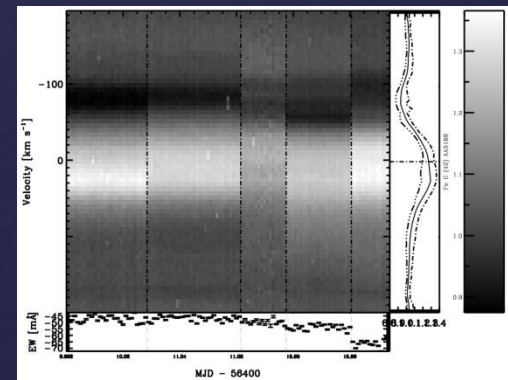
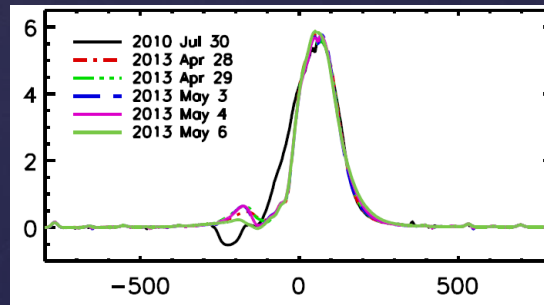


Time-series spectroscopy of Herbig Ae/Be Stars

Alicia Aarnio, University of Michigan

{ With: John Monnier (UM), Rafael Millan-Gabet (CalTech) & Stefan Kraus (Exeter)



- ⌘ Our spectroscopic+interferometric survey
 - ⌘ High-resolution optical spectra of ~60 HAeBe stars (including a few IMTTS)
 - ⌘ Interferometric observations of ~40 of those targets
- ⌘ Multi-epoch sample
 - ⌘ Our MIKE data + archival spectra (33 objects)
- ⌘ High-cadence observations
 - ⌘ Follow up on 2 interesting sources

Outline/introduction

⌘ Our MIKE observations + archival HARPS, UVES spectra

⌘ 33 objects total

⌘ Magellan Inamori Kyocera Echelle, 3200Å-9400Å,
R_B~80k, R_R~65k

⌘ Broad summary:

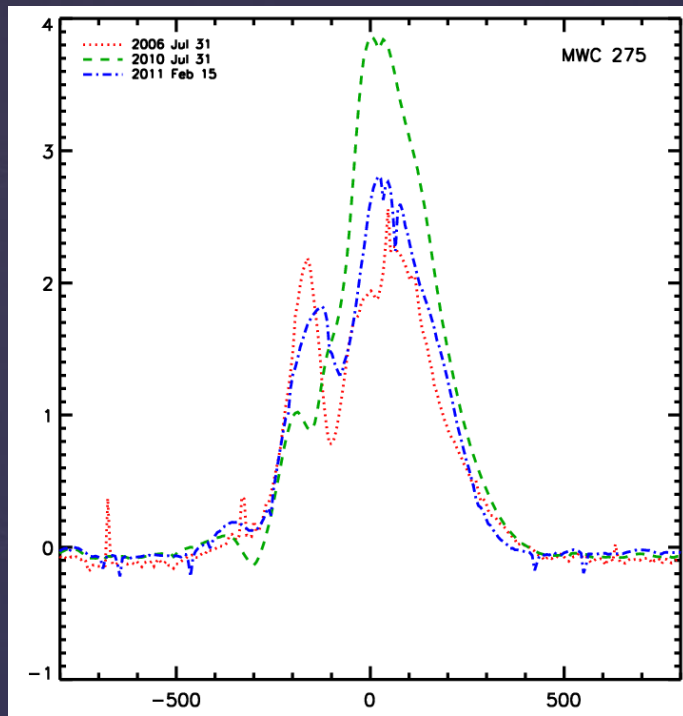
⌘ Most H α profiles type 'B' (Reipurth+1996)

⌘ Very few (3) change morphological class over multiple epochs

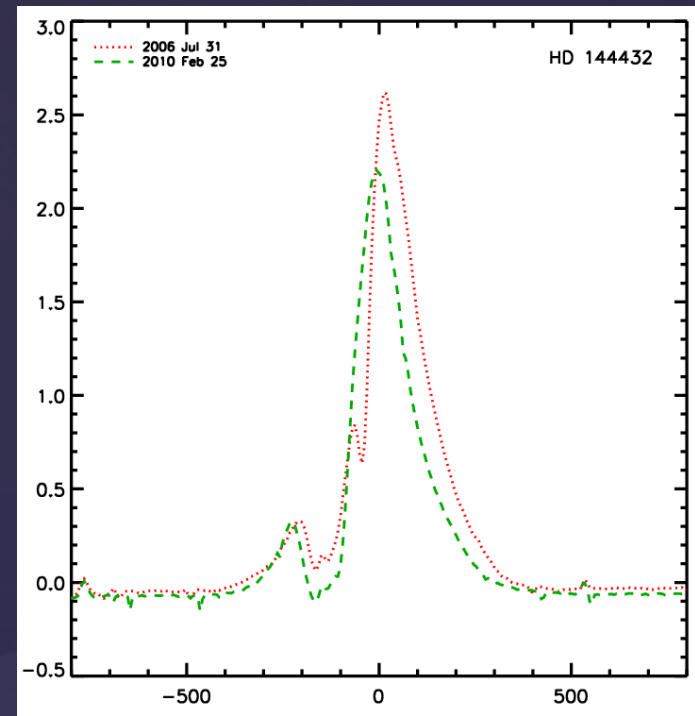
⌘ IV-B types (P-Cygni profiles) show most variability

⌘ Least variability shown by objects thought to be edge-on systems

Multi-epoch data



Velocity [km s⁻¹]



Velocity [km s⁻¹]

