Ultracompact AM CVn binaries and their progenitors

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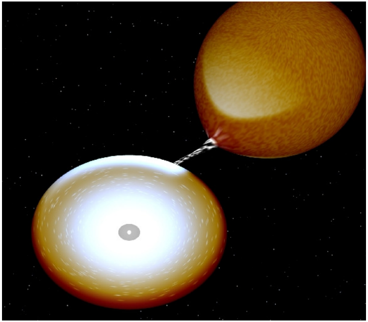

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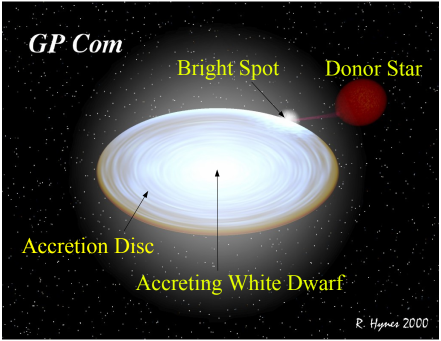
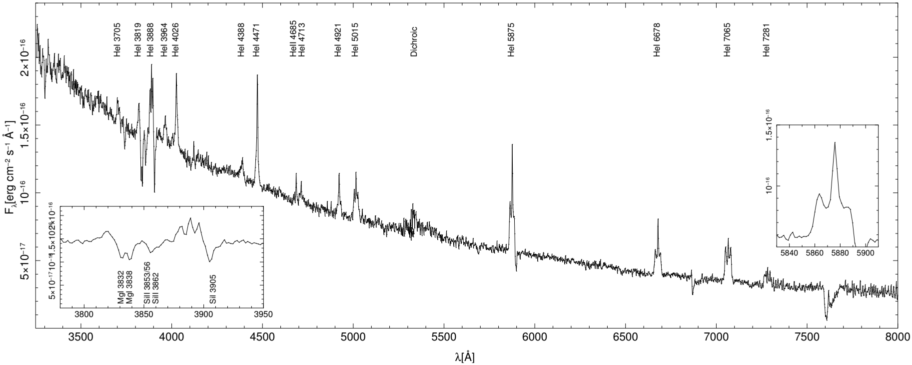
1. What is an AM CVn system?
2. Spectroscopic and kinematic analysis of four AM CVn systems
3. SDSS J1908+3940 - AM CVn with a rich metal line spectrum
4. CD-30 11223 - An AM CVn progenitor and a good candidate for an underluminous supernova
5. Search for AM CVns and progenitor systems in the UVEX database

What is an AM CVn?



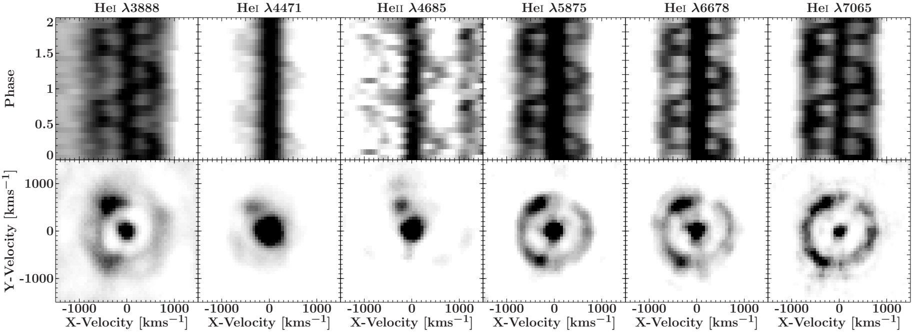
- Interacting binaries
- Ultimate survivors:
  Two common envelope +
  one direct impact phase
- Orbital periods between only
  5.4 - 65 min!
- Spectra show lack of hydrogen
  $\Rightarrow$ In highly evolved stages
- Evolution set by gravitational
  wave radiation
  $\Rightarrow$ Strong gravitational wave
  emitters

