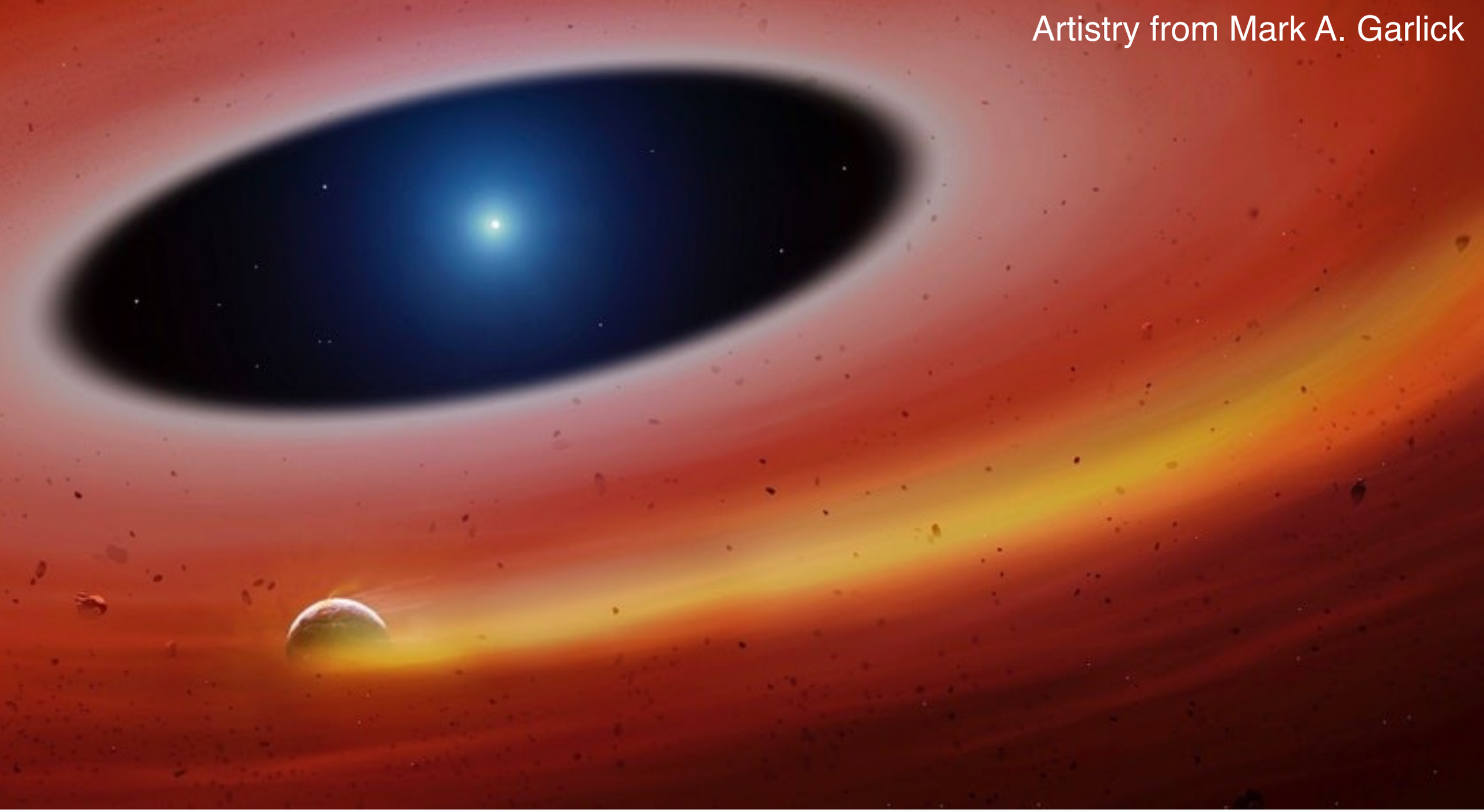


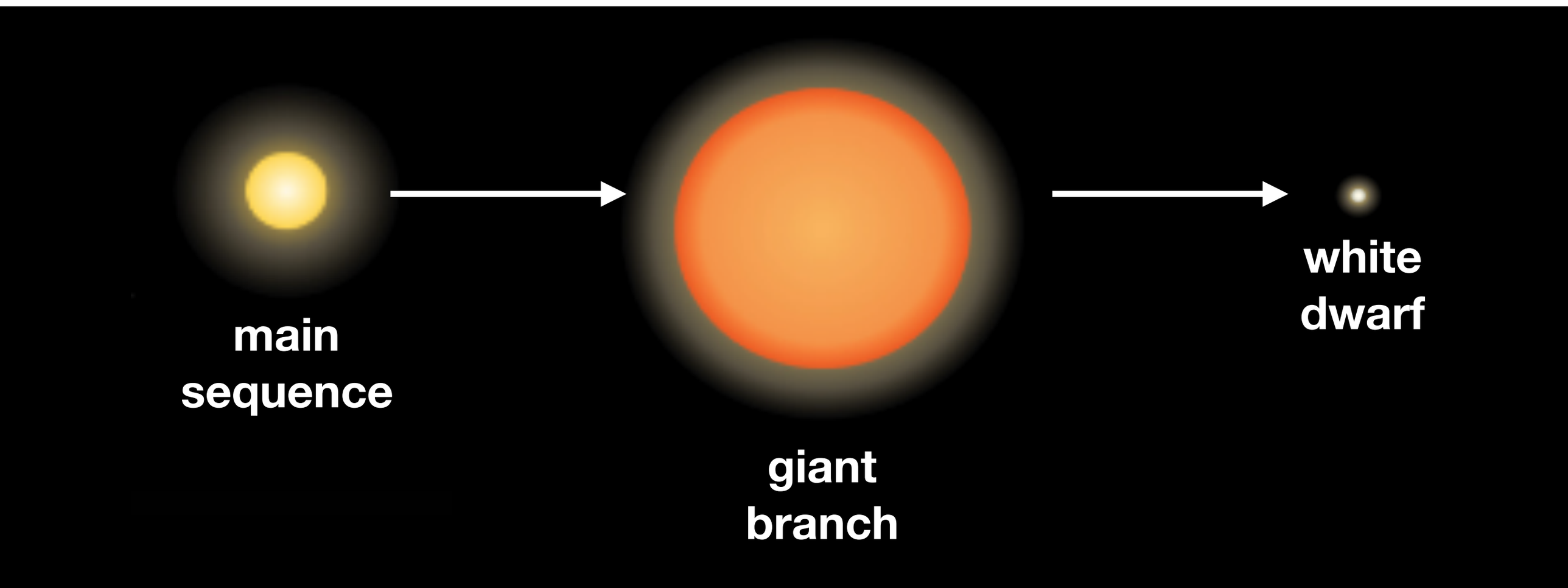
Overview of white dwarf planetary systems

Dimitri Veras **University of Warwick (UK)**

Conference evolution

Most of this conference

Smadar Naoz talk on Tuesday



White dwarfs are very dense

Earth

White dwarf

$g \approx 10 \ \frac{\mathrm{m}}{\mathrm{s}^2}$

$g \approx 10^6 \ \frac{\mathrm{m}}{\mathrm{s}^2}!$

$R \approx 1.1 R_\oplus$

$M \approx 0.6 M_\odot$

Image: Mark Hollands

White dwarf planetary systems

Planetary remnants in atmospheres "metal pollution"	**> 1,000 systems (published)**
Planetary debris discs	**~40 systems (published)**
Orbiting exo-minor planets	**2 systems (published)**

nature

WD 1145+017

A disintegrating minor planet transiting a white dwarf

Andrew Vanderburg[1], John Asher Johnson[1], Saul Rappaport[2], Allyson Bieryla[1], Jonathan Irwin[1], John Arban Lewis[1], David Kipping[1,3], Warren R. Brown[1], Patrick Dufour[4], David R. Ciardi[5], Ruth Angus[1,6], Laura Schaefer[1], David W. Latham[1] David Charbonneau[1], Charles Beichman[5], Jason Eastman[1], Nate McCrady[7], Robert A. Wittenmyer[8] & Jason T. Wright[9]

Science

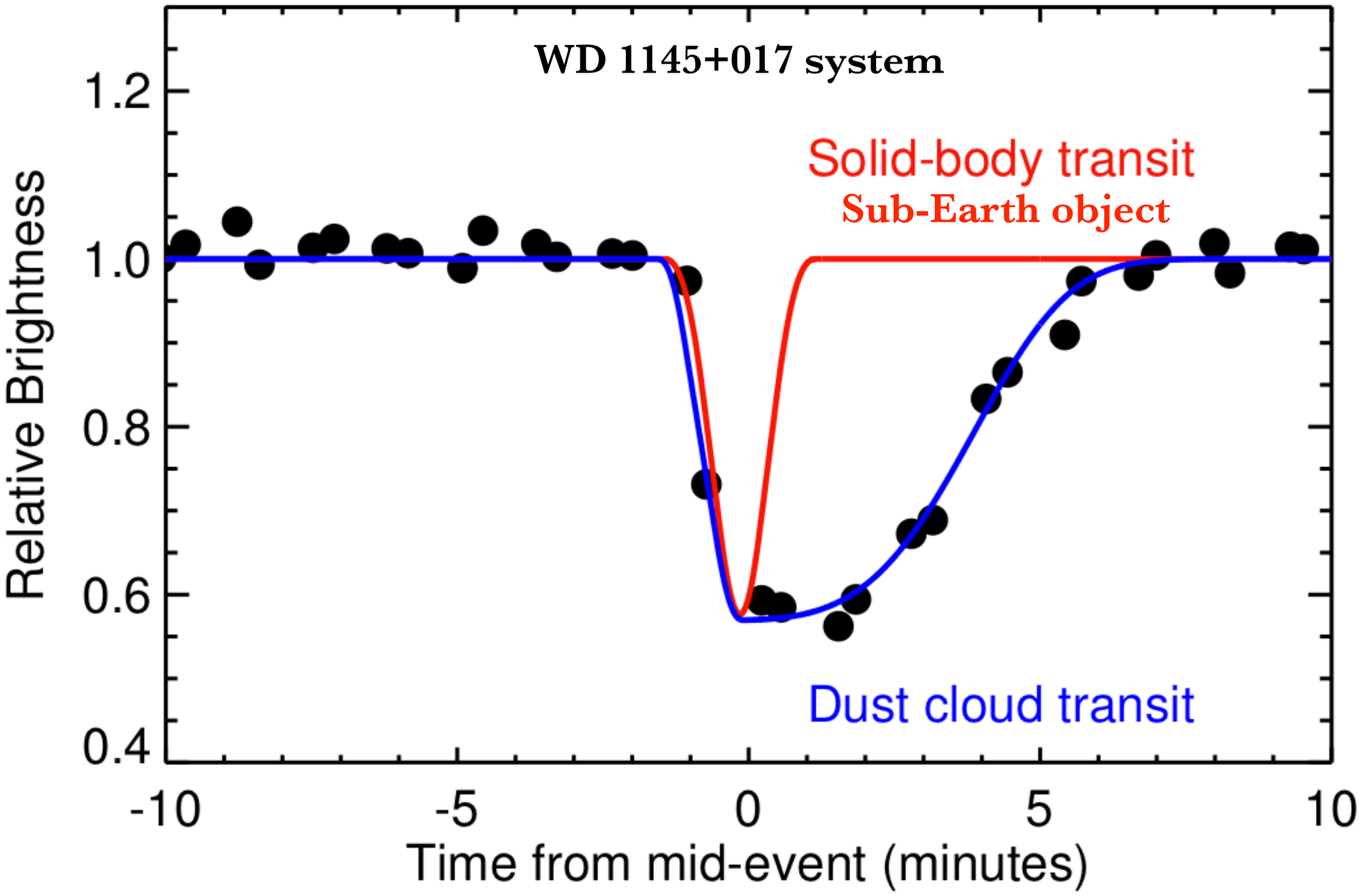
SDSS J1228+1040

A planetesimal orbiting within the debris disc around a white dwarf star

Christopher J. Manser[1]*, Boris T. Gänsicke[1,2], Siegfried Eggl[3], Mark Hollands[1], Paula Izquierdo[4,5], Detlev Koester[6], John D. Landstreet[7,8], Wladimir Lyra[3,9], Thomas R. Marsh[1], Farzana Meru[1], Alexander J. Mustill[10], Pablo Rodríguez-Gil[4,5], Odette Toloza[1], Dimitri Veras[1,2], David J. Wilson[1,11], Matthew R. Burleigh[12], Melvyn B. Davies[10], Jay Farihi[13], Nicola Gentile Fusillo[1], Domitilla de Martino[14], Steven G. Parsons[15], Andreas Quirrenbach[16], Roberto Raddi[17], Sabine Reffert[16], Melania Del Santo[18], Matthias R. Schreiber[19,20], Roberto Silvotti[21], Silvia Toonen[22]†, Eva Villaver[23], Mark Wyatt[24], Siyi Xu[25], Simon Portegies Zwart[26]