⌘ Chose two interesting objects from this sub-set
for further followup

Multi-epoch data

↳ HD 98922

- ⌘ 10600K, $5M_{\odot}$, $9R_{\odot}$
(Wade+2007;
Kraus+2008)
- ⌘ $\langle B_z \rangle < -144$ G
(Alecian+2013)
- ⌘ $V_{\text{sini}} \sim 44$ km/s
- ⌘ $i \sim 45^\circ$

↳ HD 190073 (V1295 Aql)

- ⌘ 9250K, $2.9M_{\odot}$, $3.6R_{\odot}$
(Alecian+2013)
- ⌘ Detected field
(Catala+2007;
Alecian+2013)
- ⌘ $V_{\text{sini}} \sim 0-8$ km/s
(Acke+2004,
Catala+2007)
- ⌘ $i < 65^\circ$ (Eisner+2004,
Isella+2006)
- ↳ Strange [O I] features got
my attention (blueshifted:
Cowley & Hubrig, 2012;
redshifted, my own data)

A(nother) tale of 2 Herbig

⌘ 5 nights of hour-long observations with MIKE
blue/red chips

⌘ Cadence B/R: 6min/4.5min

⌘ ~100 spectra per object

⌘ Looking for variability $< \sim P_{\text{rot}}$

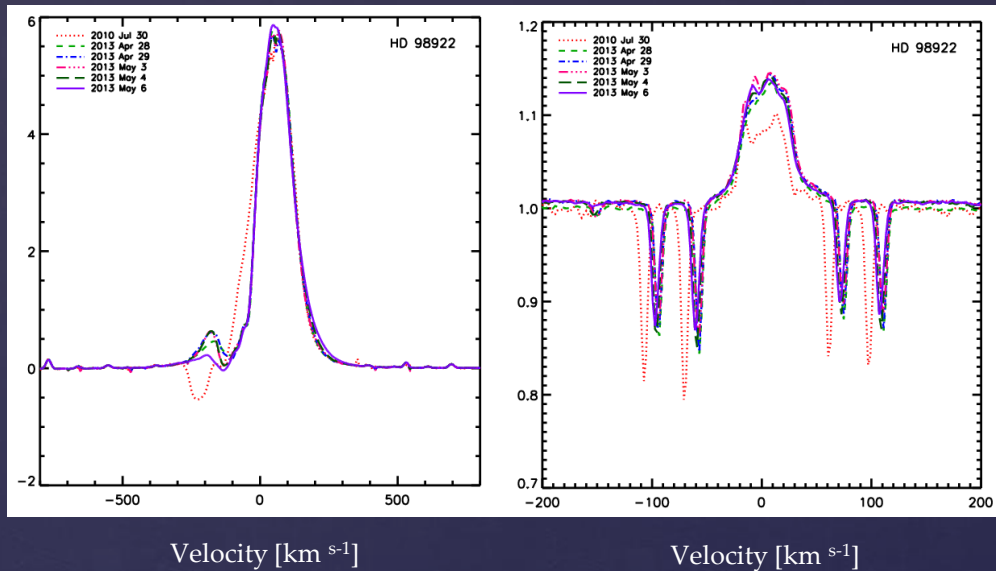
High-cadence data

⌘ Focusing on HD 98922, V1295 Aql

⌘ Relationship between wind, accretion indicators

⌘ Wind is more variable on all timescales

⌘ [O I] 6300Å: wind or accretion related? Both?



Corcoran & Ray (1998): [O I] ~ IR excess (thus, accretion) more strongly correlated than [O I], M_w
- HD 98922: [O I] line, wind signature variability more strongly correlated than accretion signatures

