Evolved (post-RGB) planetary systems

Roberto Silvotti
INAF - Osservatorio Astrofisico di Torino

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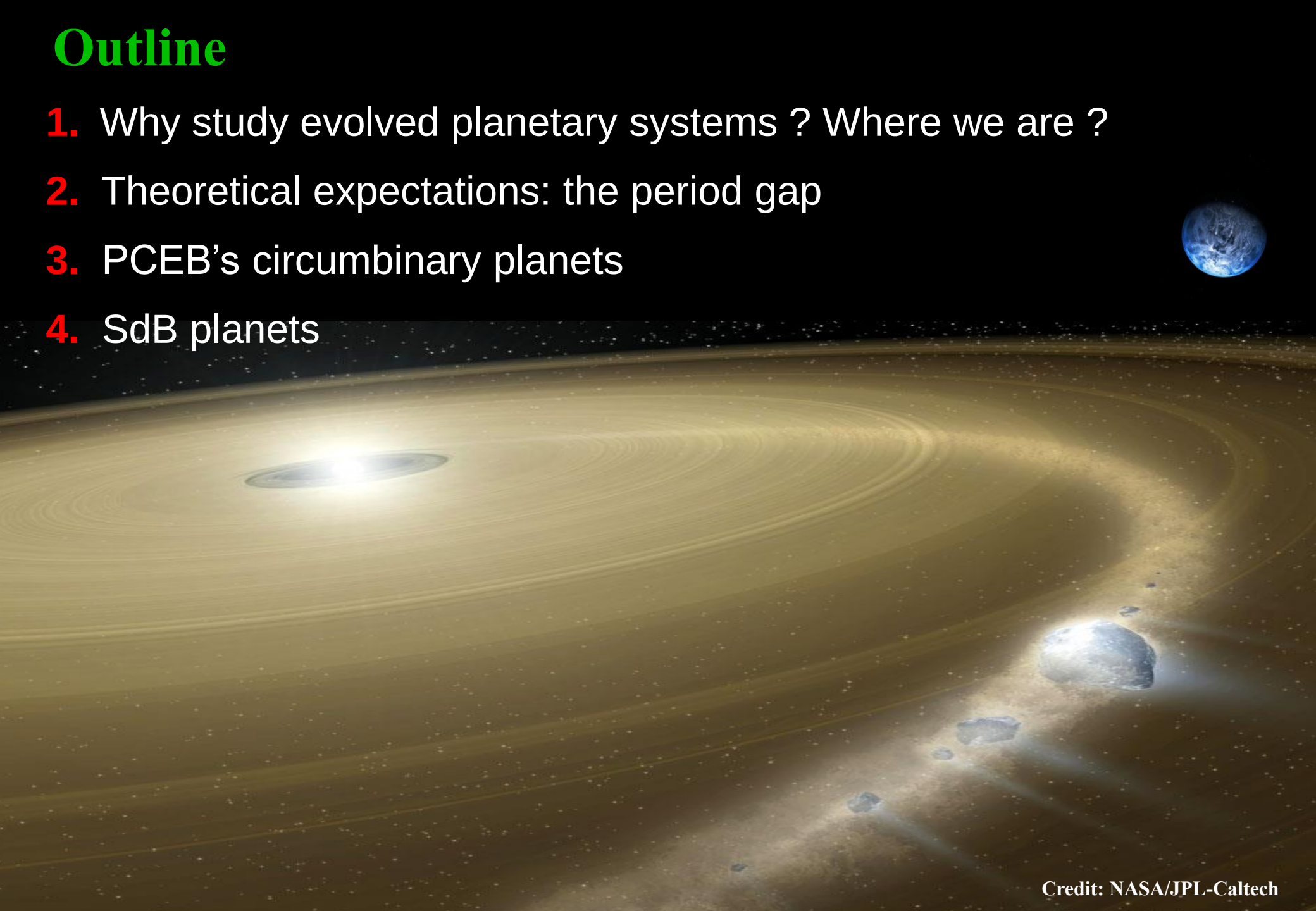
Credit: NASA/JPL-Caltech

Outline

1. Why study evolved planetary systems ? Where we are ?
2. Theoretical expectations: the period gap
3. PCEB's circumbinary planets
4. SdB planets



Credit: NASA/JPL-Caltech

1. Evolved planetary systems: where we are ?

In the last years we are witnessing the beginning of a transition from stellar evolution to planetary system's (PS) evolution.

