The roles of rotation and pulsation in the new B- and A-type periodic variables in NGC3766

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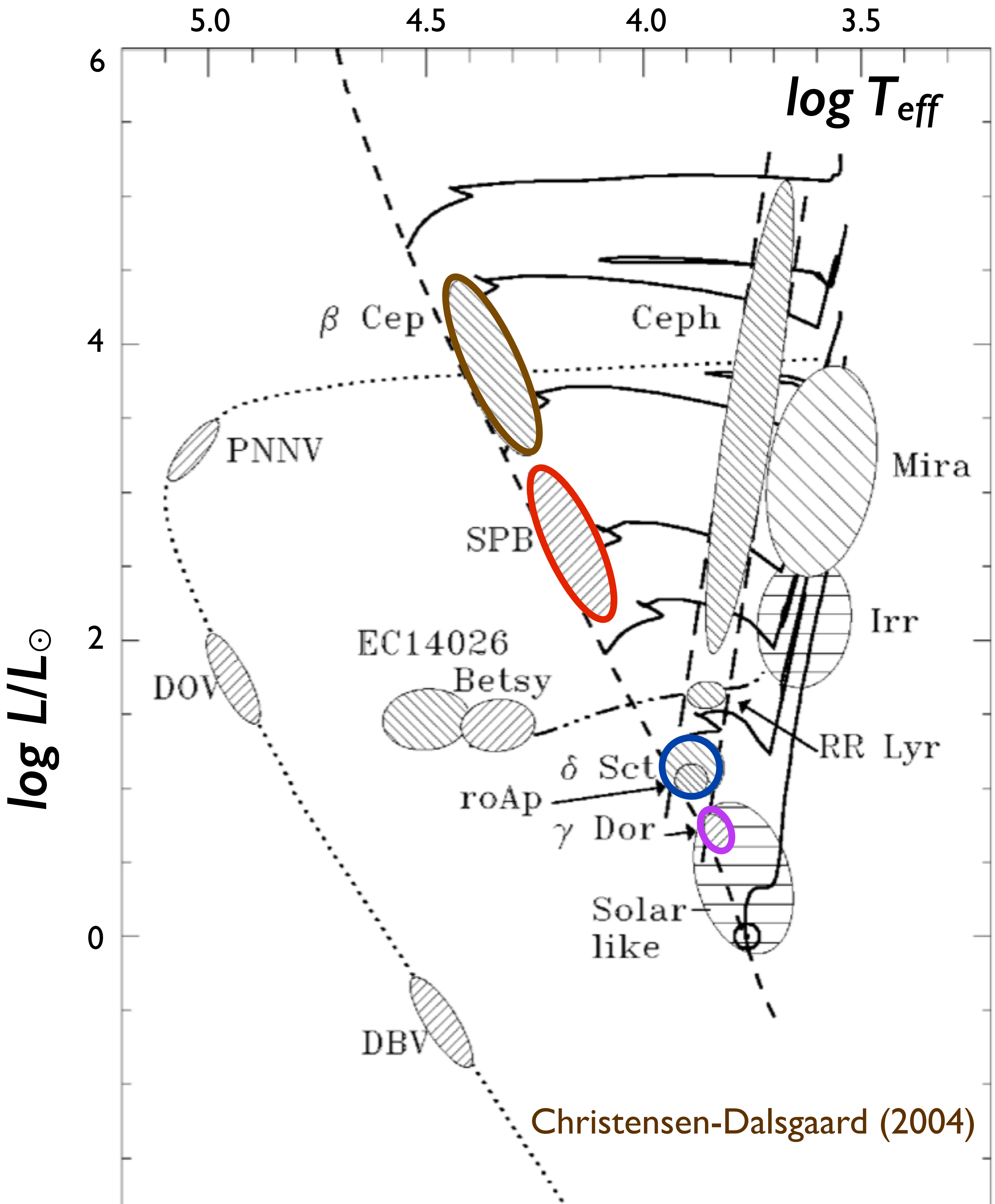
* New variable stars in NGC 3766 : **Reminder**
  → Mowlavi et al. (2013, Paper I)

* VLT spectra : **New insight**
  → Mowlavi et al. (2016, submitted)

Stellar pulsation in the HR diagram



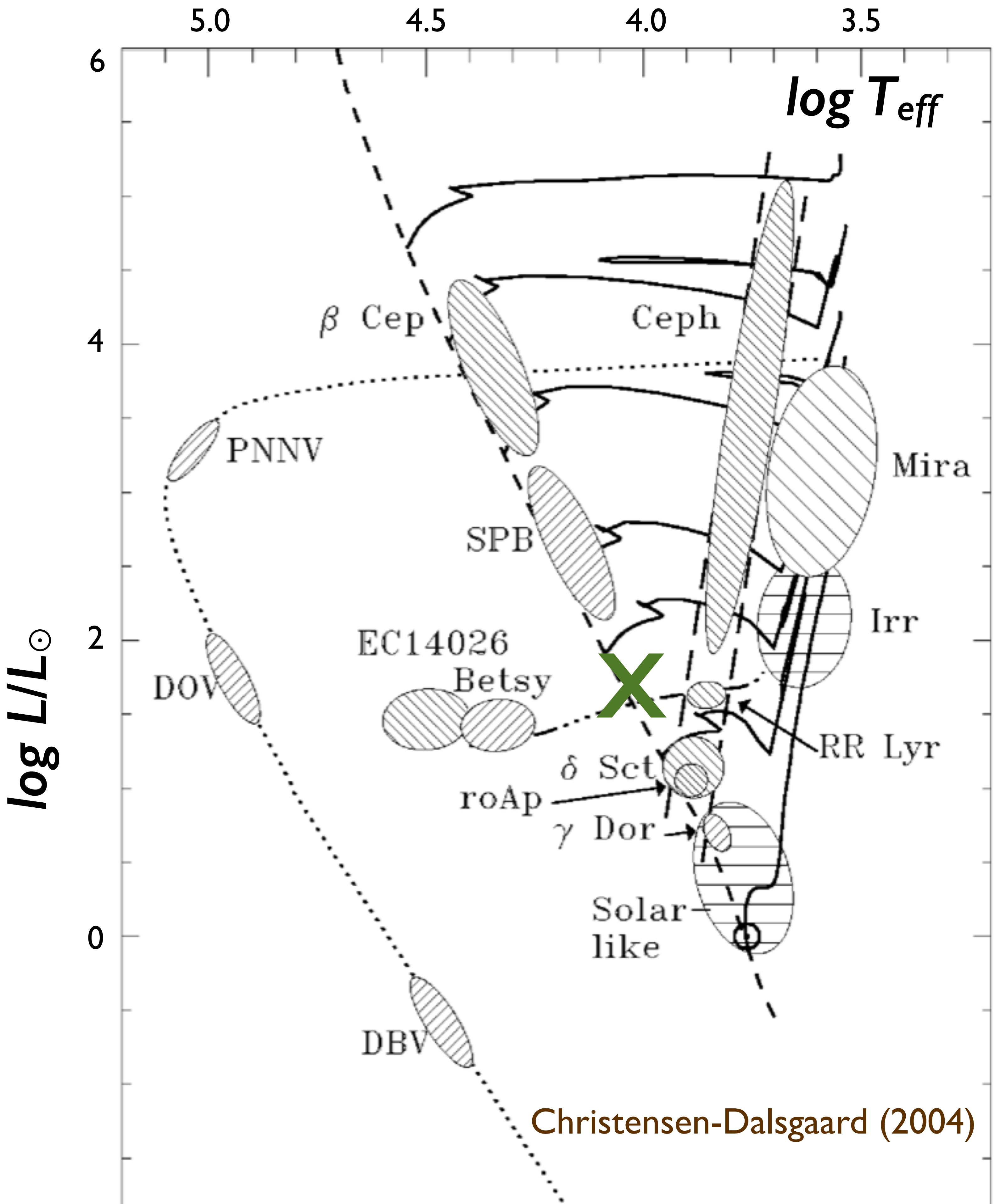
β Cep stars *0.1-0.6 d*

SPB stars *0.5 - 5 d*

δ Sct stars *0.02-0.25 d*

γ Dor stars *0.3-1.7 d*

Stellar pulsation in the HR diagram



No pulsation

Photom. survey 2002-2009

(1.2m Euler telescope, La Silla)