SDSS J1208+3550 observed with the WHT



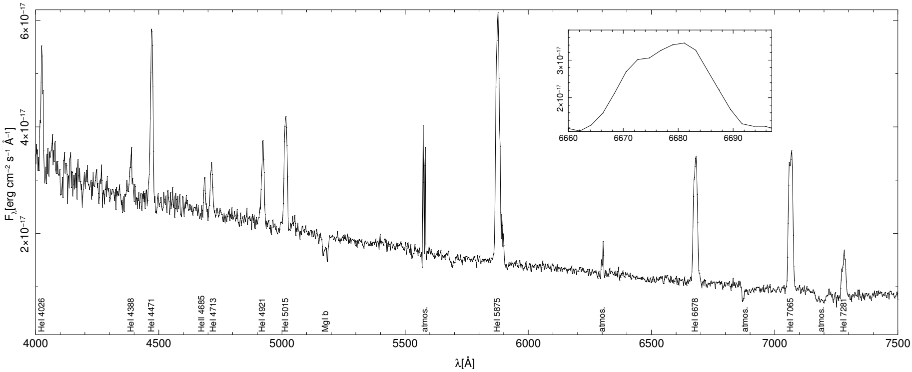
- Typical emission lines for long period system with strong central spike
- Strong absorption features in the blue side of the spectrum

Spectroscopic period of SDSS J1208+3550



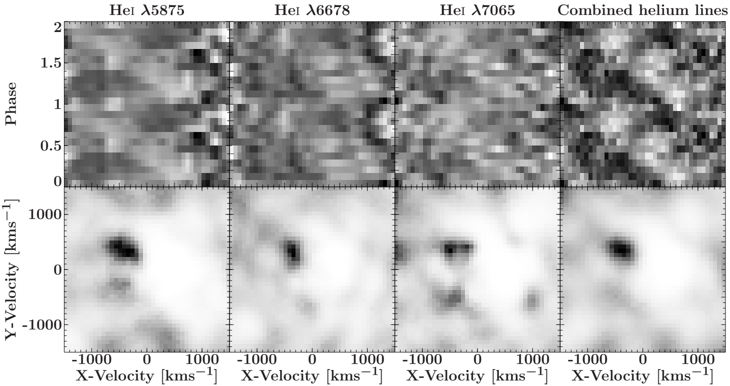
- Kinematics analysis gives period of 52.96±0.40 min
- Trailed spectra revealed second bright spot
- Origin unclear

SDSS J1642+1934 observed with the GTC



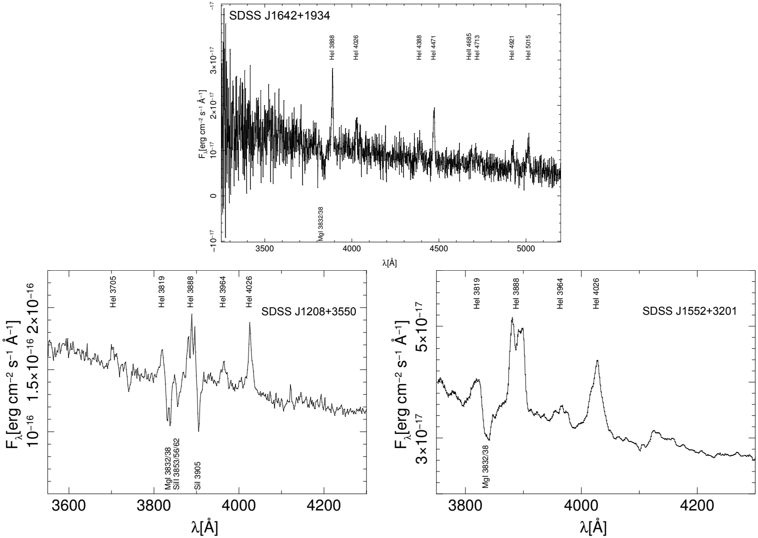
- Very strong and narrow emission lines
- No central spike

Kinematics of SDSS J1642+1934



- Only trail with combined lines revealed bright spot
- P_{orb}=54.20±1.60 min ⇒ Third longest known orbital period
- Dimming of bright spot

Metal lines in SDSS J1208, SDSS J1642 and SDSS J1552



- Absorption lines known from accreting DBZ white dwarfs
  $\Rightarrow$ **But** In DBZ white dwarfs Mg always shows up with Ca

