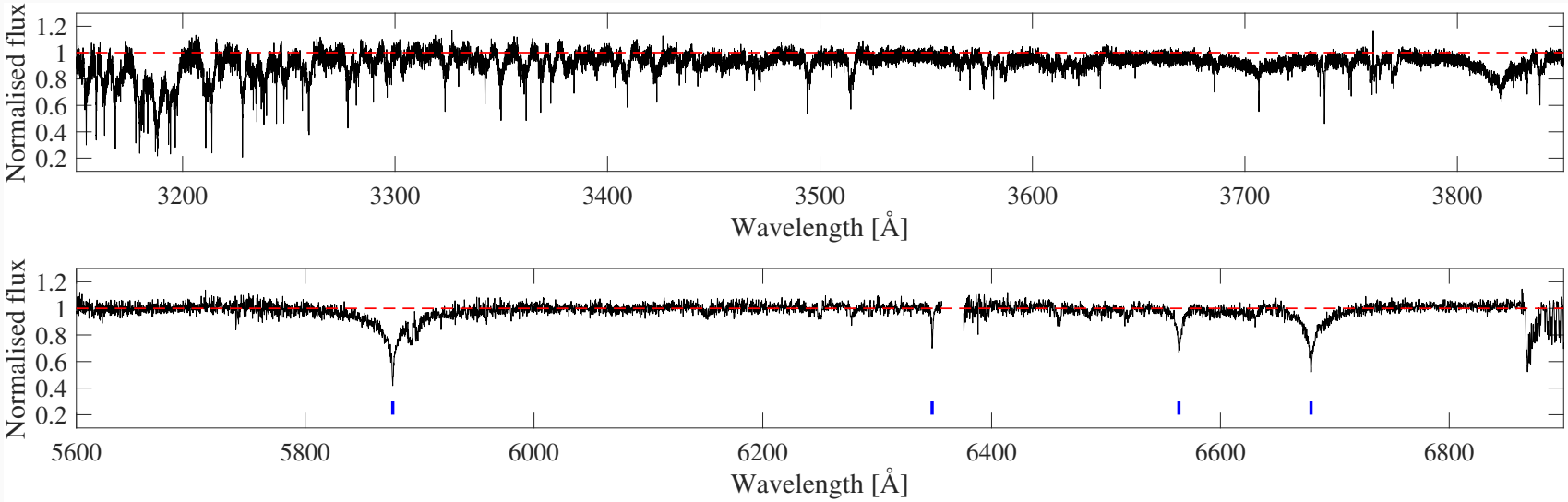


Bluing III: Circumstellar lines?

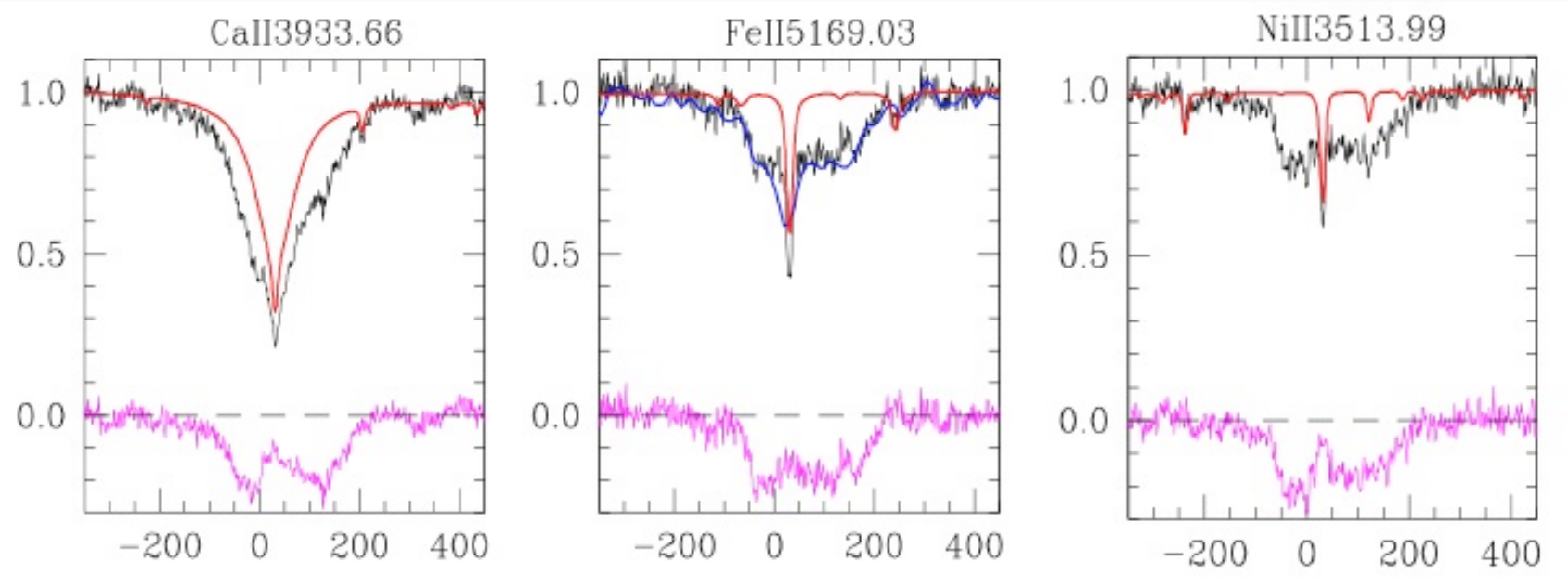
u'-band (top, HIRES data) vs. *r*'-band (bottom, X-SHOOTER):



$\Rightarrow$ Most CS lines are between $3000 - 4000$ Å

Bluing III: Circumstellar lines?

Broad absorption lines:

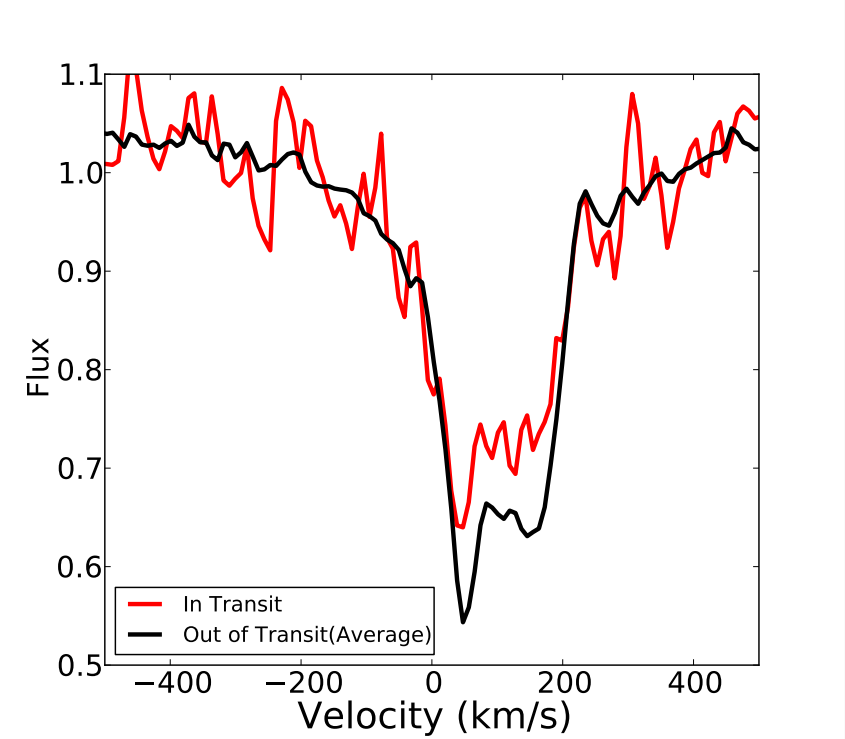


Xu+2016

⇒ Cool gas in a close orbit

Bluing III: Circumstellar lines?

