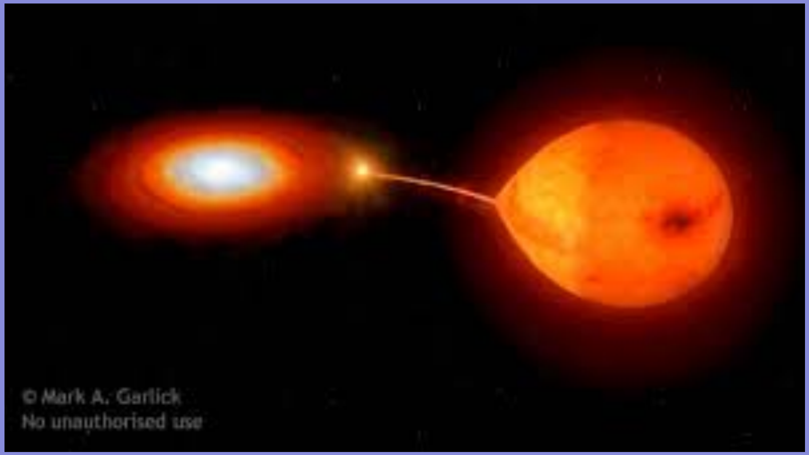
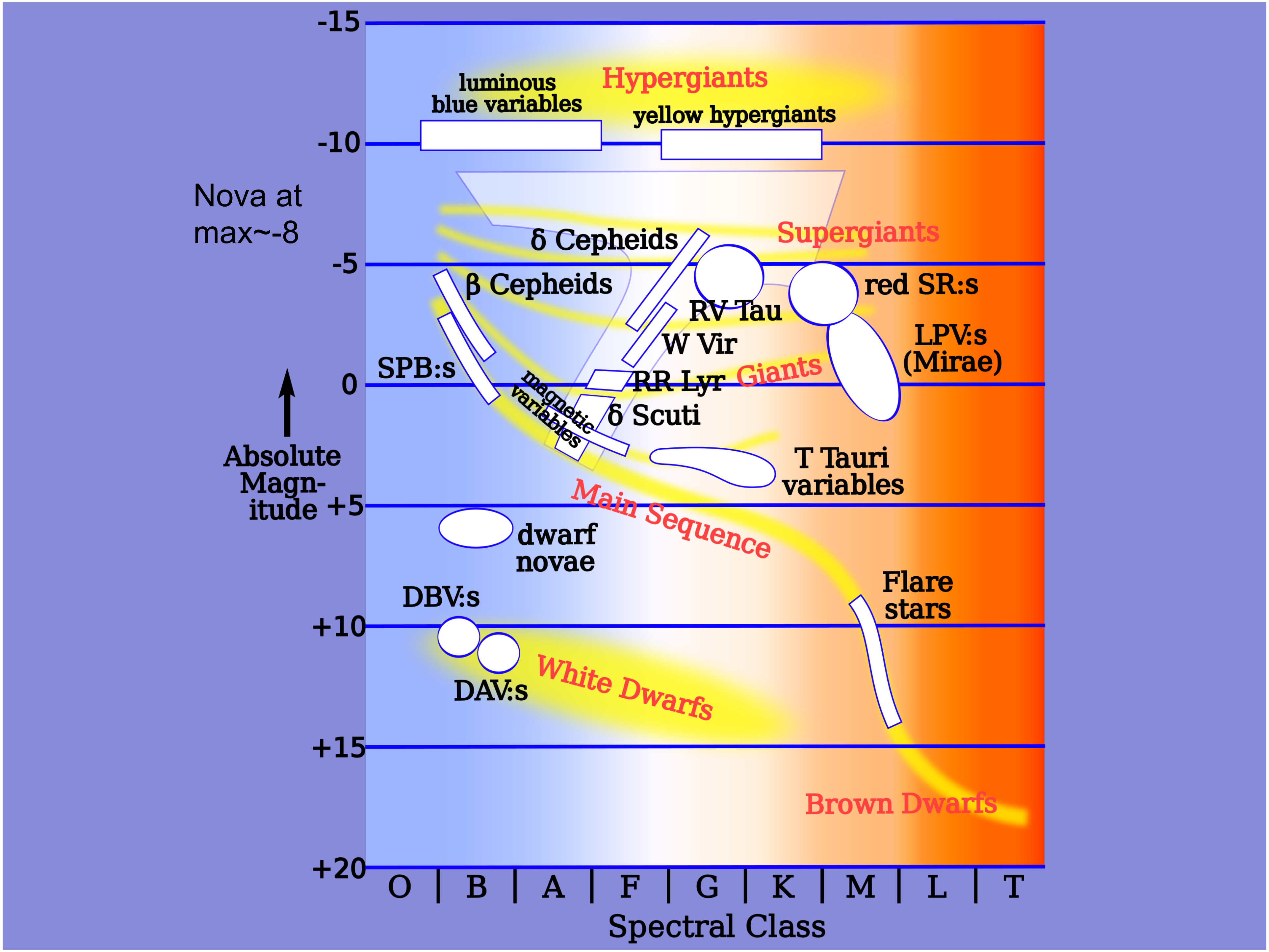
The Impact of TMT on Close Binary Systems



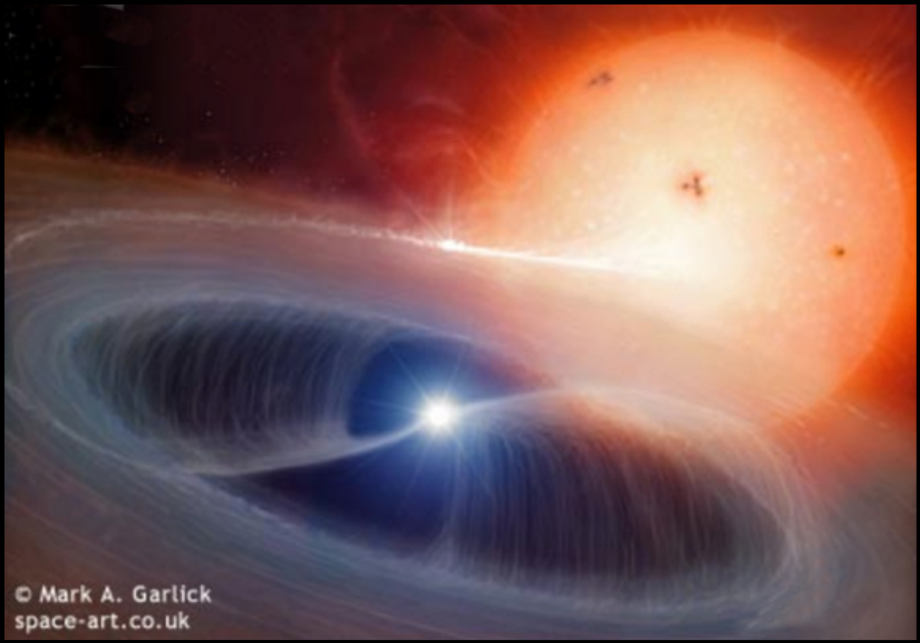
Paula Szkody University of Washington TMT Kyoto May 24, 2016

Close Binary Systems in Milky Way

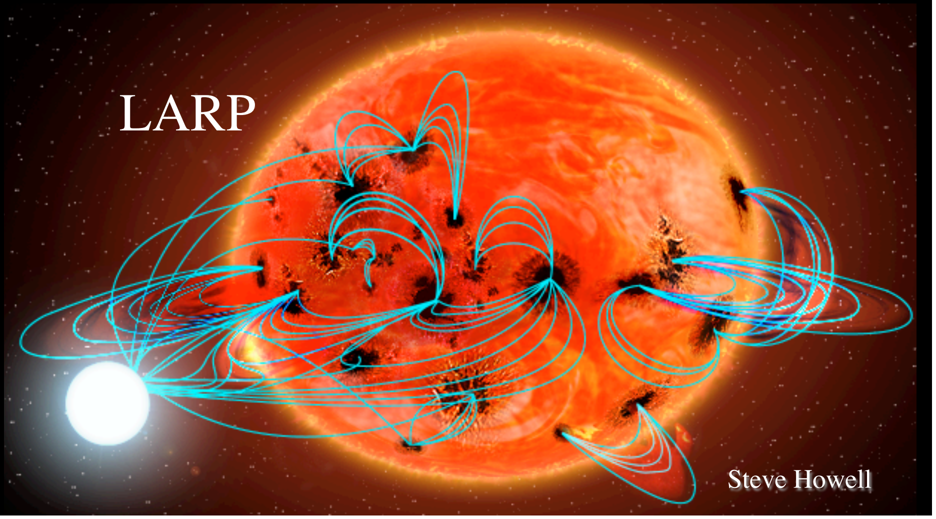
- Luminous Blue variables (~20)
- Low Mass X-ray Binaries (~100)
- Cataclysmic Variables (~2000+)

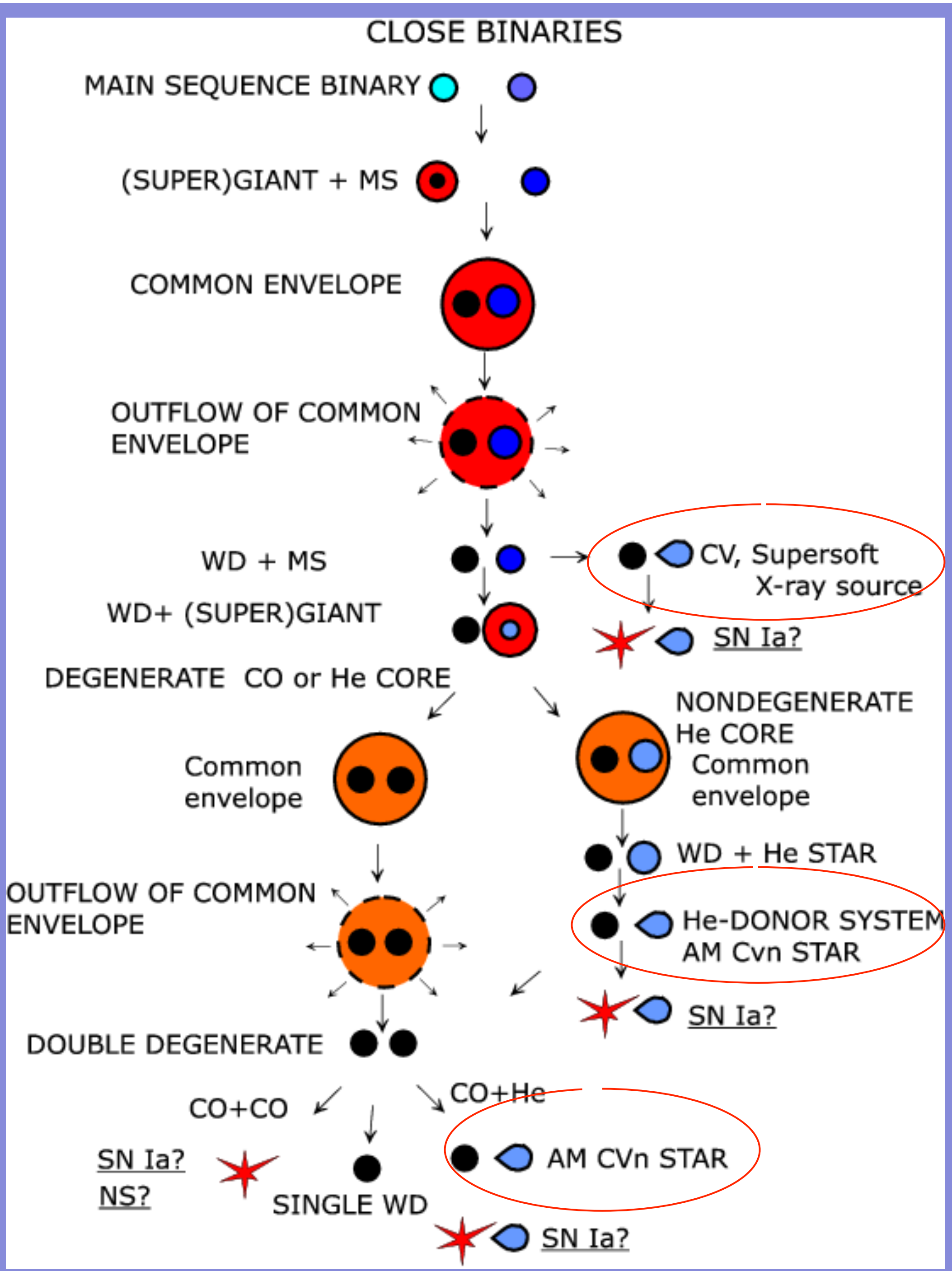

-15
-10
-5
0
+5
+10
+15
+20
Hypergiants
luminous
blue variables
yellow hypergiants
Nova at
max~-8
δ Cepheids
Supergiants
β Cepheids
red SR:s
RV Tau
W Vir
LPV:s
(Mirae)
SPB:s
RR Lyr
Giants
magnetic
variables
δ Scuti
Absolute
Magn-
itude
T Tauri
variables
Main Sequence
dwarf
novae
Flare
stars
DBV:s
DAV:s
White Dwarfs
Brown Dwarfs
O
B
A
F
G
K
M
L
T
Spectral Class