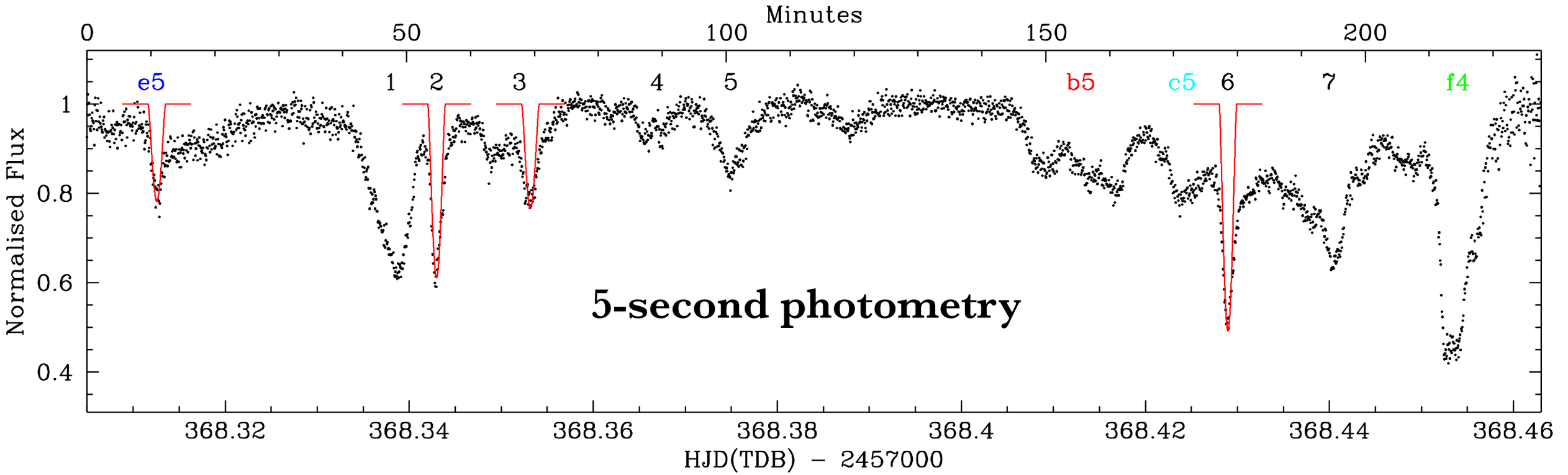
Disintegrating asteroid

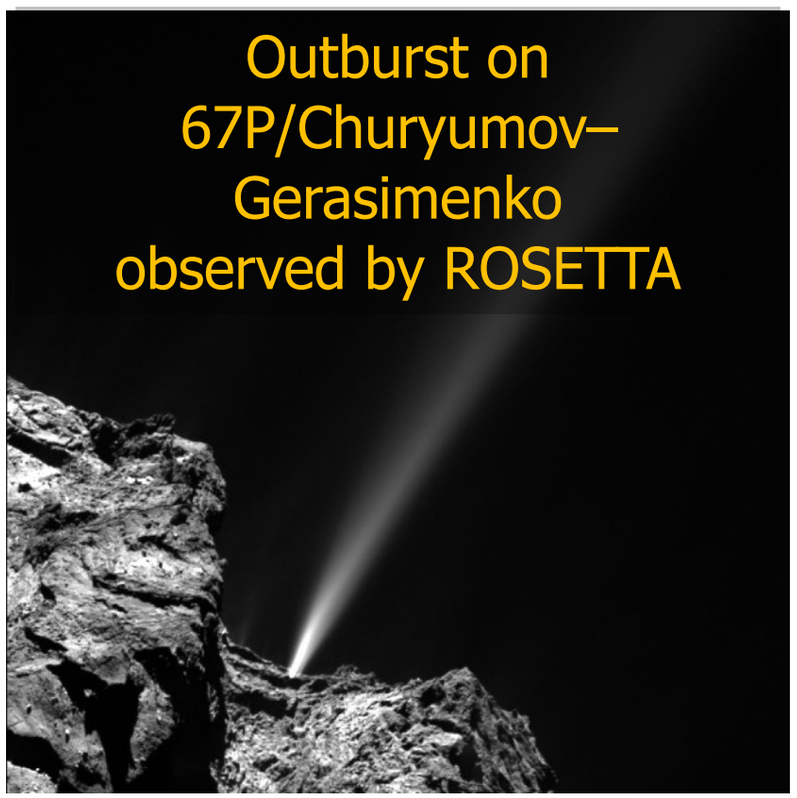
Vanderburg, Johnson, Rappaport et al. (Nature, 2015)



WD 1145+017 transits

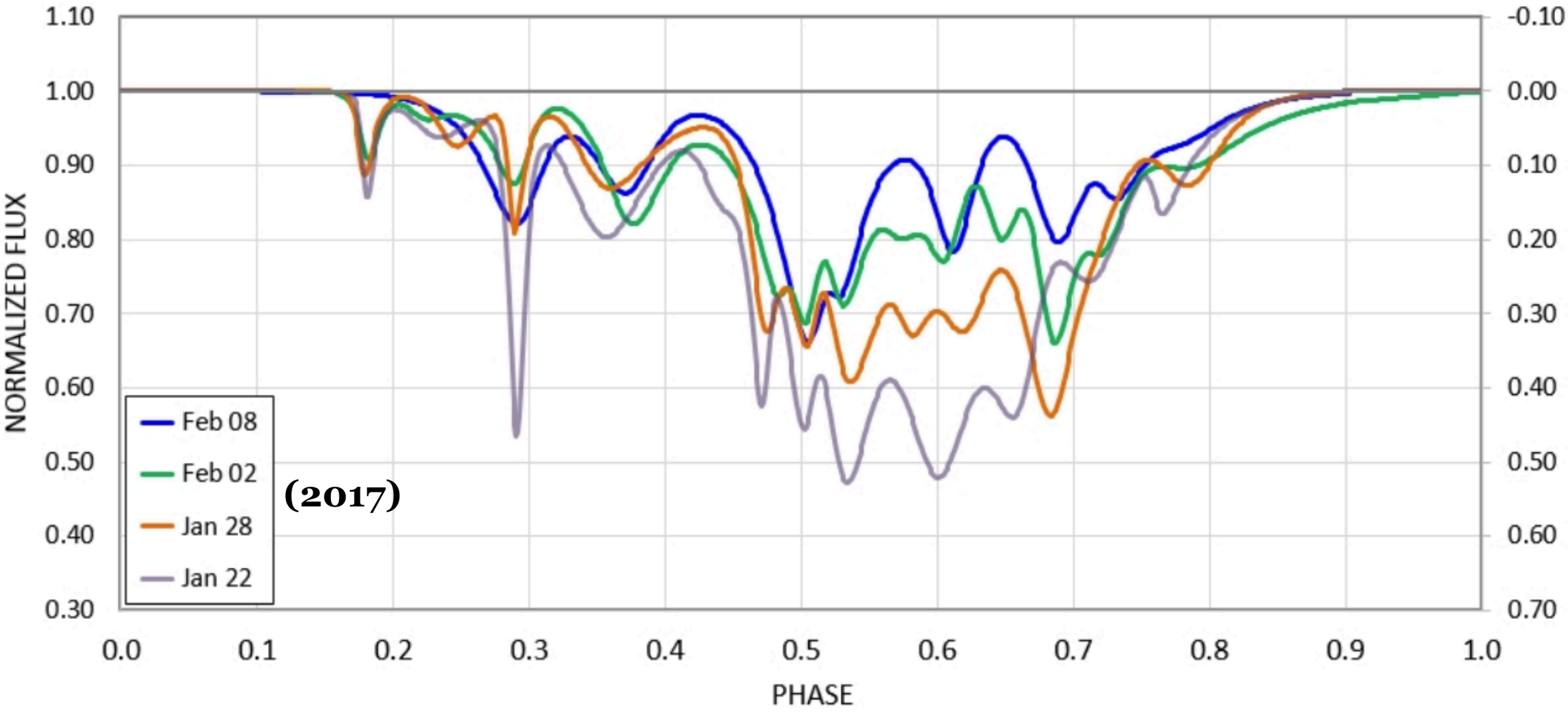
Gänsicke, Aungwerojwit, Marsh et al. (2016)





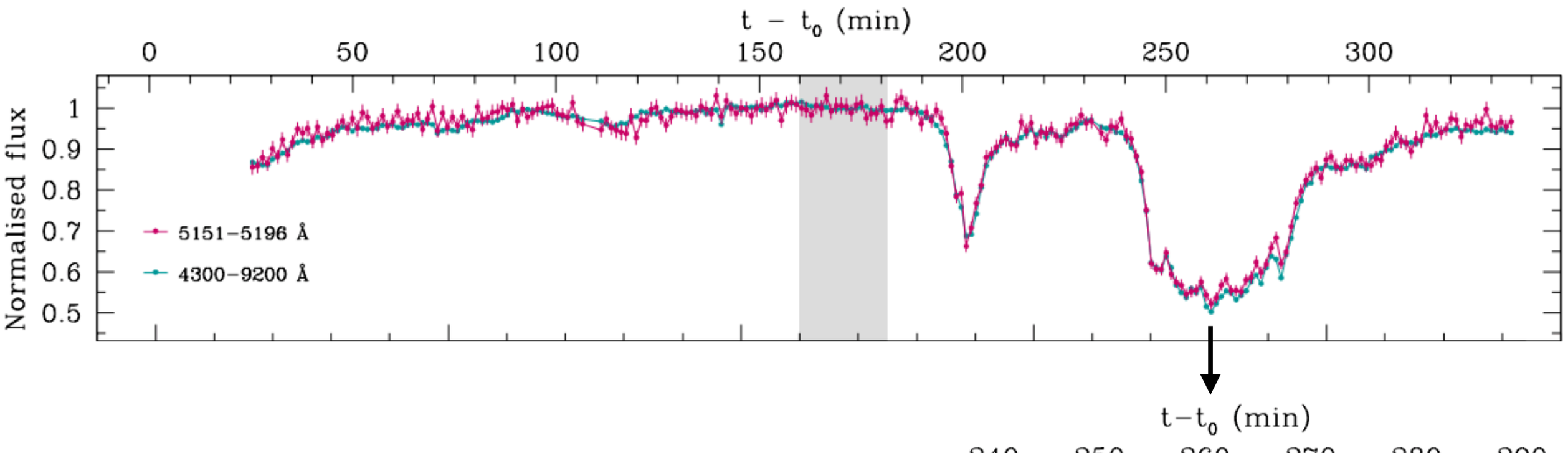
WD 1145+017 transits

Rappaport, Gary, Vanderburg et al. (2018)

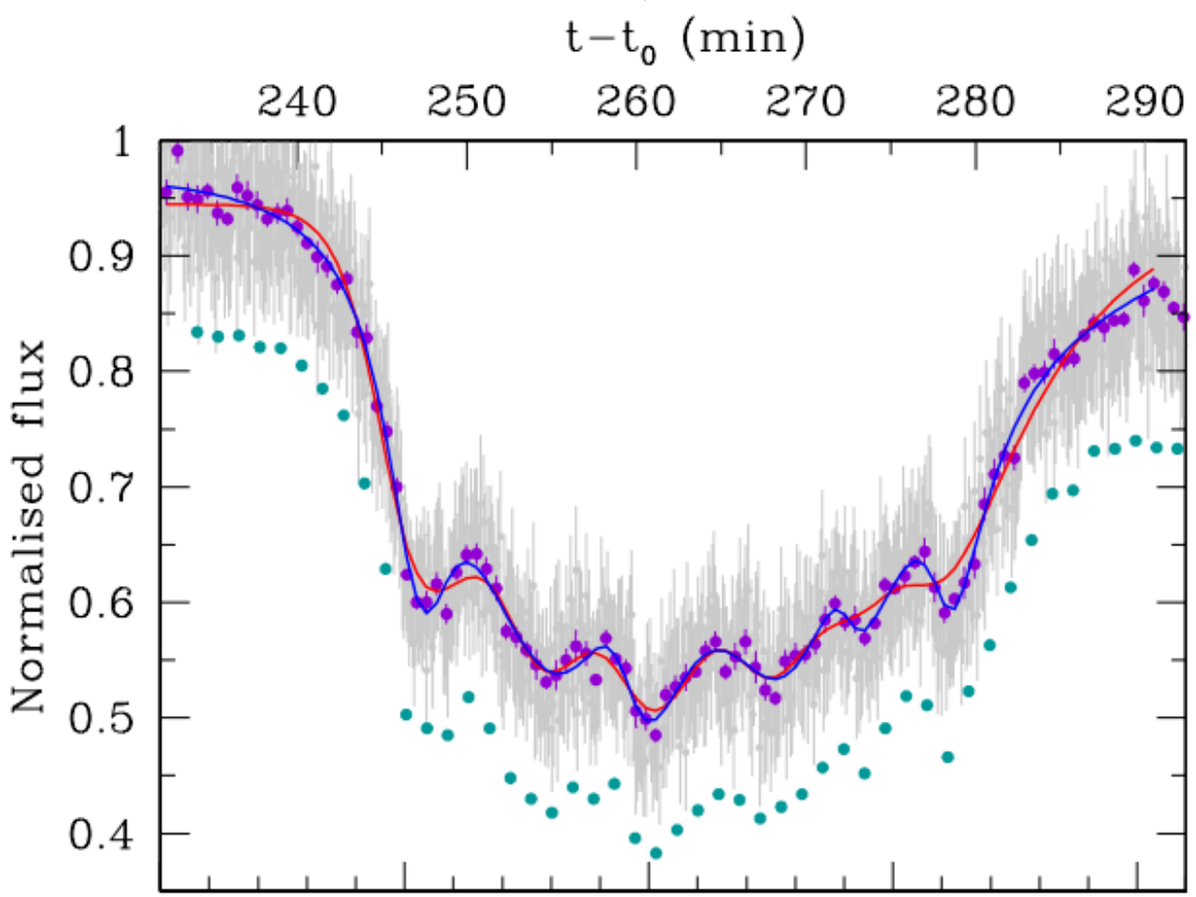


WD 1145+017 transits

Izquierdo, Rodríguez-Gil, Gänsicke et al. (2018)