Metal lines in SDSS J1208, SDSS J1642 and SDSS J1552

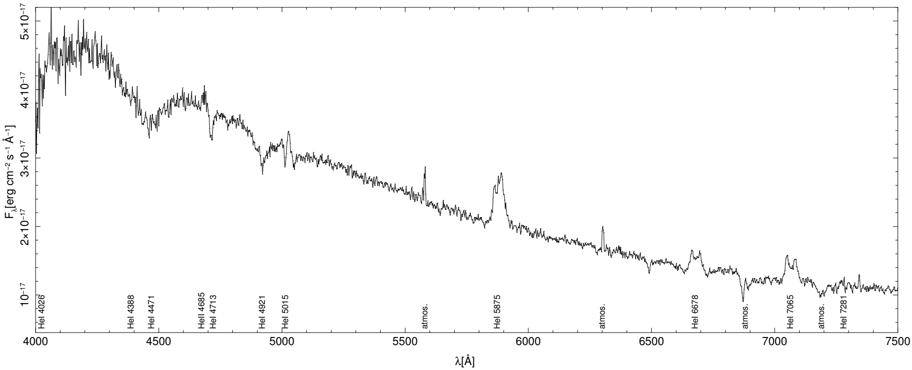
- All three systems with periods between 50 and 60 min orbital period show Mg and no Ca
- Origin most likely in the photosphere of the accretor but lines in all spectra are not resolved

Possible explanations:

- Accretion of sedimanted material from the donor star
- Differential gravitational settling of various elements

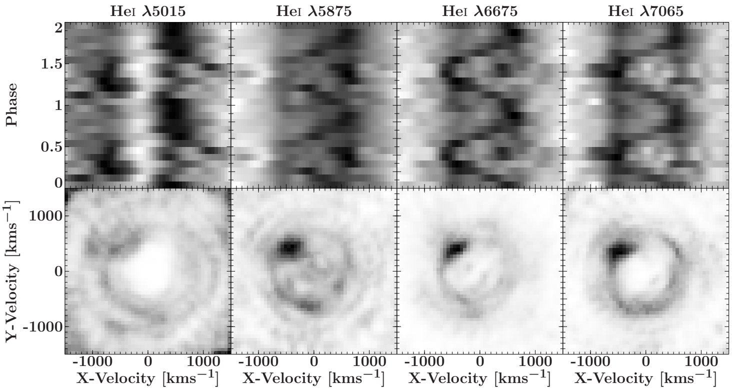
$\Rightarrow$ Phase resolved spectroscopy on SDSS J1642 with XShooter

SDSS J1525+3600 observed with the GTC



- Strong emission features from the disc and absorption lines from accreting white dwarf
  $\Rightarrow$ Temperature of white dwarf still high
  $\Rightarrow$ Expected $P_{\mathrm{orb}} < 40$ min

Kinematics of SDSS J1525+3600

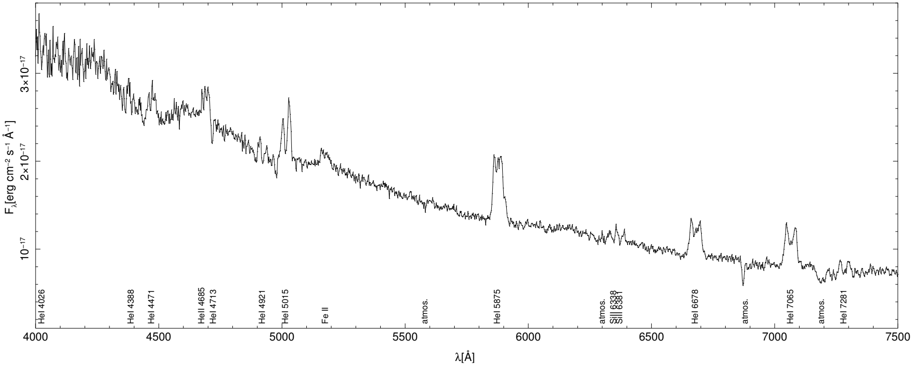


- Kinematic analysis gives an orbital period of 44.32±0.18 min
- System is as an AM CVn already several billion years old