Shallower CS lines during transit:



S. Xu

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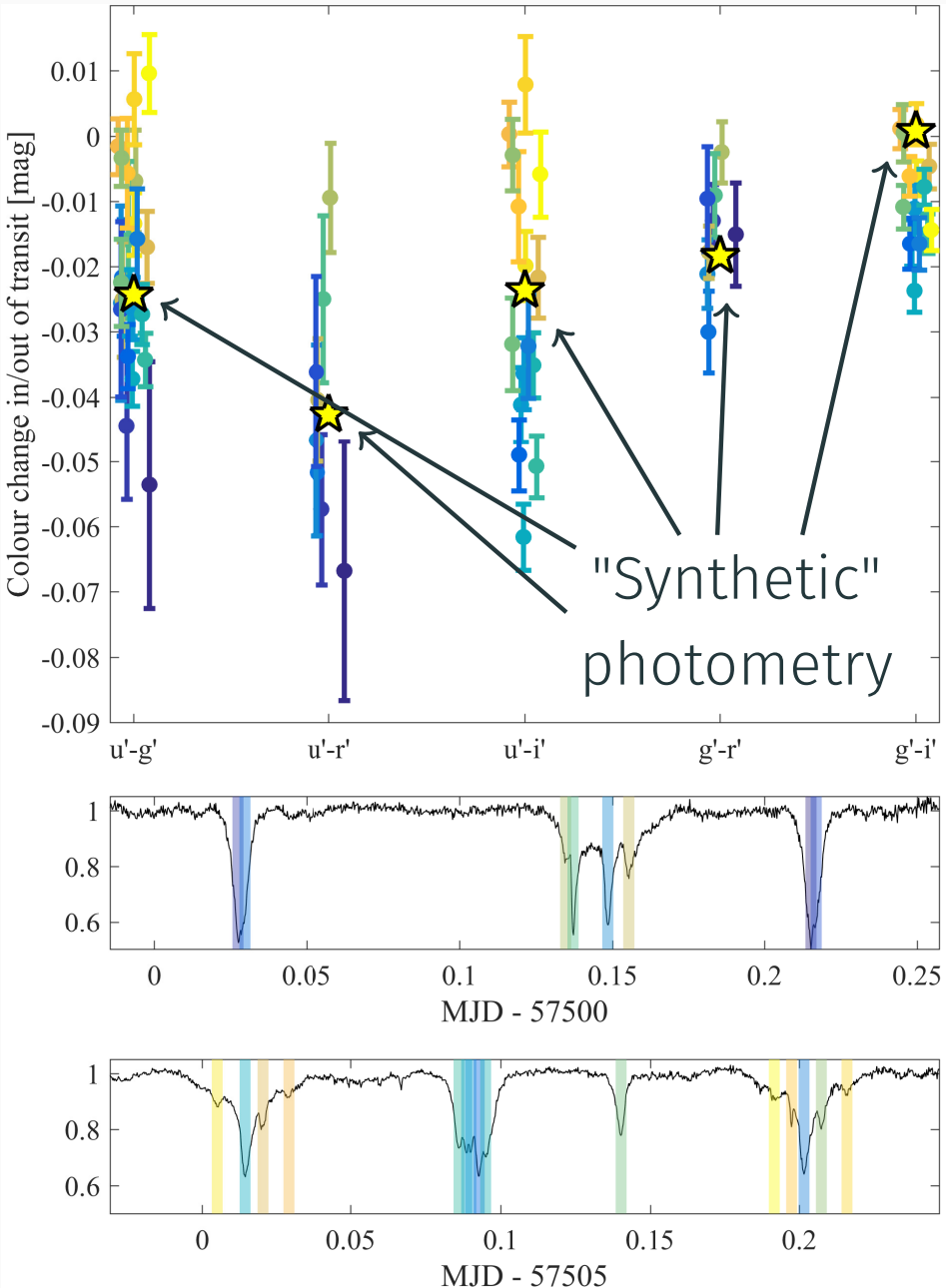
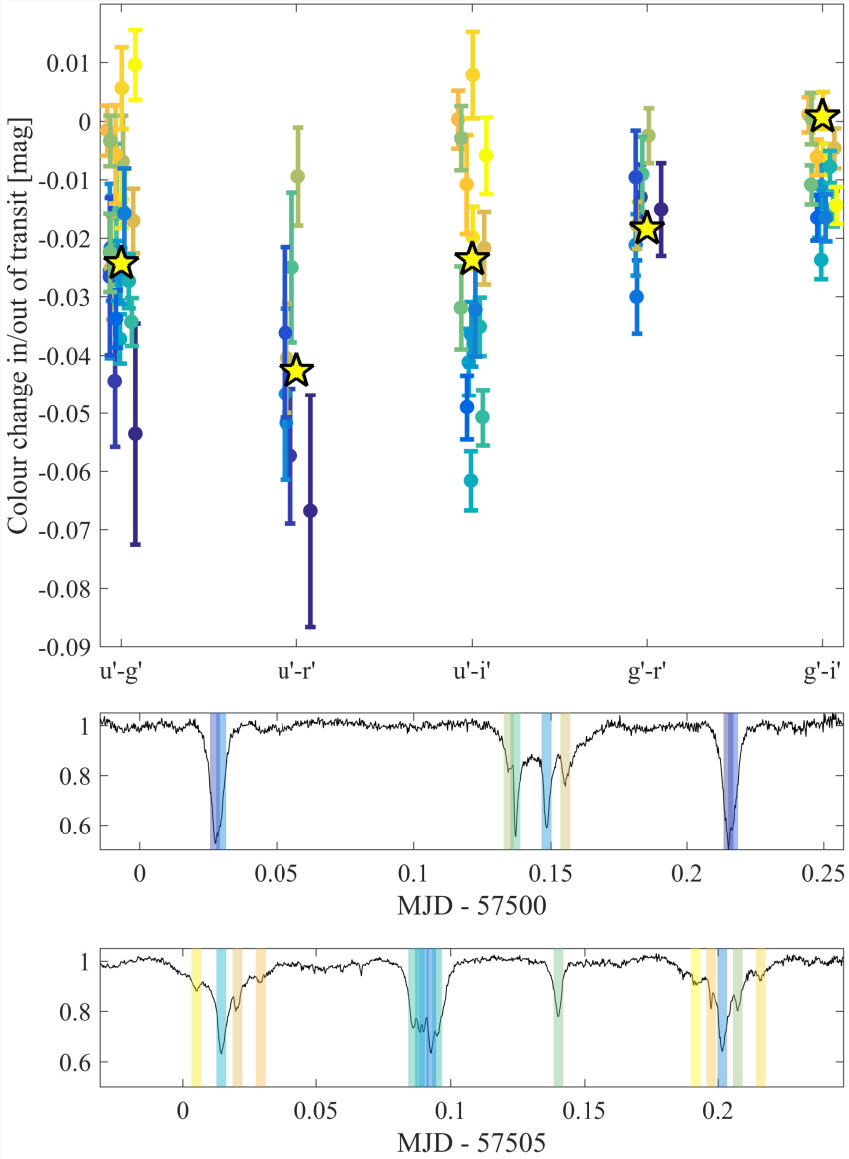


Bluing III: Circumstellar lines?