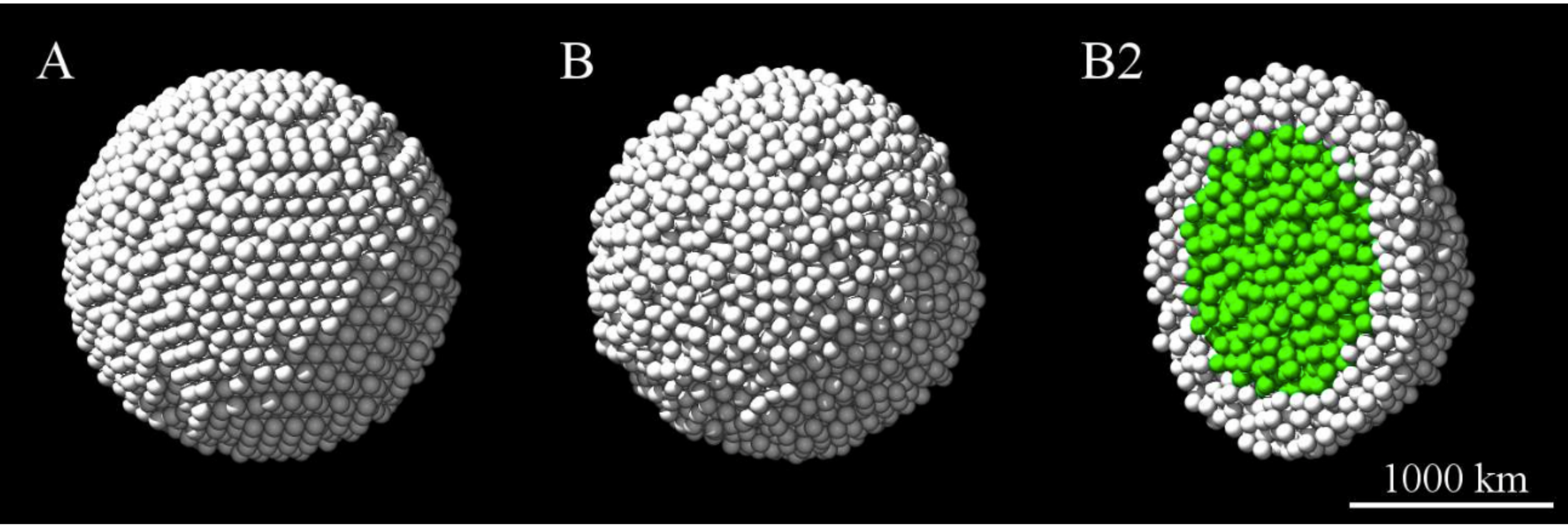
overlapping dust clouds?



Rubble pile representations

Veras, Carter, Leinhardt, Gänsicke (2017)

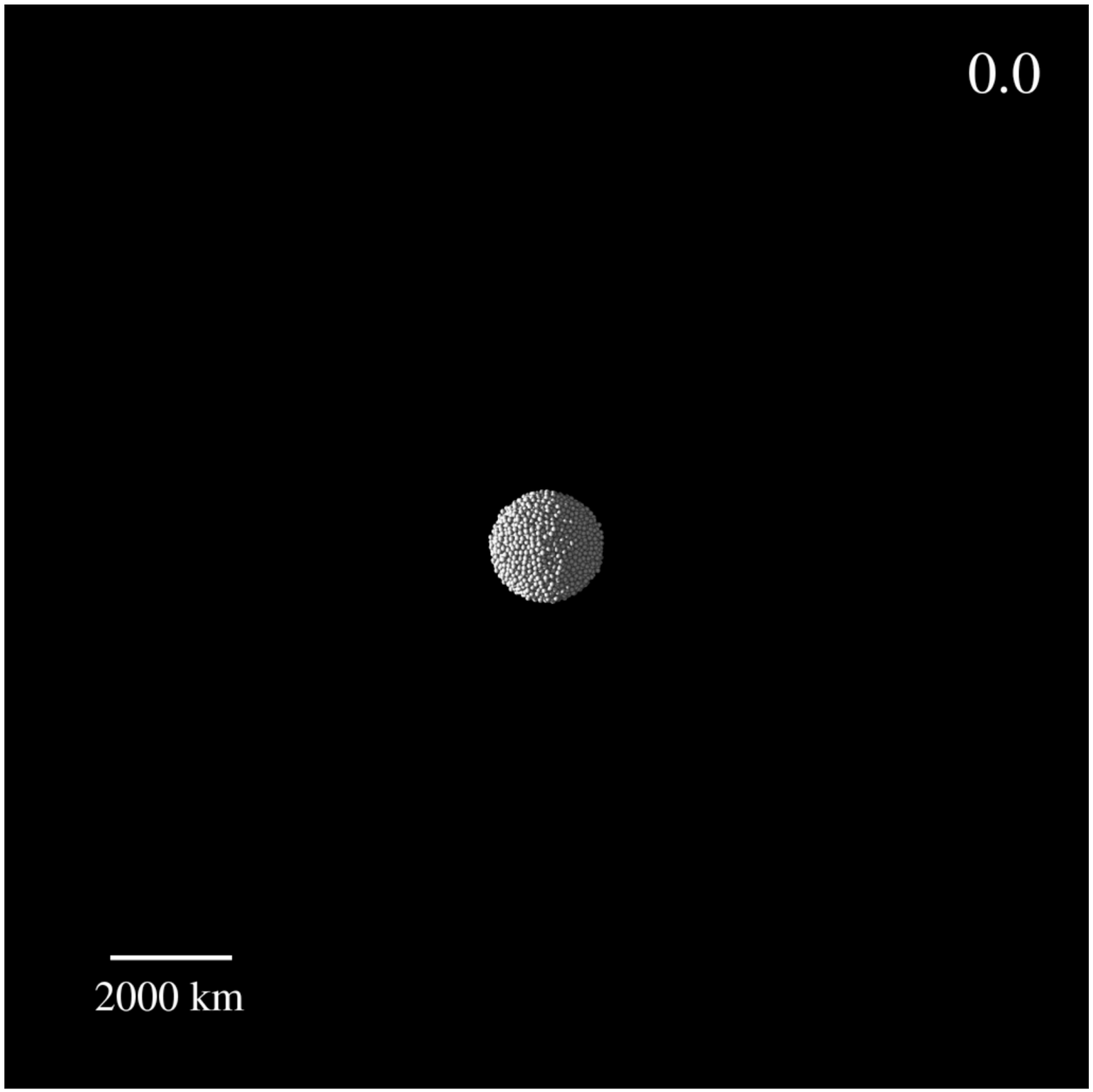
Homogeneous	**Homogeneous**	**Differentiated**
Hexagonal Closest Packing	Random Packing	Core + Mantle



Differentiated: Total disruption

Veras, Carter, Leinhardt, Gänsicke (2017)

differentiated
$\rho = 3.5$ g/cm^3
$e = 0.1$
$P = 4.499$ h



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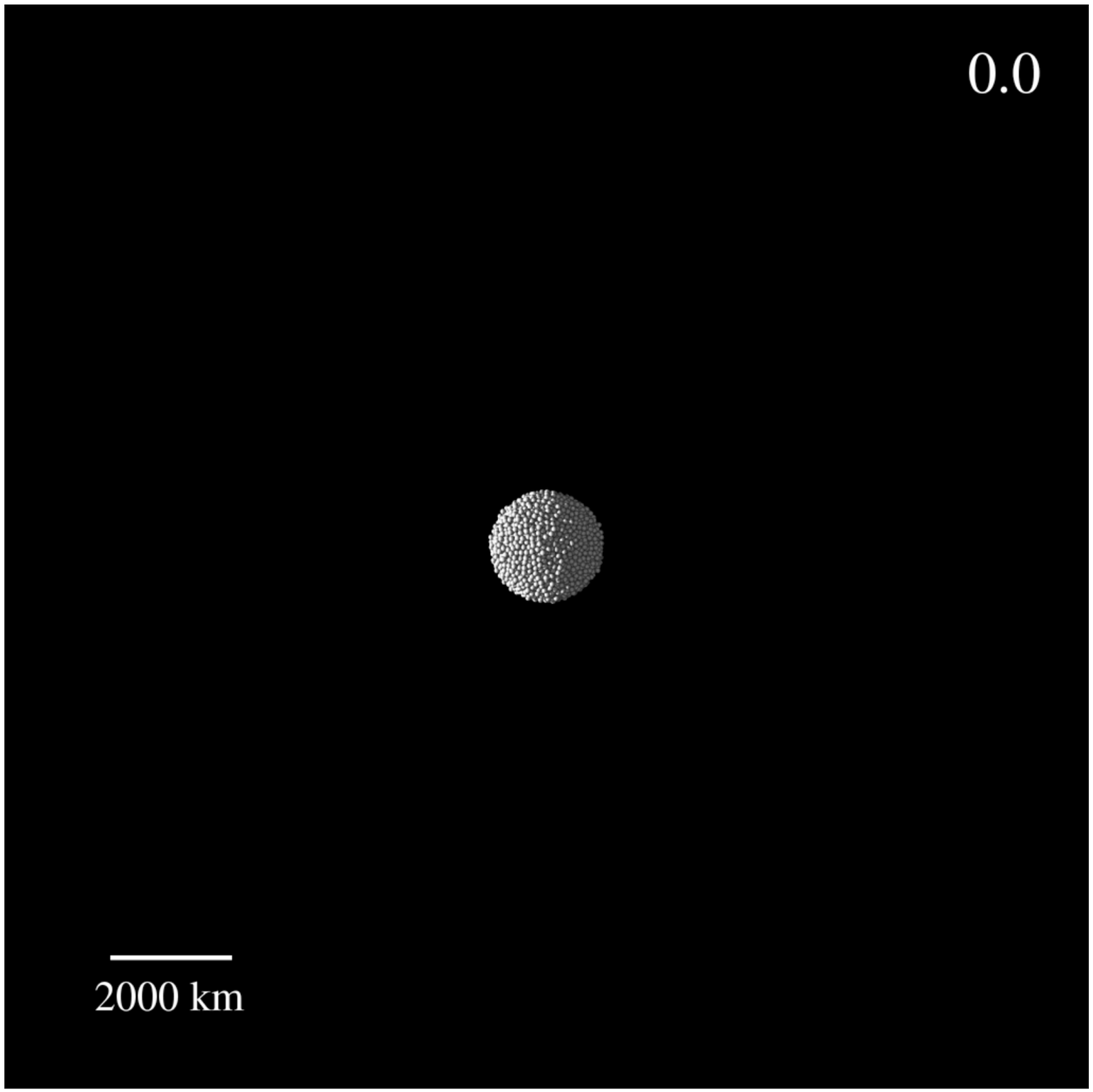

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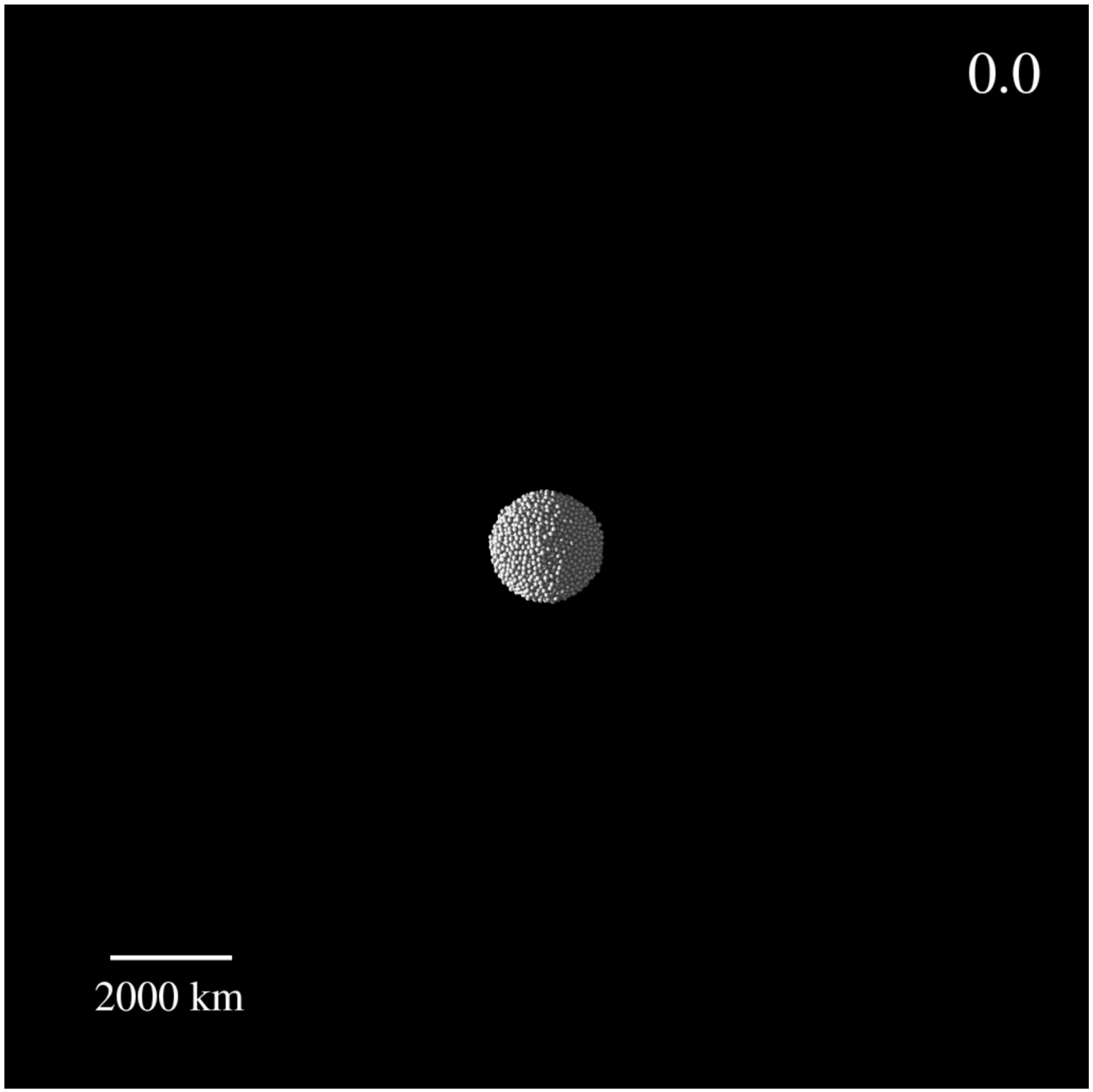