  (Bildsten et al. (2006))

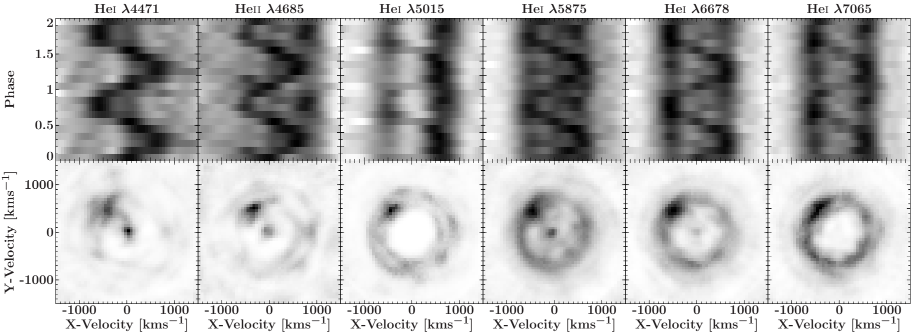
  ⇒ What keeps accreting white dwarf so hot??

SDSS J0129+3842 observed with the GTC



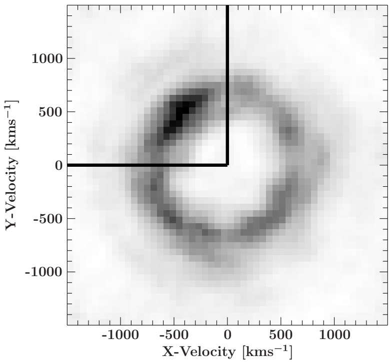
- Helium emission from the disc
- Weak absorption lines from accreting white dwarf

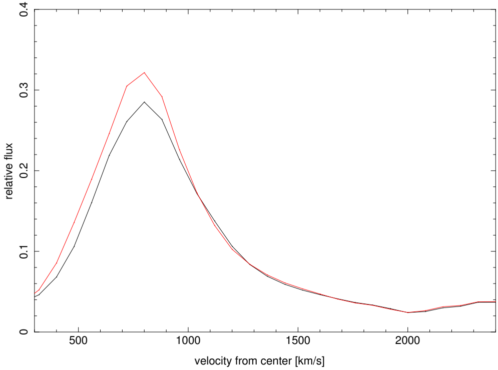
Kinematics of SDSS J0129+3842



- Kinematics analysis gives period of 37.555±0.003 min
- Shears et al. (2011) obtained a superhump period of 37.9 min
  ⇒ Results in period excess ϵ=0.0092
  ⇒ With Patterson et al. (2005): Mass ratio q=0.031±0.018

Radial emission profile from Doppler tomograms



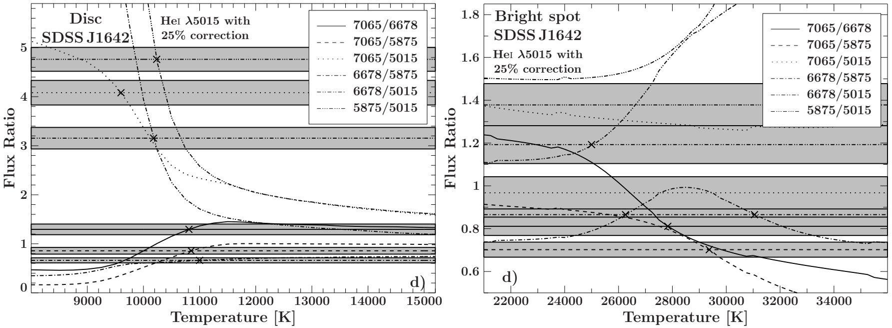


- Every Doppler tomogram was divided into radius bins
- The binned Doppler tomogram was divided into two sections
  ⇒ disc and bright spot region
- For each section was the average flux per radius bin computed
  ⇒ radial emission profile
- The sum over the radial emission profile gives the full flux

