# Spectroscopic follow-ups of Near-IR eruptive objects discovered from the VVV survey

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VVV Survey

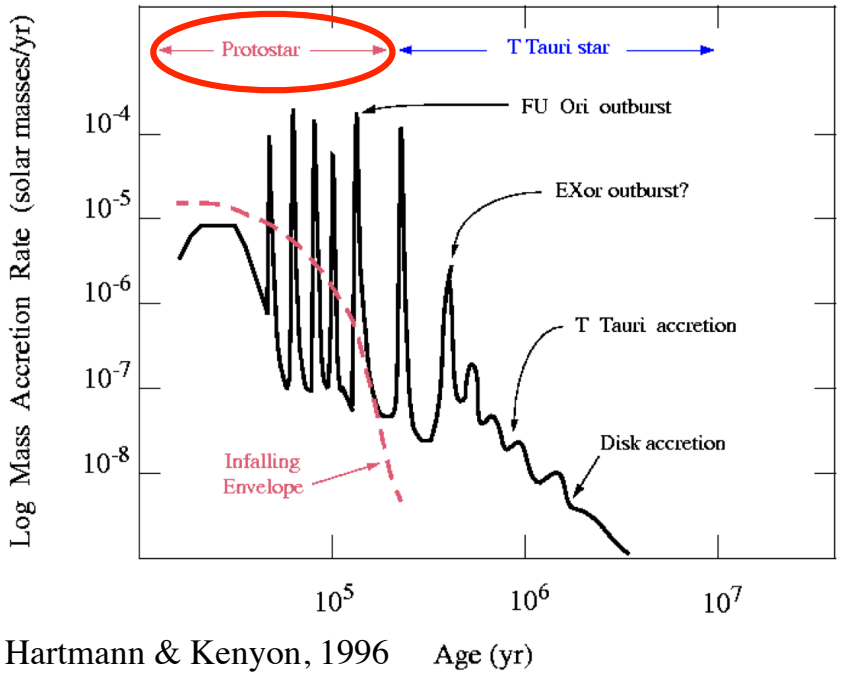
University of Hertfordshire UH

# Introduction

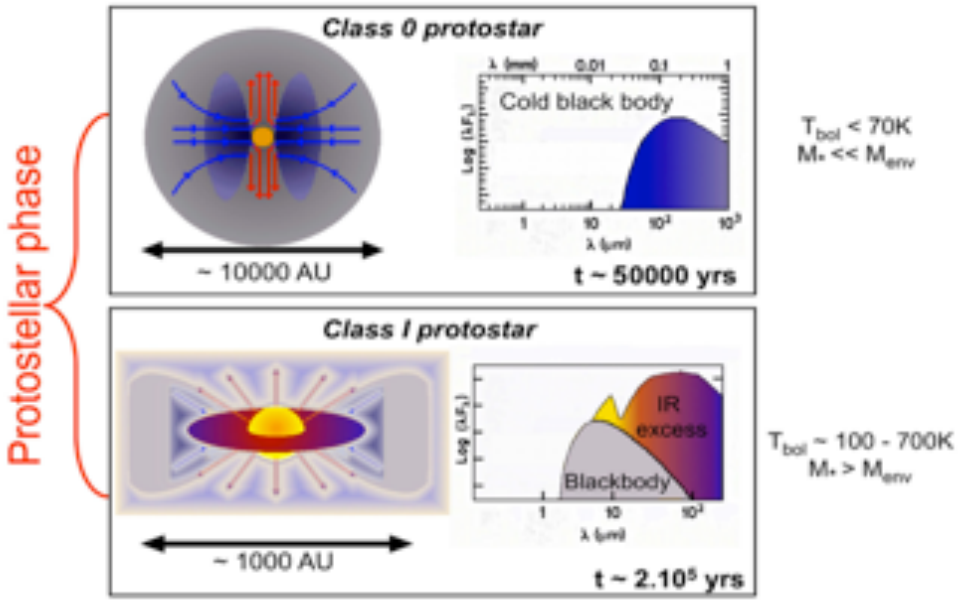
Most YSOs are variable stars

Episodic accretion:

- dominated the variability of protostars
- mass accretion history (the luminosity problem)
- mechanisms (theoretical talks on Tues.)
- duration & frequency
- effect on disc/planetesimals

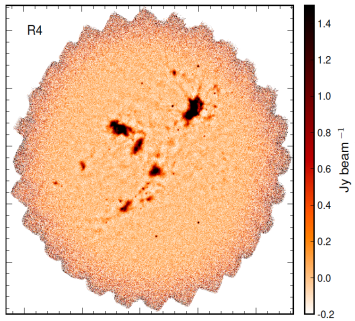



Hartmann & Kenyon, 1996

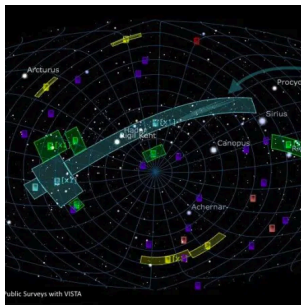



$T_{bol}$ < 70K
$M_* << M_{env}$

$T_{bol}$ ~ 100 - 700K
$M_* > M_{env}$




Sub-mm survey
(JCMT Transient)




Near-IR survey
(VVV/VVVX)