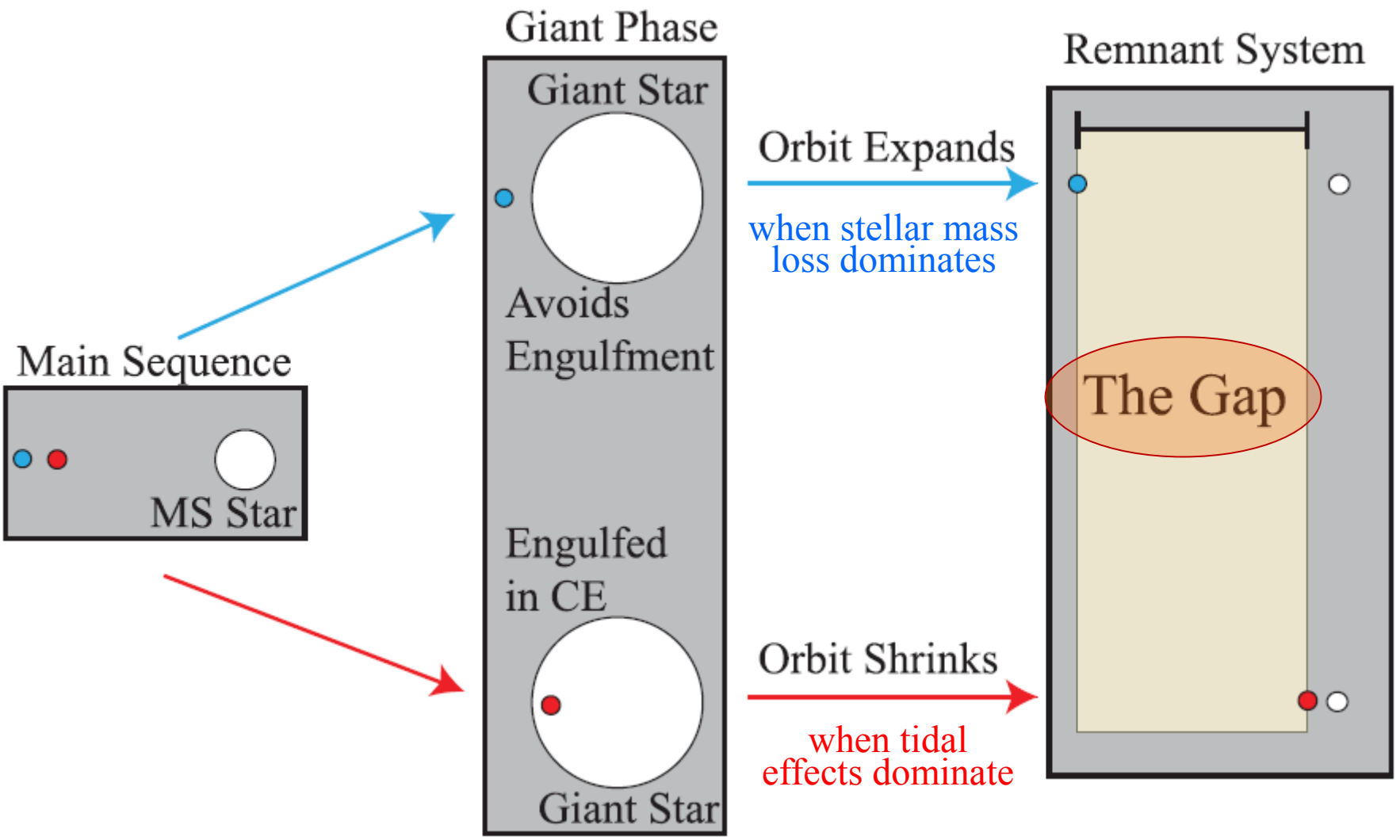
In this context the late-stage evolution of PSs is one of the main missing steps for various reasons, both "philosophical" (it's more difficult to imagine life near a hot and UV-bright WD) and observational:

1) **old planets are extremely faint;**
2) **RV detection is difficult because of the WD wide absorption lines due to the huge gravity;**
3) **WD transits have a low probability for planets in wide orbits, while close planets are potentially easy to detect (*IF* they exist, see next slides !).**

However, our galaxy is plenty of WDs (~97% of stars end their evolution as a WD) and thus WD planets are, at least statistically, important !

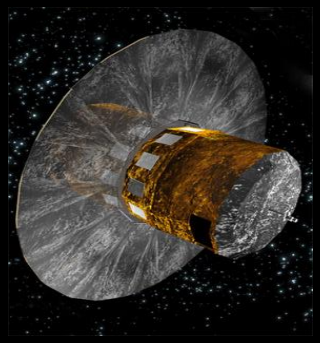
Moreover, 2nd generation planets might exist (difficult to imagine that the pulsar planets survived a SN explosion) and those younger and brighter could be more easily detectable.