Interactive Binaries WD primary



Intermediate Polar





or AM CVn with H

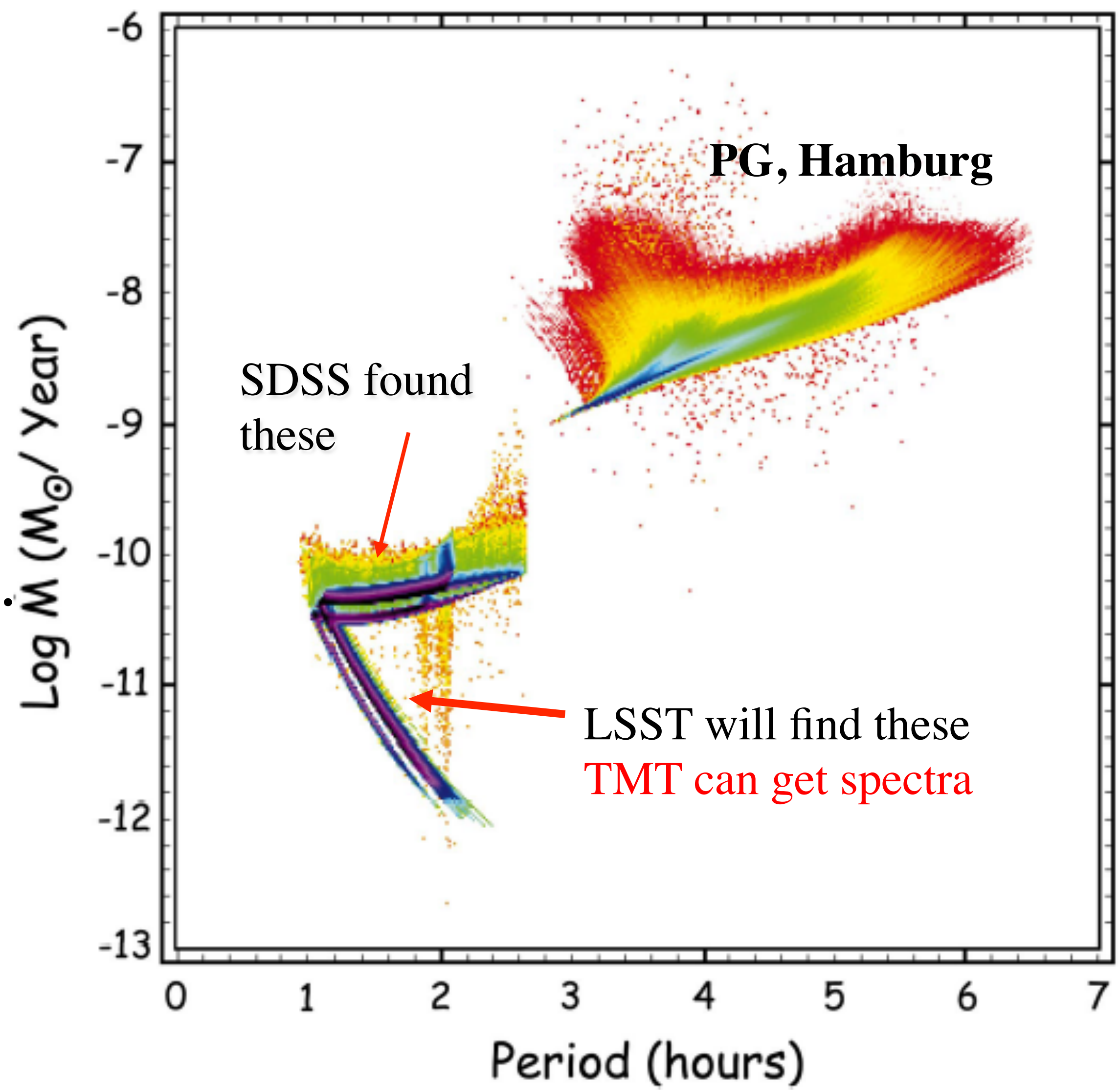
Key Science Questions:

- How many are there? (space density,distribution)
- How do they evolve? (CE, ang mom, mag field)
- Is mass lost or gained (Type Ia SN)?

How can TMT help provide answers?

TMT will find the faint ones

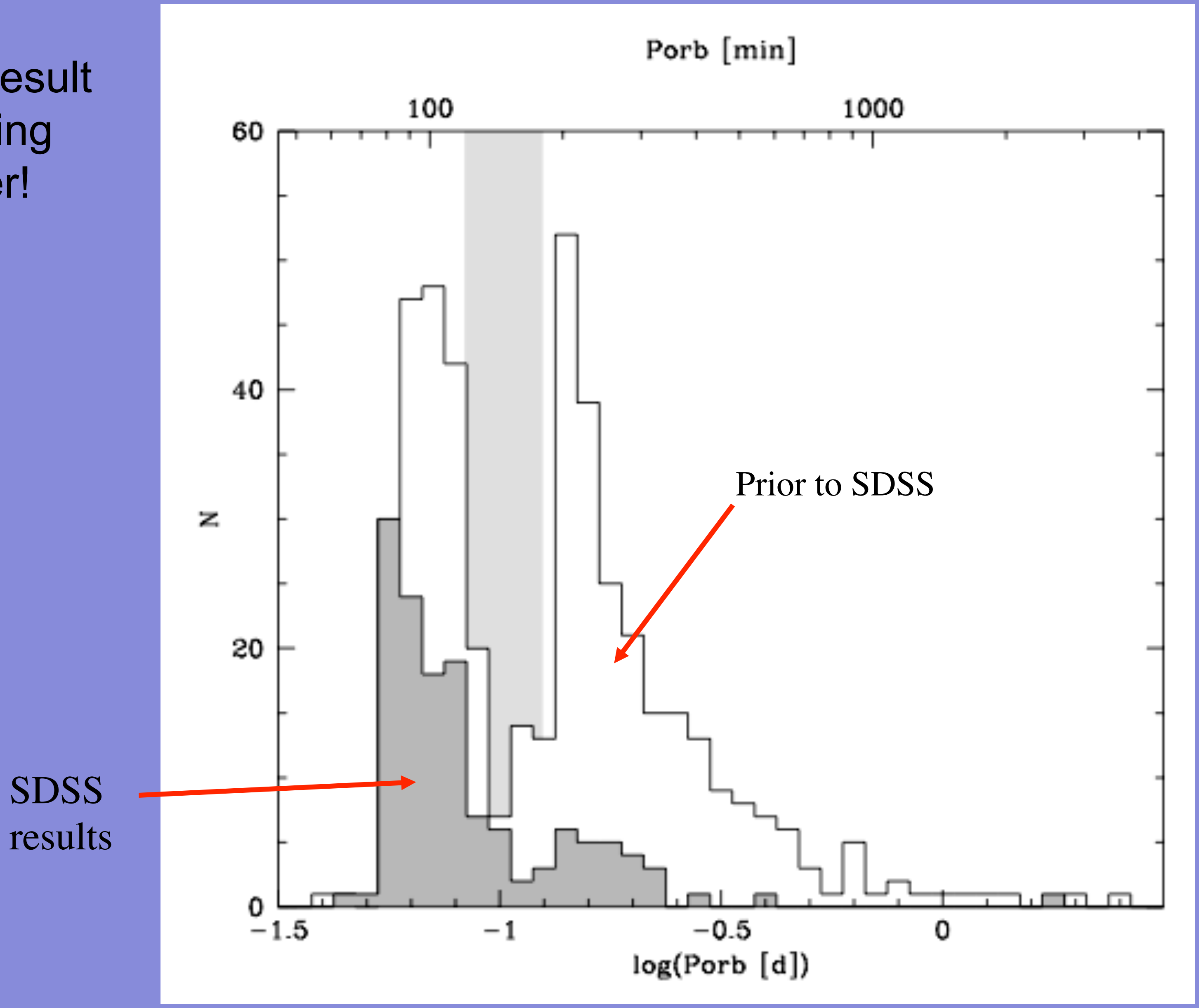
Howell, Nelson, Rappaport 2001, ApJ, 550



Log number of CVs

Need numbers to understand evolution – spectra!

The result of going fainter!



Gansicke et al. 2009, MNRAS, 397, 2170 from 126 periods (disks)

To classify a variable correctly, we need:

- **amplitude of variation**
- **color of variation**
- **timescale of variation (periodic or not)**
- **shape of variation**
- **spectrum of 24-27 mag**

L S S T

TMT

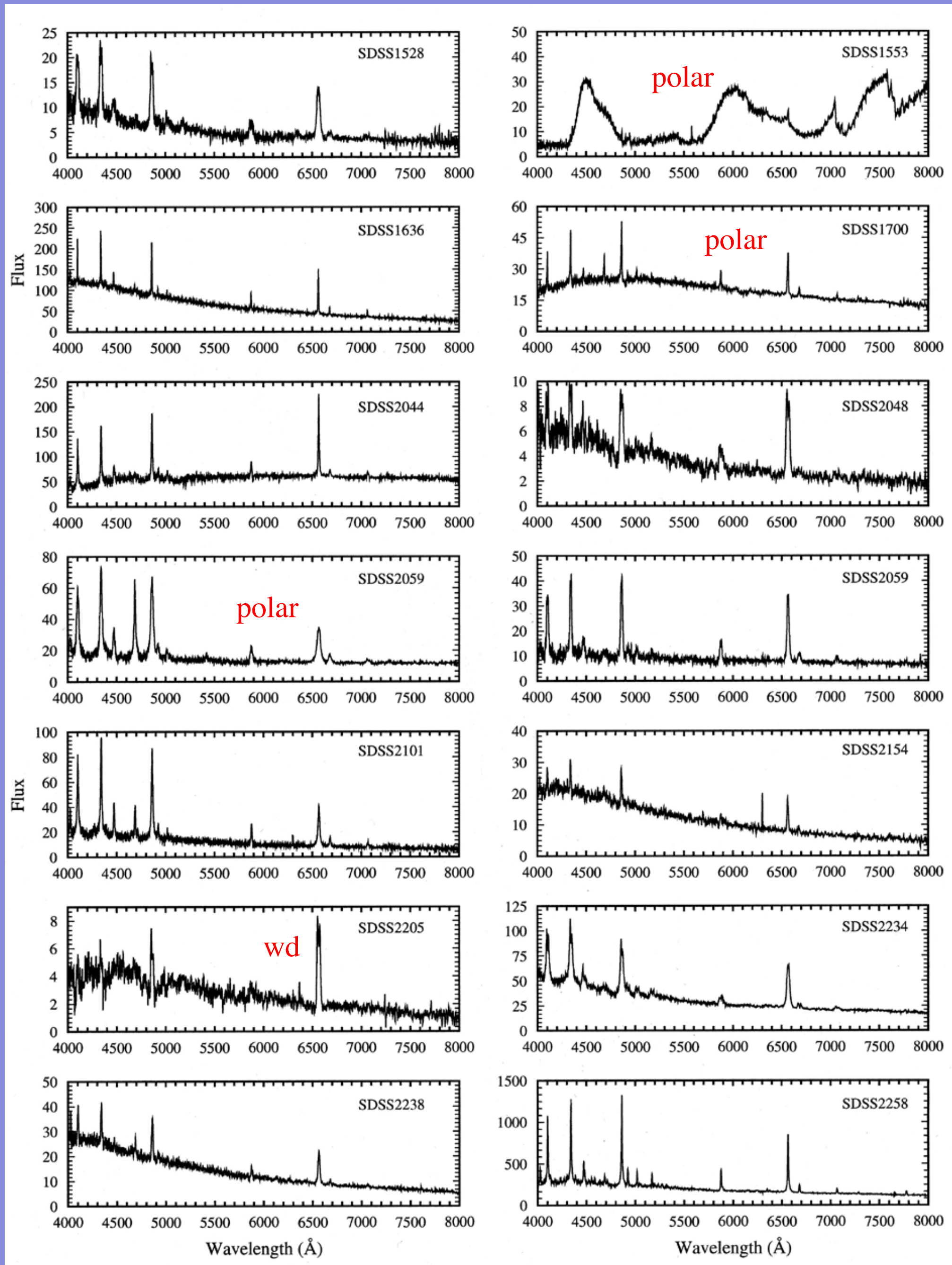
After ID, followup time-resolved spectra for orbital P

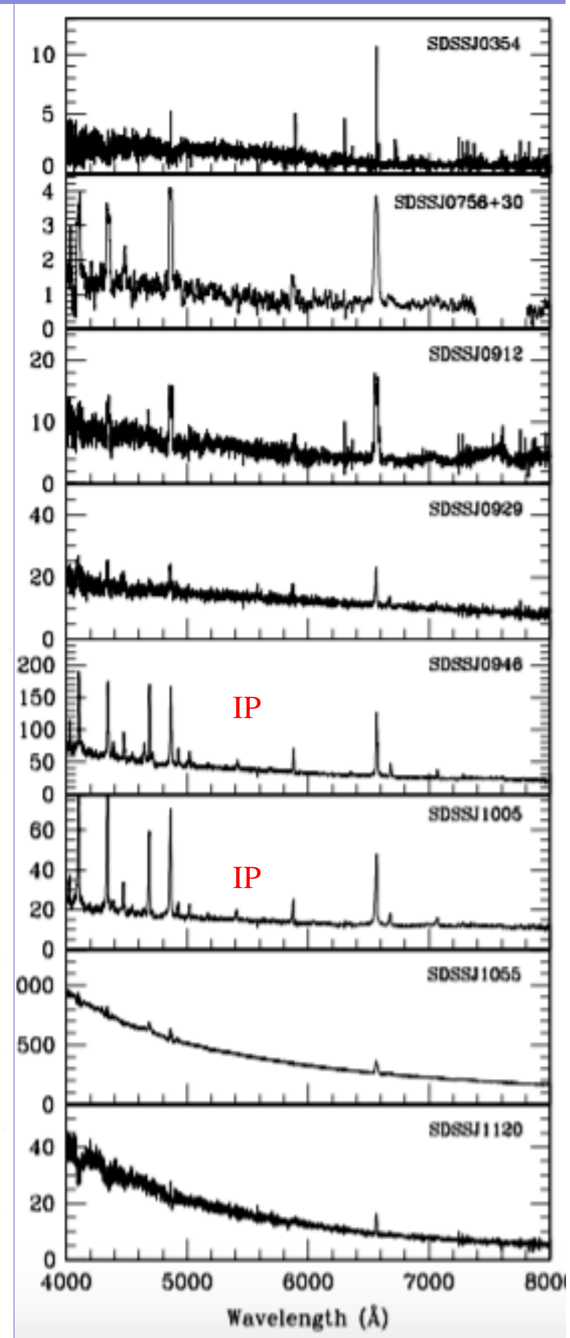
TMT Low Resolution Spectra (WFOS)