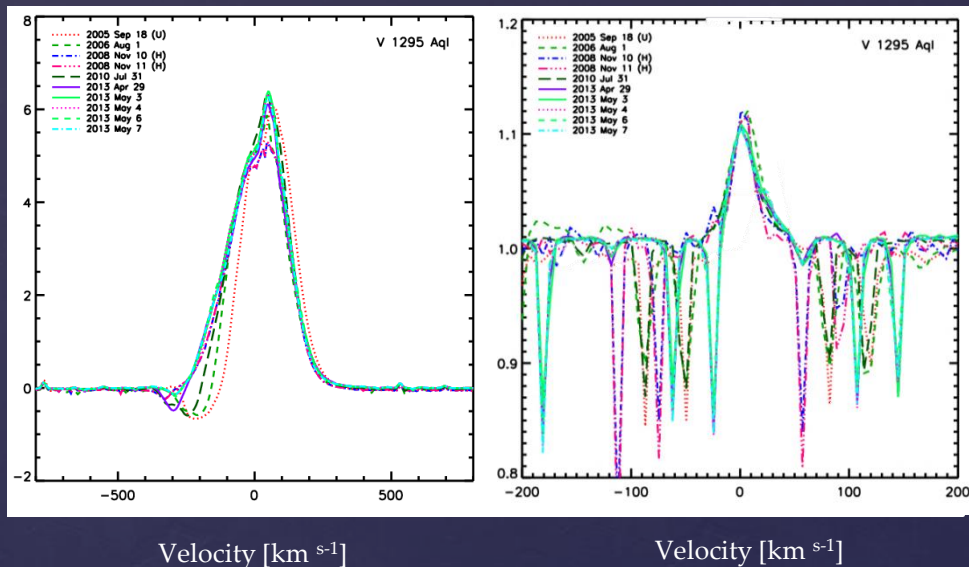
High-cadence data

⌘ Focusing on HD 98922, V1295 Aql

⌘ Relationship between wind, accretion indicators

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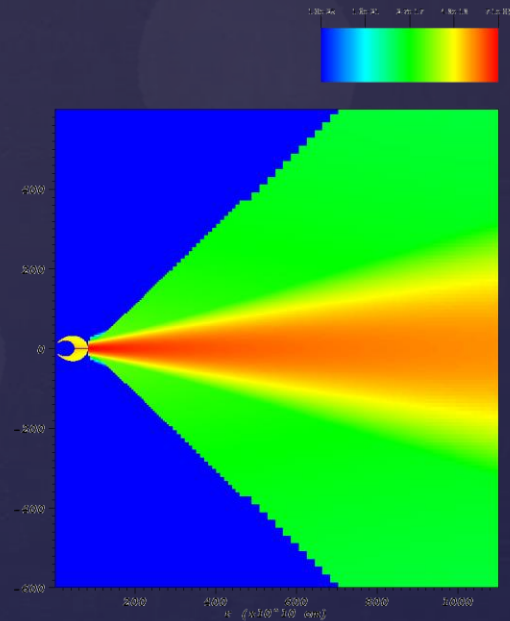
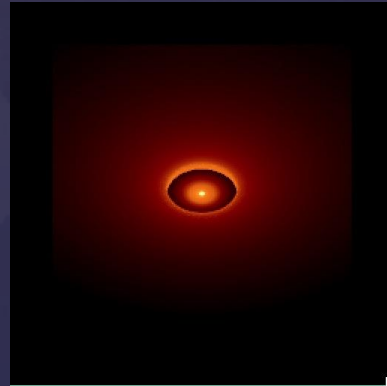
⌘ [O I] 6300Å: wind or accretion related? Both?



-HD 190073: [O I] (mostly) static...
geometry? Stellar vs disk wind?
(Pogodin, Franco, & Lopes 2005)

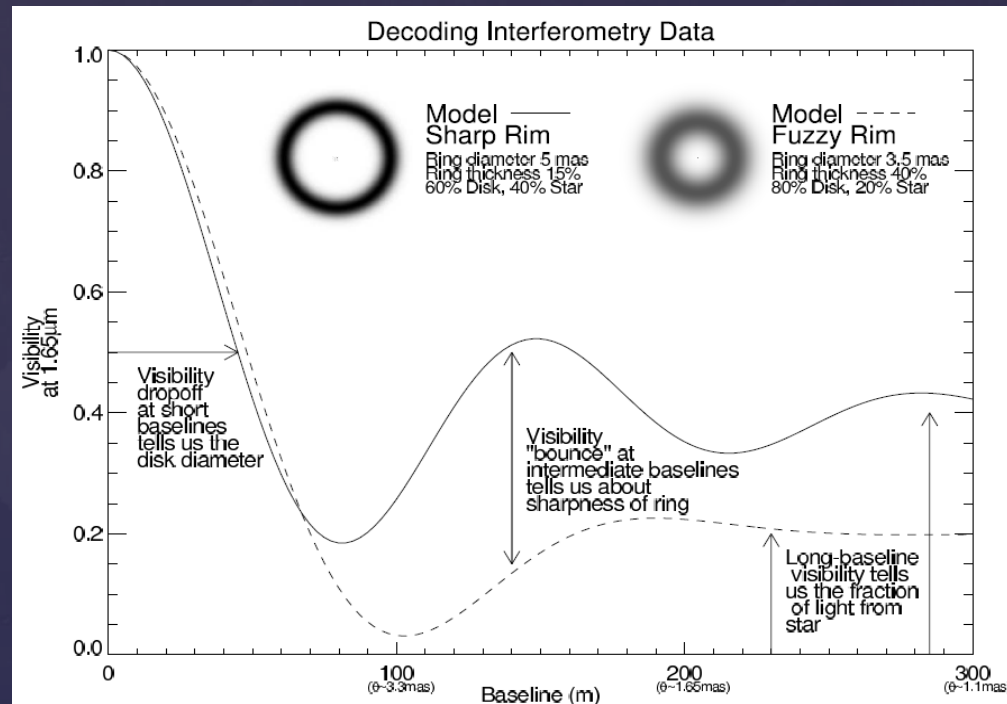
High-cadence data

- ⌘ Radiative transfer models computed with TORUS (Harries, 2001)
 - ⌘ Disk geometry: interferometry, SED modeling
 - ⌘ Disk wind, magnetosphere, stellar parameters: spectra