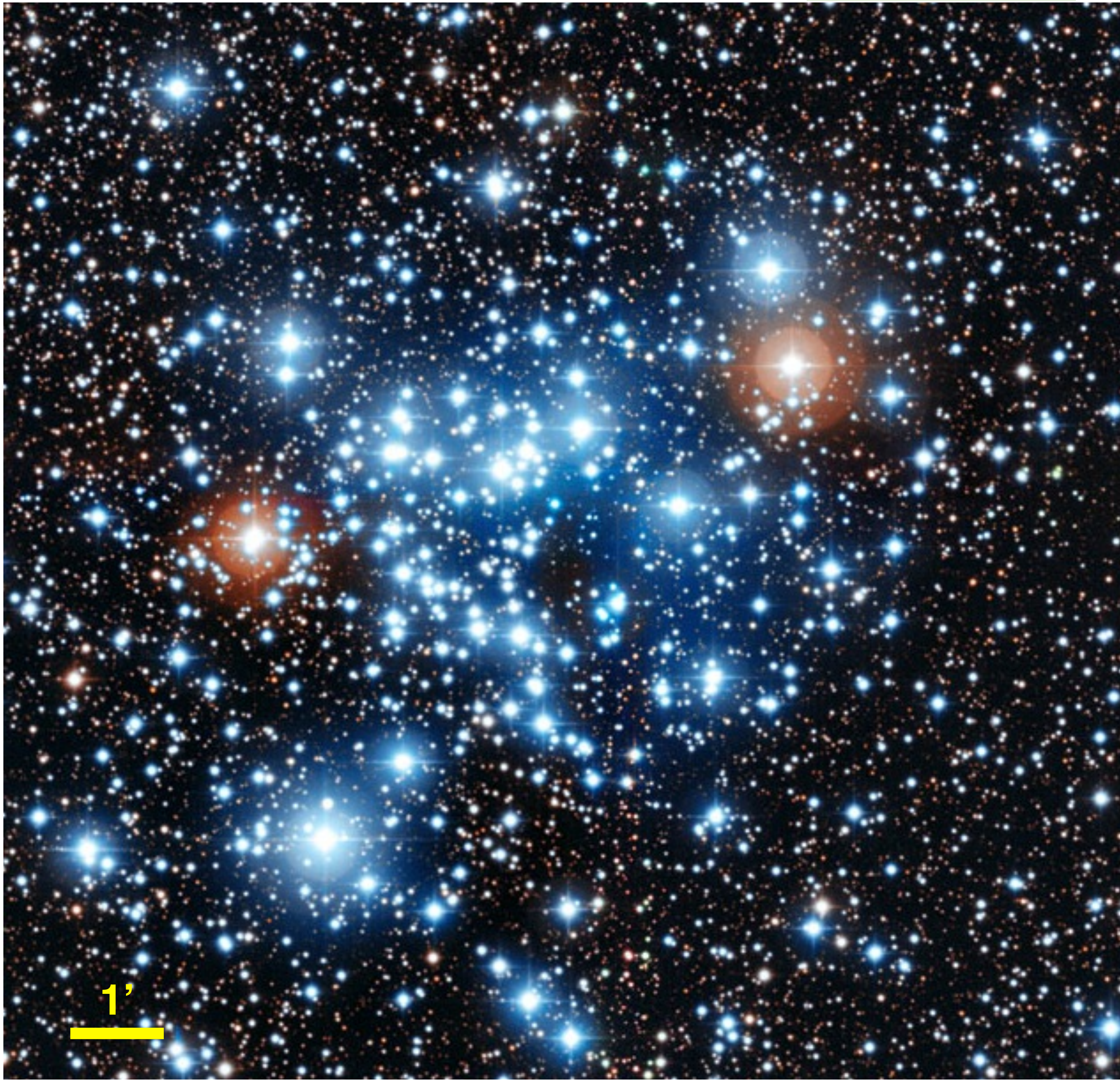
Open cluster NGC 3766

14 - 30 My

→ 2545 images in V'

430 images in B'

376 images in U'



ESO Press Release 1326 (2013)

Photom. survey 2002-2009

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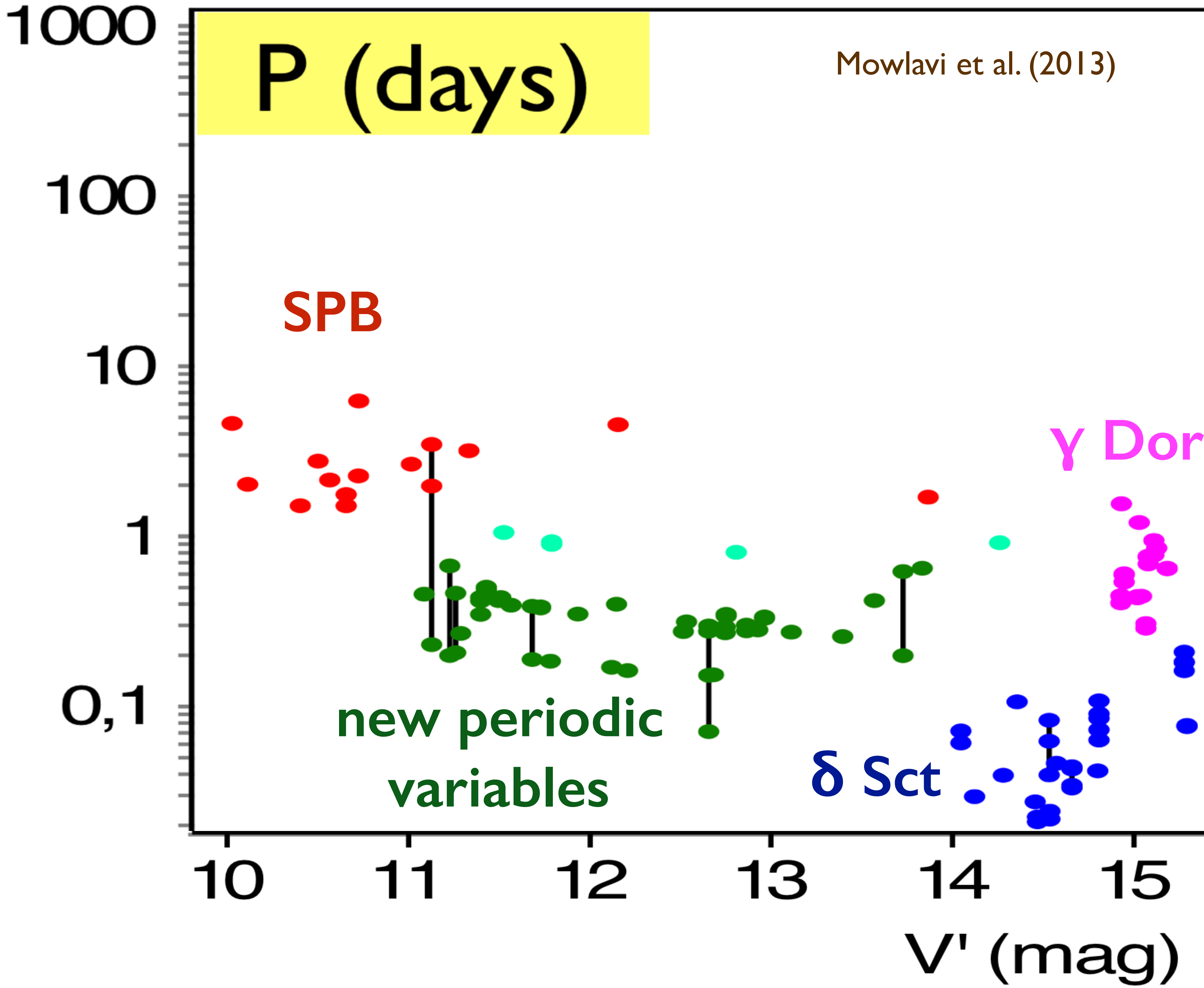


Previously reported periodic variables in the gap ?

Before Paper I *(not exhaustive)*

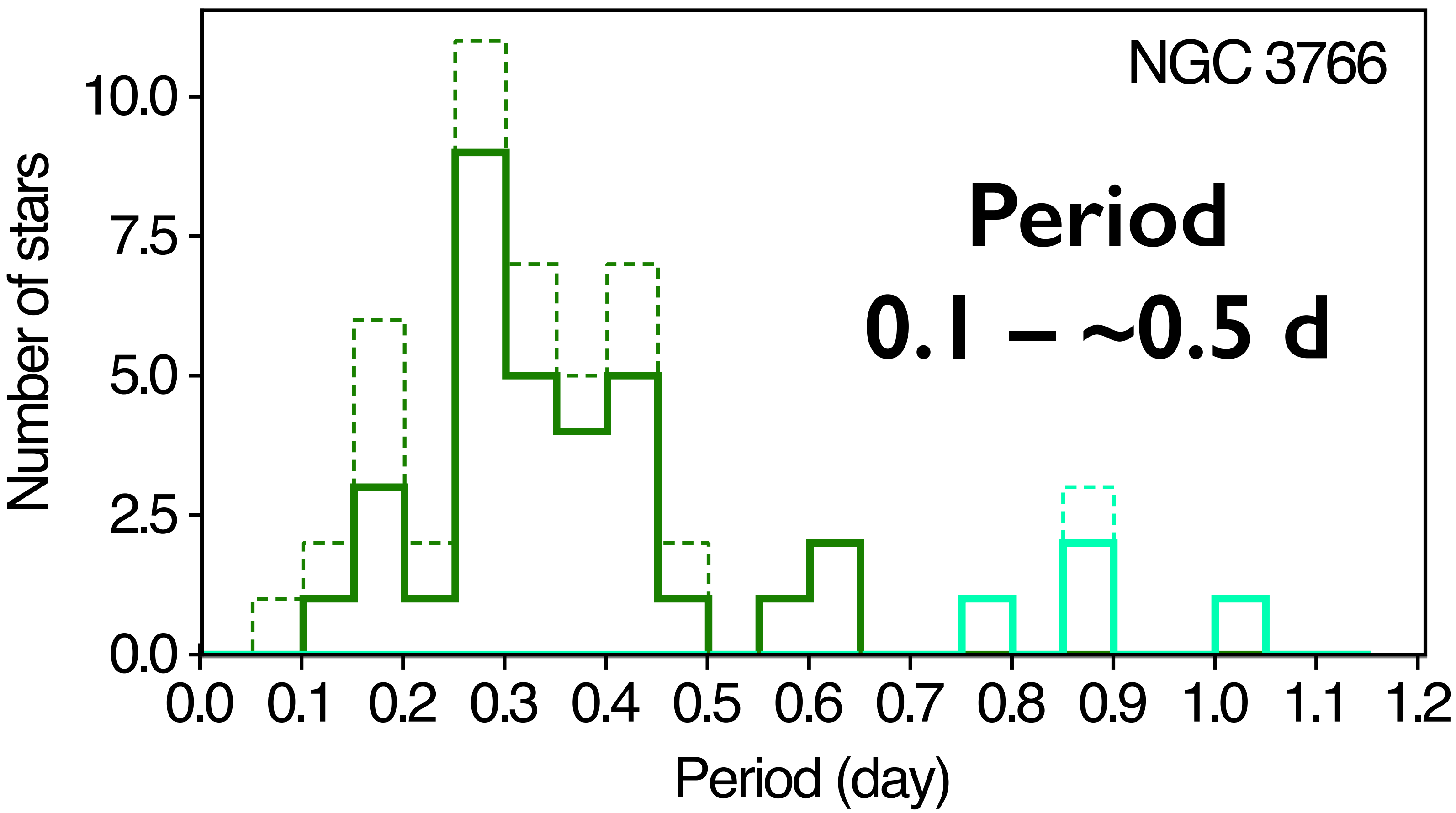
* **Maia stars (?)**	Struve (1955), ..., Scholz et al. (1998)
* **Individual stars**	Ex: Waelkens et al (1998), Aerts & Kolenberg (2005)
* **CoRoT**	Yes, pulsation proposed (Degroote et al. 2009)
* **Kepler**	Yes, spots proposed (Balona 2013)
* **NGC 7654**	Yes, but not recognized as such (Luo et al 2012)