- classification of objects
- identification of white dwarfs + brown dwarfs
- find strong magnetic fields

What we learned from SDSS:

Szkody et al. AJ 2002-2011 Papers I-VIII



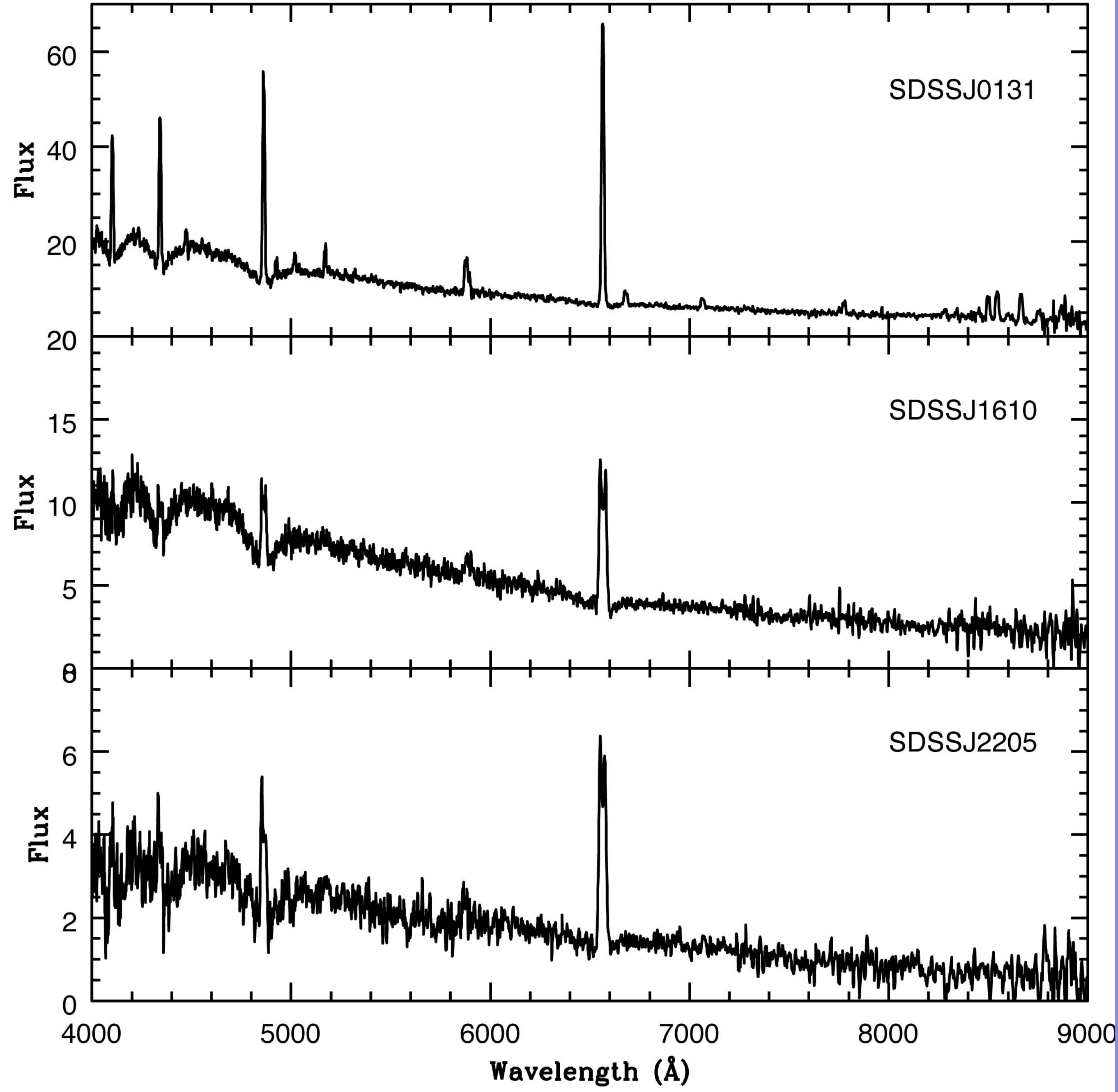


Need lots of follow-up spectra for ID and properties!

Detecting white dwarfs

SDSS spectra (2.5m) 1 hr exposure

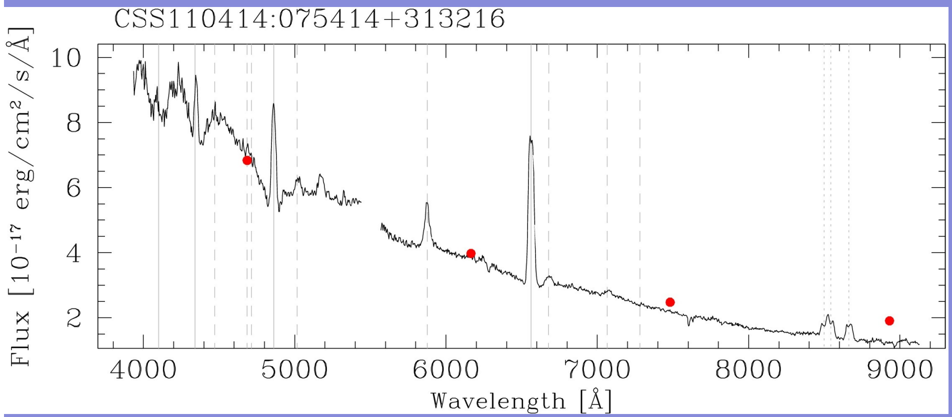
19 th mag

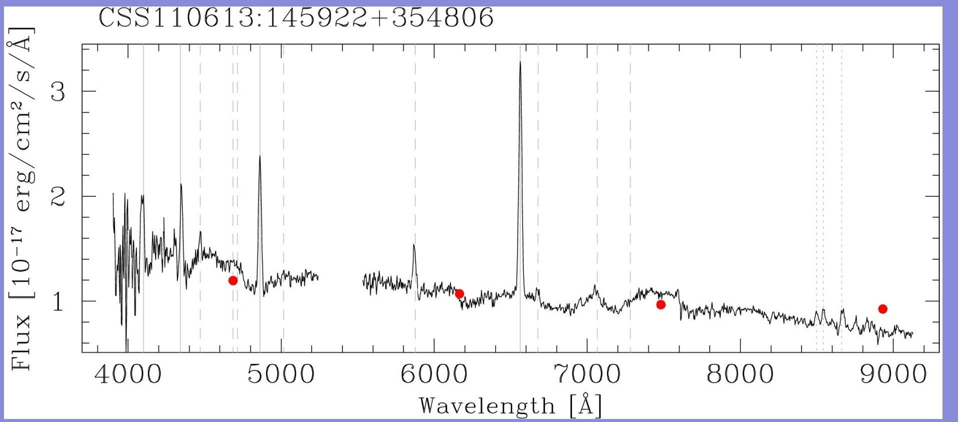


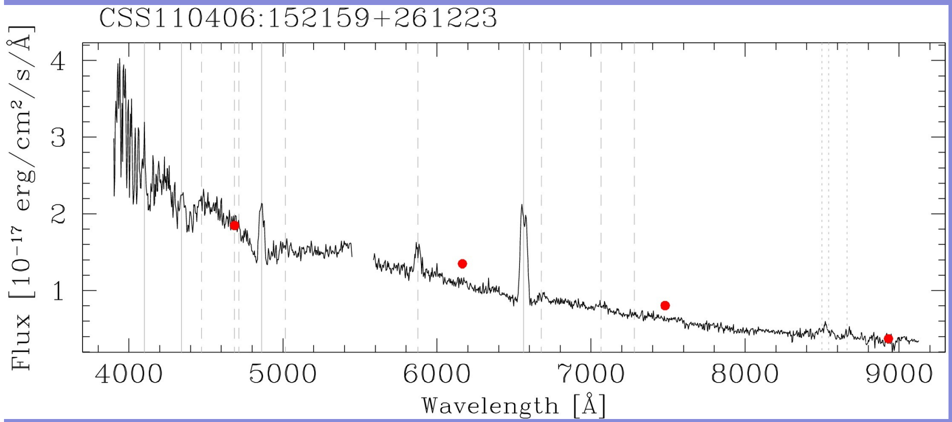
Spectral Followup of systems found by CRTS (Woudt et al. 2012, Thorstensen & Skinner 2012, Szkody et al. 2014) V=17-19

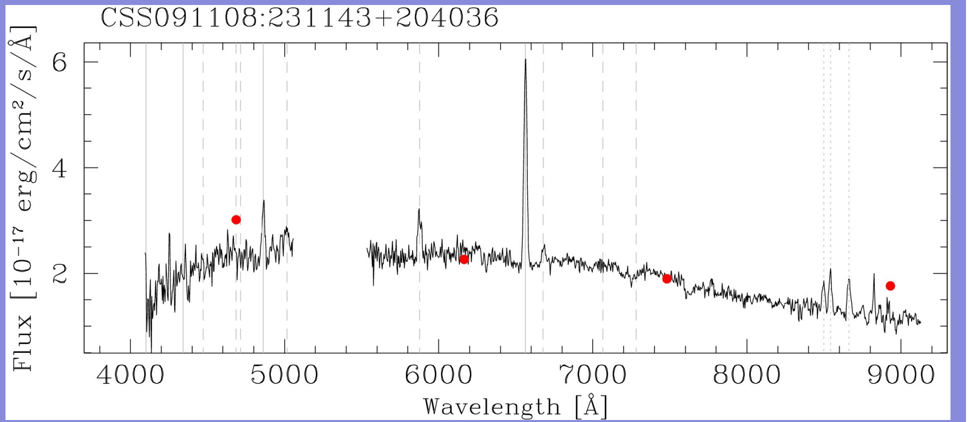
Gemini GMOS followup of 19-22 mag CRTS sources in SDSS (Breedt et al. 2014)