- Bluing can be explained by CS lines
- Previous studies did not observe the $3000 - 4000$ Å range:
  - Croll+2015: $5500 - 6400$ Å
  - Alonso+2016: $4800 - 9200$ Å
  - Zhou+2016: $5000 - 12000$ Å

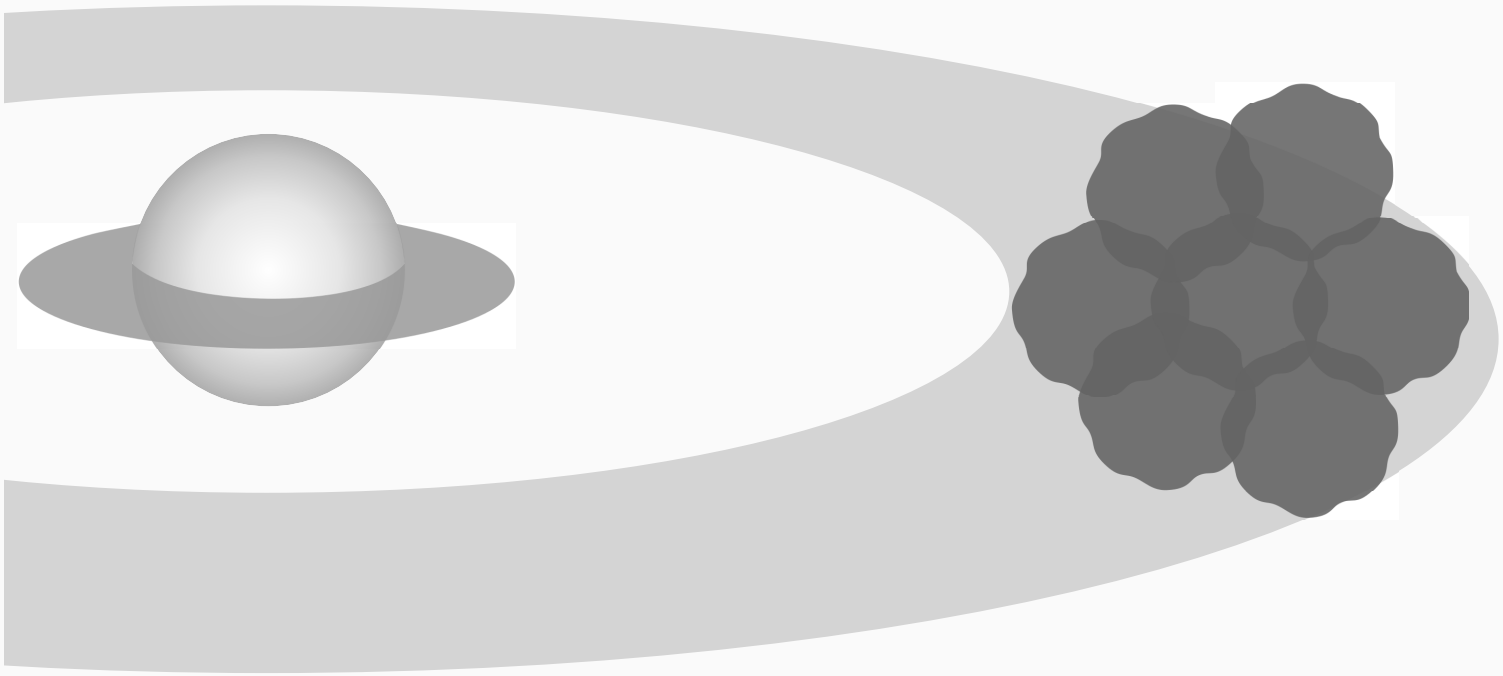


Where is the gas?

If the bluing is caused by the CS gas

- The gas and the dust clouds share the line-of-sight
- The gas covers the WD only partially
- The gas, the orbiting objects, and the dust disc, could be part of the same general disc structure

Where is the gas?



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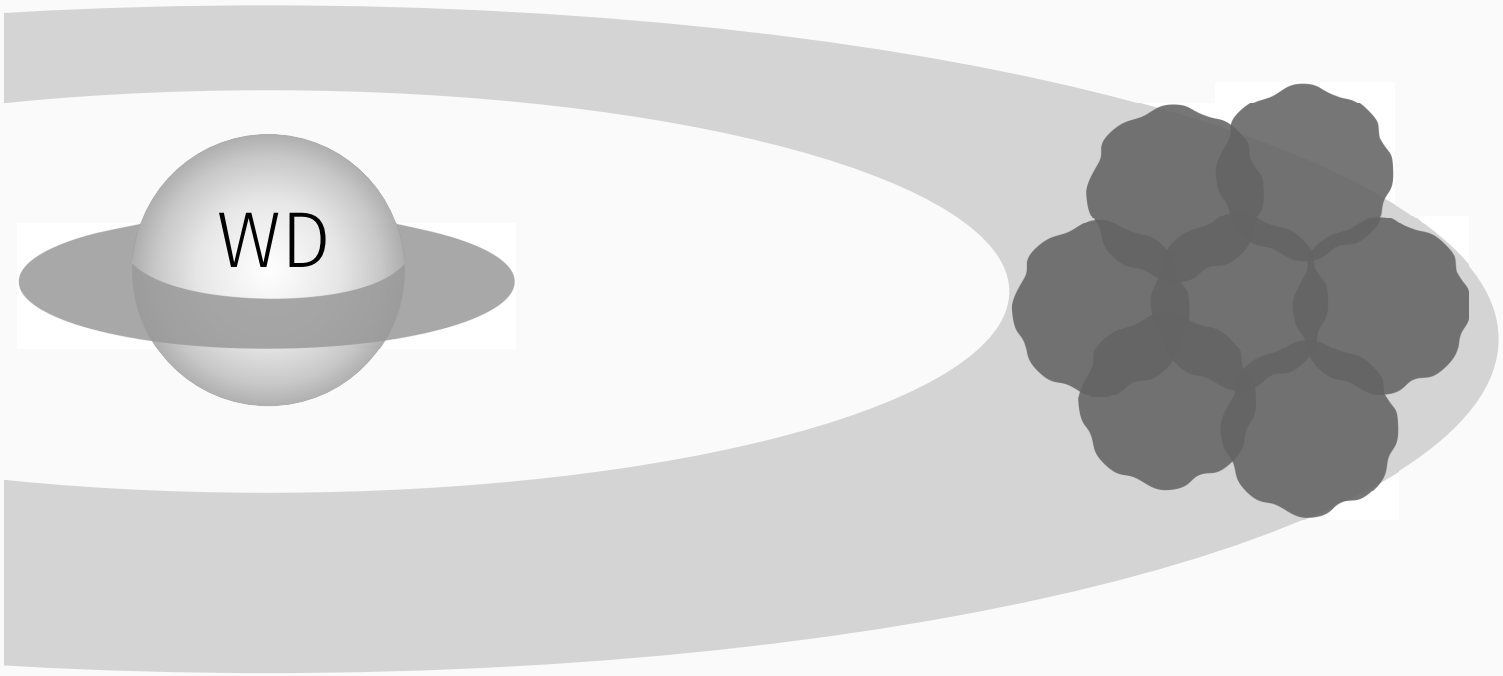

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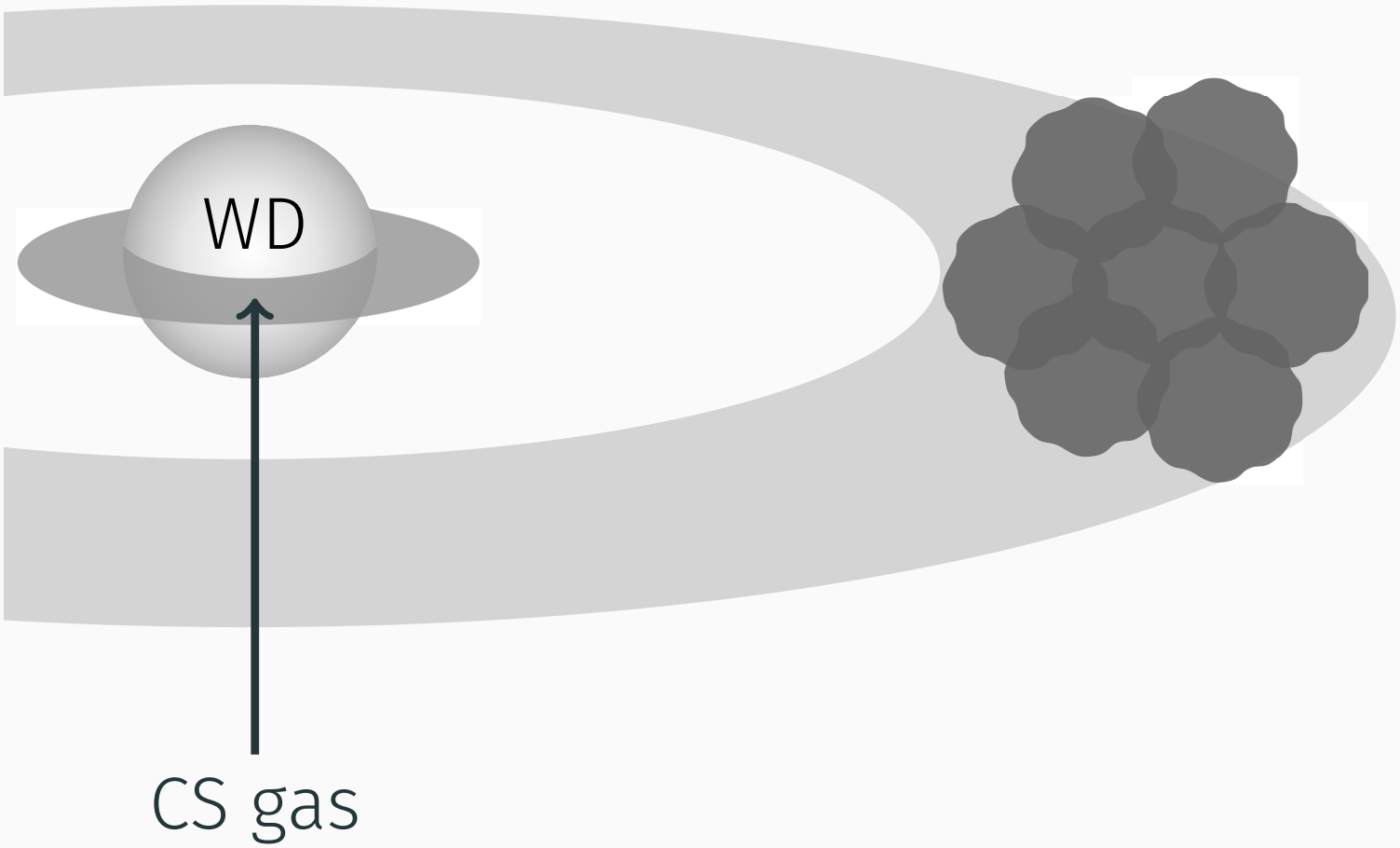