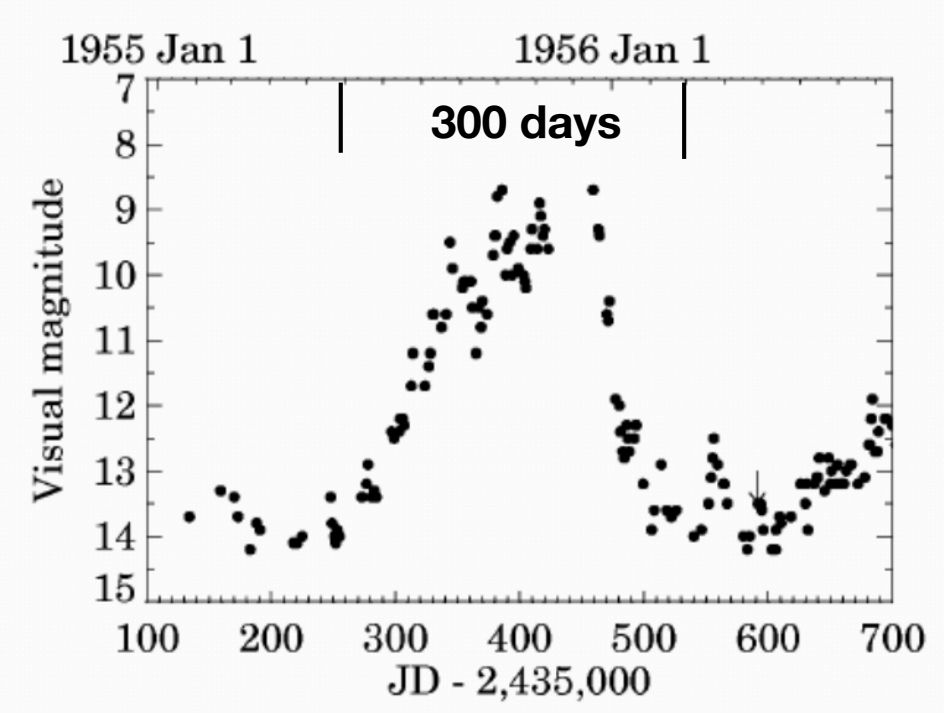
# Introduction

Two prototypes of episodic accretion event

EXors:

Duration ~10^2 days, repeatable

Spectral features: Magnetospheric accretion

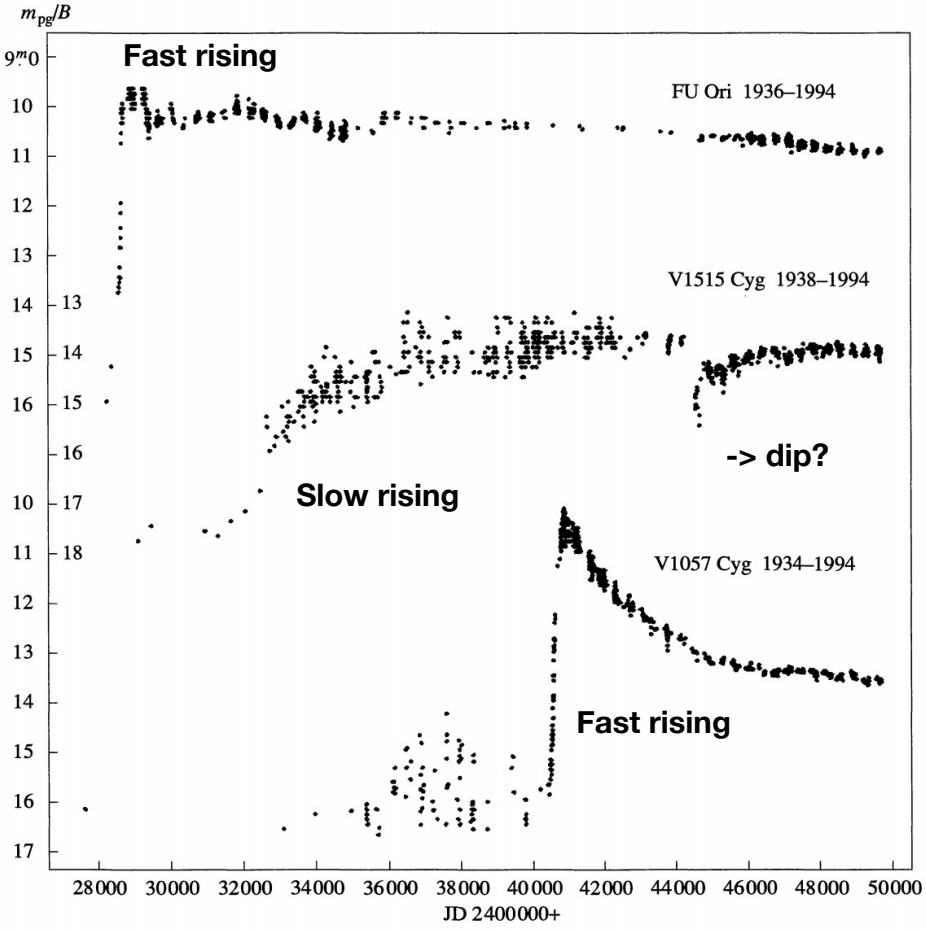



Abraham et al., 2009

FUors:

Duration ~10^4 days, 1 per 10^4 years

Self-luminous disc (absorption features)



# Photometric observation

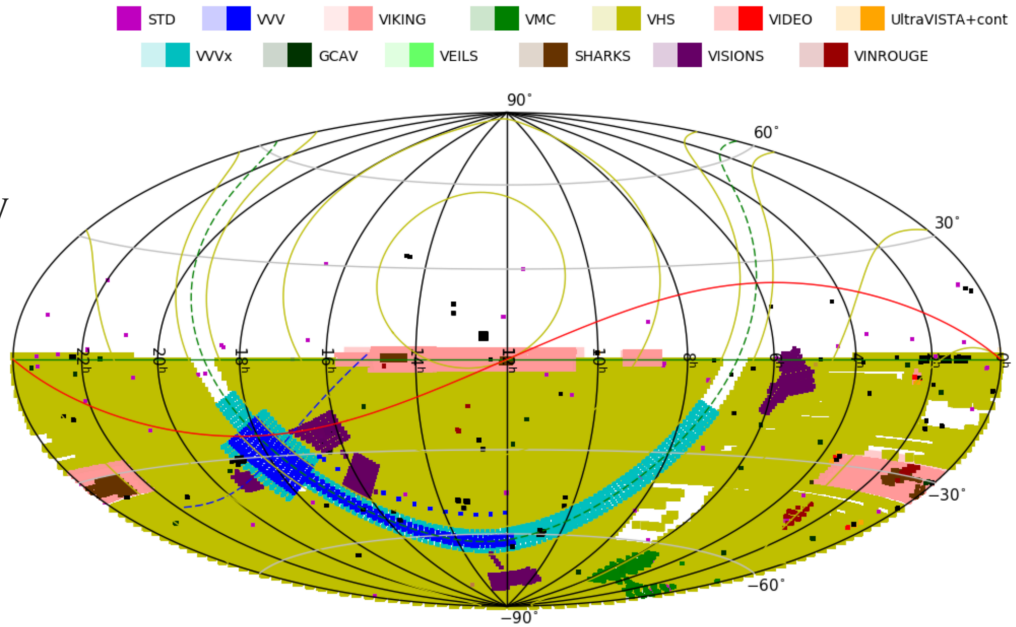
**V**isible and **I**nfrared **S**urvey **T**elescope for **A**stronomy

**VVV/VVVX**: **V**ista **V**ariables in the **V**ía Láctea

Target: the Galactic bulge and part of the inner disc

Decade-long Ks-band LCs + multi band photometry

184+ papers now!