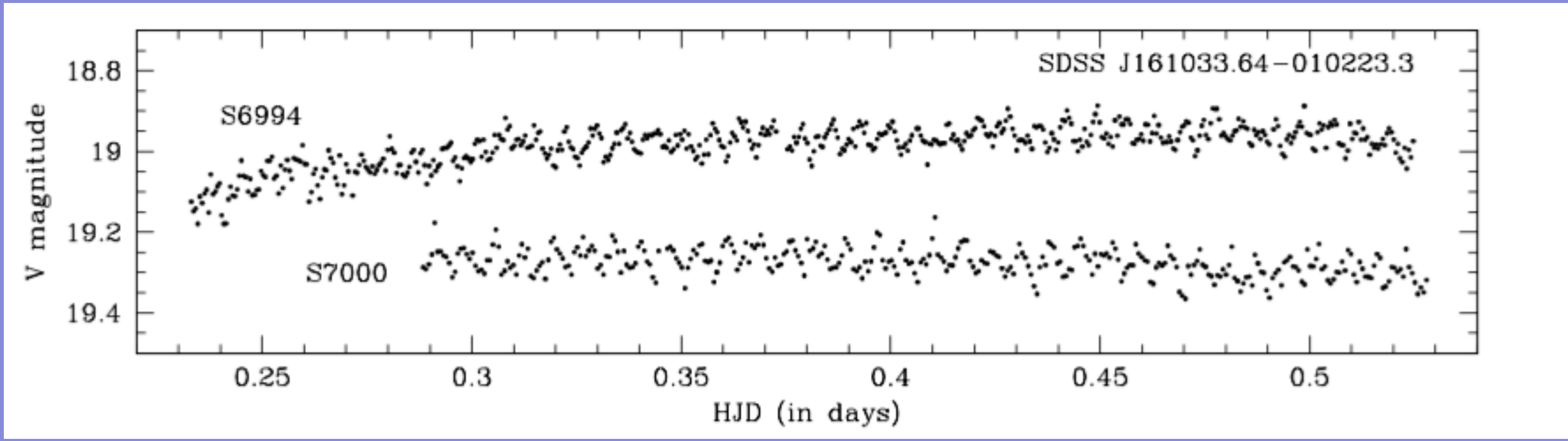
8m – 45 min exposures





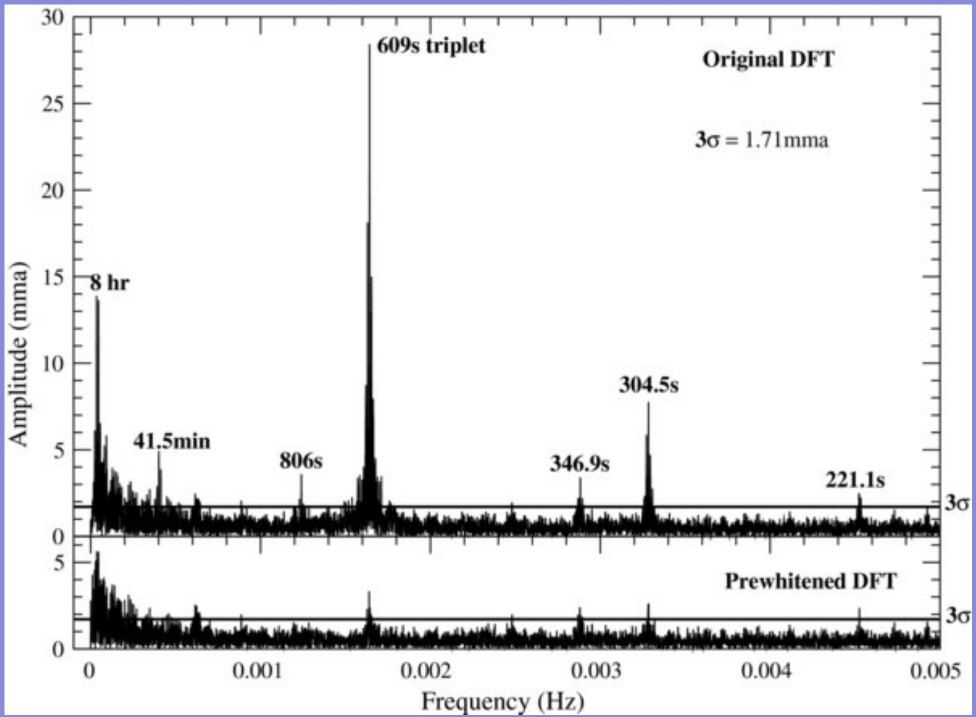






Followup photometry often shows non-radial pulsations -18 known

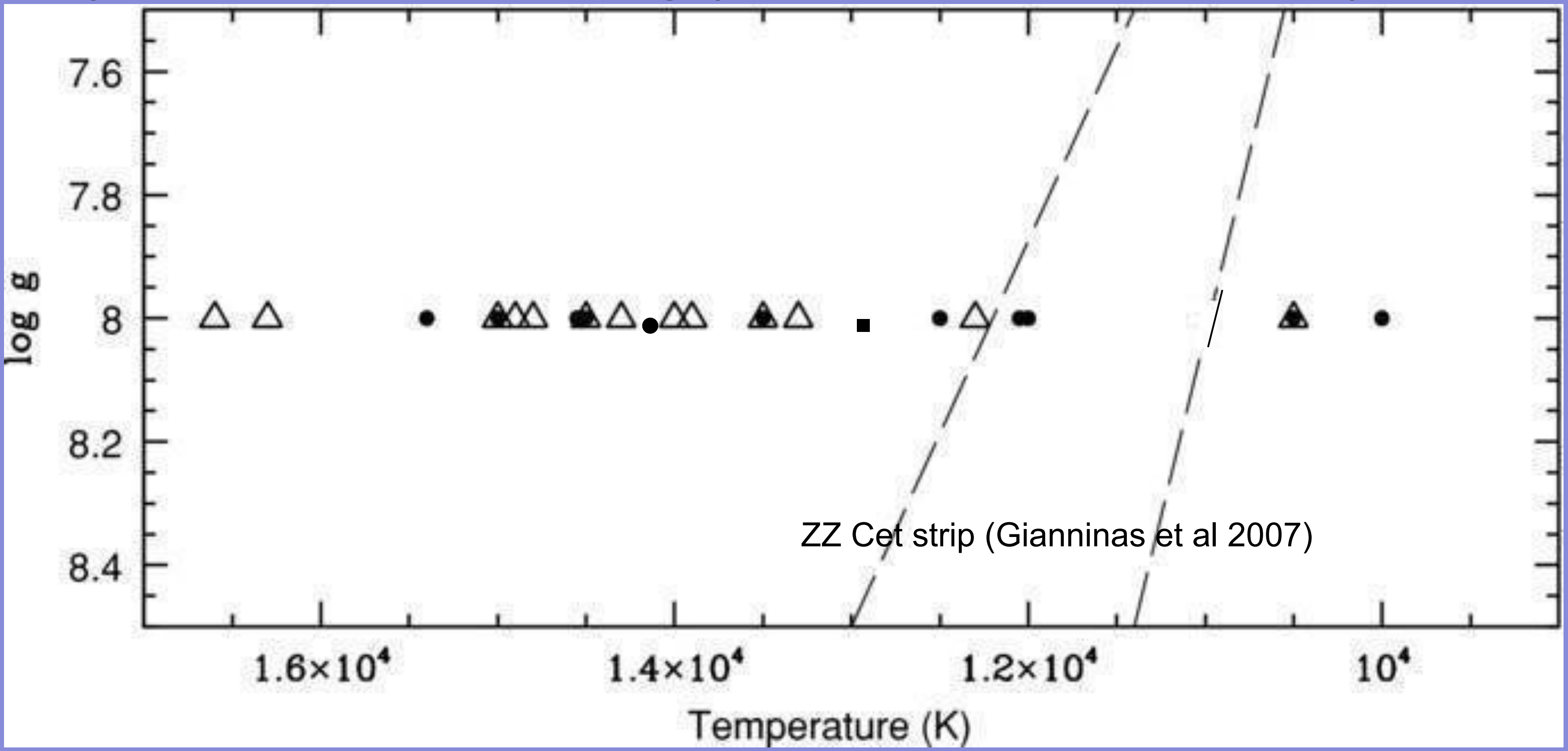
Finding WDs allows study of the instability strip for accreting sysems



Accreting Binary Pulsators have a Different Instability Strip:

Instability strip is wider than ZZ Ceti (He- Arras et al. 2006, ApJL)

Objects can stop pulsating (after outbursts + random)



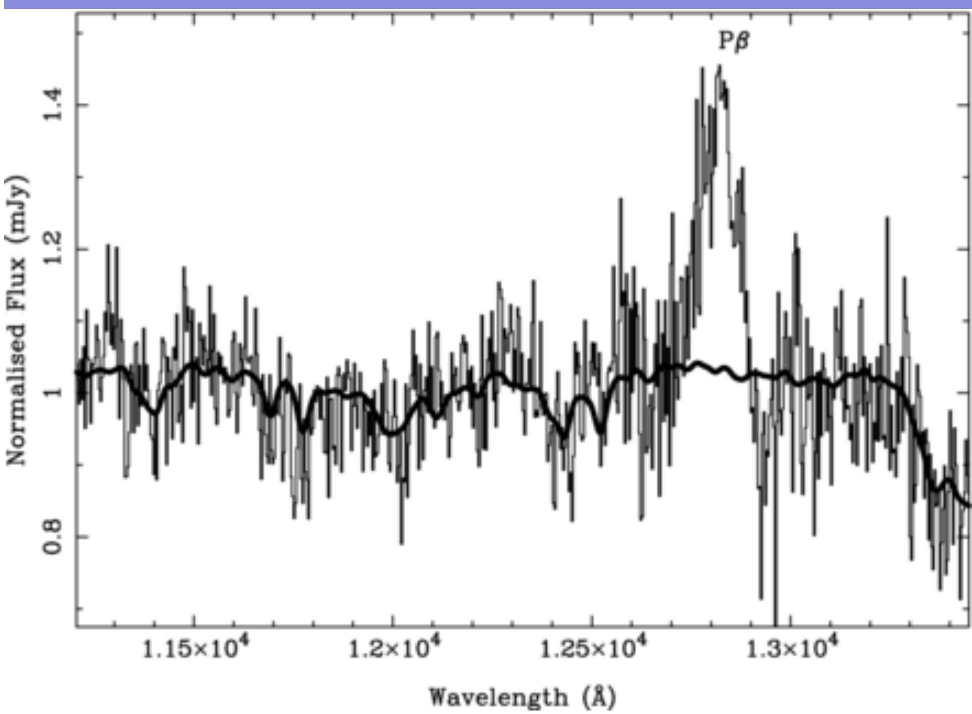
Szkody et al. 2010, ApJ, 710

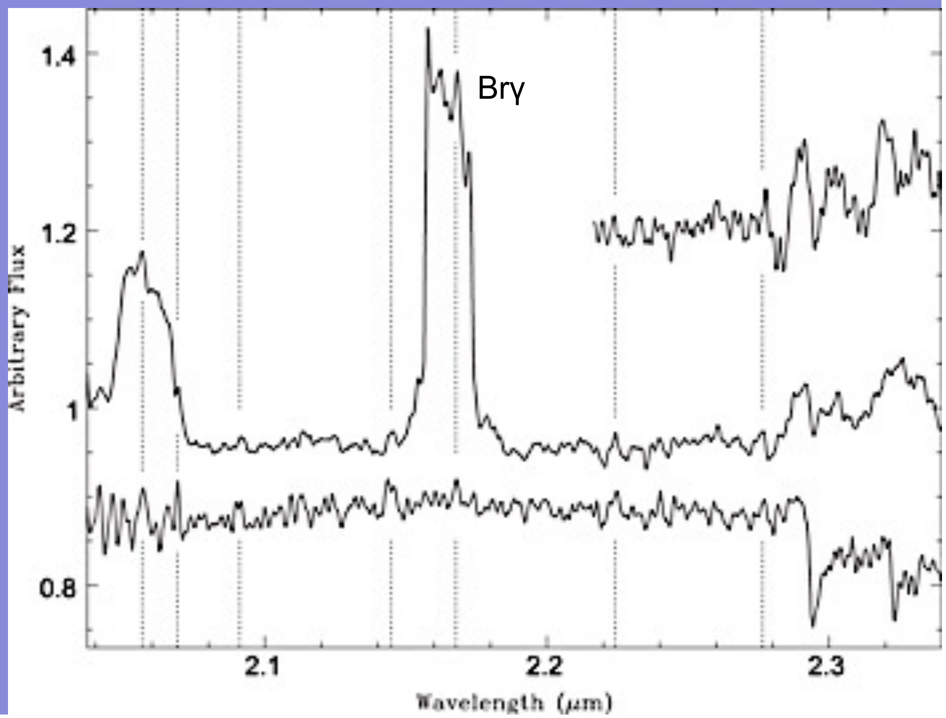
Detecting L2 Brown dwarf secondaries

TMT IRIS R=4000, 10xSignal

SDSS1433+10 (V~18.5)
Gemini-NIRI, R=454
Littlefair et al. 2013

WZ Sge (V~15.5)
Keck-NIRSPEC,
R=2300
Harrison 2016





Finding AM CVns – 3 evolution channels

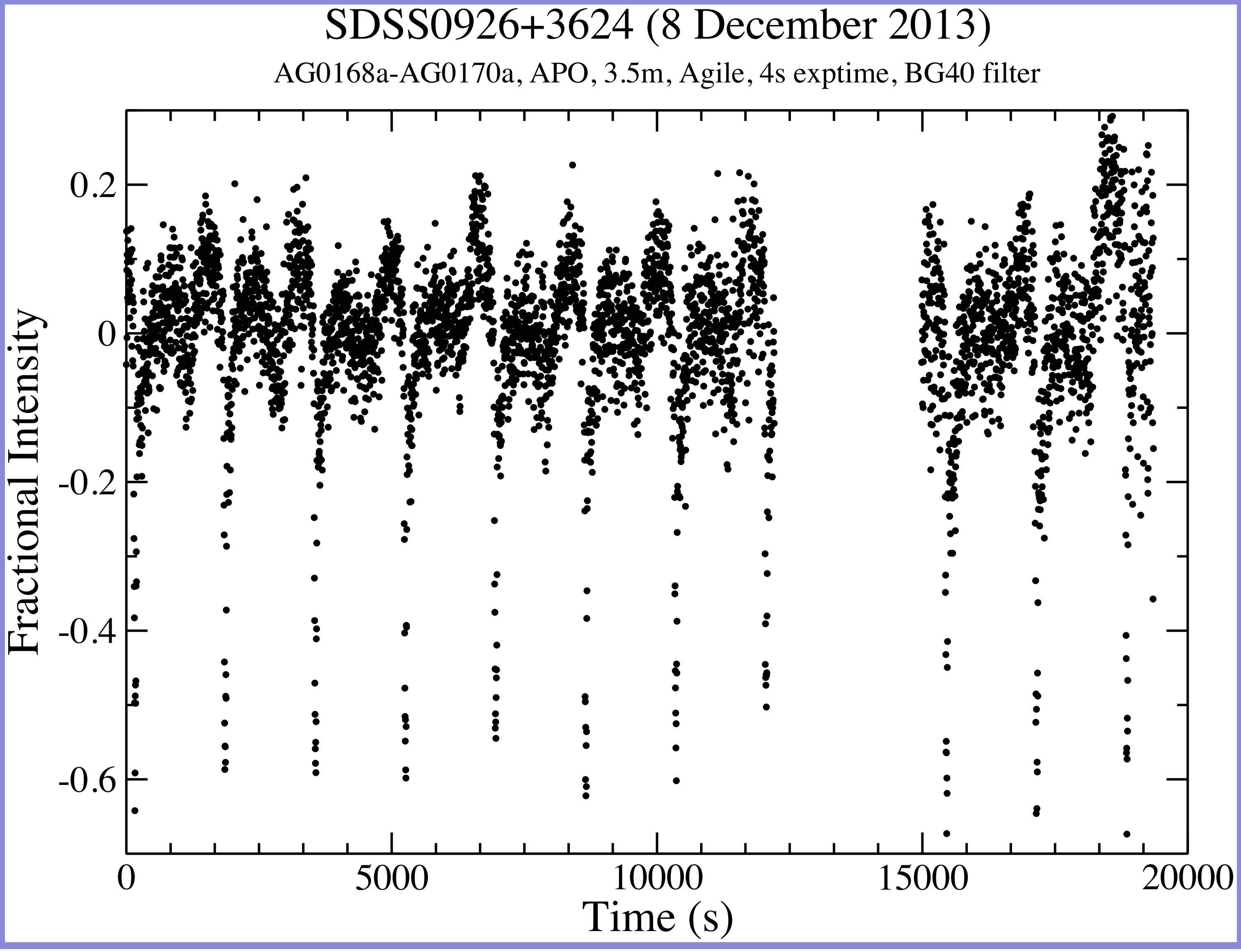
50 now known, periods 10-60 min, He spectrum