Comparison with LTE models

- Extracted flux ratios for different lines were compared to computed flux ratios from a single slab LTE model
- Models use uniform temperature and density
  $\Rightarrow$ Models are only a simplification to real conditions

Temperature estimation in SDSS J1642 as an example



Disc:

- Good agreement in three systems for the disc region
- All systems show similar temperature for the disc (∼10 500 K)

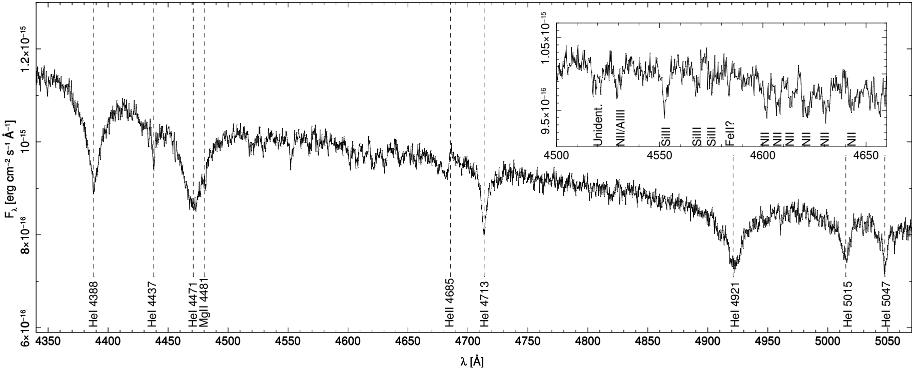
  ⇒ Single slab model works pretty well for the disc

Bright spot:

- Only one system is in agreement with models

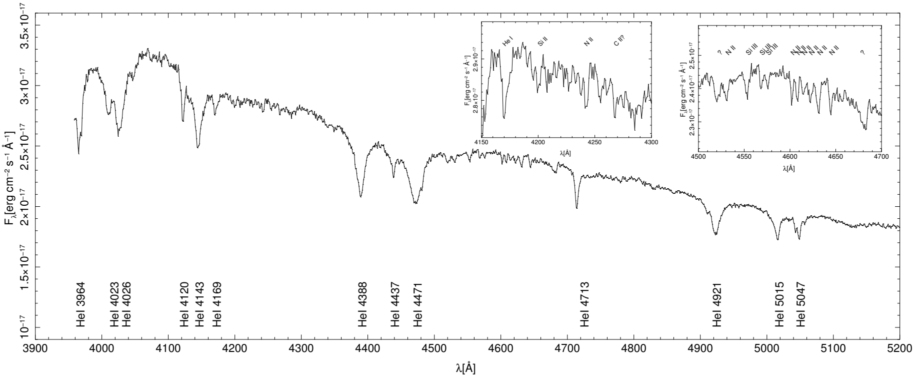
  ⇒ Single slab model do not work in the bright spot region

SDSS J1908+3940 an AM CVn candidate



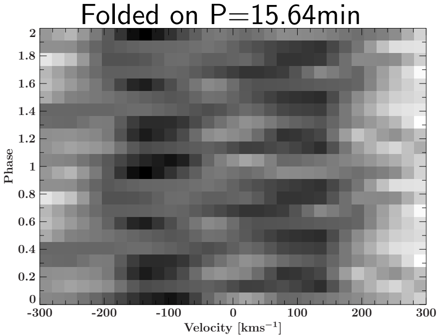
- AM CVn candidate found by the Kepler satellite
- Two photometric periods detected in the Kepler data ($P_{\rm orb/sh}$=15.89min and $P_{\rm orb/sh}$=15.64min)
- Strong helium absorption lines typical for a high state system
- Large sample of metal lines from different species $\Rightarrow$ NII, SiII/III, MgII and possibly CII and OII

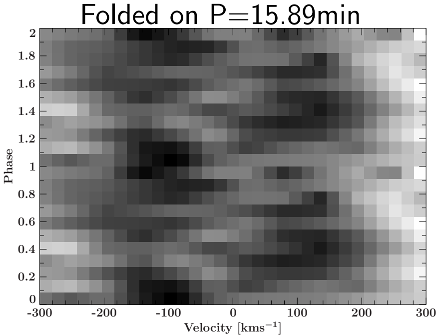
SDSS J1908+3940 observed with the GTC



- Phase resolved spectroscopy with the GTC over 3 nights
  ⇒ Resulting in 222 spectra
- Lower resolution but greater wavelength coverage than in WHT data
- Average spectrum (SNR∼200) shows even more weak metal lines