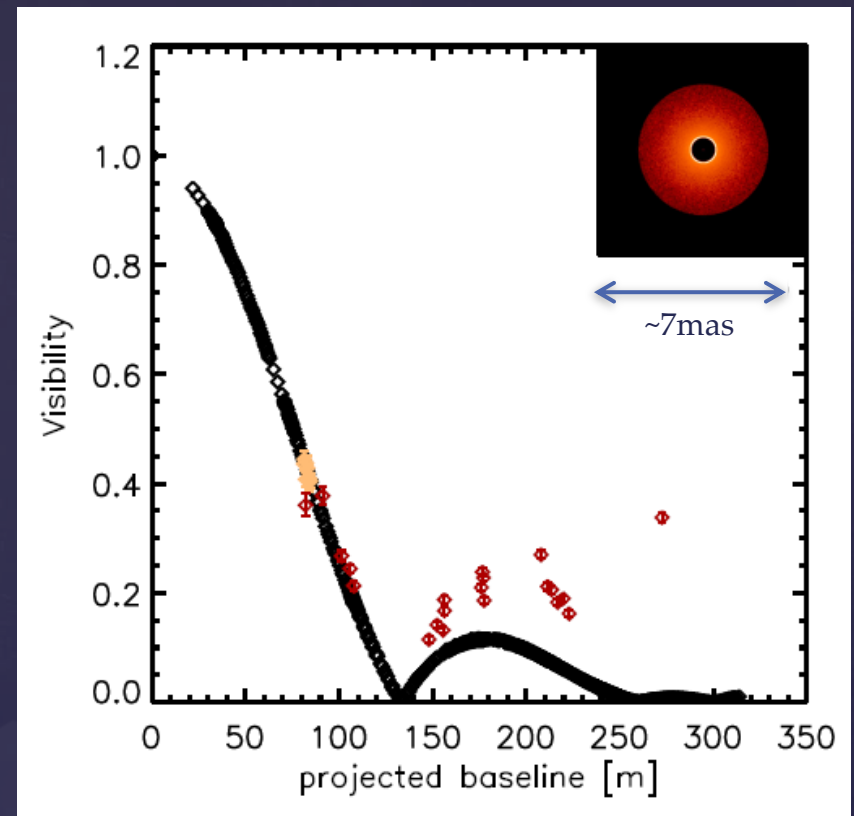
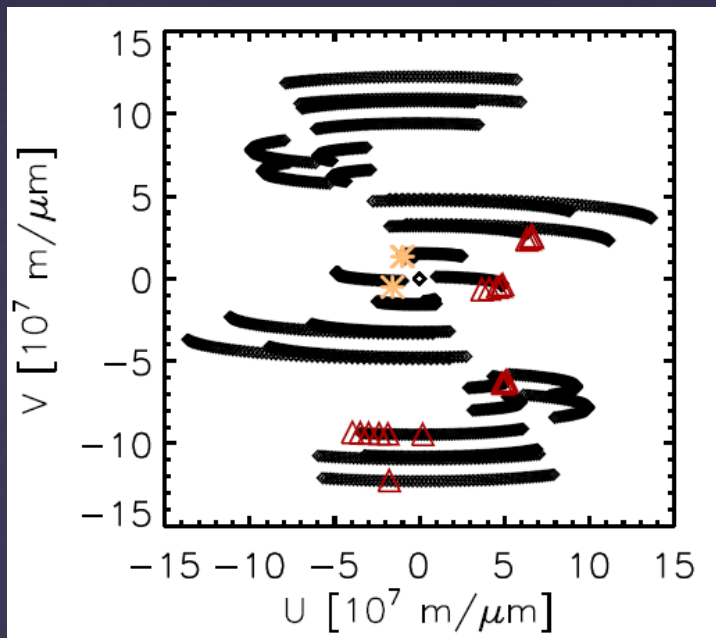
RT modeling

& Analytical disk model to fit interferometry first;
then RT modeling



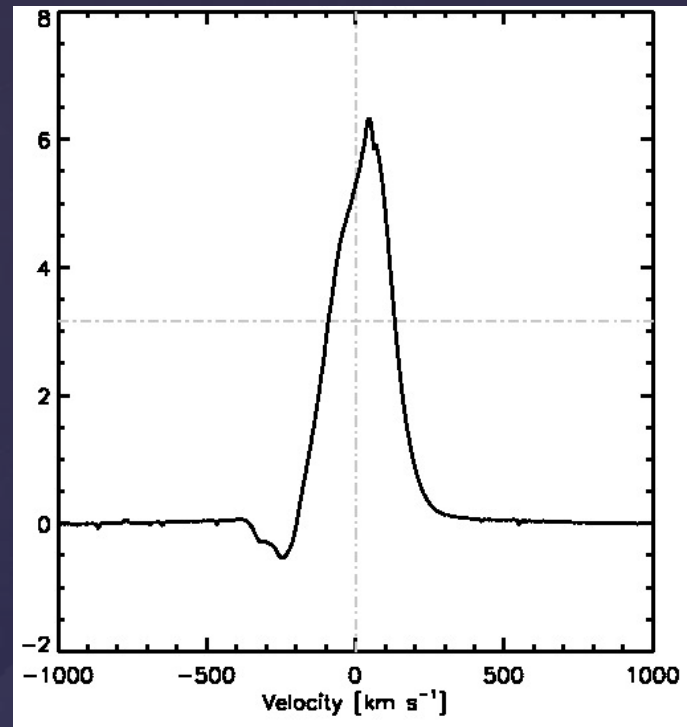
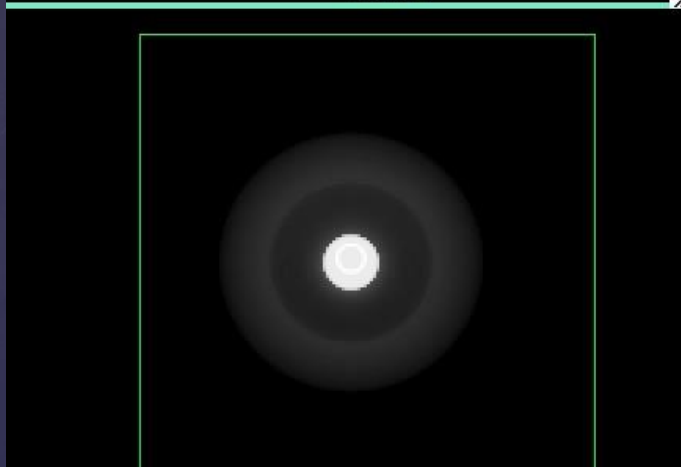
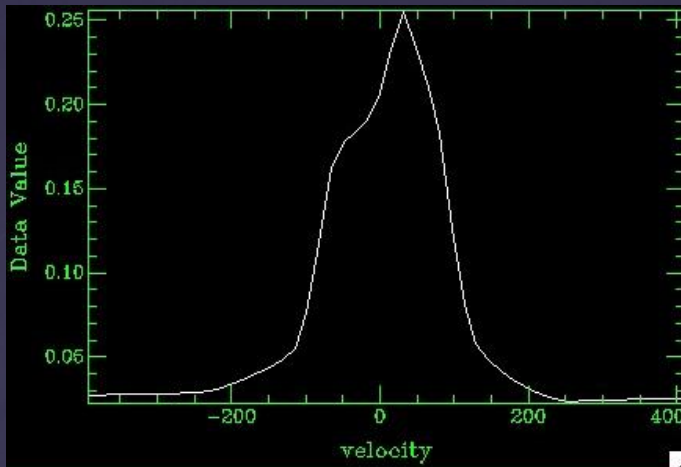
Dullemond & Monnier (2010)