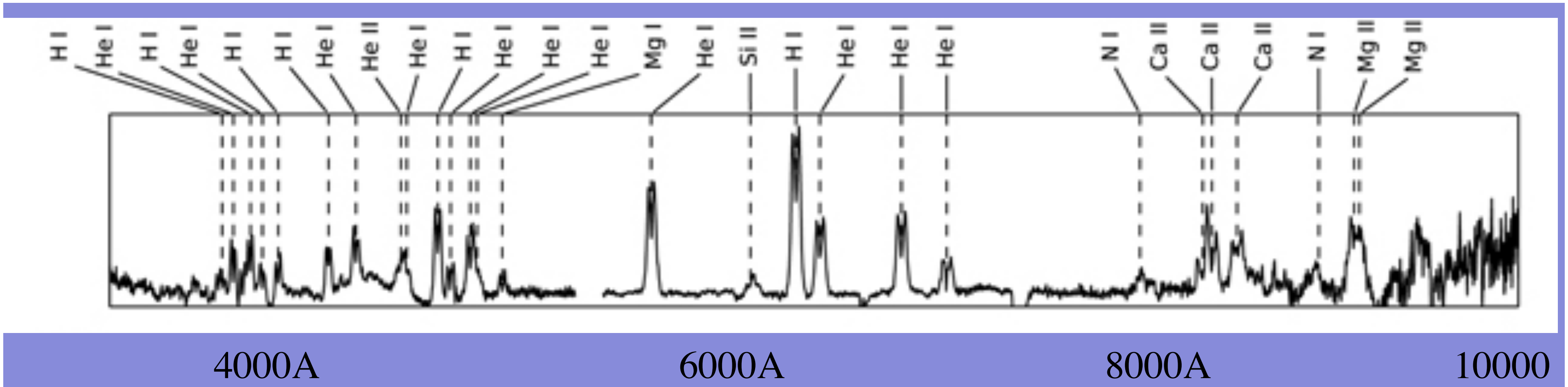
- How many are there (LISA)? fast photometry
- How many in each evolution path? spectra
- What are the white dwarf masses? rv curves

WFOS medium resolution, fast readout

Rapid timescale spectra needed

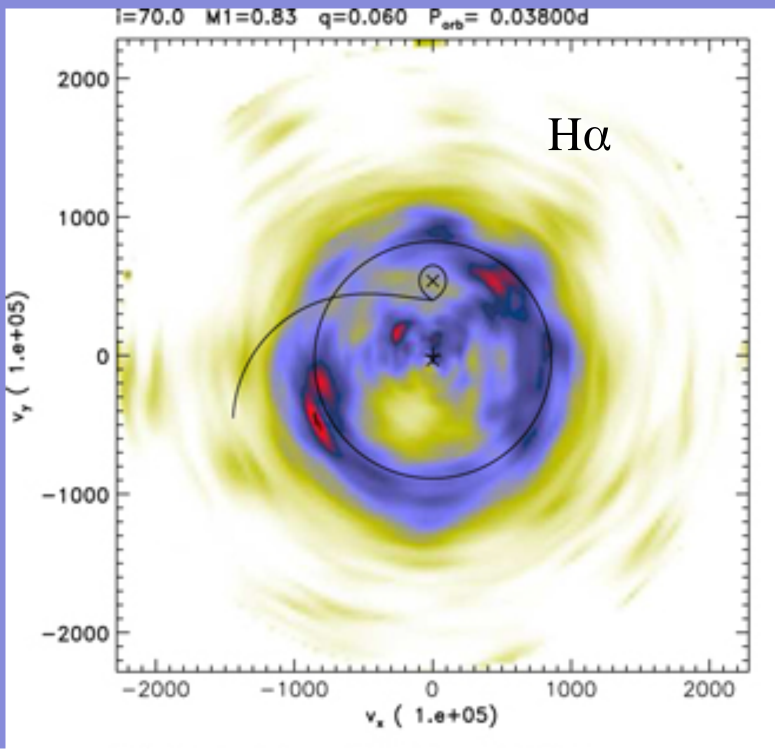
Eclipsing AM CVn P=28 min, eclipse=1 min

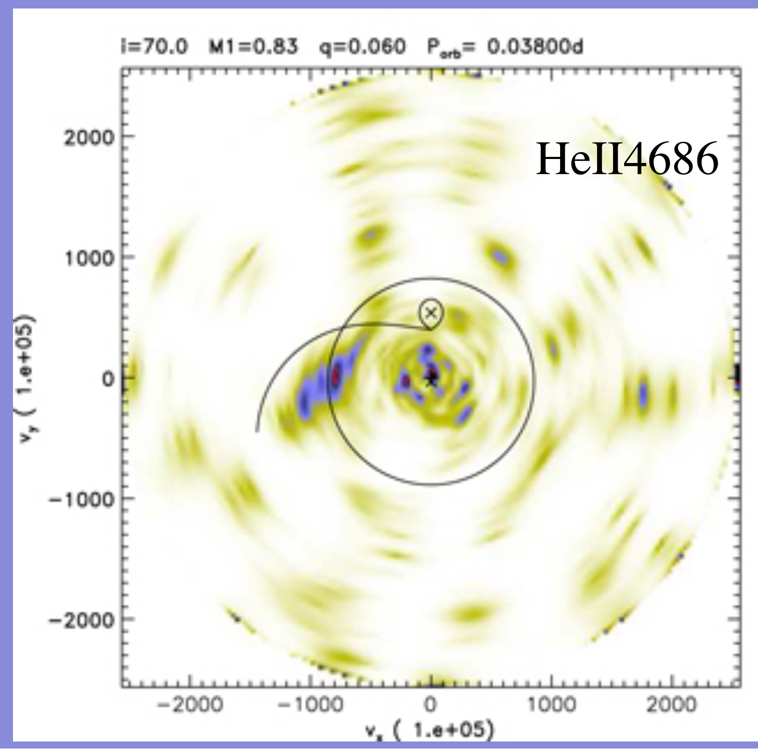




Evolved Main-sequence Channel: LBT Observations of CSS120422:111127+571239
Kennedy et al. 2015

Need 2% time resolution for tomography



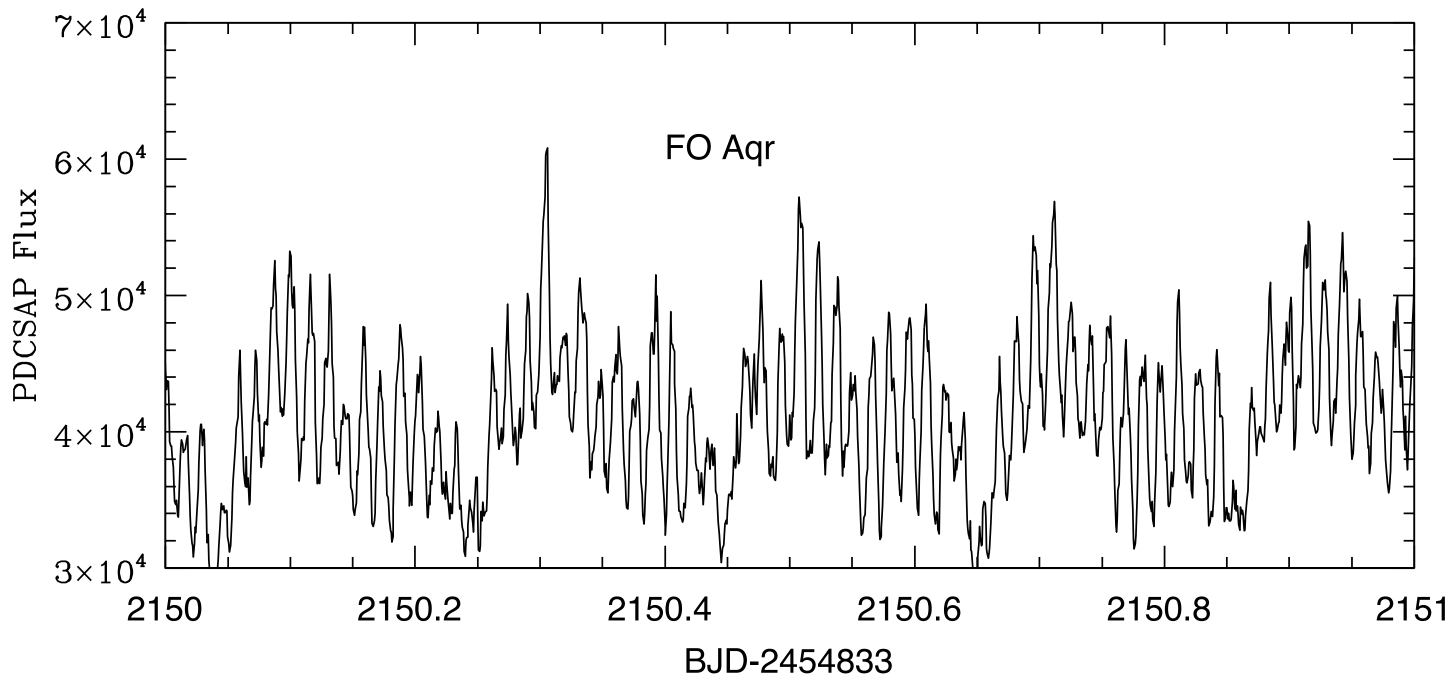


Finding Magnetic WDs – IPs and Polars

- How many are there? 10-50%?
- What are the precursors? LARPS?
- What are the masses? 0.6, 0.8(CV), 0.9(mag)
- Are IPs the Galactic Ridge Sources?

Followup of low res WFOS with med res +
IRIS time-resolved spectra + photometry

IPs identified from WD spin P ~ 1/10 orbit period



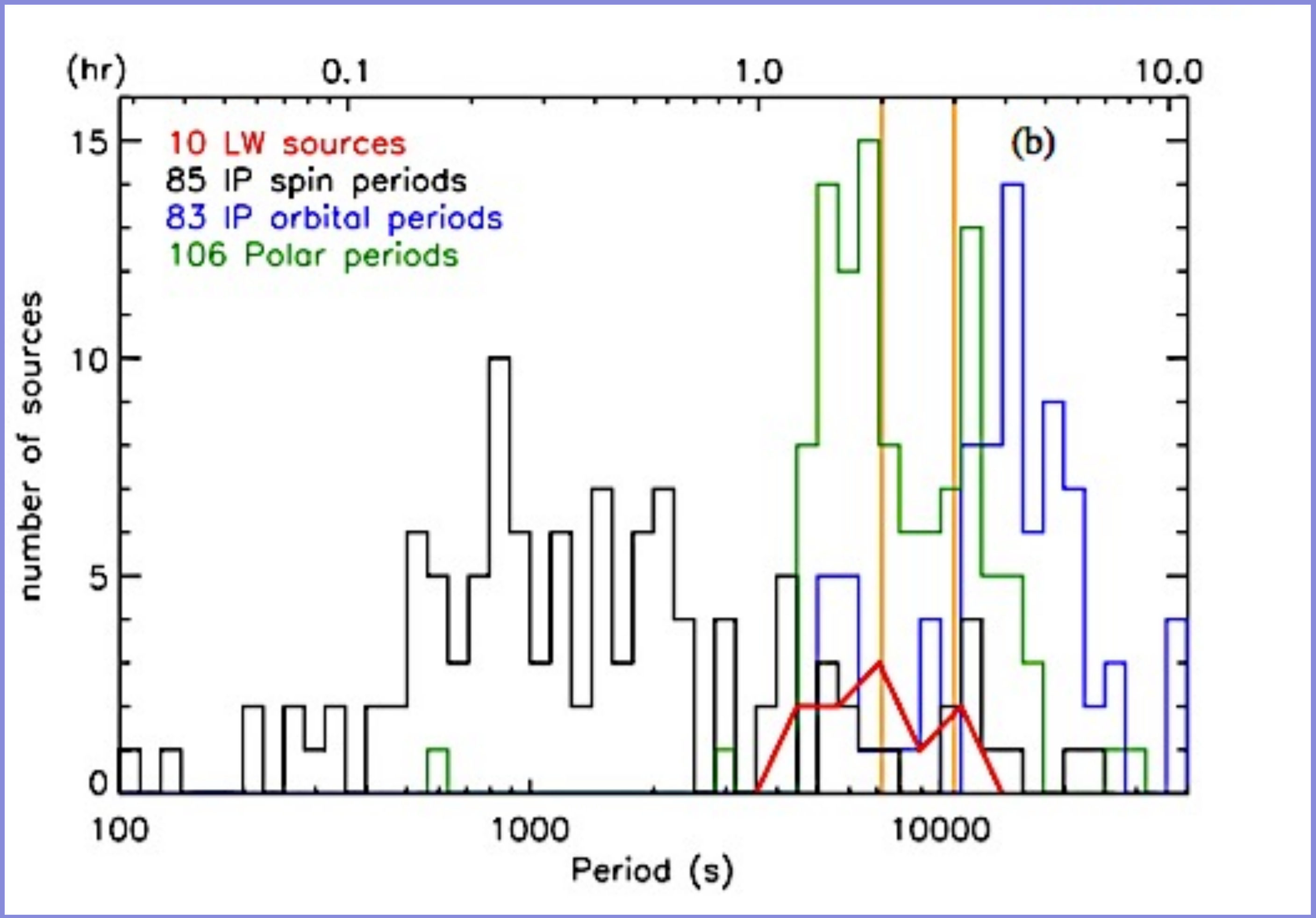
K2-3 Intermediate Polar FO Aqr
1 day of SC observations

P_{orb} = 4.85 hr P_{spin} = 20.9 min

Are GRXE Polars, IPs or Dwarf Novae?