Differentiated: Partial disruption

Veras, Carter, Leinhardt, Gänsicke (2017)

differentiated
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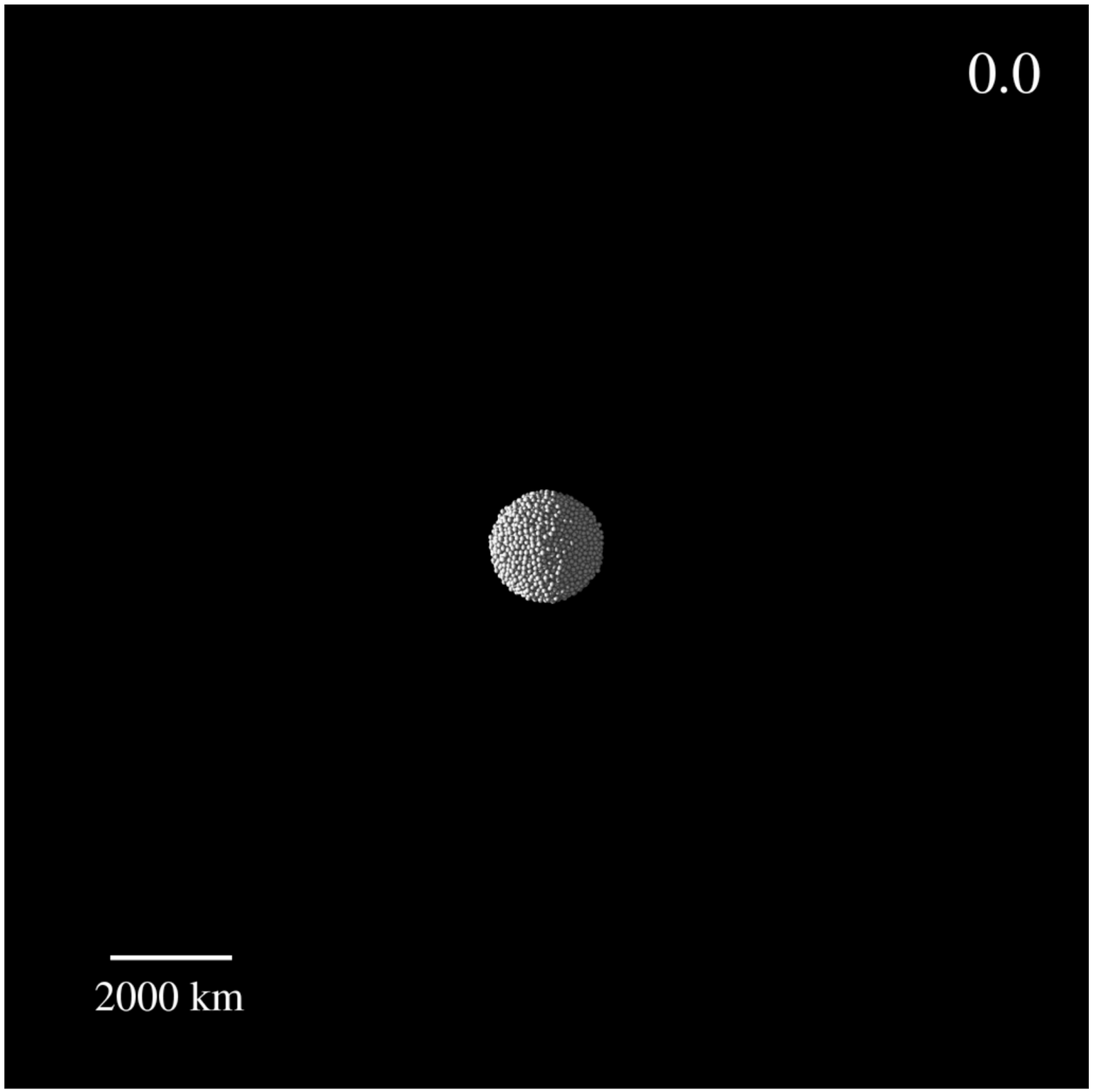
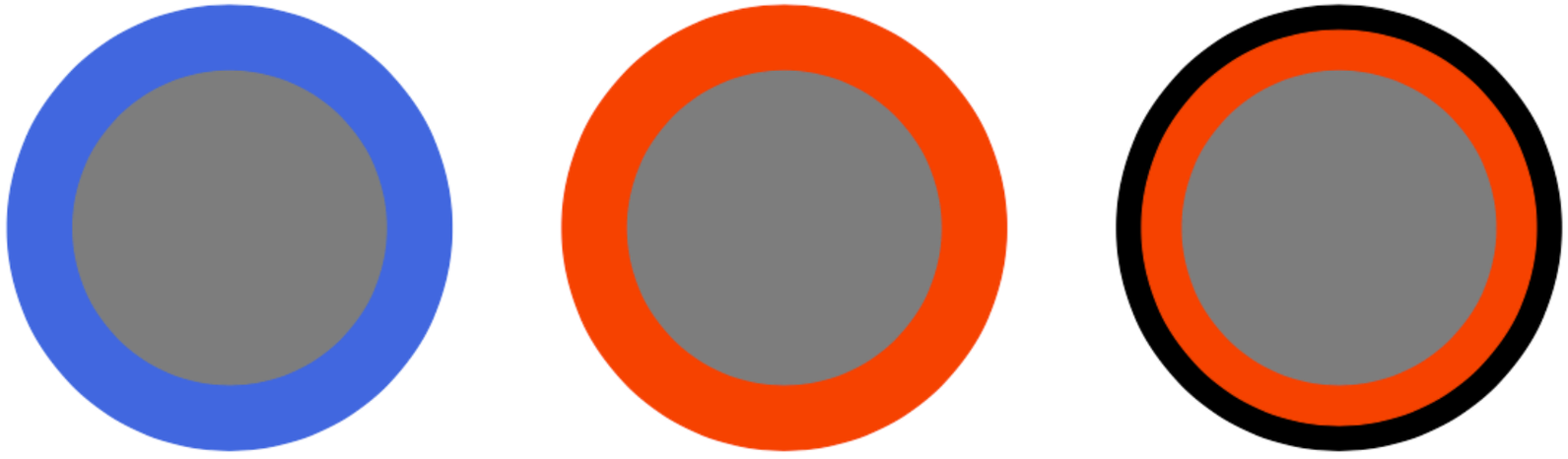
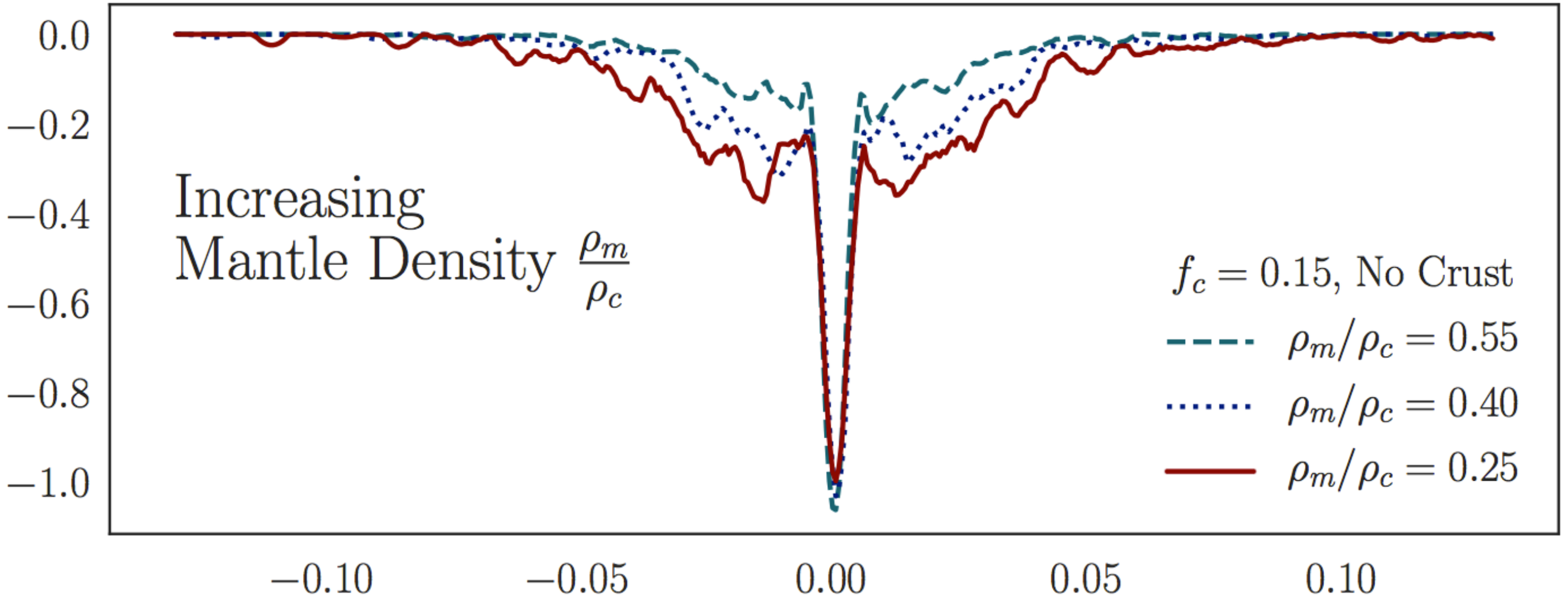


Constraining internal structure

Duvvuri, Redfield & Veras (Submitted)

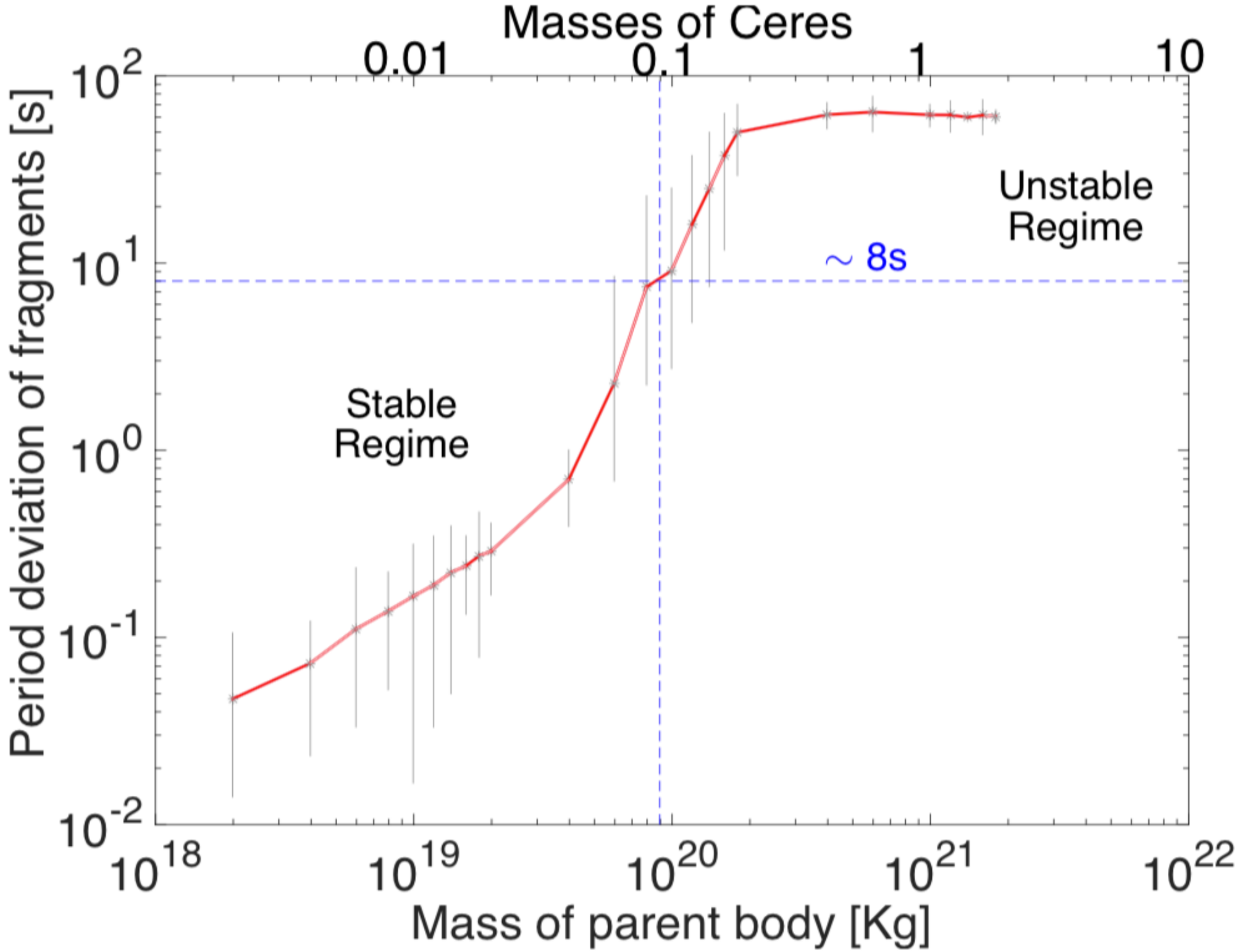


Girish Duvvuri



Constraining mass

Gurri, Veras & Gänsicke (2017)