Since 2013 *(not exhaustive)*

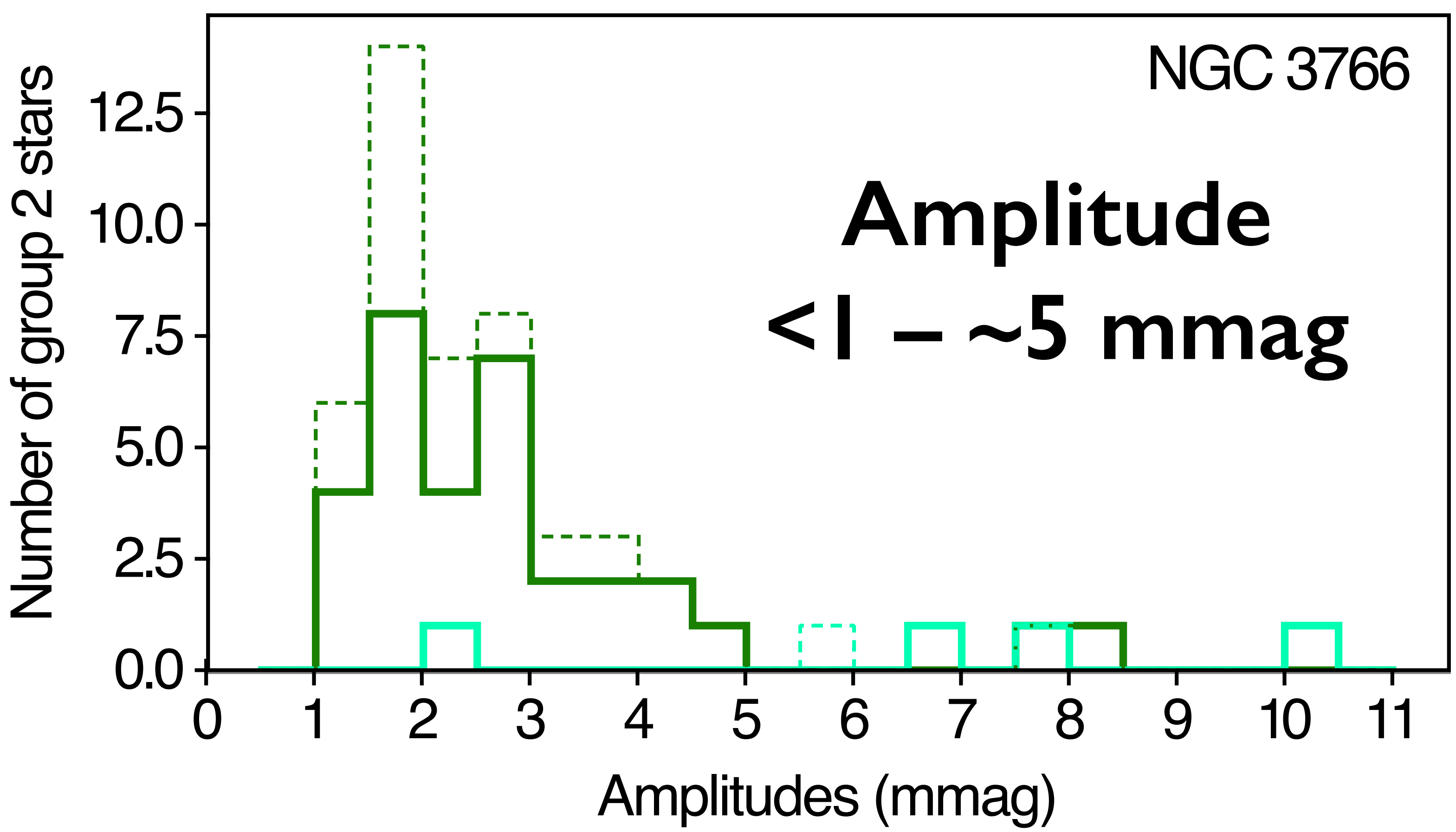
- Lata et al. (2014) *"Main-sequence variable stars in young open cluster NGC 1893"*
- Lata et al. (2016) *"Variable stars in young open star cluster NGC 7380"*
- Balona et al. (2016) *"The hot γ Doradus and Maia stars"*

Properties of the new group

Mowlavi et al. (2013)



Shorter than SPBs
and
longer than δ Scts



Limited by
photometric precision
→ ***extends below mmag***

Binary stars ? ← **multi-epoch V_r**

Role of rotation ? ← **v*sin(i)**

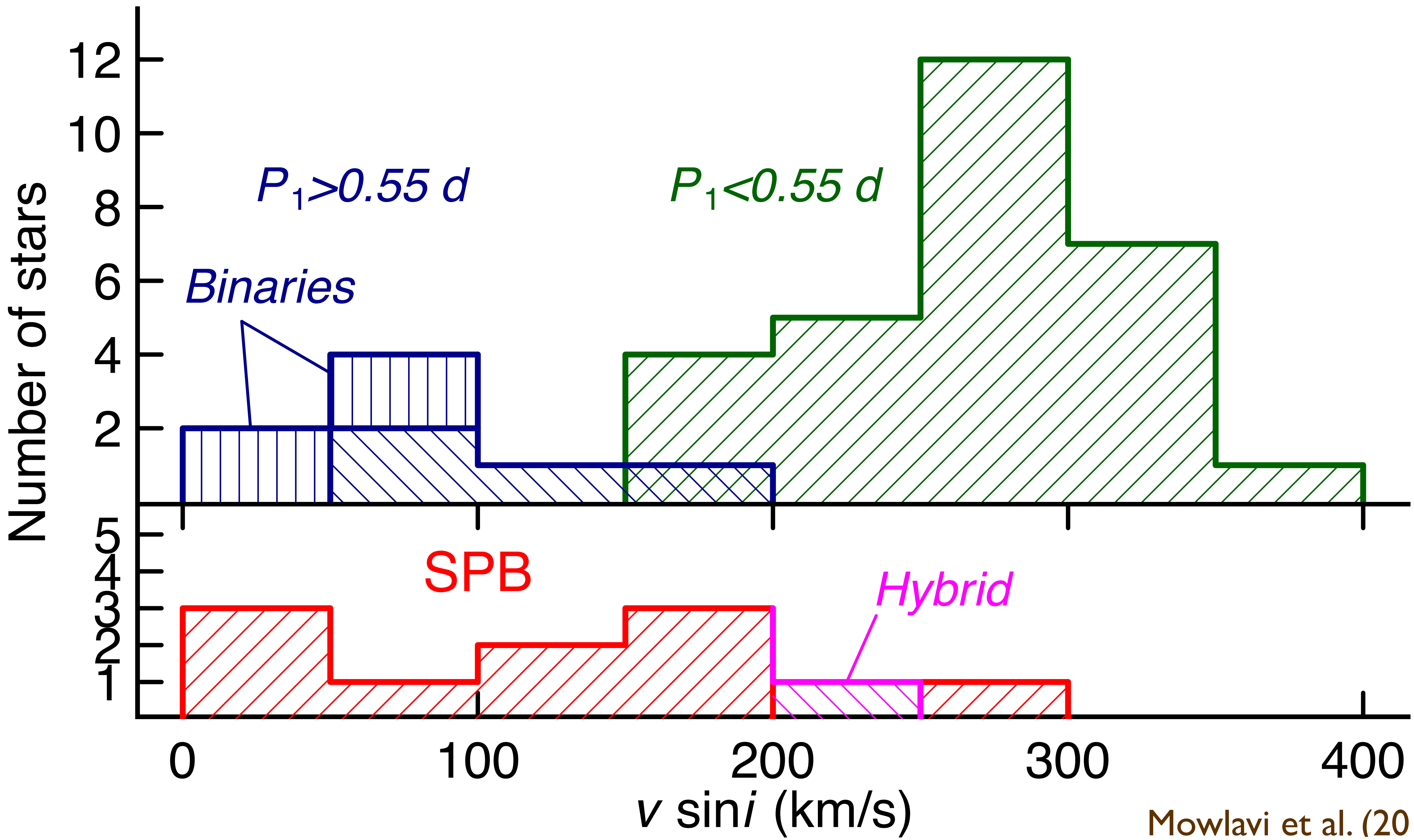
Binary stars ? ← **multi-epoch V_r**
Role of rotation ? ← **v*sin(i)**

Spectra taken with VLT/Girafe (LR02 mode) for
- ***all new variables***
- ***SPB stars***
- Many ***non-periodic stars*** in same mag range

Multi-epoch: for each star, several spectra each night during three consecutive nights

Result 1: *New variables form 2 groups*

Rotation rates



Mowlavi et al. (2016)