Revnivtsev et al. 2009;Hong et al. 2012(IPs); Xu et al. 2016(DN)

Need better numbers of each type in Milky Way.

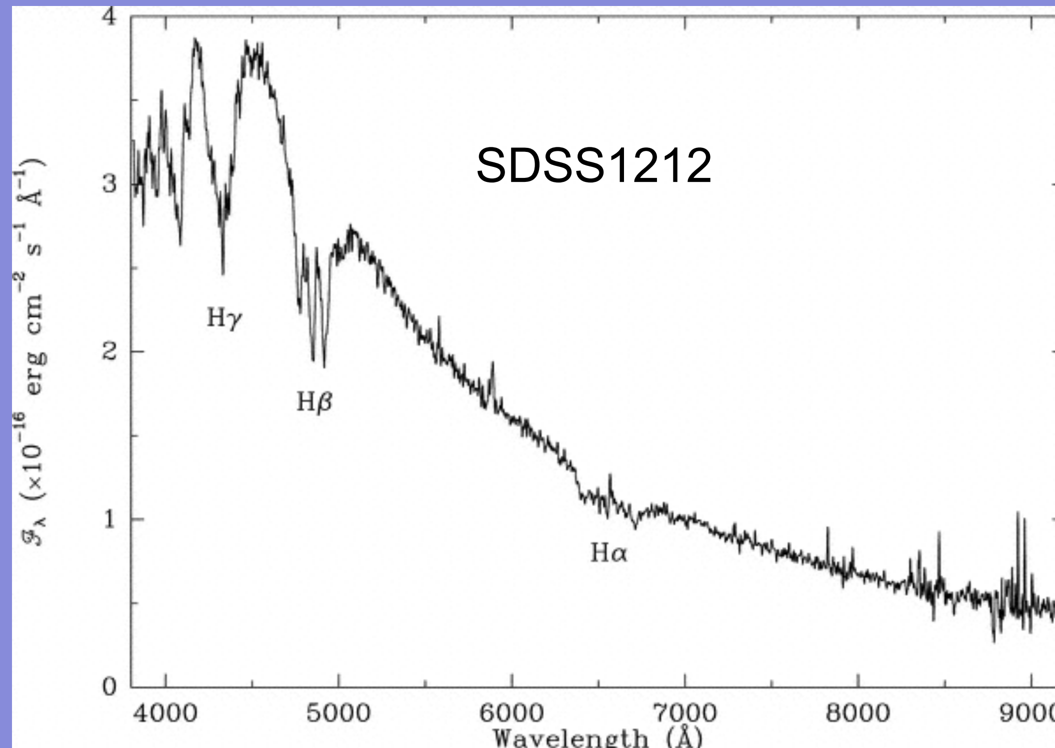


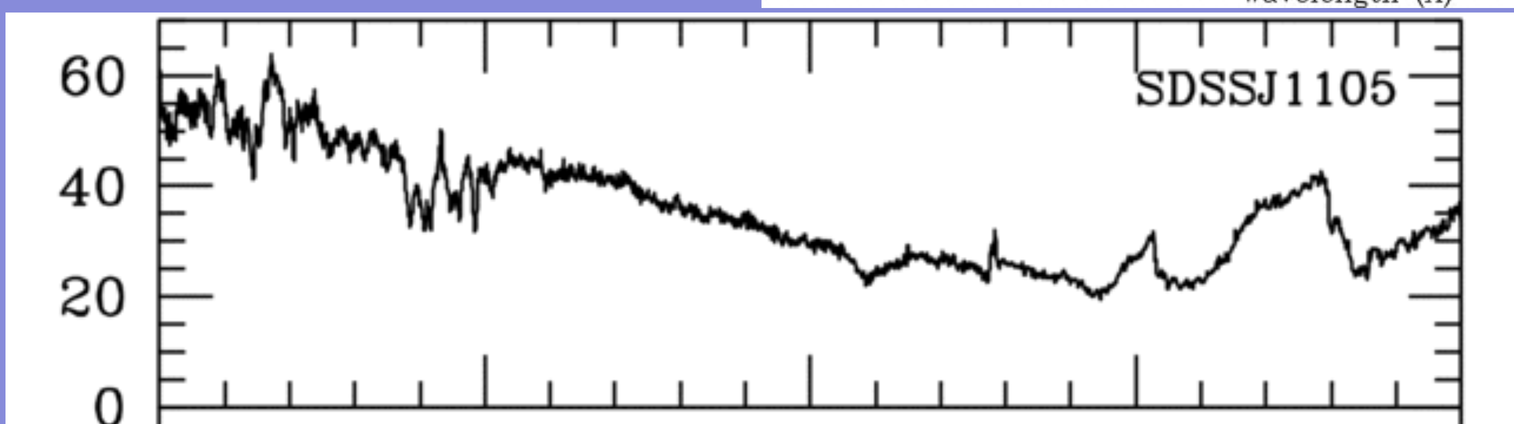
Detecting Magnetic Fields: Zeeman Splitting

Schmidt et al. 2005

Low states of polars

WFOS





4000 6000 8000

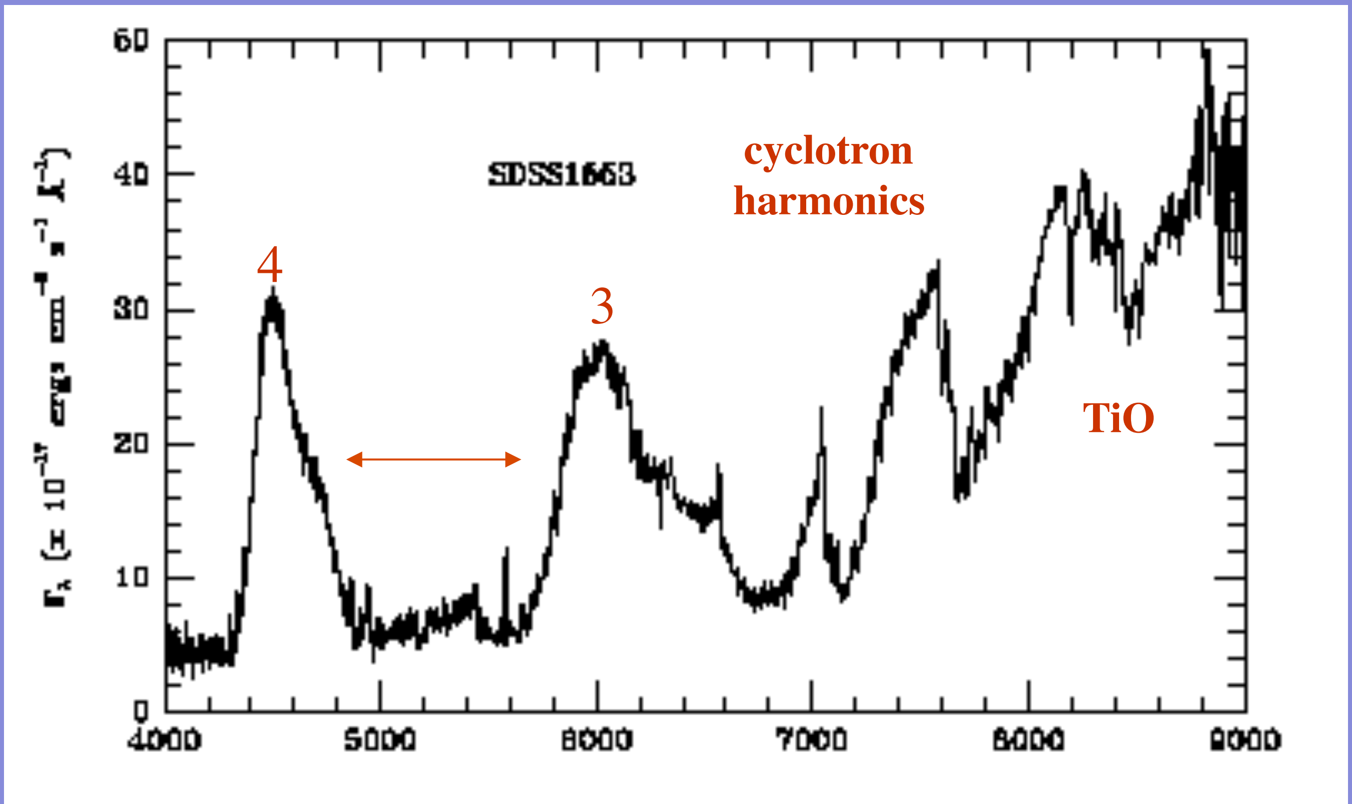
Szkody et al. 2009

Detecting Magnetic Fields: Cyclotron Harmonics

Szkody et al. ApJ, 583, 902, 2003

MQ Dra

WFOS+IRIS



B ~ 60 MG

T < 1keV

$\dot{M} \sim 10^{-14} M_\odot$ /yr

P=4.4 hrs

D=100pc

Novae- brightest and best known CVs

- What is their type and distribution in the MW and other galaxies? TMT optical+nearIR spectra WFOS
- Does the WD gain or lose mass from novae explosions? Radial velocity curves WFOS med res
- How does mass loss occur? IFS IRIS + MIRES

LSST:

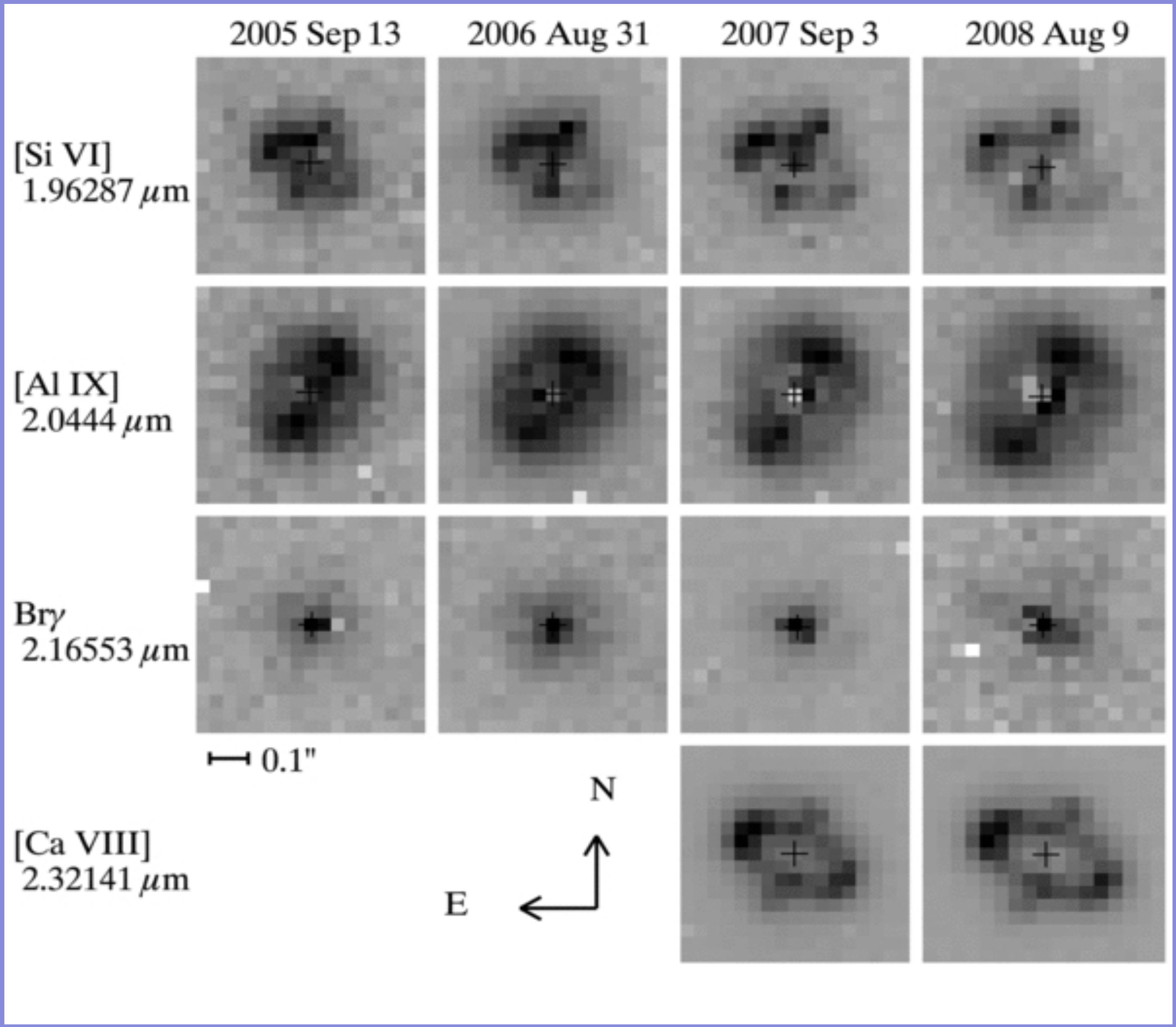
- will detect novae out to Virgo
- useful light curves will be obtained
- precursor star can be observed