HD 190073



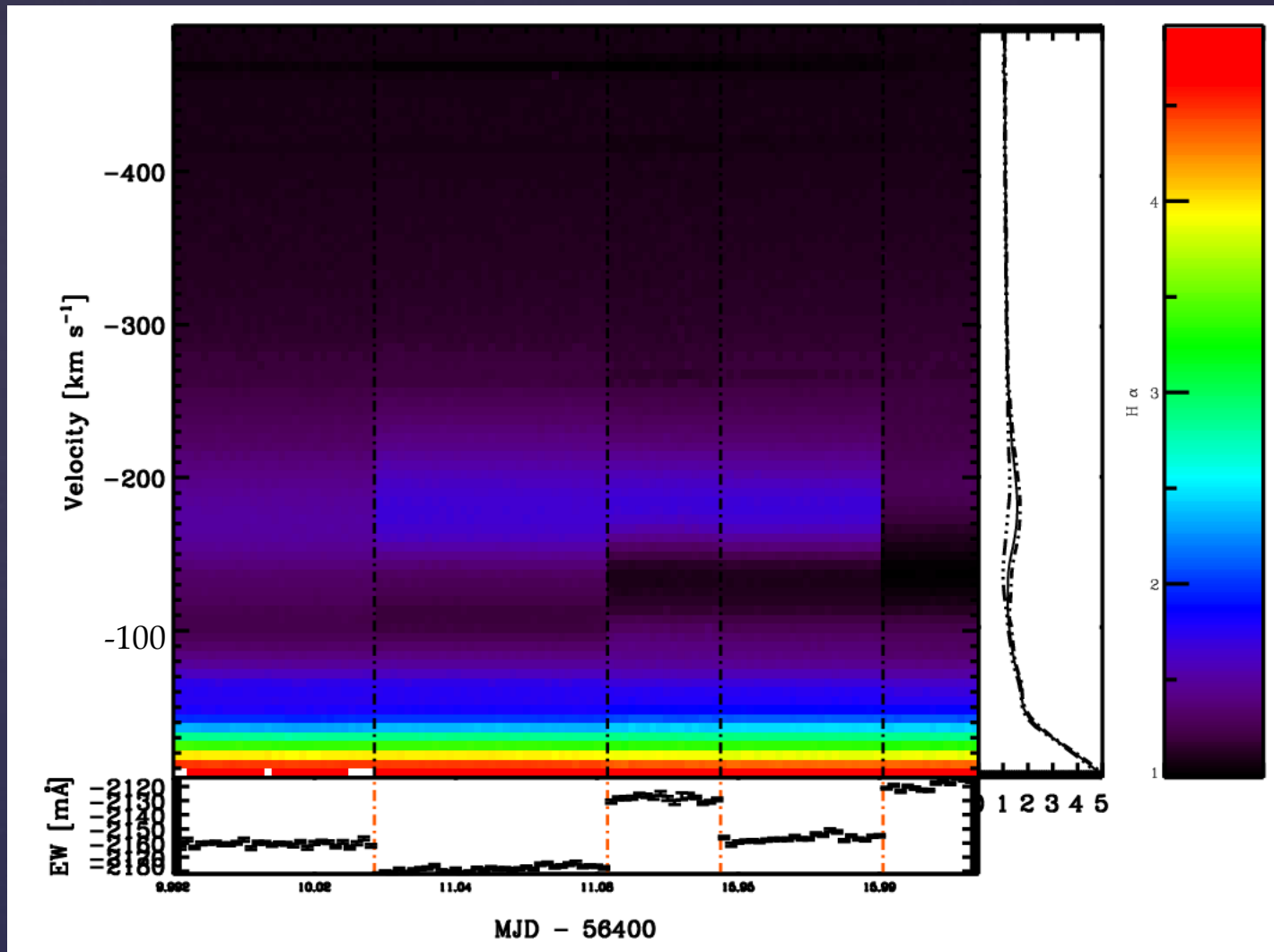
- ◆ Analytical disk model
- ◆ PTI data
- ◆ CHARA/CLASSIC K-band data (R. Millan-Gabet)