2. The Period Gap

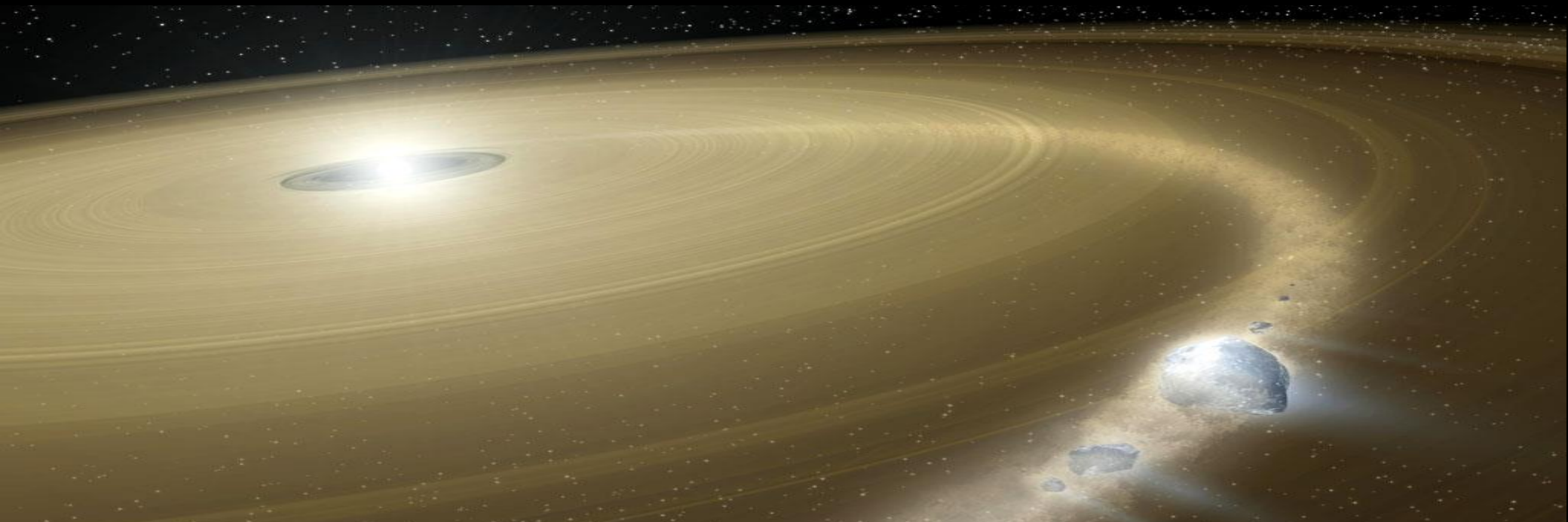


(from Nordhaus & Spiegel 2013)

WD planets in wide orbits:



Gaia will be able to detect the first massive WD planets/BDs (>few M_{JUP})



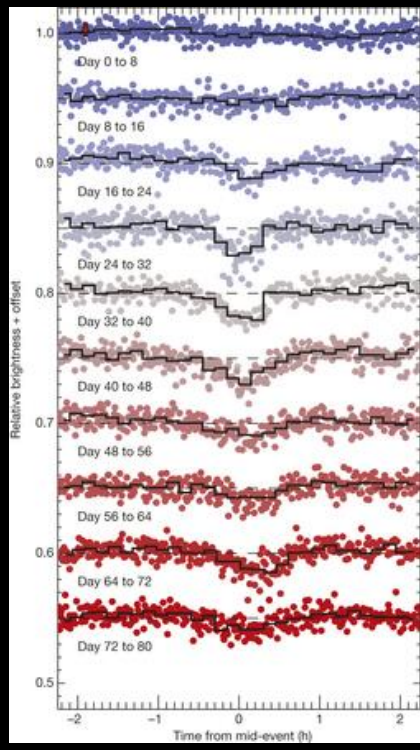
WD planets in tight orbits: a big question mark !

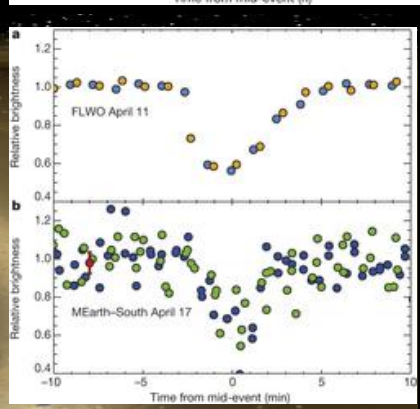
a) ≈27% of WDs accrete metal-rich material

b) ≈4% of WDs have dusty/gaseous disks within ~1 R_{SUN}

The widely accepted interpretation that we are seeing WD accretion of tidally disrupted planetary material is supported by the recent K2 detection of a disintegrating minor planet transiting a WD (Vanderburg+2015, Croll+2015).

c) The accreting material shows a chemical composition very similar to SS meteorites with evidence of water (Gansicke+2012, Farihi+2013).