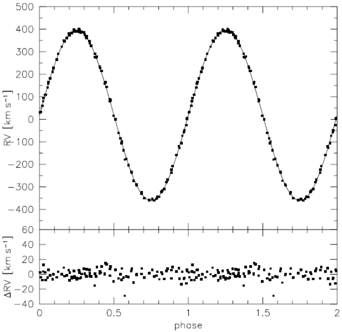
Bright spot in SDSS J1908+3940??

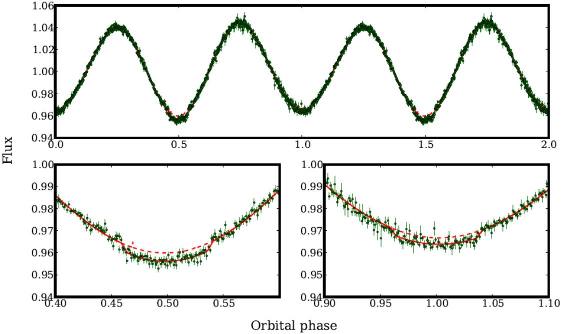




- Core of the HeI 4471 absorption line folded on the photometric periods
- Periodic variations?? Which one is the orbital period??
- 2 nights on Keck/ESI (R∼8 000) will hopefully solve the question

A compact sdB+WD binary in the Galactic disc





Geier et al. 2013, in press

- Most compact sdB+WD system with $P_{\rm orb}$=1.2h
- Light curve shows weak eclipses
  $\Rightarrow M_{\rm sdB}=0.51\,M_\odot$, $M_{\rm WD}=0.76\,M_\odot$ well constrained
- SdB will start transferring mass to the WD in about 36 Myr
- System is a good candidate for an underluminous SN Ia

What do we have?

- Many studies have been done to find compact post-common envelope binaries in the Galactic Halo (e.g. SDSS)
- Not much has been done for the Galactic plane
- Properties of compact post-common envelope binaries in the Galactic plane still unknown

  ⇒ **More follow-up work is needed**

ULTRAVIOLET EXCESS SURVEY

UVEX

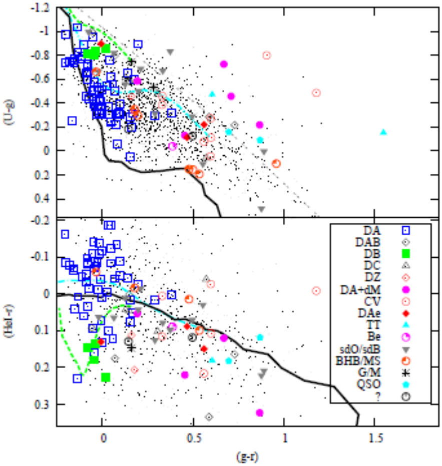
OF THE NORTHERN GALACTIC PLANE

UVEX survey

- Imaging the Northern Galactic Plane ($|b| < 5^{\circ}$) with the Isaac Newton telescope
- In the optical U, Sloan g and r, HeI 5875
- From g=14 mag, down to g=21 mag

- To select UV-excess sources, like white dwarfs and white dwarf binaries, sdbs and sdOs
- Roughly 80% is observed but so far only 15% of the data extracted

Target selection

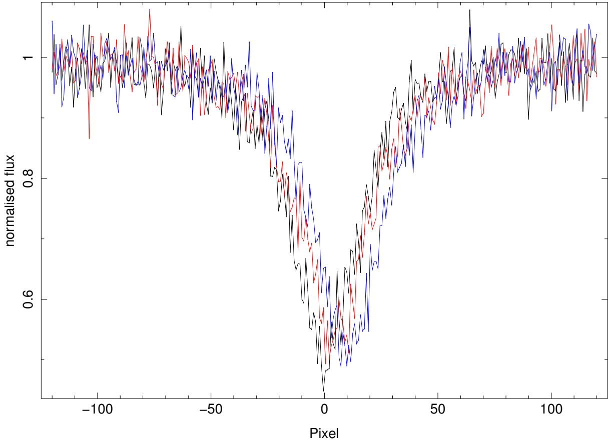


Verbeek et al. 2012

- Two approaches for follow-up observations:

1. Objects identified in Verbeek et al. 2012 used for follow-lup
2. Helium filter to pre-select unidentified targets: HeI-r>0

Observing strategy

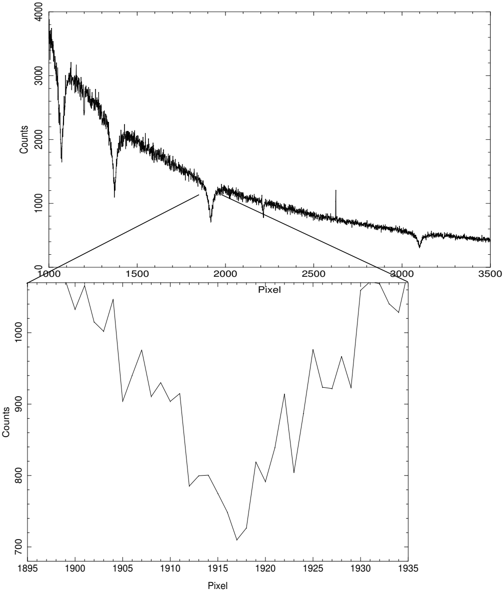


- Three subsequent spectra
- On the fly data extraction
- In case of detected velocity shifts
  $\Rightarrow$ Stay on the object for phase resolved spectroscopy

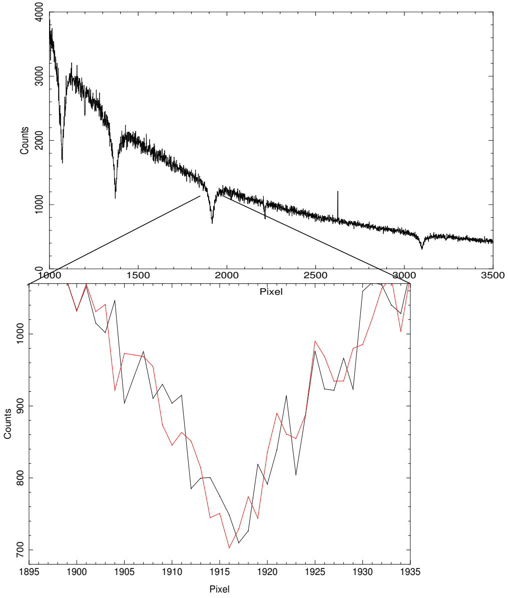
First results

- Observing of 5 selected objects from the UVEX database
- UVEXJ000355.86+632833.2 - g_{mag}=16.2 - 3x900s - sdB
  no shift detected
- UVEXJ000425.31+592220.0 - g_{mag}=16.0 - 2x600s - CV
  no shift detected
- UVEXJ001032.27+625050.0 - g_{mag}=15.9 - 2x600s - He-sdO
  no shift detected
- UVEXJ020201.85+564342.3 - g_{mag}=15.3 - 3x300s - sdB
  no shift detected
- UVEXJ032825.25+503529.8 - g_{mag}=14.0 - 3x120s - sdB
  shift detected
  $\Rightarrow$ One in five systems show variations on short timescales

