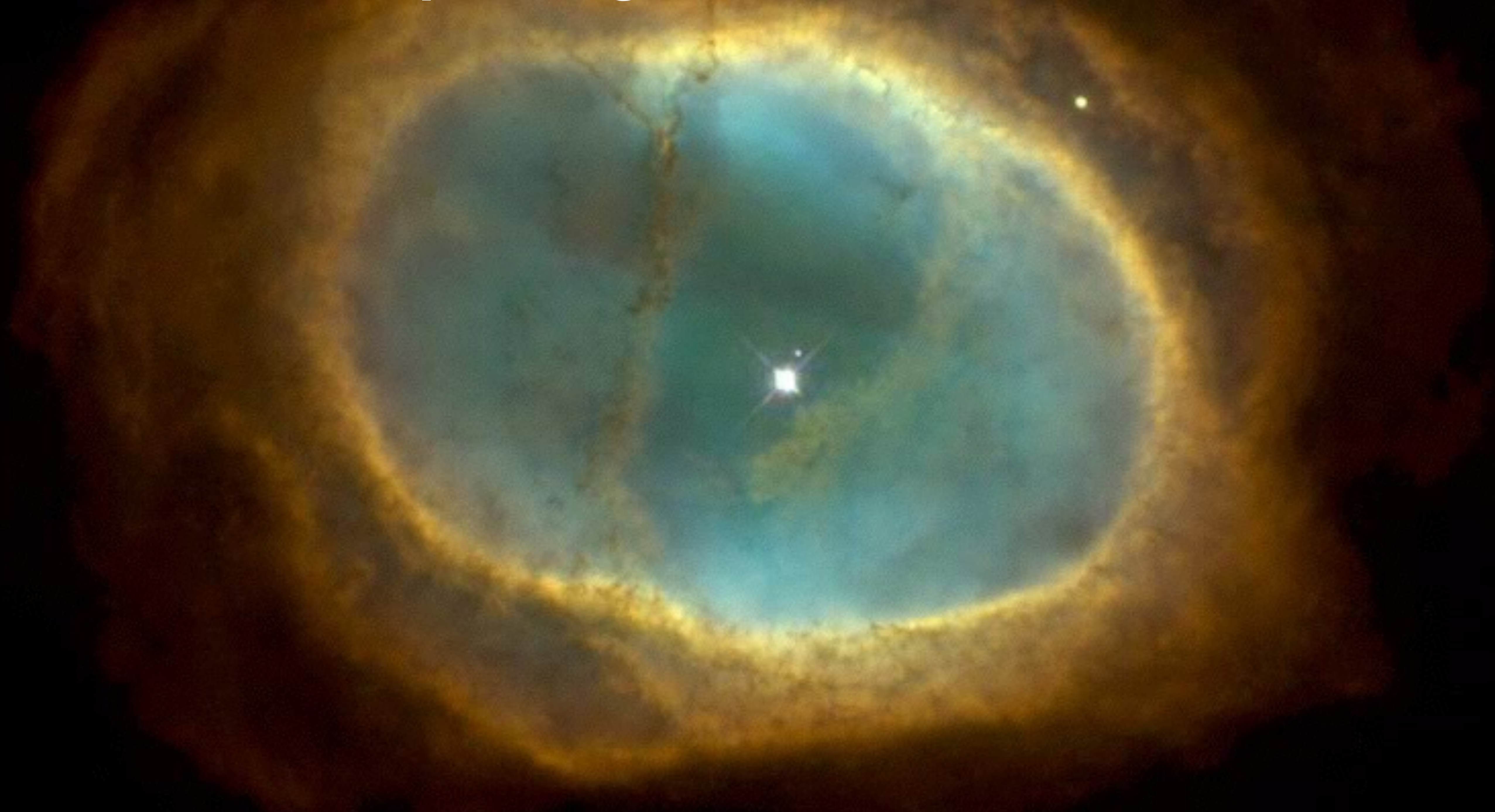
Search for binary central stars of planetary nebulae: exploiting archival data



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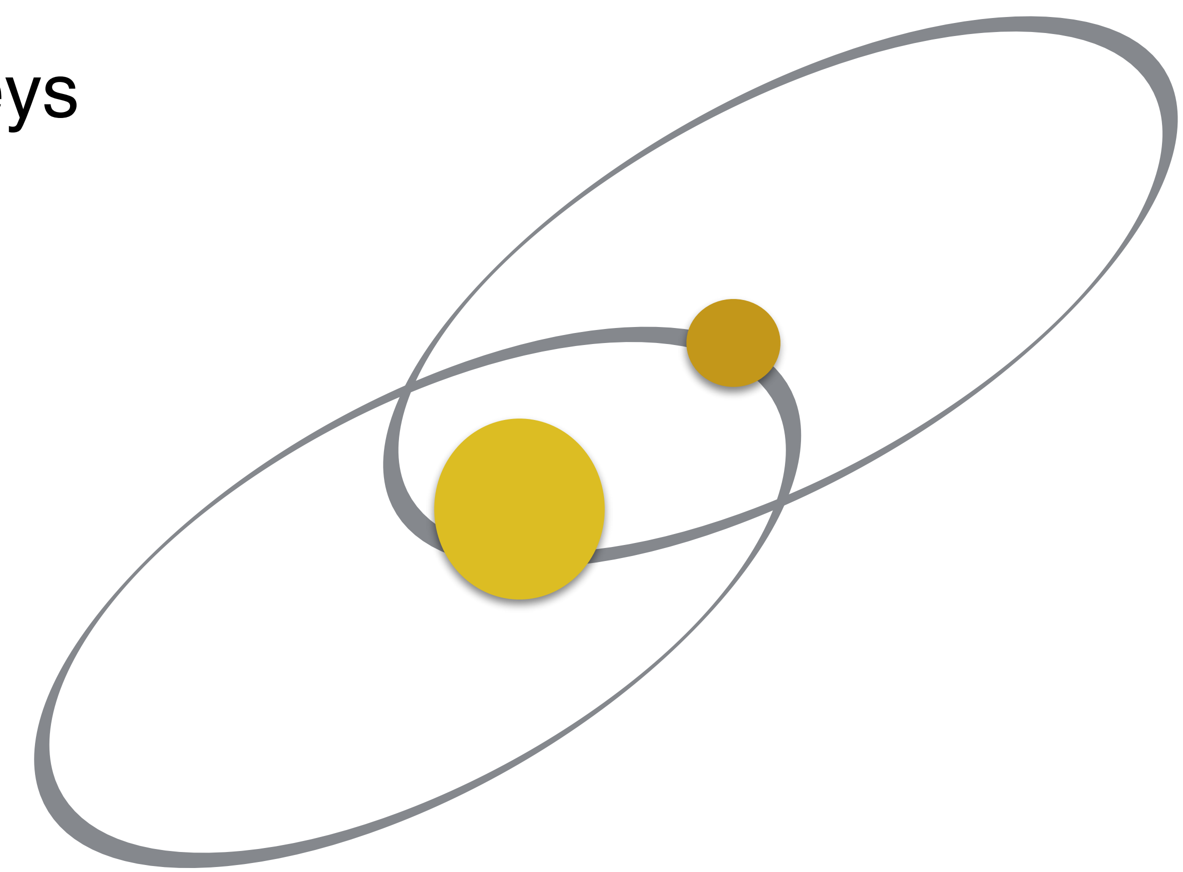
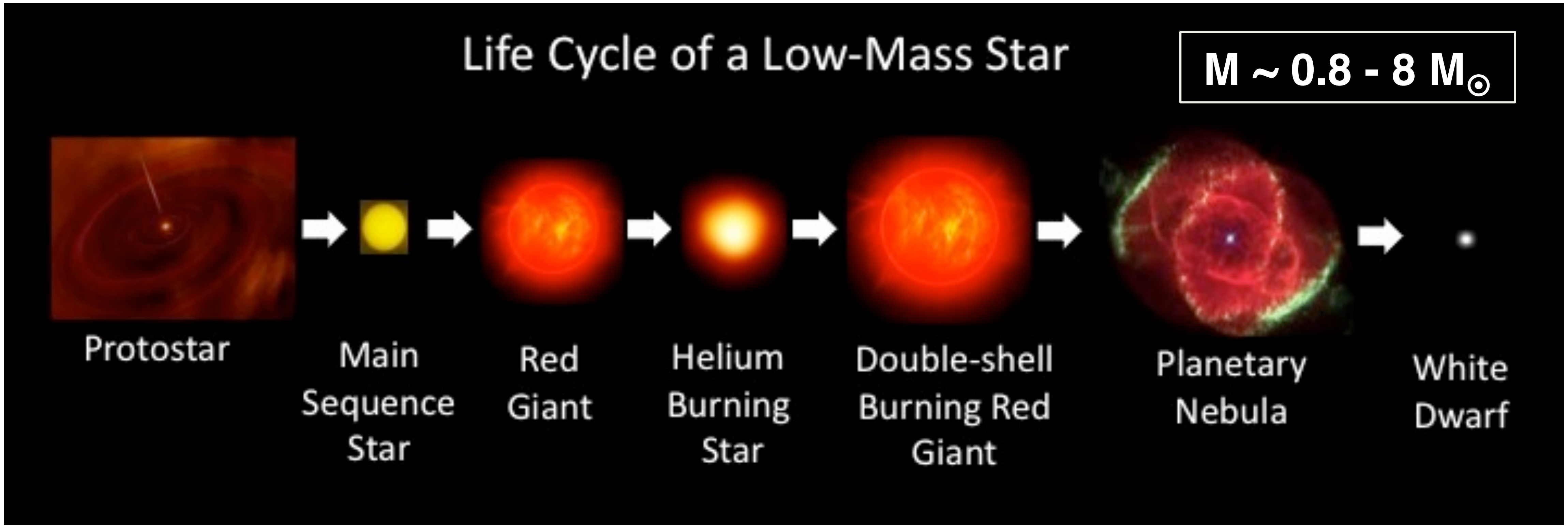
INSTITUTO FISICA y Astronomía

Outline

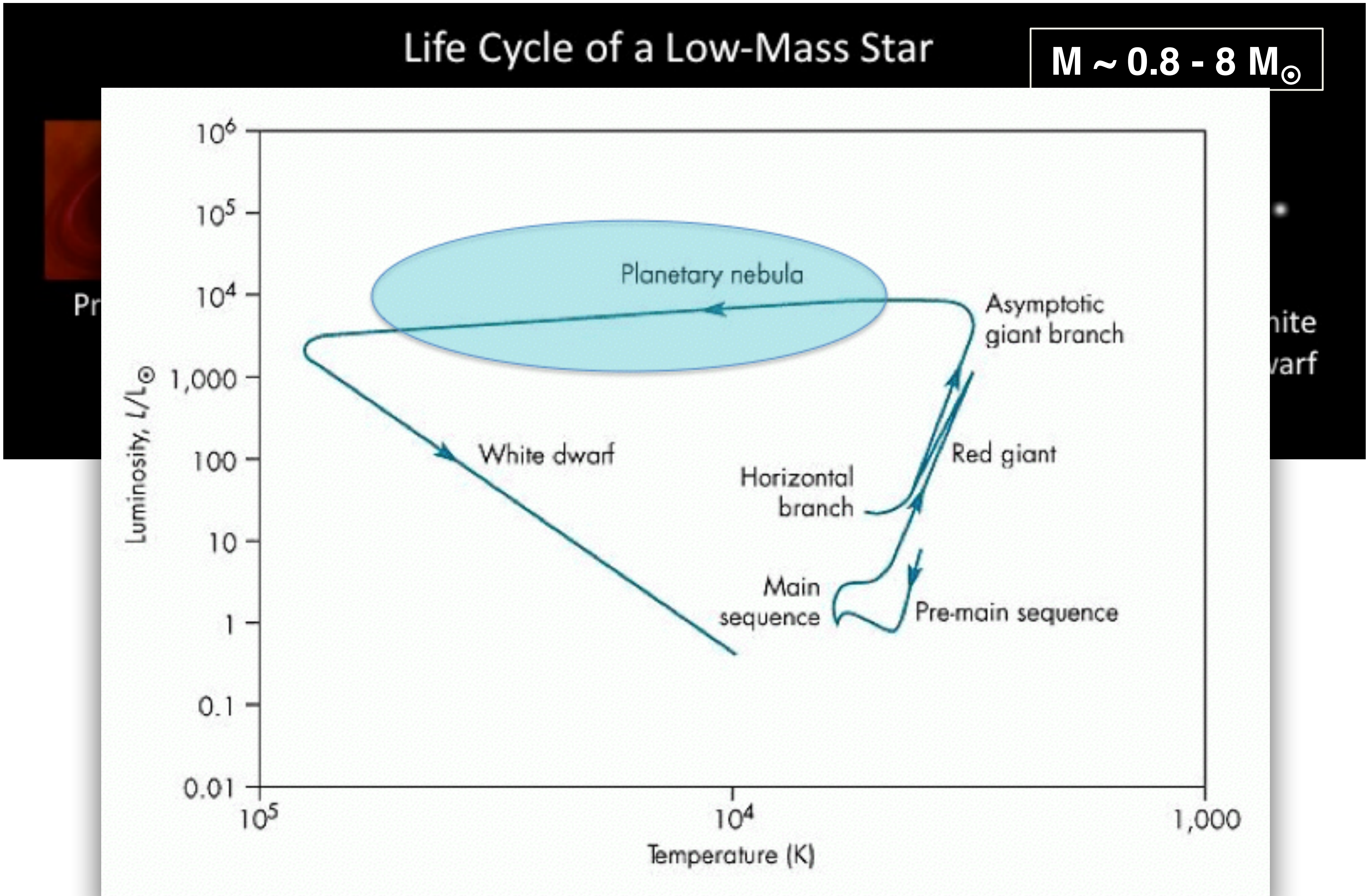
- Planetary Nebulae: how, when and why?
  - Morphology of PNe: the role of binary central stars
- A new an updated catalogue of galactic CSPNe
- Searching for binary central stars in archival data
  - Variability in photometric surveys
  - Infrared excess
- Summary



Formation of PNe



Formation of PNe



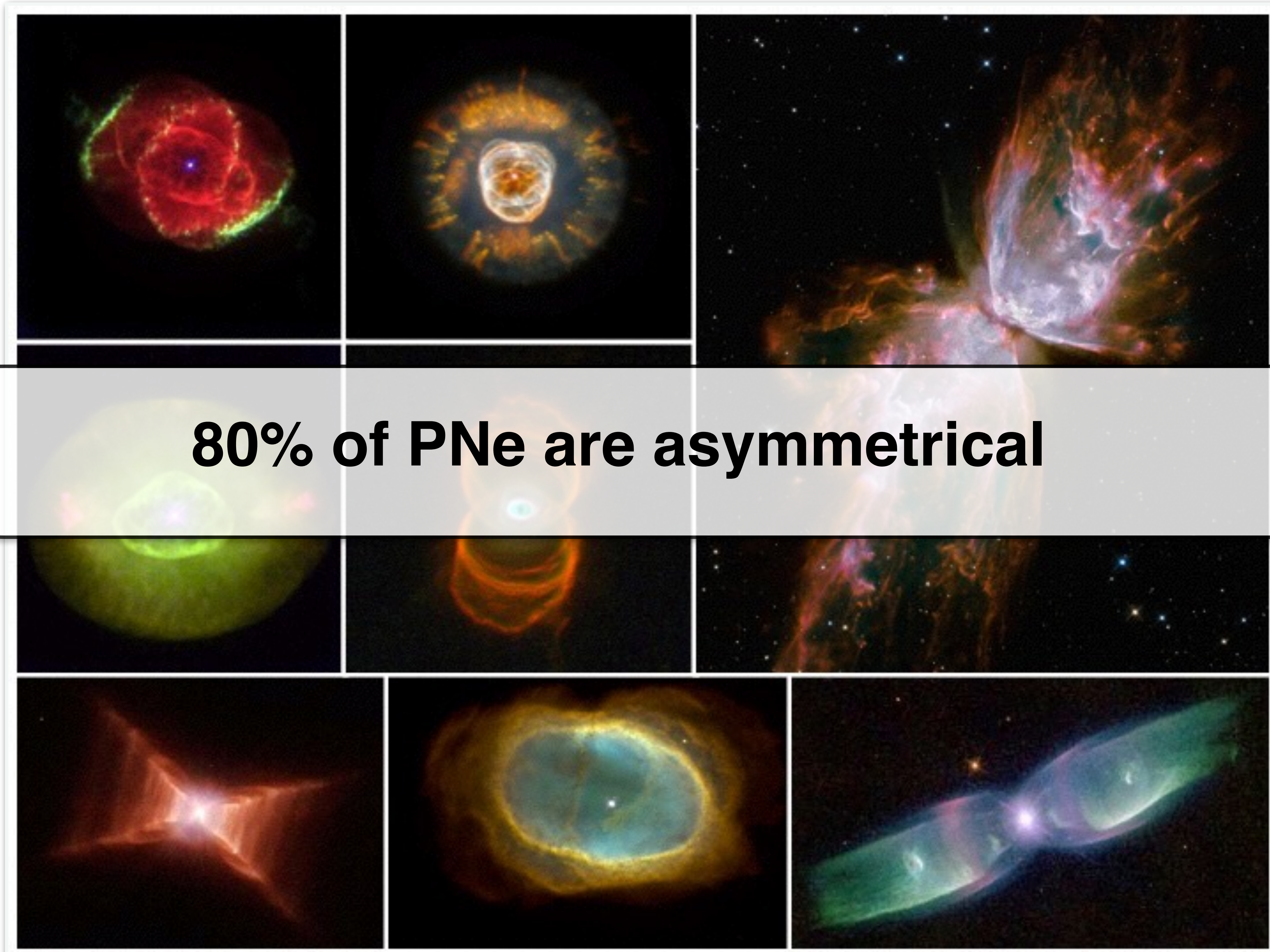
Formation of PNe

What theory says:

What we (sometimes) observe:

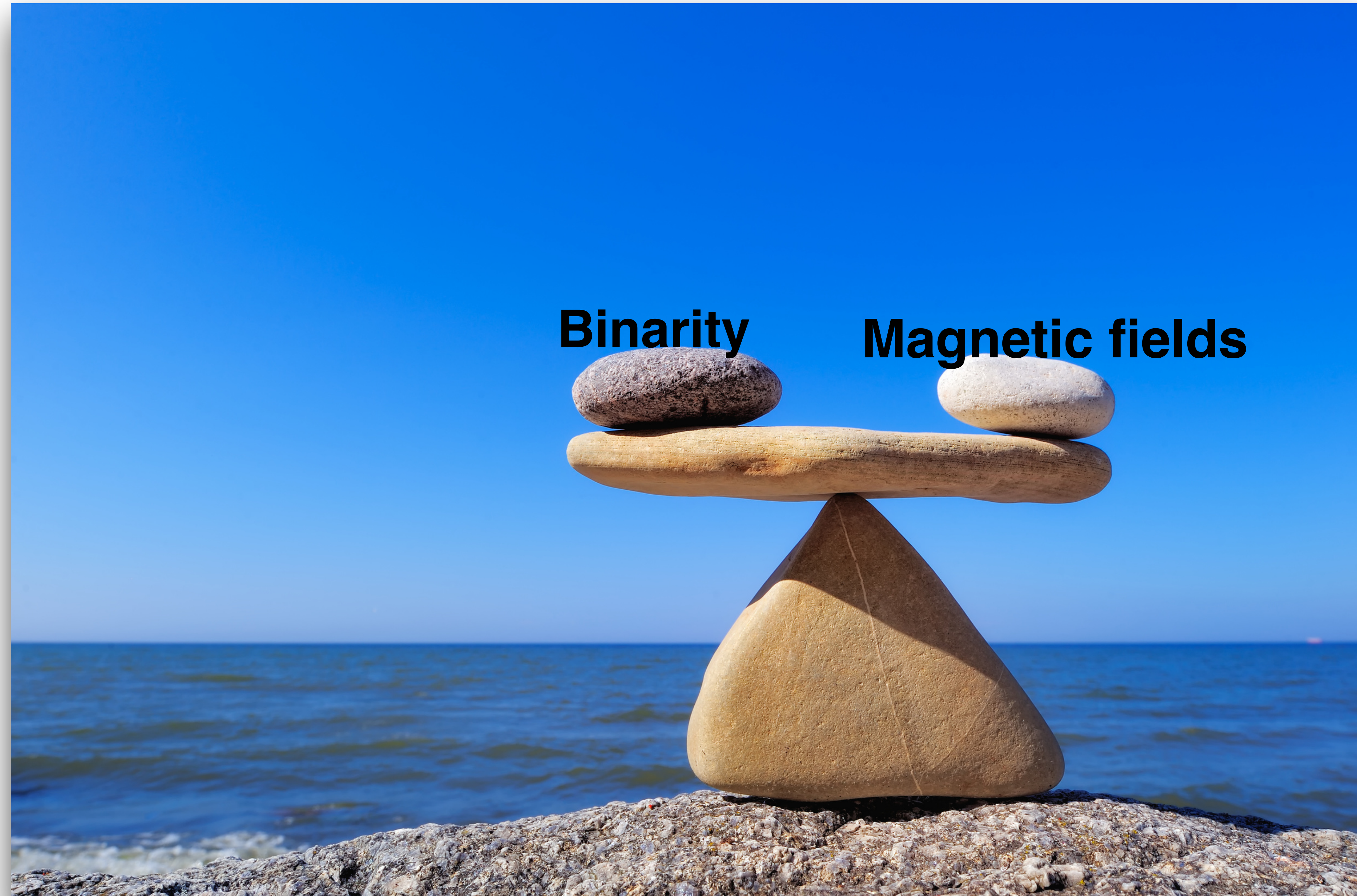
BUT WE ALSO OBSERVE…

Formation of PNe

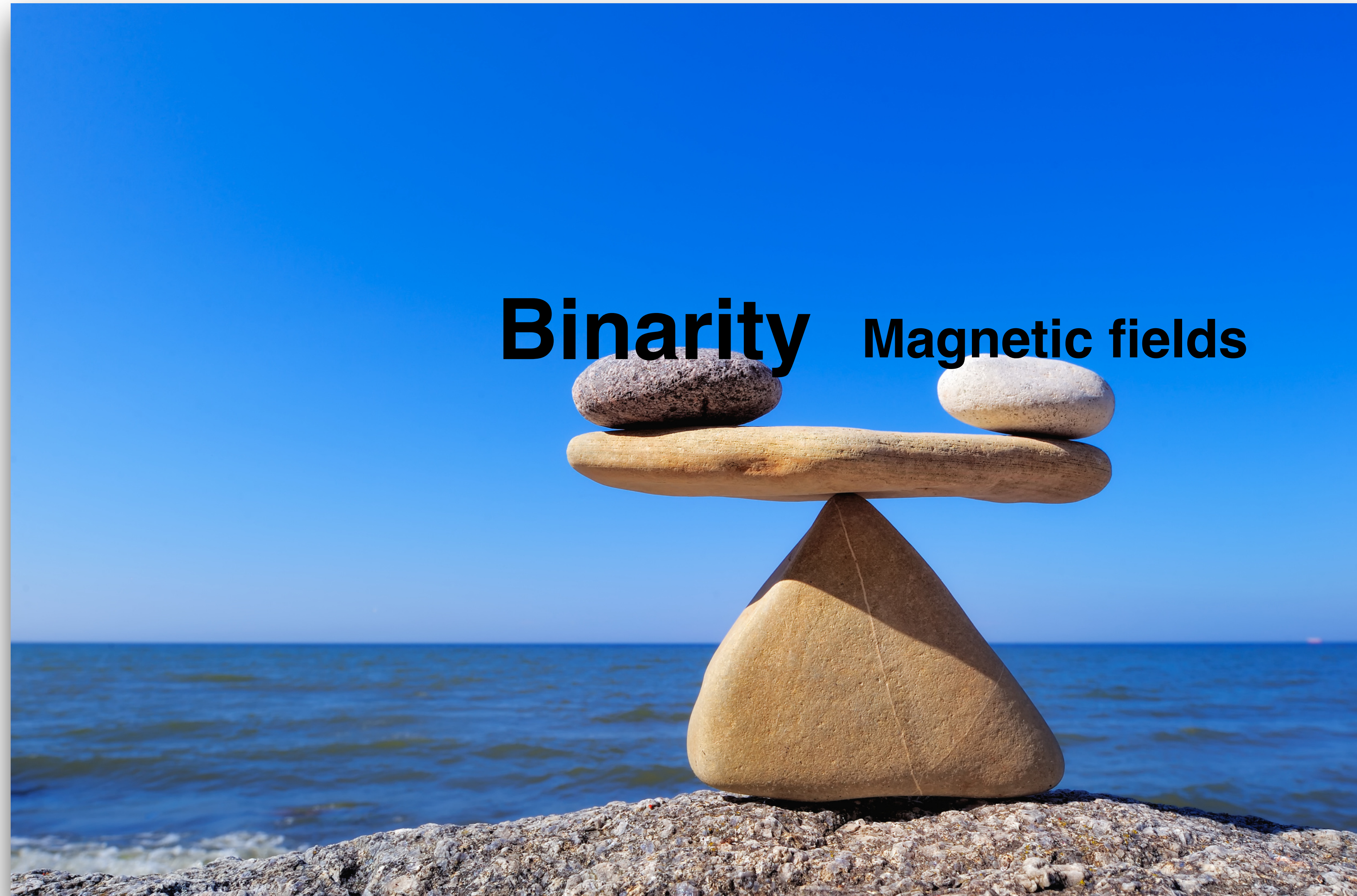


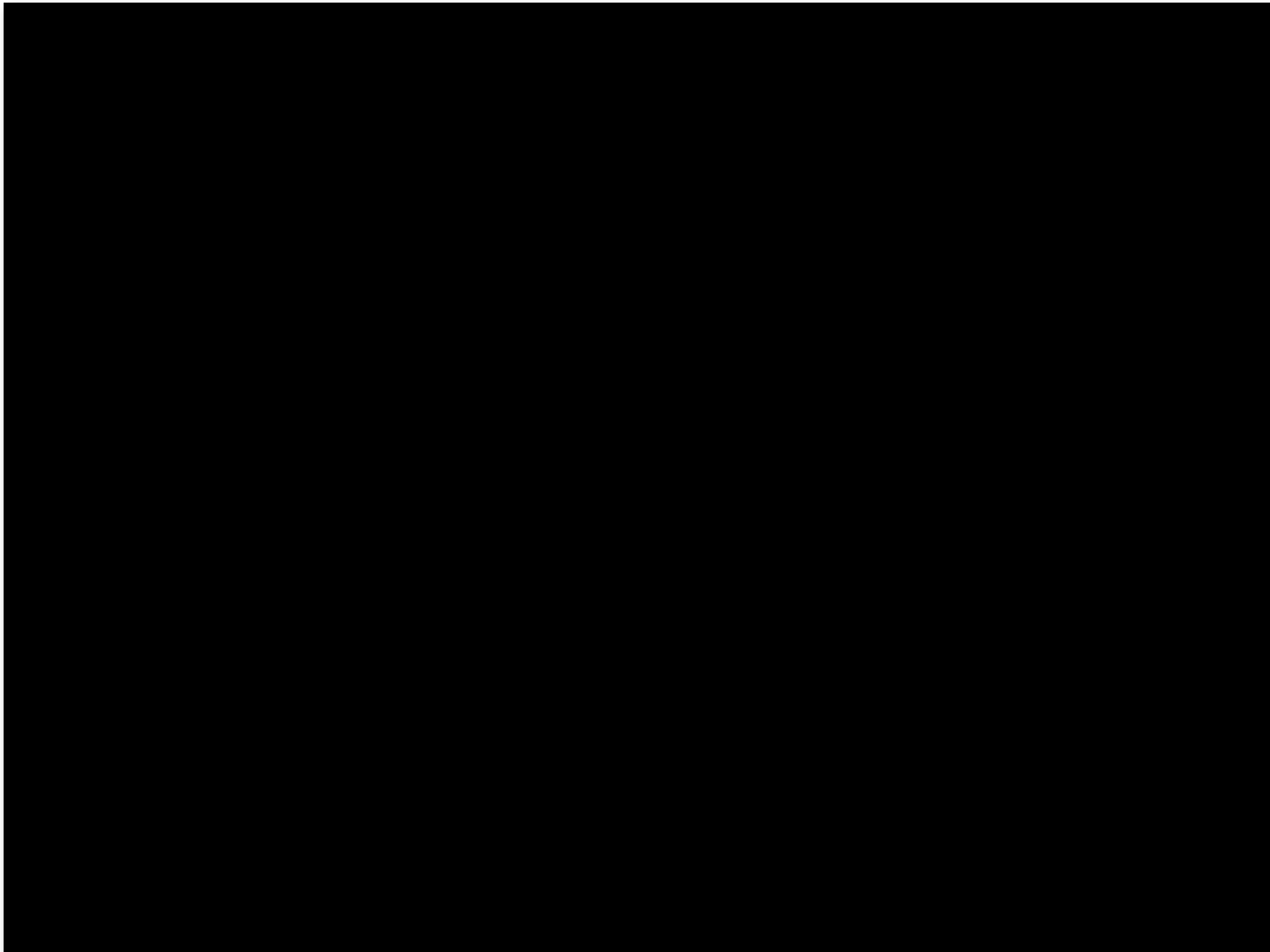
80% of PNe are asymmetrical

Formation of PNe



Formation of PNe

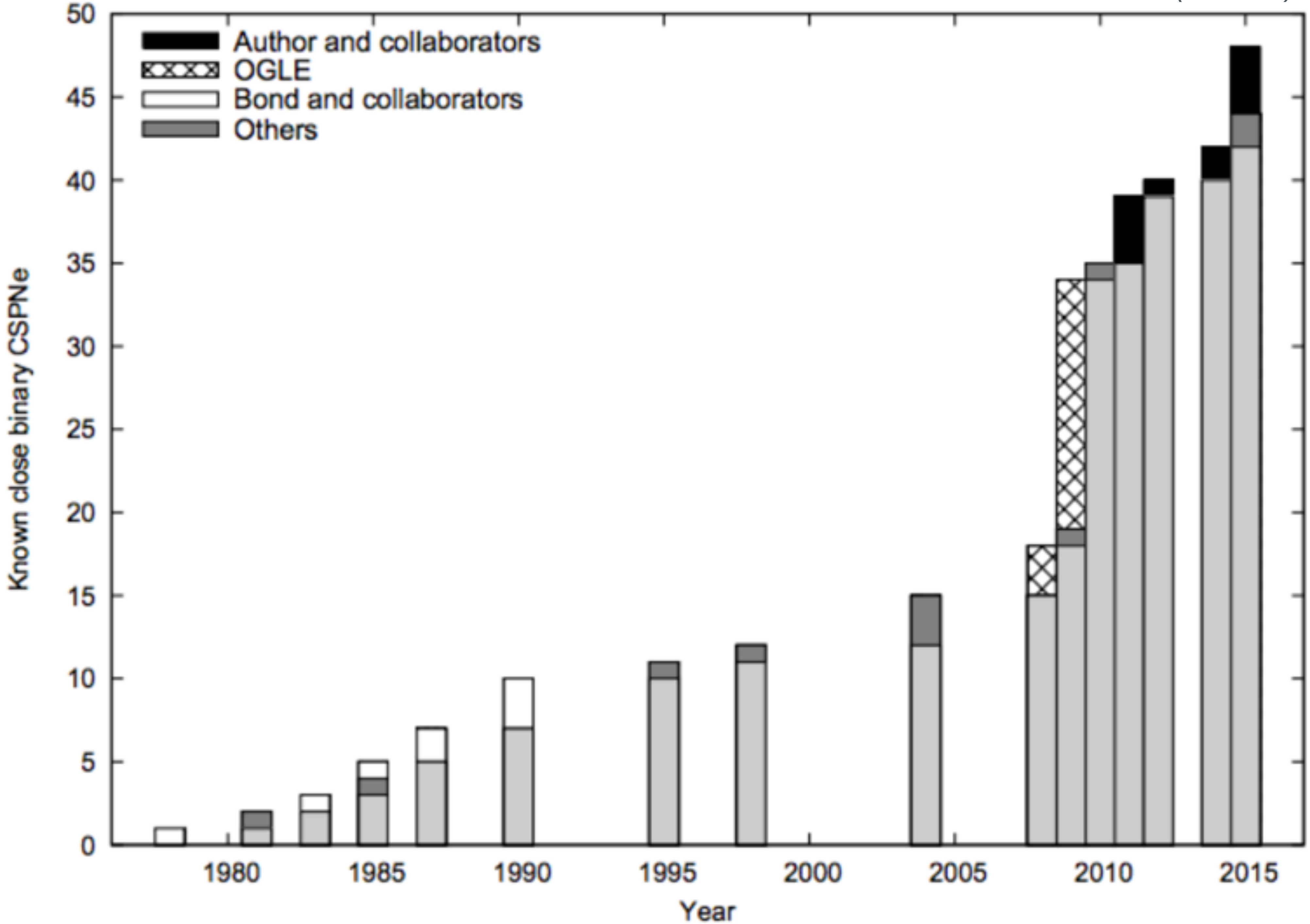




Credits: *Thomas Goertel, Space Telescope Science Institute*

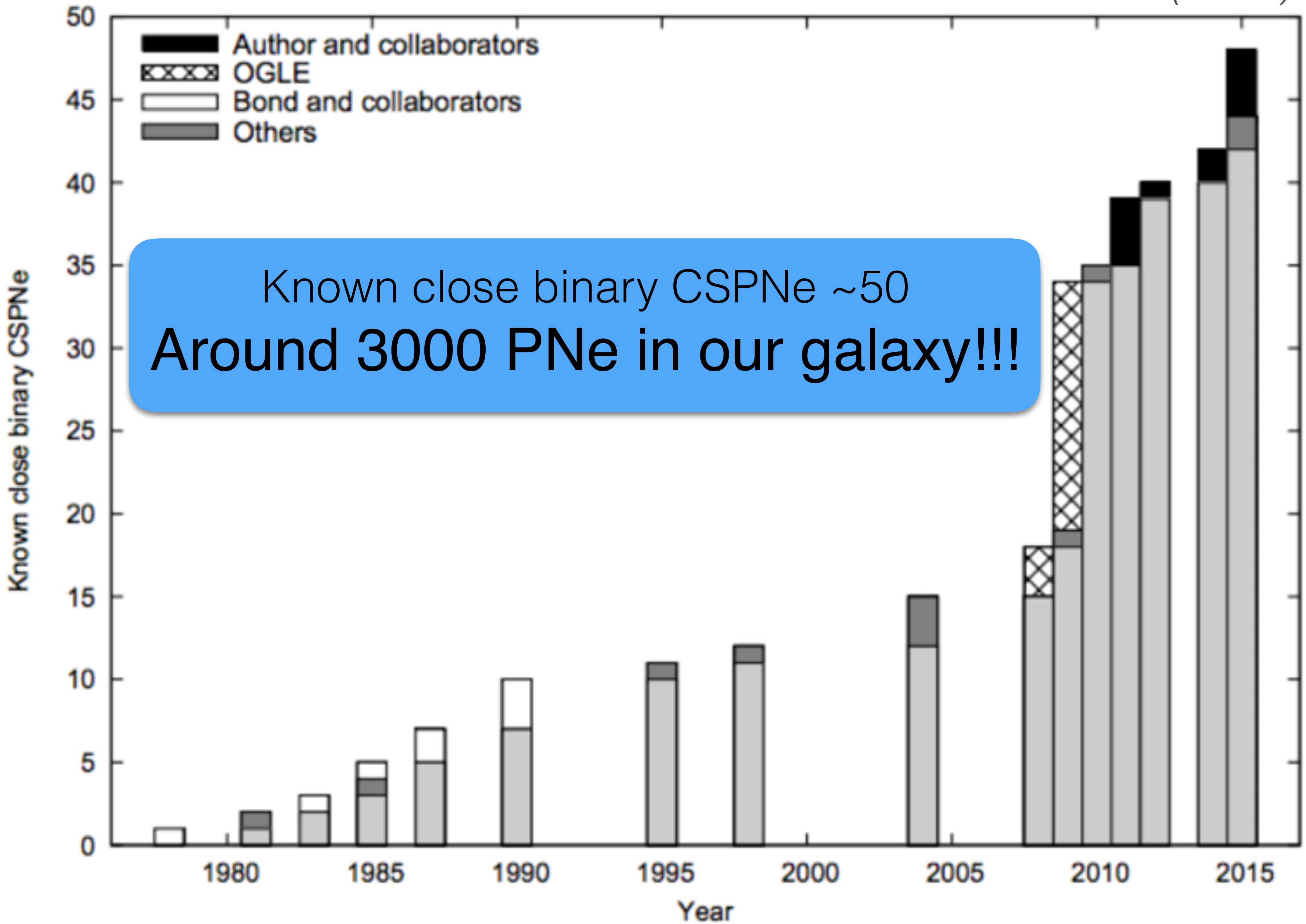
Binarity in PNe

Jones (2015)



Binarity in PNe

Jones (2015)



Known close binary CSPNe ~50

Around 3000 PNe in our galaxy!!!