nature

WD 1145+017

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Andrew Vanderburg[1], John Asher Johnson[1], Saul Rappaport[2], Allyson Bieryla[1], Jonathan Irwin[1], John Arban Lewis[1], David Kipping[1,3], Warren R. Brown[1], Patrick Dufour[4], David R. Ciardi[5], Ruth Angus[1,6], Laura Schaefer[1], David W. Latham[1] David Charbonneau[1], Charles Beichman[5], Jason Eastman[1], Nate McCrady[7], Robert A. Wittenmyer[8] & Jason T. Wright[9]

Science

SDSS J1228+1040

A planetesimal orbiting within the debris disc around a white dwarf star

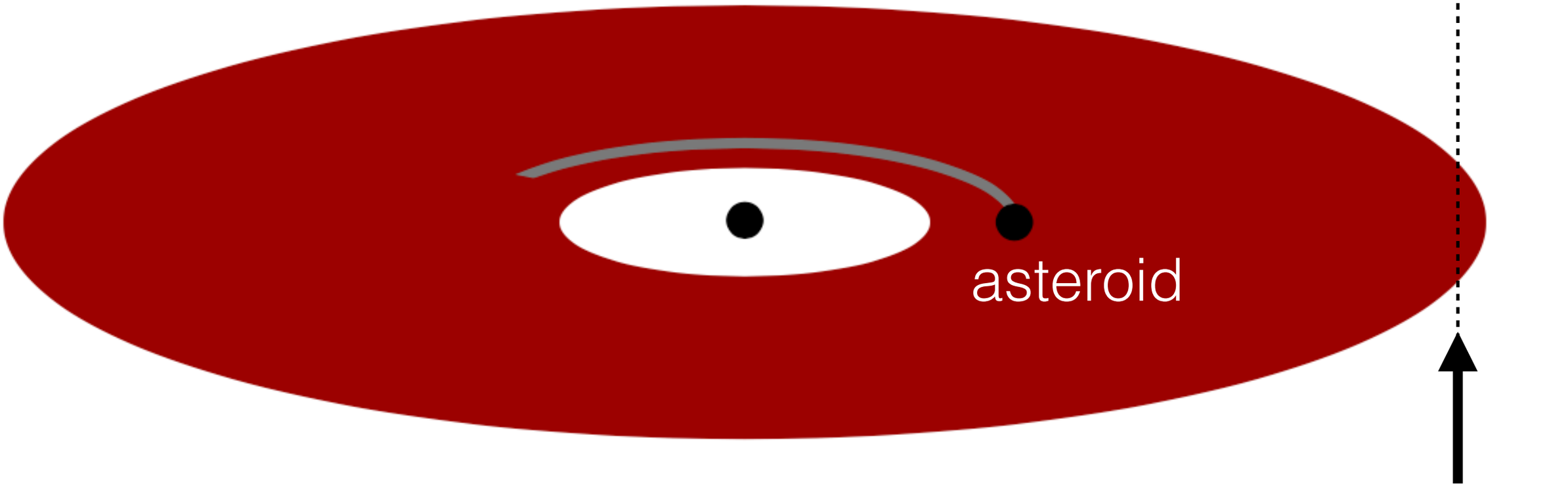
Christopher J. Manser[1]*, Boris T. Gänsicke[1,2], Siegfried Eggl[3], Mark Hollands[1], Paula Izquierdo[4,5], Detlev Koester[6], John D. Landstreet[7,8], Wladimir Lyra[3,9], Thomas R. Marsh[1], Farzana Meru[1], Alexander J. Mustill[10], Pablo Rodríguez-Gil[4,5], Odette Toloza[1], Dimitri Veras[1,2], David J. Wilson[1,11], Matthew R. Burleigh[12], Melvyn B. Davies[10], Jay Farihi[13], Nicola Gentile Fusillo[1], Domitilla de Martino[14], Steven G. Parsons[15], Andreas Quirrenbach[16], Roberto Raddi[17], Sabine Reffert[16], Melania Del Santo[18], Matthias R. Schreiber[19,20], Roberto Silvotti[21], Silvia Toonen[22]†, Eva Villaver[23], Mark Wyatt[24], Siyi Xu[25], Simon Portegies Zwart[26]

Embedded asteroid

Manser, Gänsicke, Eggl et al. (Science, 2019)

SDSS J1228+1040 system

Our view at $i = 73°$



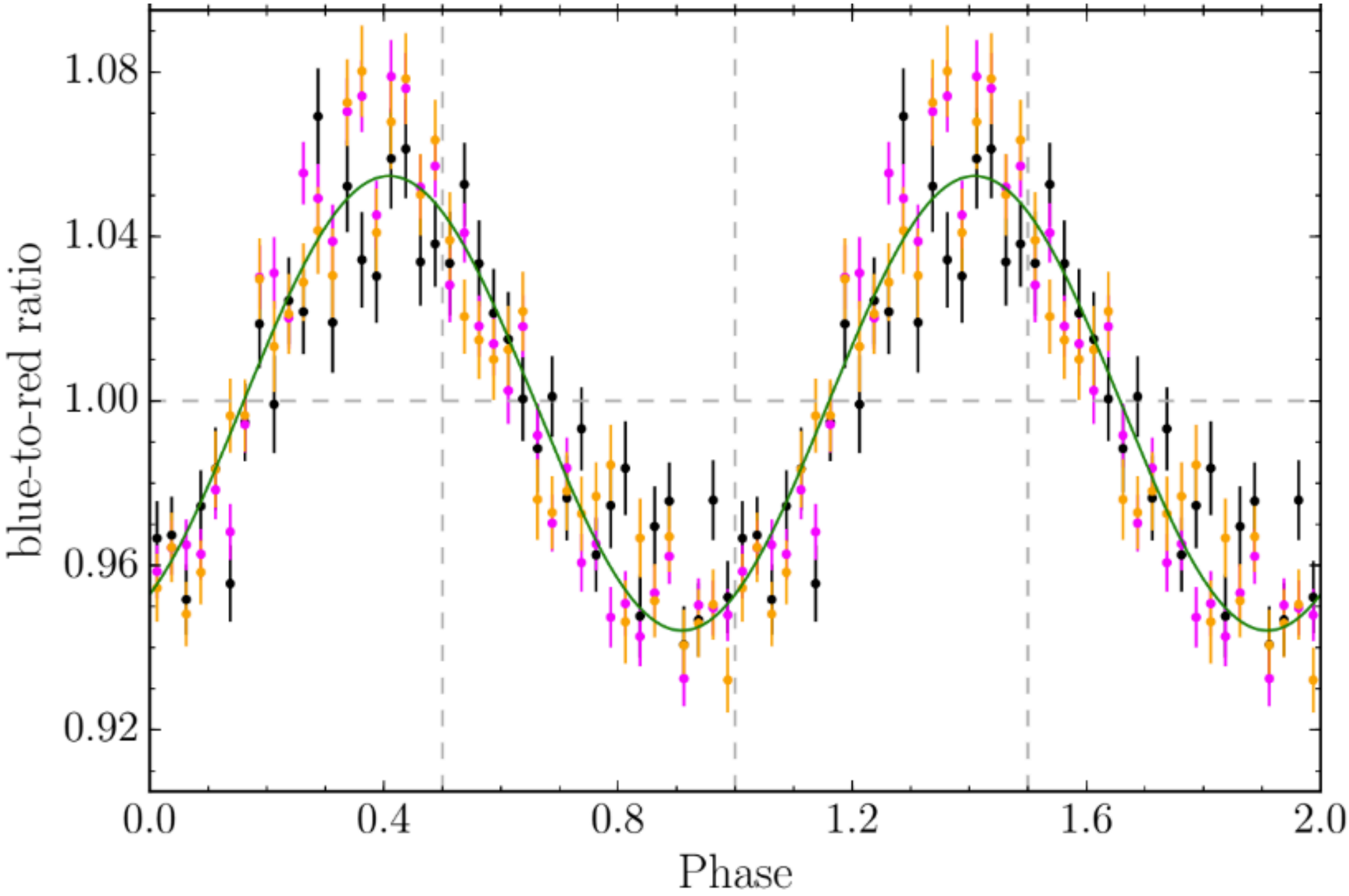
—Orbital period = 123 min

—High internal strength

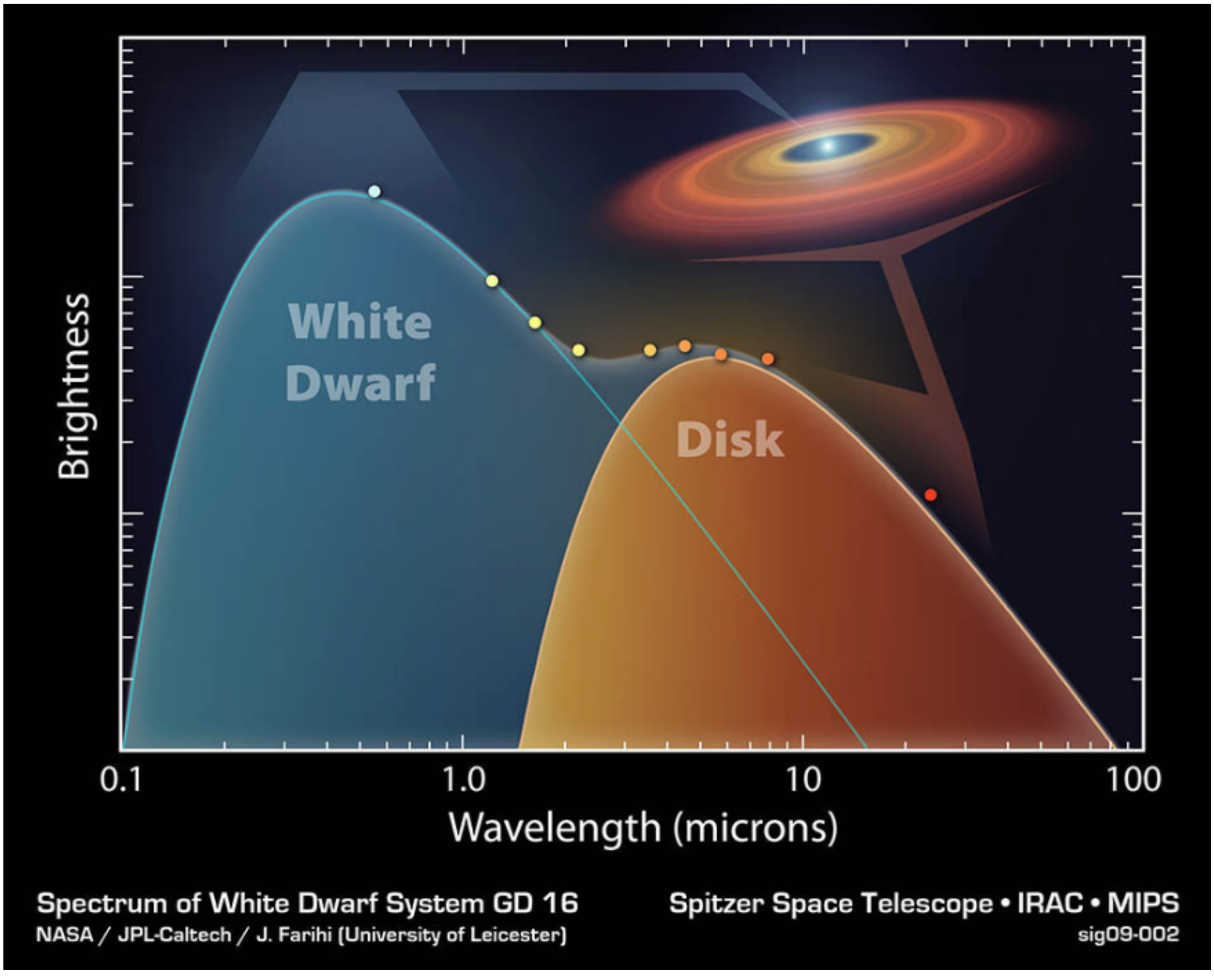
—Moderately eccentric orbit

Spectroscopic variations in Ca II

Manser, Gänsicke, Eggl et al. (Science, 2019)