Contreras Peña et al., 2017a

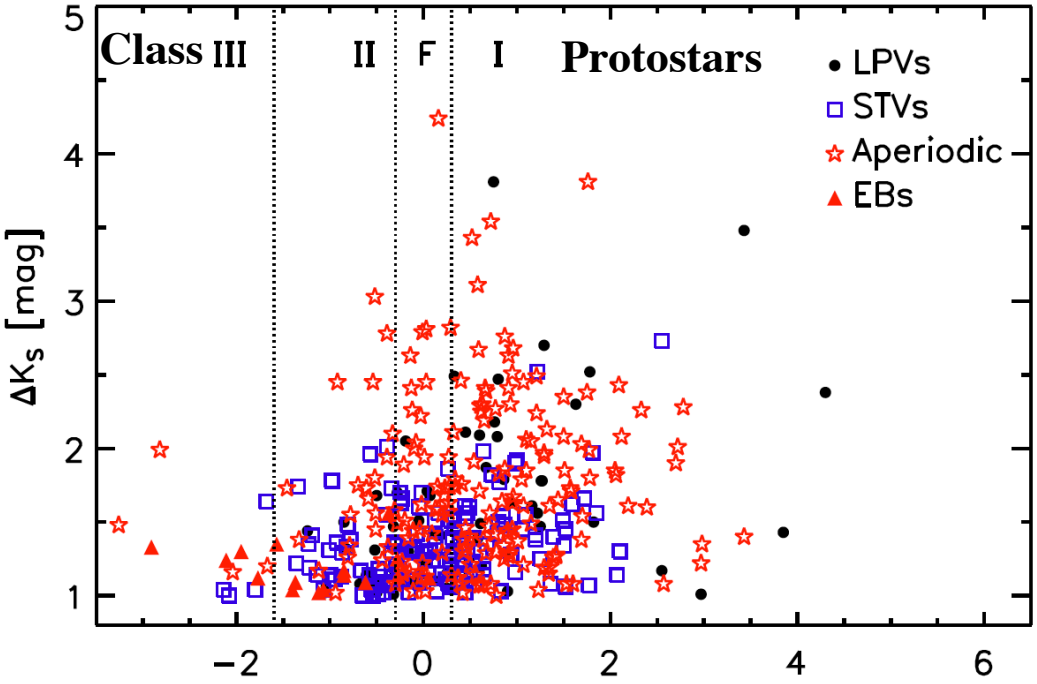
816 variables selected from VVV (2010 - 2012)

$\Delta Ks > 1$ mag, ~50% were YSOs

Large fraction of eruptive YSOs are protostars

P. Lucas: selected 105 high amplitude variables

Including: 27 eruptive YSOs ($\Delta Ks > 3$ mag)




Contreras Peña et al., 2017a

# Spectroscopic Follow ups

- Confirm eruptive YSOs
- Statistical view of variation mechanism, accretion modes and observational behaviours

2013/2014: **37** targets - spectroscopic classification (Contreras Peña et al., 2017b)

2015: **14** YSOs (from 2013/2014 list) repeated in 2 nights (Guo et al., 2020)

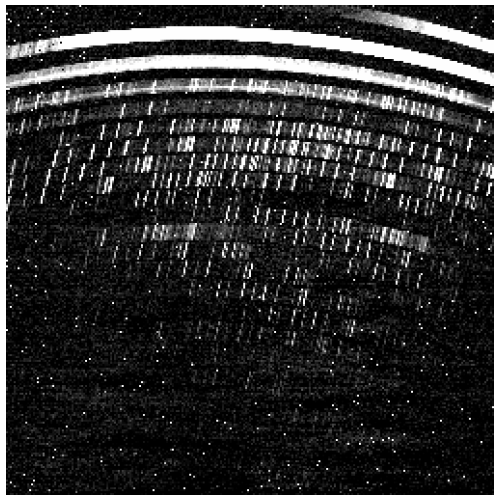
2017: **23** targets (including long-term periodic variables, outbursts & dippers)

2019: **15** high amplitude objects (VLT, $\Delta Ks > 3$ mag)