HD 190073



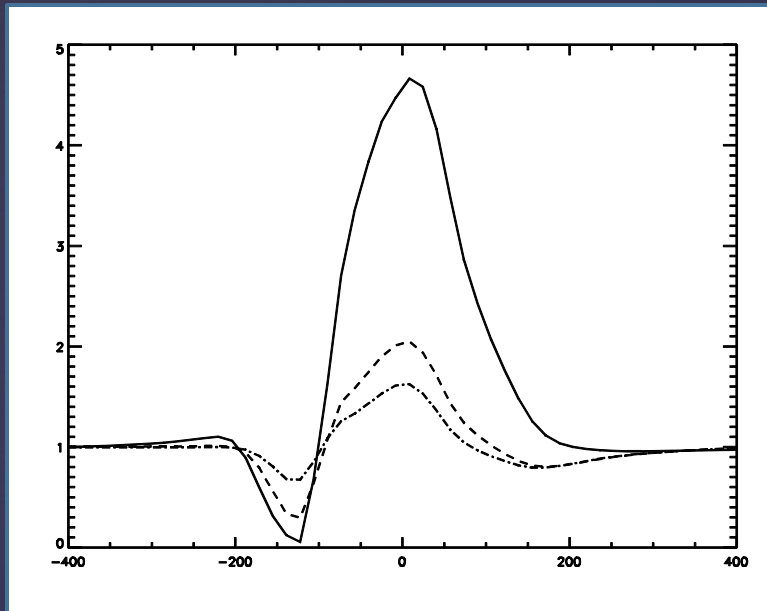
HD 190073

The Missing Link in Star Formation, 7 April, 2014

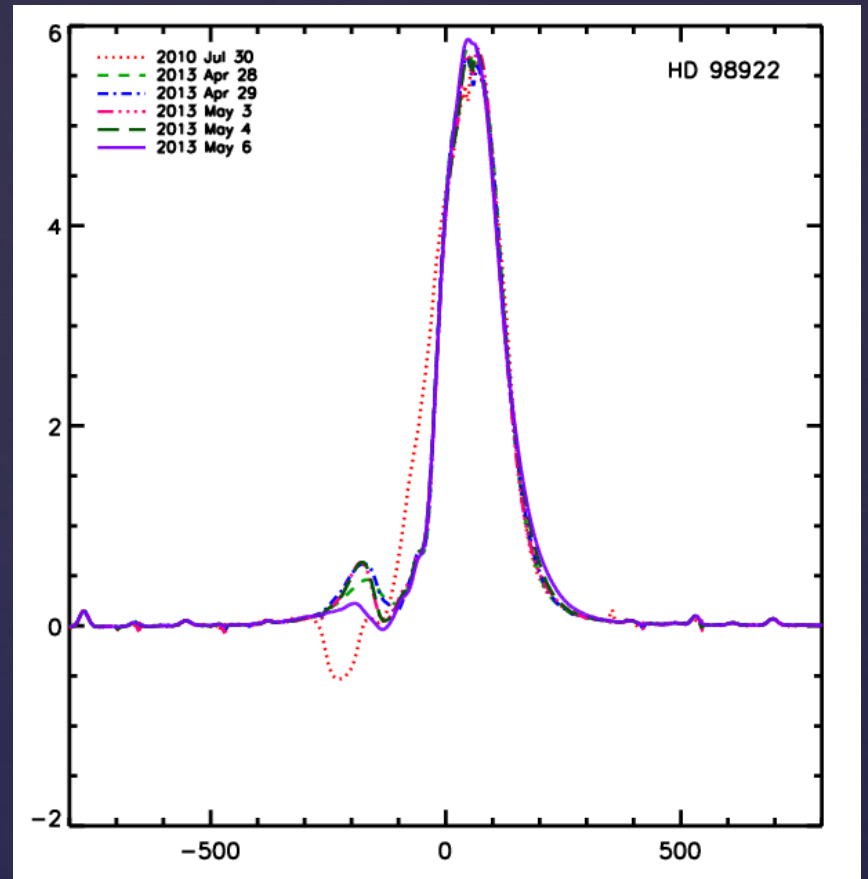


HD 98922 - H α

The Missing Link in Star Formation, 7 April, 2014

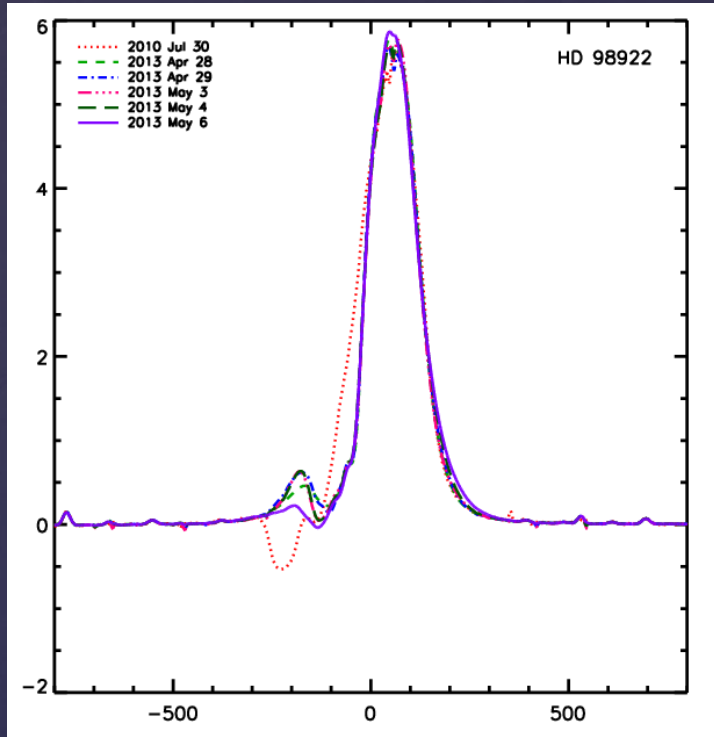


Velocity [km s⁻¹]

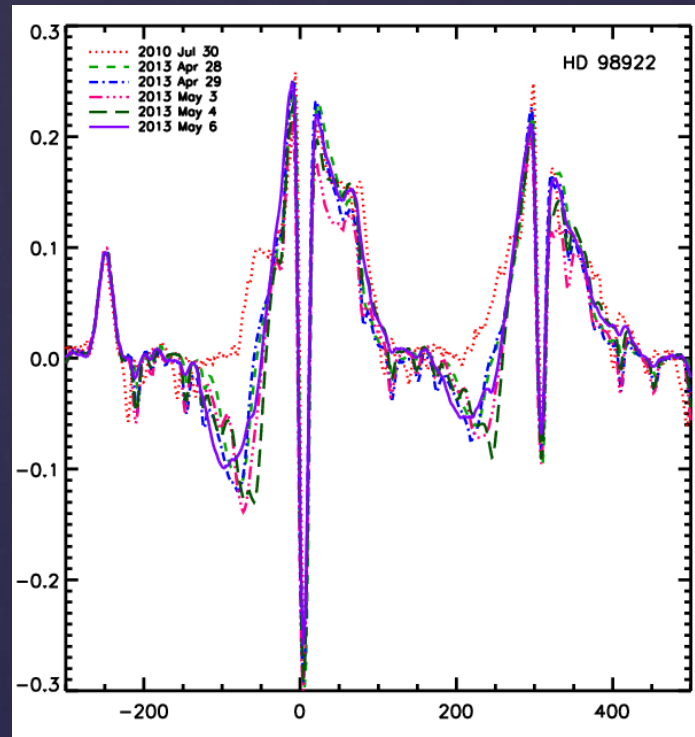


Velocity [km s⁻¹]