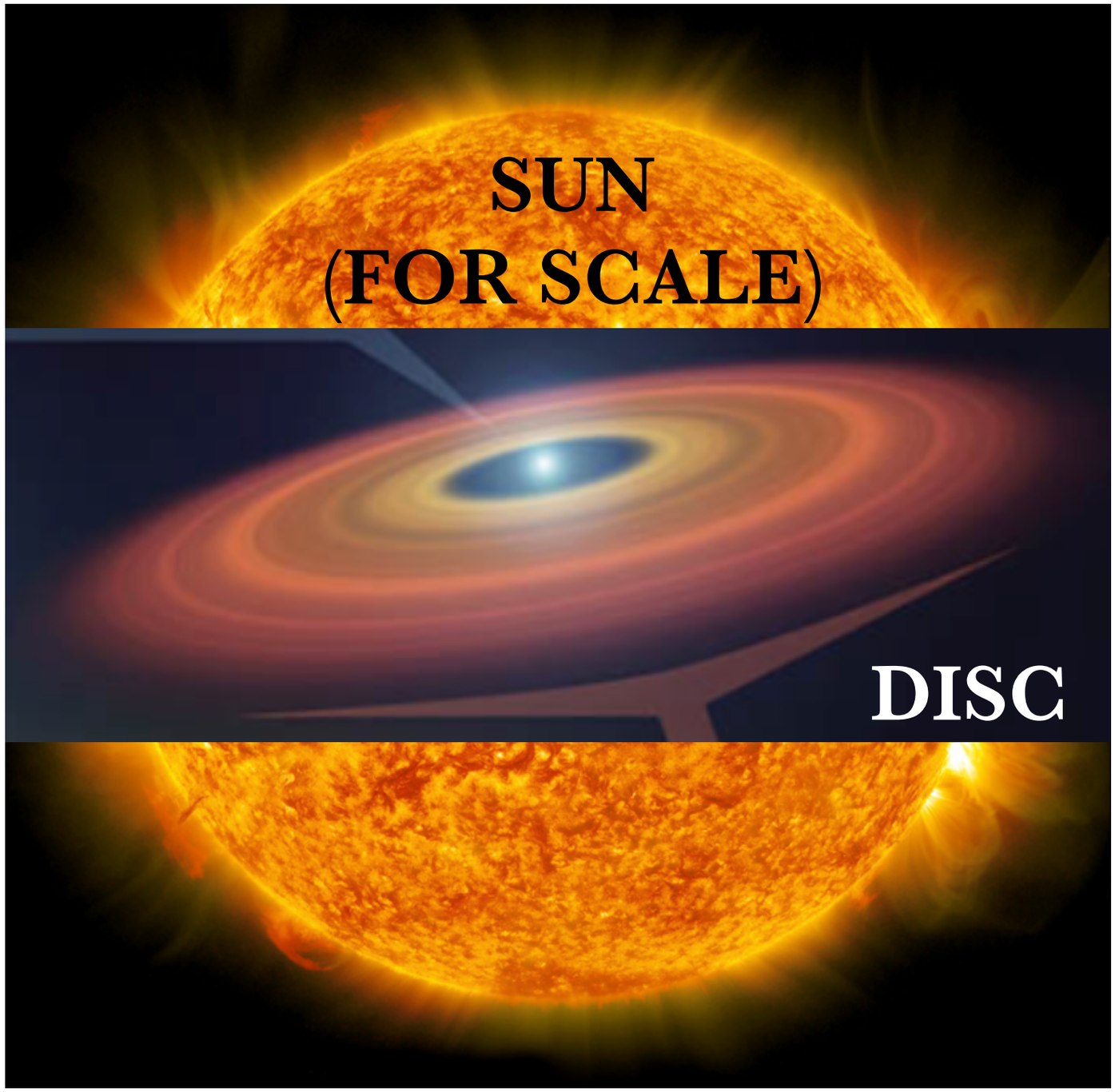


White dwarf debris discs



Size of discs

VERY COMPACT!



~0.6 -1.2 Solar radii

Frequency of discs

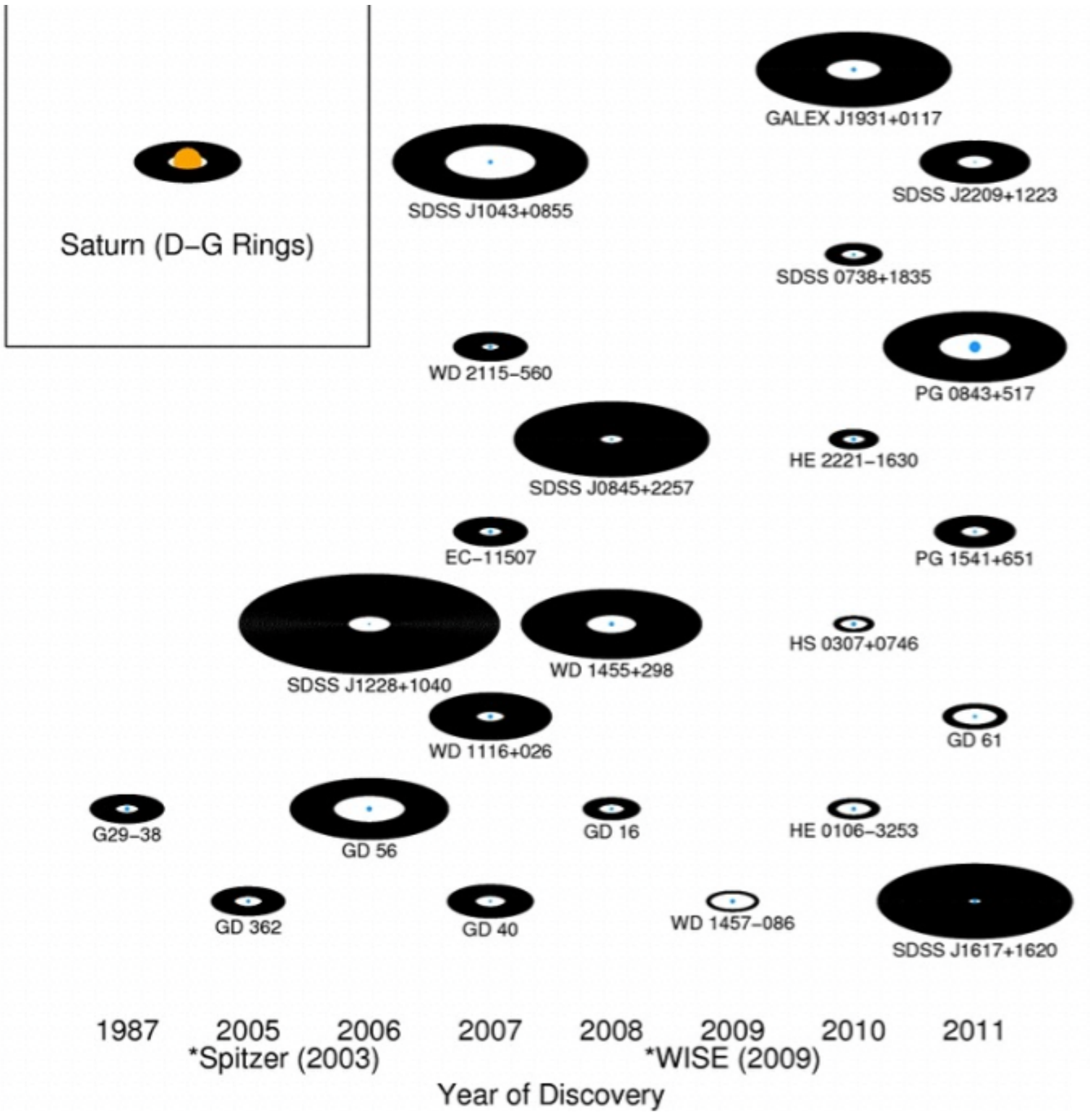


Illustration courtesy of John Debes

→ **? %**

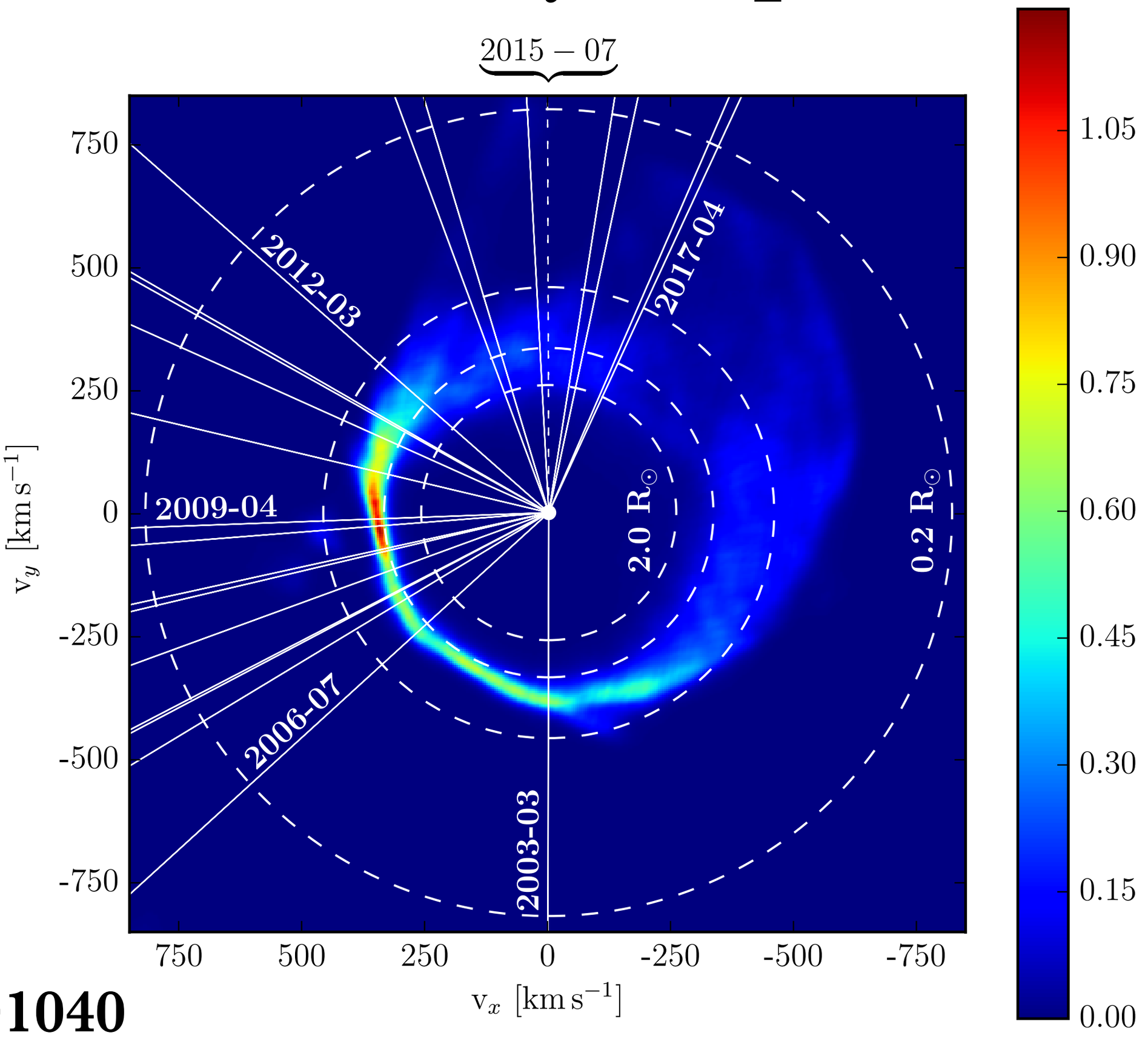
→ **Total: >40**

→ **Every disc orbits a polluted WD**

For disc review, see Farihi (2016)

Disc velocity map

Manser et al. (2016)