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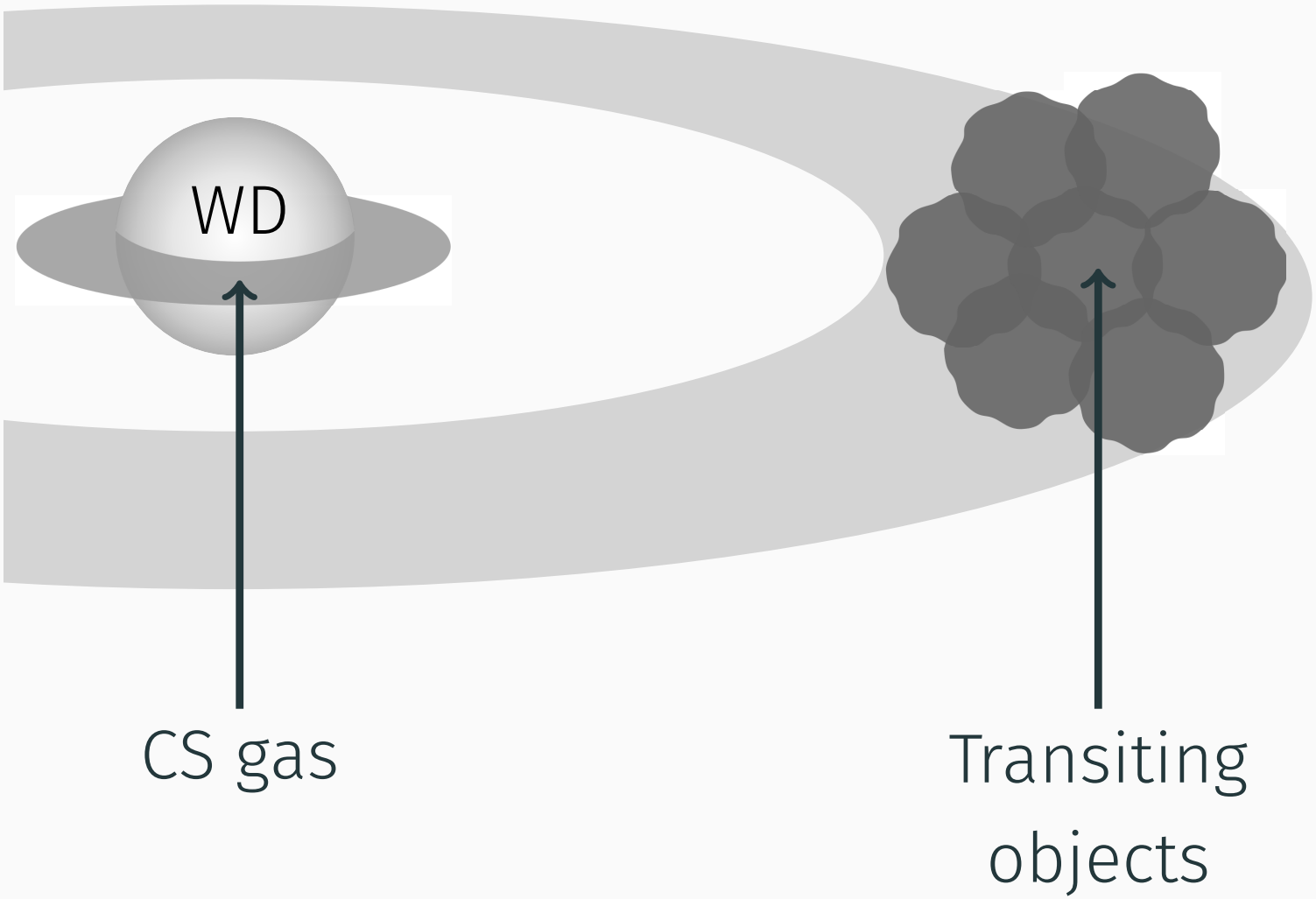