TMT spectra – FeII; He/N;O,Ne,Mg novae

MICHI- dust formation and location

V723 Cassiopeiae (Nova Cassiopeia 1995)
J. E. Lyke and R. D. Campbell 2009 The Astronomical Journal 138 1090

OSIRIS KeckII



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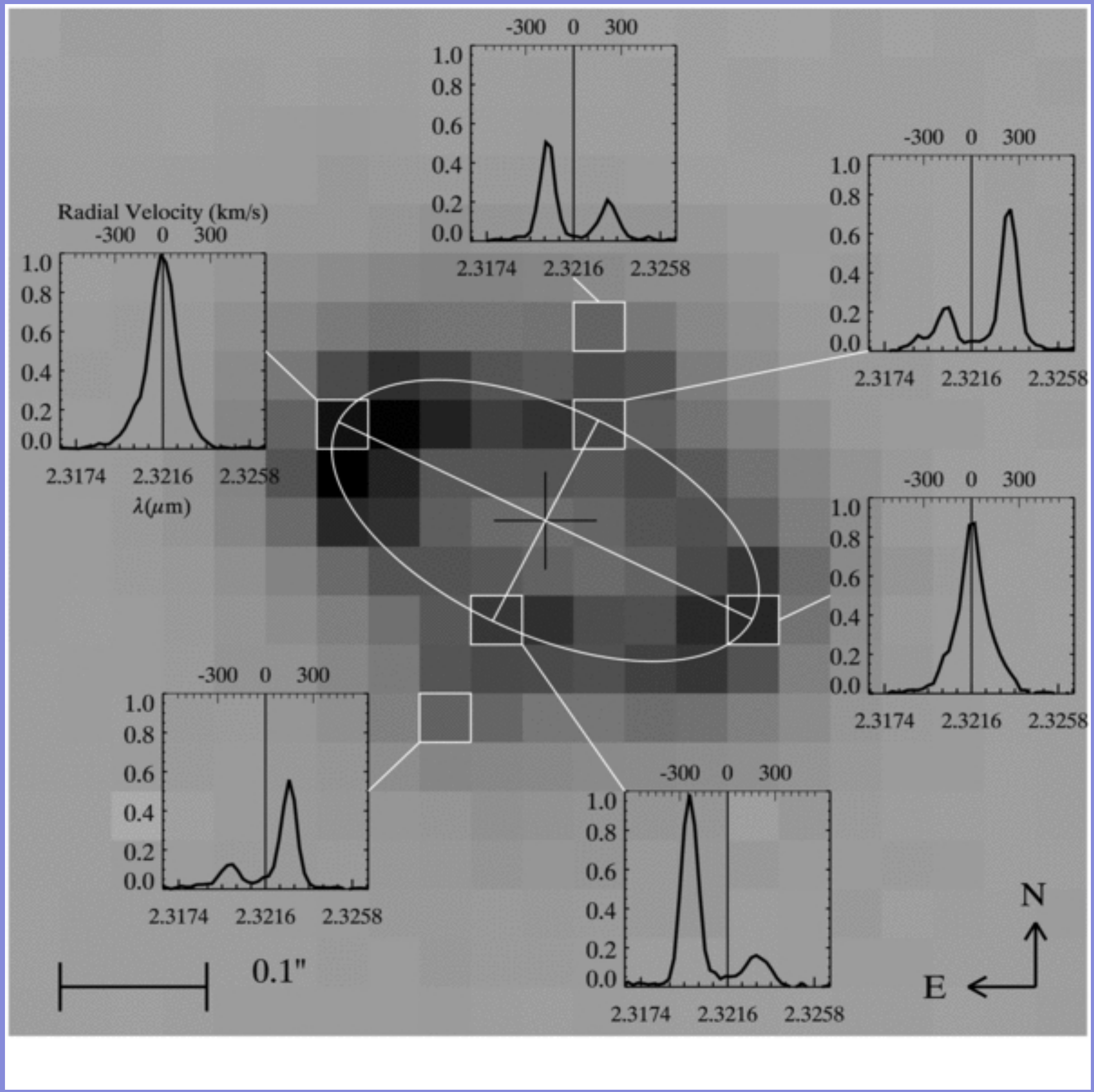

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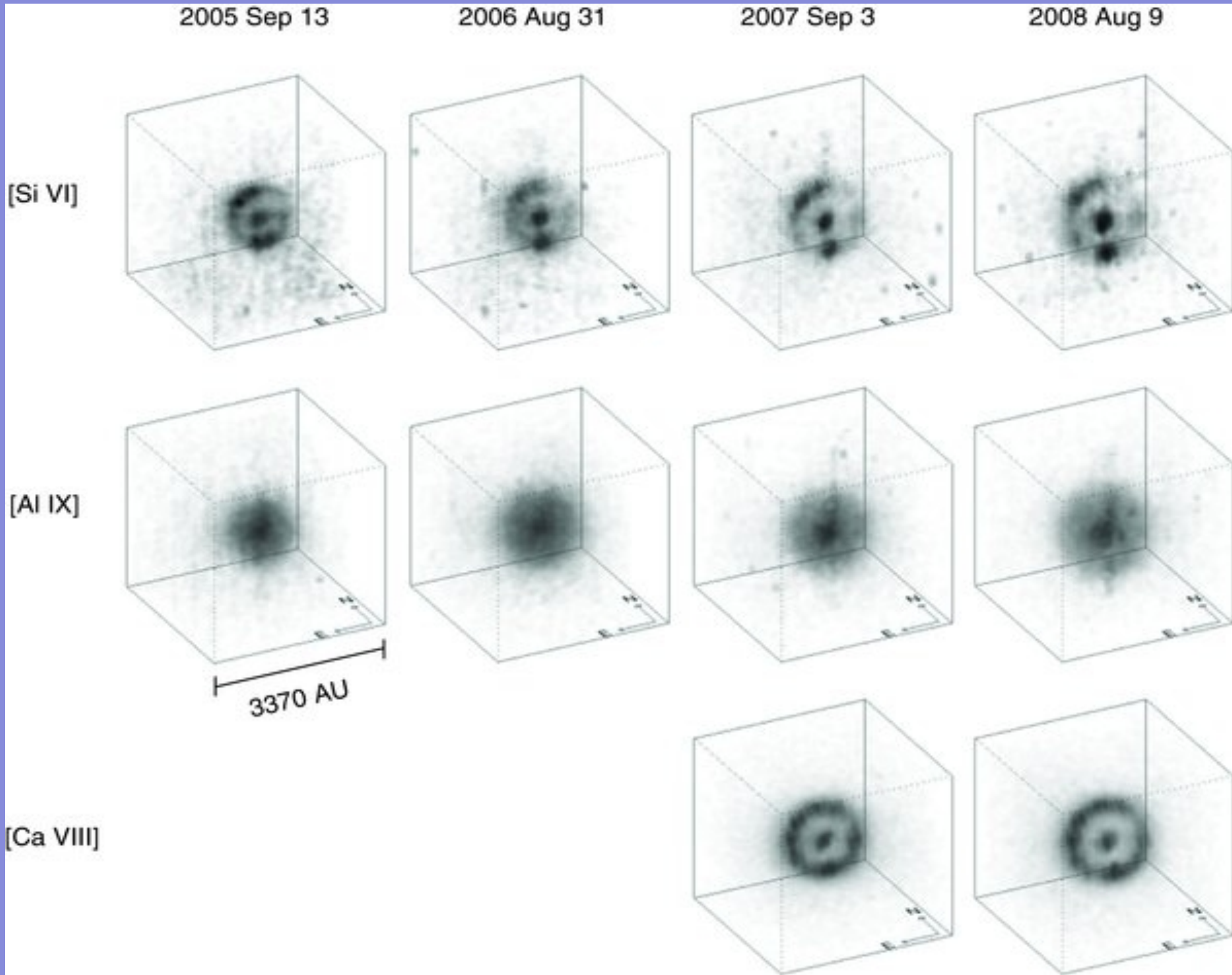
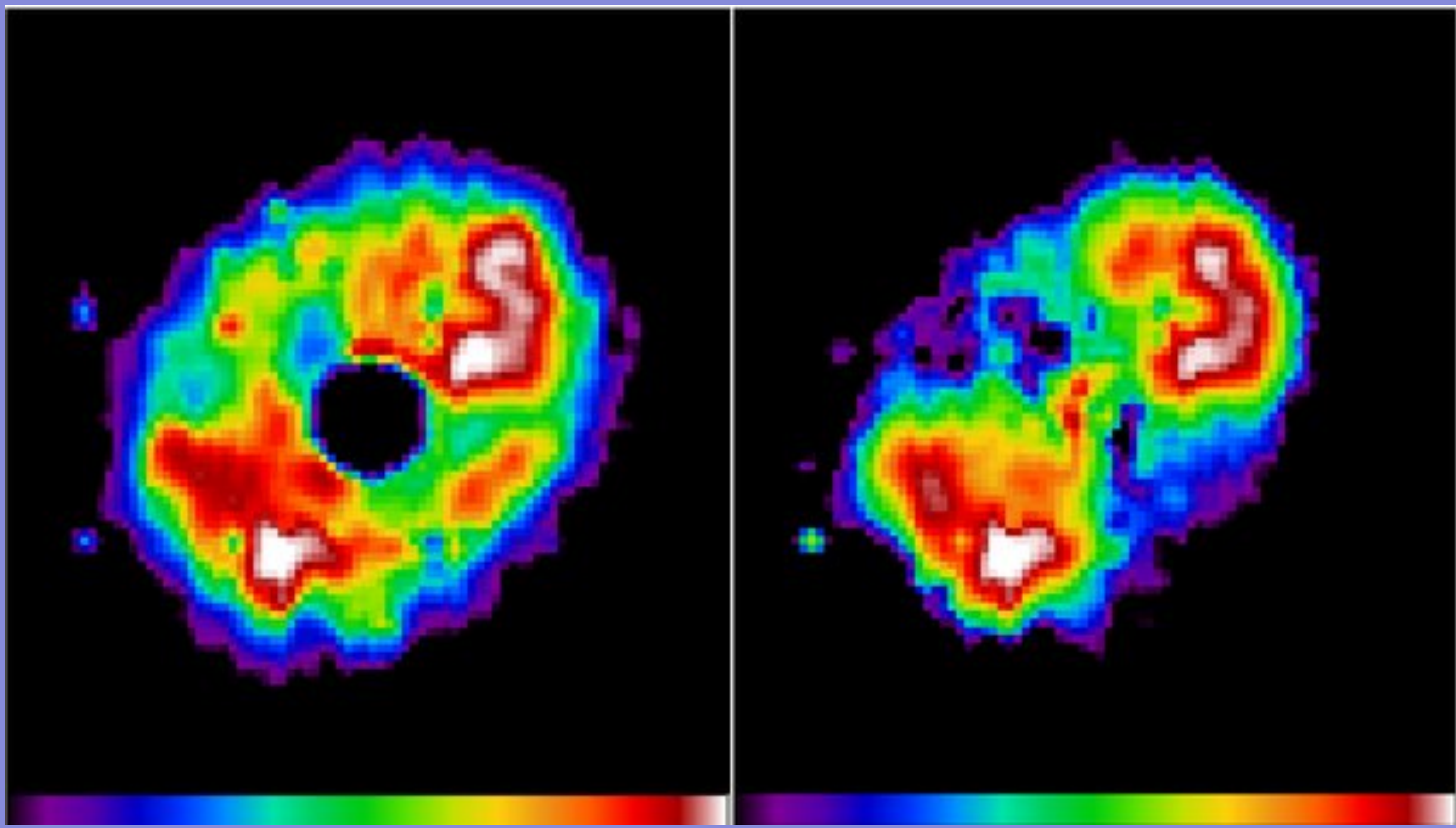




Hα + [NII]