Guo et al., in prep

-> a gallery for eruptive YSOs

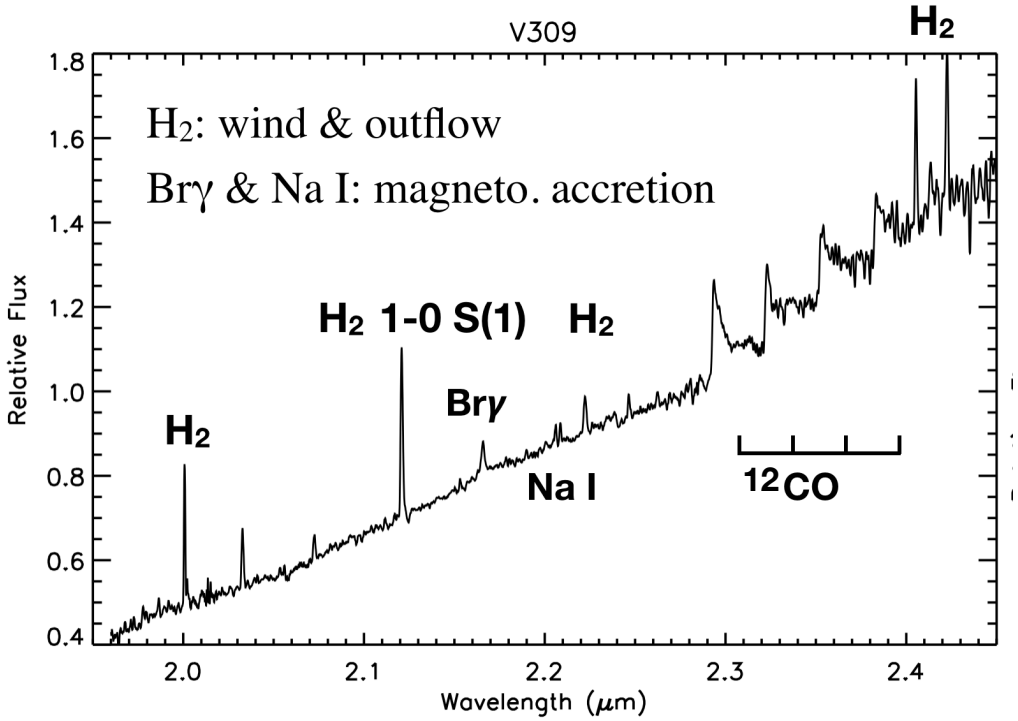
Magellan FIRE: R = 6000

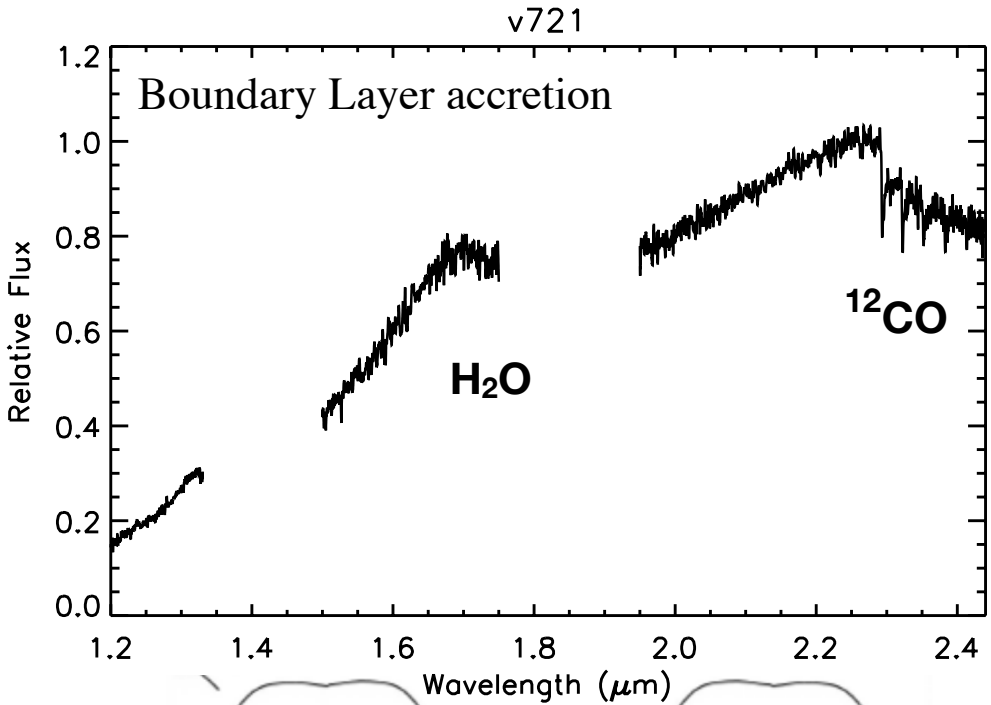


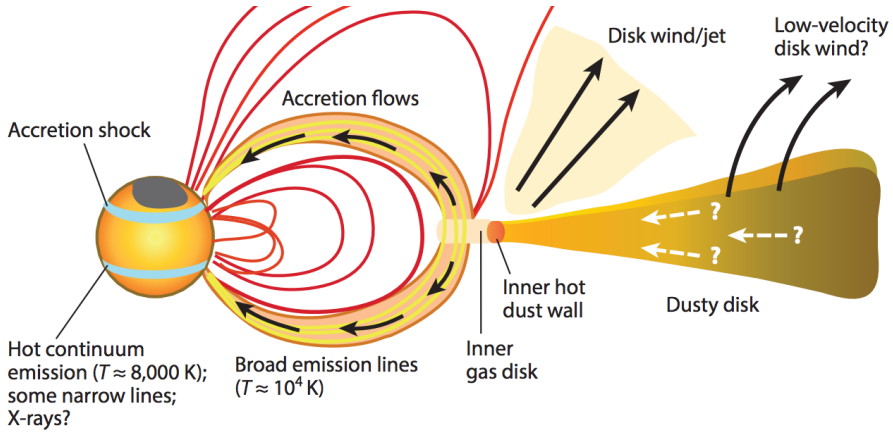

# Spectroscopic Follow ups

Total: 61 eruptive YSOs from VVV survey

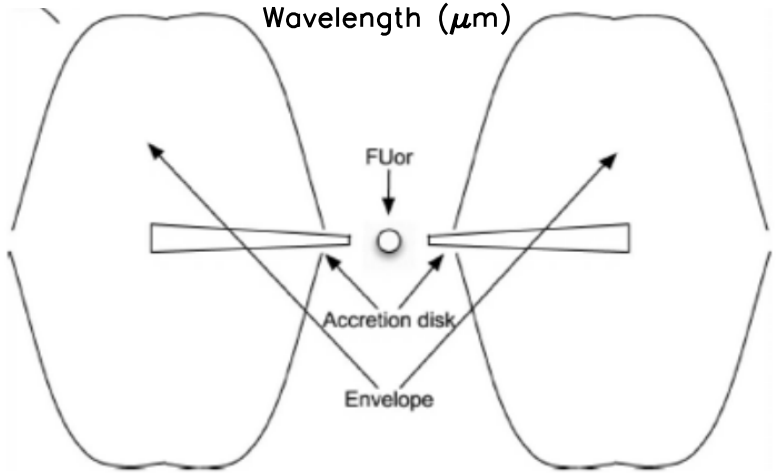
55 emission line objects (EXor-like) & 6 FUor-like YSOs