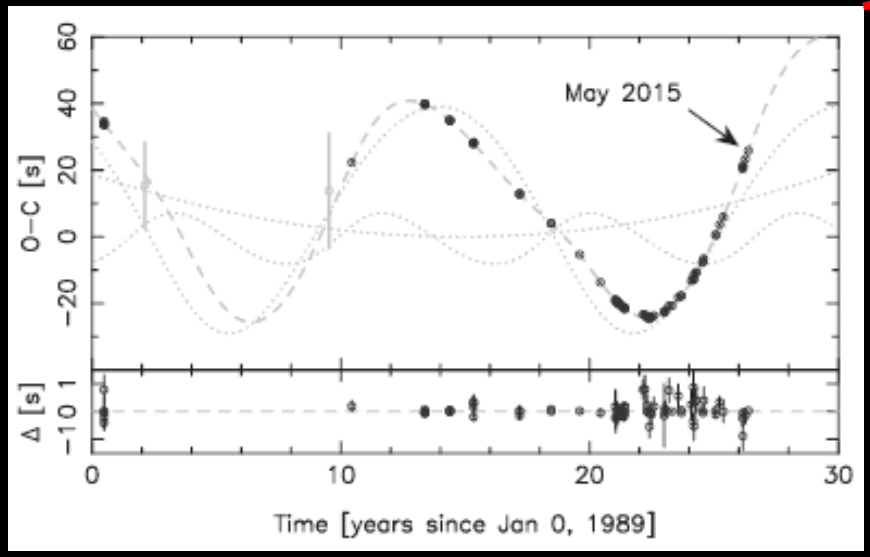
Q: Do WD planets in tight orbit exist ?

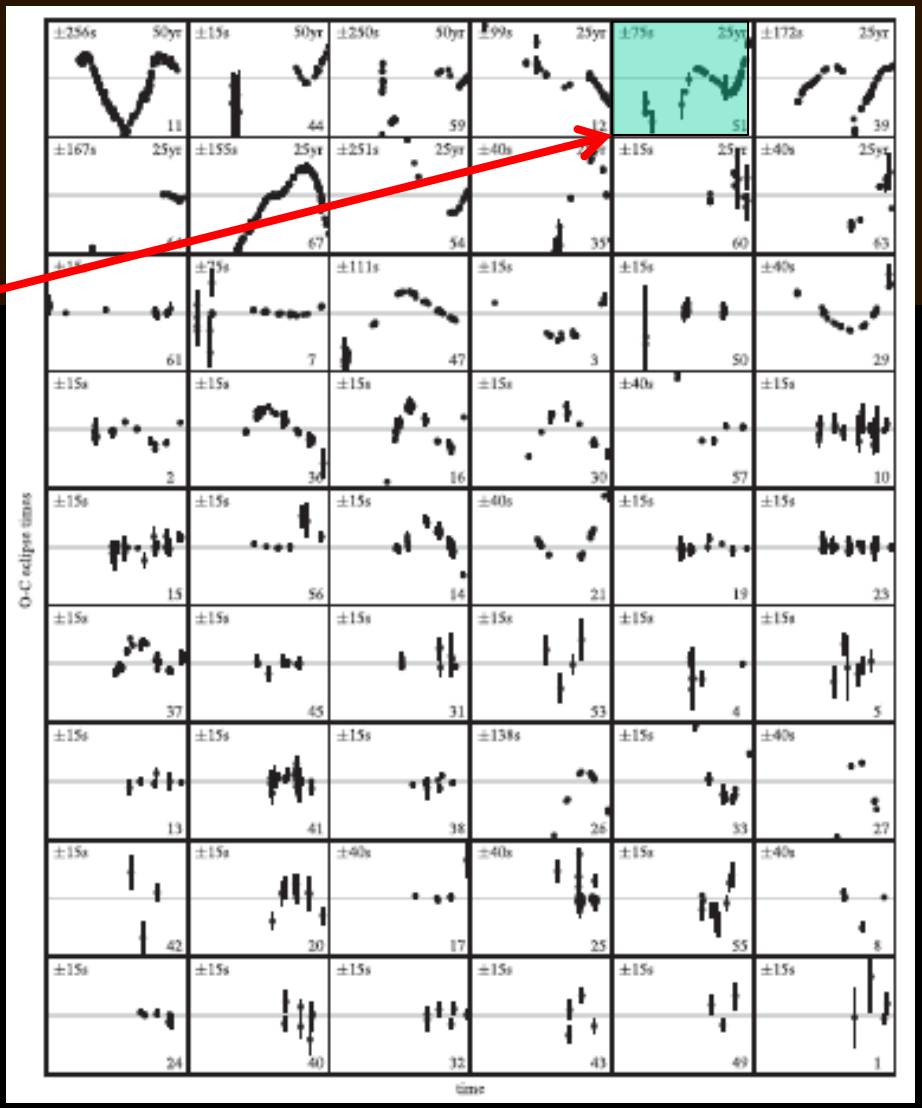
Q: What is the minimum mass to survive engulfment ?