[OIII]λ5007

HR Del with Gemini IFU-GMOS

Moraes and Diaz 2009 AJ

Polarimetry and Spectropolarimetry

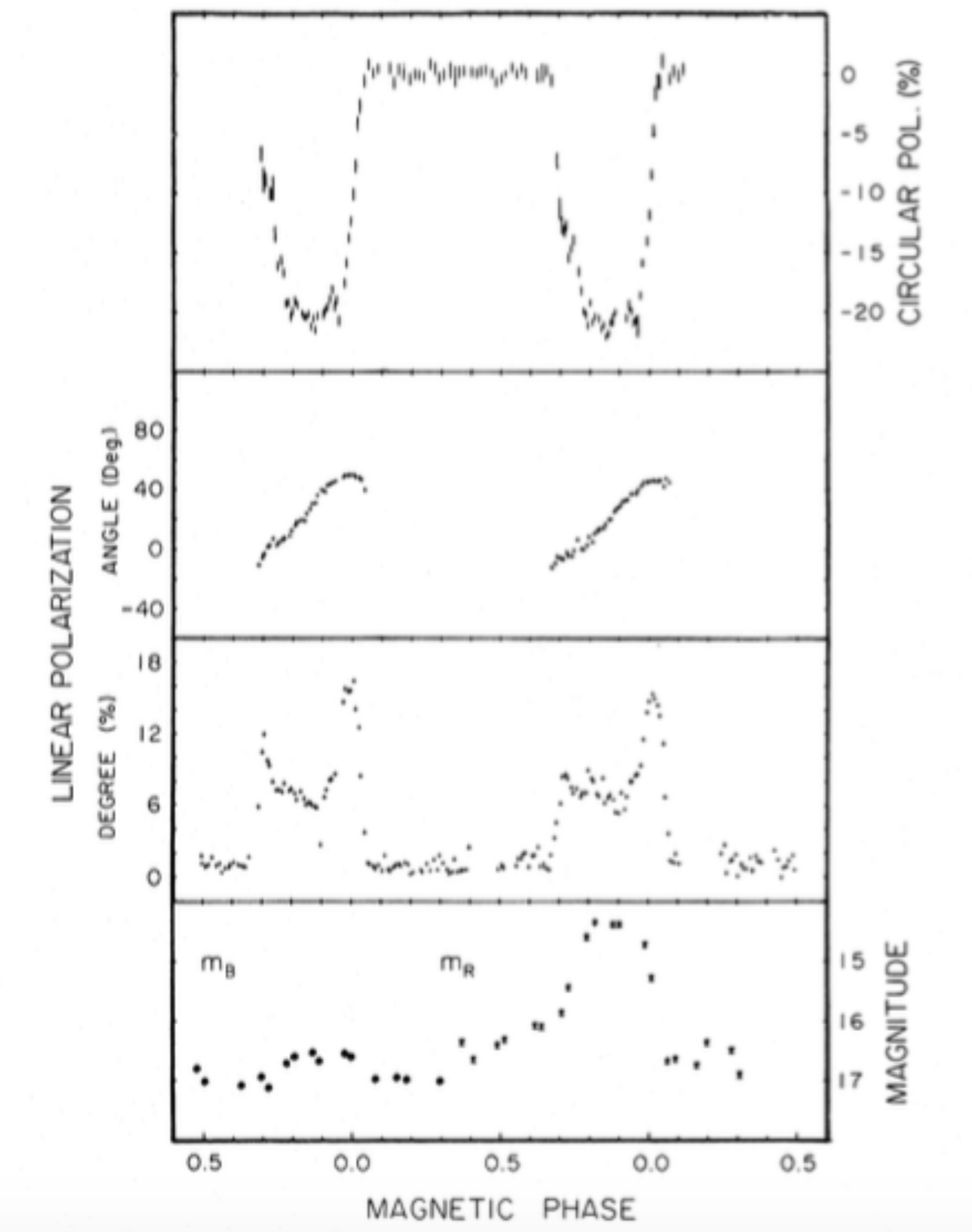
- Identifies magnetic fields
- Gives info on accretion disks

Future wish list for TMT?

Polar ST LMi

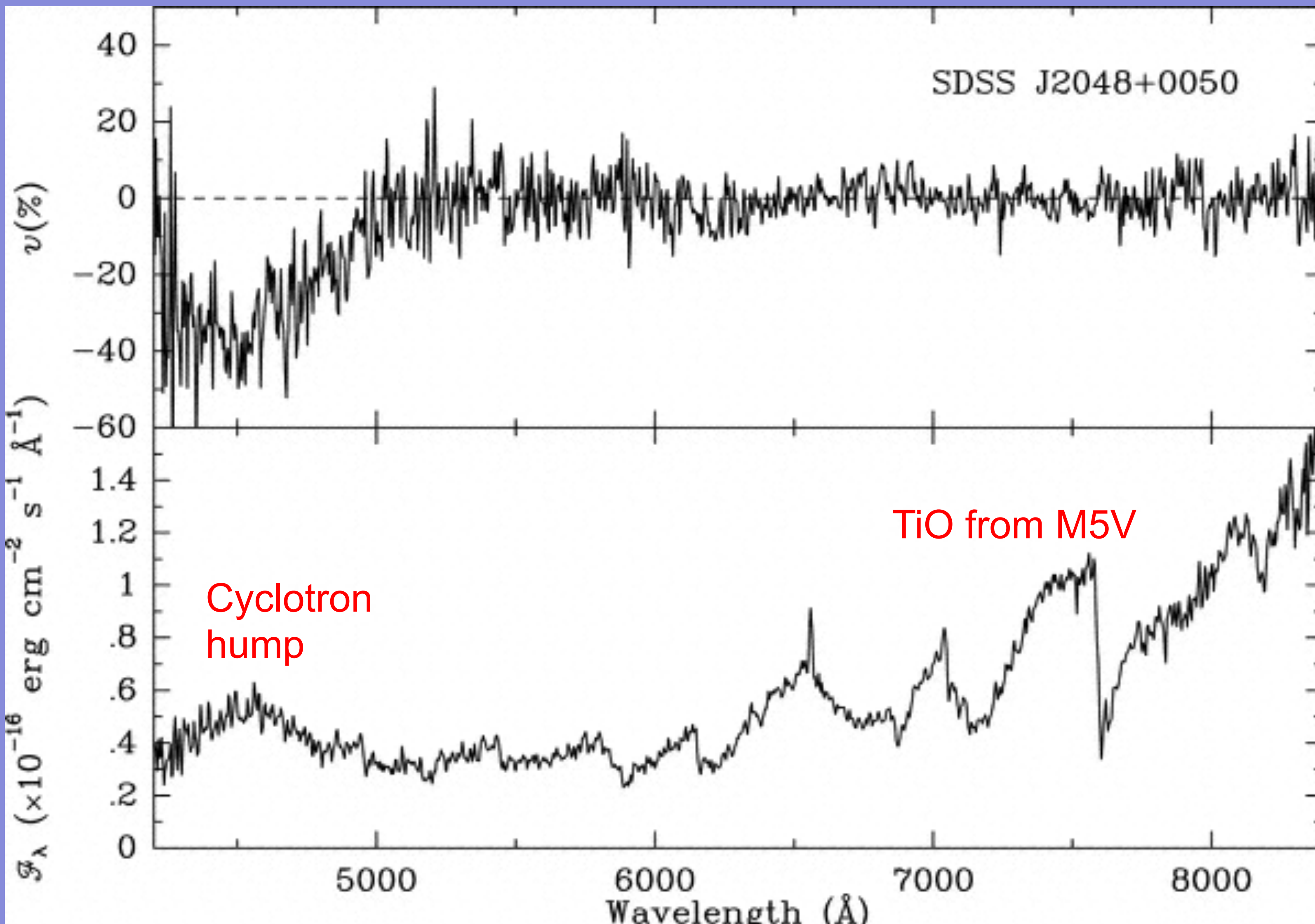
Stockman et al. 1983

Polarization changes with view of accretion column around orbit



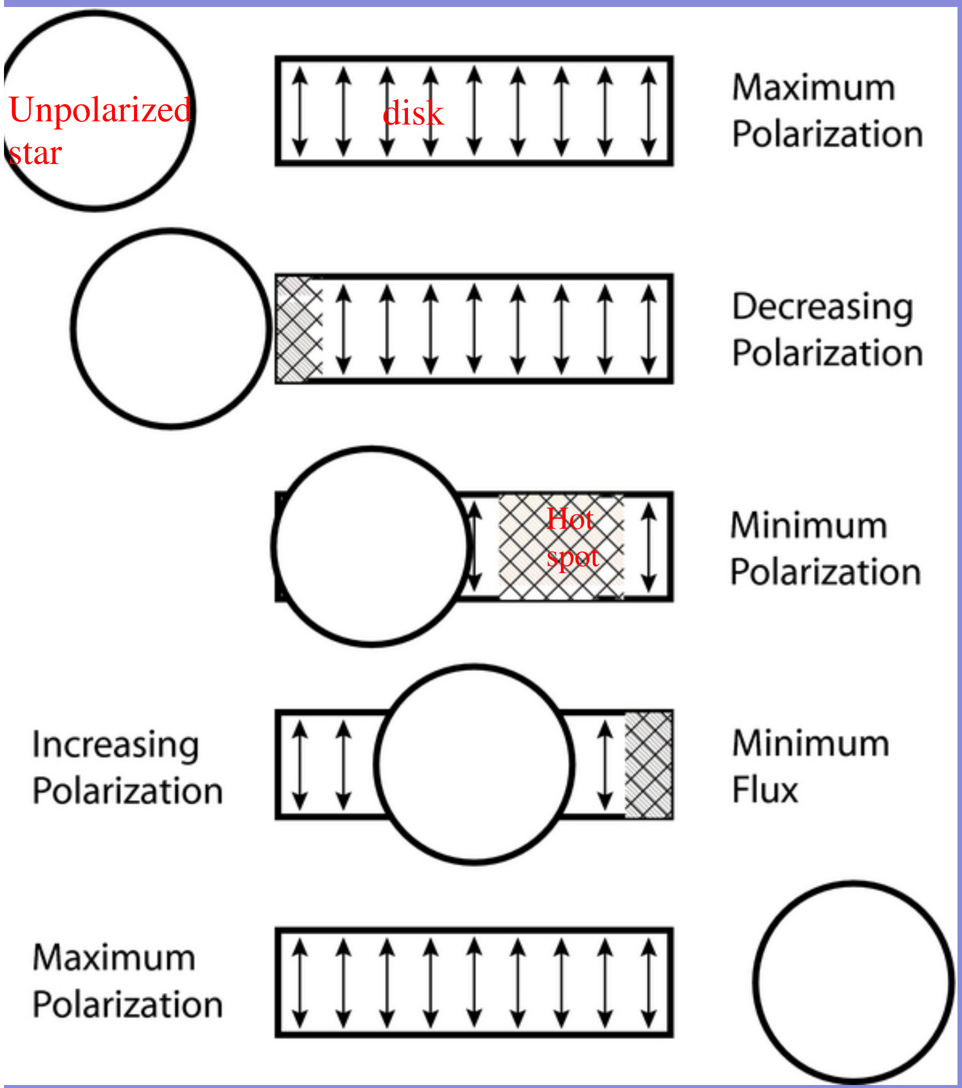
Detecting Magnetic Fields: Spectropolarimetry

Schmidt et al. 2005

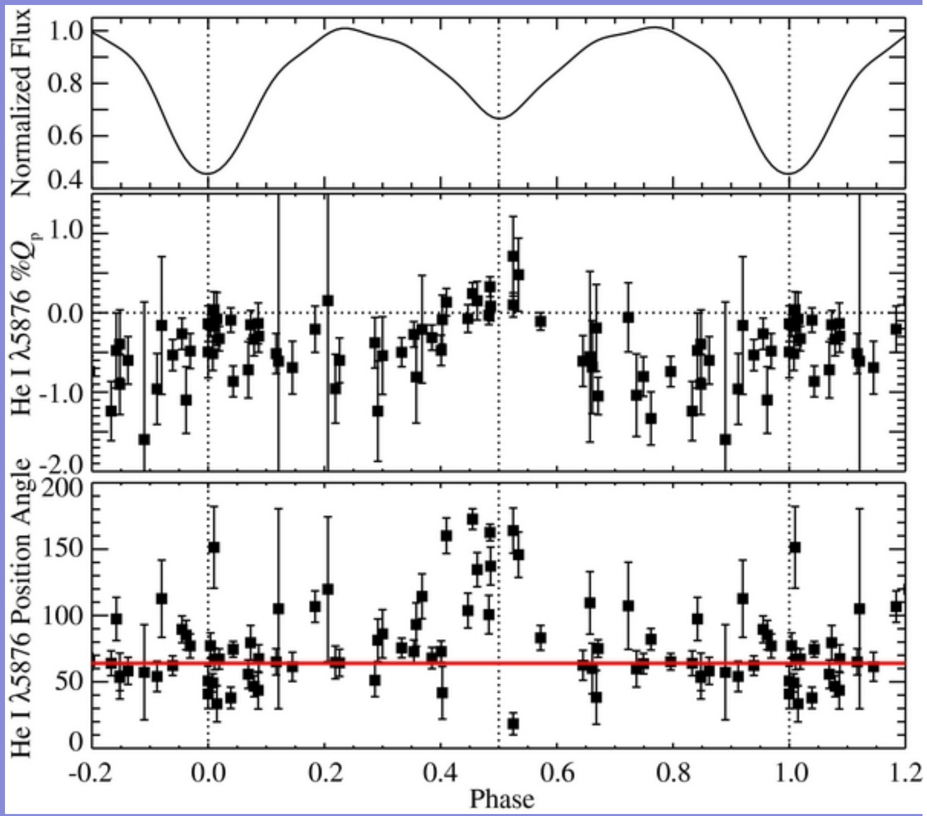


Spectropolarimetry of Algol reveals hot spot: Lomax 2012

V=2-3.5 mag



HPOL on 0.9m telescope



Summary for Maximizing Science Return from TMT/LSST:

- Fast TOO with low res spectra to identify variables
- Slower science followup with medium res spectra to obtain period, composition, radial velocities, tomography
- Slower science followup with fast-readout CCD to resolve rapid timescale phenomena (AM CVn, IPs)
- IFS and spectropolarimetry to determine mass loss characteristics, magnetic fields

Prime Advantages of TMT

- Spectra of 24-25 mag objects (nearby faint sources plus brighter extragalactic) – matches single visit mag of LSST
- Time series for faint short P, low amp variables

Collaborations Needed:

- VSNet, MASTER, LSST to identify interesting candidates for followup

- Worldwide followup consortium to narrow list and organize followup

- Multiwavelength – x-ray (Swift), Gamma-ray, radio for outbursts

ありがとうございます

Arigatogozaimasu

to Kyoto
organizers
and NSF