HD 98922



Velocity [km s^{-1}]

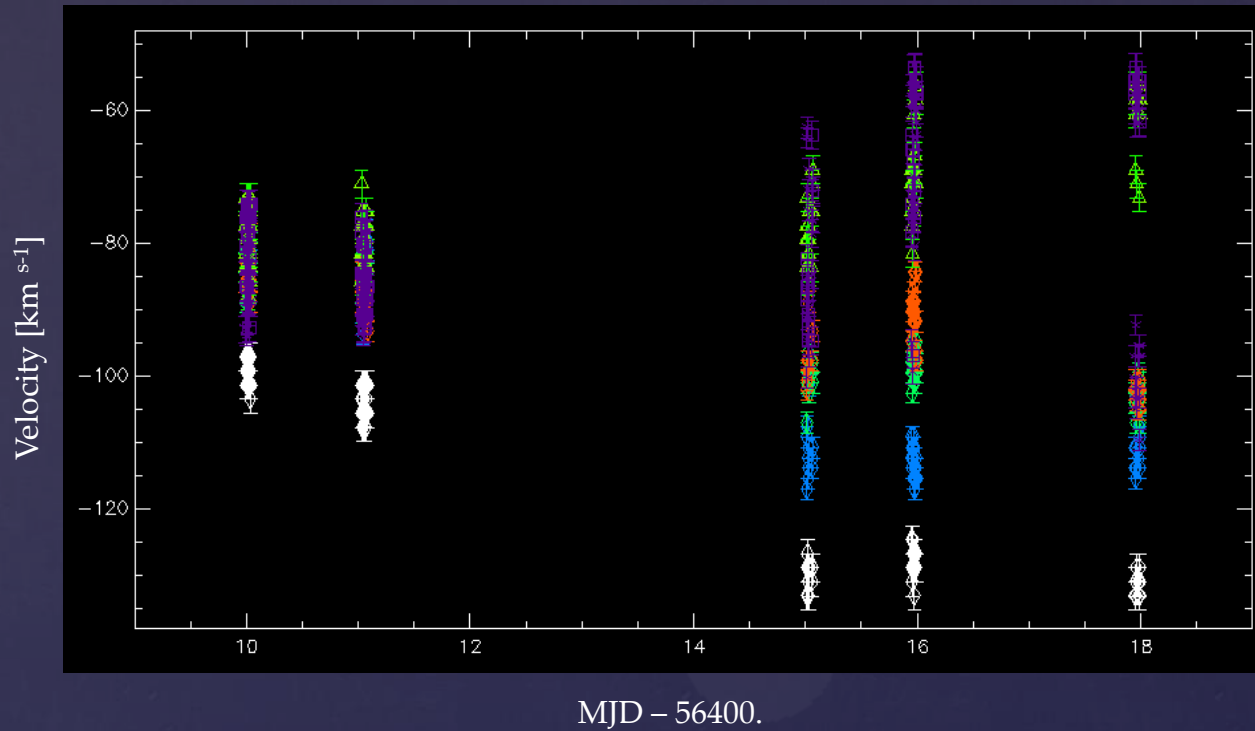


Velocity [km s^{-1}]

HD 98922

⌘ In progress:

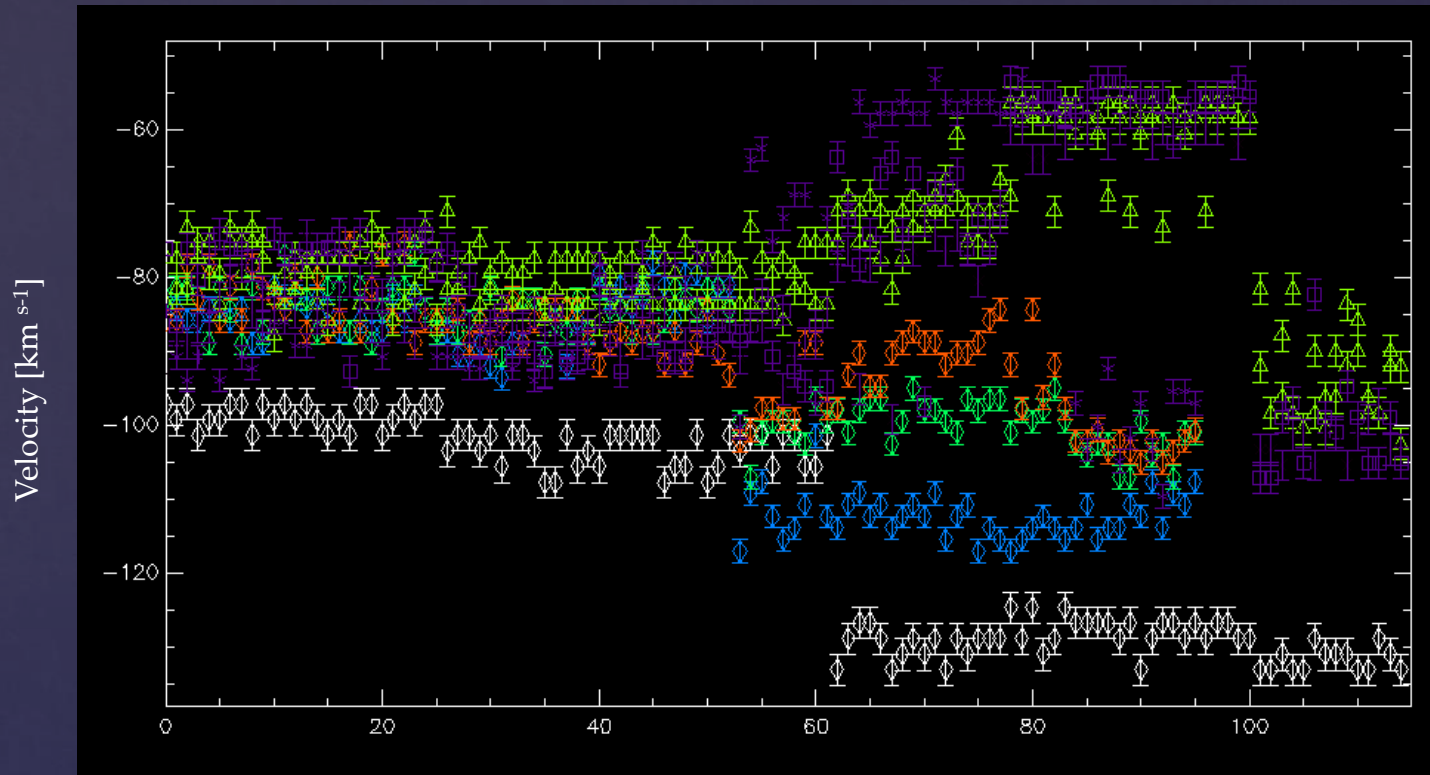
⌘ Using line evolution to probe wind structure