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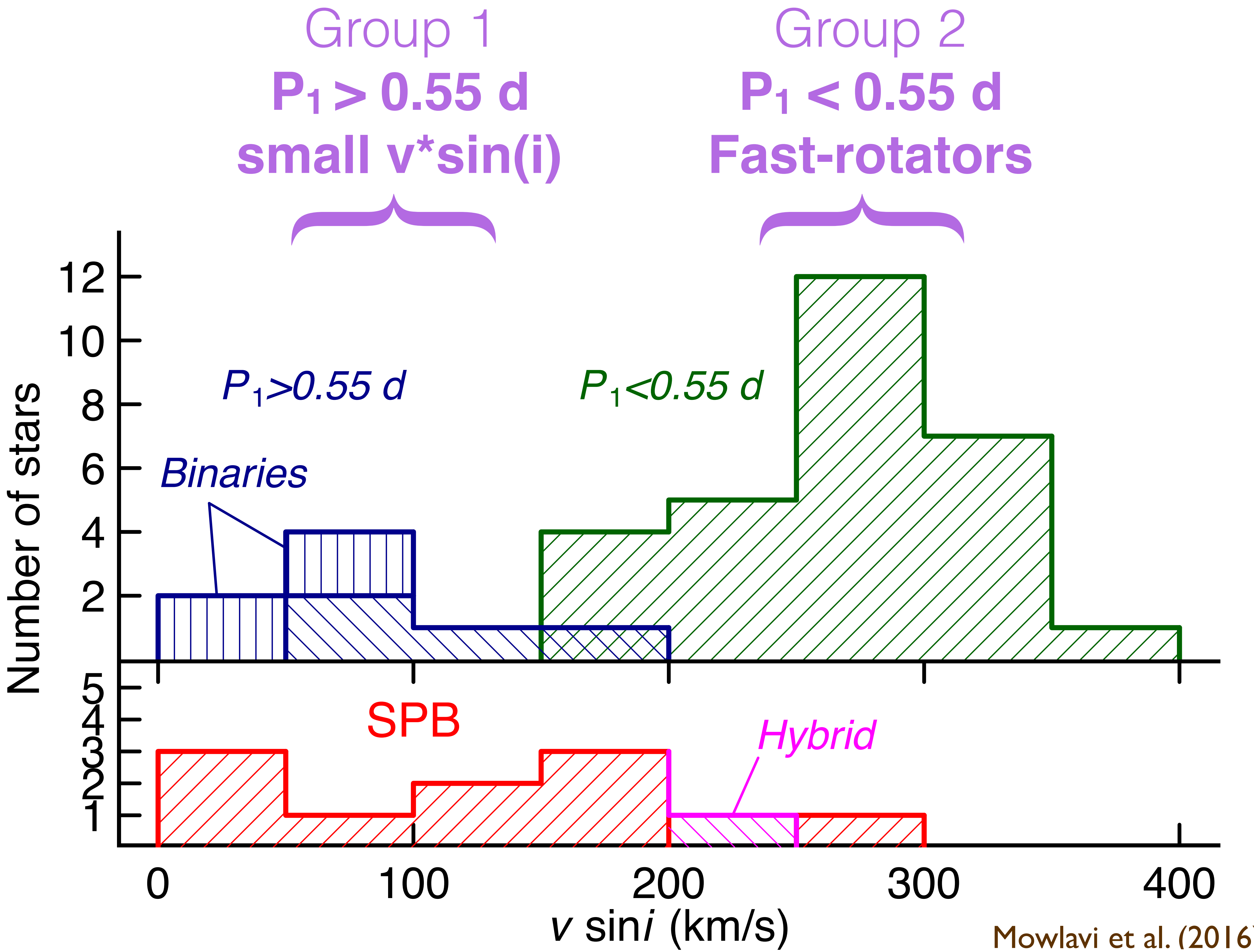
Rotation rates



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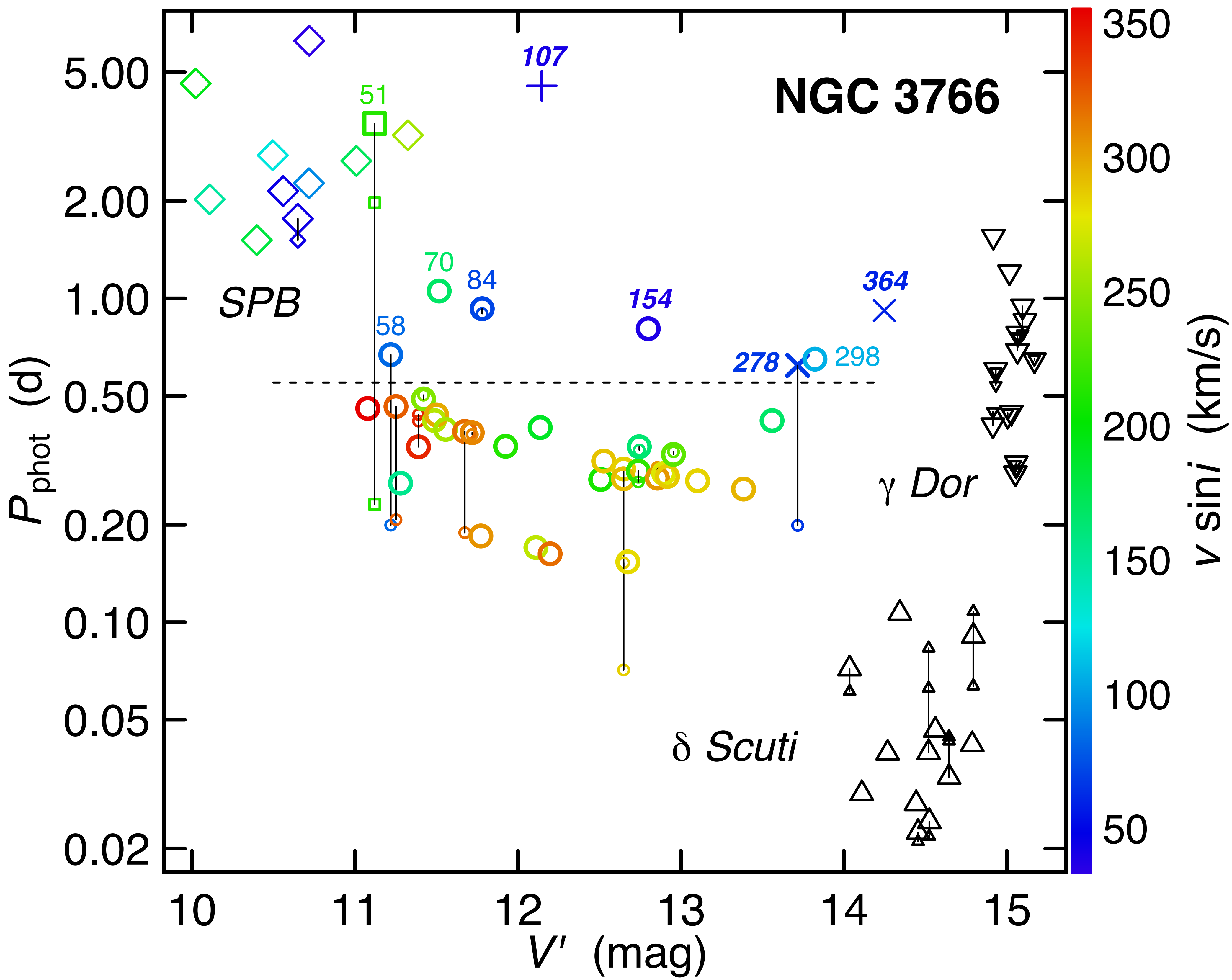
Rotation rates

Mowlavi et al. (2016)



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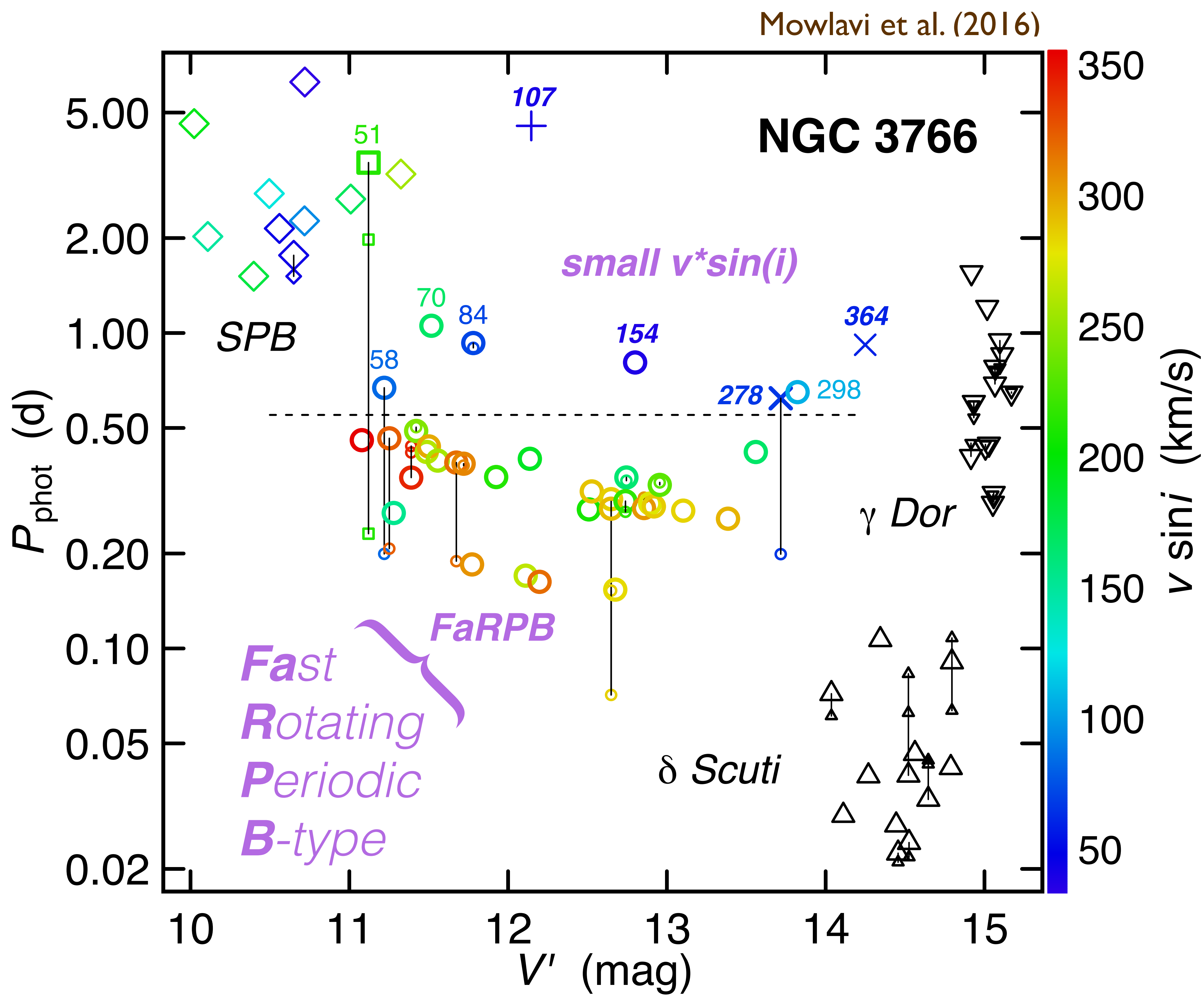
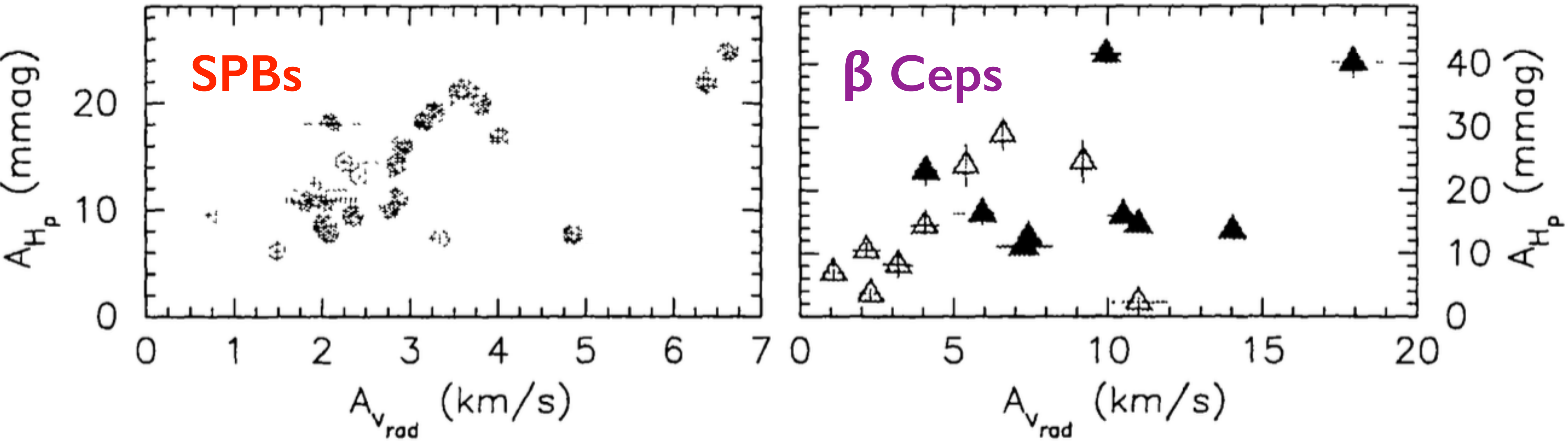