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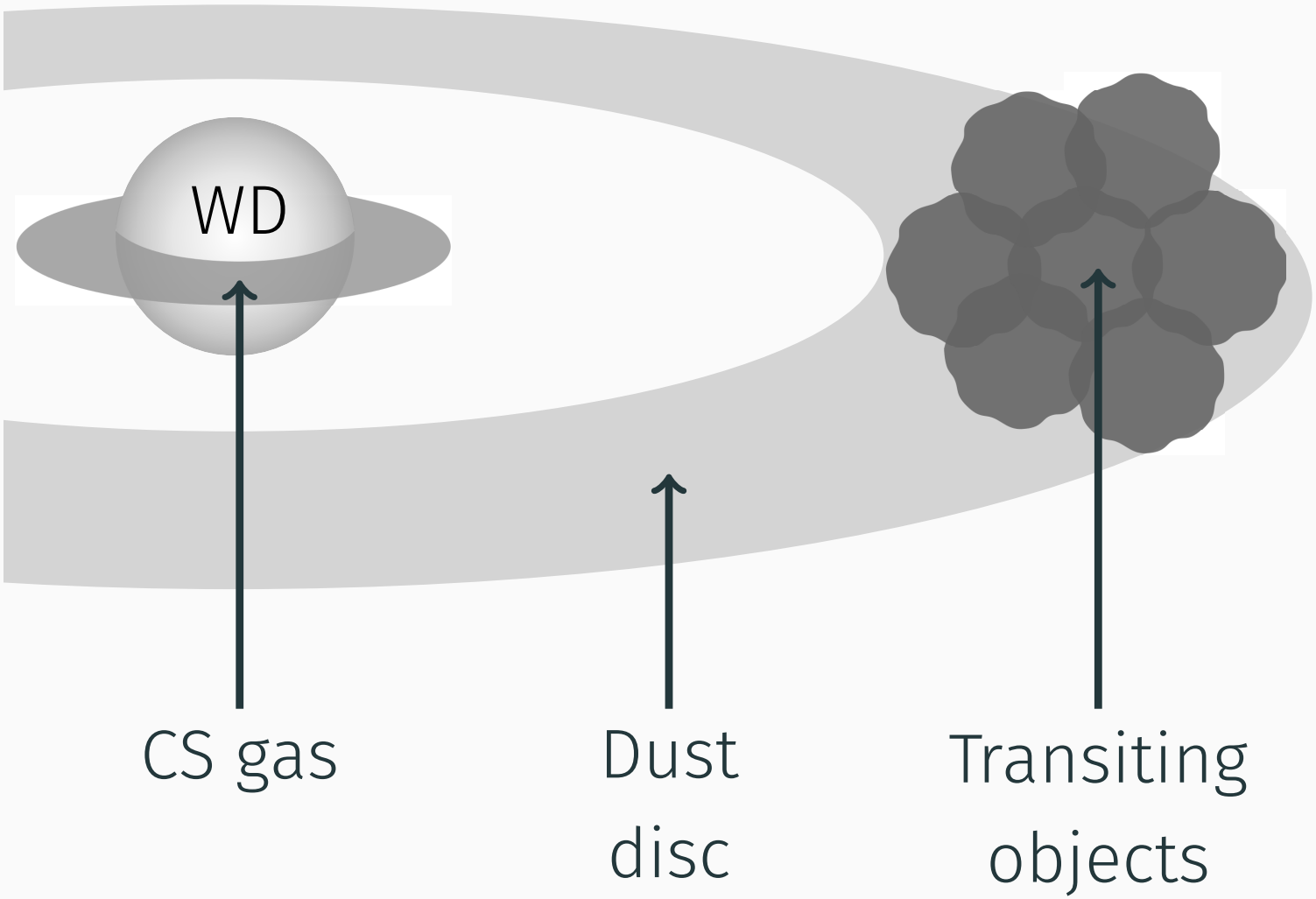
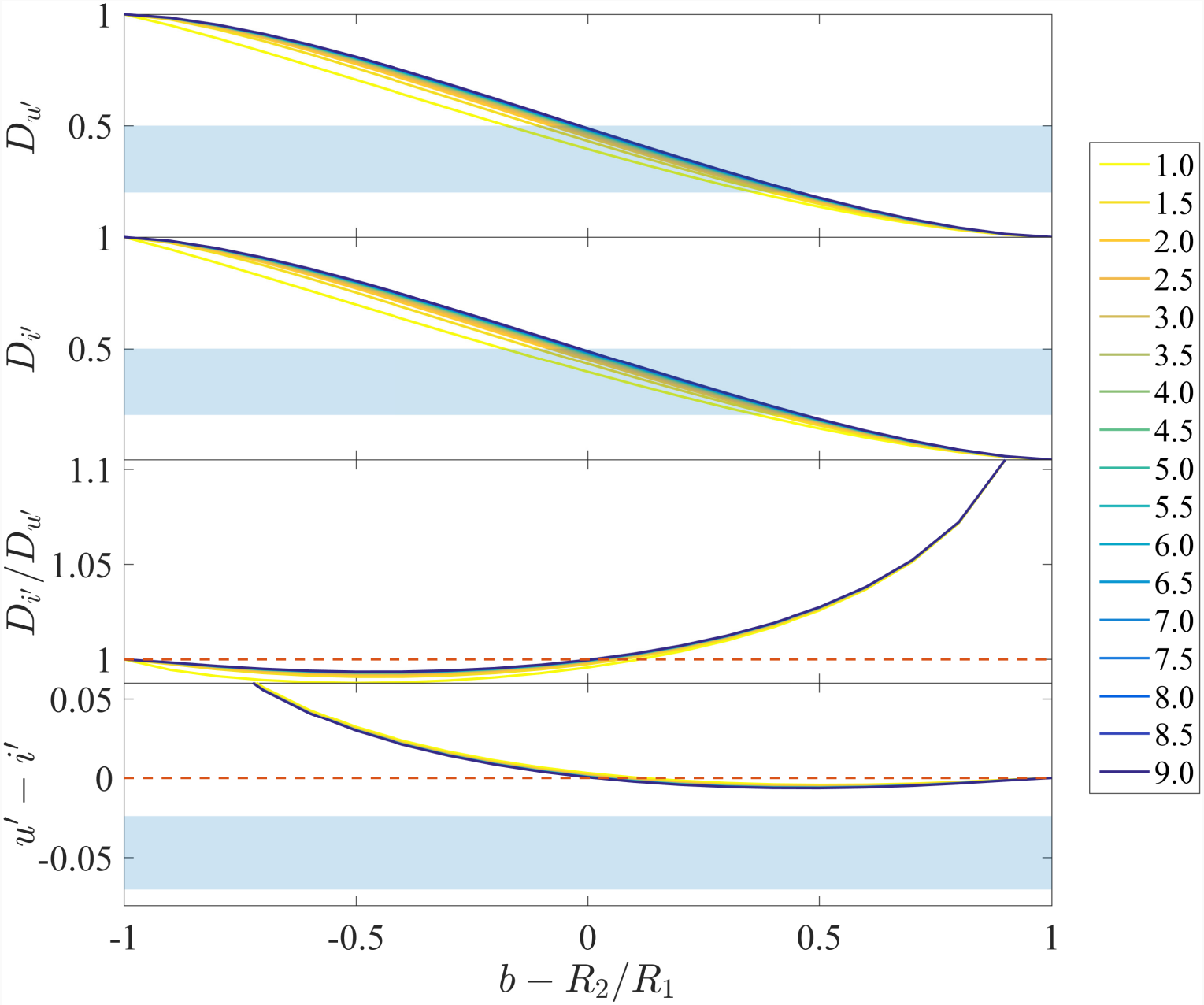


Summary

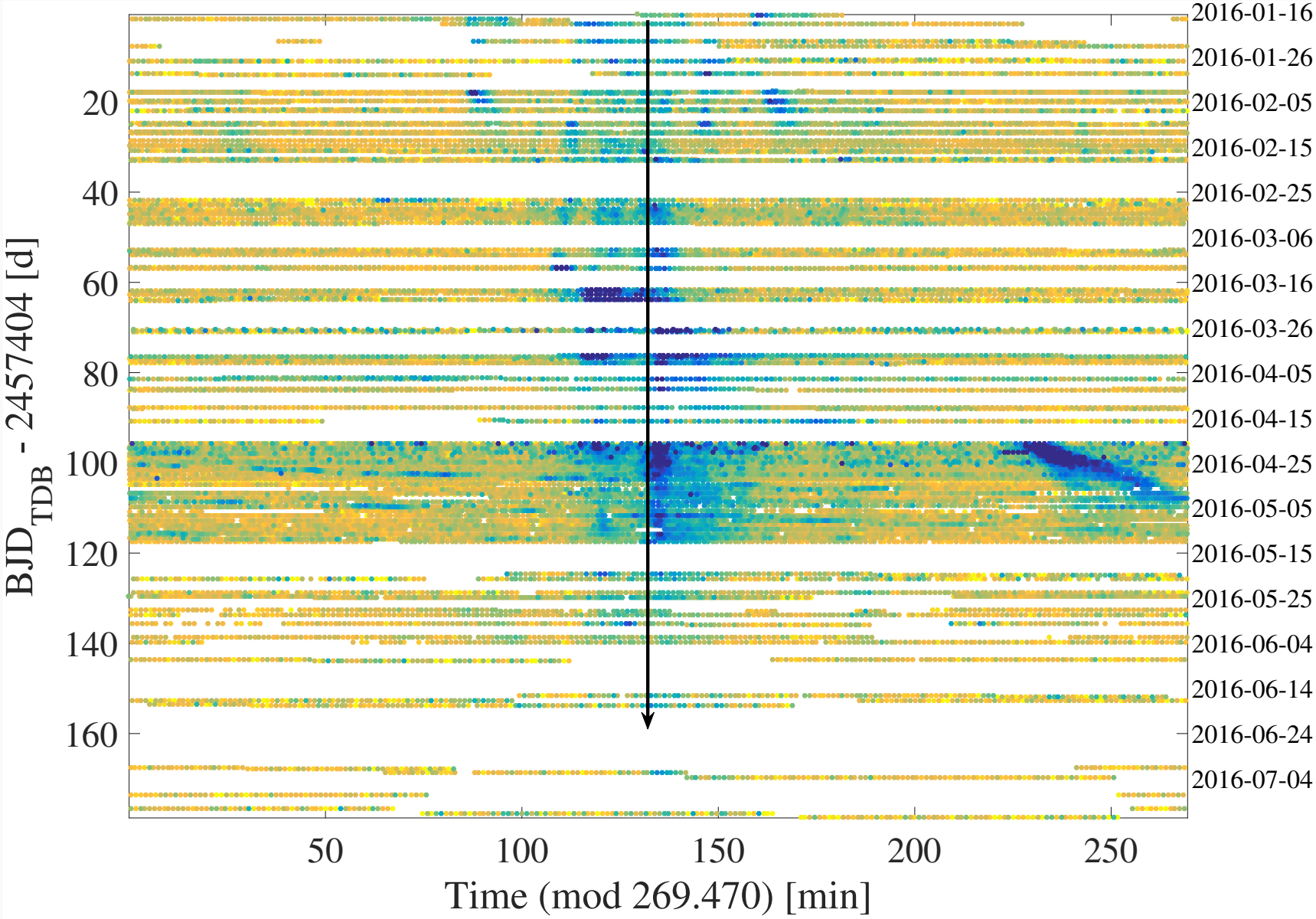
- Multiband fast-photometry shows blue transits
- The bluing can be explained by obscured circumstellar gas
- The gas, the orbiting objects, and the dust disc, could be part of the same general disc structure
- ~ 10 day monitoring shows rapid light curve evolution