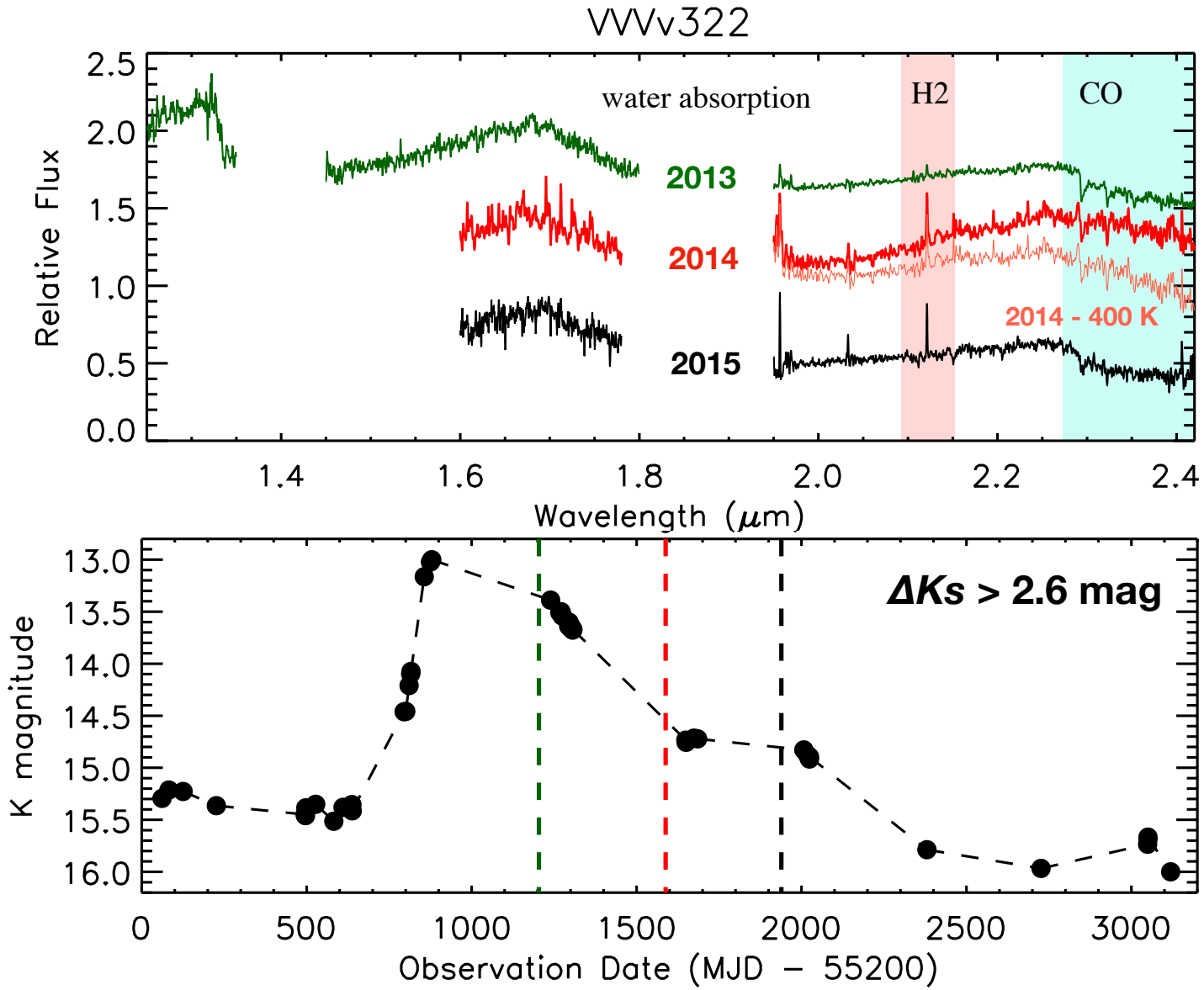

Hartmann, Herczeg, Calvet, ARAA, 2016




Quanz et al., 2007

# Results

Three years follow up of a FUor-like eruptive event



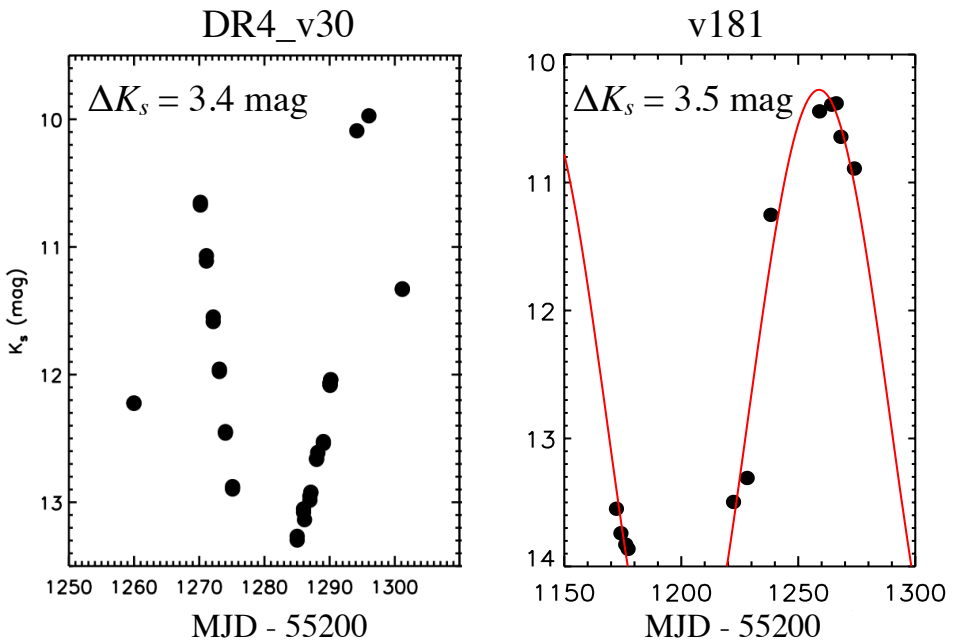

deeper CO absorption when the disc is brighter

Reconstruction of magnetospheric acc.?