$V_r \rightarrow$ Binarity ?

Expected amplitude of RV variations

de Cat (2002)



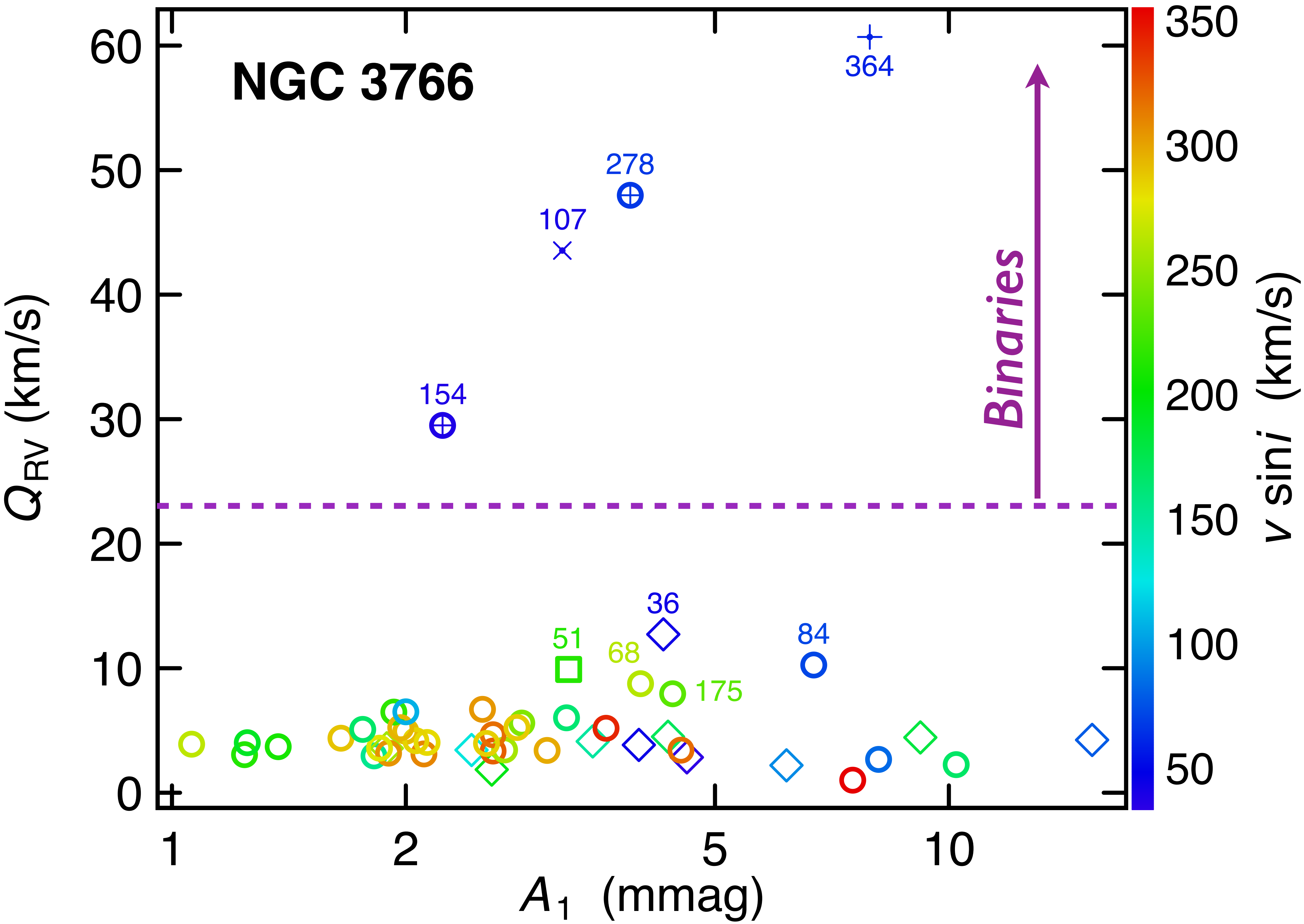
SPBs: A_{Vr} <~ 7 km/s

β Ceps: A_{Vr} <~20 km/s

→ Binary if A_{Vr} >~ 20km/s

Identification of binaries

Mowlavi et al. (2016)



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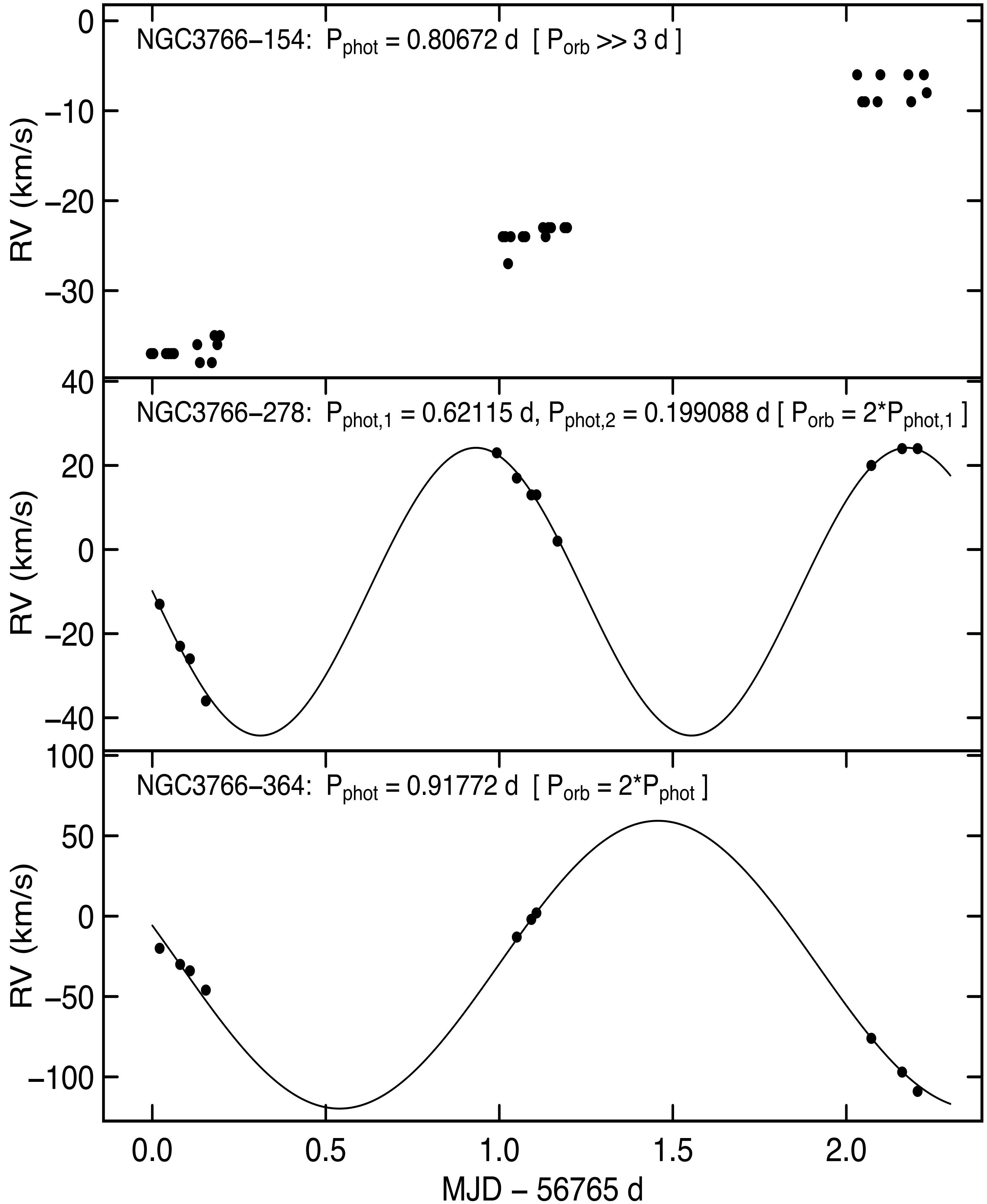

