# WHITE DWARFS FROM LAMOST AND A CANDIDATE DEBRIS DISK AROUND WD FROM SDSS

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# OUTLINE

1, White dwarfs from LAMOST DR2

2, A candidate debris disk around white dwarf from SDSS

3, Possible evidence of asteroids around Polar AR UMa

# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

- The overwhelming majority of all stars end their lives as white dwarfs(WDs). It is believed that 97% of the stars in the Galaxy will eventually evolve to WDs(Fontaine, Brassard & Bergeron 2001).

- A, Provide an accurate record of the star formation, evolution history of the Milky Way(Harris et al. 2006).
- B, Important tools of studies on the ages of Galactic populations by constraining their luminosity and mass functions(Kepler et al. 2007).
- C, Research on mass-loss and stellar evolution, providing information for the chemical evolution of the Galaxy(Kalirai et al. 2008,2009).

# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

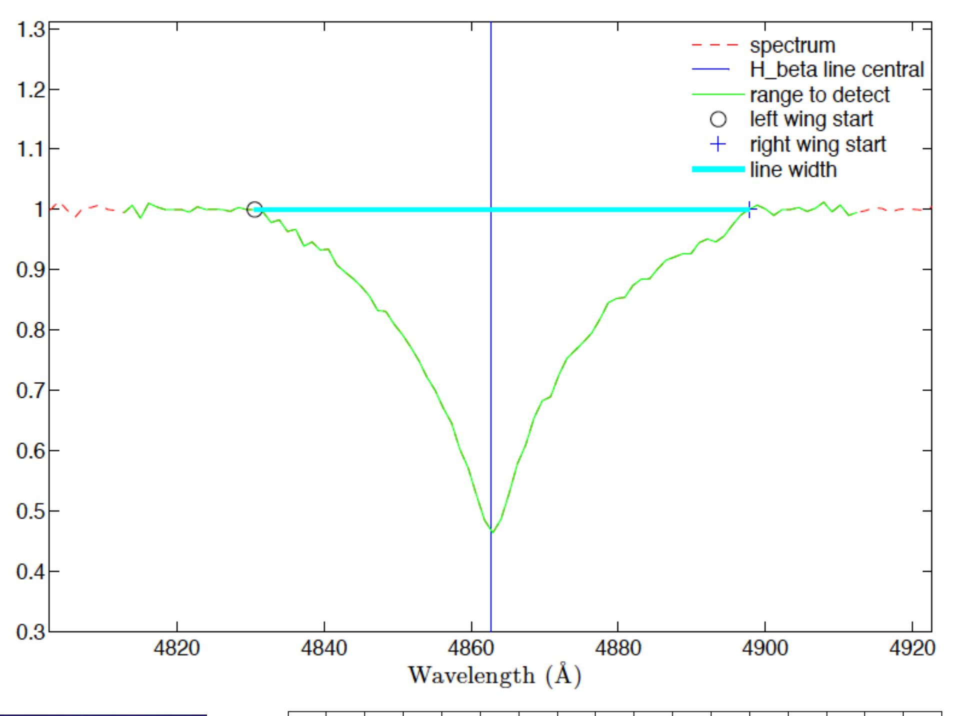
- Last three decades, efforts have been made to build large sample of WDs.

- McCook & Sion (1987) presented 1 279 spectroscopically identified WDs(now 14325).
- ……
- Kleinman et al. (2013) identified ~20 000 WDs in SDSS DR7.
- Kepler et al. (2016) identified ~6 500 new WDs from SDSS DR12.

# 1，WHITE DWARFS FROM LAMOST

- LAMOST is a 4-m reflecting Schmidt telescope with 4000 fibers
- FOV:20 deg^2
- R~1800
- Wavelength: 3800 and 9000 A
- DR4 (internal release: ~7.6 million spectra)

# 1, WHITE DWARFS FROM LAMOST



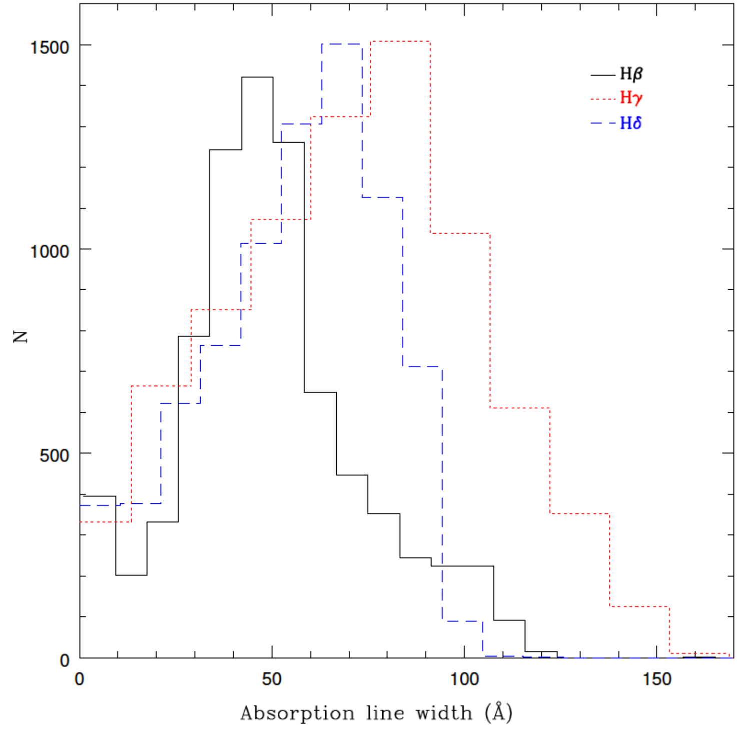

- **WD selection**

- A, LAMOST pipeline spectral type classification (Luo et al. 2012)
  "WD", "WD Magnetic", "Double Star" → ~7 000

- B, Color-color cut (Eisenstein et al. 2006). → ~4000

- C, Balmer line width.
  Based on distribution of WD sample from Kleinman et al. (2013),

30 Å at $H_\beta$, 50 Å at $H_\gamma$, 50 Å at $H_\delta$ → ~30 000




Guo et al. 2015, MNRAS

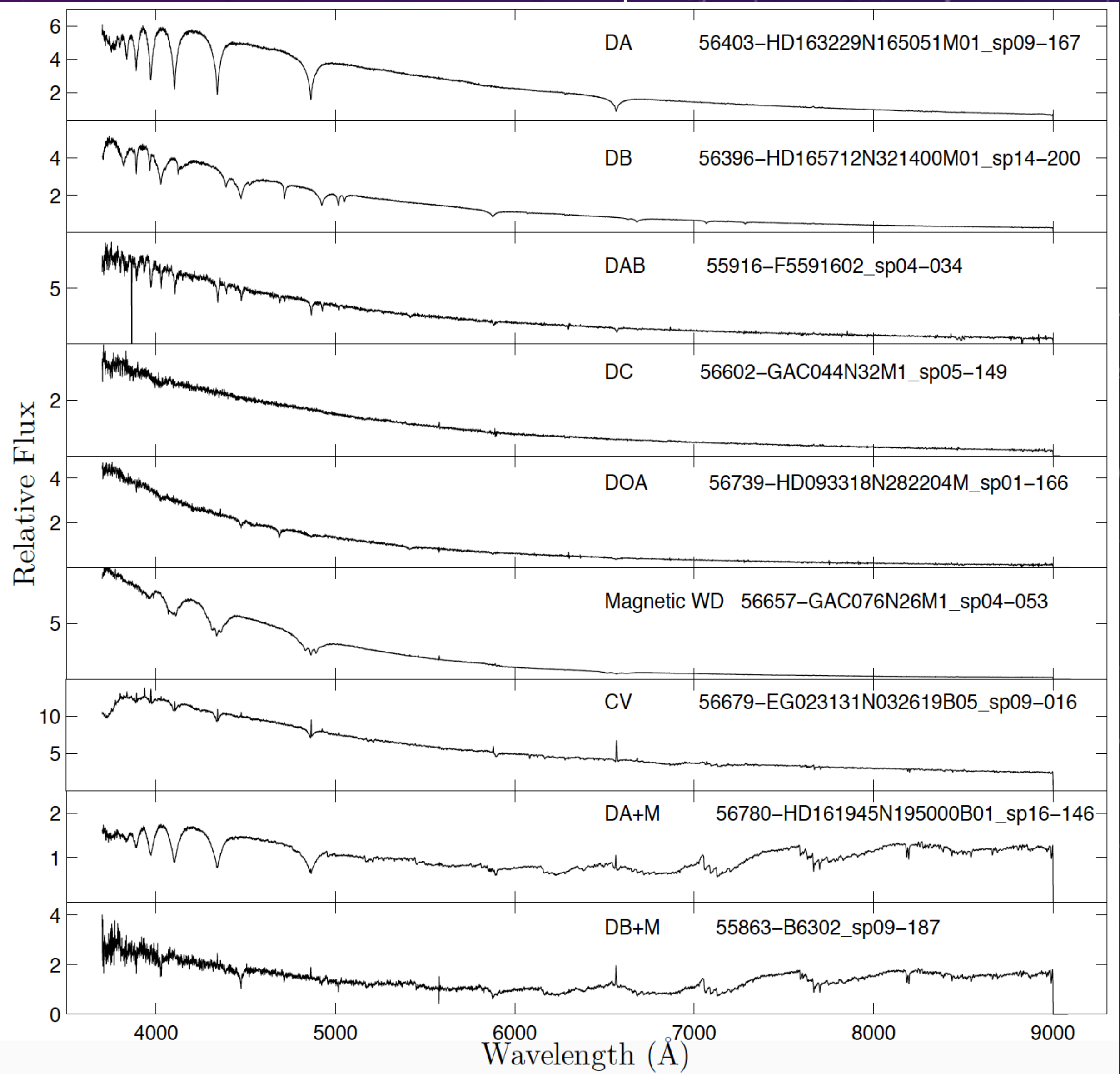
# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

- After visual inspection for each WD candidates,

表 3.2: 1509颗白矮星的光谱分类。

| Type | Number of WDs |
|---|---|
| DA | 1056 |
| DB | 34 |
| DAB/DBA | 8 |
| DO/DAO/DBO/DOA/PG1159 | 7 |
| DC | 14 |
| DAH | 2 |
| DQ/DQA | 3 |
| DZ | 61 |
| CV | 5 |
| WDMS | 276 |
| MagneticWD | 13 |
| subdwarf | 14 |
| Dwarf Nova | 5 |
| PN/DA in nebula | 10 |
| CarbonWD | 1 |