A new Galactic PNe Catalogue

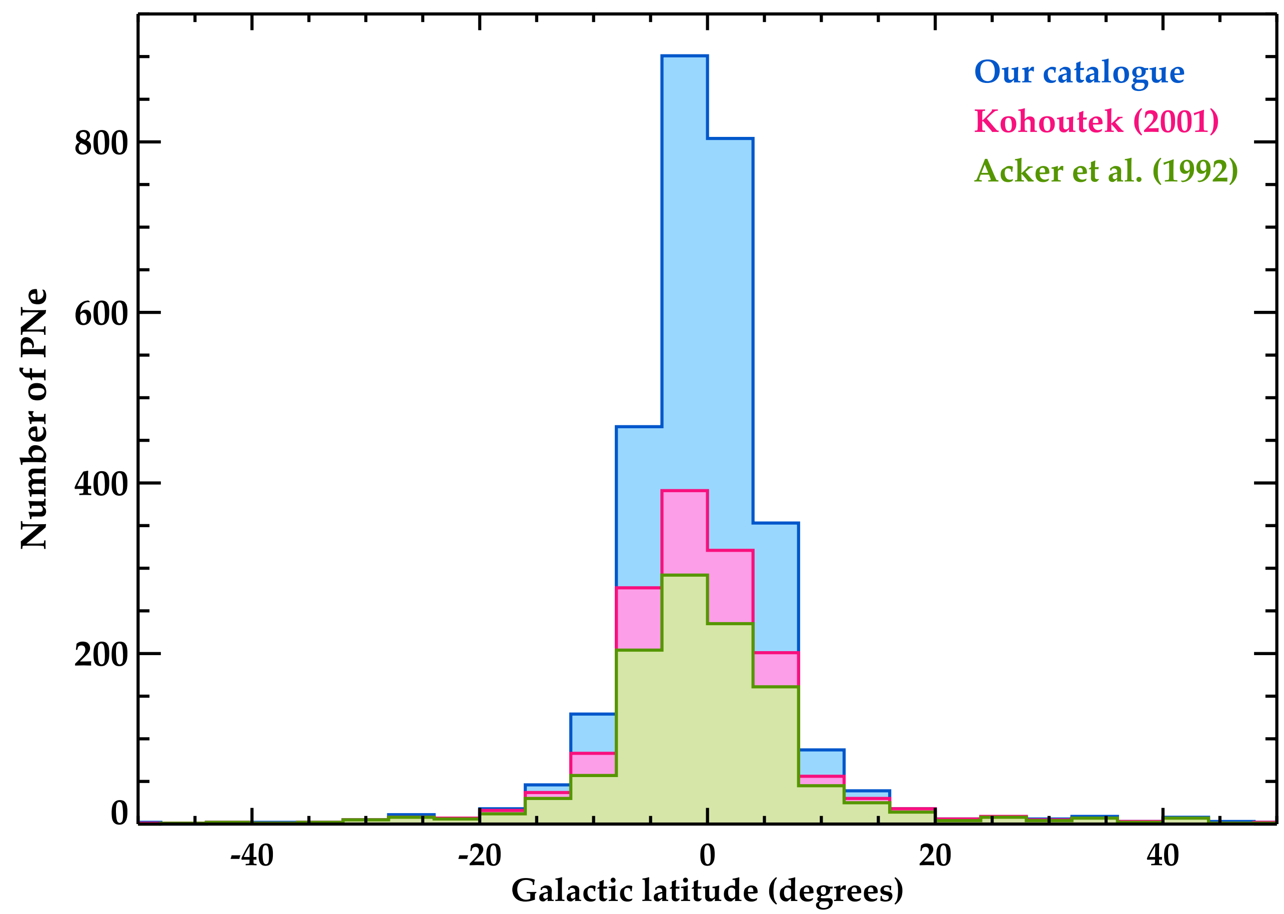
- Previous catalogues of PNe:
  - First (known) catalogue of Galactic PNe: **1063** — Perek & Kohoutek (1967)
  - Strasbourg-ESO Catalogue of Galactic PNe: **1143** — Acker et al. (1992)
  - Version 2000 of the Catalogue of Galactic PNe: **1510** — Kohoutek (2001)

- Our Catalogue:

We used **TOPCAT**, an interactive VO tool, and gathered data from 30 already published catalogues and works. Finally:

2951 Galactic PNe

+ 121 misclassified PNe



A new Galactic PNe Catalogue

Catalogue of Galactic PNe

New and updated catalogue of Galactic PNe

Home | Data retrieval | News | Documentation | Coverage Map | Help-Desk

RA (?)	DEC (?)	Radius (?)	
00 : :	00 : :	180 : :	Search Reset

all results | default verb. | (Maximum Search Radius allowed: 180 degrees)

[-] Hide additional search fields

Name (?)	
Flag_PN (?)	---

SVOCat

- List of rejected PN candidates (previously misclassified).

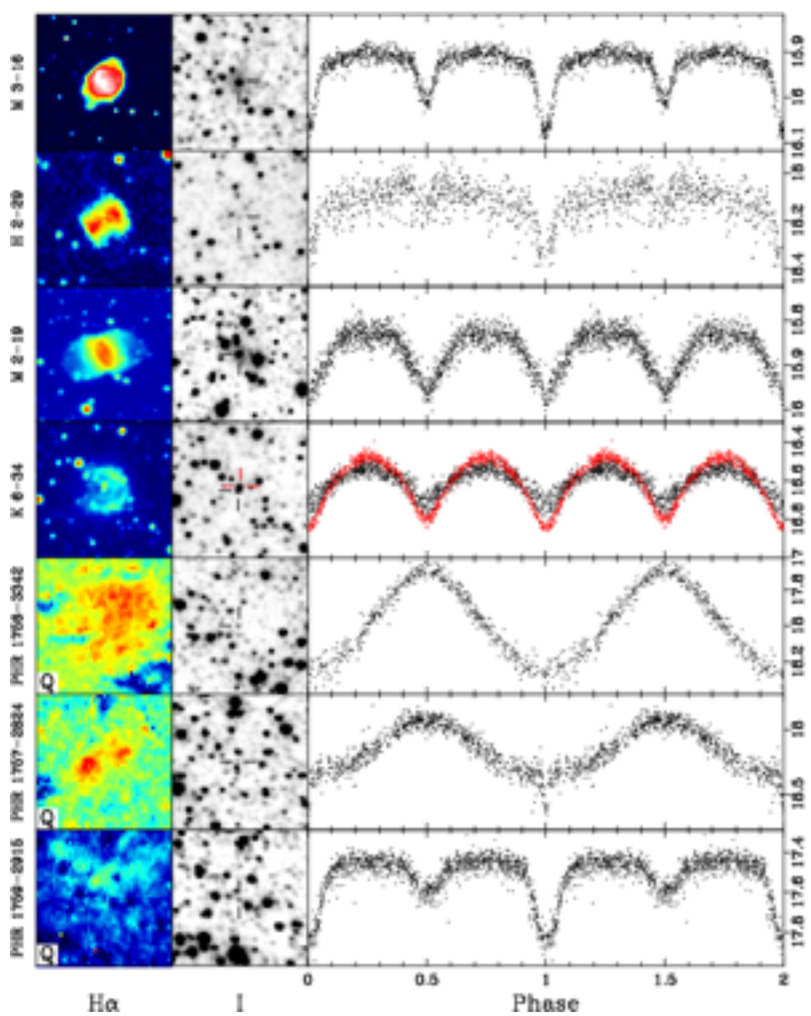
2951 data found.

Δ (?) (arcsec)	RA (J2000) (deg)	DEC (J2000) (deg)	RA (J2000) (hh:mm:ss)	DEC (J2000) (hh:mm:ss)	GAL_LONG (?) (deg)	GAL_LAT (?) (deg)	PNG (?)	Name (?)	Lum [Malkov] (?) (Lsun)
59511.33	9.31679	-13.71628	00:37:16.03	-13:42:58.61	108.371	-76.1858	108.4-76.1	BoBn 1	3700
59952.75	11.76390909	-11.8719284	00:47:03.34	-11:52:18.94	118.8646	-74.709	118.8-74.7	NGC 246	
76613.32	18.0954	11.3936	01:12:22.90	11:23:36.96	131.13	-51.1445		PG 0109+111	
109284.72	337.410588	-20.837122	22:29:38.54	-20:50:13.64	36.1612	-57.1179	036.1-57.1	NGC 7293	77
111609.66	353.97221	30.46844	23:35:53.33	30:28:06.38	104.2076	-29.6416	104.2-29.6	Jn 1	
112639.97	29.49612	10.94394	01:57:59.07	10:56:38.18	148.1113	-48.6473		GR 0155+10	
135744.73	324.22071	12.78861	21:36:52.97	12:47:19.00	66.778	-28.2022	066.7-28.2	NGC 7094	
140943.69	322.49742	12.17431	21:29:59.38	12:10:27.52	65.022	-27.3113	065.0-27.3	Ps 1	3300
150596.47	319.625	12.0267	21:18:30.00	12:01:36.12	62.9330580069826	-25.2133682993338		Fr 2-16	
151849.00	327.79592259	28.86398793	21:51:11.02	28:51:50.36	81.8738	-19.2931		BD+28 4211	
155594.95	351.4733	42.535	23:25:53.59	42:32:06.00	106.5584	-17.6006	106.5-17.6	NGC 7662	6200
162387.47	316.045321	-11.363406	21:04:10.88	-11:21:48.26	37.7623	-34.5715	037.7-34.5	NGC 7009	6500
166663.98	319.217808	24.147719	21:16:52.27	24:08:51.79	72.6626	-17.1519	072.7-17.1	A 74	
167717.95	323.87242	31.69592	21:35:29.38	31:41:45.31	81.296	-14.9127	081.2-14.9	A 78	

Aller et al. (2016, in prep.)

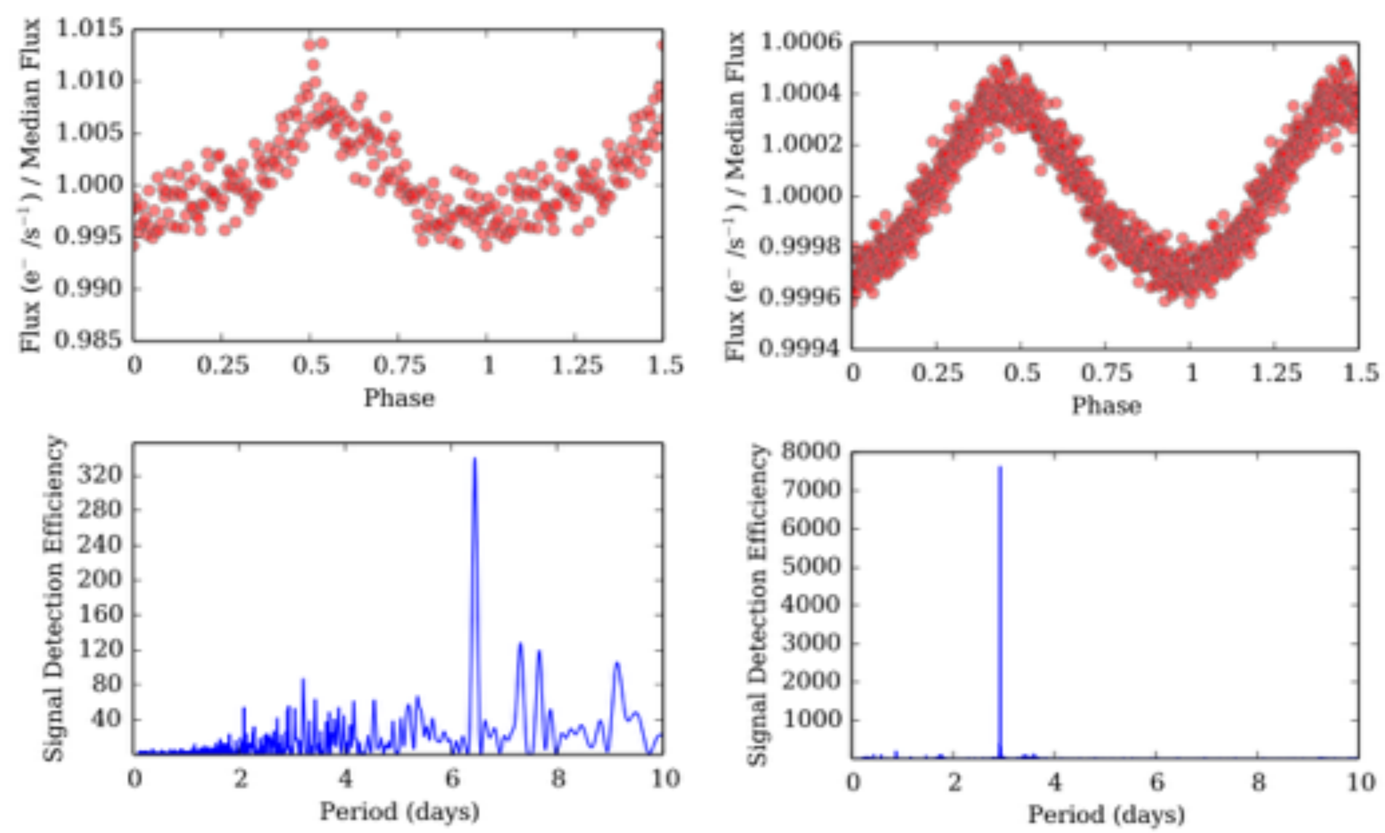
Exploiting archival data

- **OGLE** (Optical Gravitational Lensing Experiment):
  - Extensive I-band photometric database (LCO)
  - Limiting magnitude I ~ 20



Miszalski et al. (2009)

- **Kepler**:
  - Space mission (high photometric precision)
  - Limiting magnitude V ~ 16



De Marco et al. (2015)

Exploiting archival data

- ASAS (All Sky Automated Survey):
  - Two observing stations (LCO and Maui)
  - Monitoring stars brighter than V ~ 14
- OMC (Optical Monitoring Camera):
  - Monitoring stars brighter than V ~ 18
- SuperWASP (Wide Angle Search for Planets):
  - Two observatories (ING and SAAO)
  - Magnitude range V ~ 7-15
- Catalina Sky Surveys
  - Three telescopes (2 Arizona + 1 Australia)
  - Limiting magnitude V ~ 21

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Las Campanas Observatory (Chile)

Pojmanski (2002)

Exploiting archival data

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Integral observatory esa

Mas-Hesse et al. (2003)

Exploiting archival data

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  - Two observing stations (LCO and Maui)
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- OMC (Optical Monitoring Camera):
  - Monitoring stars brighter than V ~ 18
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  - Two observatories (ING and SAAO)
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- Catalina Sky Surveys
  - Three telescopes (2 Arizona + 1 Australia)
  - Limiting magnitude V ~ 21

SuperWASP- South observatory
Pollacco et al. (2006)

Exploiting archival data

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  - Two observing stations (LCO and Maui)
  - Monitoring stars brighter than V ~ 14
- OMC (Optical Monitoring Camera):
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  - Two observatories (ING and SAAO)
  - Magnitude range V ~ 7-15
- **Catalina Sky Surveys**
  - Three telescopes (2 Arizona + 1 Australia)
  - Limiting magnitude V ~ 21

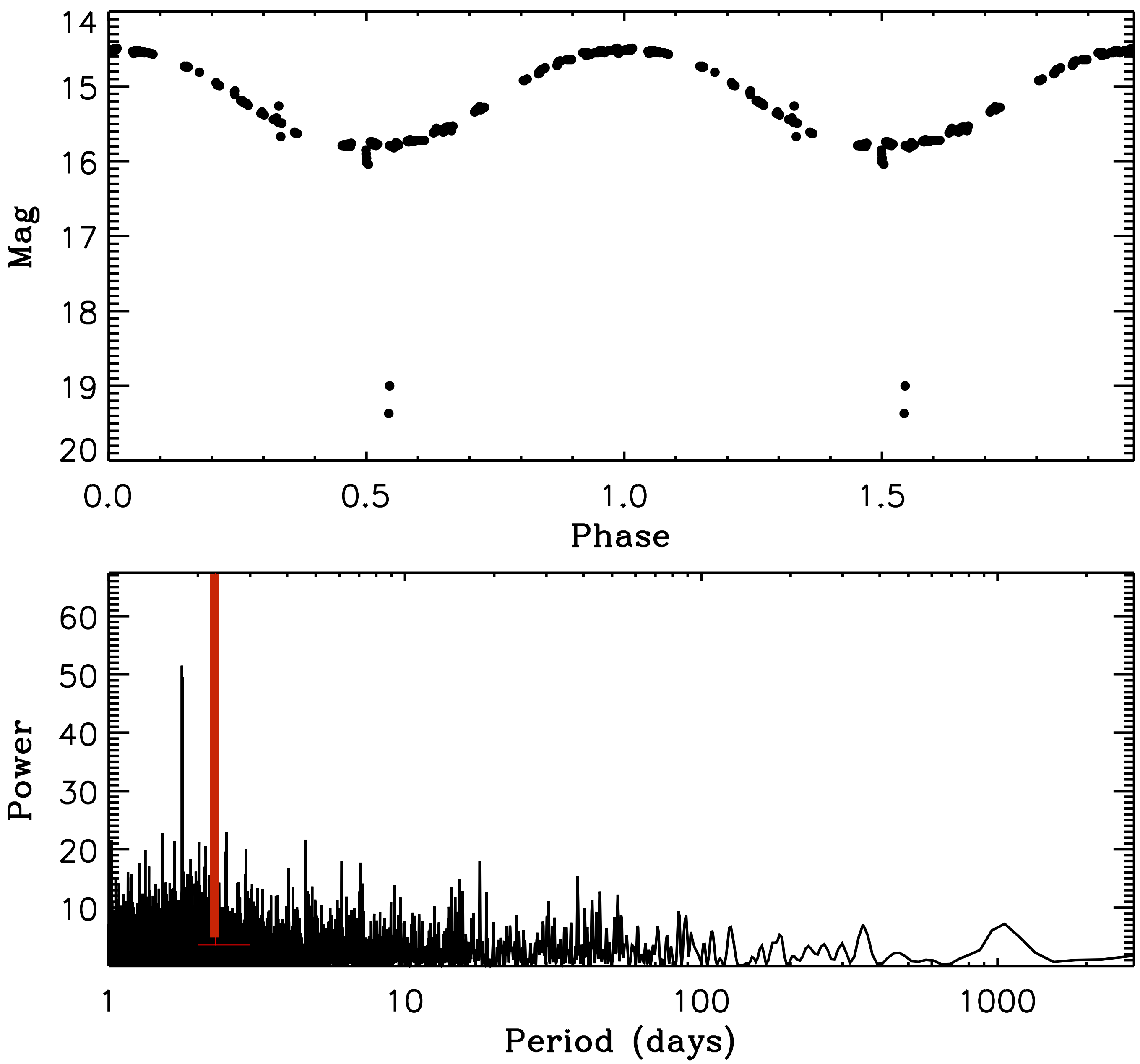
Catalina Sky Survey, University of Arizona