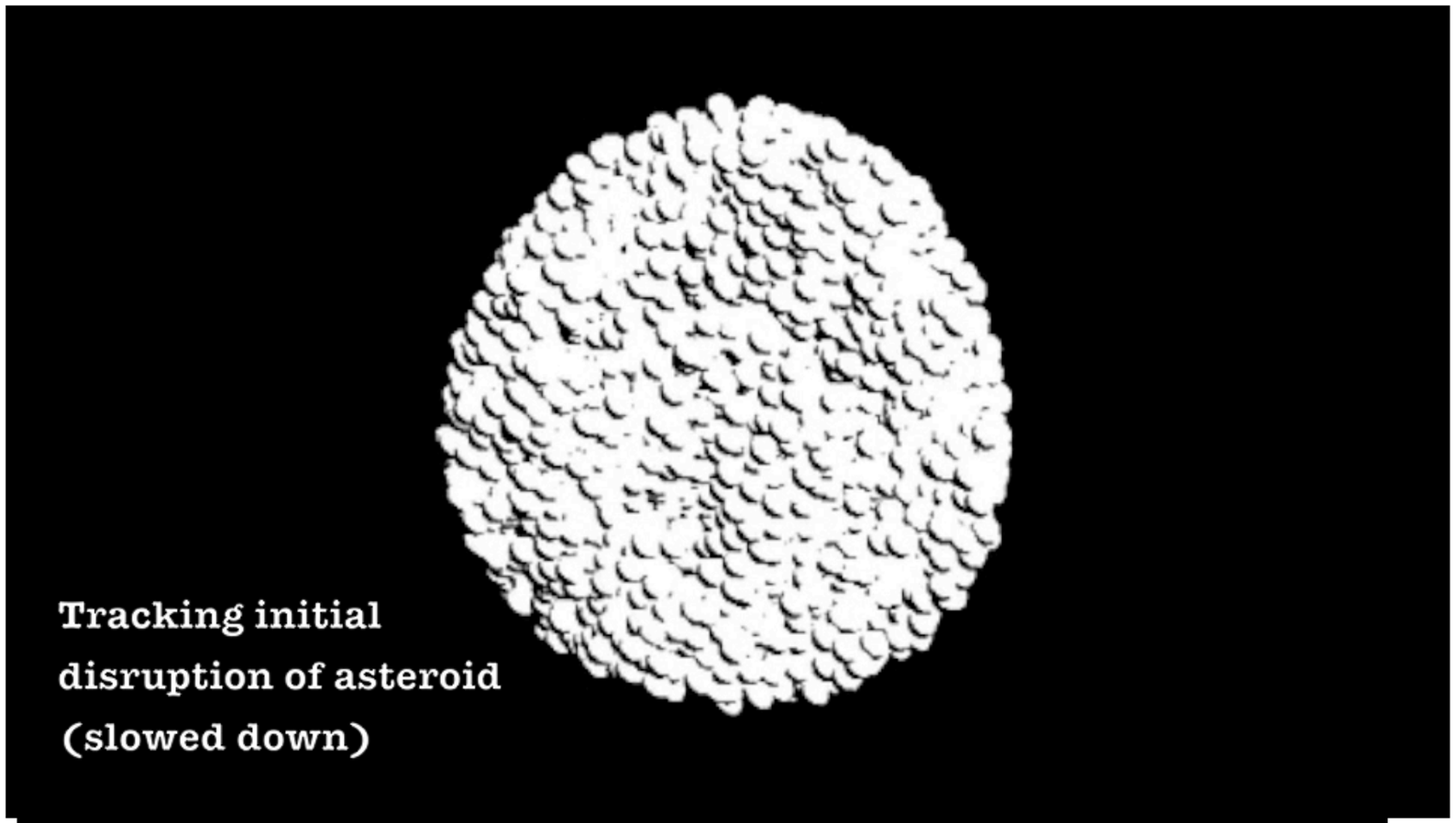


SDSS J1228+1040

Formation of white dwarf discs

Veras, Leinhardt, Bonsor, Gänsicke (2014)

Disruption

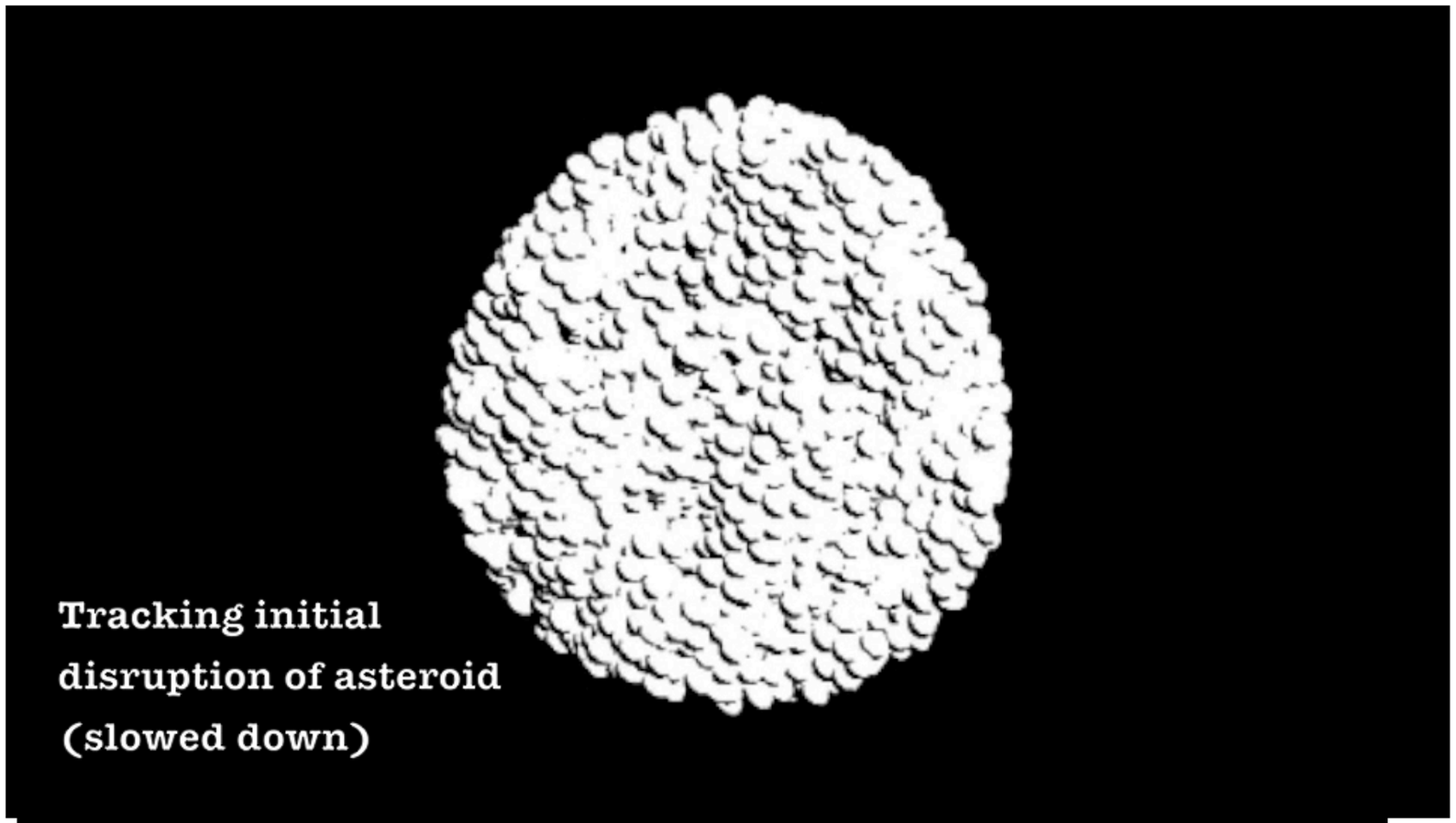


Spreading

Formation of white dwarf discs

Veras, Leinhardt, Bonsor, Gänsicke (2014)

Disruption

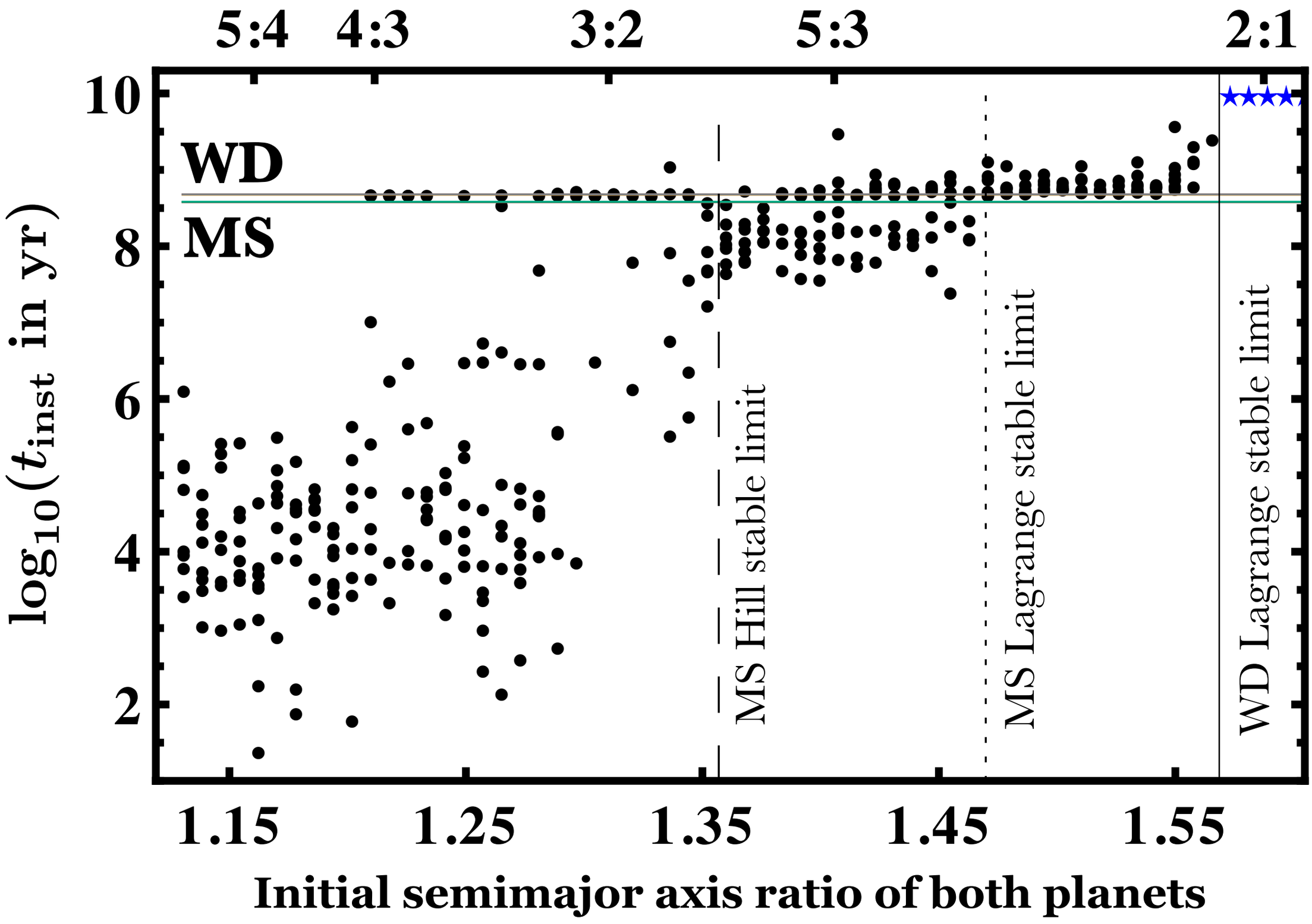


Spreading

Stability boundary changes

—From mass loss

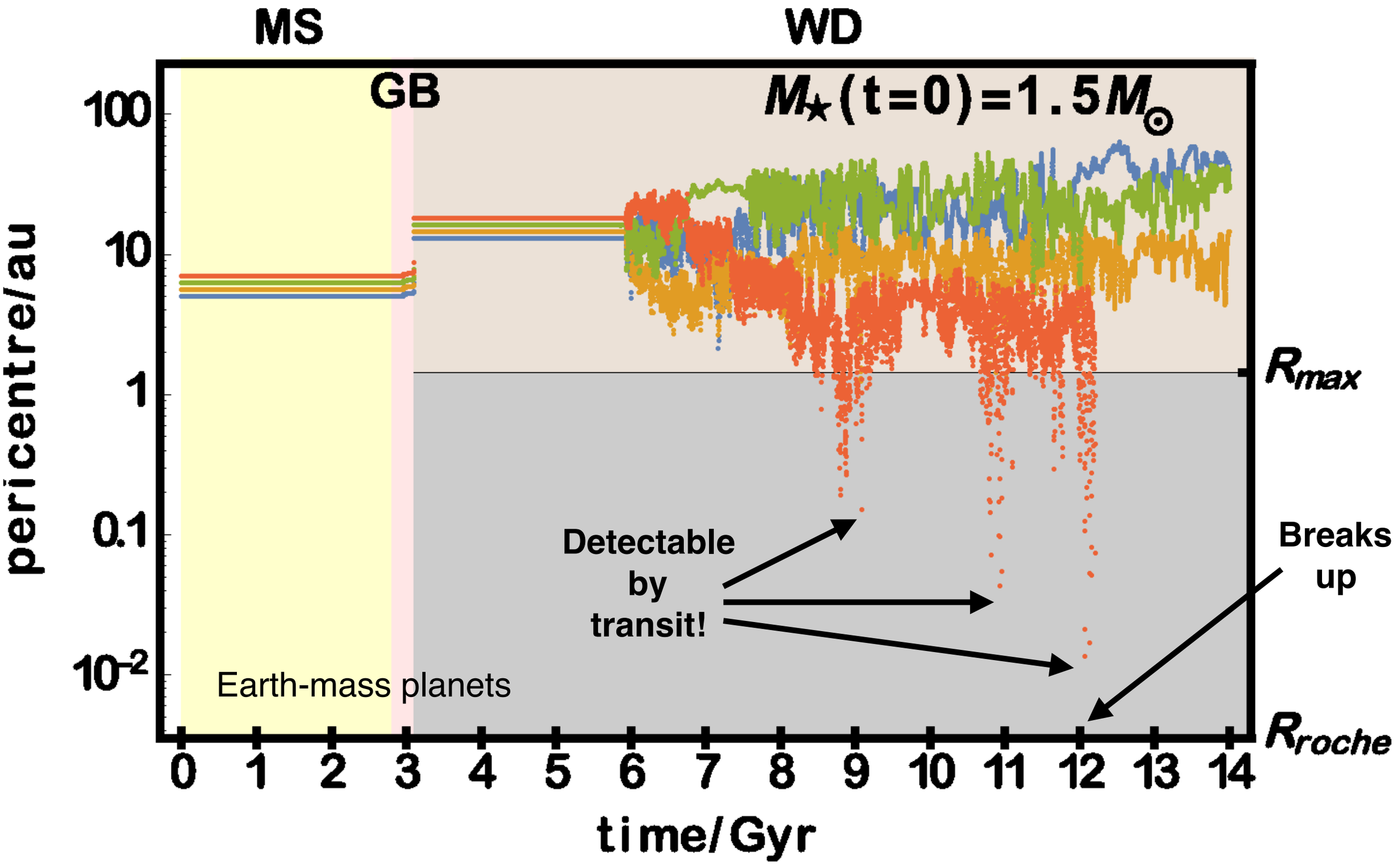
Veras, Mustill, Bonsor, Wyatt (2013)