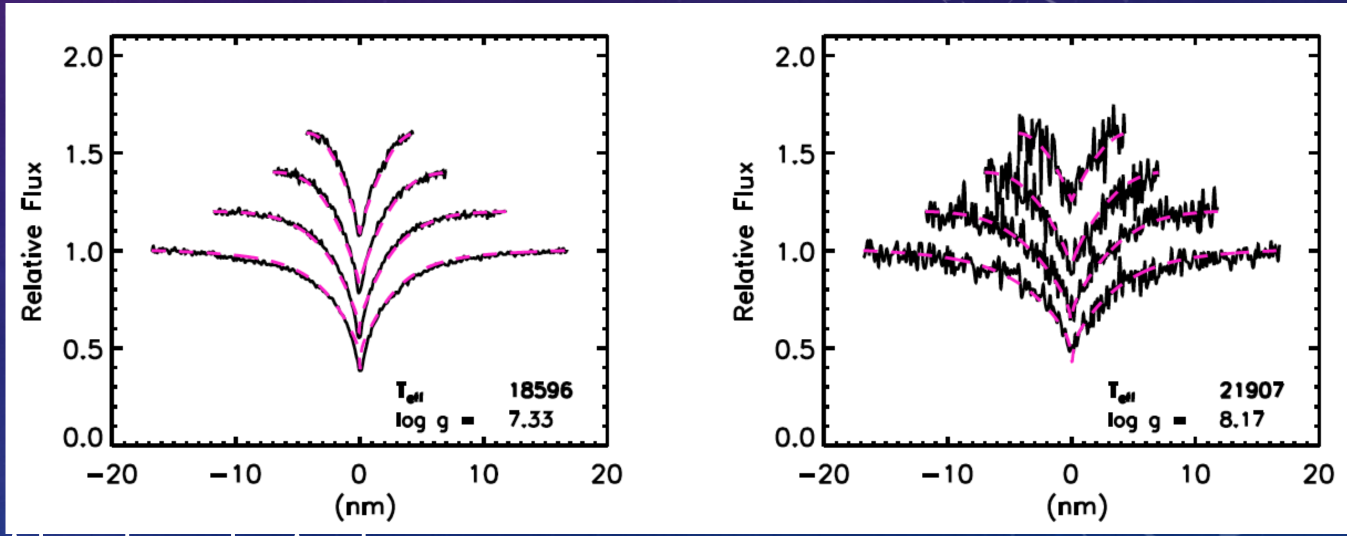
# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

- **Parameter determination of DAWD** (only S/N>=10)
- A, **Teff and log g**

  Line profiles fitting from Hβ to Hε

  WD atmosphere models provided by Koester(2010)




- B, **Mass and cooling time**

  Based on Bergeron's cooling sequences,

$T_{eff}$ and log g → mass and cooling time

- C, **Distance**

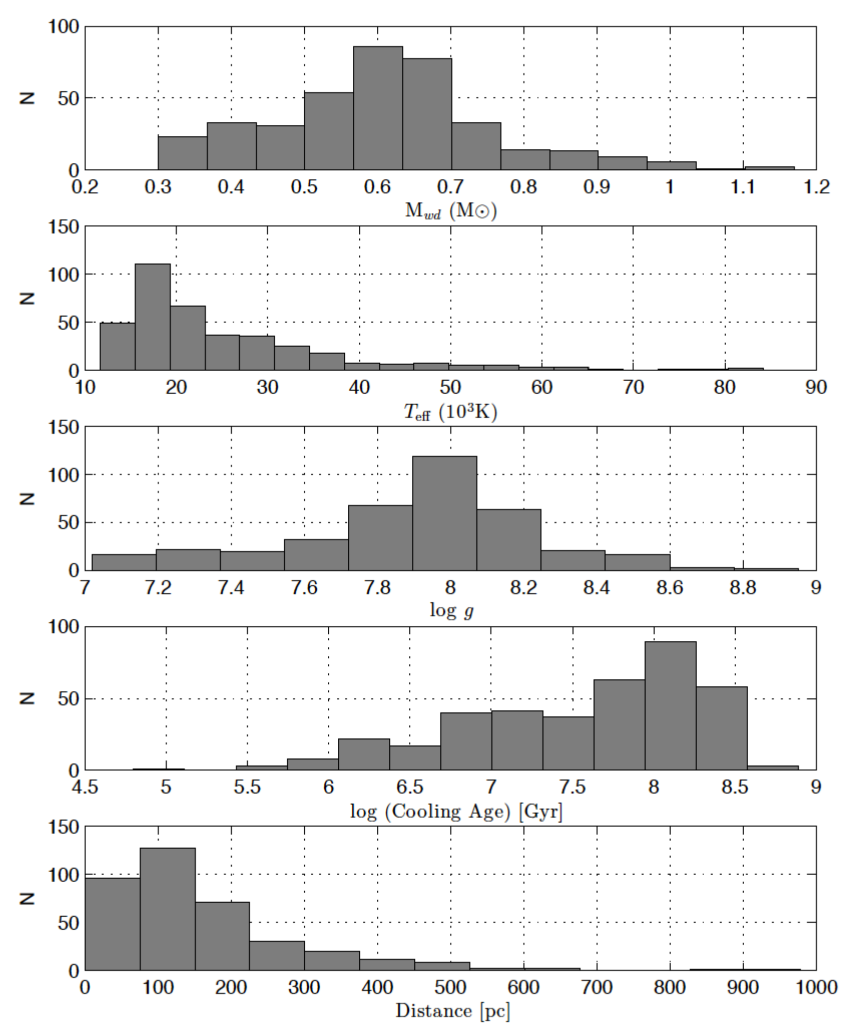
  Synthetic spectral distance estimated using multi-band synthetic photometry

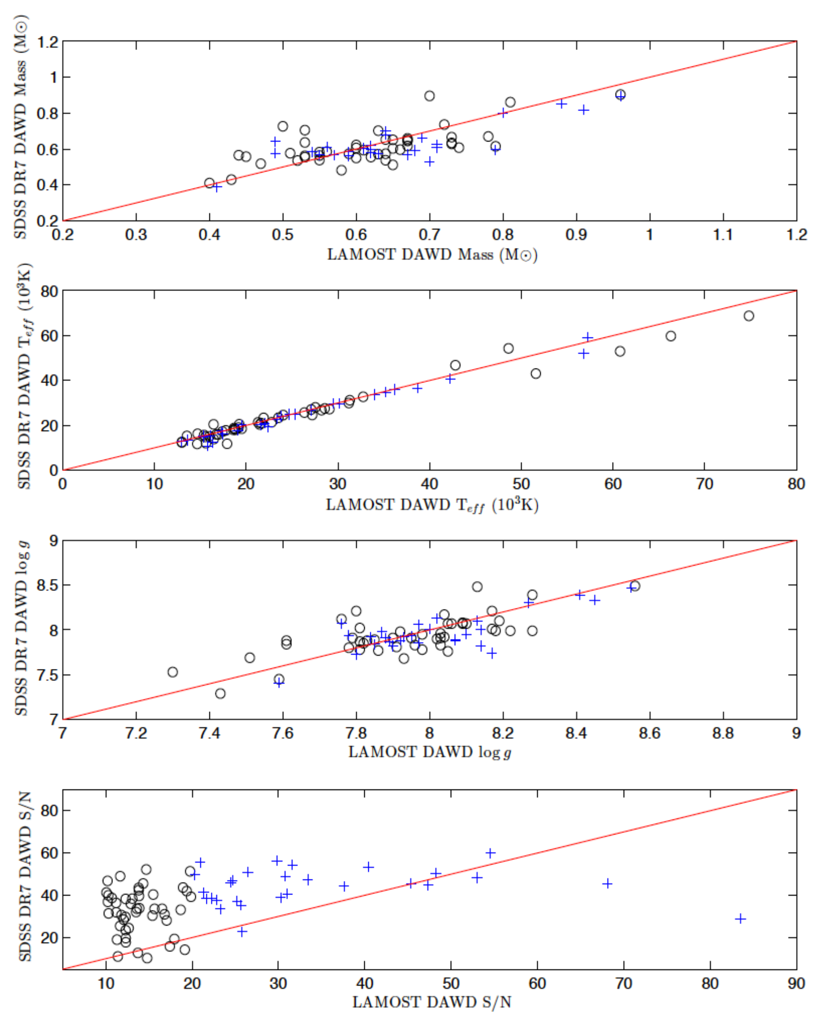
based on $T_{eff}$ and log g.

$$m_i = \sum_{i=(u,g,r,i,z,V)} M_i(\log g, T_{\rm eff}) + a_i A_g + 5 \log d - 5.$$

# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

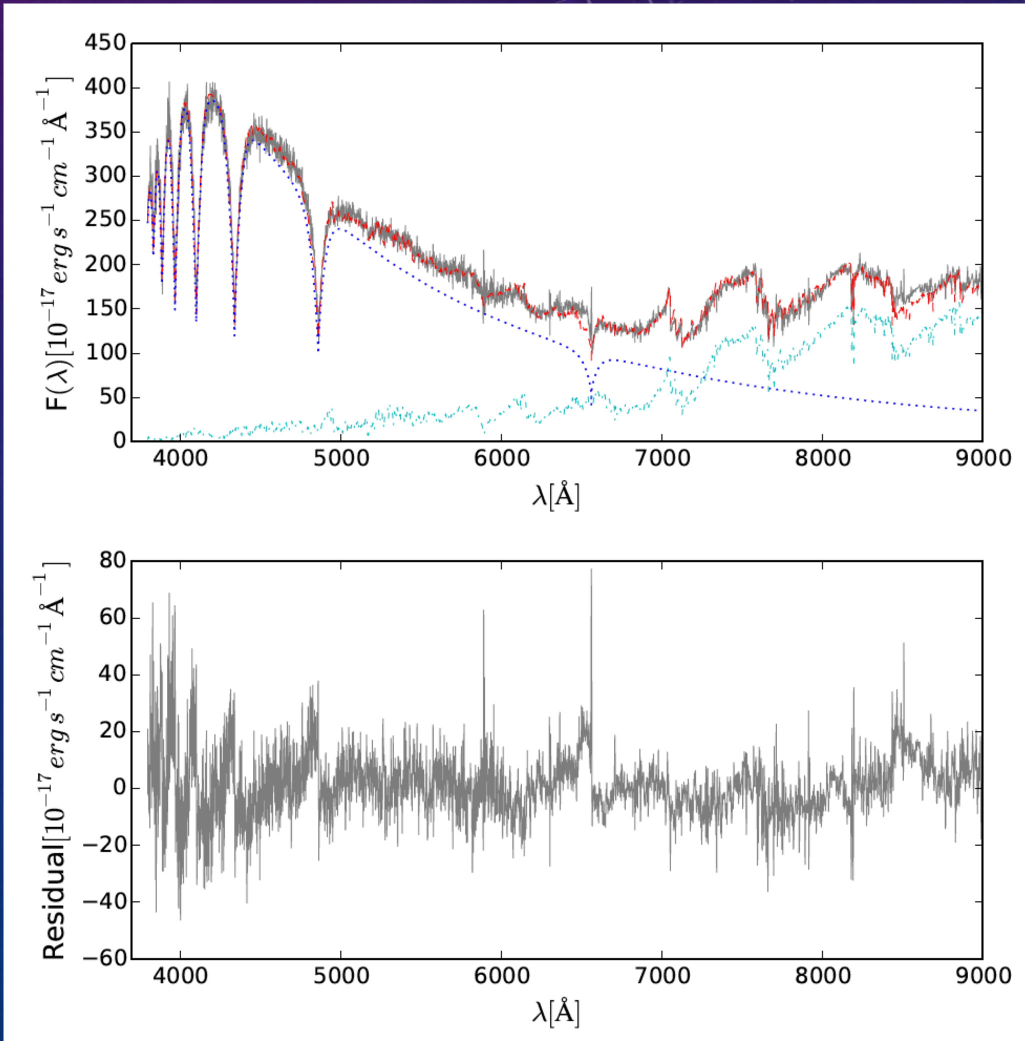


# 1， WHITE DWARFS FROM LAMOST

Guo et al. 2015, MNRAS

**White dwarf-main sequence binary (WDMS)**



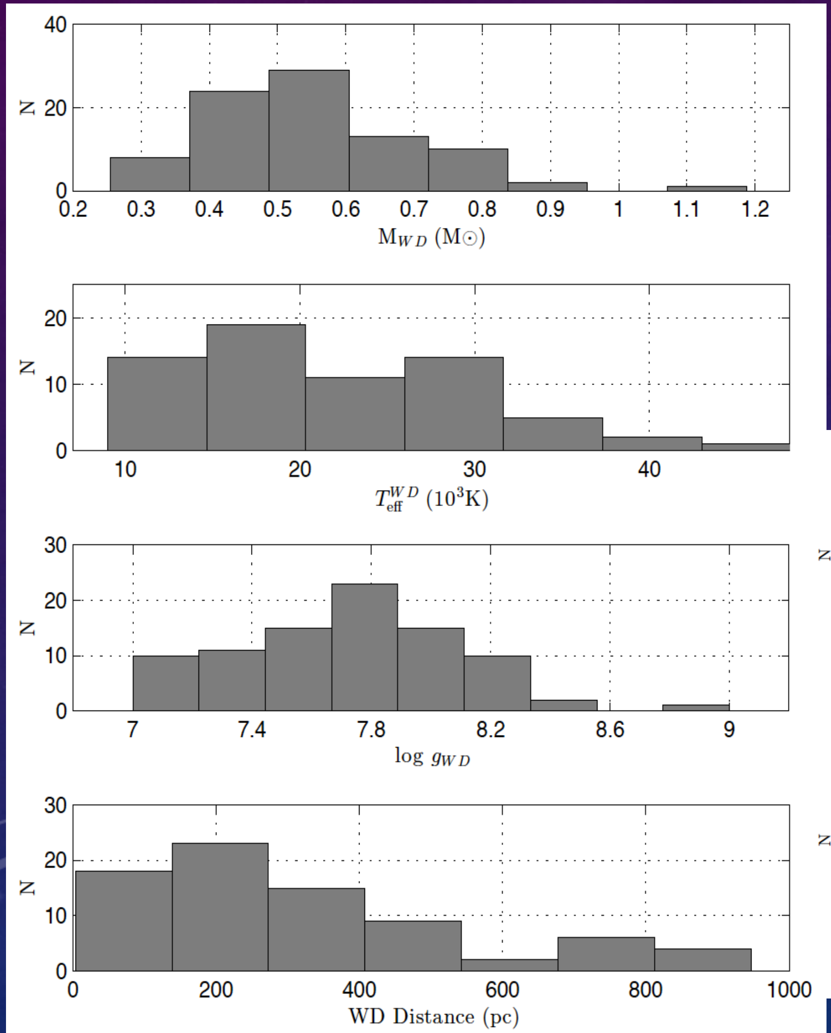

- We used a spectral decomposition and fitting method, described in Li et al.(2014), to estimate the WD and MS parameters.
- Combine models of WD (Koester 2010) and MS (PHONENIX), parameter spaces are constructed.
- $T^{M}_{eff}$,Log $g_M$, $[Fe/H]_M$ for M star and $T^{WD}_{eff}$,log $g_{WD}$ for WD

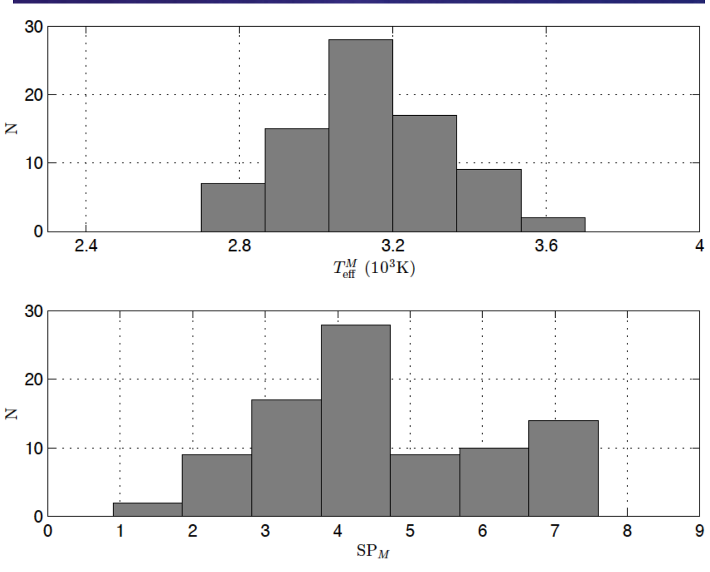
# 1， WHITE DWARFS FROM LAMOST

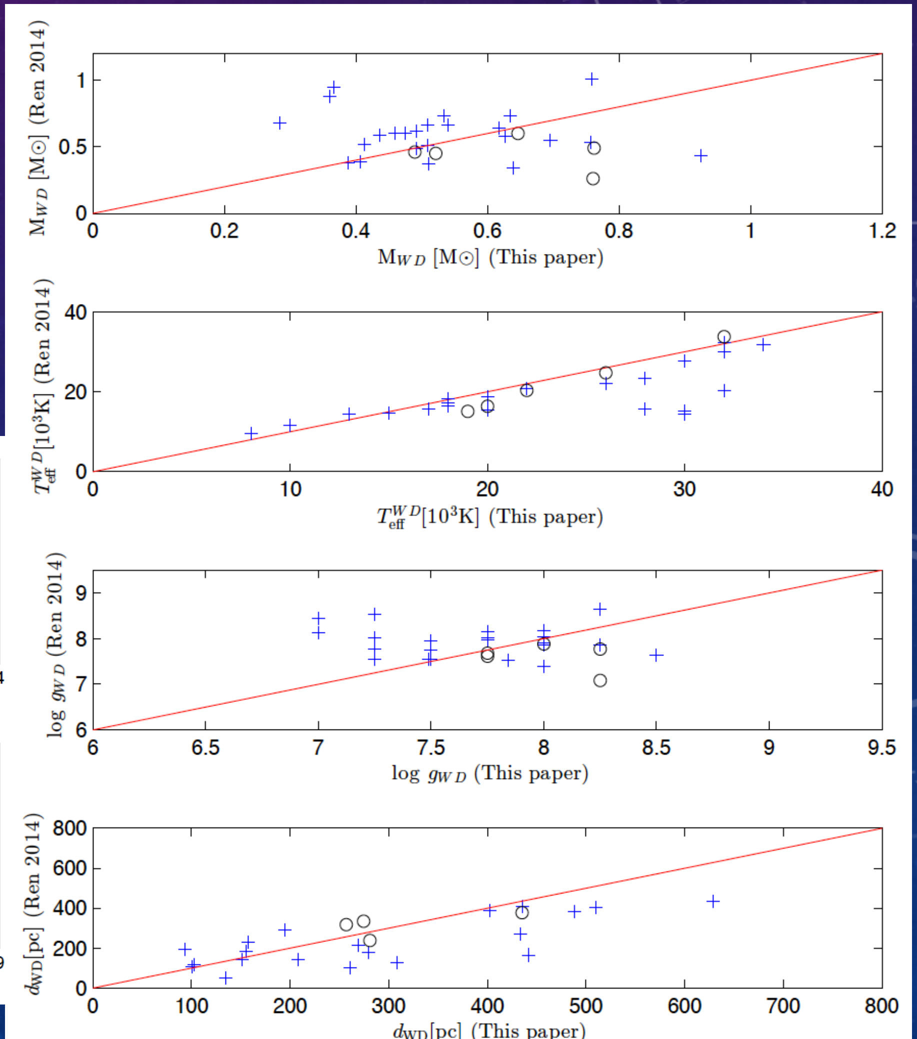
Guo et al. 2015, MNRAS

- WDMS parameter distribution (87 WDMSs)

Comparison with Previous work(29, Ren et al. 2014)