Drake et al. (2009)

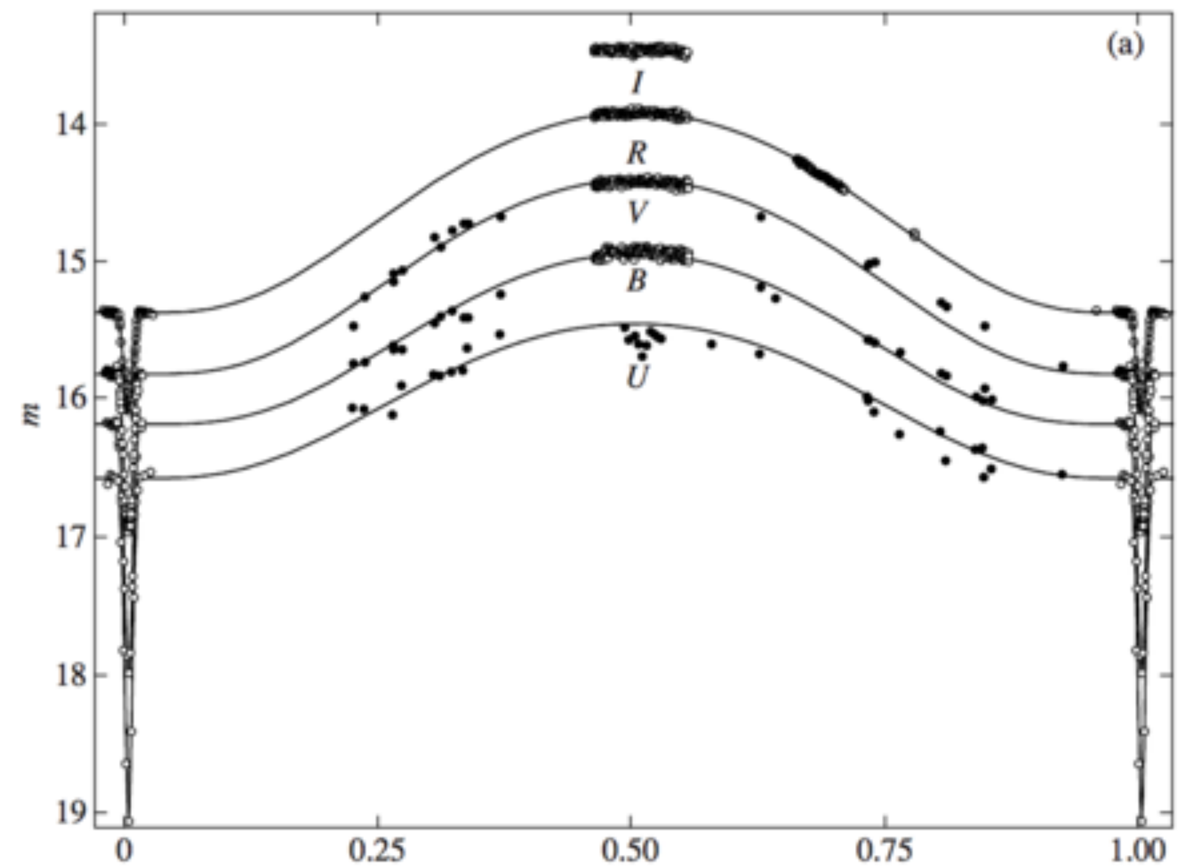
Preliminary results (known binaries)

Be UMa

This work



Shimanskii et al. (2008)

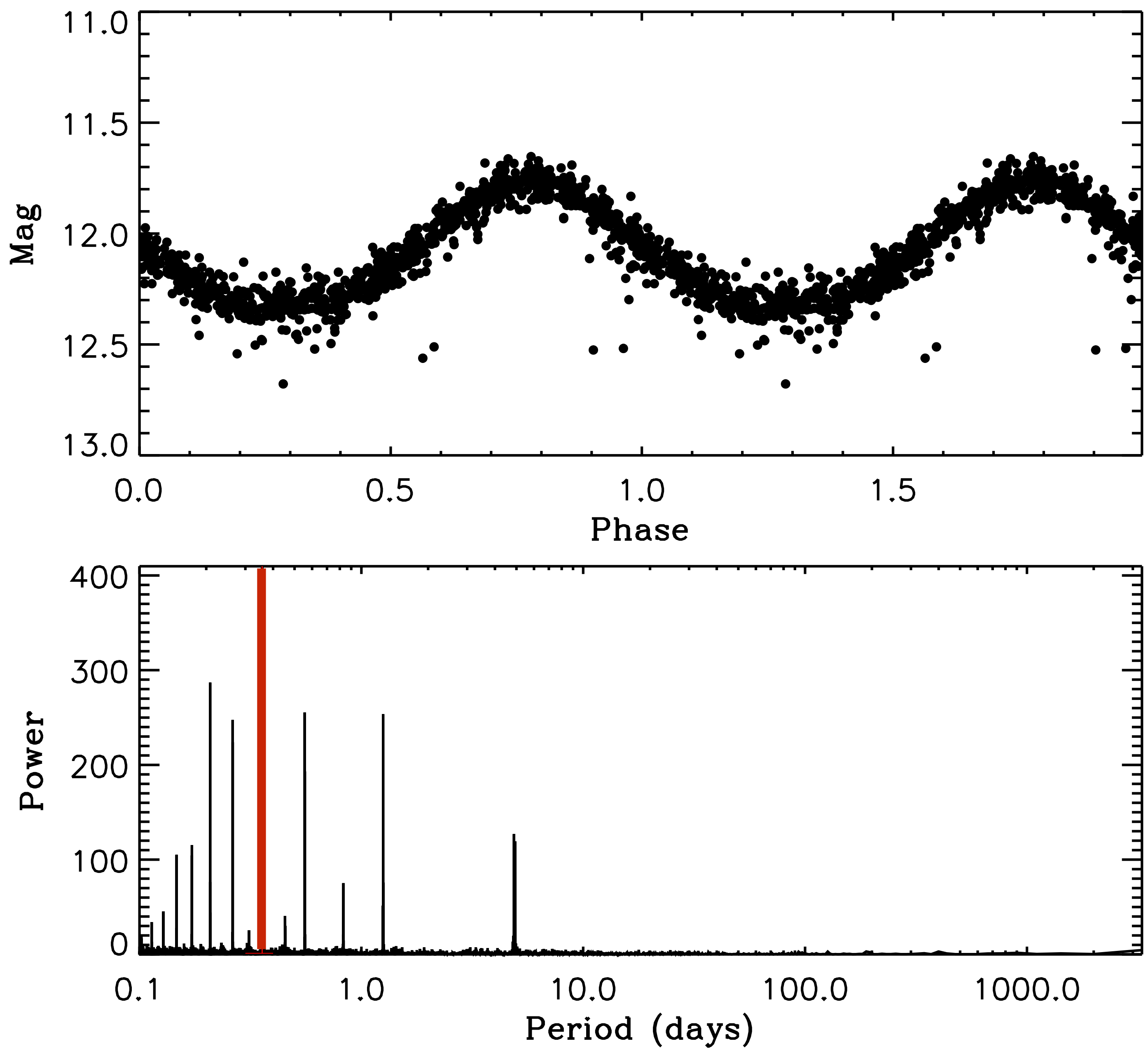


P_{orb} = 2.29 days

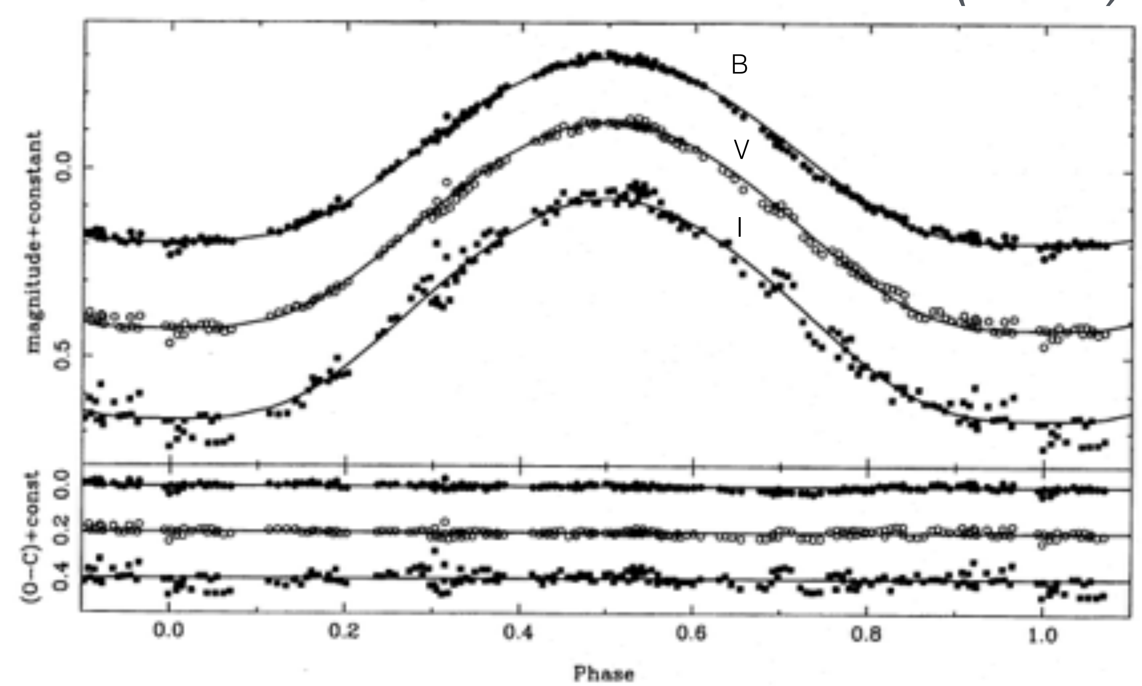
Preliminary results (known binaries)

LSS 2018

This work



Hilditch et al. (1996)

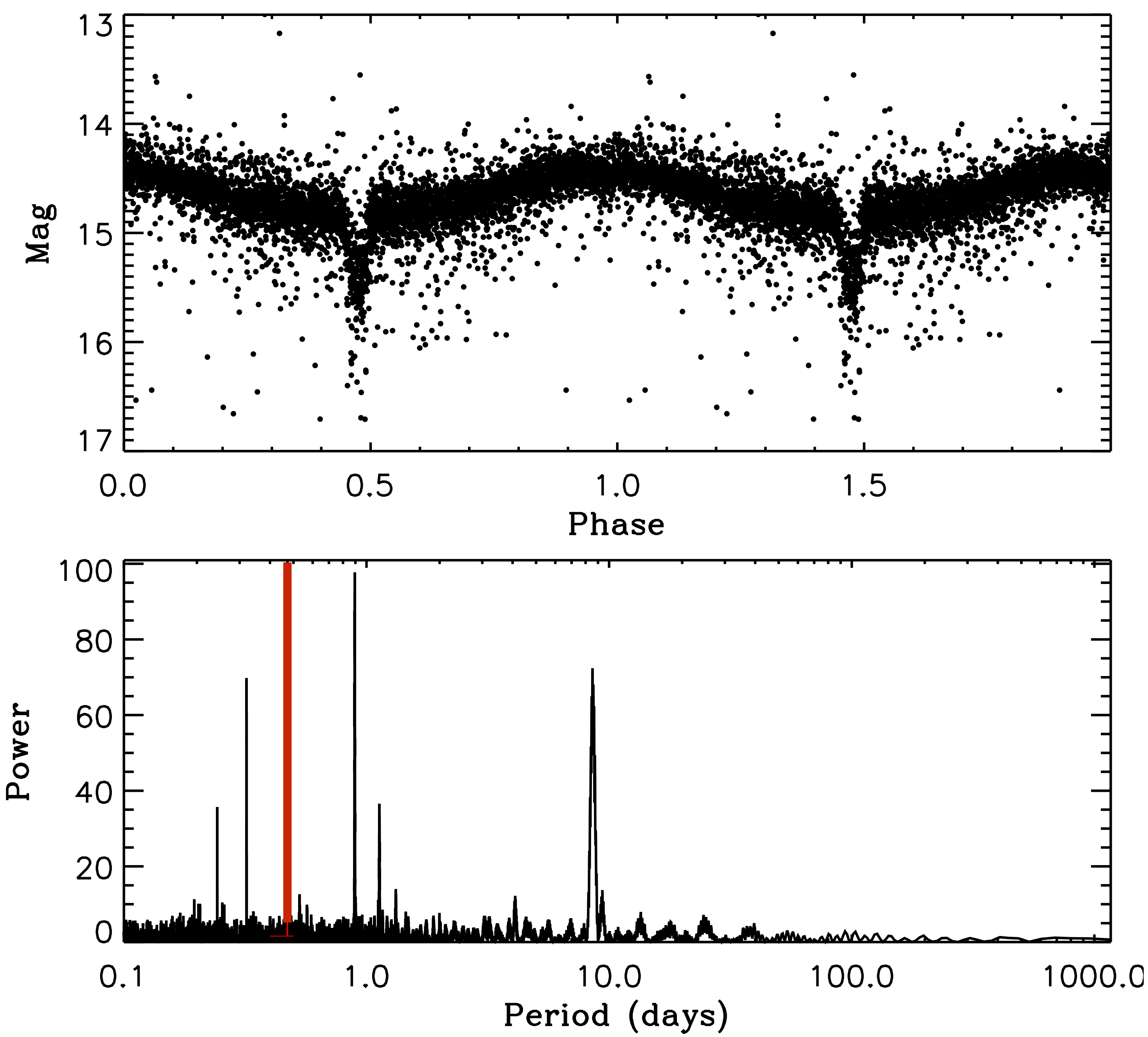


P_{orb} = 0.357 days

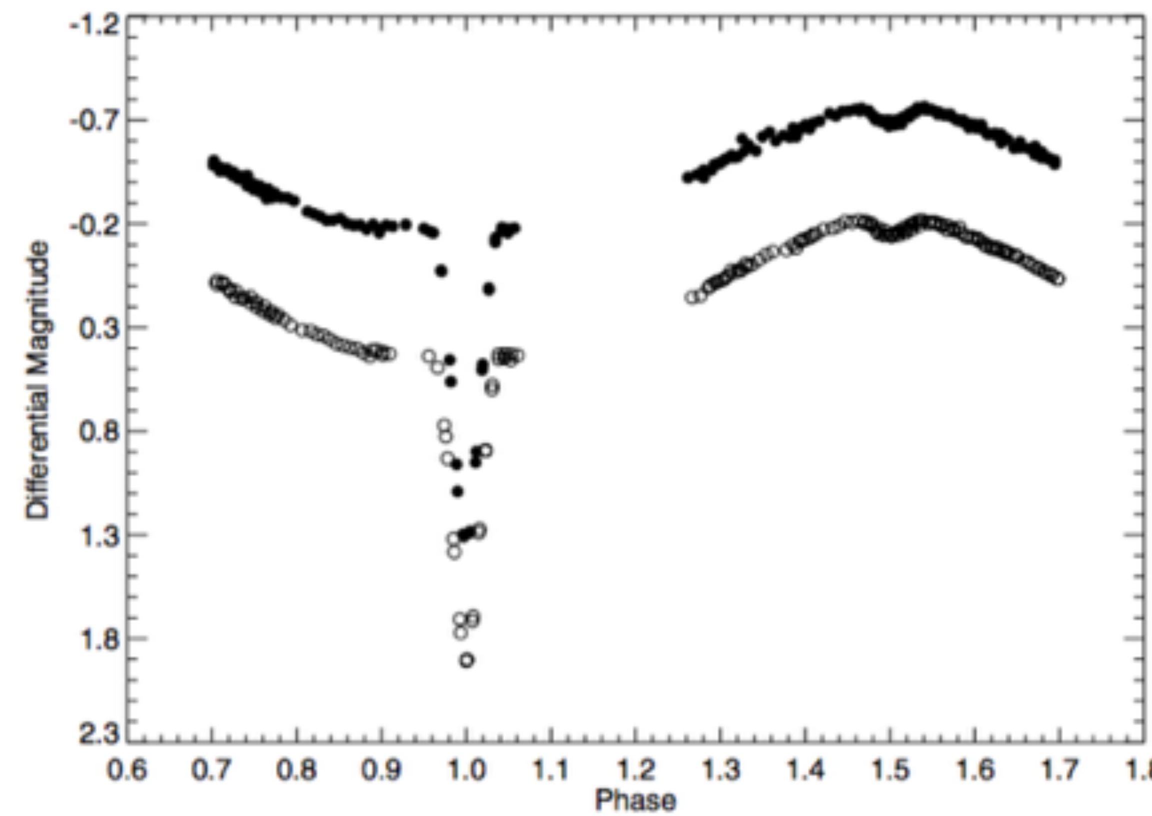
Preliminary results (known binaries)