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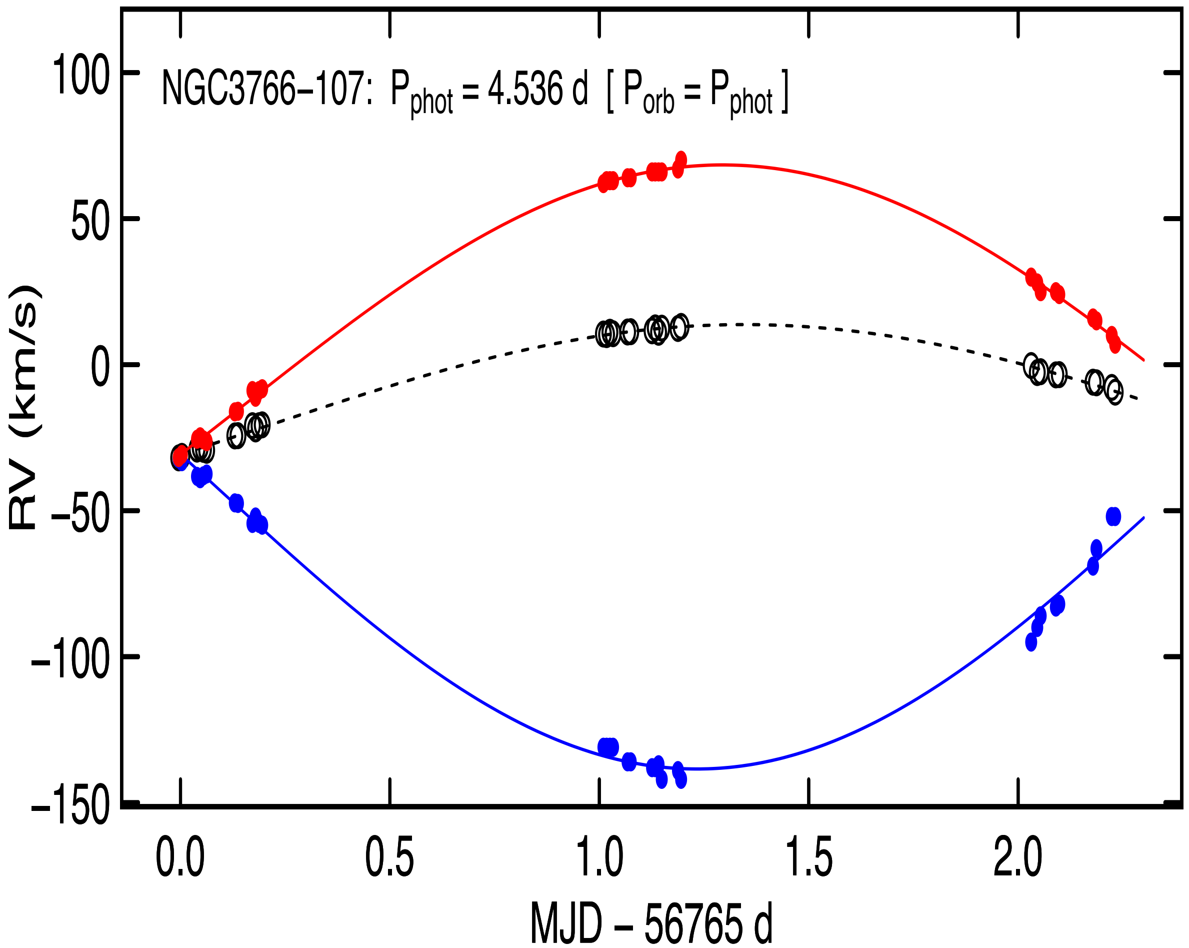

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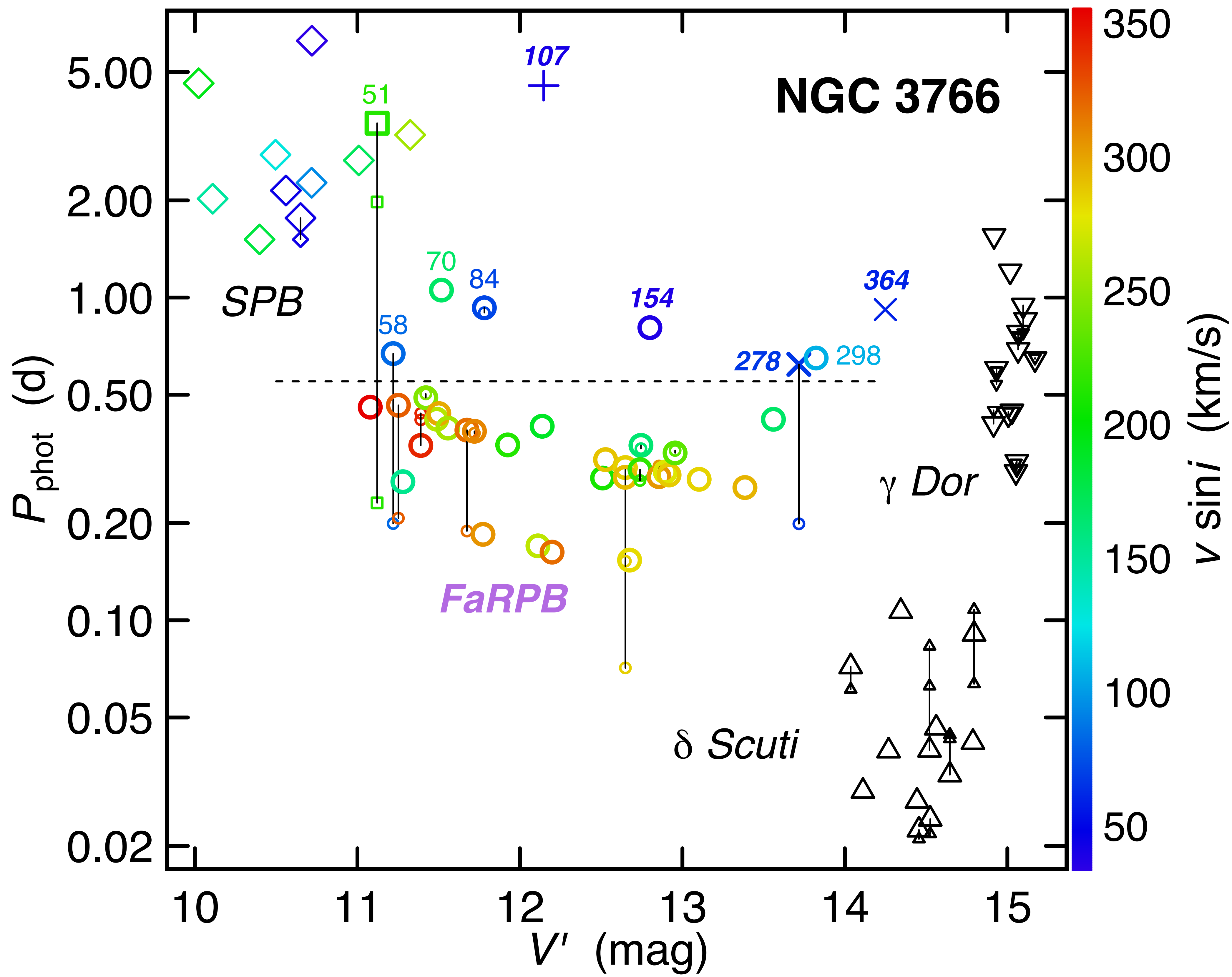
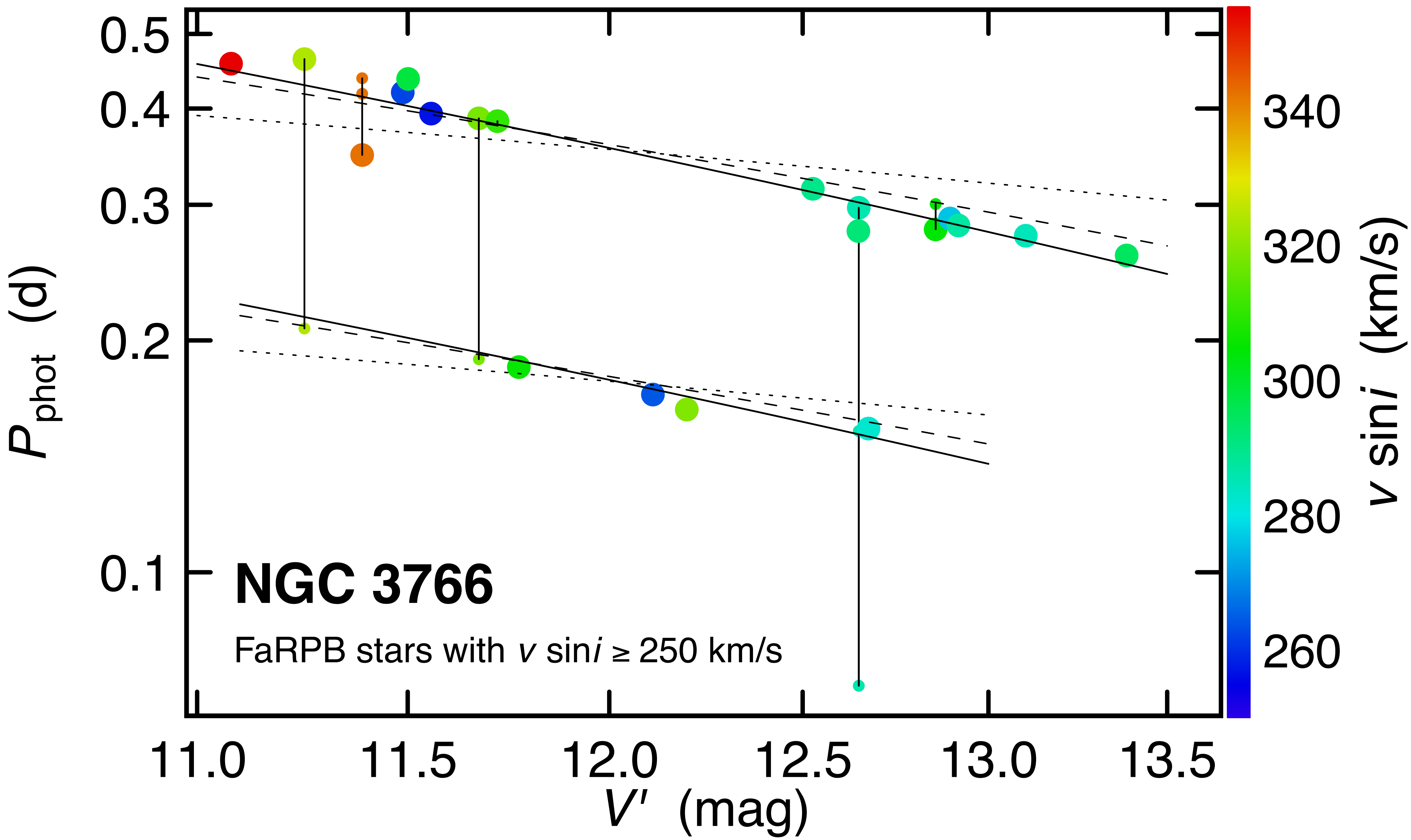