arXiv:1702.05483

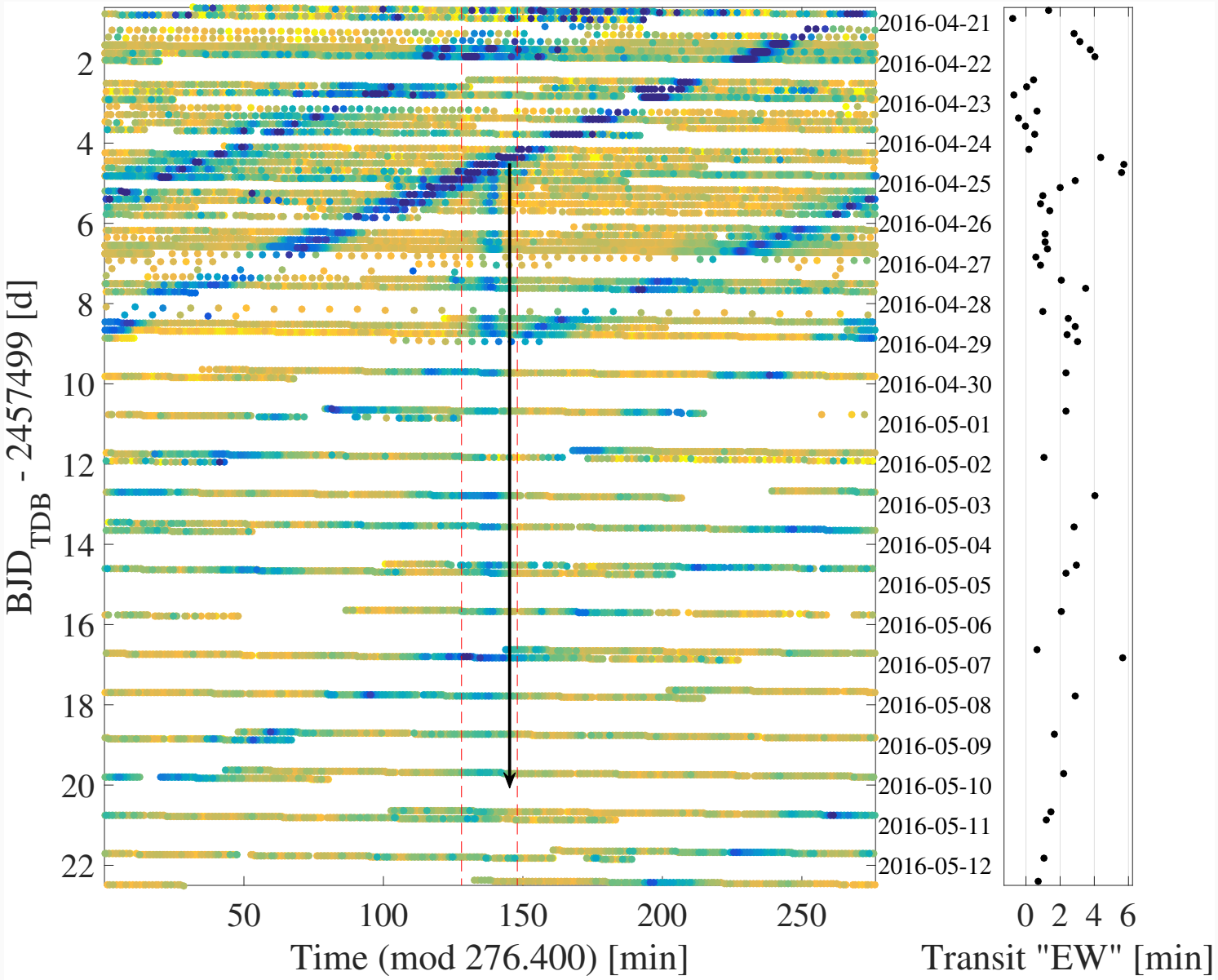
Bluing: Limb darkening?



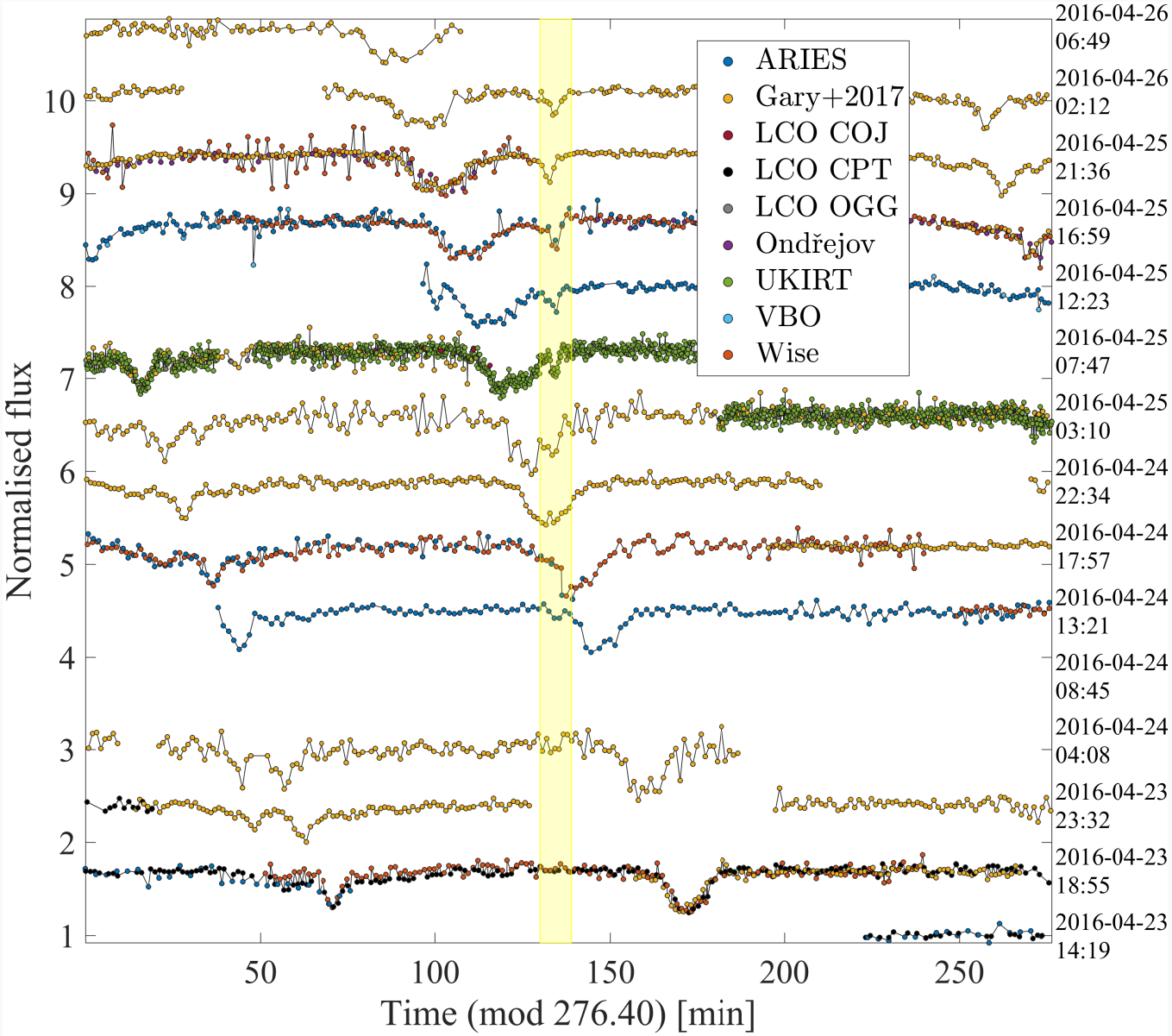
Light curve evolution: gradual disappearance of a cloud