HD 98922

⌘ In progress:

⌘ Using line evolution to probe wind structure

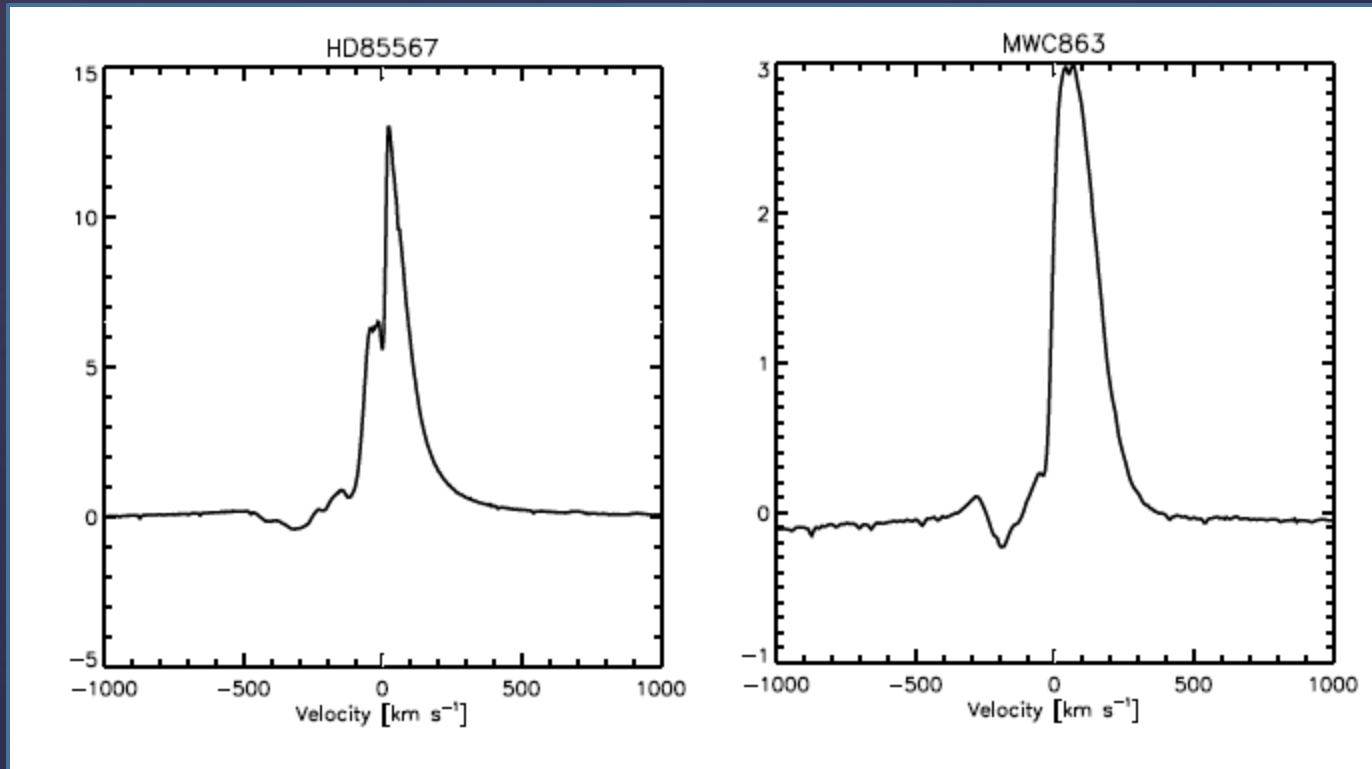


HD 98922

- ⌘ Sample at large
 - ⌘ No inverse P-Cygni in H lines
 - ⌘ Some infall in Na D lines (~8/60 objs)
 - ⌘ Blueshifted abs in Na D lines (~14/60 objs)
- ⌘ Multi-epoch observations
 - ⌘ Objects don't tend to 'switch' morphology classes
 - ⌘ Most dramatic changes: objects with strong winds, jets
 - ⌘ High-inclination systems show little/no variability
- ⌘ High-cadence observations
 - ⌘ Variability observed on short, ~day timescales
 - ⌘ *Possibly bad news for combining non-simultaneous measurements of inner disk/wind tracers.*
 - Match observational cadence to dynamical timescale of region probing

Results

- ⌘ More time series observations, modeling!
 - ⌘ New TORUS modules, more atomic lines implemented
- ⌘ Exploit high resolution of MIKE to study fine structure



Future work

The Missing Link in Star Formation, 7 April, 2014