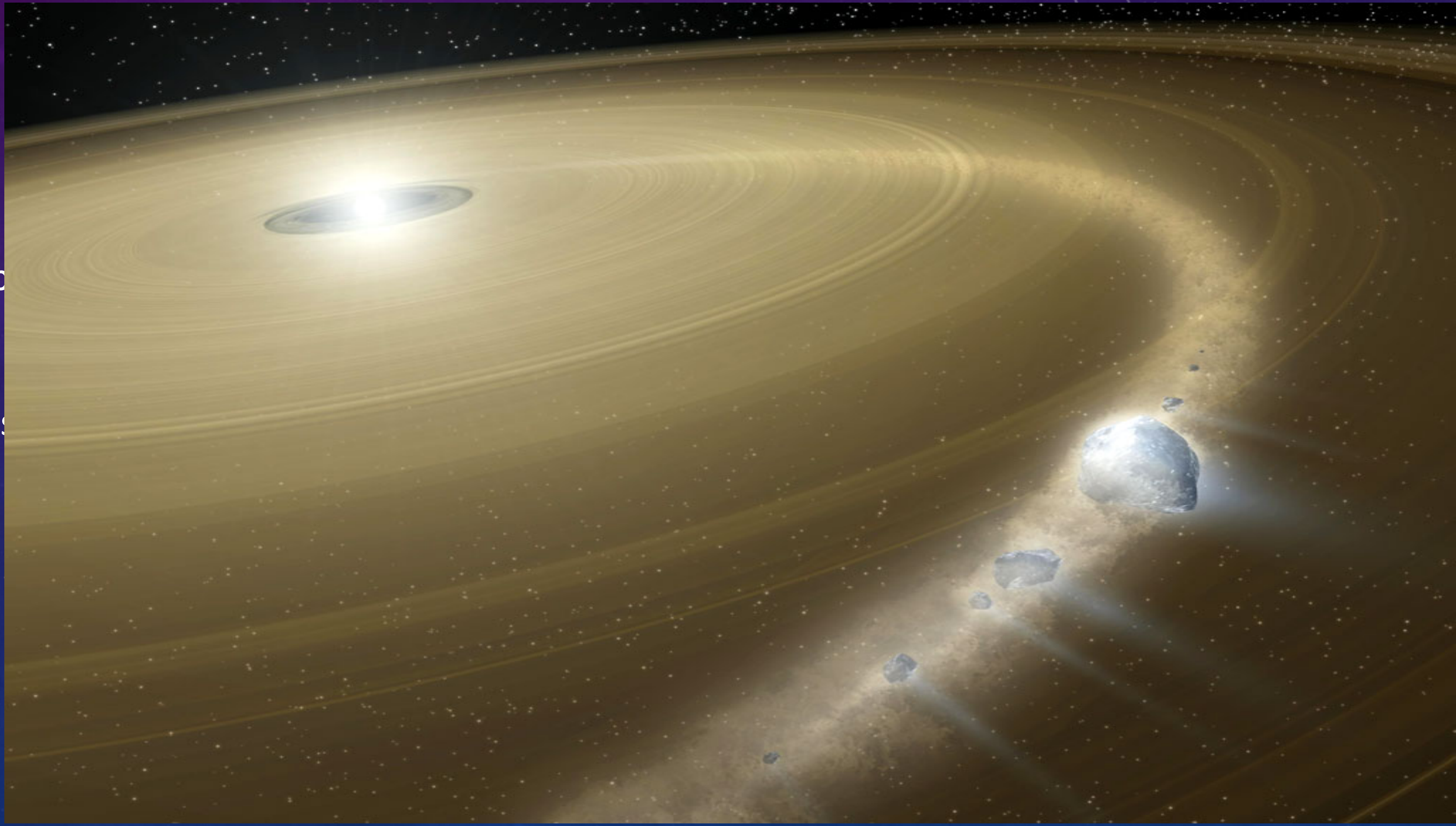
# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

- **Introduction**

- G29-38 is the first white dwarf with a deb

- The use of Spitzer and ground based teles

- They are formed from tidal disruption of



# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

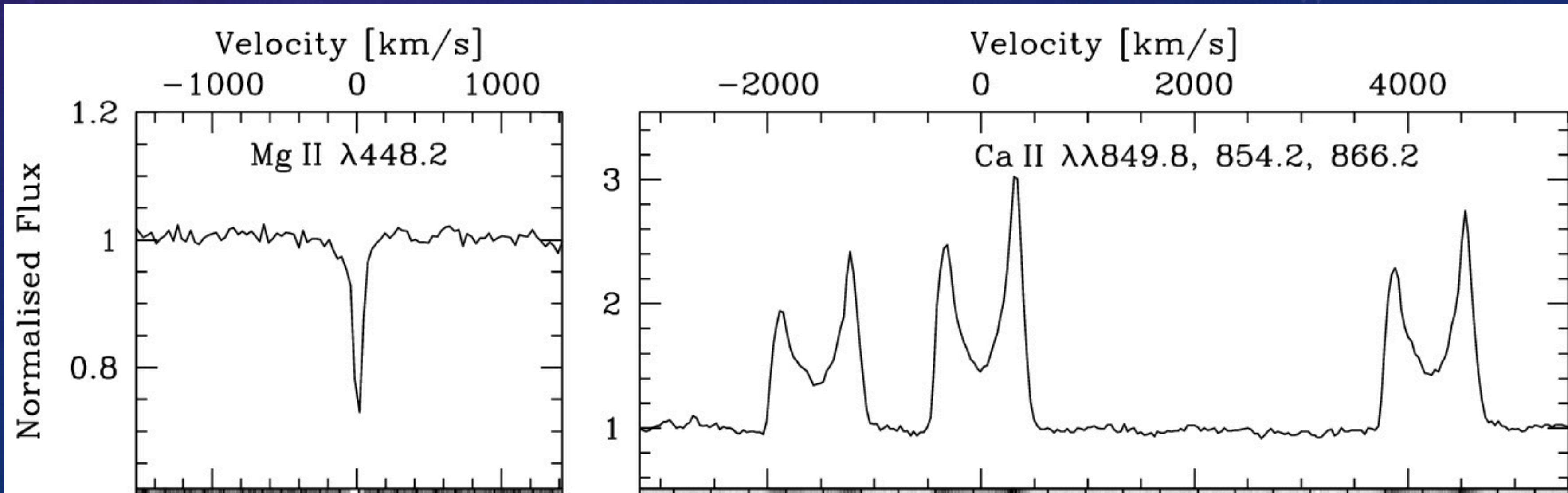
- **Observational evidence:**

- Metal absorption lines

Gansicke et al. (2006)

- Excessive emission at near and mid infrared bands

- Double-peaked emission lines



# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

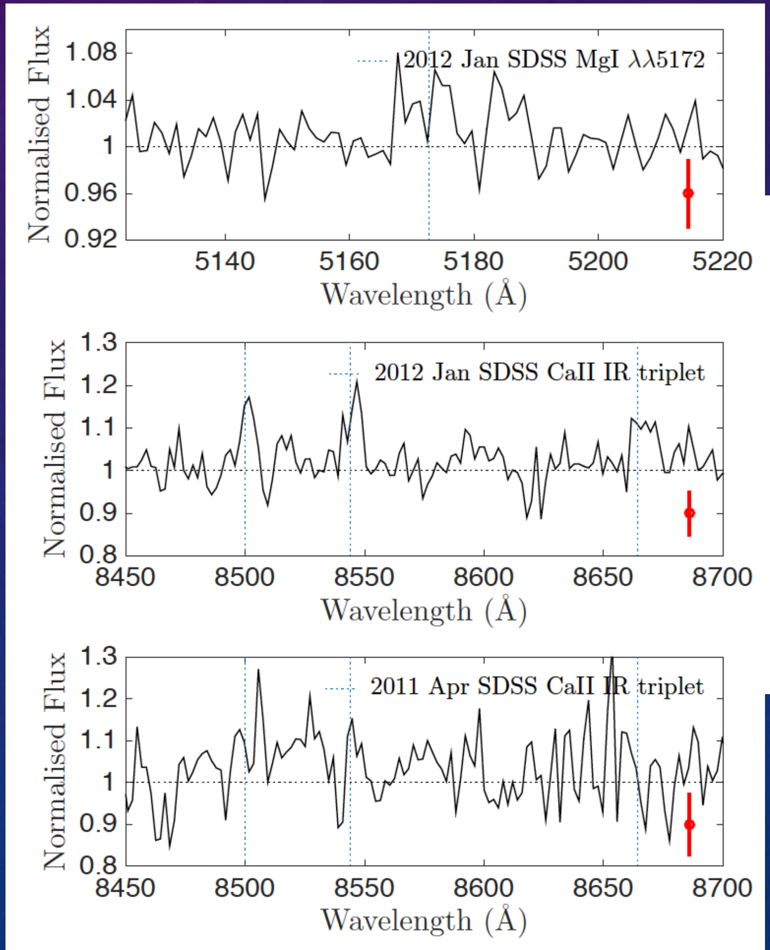
While inspecting SDSS spectra of WDs, we serendipitous discovered a DAWD(SDSS J1144+0529) with possible double-peaked emission lines arising from a gaseous disk.

## Spectral data

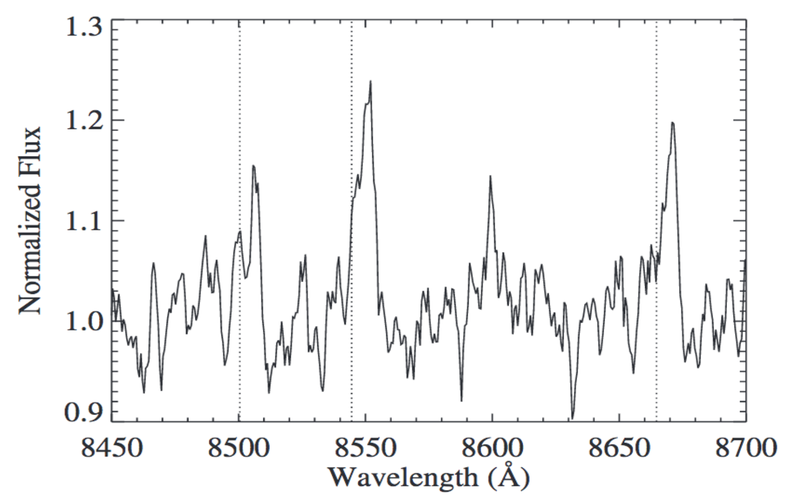
First identified as DAWD by Kepler et al.(2015) in SDSS DR10, then observed again in DR12.

Possible double peaked CaII IR triplet emission lines from SDSS spectra.

Quite similar to that seen in HE 1349-2305(Melis et al. 2012).