Abell 46

This work

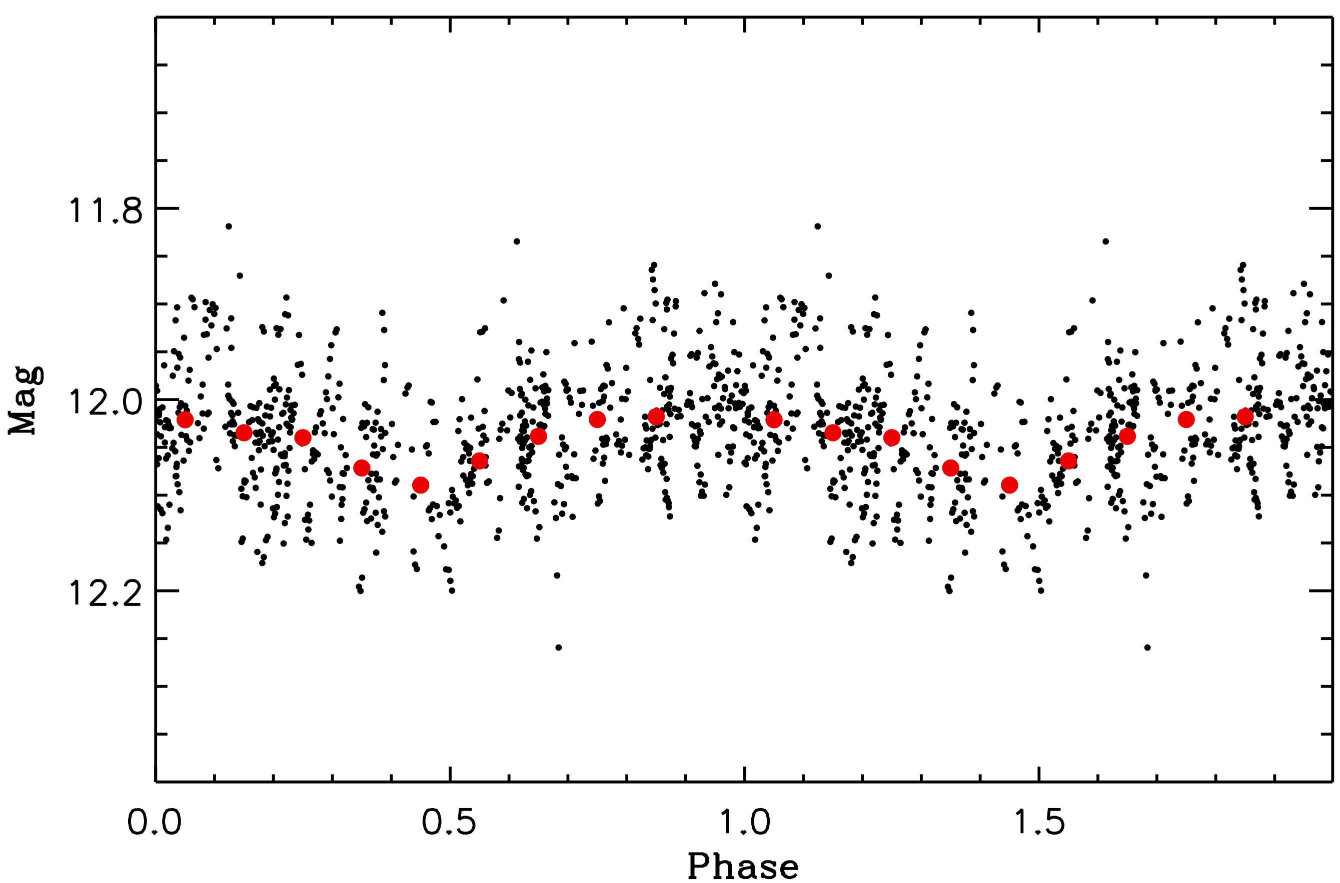


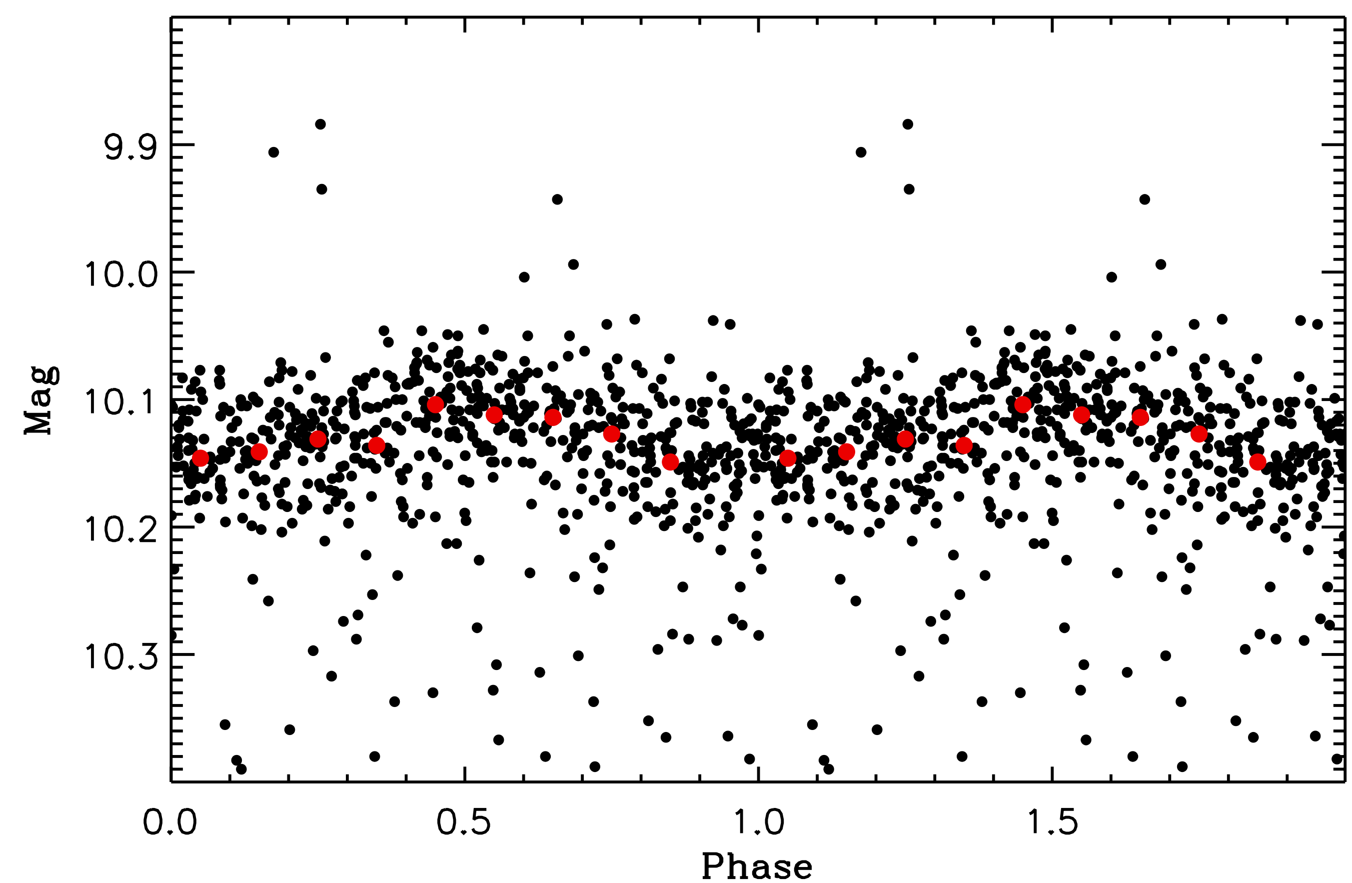
Afsar & Ibanoglu (2008)



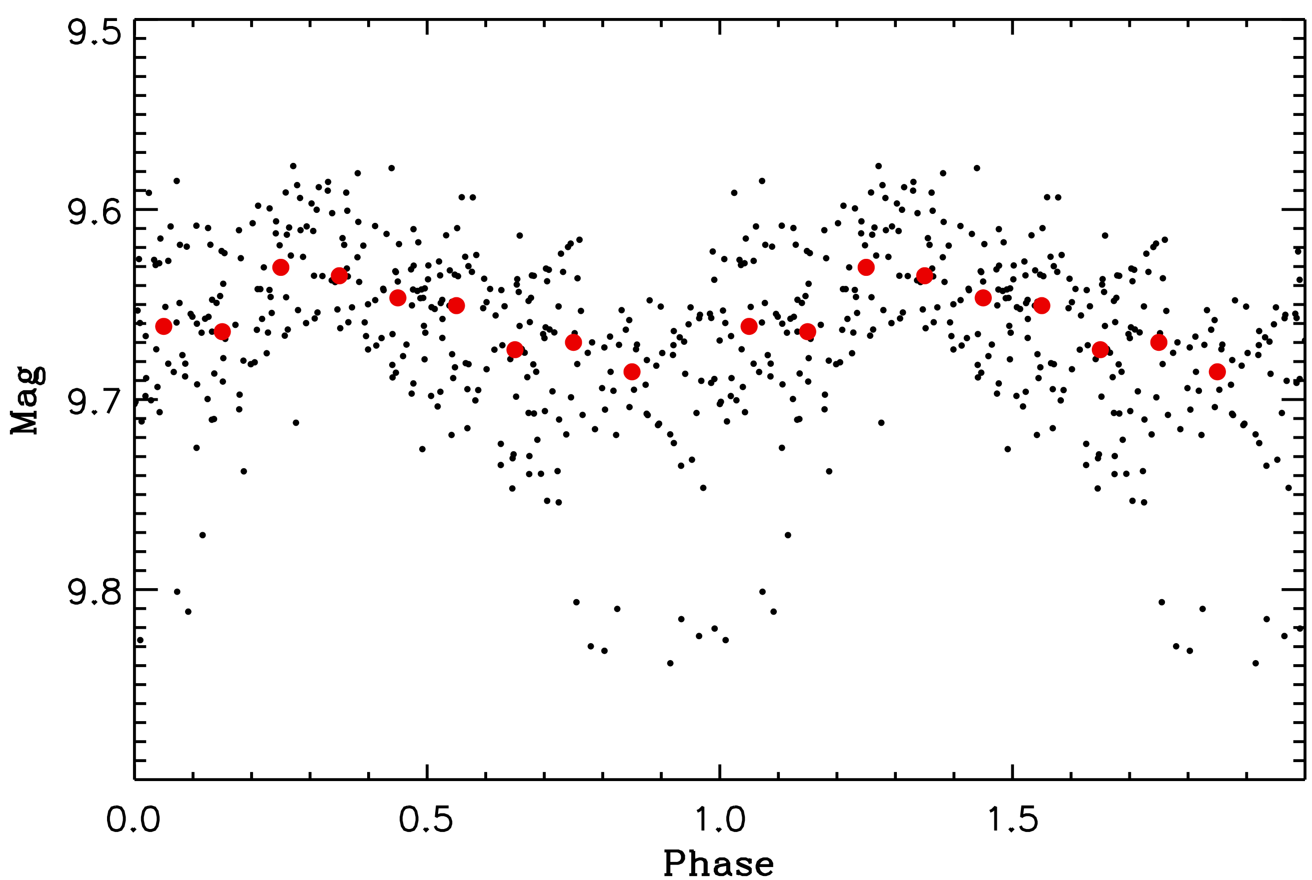
P_{orb} = 0.472 days

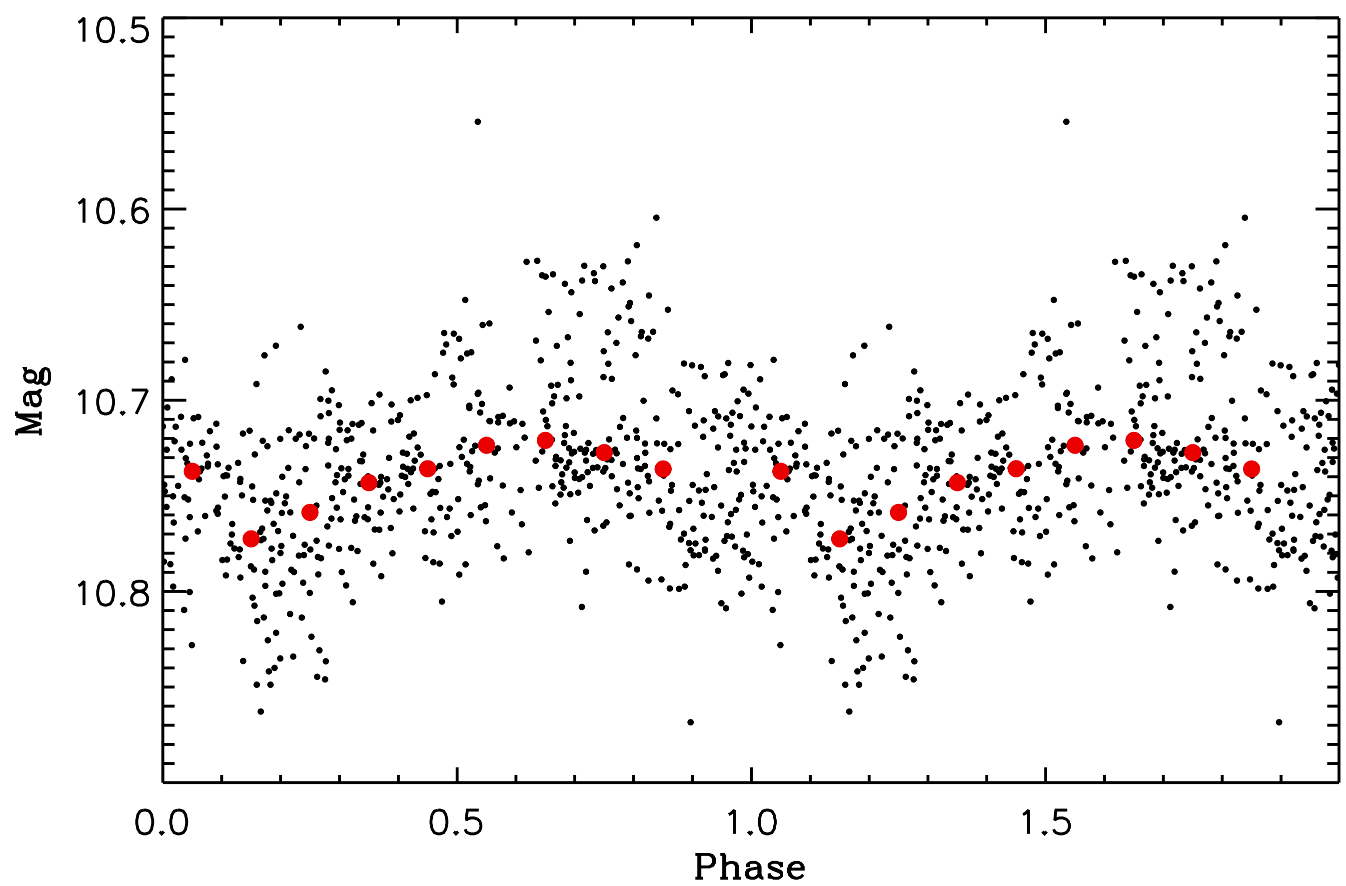
Preliminary results (new candidates)



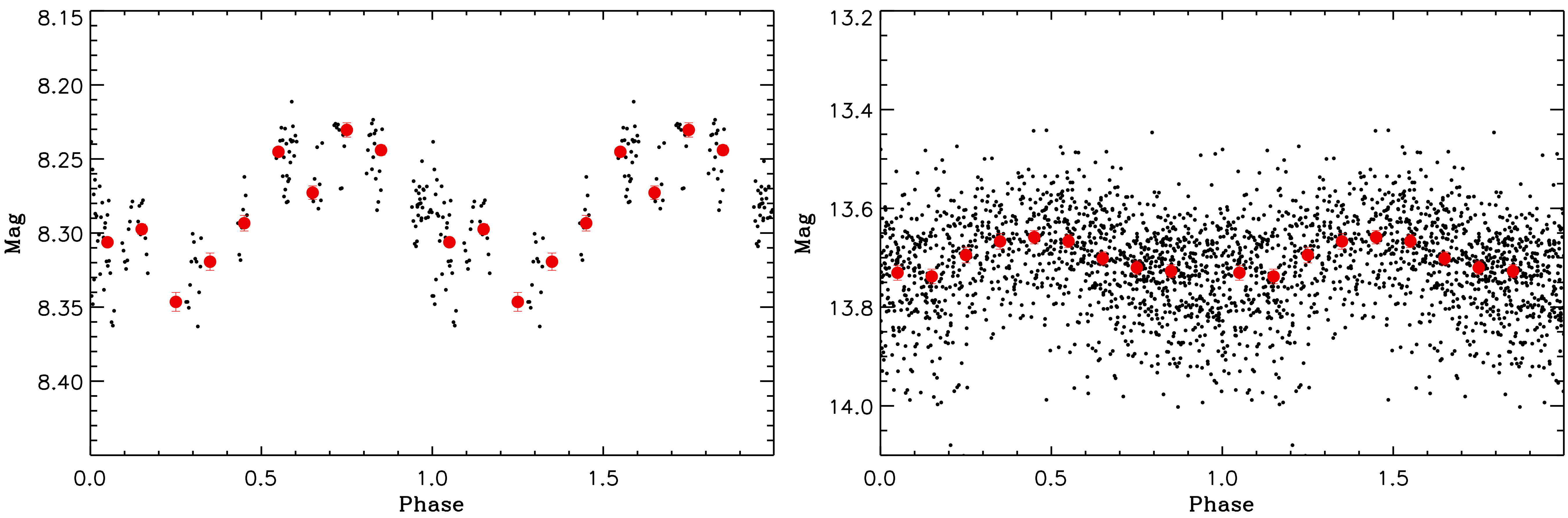


Preliminary results (new candidates)





Preliminary results (new candidates)



Search for infrared excess

Monthly Notices of the Royal Astronomical Society
MNRAS 428, 2118–2140 (2013) doi:10.1093/mnras/sts180

The binary fraction of planetary nebula central stars – I. A high-precision, *I*-band excess search

Orsola De Marco,[1,2,3]★ Jean-Claude Passy,[4,3] D. J. Frew,[1,2] Maxwell Moe[5] and G. H. Jacoby[6]
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[3]*Department of Astrophysics, American Museum of Natural History, New York, NY 10024, USA*
[4]*Department of Physics and Astronomy, University of Victoria, Victoria, Canada*
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Accepted 2012 October 9. Received 2012 October 3; in original form 2012 August 10

ABSTRACT
We still do not know what causes aspherical planetary nebula (PN) morphologies. A plausible hypothesis is that they are due to the presence of a close stellar or substellar companion. So far, only ~40 binary central stars of PN have been detected, almost all of them with such short periods that their binarity is revealed by photometric variability. Here we have endeavoured to discover binary central stars at any separation, thus determining the unbiased binary fraction of central stars of PN. This number, when compared to the binary fraction of the presumed parent population, can give a first handle on the origin of PN. By detecting the central stars in the *I* band we have searched for cool companions. We have found that 30 per cent of our sample have an *I*-band excess detected between 1 and a few σ, possibly denoting companions brighter than M3–4V and with separations smaller than ~1000 au. By accounting for the undetectable companions, we determine a debiased binary fraction of 67–78 per cent for all companions at all separations. We compare this number to a main-sequence binary fraction of (50 ± 4) per cent determined for spectral types F6V–G2V, appropriate if the progenitors of today's PN central star population are indeed the F6V–G2V stars. The error on our estimate cannot be constrained tightly, but we determine it to be between 10 and 30 per cent. We conclude that the central star binary fraction may be larger than expected from the putative parent population. However, this result is based on a sample of 27 bona fide central stars and should be considered preliminary. The success of the *I*-band method rests critically on high-precision photometry and a reasonably large sample. From a similar analysis, using the more sensitive *J* band of a subset of 11 central stars, the binary fraction is 54 per cent for companions brighter than ~M5–6V and with separations smaller than about 900 au. Debiasing this number in the same way as was done for the *I* band we obtain a binary fraction of 100–107 per cent. The two numbers should be the same and the discrepancy is likely due to small-number statistics. Finally, we note how the previously derived short-period PN binary fraction of 15–20 per cent is far larger than expected based on the main-sequence binary fraction and period distribution.
As a byproduct of our analysis we present an accurately vetted compilation of observed main-sequence star magnitudes, colours and masses, which can serve as a reference for future studies. We also present synthetic colours of hot stars as a function of temperature (20–170 kK) and gravity ($\log g$ = 6–8) for Solar and PG1159 compositions.