Full-lifetime simulations

—Radial incursions of planets alone

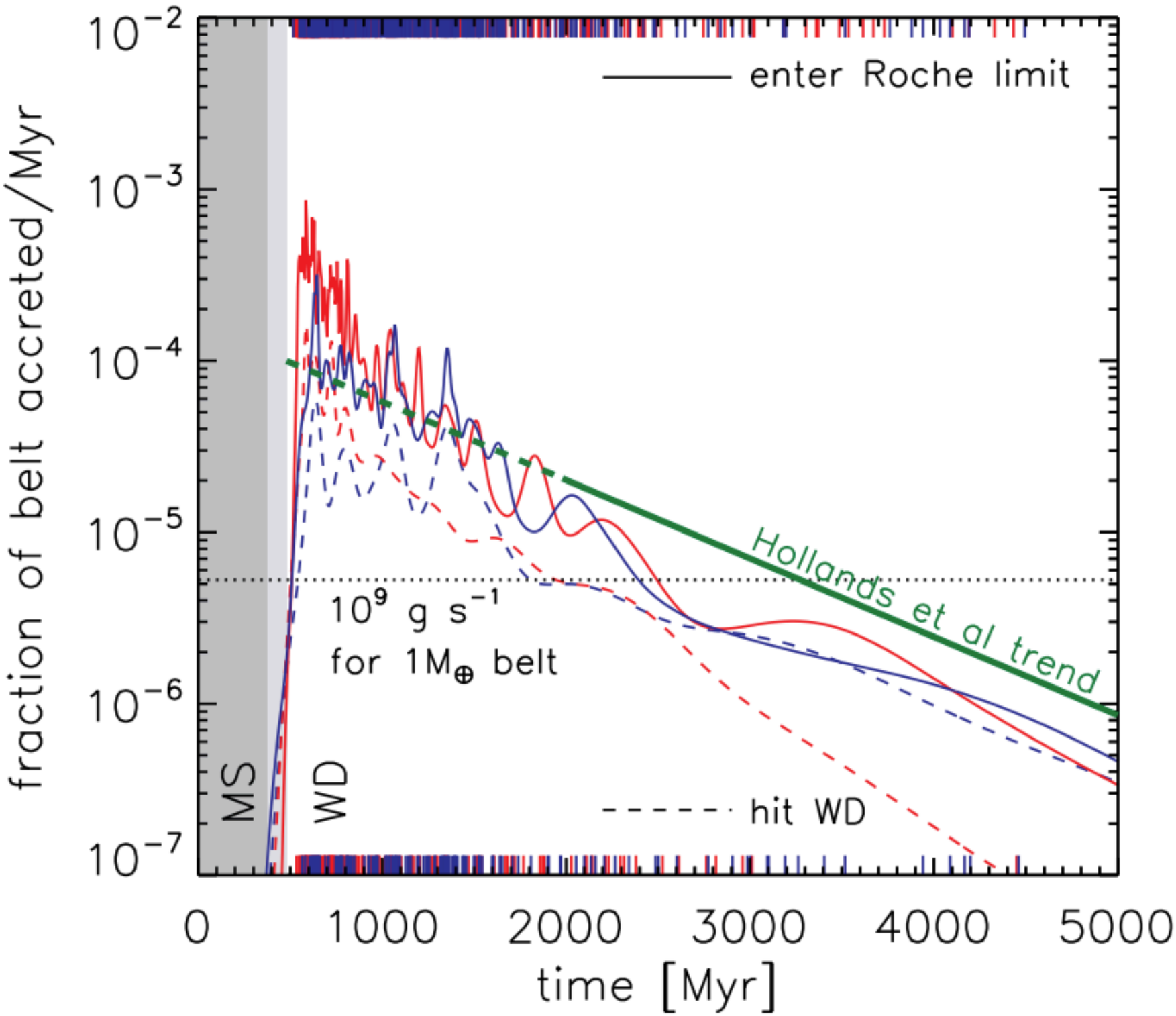
Veras & Gänsicke (2015)



Full-lifetime simulations

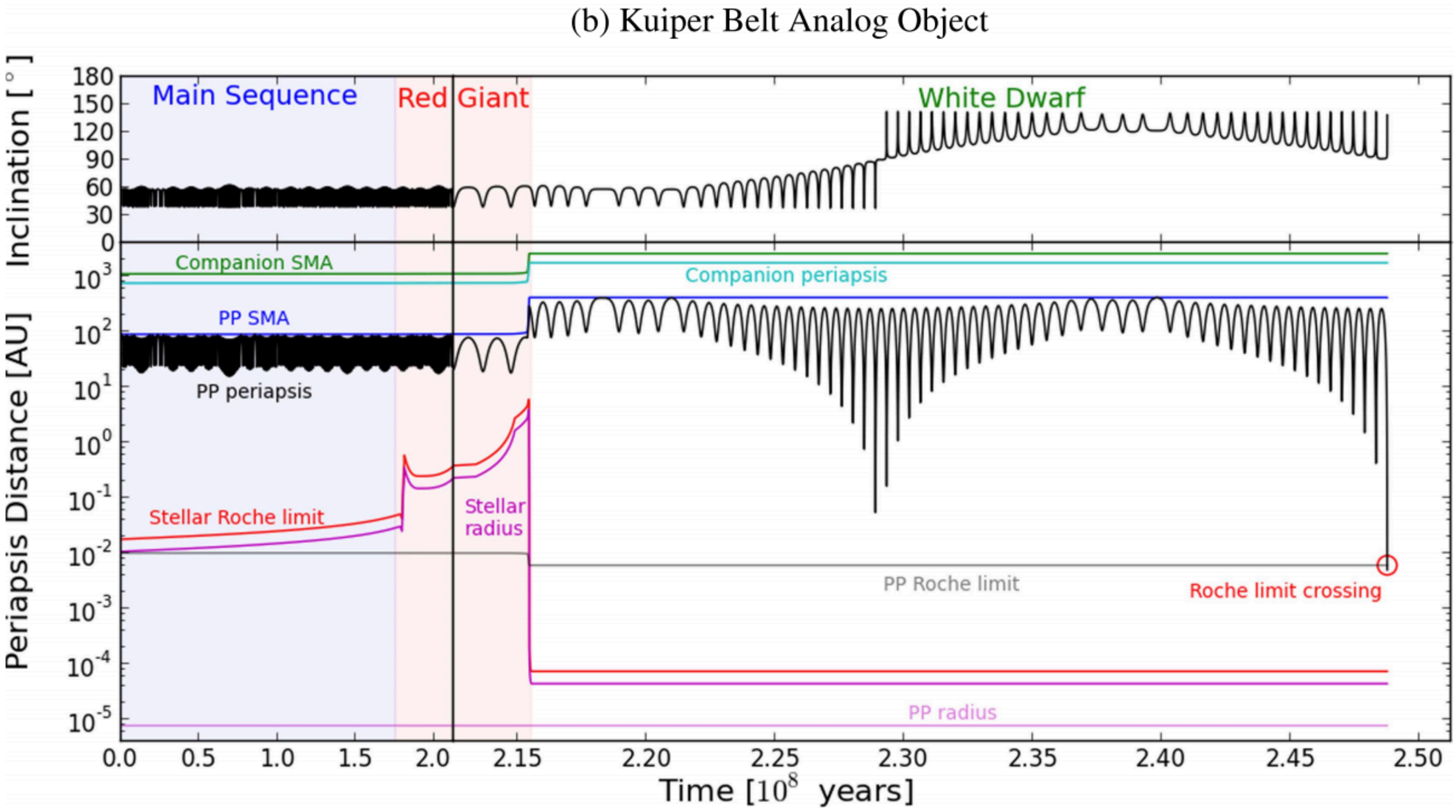
—Planets and asteroids together

Mustill, Villaver, Veras et al. (2018)



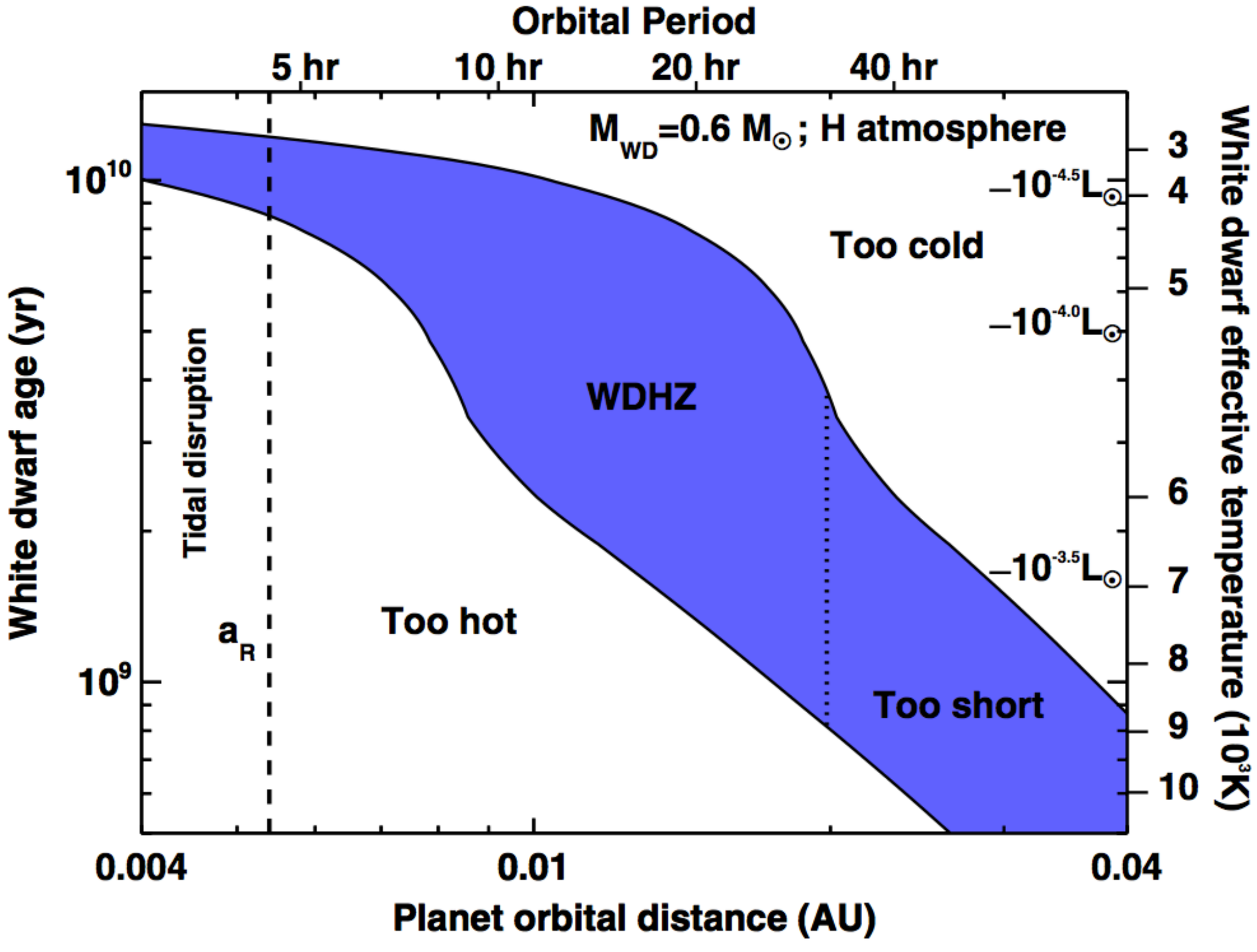
Smadar's talk in context
—Binary-induced scattering

Stephan, Naoz et al. (2017, 2018)



Habitable zone for WD planets

Agol (2011)



Resources

Invited Review Articles

—WD+GB theory: **Veras** (2016, *Royal Society Open Science, 3, 150571*)

—WD discs: **Farihi** (2016, *New Astronomy Reviews, 71, 9-34*)

—WD chemistry: **Jura & Young** (2014, *Annual Review of Earth and Planetary Sciences, 42, 45-67*)

Book Chapters

—WD systems: **Bonsor & Xu, in *Formation, Evolution and Dynamics of Young Solar Systems***

—WD 1145+017: **Vanderburg & Rappaport, in *Handbook of Extrasolar Planets***

—WD chemistry: **Zuckerman & Young, in *Handbook of Extrasolar Planets***