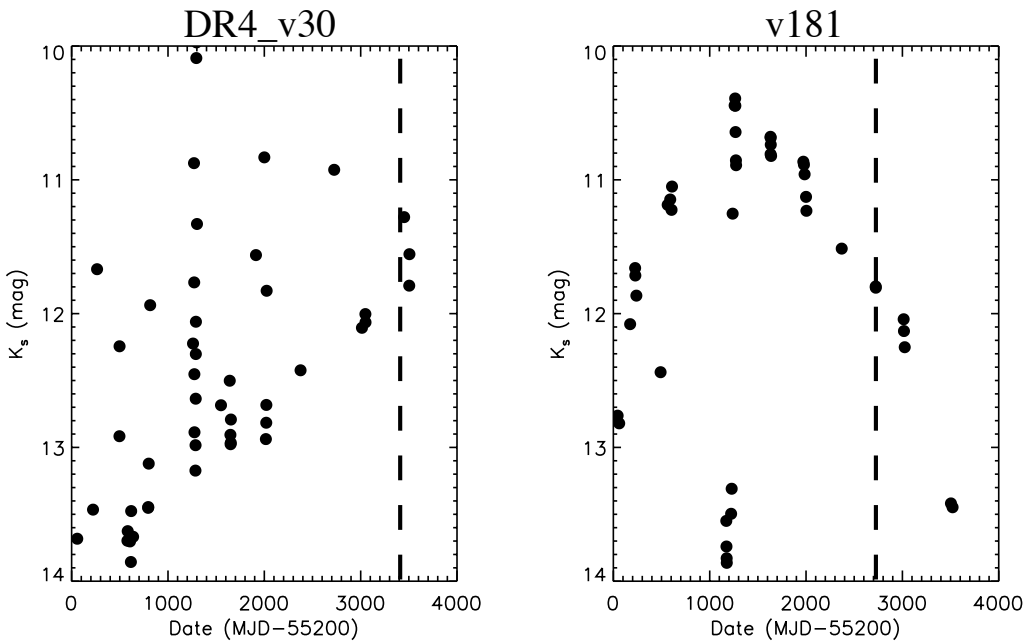
# Results

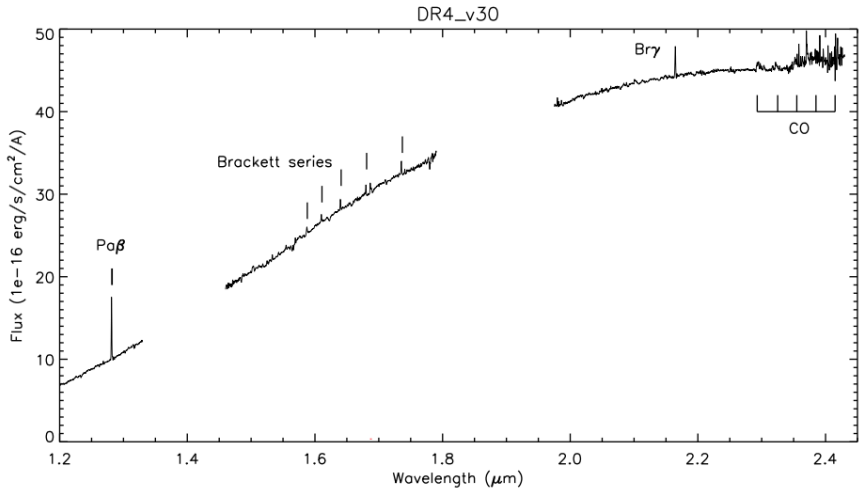
## Multiple timescale variables (short & long timescale variability)

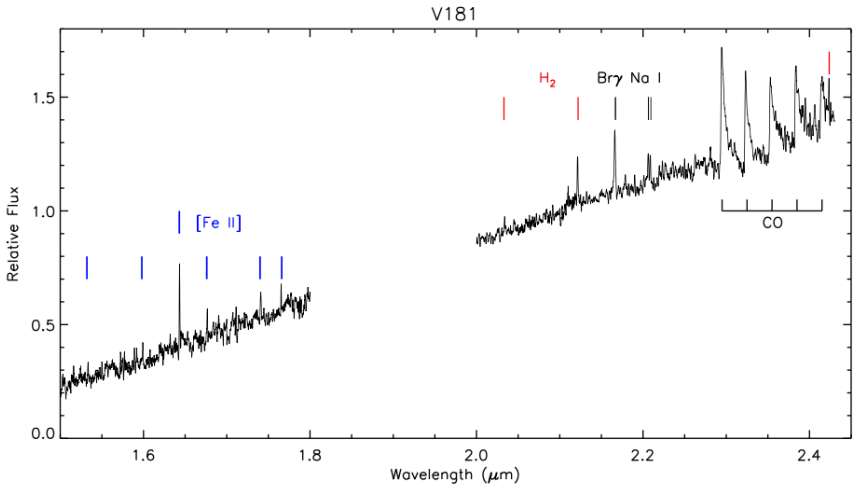
### short timescale: inner disc structure?




### long timescale: eruptive object?



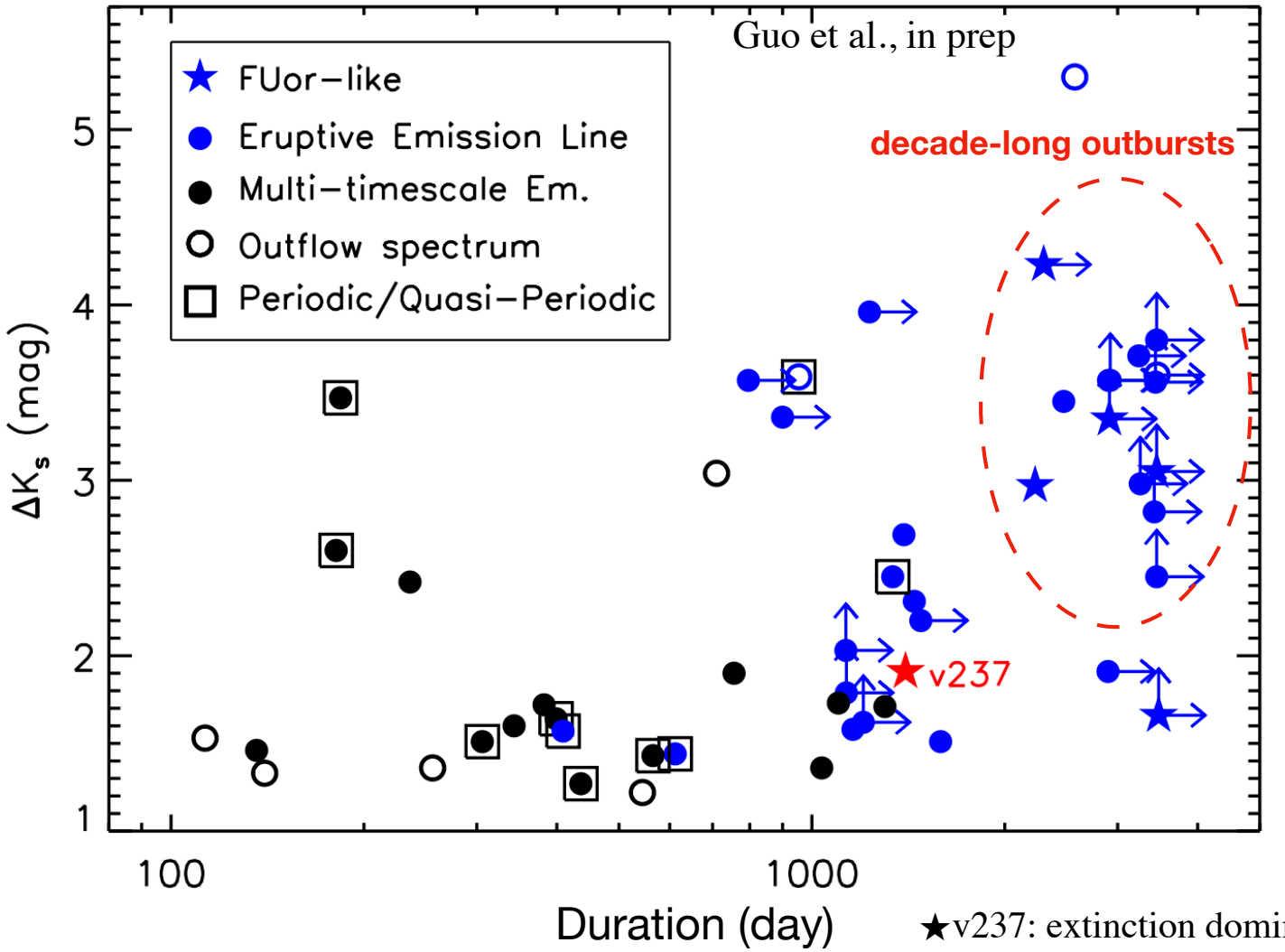



# Results

Outburst duration vs. *Ks*-band amplitude

- FUors have long duration
- Emission line objects have variation on all timescales