3. PCEB's Circumbinary Planets

a) **Most PCEBs show orbital period variations which, among other interpretations like Applegate-like mechanisms (Applegate 1992, Lanza 2006), may be caused by low-mass (substellar) companion.**

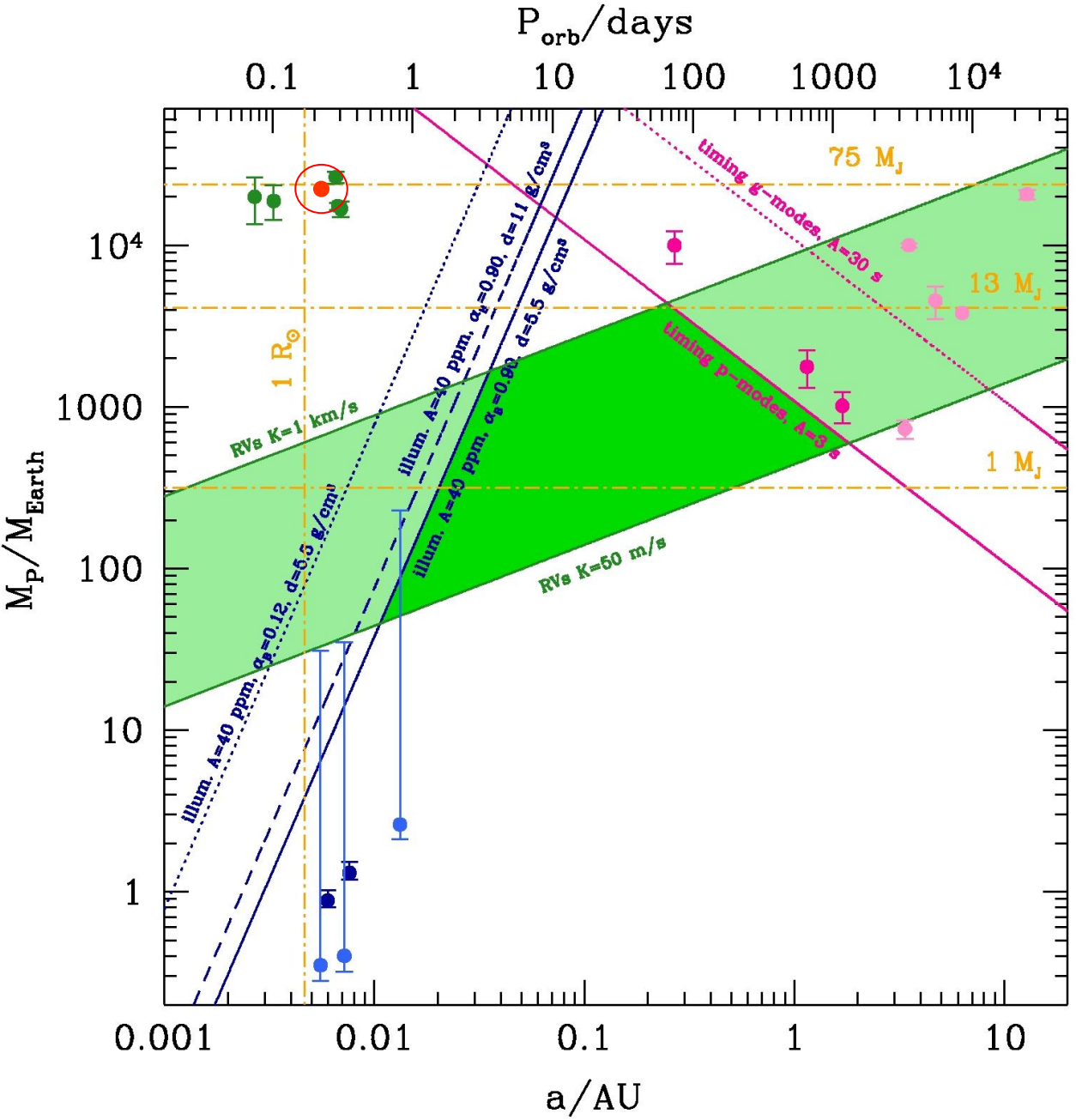
b) **The most compelling case is given by the pre-CV NN Ser, whose O-C plot (below) is compatible with the presence of 2 Jovian planets in 2:1 resonance (Bours+2016).**





Q: For how many PCEBs eclipse time variations are due to circumbinary planets ?

3. SdB Planets



Although sdBs are rare (only 1-2% of stars become sdBs), sdB planets are interesting as they allow to disentangle the effects of the RGB expansion alone (while WD planets suffer also RGB expansion, thermal pulses, PN ejection).