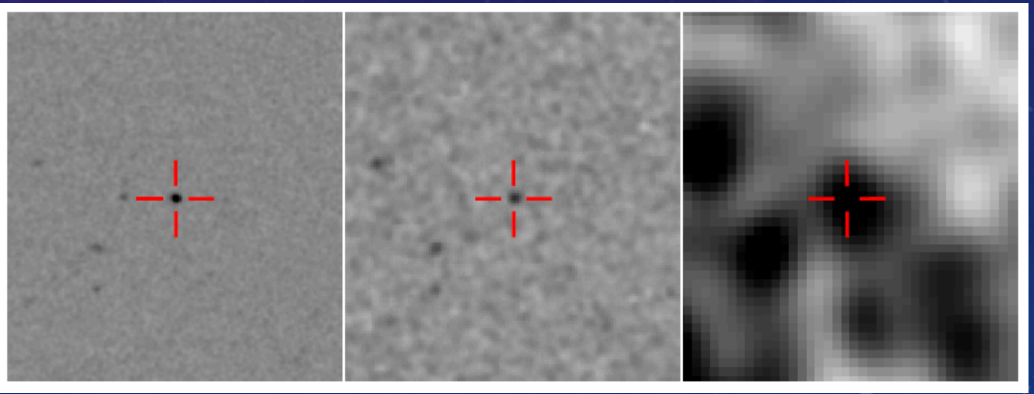

Melis et al. 2012



# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

- **Photometry DATA**
- Photometry of UV, optical, IR from GALEX, SDSS, UKDISS and WISE.

| | | | | | |
|---|---|---|---|---|---|
| | | | GALEX—Ultraviolet | | |
| Band | FUV | NUV | | | |
| Wavelength (nm) | 152.9 | 231.2 | | | |
| m (mag) | 16.495 ± 0.032 | 16.861 ± 0.025 | | | |
| $\mathrm{Flux_{obs}}$ (mJy) | 0.912 ± 0.025 | 0.665 ± 0.018 | | | |
| | | | SDSS — Optical | | |
| Band | u′ | g′ | r′ | i′ | z′ |
| Wavelength (nm) | 355.1 | 468.6 | 616.5 | 748.1 | 893.1 |
| m (mag) | 17.270 ± 0.009 | 17.292 ± 0.005 | 17.697 ± 0.006 | 17.951 ± 0.009 | 18.263 ± 0.033 |
| Flux (mJy) | 0.490 ± 0.004 | 0.469 ± 0.002 | 0.317 ± 0.002 | 0.248 ± 0.002 | 0.184 ± 0.006 |
| | | | UKIDSS — IR | | |
| Band | *J* | *H* | *K* | | |
| Wavelength (nm) | 1248 | 1631 | 2201 | | |
| m (mag) | 17.793 ± 0.031<br>17.767 ± 0.028 | 17.796 ± 0.106<br>17.588 ± 0.083 | 17.454 ± 0.123<br>17.810 ± 0.164 | | |
| $\mathrm{Flux_{average}}$ (mJy) | 0.120 ± 0.005 | 0.086 ± 0.011 | 0.056 ± 0.012 | | |
| | | | WISE — Infrared | | |
| Band | W1 | W2 | W3 | W4 | |
| Wavelength ($\mu$m) | 3.4 | 4.6 | 12 | 22 | |
| m (mag) | 17.31 ± 0.16 | 16.54 | 11.91 | 8.49 | |
| Flux (mJy) | 0.037 ± 0.006 | 0.04 | 0.50 | 3.34 | |



J, K, W1

# 2, DEBRIS DISK AROUND WHITE DWARF FROM SDSS

- **Analysis and results**

1, White dwarf parameters

Re-analyzed the source with 2012 SDSS spectrum.

$T_{eff}$=23 027±219 K,

log g=7.74±0.03,

Mass=0.49±0.03 $M_\odot$ ,

cooling age=21.2±1.9 Myr (very young for WD),

distance= 284.9±13.2 pc,

$R_{wd}$~0.016 $R_\odot$ .

Consistent with those derived from Kepler et al. (2015).

# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

## Analysis and results

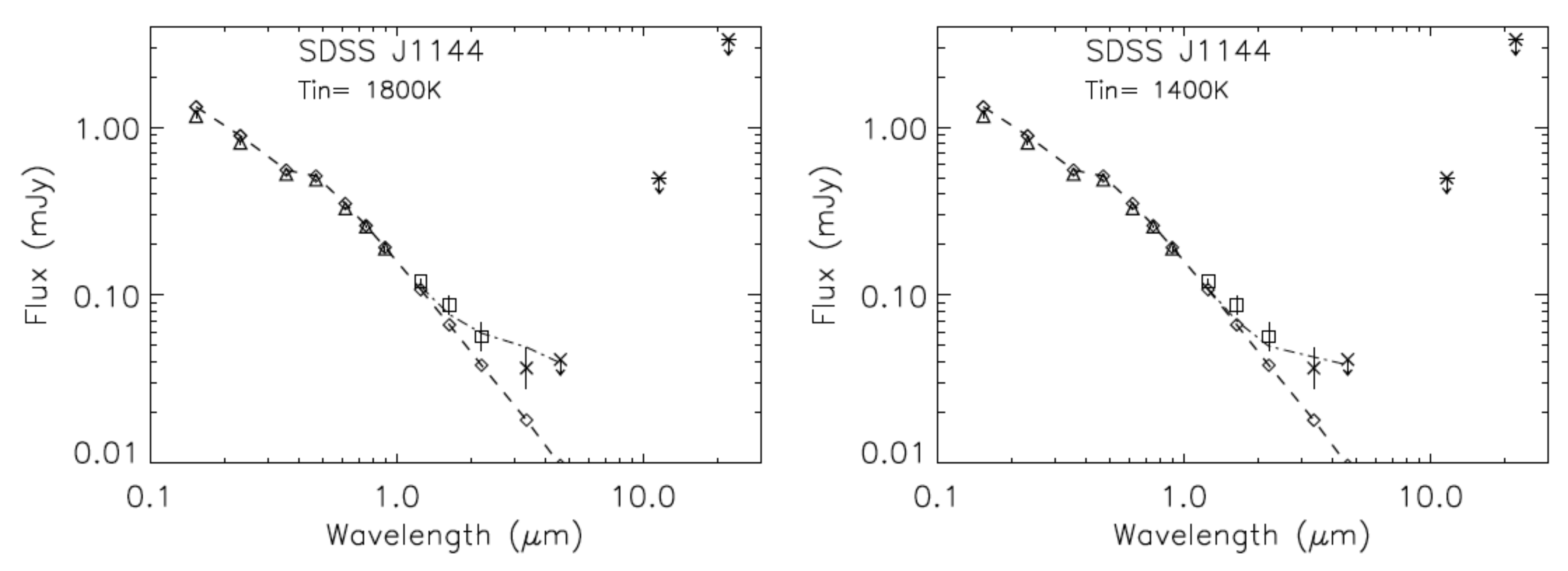
2, IR Excesses

First construct the broadband spectrum.
Based on Teff and log g, WD model spectrum is plotted as diamonds.
Excess emissions of ~2**σ** at K and ~3**σ** at W1 are detected, indicating the possible existence of a dust disk.

A flat, opaque disk model (Juna 2003) was used to fit the excesses from J to W2.

Set inner disk temperature $T_{in}$ at 1800K(18$R_{WD}$)→best fit $T_{out}$ ~800K(53$R_{WD}$), i=82°, $\chi^2$=3.9/2.

Set $T_{in}$ at 1400K(25$R_{WD}$)→$T_{out}$~600K(74$R_{WD}$),i =82°,$\chi^2$=8.1/2.



# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

## Analysis and results

3, Gas emission lines

The Ca II IR triplet emission lines were weakly detected in 2012 SDSS spectrum with EWs of -1.3±0.4 Å, -1.7±0.4 Å and -1.5±0.5 Å.

Possible detection of Mg I λλ5172 with EW of -0.6±0.4 Å.

Marginally detection of Ca II K absorption line in 2012 spectrum.

Upper limits of EWs in 2011 spectrum <-1.6 Å, <-0.7 Å, <-0.3 Å.

The double-peaked line profile can be used to constrain the physical size of the gaseous disk. (Horne & Marsh 1986; Gansicke et al. 2006)

→ $V_{max}$sin i=-354±141/211±106 km/s, $V_{max}$sin i=-179±70/313±140 km/s and $V_{max}$sin i=-143±69/411±138 km/s.

Considering i~82°, inner radii of the gas disk is ~30 $R_{WD}$. While the uncertainties are large, the value is in agreement with those of previously reported gaseous disks(Gansicke et al.2008;Melis et al.2012;Wilson et al. 2014).

# 2， DEBRIS DISK AROUND WHITE DWARF FROM SDSS

- **Discussion**

- We have discovered a highly likely debris disk around the recently identified DA WD.

- In the study of the IR excesses in four WD gaseous disks, Brinkworth et al. (2012) noted that $T_{in}$ higher than the 1400K (sublimation temperature) is favored when the commonly used debris-disk model, proposed by Juna (2003), is used to fit the excesses. This is also true in our case.

  It is possible that the debris-disk model is too simplified.

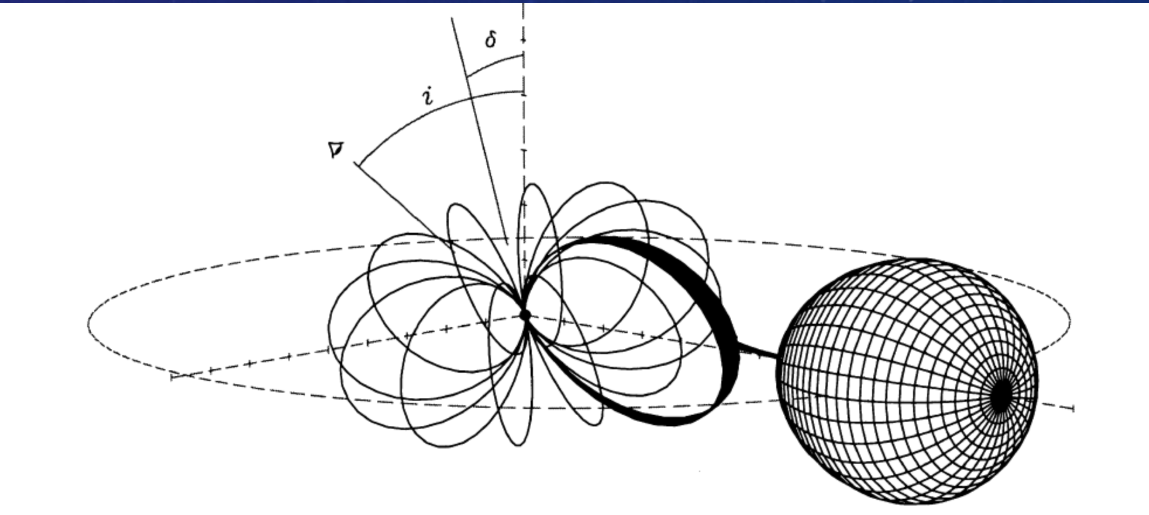
Or as suggested by Rafikov & Garmilla (2012), the inner part of a debris disk could have a much higher sublimation temperature because of the high metal vapor pressure.

- In any case, the properties of ~23,000 K temperature and a cooling age of ~21 Myr make SDSS J1144+0529 one of the hottest and youngest WDs with a debris disk.