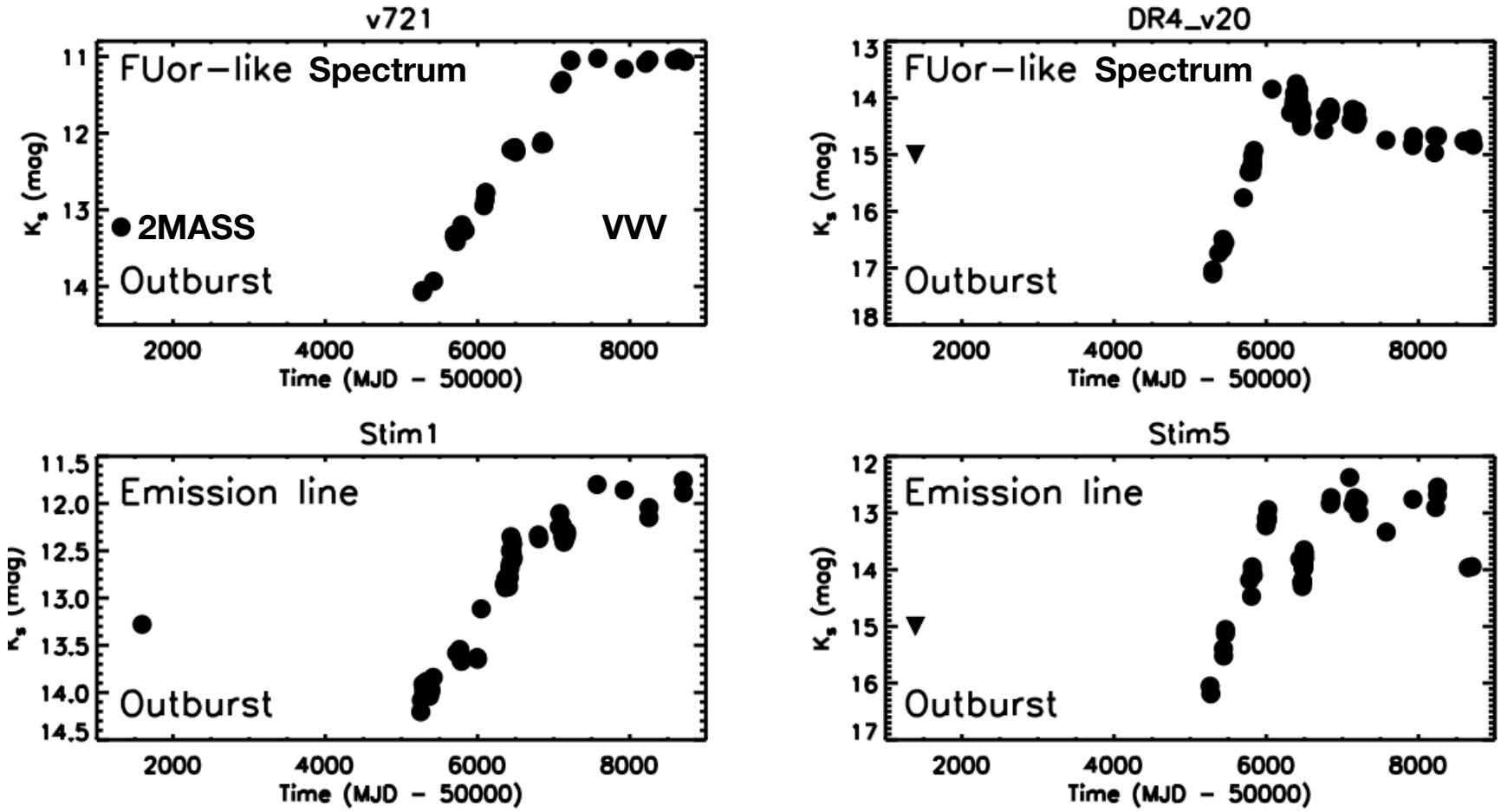

★v237: extinction dominated

# Results

Light curves are not telling the whole story

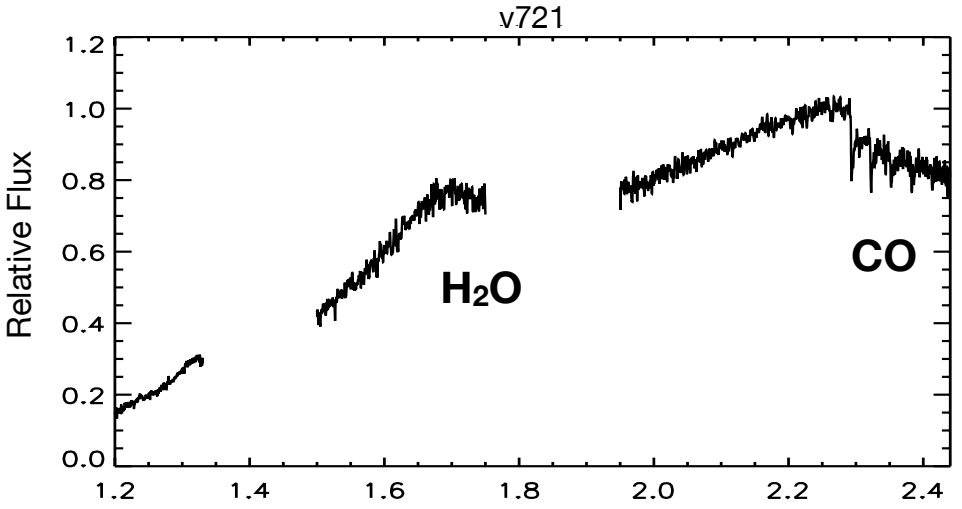
Slow rising > 2000 days $\Delta Ks > 3$ mag

