Time-series spectroscopy of Herbig Ae/Be Stars

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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, \(R_B \sim 80k\), \(R_R \sim 65k\)

**Broad summary:**

- Most Hα 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*
Chose two interesting objects from this sub-set for further followup

Multi-epoch data

The Missing Link in Star Formation, 7 April, 2014
A(nother) tale of 2 Herbigs

- HD 98922
  - 10600K, 5M☉, 9R☉
  - \( < -144 \text{ G} \)
  - Vsini~44km/s
  - i~45°

- HD 190073 (V1295 Aql)
  - 9250K, 2.9Mo, 3.6Ro
  - Detected field
  - Vsini~0-8km/s
  - i<65°
  - Strange [O I] features got my attention (blueshifted: Cowley & Hubrig, 2012; redshifted, my own data)

The Missing Link in Star Formation, 7 April, 2014
5 nights of hour-long observations with MIKE blue/red chips
- Cadence B/R: 6min/4.5min
- ~100 spectra per object
- Looking for variability < ~$P_{\text{rot}}$

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

The Missing Link in Star Formation, 7 April, 2014
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

Decoding Interferometry Data

Model Sharp Rim
- Ring diameter: 5 mas
- Ring thickness: 10%
- 60% Disk, 40% Star

Model Fuzzy Rim
- Ring diameter: 3.5 mas
- Ring thickness: 9%
- 80% Disk, 20% Star

- Visibility dropoff at short baselines tells us the disk diameter
- Visibility "bounce" at intermediate baselines tells us about sharpness of ring
- Long baseline visibility tells us the fraction of light from star

Dullemond & Monnier (2010)

HD 190073

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

HD 190073

The Missing Link in Star Formation, 7 April, 2014
HD 190073

The Missing Link in Star Formation, 7 April, 2014
HD 98922 - Ha

The Missing Link in Star Formation, 7 April, 2014
HD 98922

The Missing Link in Star Formation, 7 April, 2014
Velocity [km s$^{-1}$]

HD 98922

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In progress:
Using line evolution to probe wind structure

HD 98922

The Missing Link in Star Formation, 7 April, 2014
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
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