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34 objects in total

Monthly Notices of the Royal Astronomical Society
MNRAS 448, 3132–3155 (2015) doi:10.1093/mnras/stu2700

The binary fraction of planetary nebula central stars – II. A larger sample and improved technique for the infrared excess search

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[3]*Laboratoire Univers et Particules, Université Montpellier 2, F-34095 Montpellier Cedex 5, France*
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[5]*Department of Physics and Astronomy, University of Victoria, Victoria, BC V8P5C2, Canada*
[6]*Kitt Peak National Observatory, NOAO, PO Box 26732, Tucson, AZ 85719, USA*
[7]*Department of Physics and Astronomy, Valparaiso University, Valparaiso, IN 46383, USA*
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ABSTRACT
There is no conclusive explanation of why ~80 per cent of planetary nebulae (PNe) are non-spherical. In the *Binary Hypothesis*, a binary interaction is a preferred channel to form a non-spherical PN. A fundamental step to corroborate or disprove the *Binary Hypothesis* is to estimate the binary fraction of central stars of PNe (CSPNe) and compare it with a prediction based on the binary fraction of the progenitor, main-sequence population. In this paper, the second in a series, we search for spatially unresolved *I*- and *J*-band flux excess in an extended sample of 34 CSPN by a refined measurement technique with a better quantification of the uncertainties. The detection rate of *I*- (*J*-)band flux excess is 32 ± 16 per cent (50 ± 24 per cent). This result is very close to what was obtained in Paper I with a smaller sample. We account conservatively for unobserved cool companions down to brown dwarf luminosities, increasing these fractions to 40 ± 20 per cent (62 ± 30 per cent). This step is very sensitive to the adopted brightness limit of our survey. Accounting for visual companions increases the binary fraction to 46 ± 23 per cent (71 ± 34 per cent). These figures are lower than in Paper I. The error bars are better quantified, but still unacceptably large. Taken at face value, the current CSPN binary fraction is in line with the main-sequence progenitor population binary fraction. However, including white dwarfs companions could increase this fraction by as much as 13 (21) per cent points.

Key words: techniques: photometric – surveys – binaries: general – stars: evolution – stars: statistics – planetary nebulae: general.

1 INTRODUCTION

It is not understood yet why a high 80 per cent of planetary nebulae (PNe) are non-spherical (Parker et al. 2006). The *Binary Hypothesis* – the paradigm in which PNe are preferentially produced by a binary interaction (De Marco 2009) – may enable us to explain such figures. A first important step to test the *Binary Hypothesis* is to estimate the binary fraction of central stars of PNe (CSPNe) and compare it with the binary fraction of the progenitor population, the main-sequence stars. If the binary fraction of CSPNe were higher than the prediction based on the progenitor population, this would imply that PNe are indeed preferentially formed via a binary channel.

The short-period, post-common-envelope binary fraction, 15–20 per cent, was determined by two-independent photometric close-binary surveys (Bond 2000; Miszalski et al. 2009a,b). This fraction is however limited to very short periods. Estimating the fraction of CSPN that are in binaries with any separation requires an efficient method for detecting binaries, a reasonable sample size and a clear understanding of the intrinsic biases of the method and sample. Our

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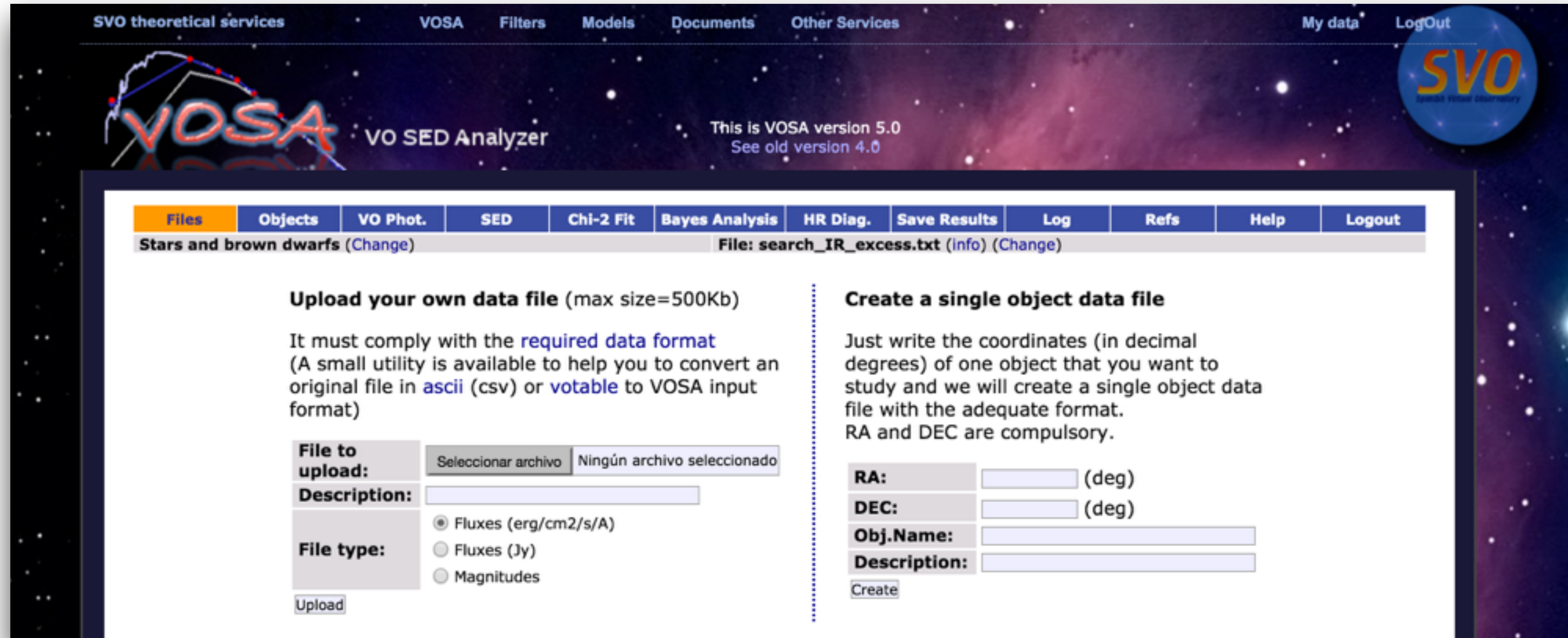
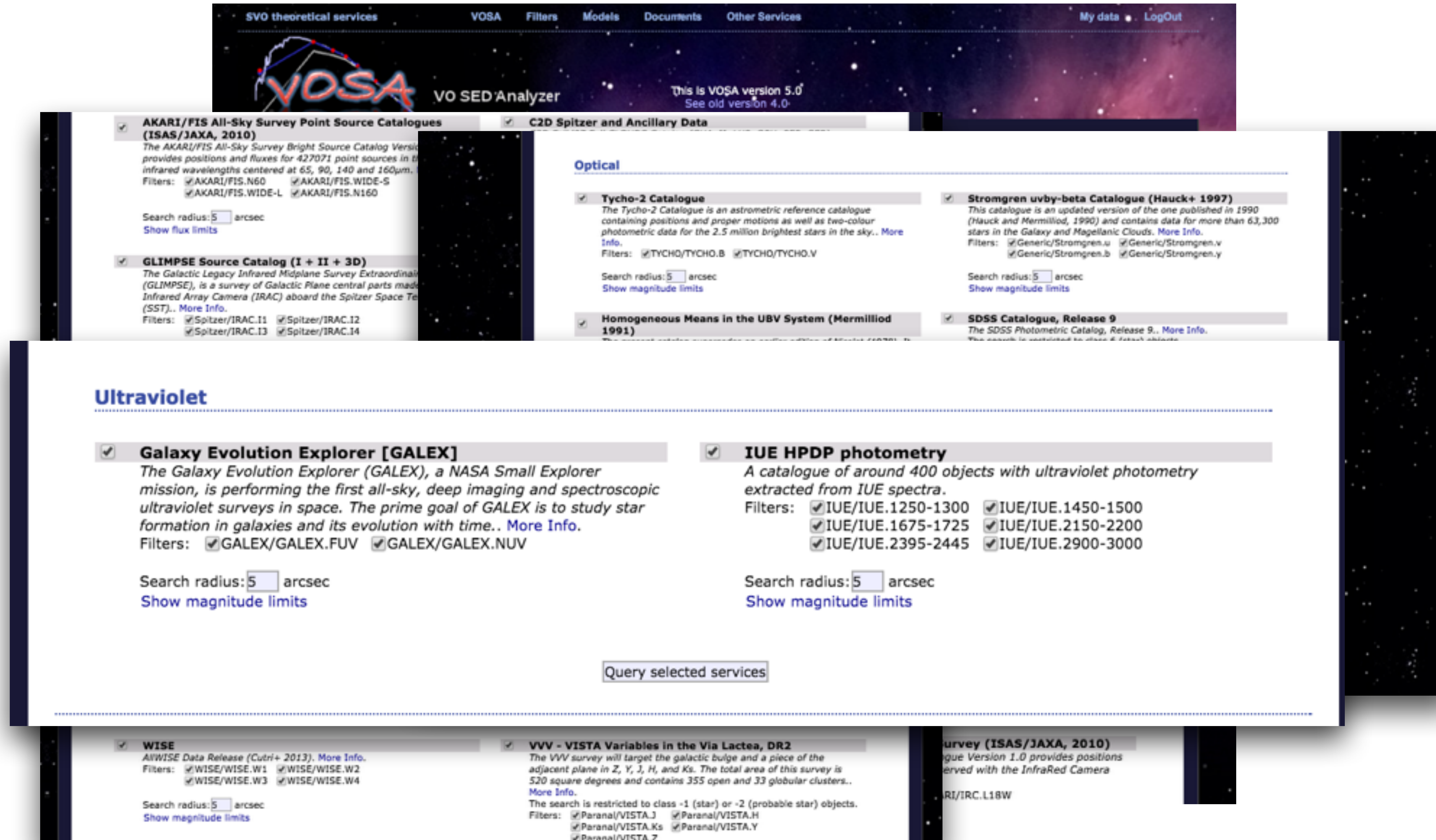
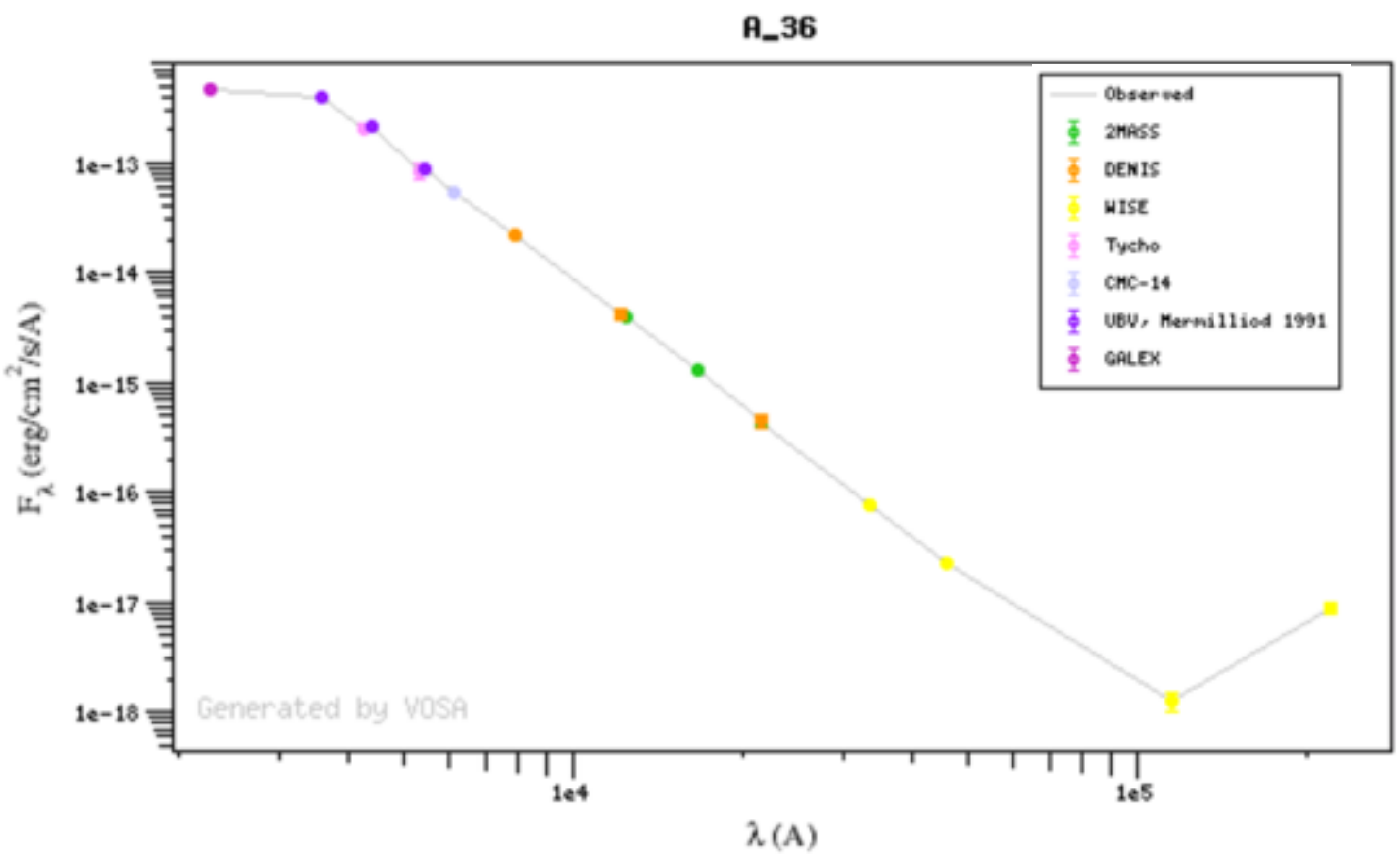
Search for infrared excess