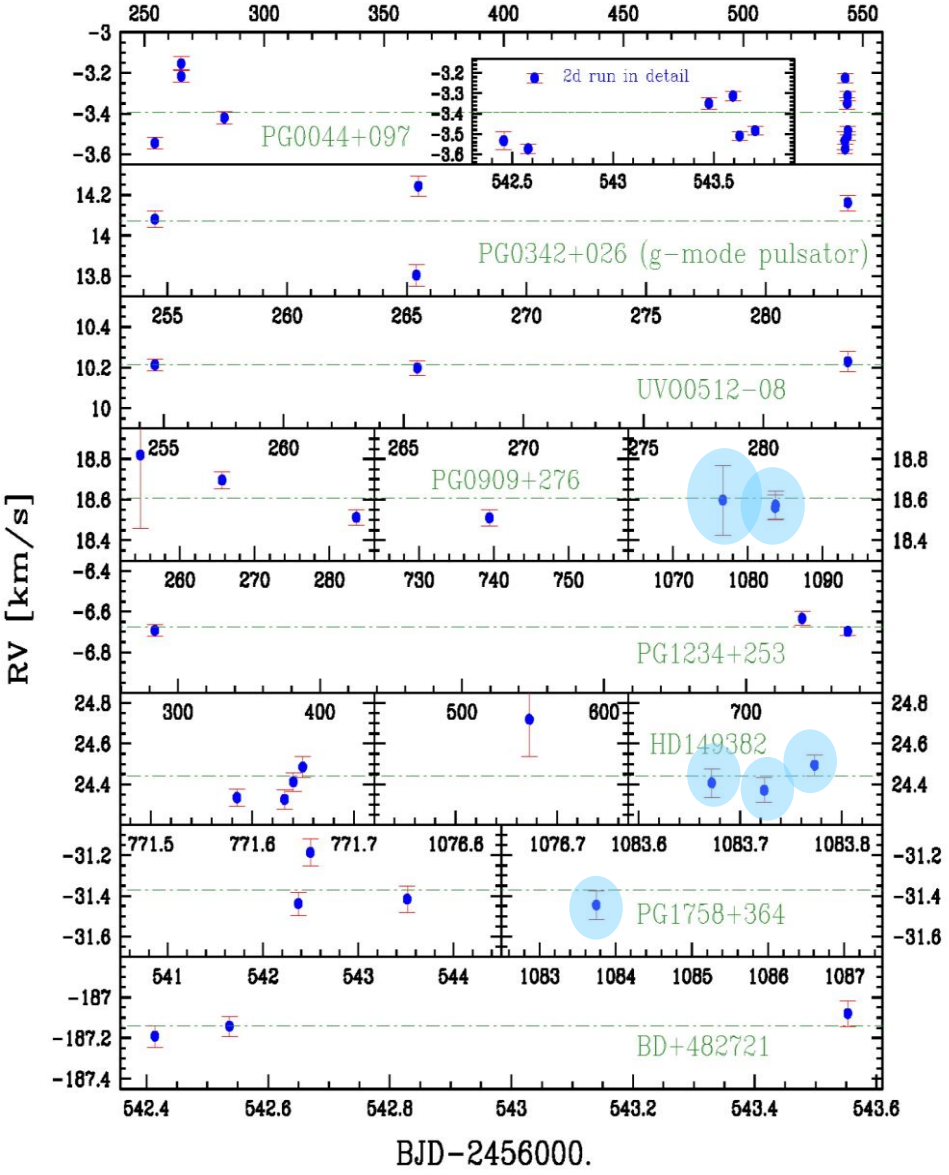
Among the sdB planet candidates on the left, only one (in red) is confirmed through 2 independent methods !

⇒ To confirm more candidates is essential !