# 3,POSSIBLE EVIDENCE OF ASTEROIDS AROUND POLAR AR UMA

Bai et al. ApJ (2016)

- Discovered by *Einstein*, extremely soft ($T_{bb}$~22eV)
- *I* band, P=1.923hr (Remillard et al. 1994 )
- Low-state spectrum, Blue+MD
- Spectropolarimetry, polar (~240 MG) (Schmidt et al. 1996)

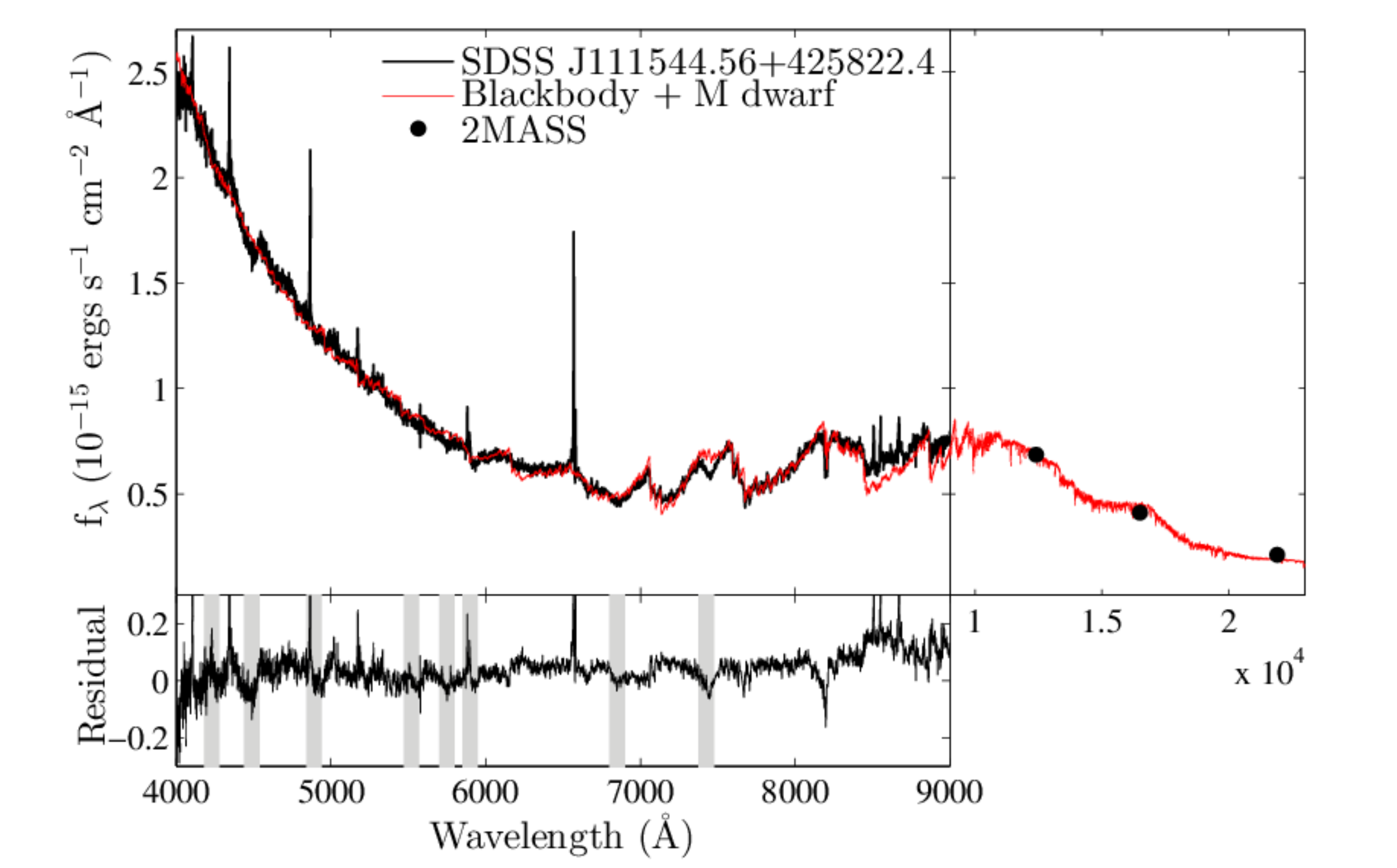


# 3,POSSIBLE EVIDENCE OF ASTEROIDS AROUND POLAR AR UMA

Bai et al. ApJ (2016)

Our observation features:

- Low state
- Two components
- Emission
- Absorption

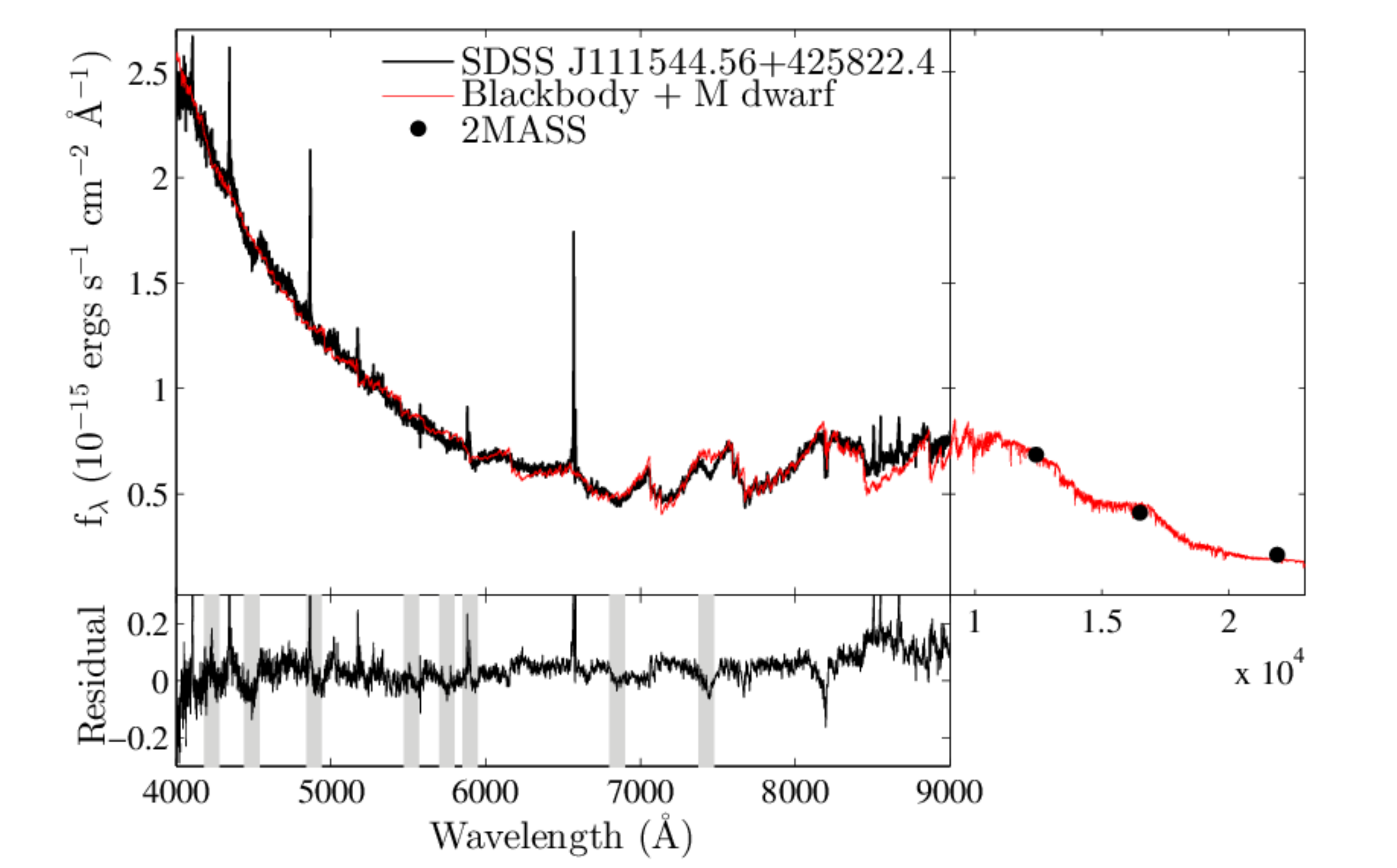


# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)

BB + MD templates

- $T_{bb}$ = 46300 K, $T_{eff}$ = 3200 K
- log $g$ = 5.0, [Fe/H] = 1.0
- $R_{MD}$ = 0.15 ± 0.02 $R_{\odot}$ (86 pc)
- $R_{blue}$ = 0.0034 ± 0.0004 $R_{\odot}$



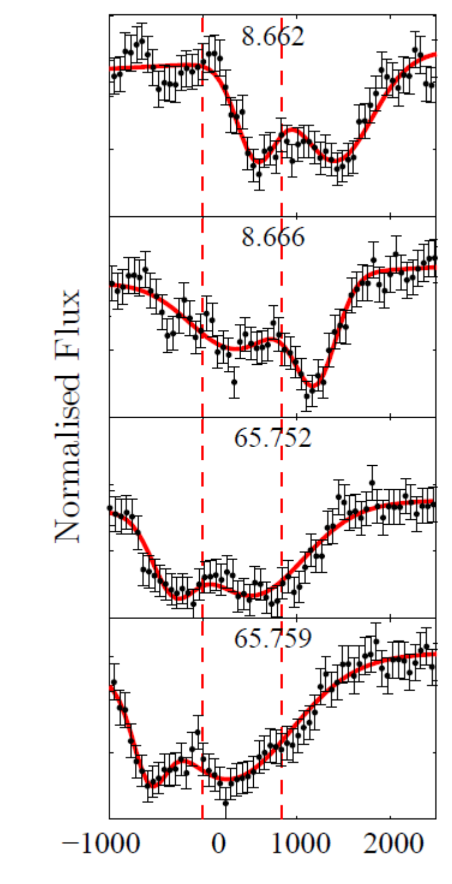
# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)