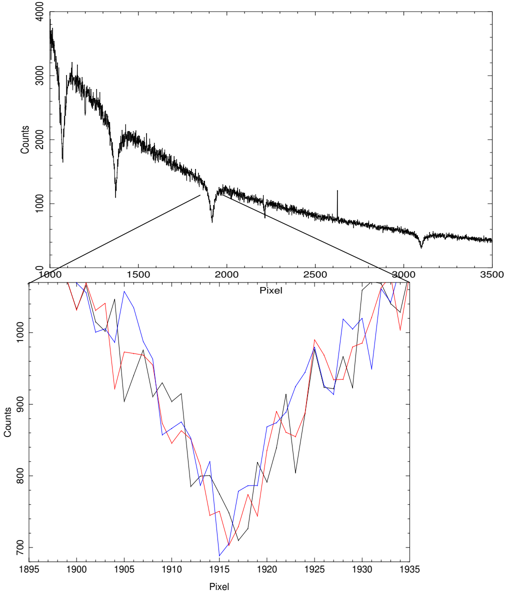
UVEXJ032855.25+503529.8



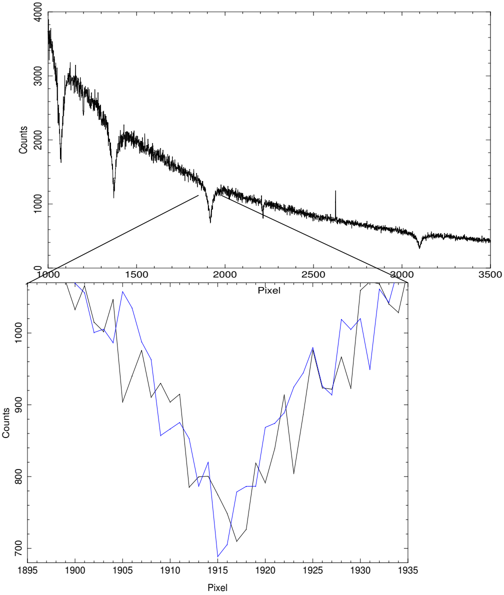
UVEXJ032855.25+503529.8



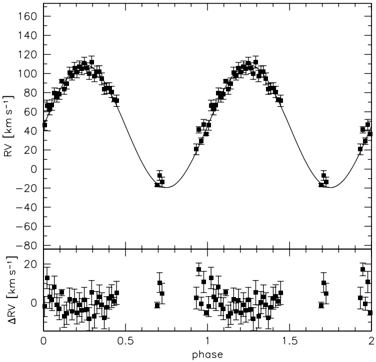
UVEXJ032855.25+503529.8



UVEXJ032855.25+503529.8

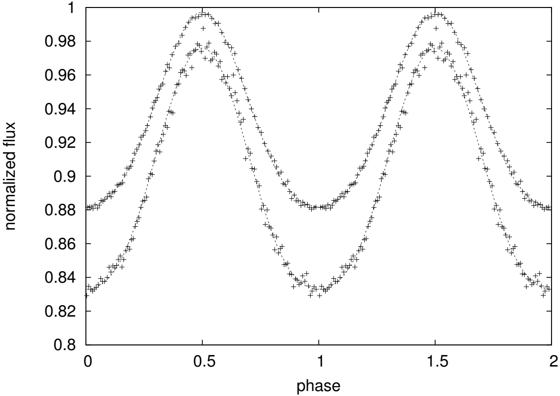


UVEXJ032855.25+503529.8



- Sinus fit gives semi-amplitude K=64 kms^{-1} and P_{orb}=0.1 d
- With a canonical mass for the sdB of 0.47 $M_\odot \Rightarrow M_2 > 0.1\,M_\odot$
- No companion visible and no infrared excess detected
- Data points from PTF indicate a variation of 0.2 mag
  $\Rightarrow$ Possible reflection effect from a M-dwarf companion

UVEXJ032855.25+503529.8 - A new sdB+Mdwarf system



- Light curves with 50 cm telescope and 1 m telescope
  $\Rightarrow$ $\mathbf{P_{orb}=0.11016\,d}$
- Strong reflection effect from the heated atmosphere of the M-dwarf
- Very preliminary analysis gives $\mathbf{M_{sdB}=0.49}$ **and** $\mathbf{M_{Md}=0.12}$

Outlook

- First observations showed that our method works to find short period binaries
- 3 dedicated nights starting tomorrow using WHT/ISIS
- Follow up on the 55 brightest UVEX targets with HeI-r>0 and g_{mag} <17.6
- Simulations show that RV-shifts$\geq$50 $\mathrm{km s^{-1}}$ can be detected at the first view