Search for infrared excess

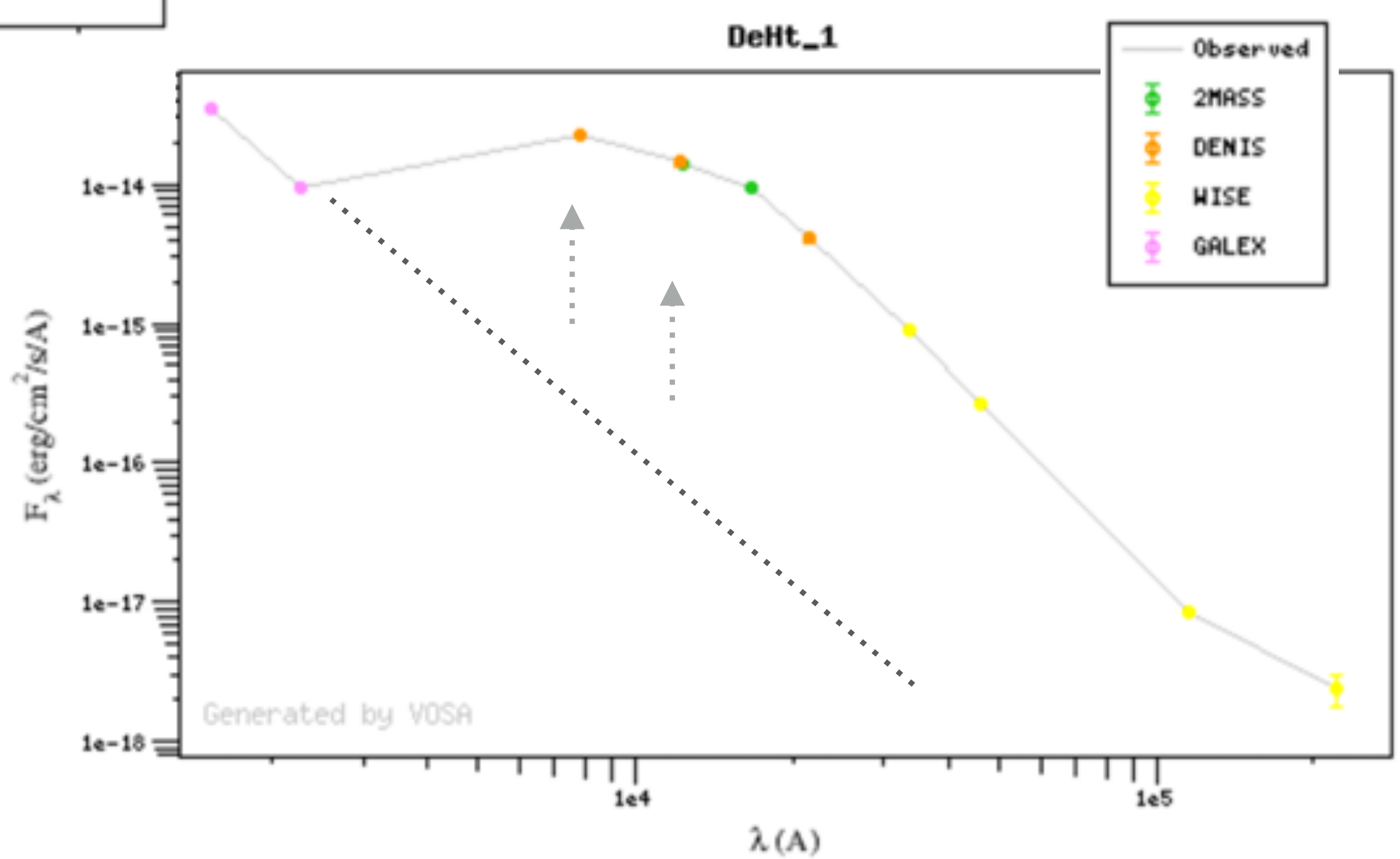


Search for infrared excess

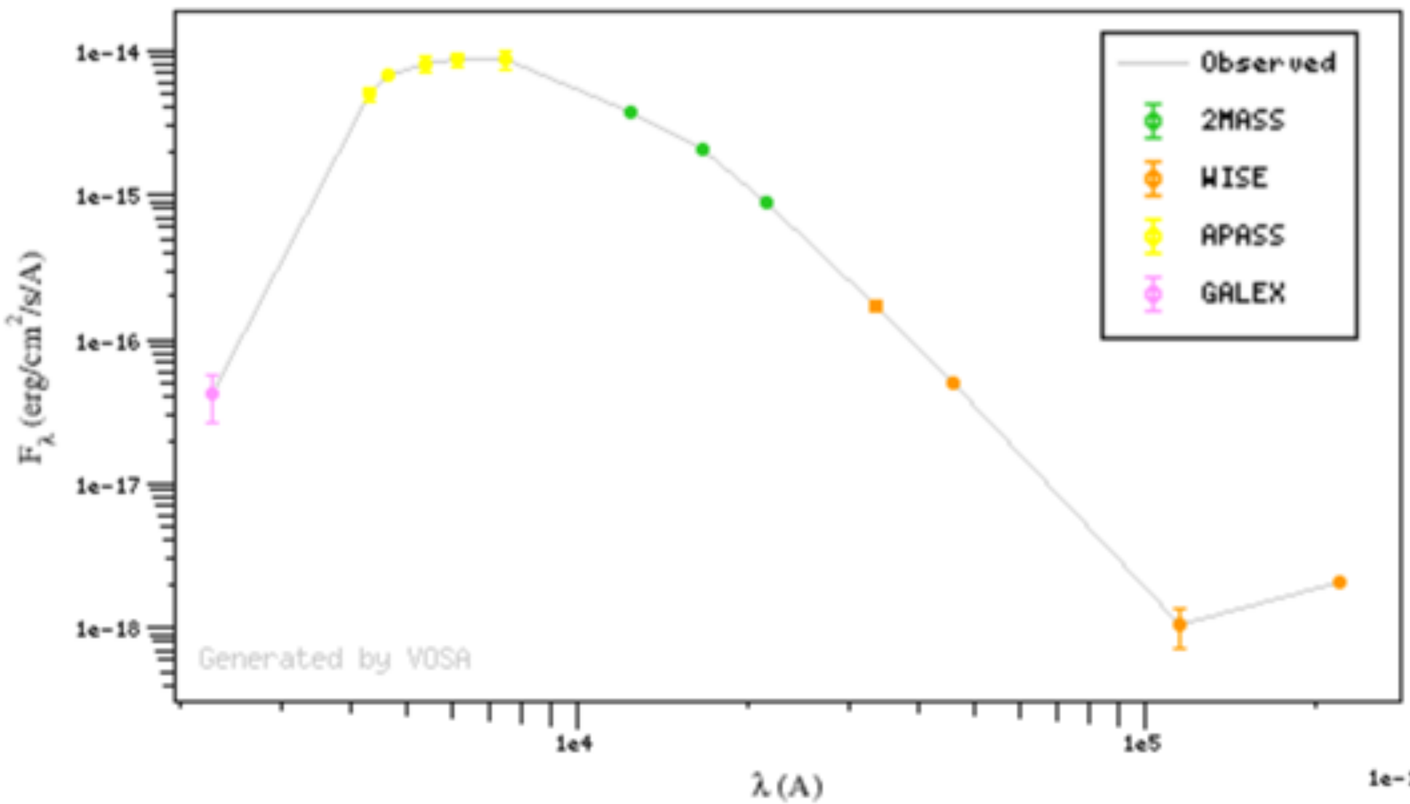


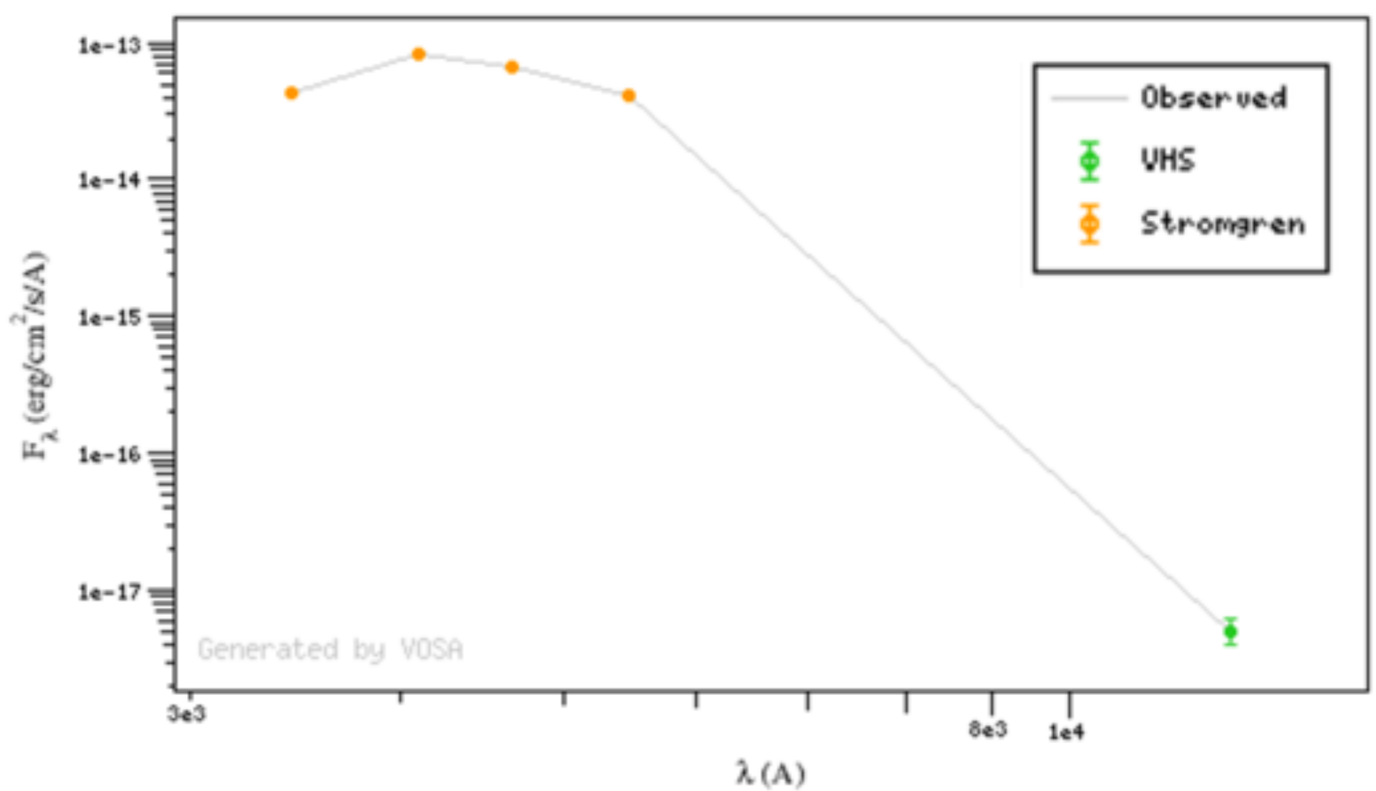
No binary detected

Hot star+ K type star



Preliminary results (new candidates)





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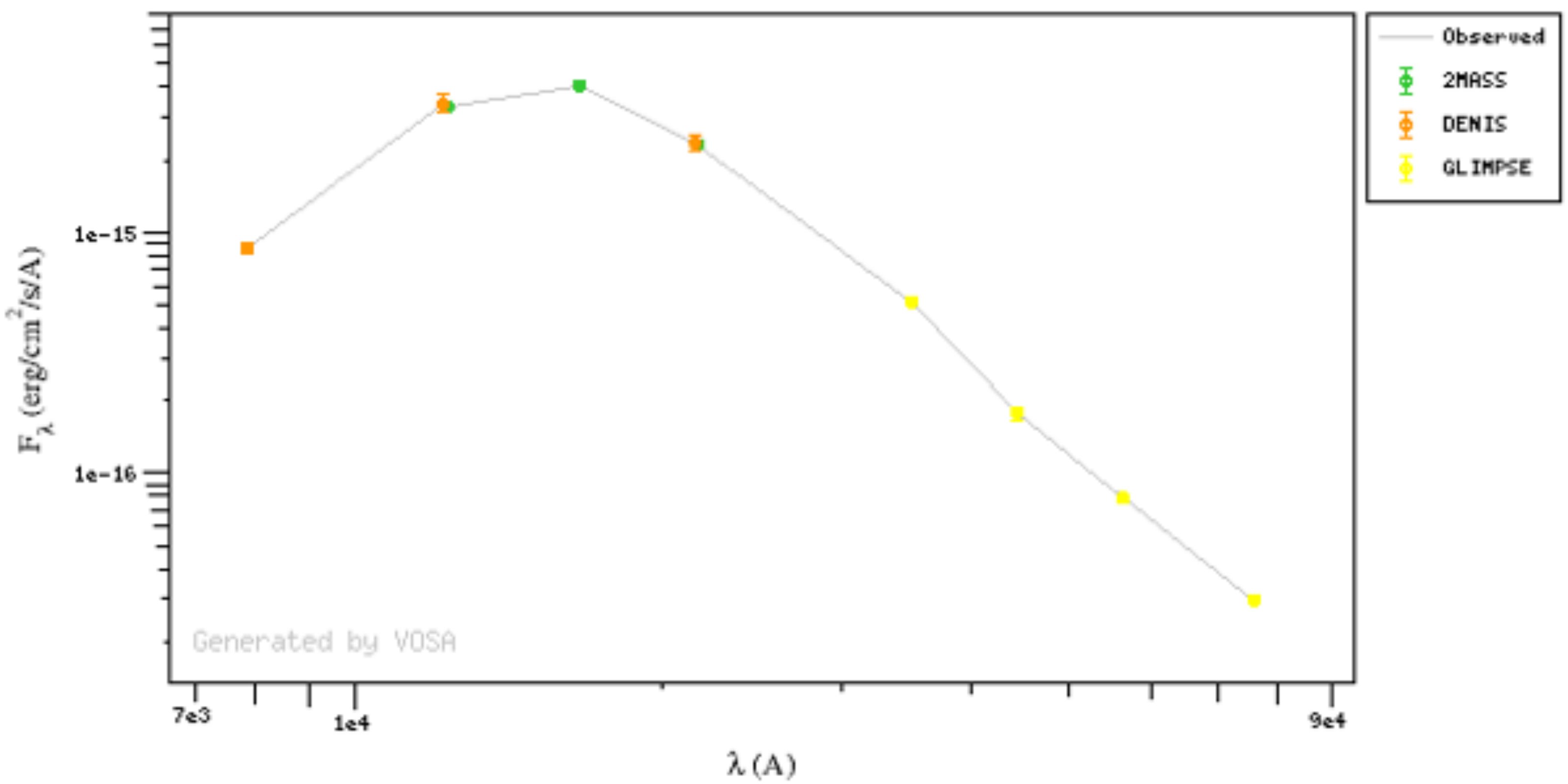

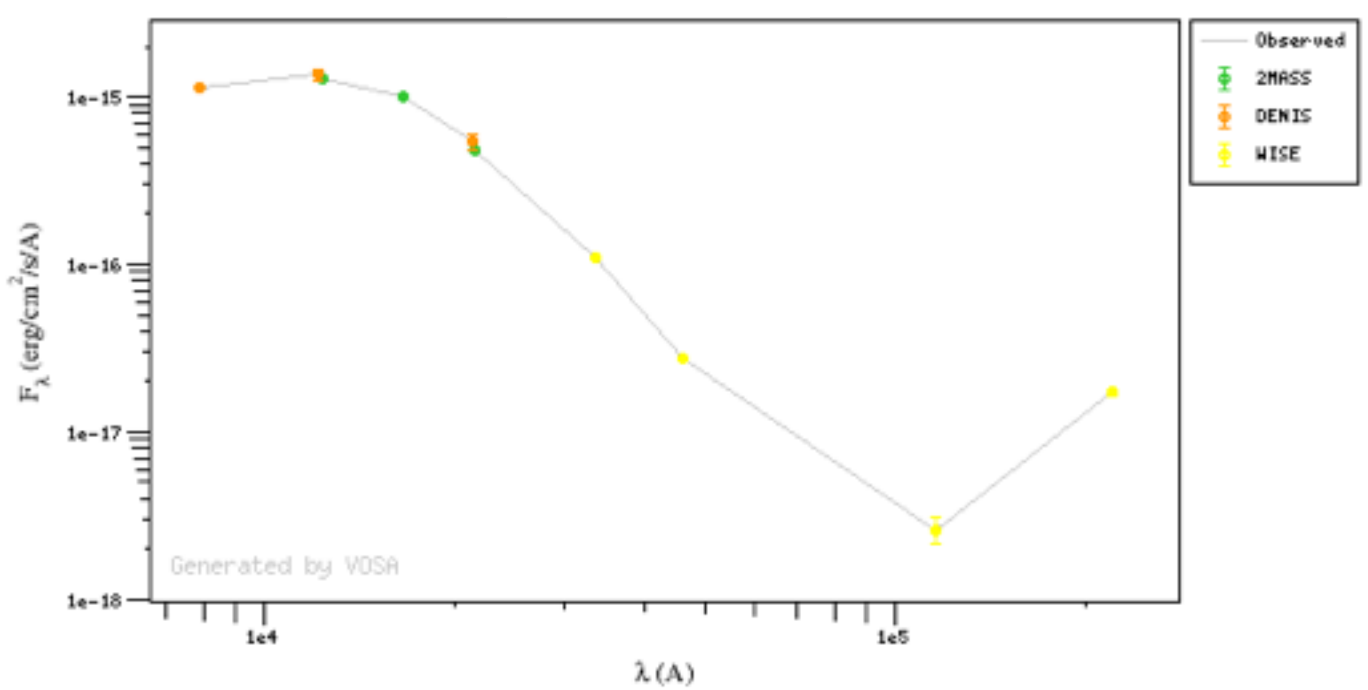

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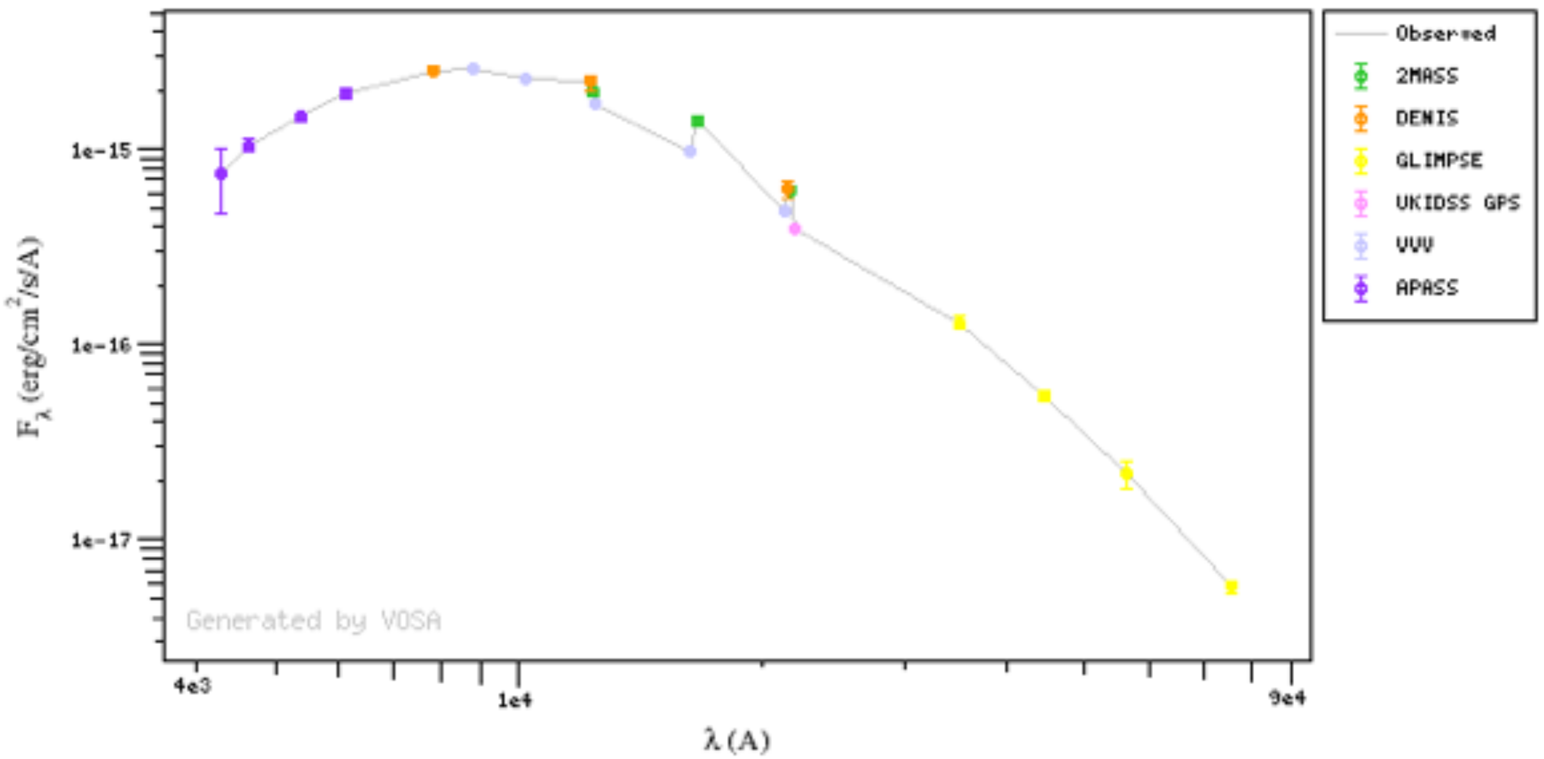
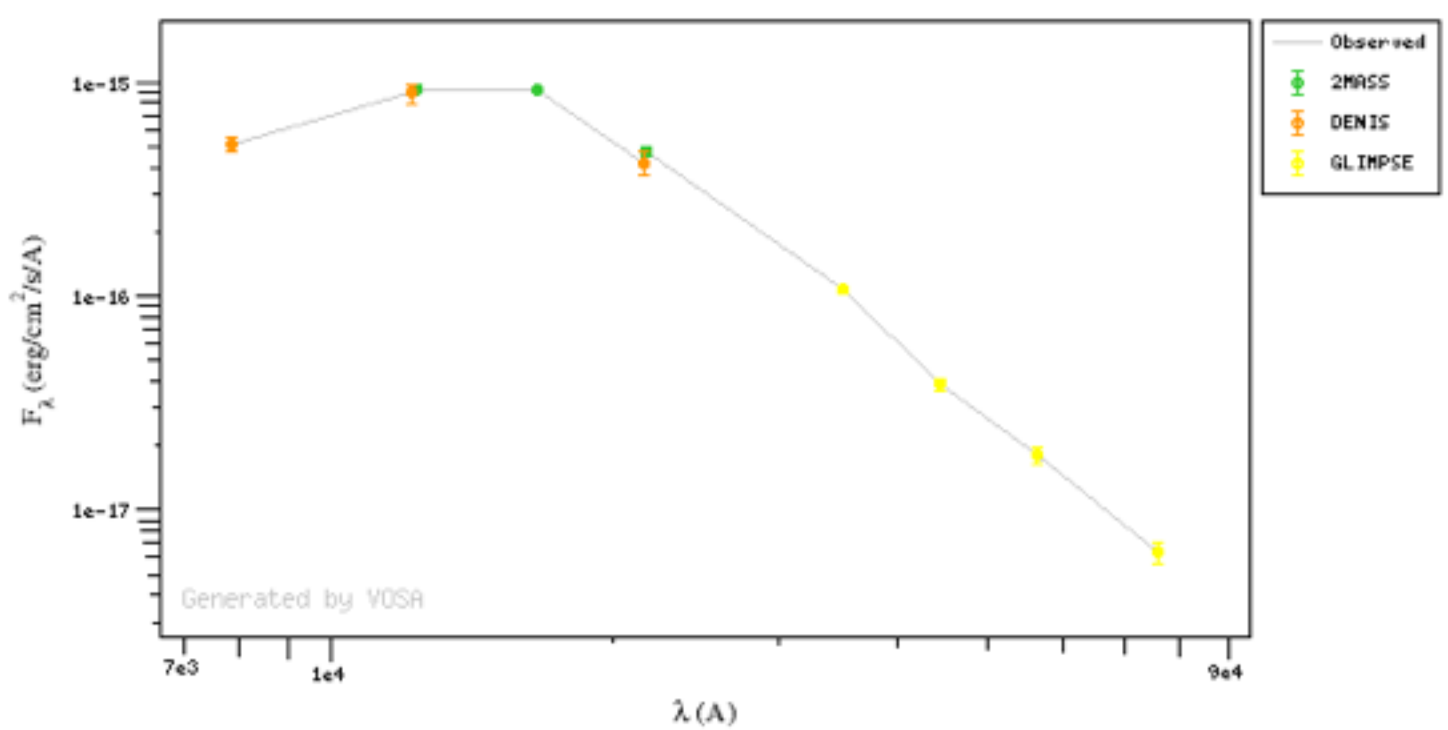