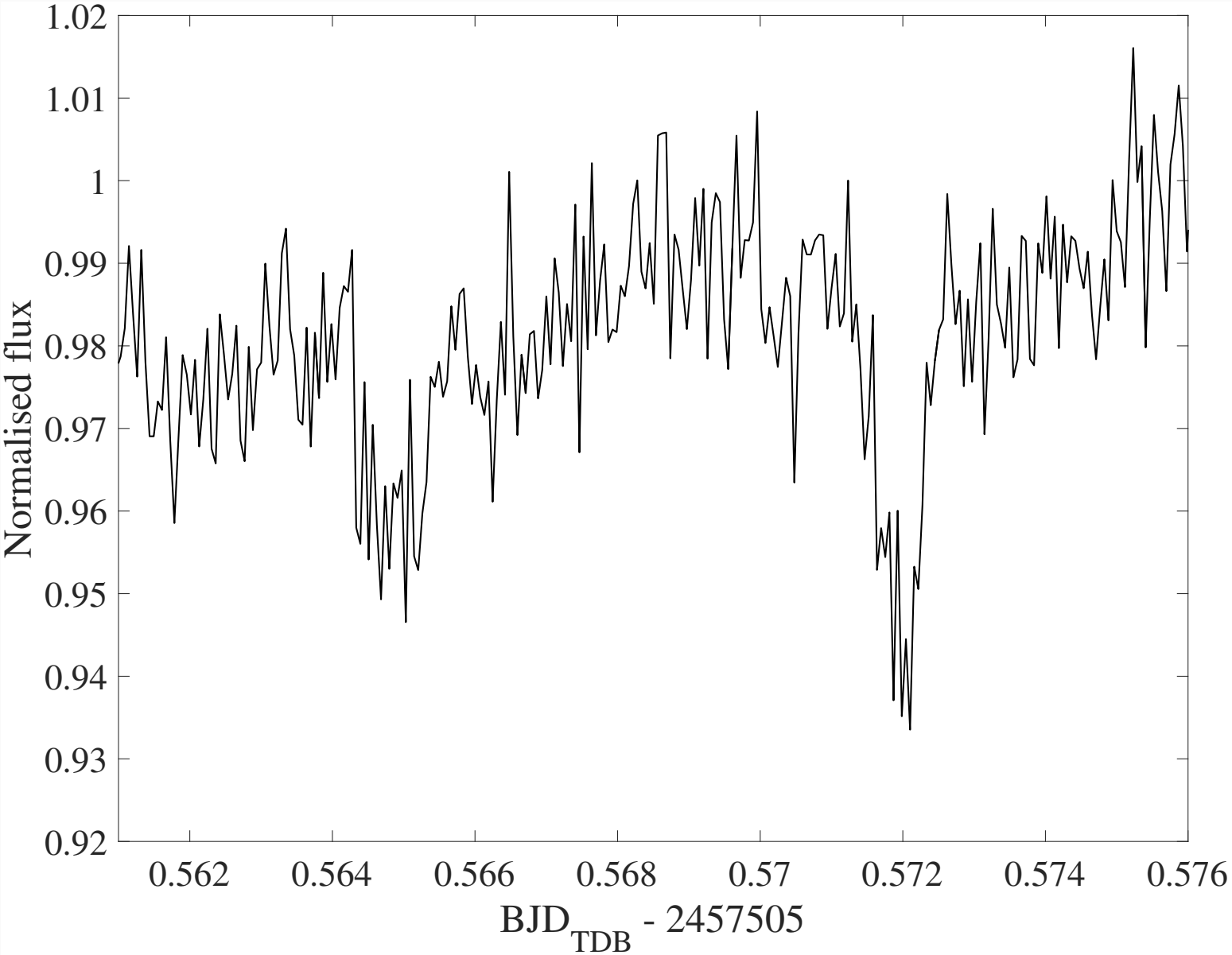
Light curve evolution: sudden appearance of the B-cloud!



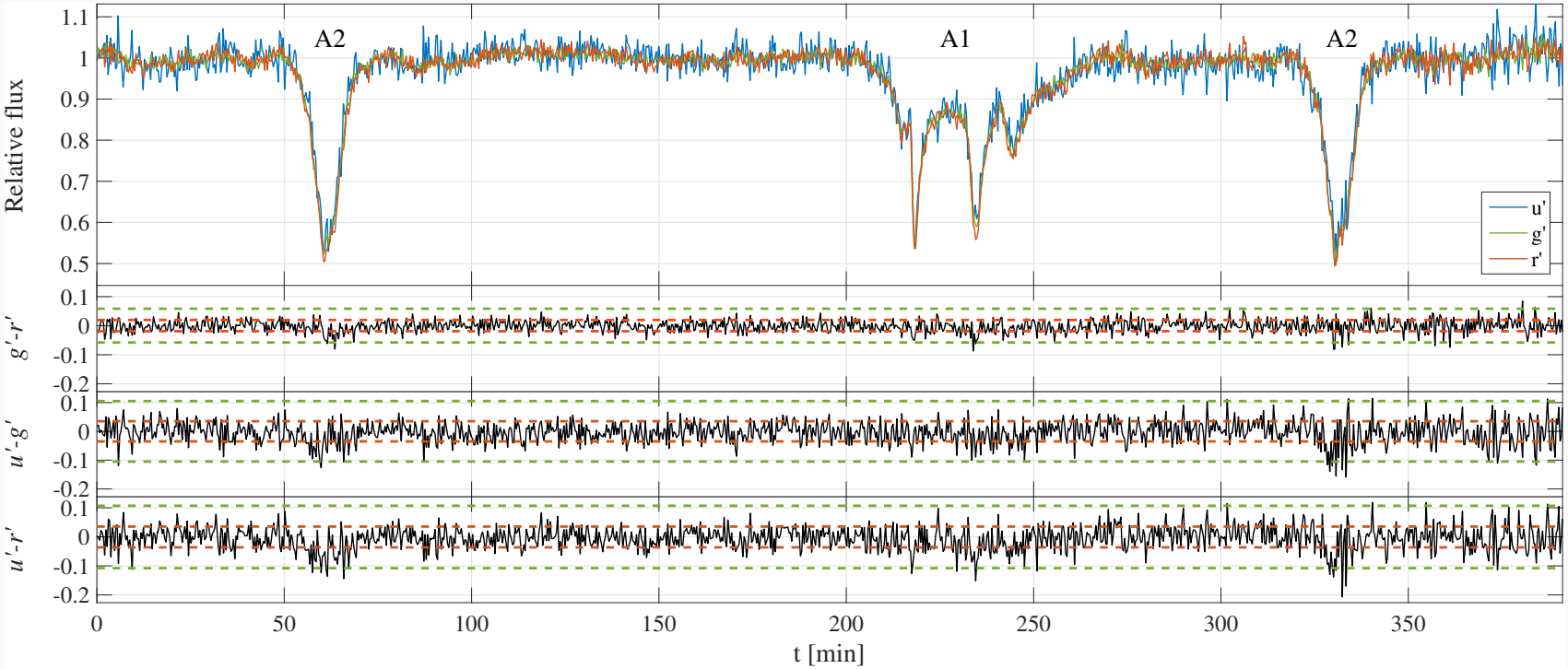
The B-dip


ARIES
Gary+2017
LCO COJ
LCO CPT
LCO OGG
Ondřejov
UKIRT
VBO
Wise
Normalised flux
Time (mod 276.40) [min]
2016-04-26 06:49
2016-04-26 02:12
2016-04-25 21:36
2016-04-25 16:59
2016-04-25 12:23
2016-04-25 07:47
2016-04-25 03:10
2016-04-24 22:34
2016-04-24 17:57
2016-04-24 13:21
2016-04-24 08:45
2016-04-24 04:08
2016-04-23 23:32
2016-04-23 18:55
2016-04-23 14:19