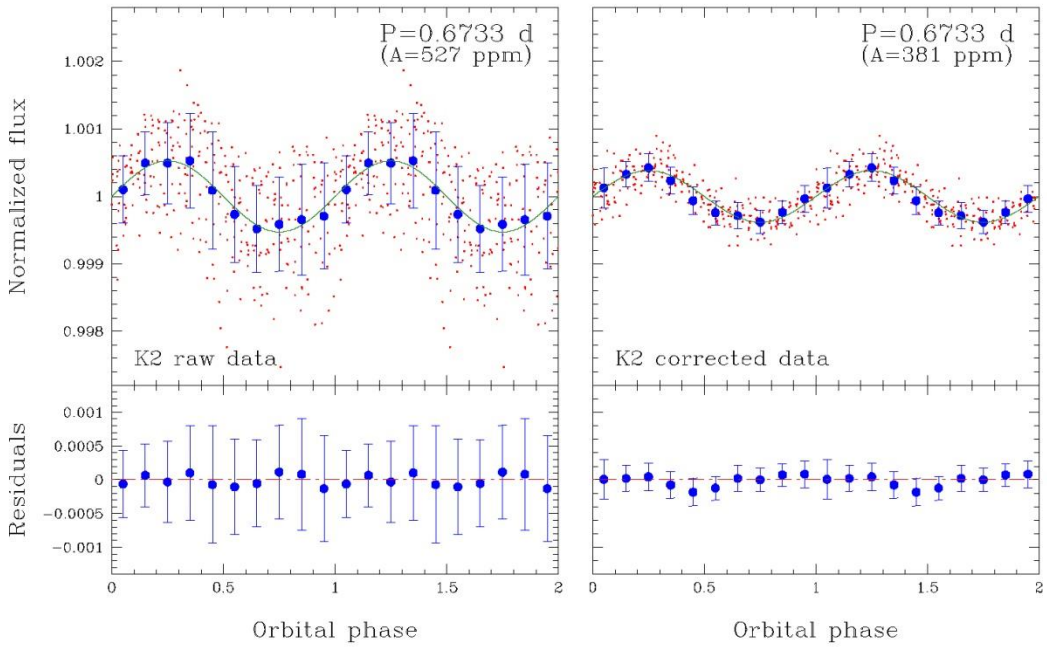
Q: How many single sdBs have planets ?

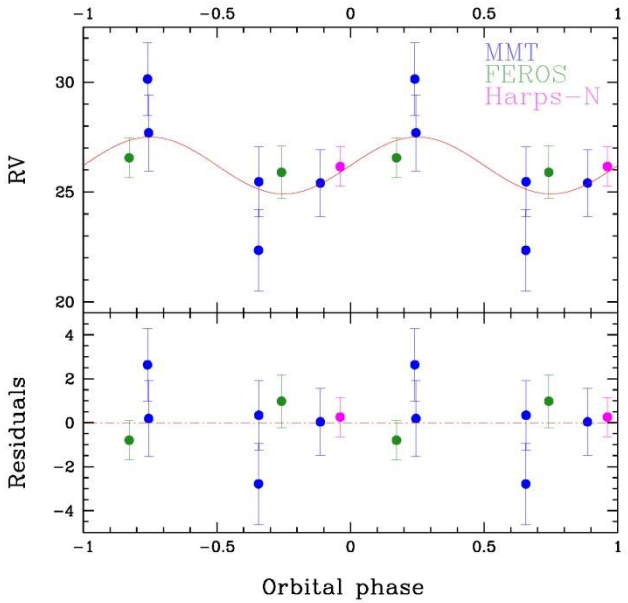
Q: For how many of them planets are responsible for envelope's loss ?

SdB planets: RVs and K2 reflection effects



Harps-N program
[Silvotti, Telting, Østensen, Lovis, ongoing]