Result 2: *New Period-Luminosity relation*

Mowlavi et al. (2016)



$$\log(P_{\mathrm{phot}}) = (-0.11 \pm 0.01)\ (V - 12) - (0.449 \pm 0.006)$$

(solid line)

Result 2: *New Period-Luminosity relation*

P-L relation

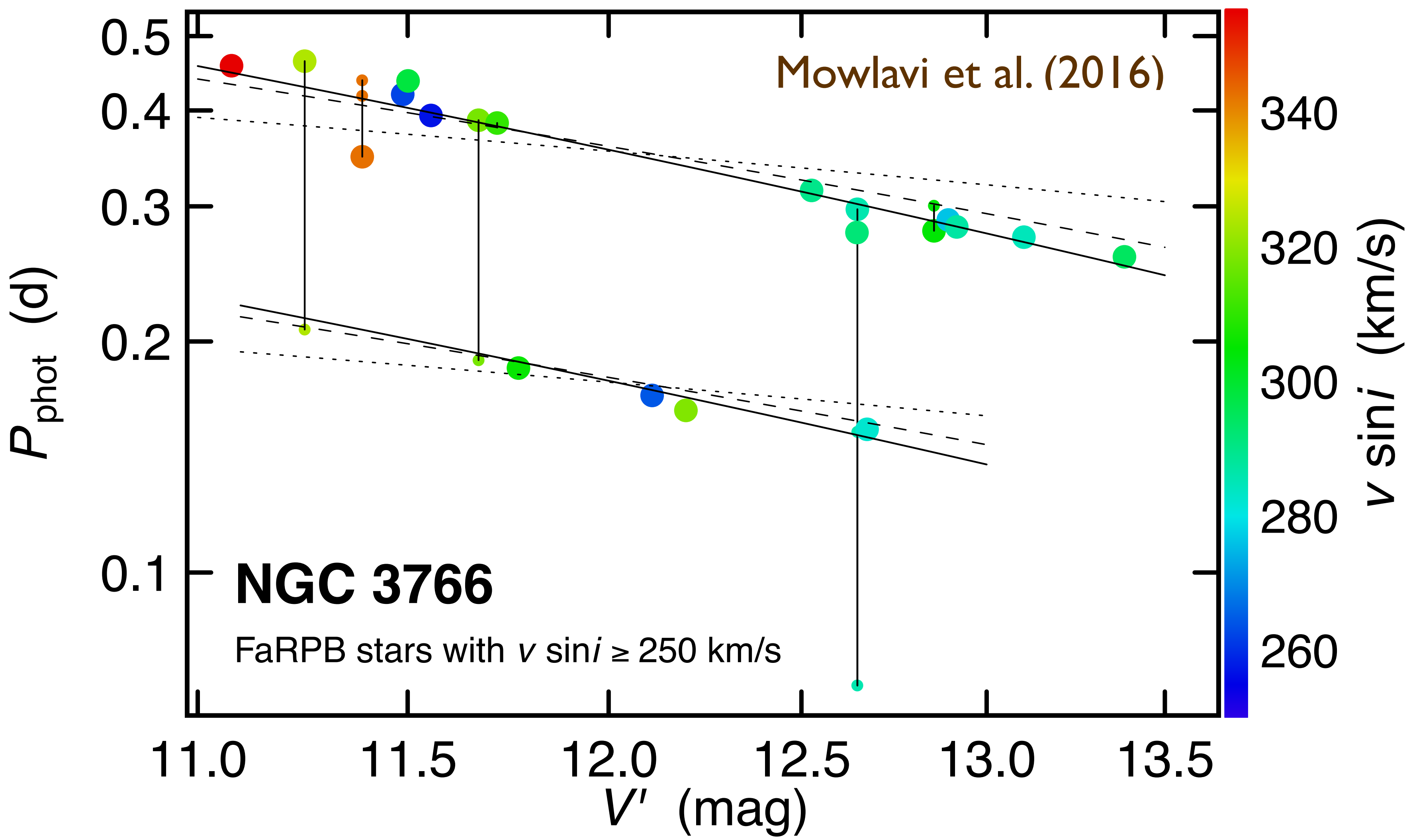
Cepheid-like pulsation mechanism ?

$\alpha \simeq 3.8, \beta \simeq 0.5$

$$P_{\text{puls}} \propto 1/\sqrt{\bar{\rho}} \qquad L \propto M^{\alpha} \qquad R \propto M^{\beta} \qquad V \simeq 0.6 M_{\text{bol}} + \text{cte}$$

$$\rightarrow \log(P_{\text{puls}}) \simeq -\frac{3\beta - 1}{3\alpha} V + \text{cte} \simeq -0.044\, V + \text{cte}$$

(dotted line)



Marginal agreement

Result 2: *New Period-Luminosity relation*

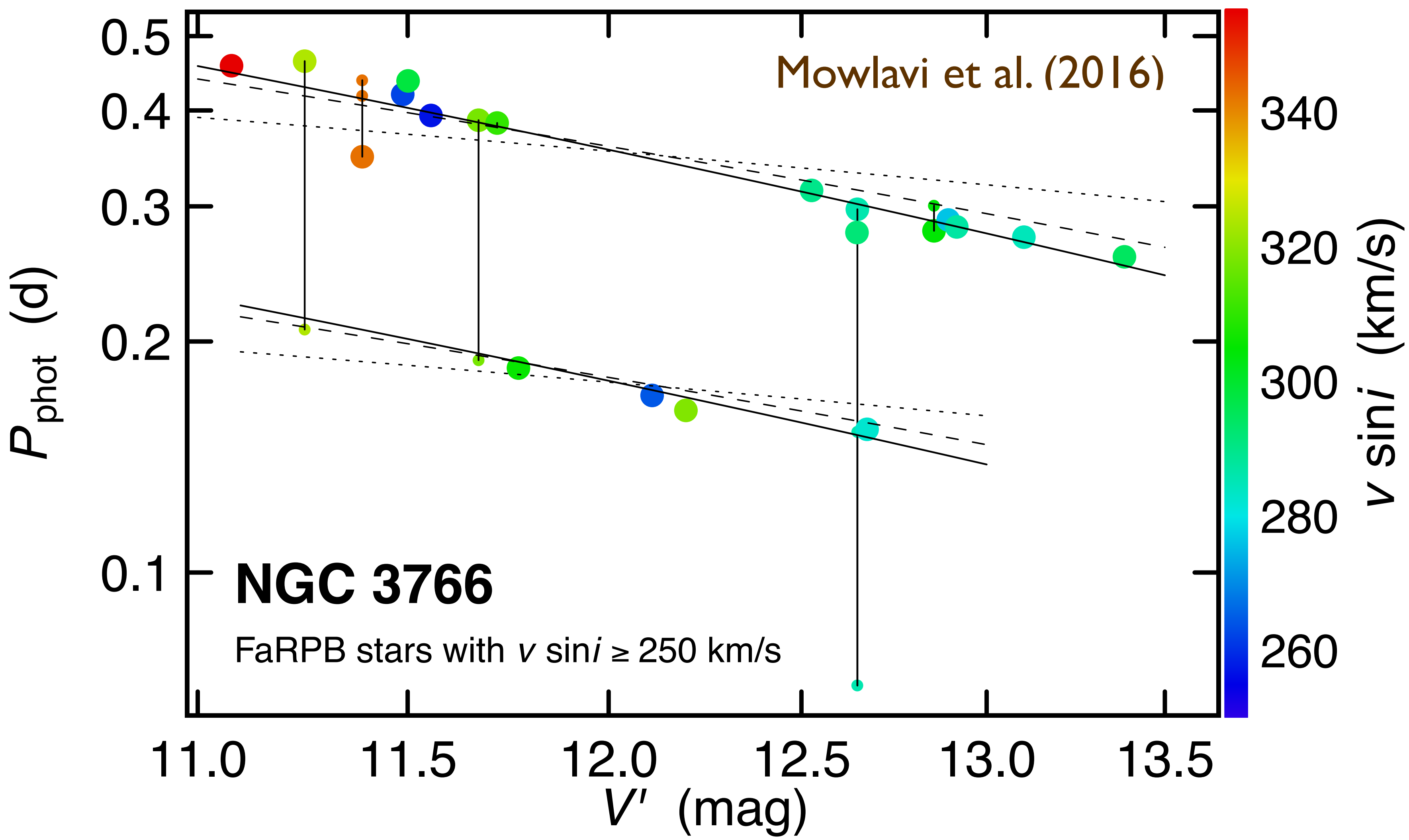
P-L relation

Rotation-related ?