Fine details



ULTRACAM: 2016 April 21



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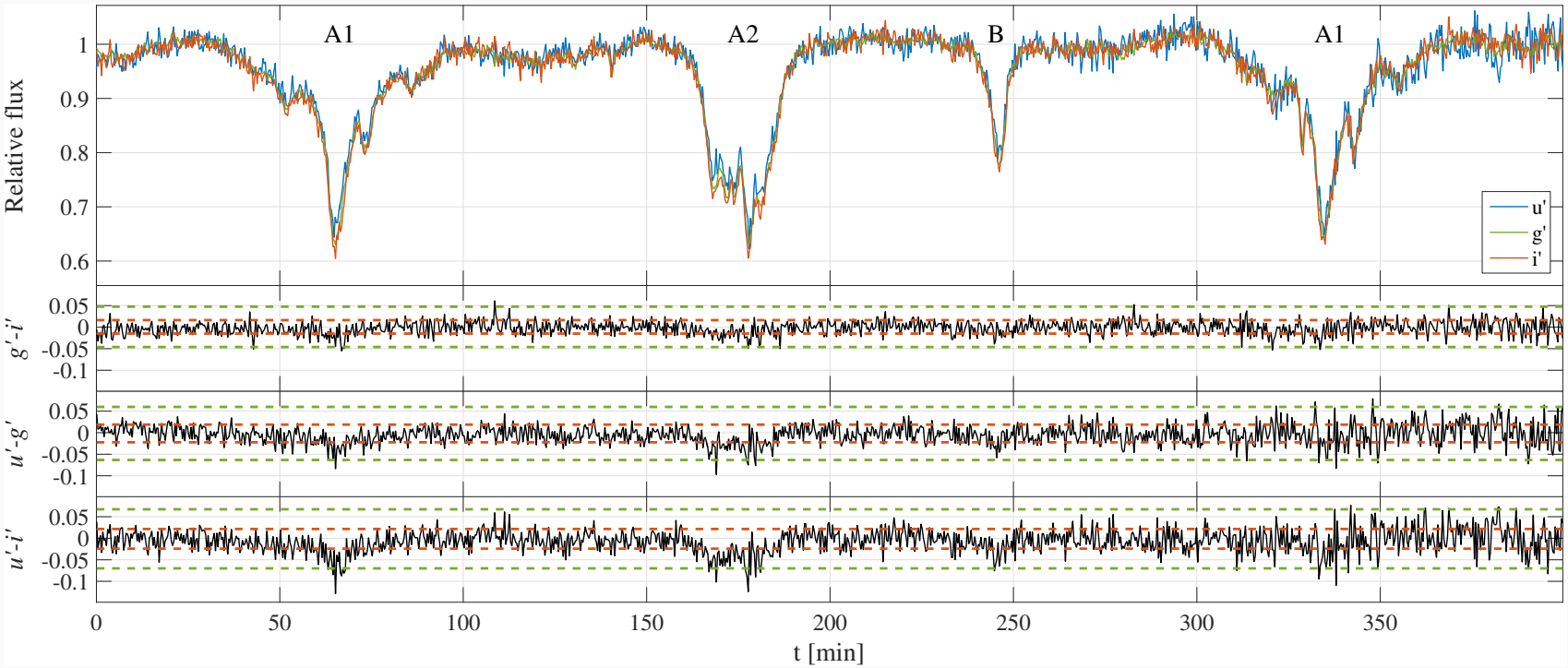

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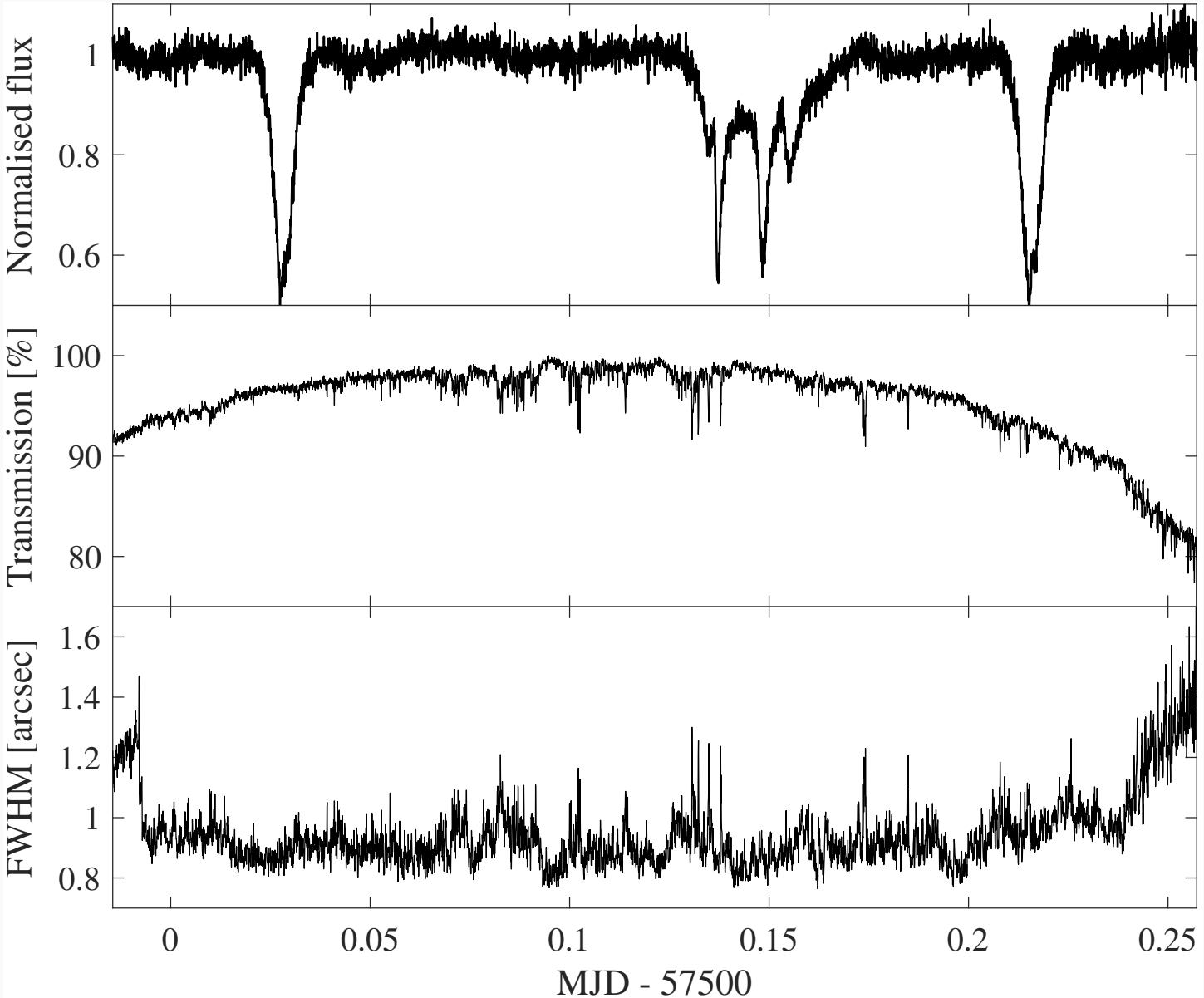

ULTRACAM: 2016 April 26