Mass Constrained by Na I

$K$ = 409 ± 26 km $s^{-1}$
$\theta < 75^{\circ}$

Semi-empirical relation,
$M_{MD}$=0.154 $M_{\odot}$
$M_{WD} > 0.87\ M_{\odot}$



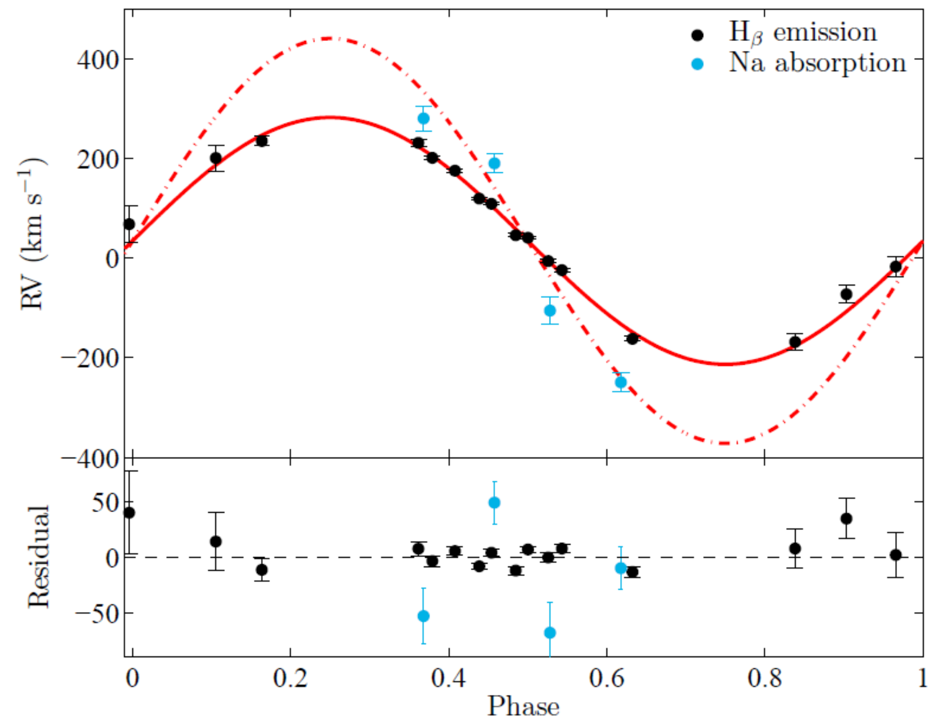



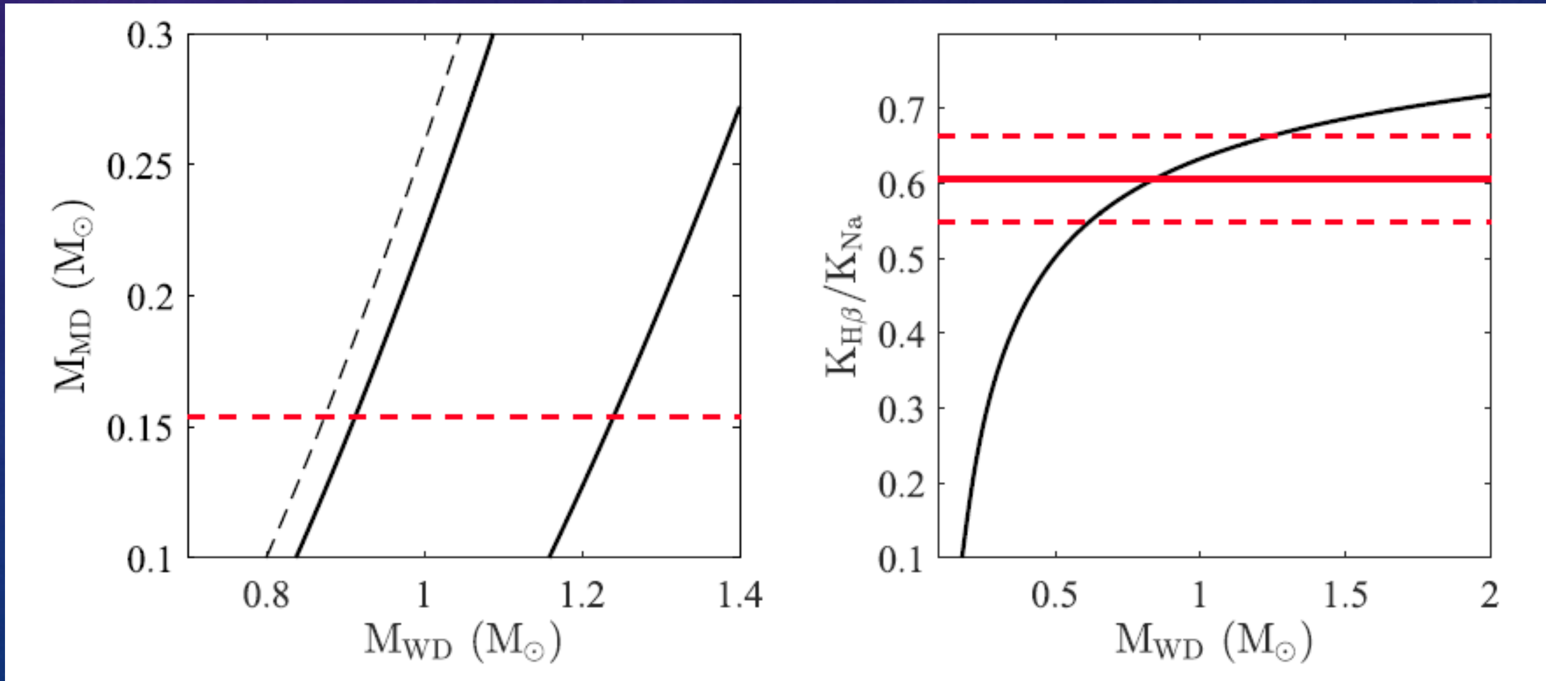

FIG. 2.— *Top*: radial velocity of $H_{\beta}$ and Na I. *Bottom*: the residual to the fitting.

# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)

Mass Constrained by $K_{H\beta}/K_{na}$

$K_{H\beta}/K_{Na} = 0.628 \pm 0.039$
$0.87\ M_\odot < M_{WD} < 1.24\ M_\odot$

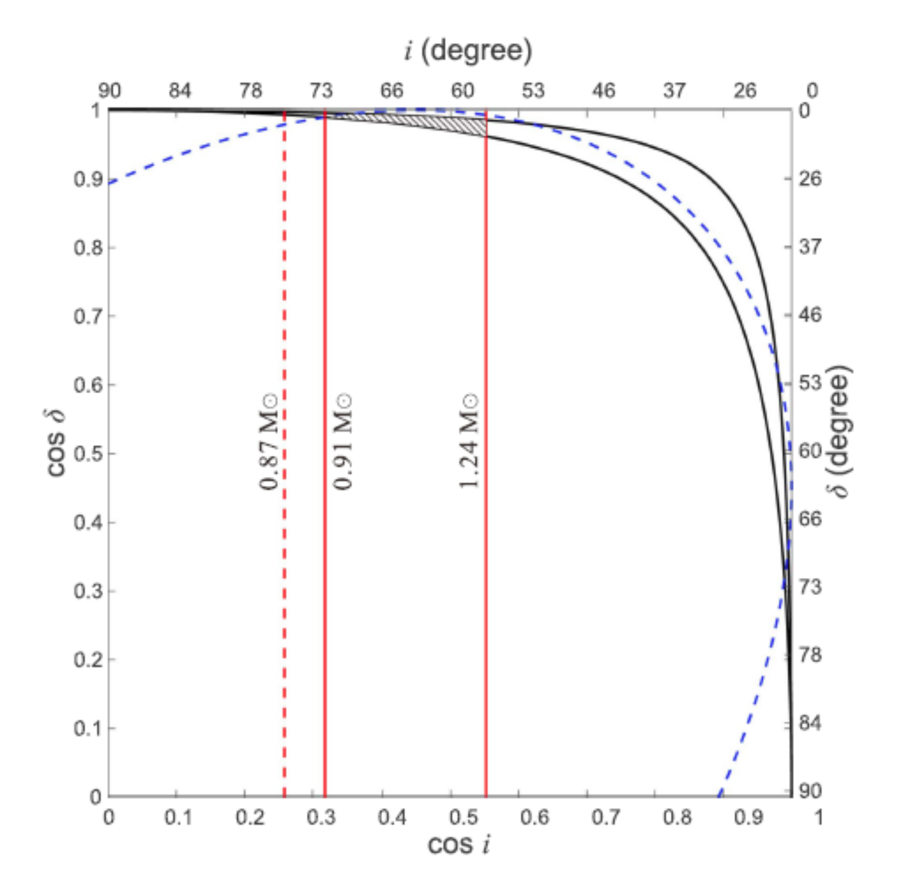


# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)

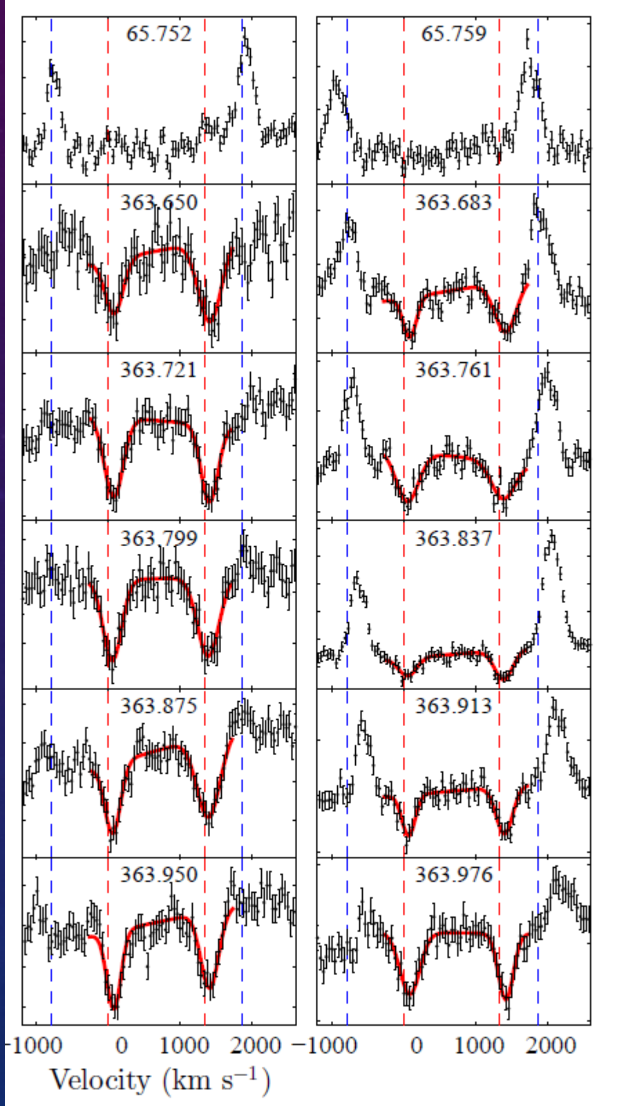
Mass Constrained by Geometry

$0.91\ M_\odot < M_{WD} < 1.24\ M_\odot$



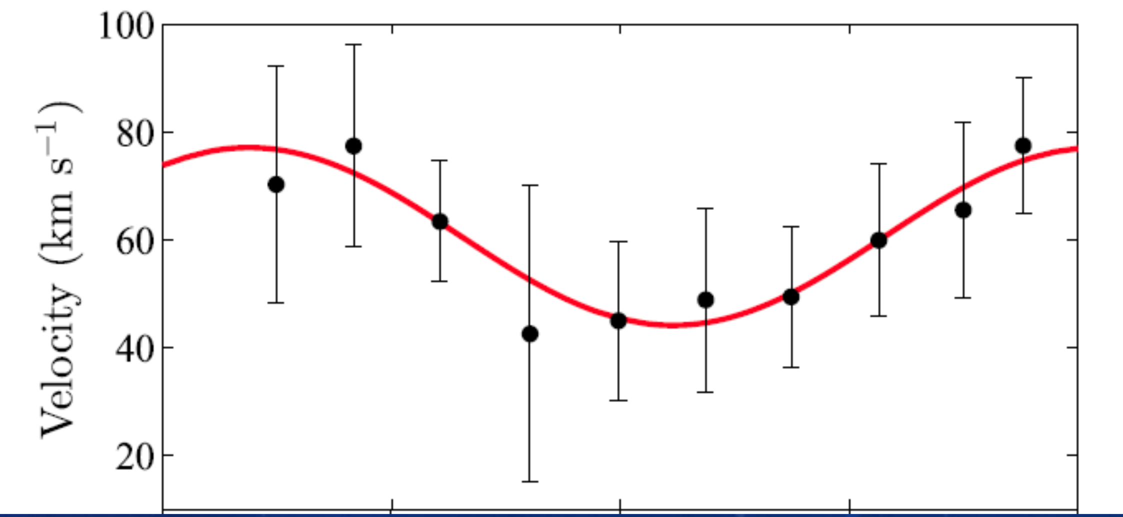
# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)