$$P_{\rm rot} = 2\pi R_{\rm eq}/v, \qquad L \propto M^{\alpha} \qquad R \propto M^{\beta} \qquad V \simeq 0.6 M_{\rm bol} + \text{cte}$$

$\alpha \simeq 3.8, \beta \simeq 0.5$

$$\rightarrow \quad \log(P_{\rm rot}) \simeq -\frac{2}{3}\frac{\beta}{\alpha} V + \text{cte} \simeq -0.088\, V + \text{cte}$$ **(dashed line)**



Better agreement

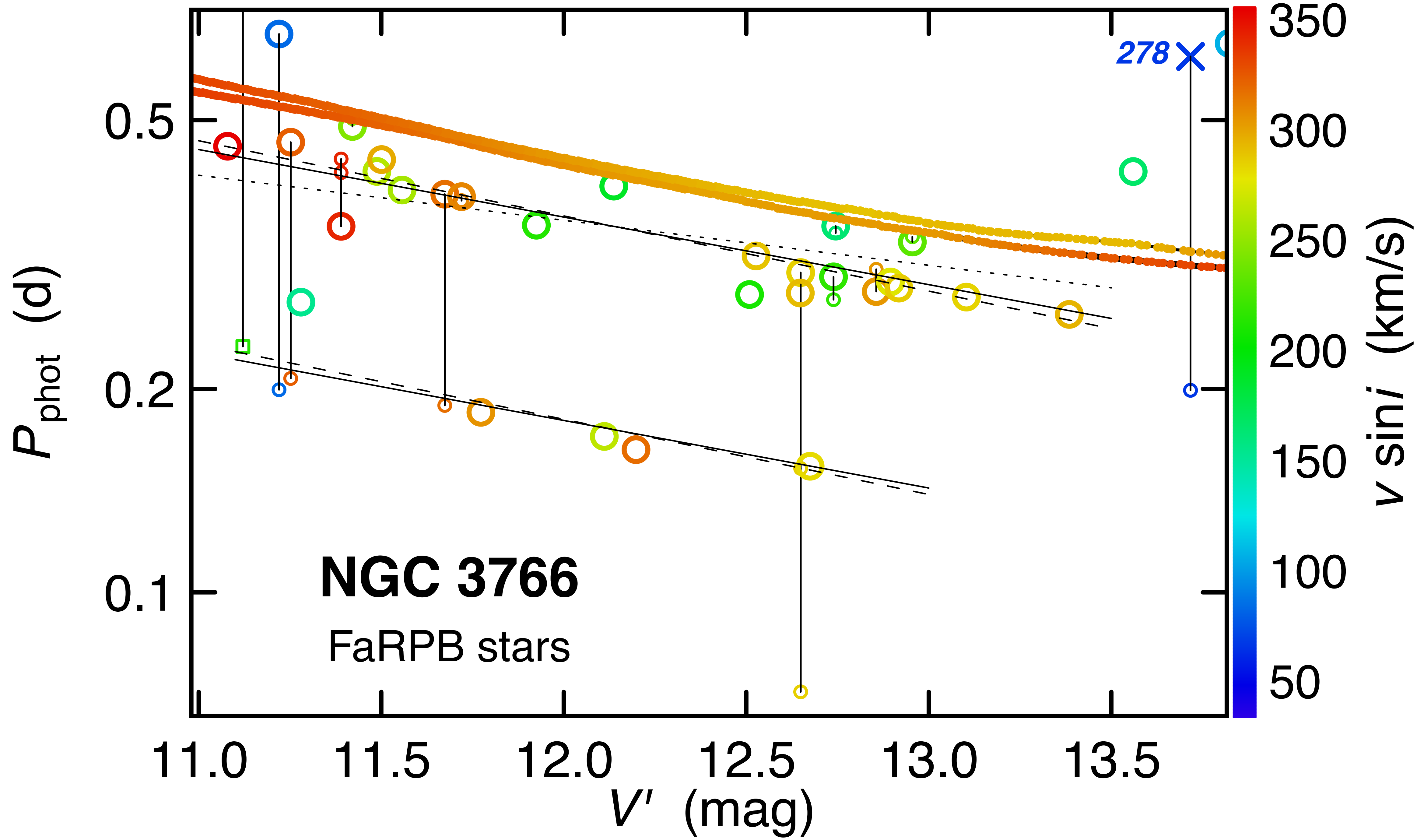
+ factor of 2 between the two sequences

Result 2: *New Period-Luminosity relation*

P-L relation

Rotation rates from model predictions

Geneva isochrones   log(age[y]) : 7.4   d = 2.3 kp
7.2



Result 2: *New Period-Luminosity relation*

Origin: Pulsation in fast rotating stars?

$\omega_{obs} \simeq \omega_{corot} - m\Omega$ (*m*: azimuthal order)

Fast-rotating stars:

$\omega_{corot} << \Omega$ for prograde sectoral modes ($m = -\ell$)

(e.g. Townsend 2005, Salmon et al. 2014)

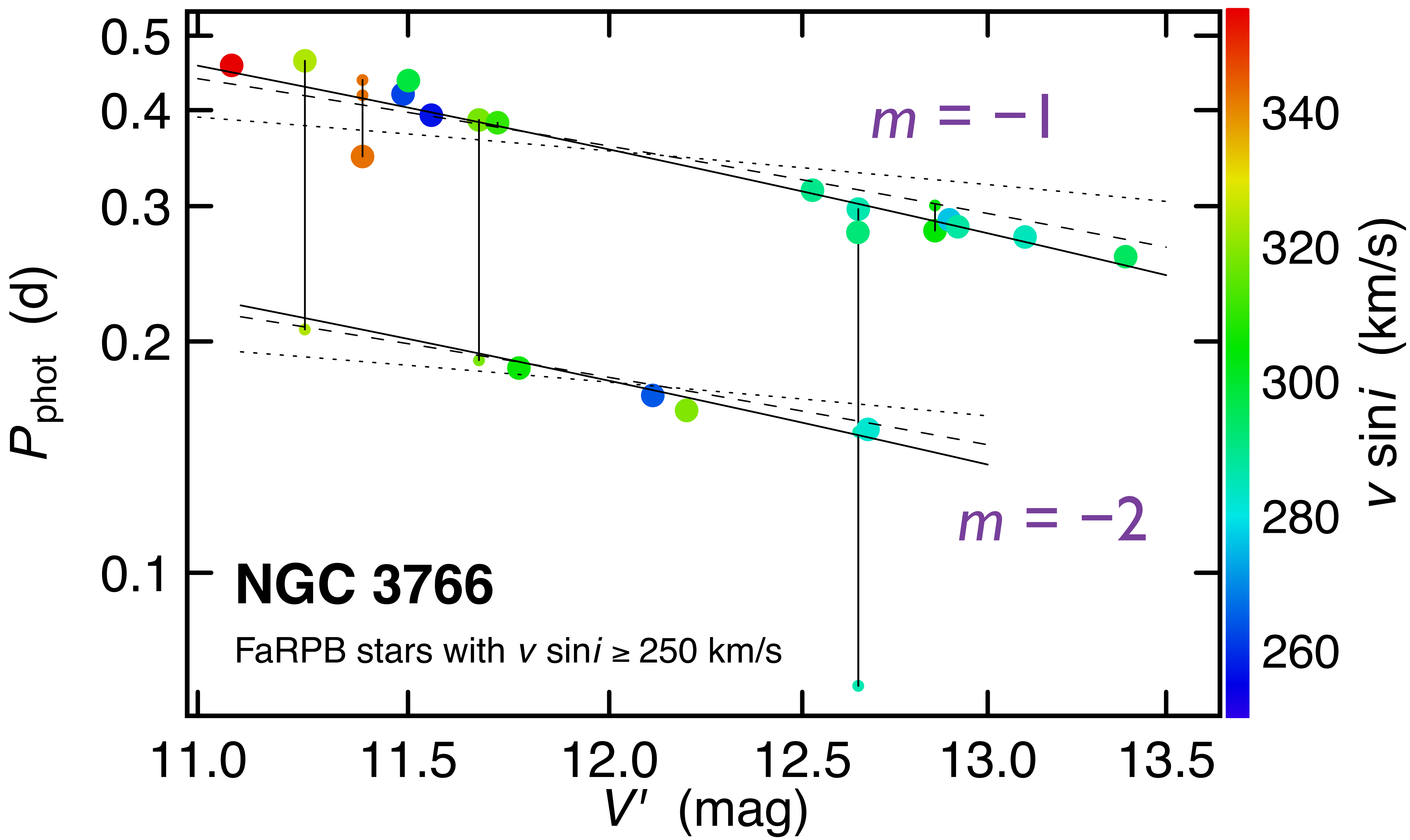
$\rightarrow \omega_{obs} \simeq -m\Omega$

Result 2: *New Period-Luminosity relation*

***P-L* relation**

Origin: Pulsation in fast rotating stars?

prograde sectoral modes



***FaRPB** stars = **Fa**st **R**otating ~~**P**eriodic~~ **B**-type stars*

***P**ulsating*

Conclusions

- All new variables with **P < 0.5 d are fast rotators**
  → **FaRPB stars** (**F**ast **R**otating **P**ulsating **B-**type) stars

- They obey a new **P-L relation**
  → 2 sequences (maybe 3)
  Most probably prograde sectoral modes at ℓ = 1 and 2

Details in Mowlavi et al. (2016, submitted)