Coming soon

The next step is to monitor the candidates by means of:

Photometric survey + Radial velocity survey

Coming soon

Ultimately: Spectral analysis of CSPNe

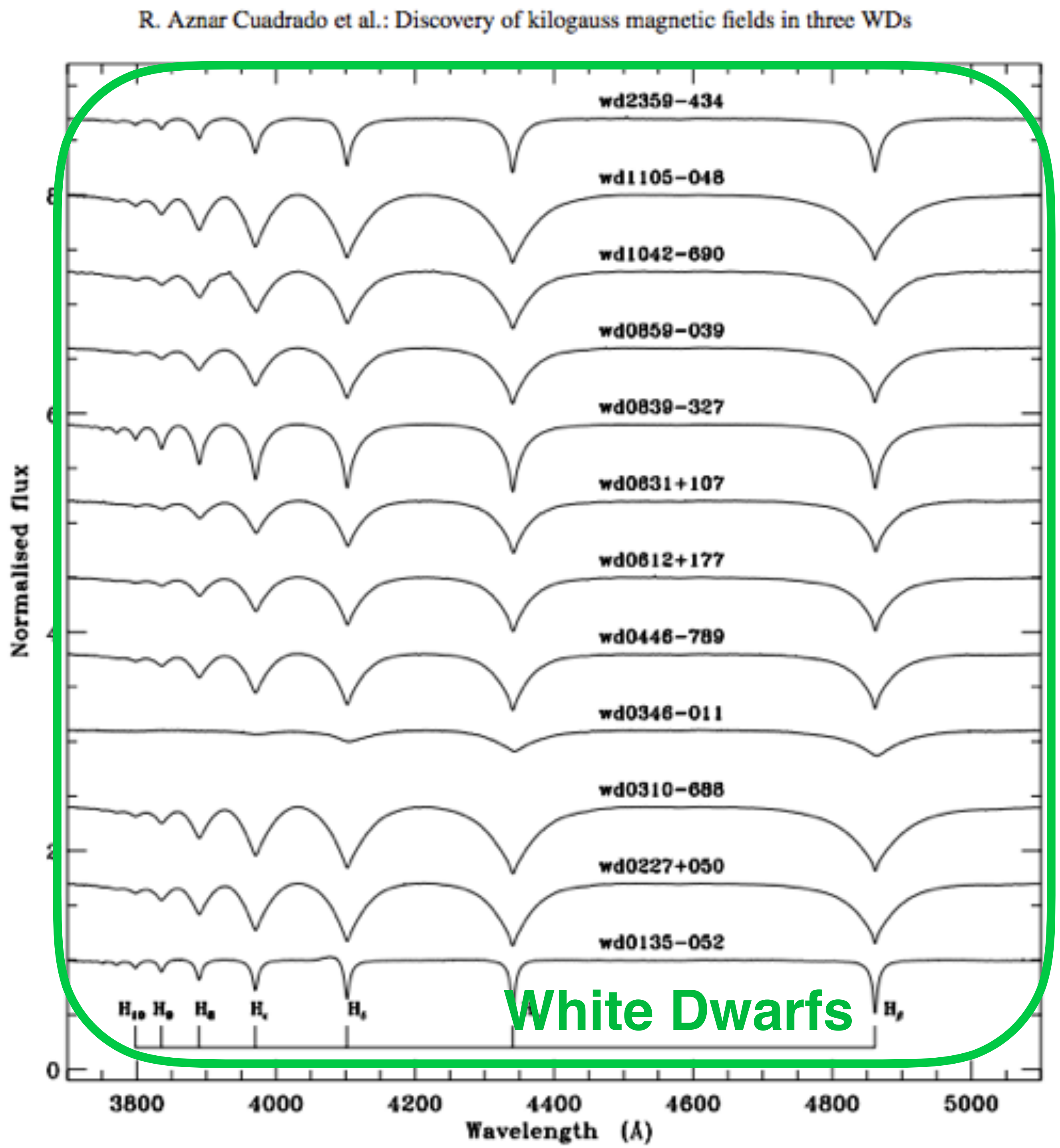
There are about 3000 confirmed Galactic planetary nebulae but… **spectroscopic information** of their central stars is **available for only 13%** of them!!! *(Weidmann & Gamen 2011).*

Table 1. Summary of the spectral types of CSPN compiled in our catalogue, grouped by their atmospheric hydrogen abundance.

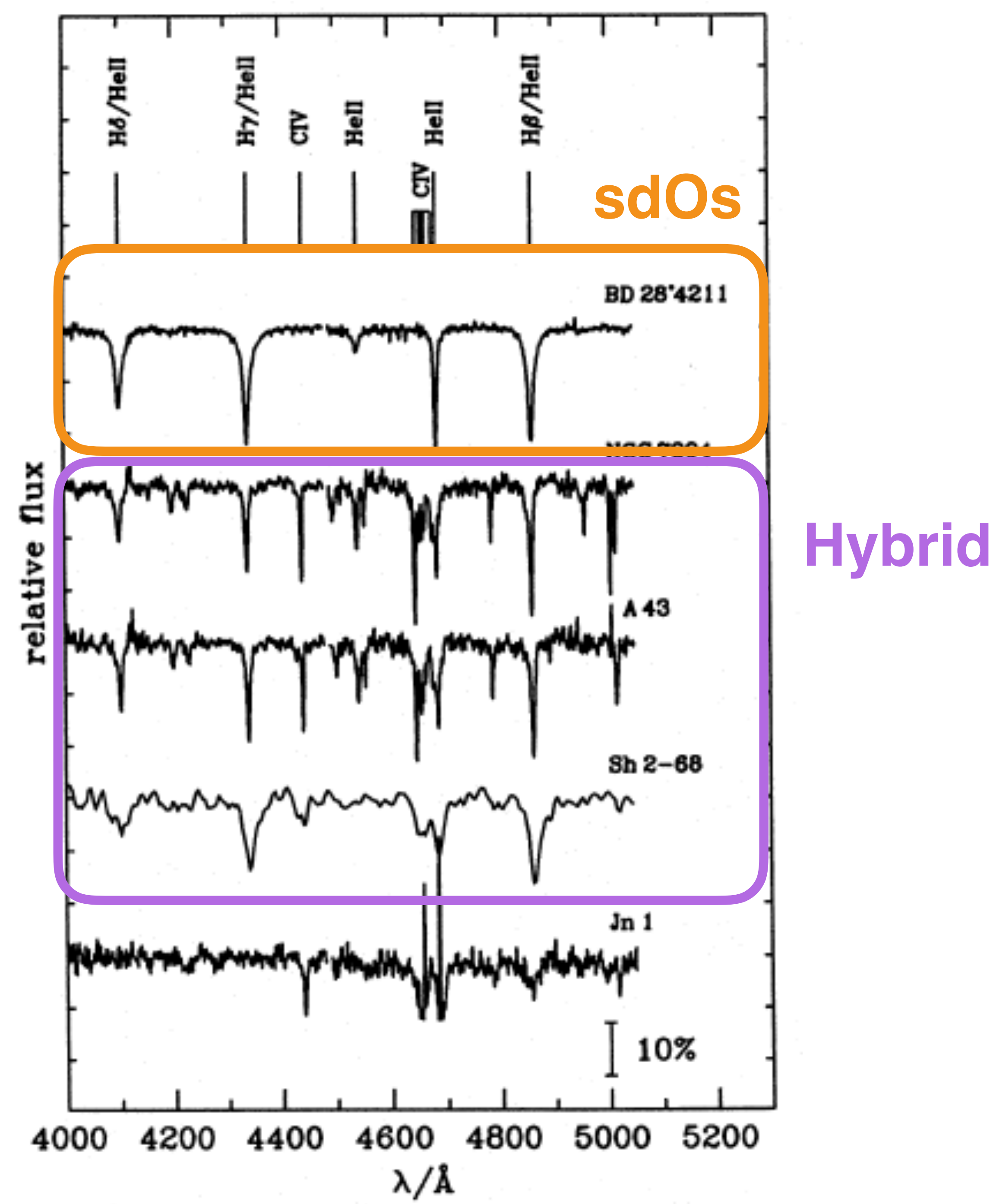
H-rich				H-poor	
Sp.Type	Sample	Sp. Type	Sample	Sp. type	Sample
O3-9+B_{early}	64	sdB	1	[WC4-11]	57
Of	20	Hybrid	3	[WO1-4]	33
Later that B5	38	Symbiotic star?	7	[WR]	11
B[e]	6	Blue	50	[WN]	5
DA+WD	12	Emission-line	25	PG 1159	15
DAO	14			[WC]-PG1159	2
sdO	3			O(He)	3
hgO(H)	16			O(c)+Of(c)	2
Cont.	16			H-poor	1
H-rich	3			DO	4
				wels	72
Total	192	Total	86	Total	205

Notes. Here, we have discarded 9 objects without any specific spectral type.

Coming soon

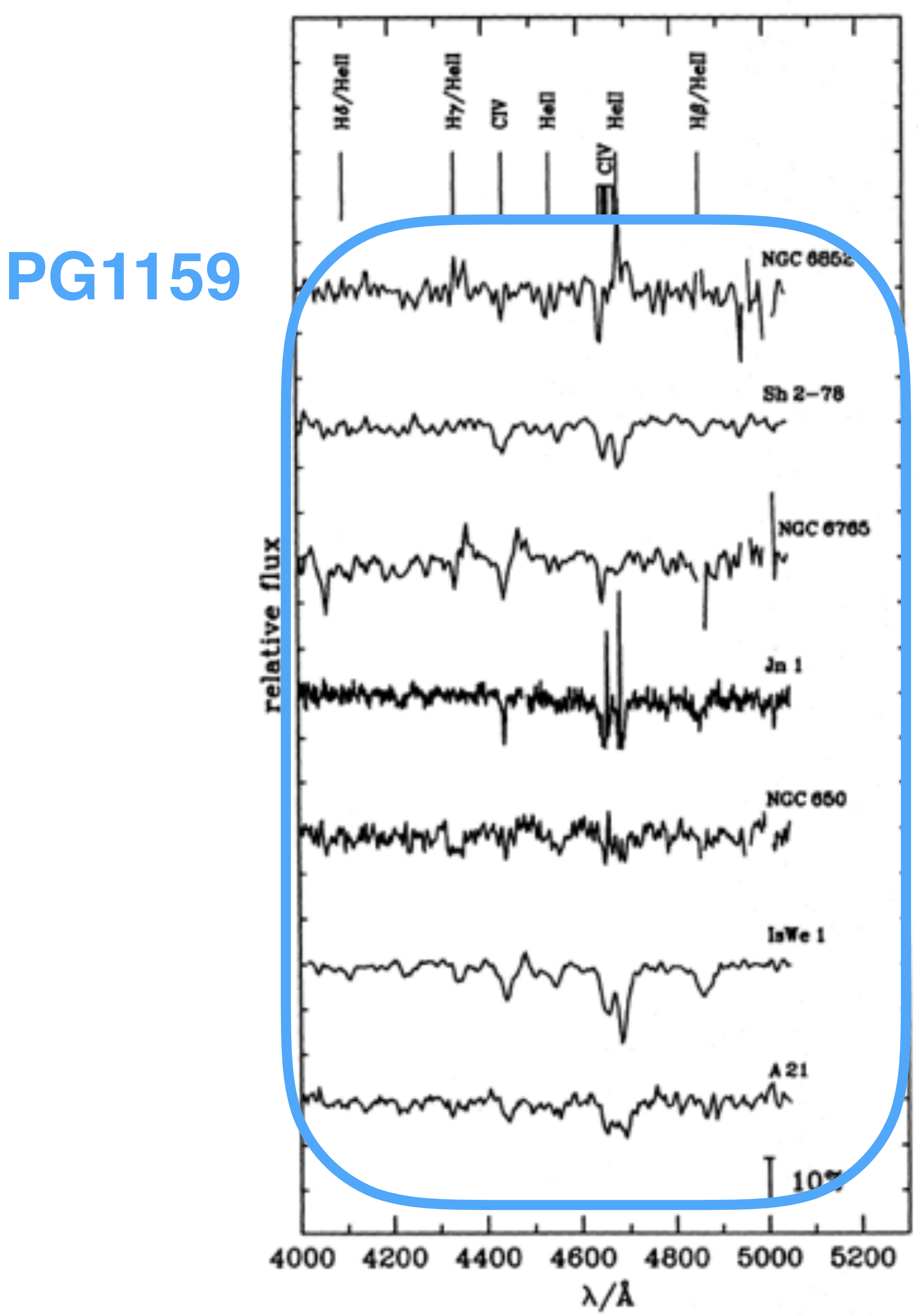


Aznar Cuadrado et al. (2004)

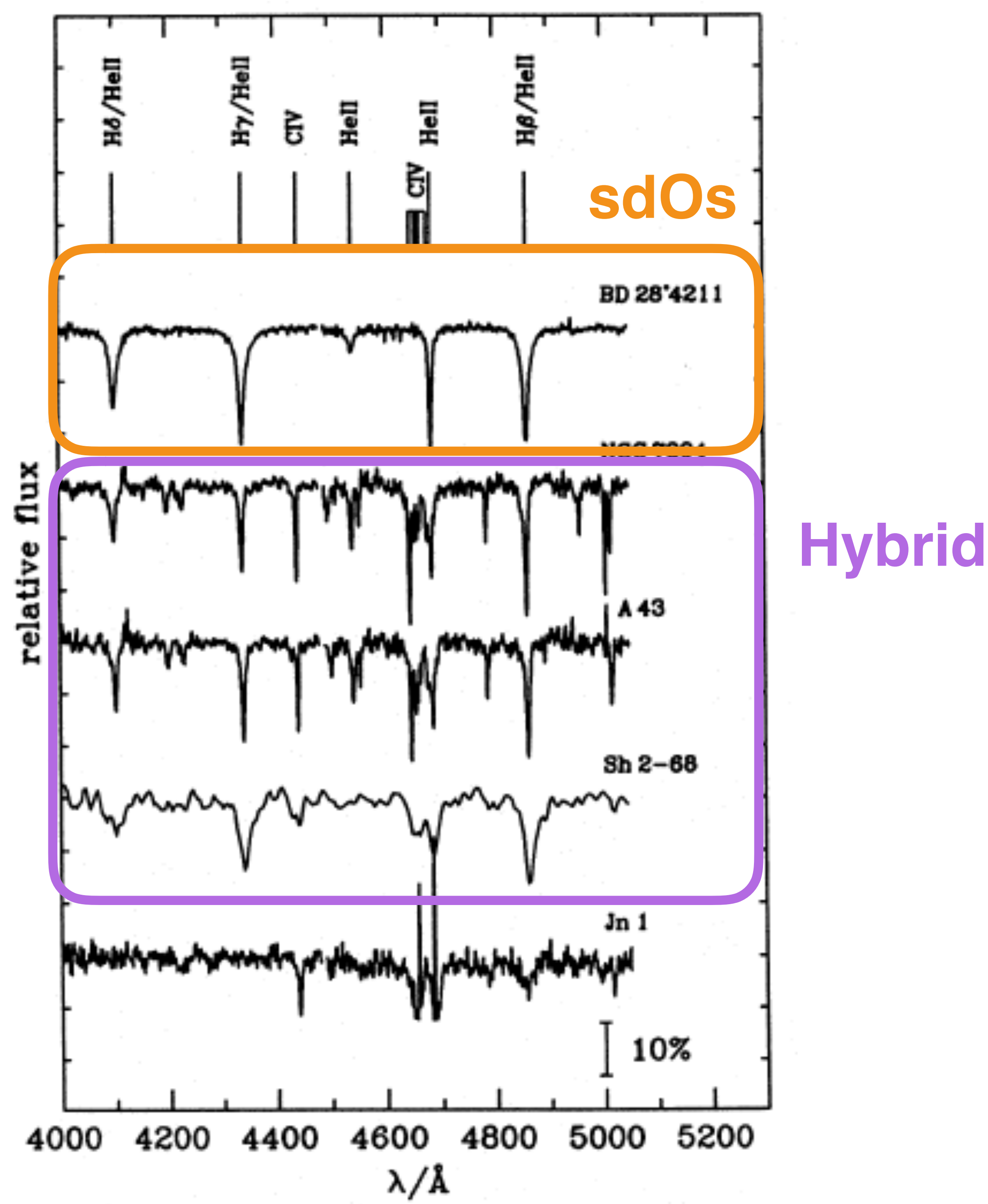


Napiwotzki & Schonberner (1995)

Coming soon



Napiwotzki & Schonberner (1995)



Napiwotzki & Schonberner (1995)

Summary

★ PNe are the late stage of low- and intermediate- mass stars (~ 0.8 - 8 $M_\odot$)

★ **Binary** central stars: **key** to explain the complex and **non-spherical PNe**

★ Highly needed to **search for new binary CSPNe**. Four steps:

1. To have a **census of all CSPNe**: Build a catalogue
2. Search for **light curves in archival data**
3. Search for **infrared excess with archival photometry**

4. **Follow-up the candidates** to confirm and characterize them by means of both photometric and radial velocity observations

Gracias!