Fitting Parameters of Radial Velocities

| Line | $K$ (km s$^{-1}$) | $\gamma$ (km s$^{-1}$) | P (hr) |
|---|---|---|---|
| Al | 17 ± 9 | 61 ± 6 | 8.891 ± 0.001 |
| $H_\beta$ | 248 ± 4 | 34 ± 5 | 1.93201522[a] |
| Ca II | 275 ± 15 | 30 ± 7 | 1.93201522[a] |
| Na I | 409 ± 26 | 34[b] | 1.93201522[a] |



# 3,POSSIBLE EVIDENCE OF ASTEROIDS IN POLAR AR UMA

Bai, Justham, Liu, Guo, et al. ApJ (2016)

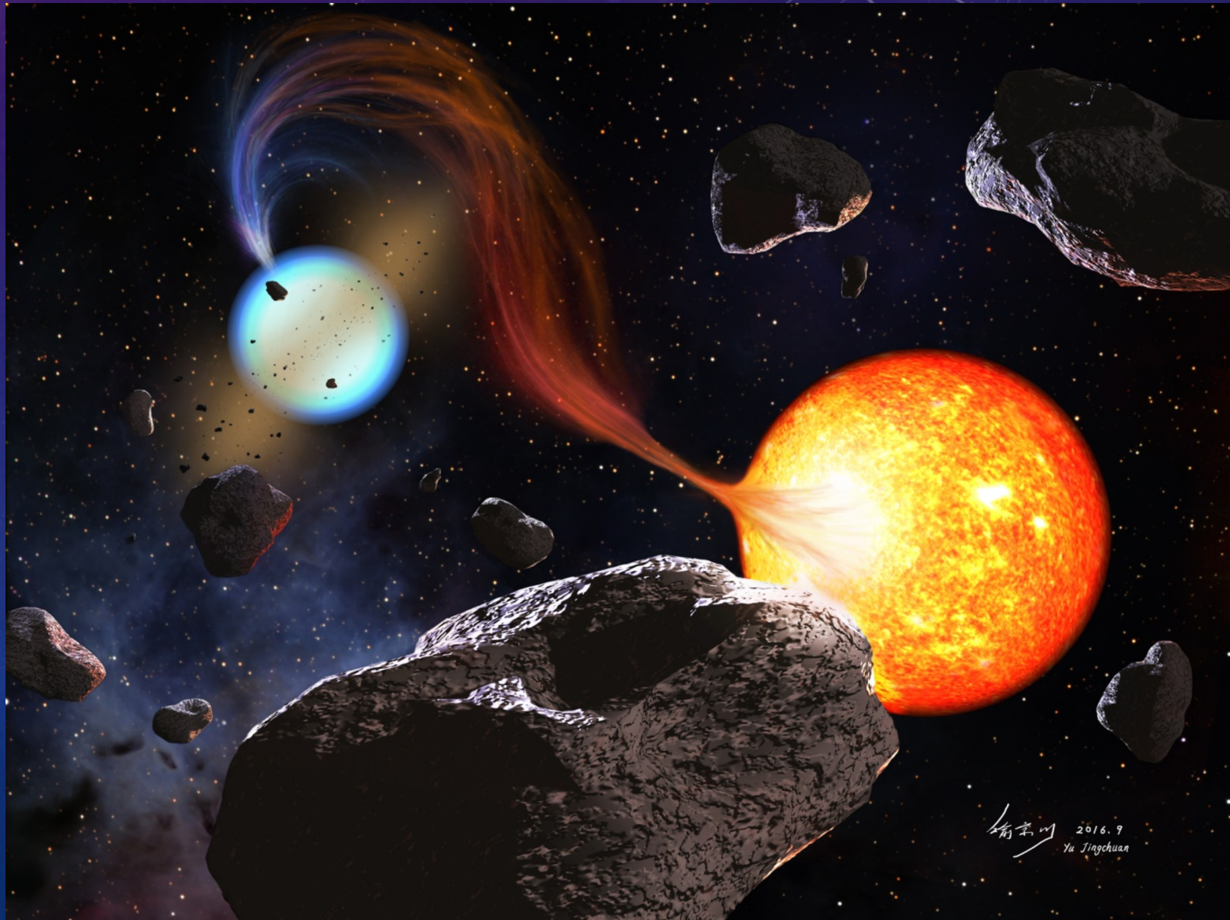
Telluric origin or an artifact?

ISM?

From secondary?

From the WD?

From circumstellar material



# 3,POSSIBLE EVIDENCE OF ASTEROIDS AROUND POLAR AR UMA

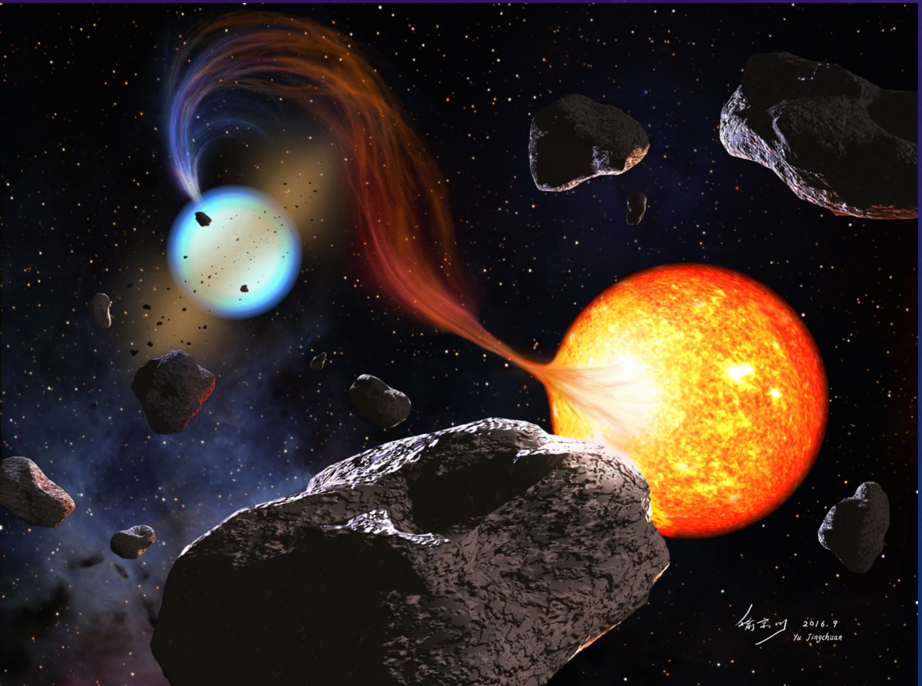
Bai et al. ApJ (2016)

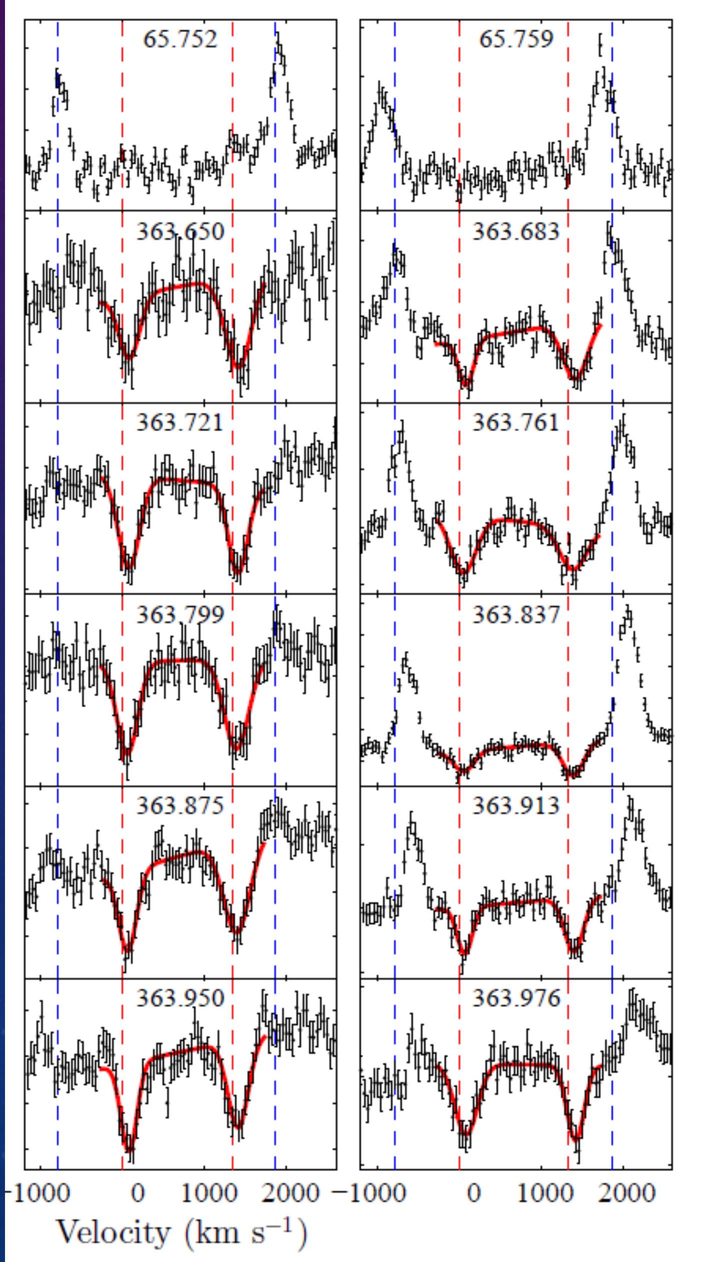
$0.91\ M_{\odot} < M_{WD} < 1.24\ M_{\odot}$

Al I λλ 3944.01, 3961.52 doublet

From circumstellar material

More details in arXiv:1608.04464





# THANKS!

Looking for Postdoc, visiting, collaboration opportunities.

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