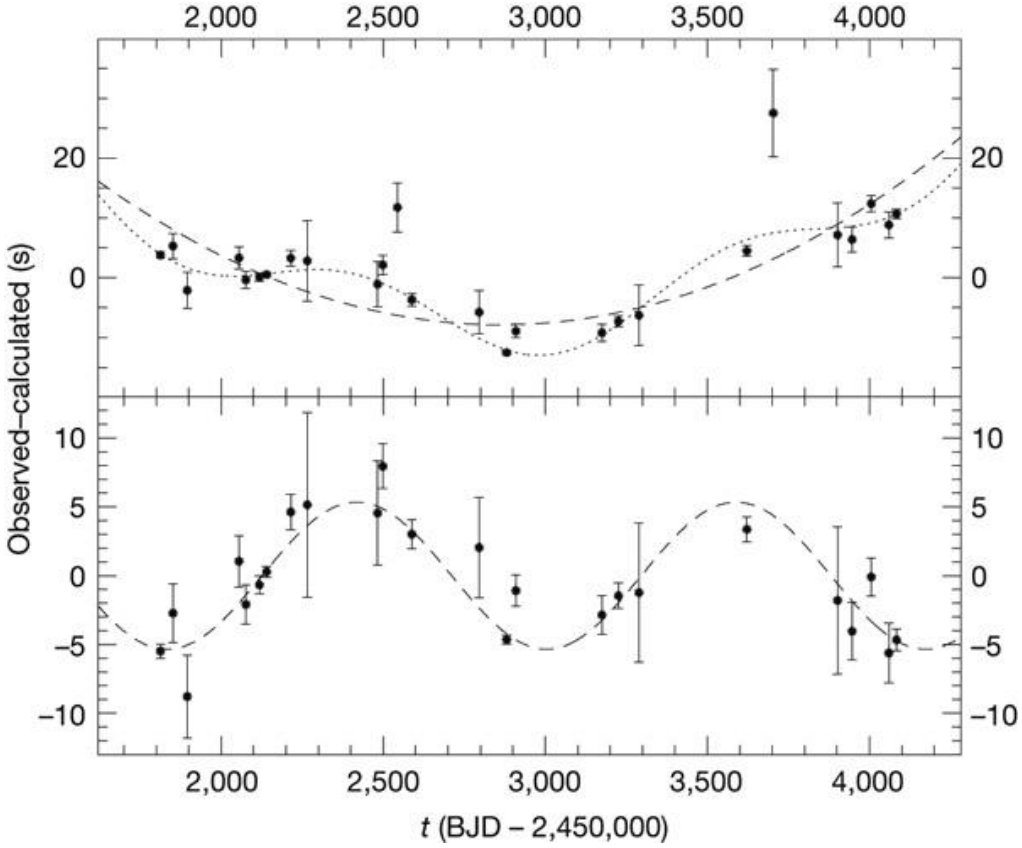




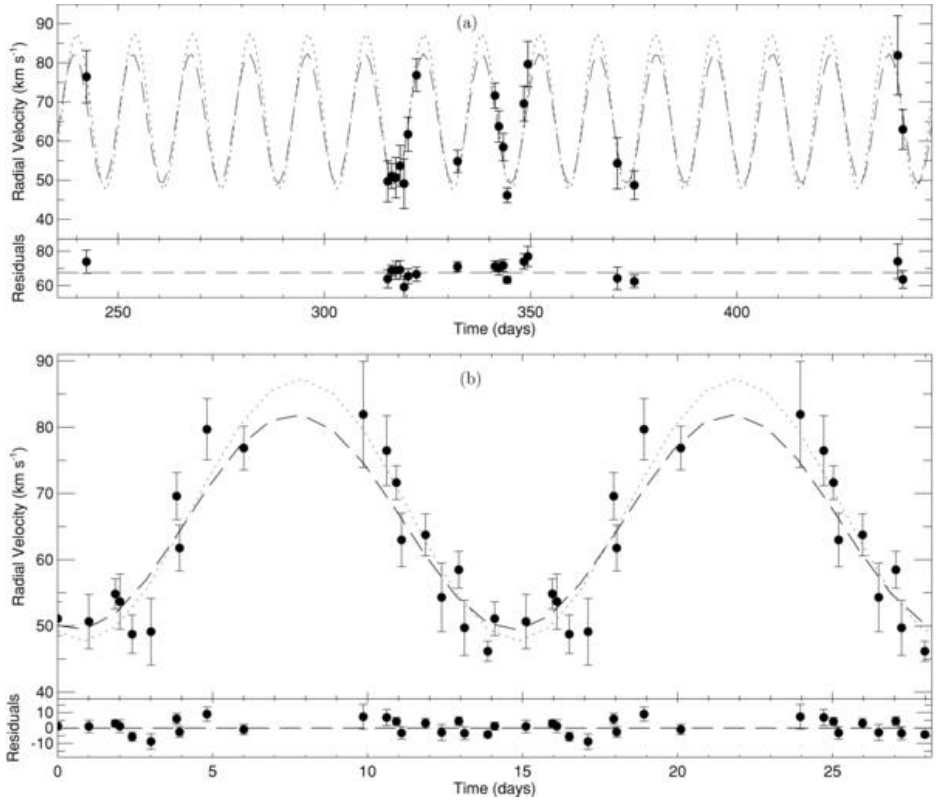
A new sdB planet candidate from K2

[Silvotti, Green, Geier, Ostensen, ongoing]

SdB planets: pulsation timing



V391 Peg, *Silvotti et al. 2007*



CS 1246: RV confirmation of a binary detected from pulsation timing (*Barlow+2011*)

Summary, open questions and perspectives

a) Period gap and (single) WD planets:

Q1: does the period gap exist as expected ?

Q2: which are the inner and outer edges ?

Q3: do WD planets in wide orbits exist ?

A3: presumably yes, but we want to find them !

Gaia

Q4: do WD planets in tight orbits exist ?

A4: we don't know ! If yes, we want to explore the parameter space, starting from the minimum mass to avoid engulfment.

PLATO/LSST can detect WD transits. Assuming 1% of MS planets with P_{ORB}<200 d and M>10 M_J and a 0.1 transit prob. at 0.005 AU from the star, we need to observe ≈1000 WDs to catch 1 transit

b) PCEB planets:

Q5: for how many PCEBs the eclipse time variations that we see are caused by circumbinary planets ?

c) SdB planets:

Q6: how many single sdB stars have planets ?

Q7: for how many of them planets are responsible for envelope's loss ?

d) WD-PCEB-sdB planets:

Q8: do 2nd generation planets exist ?

If yes, those young and bright might be not so difficult to detect …