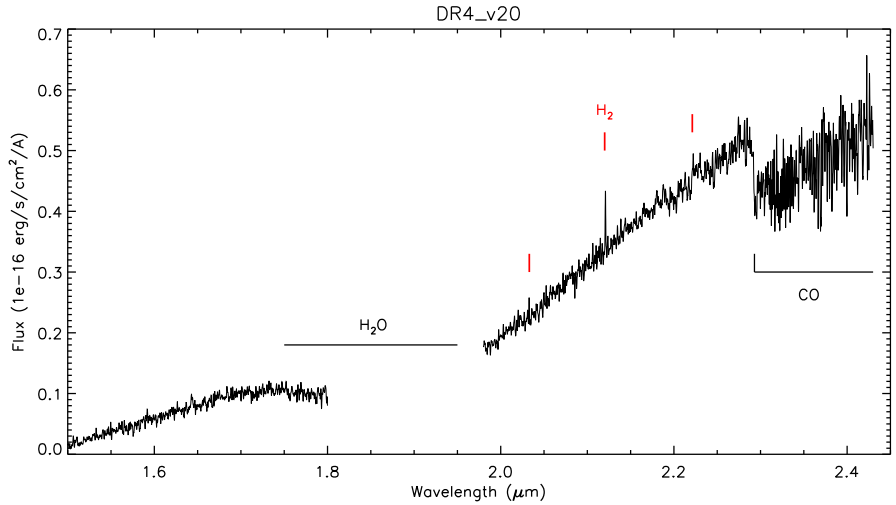
< 1000 days $\Delta Ks > 3$ mag

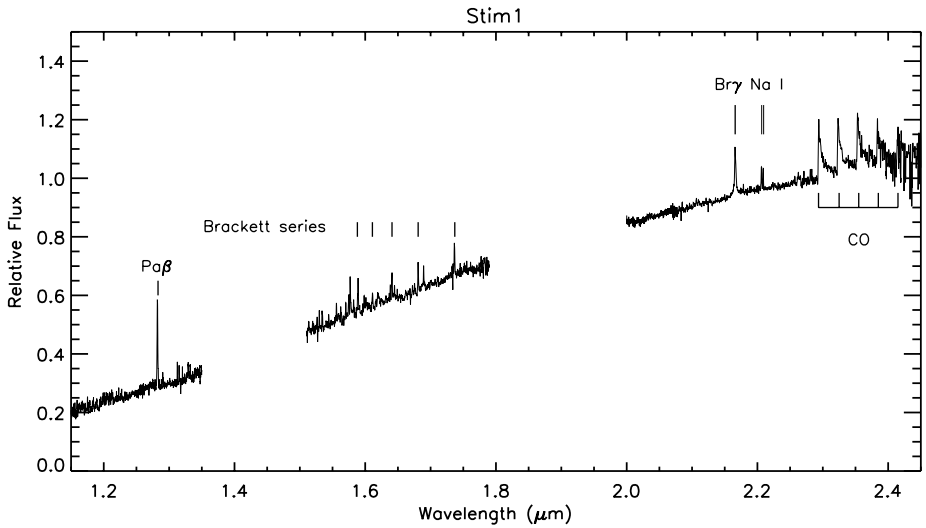


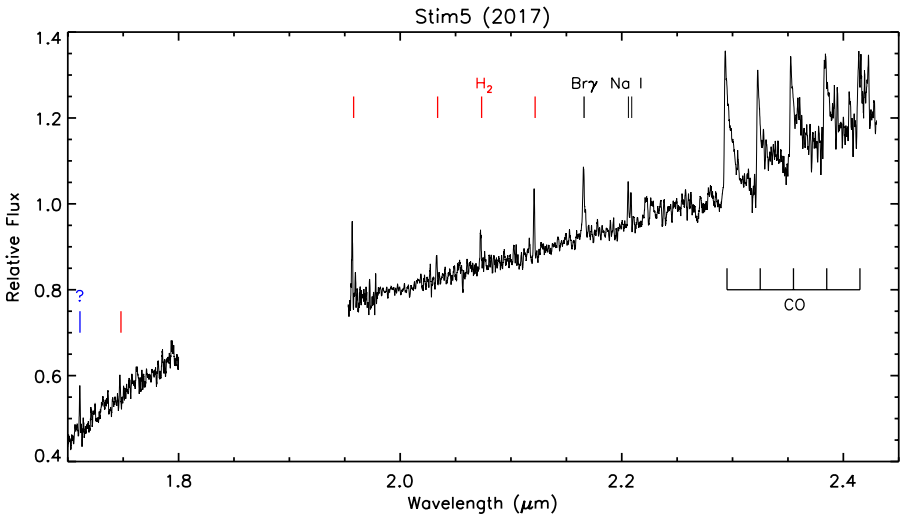
# Results

What is the real boundary between two accretion scenarios?



# Periodic objects

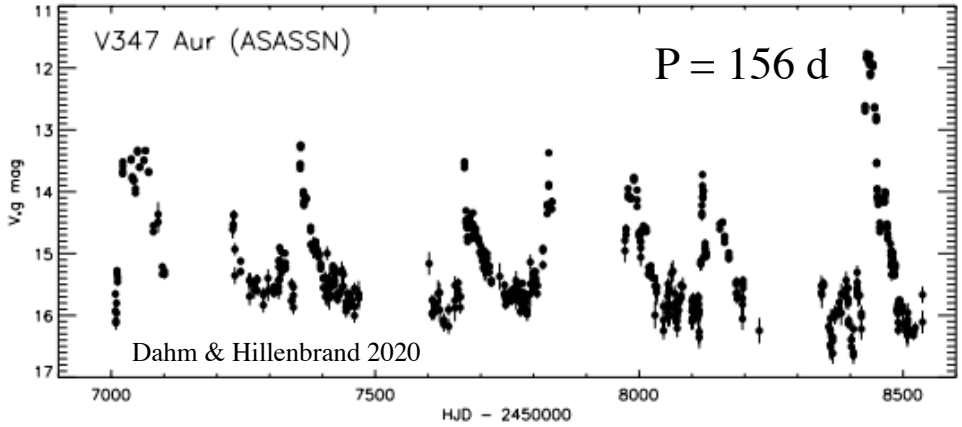
Period on YSOs:

Stellar rotation (spots/funnel flow)

Disc rotation (periodic extinction)

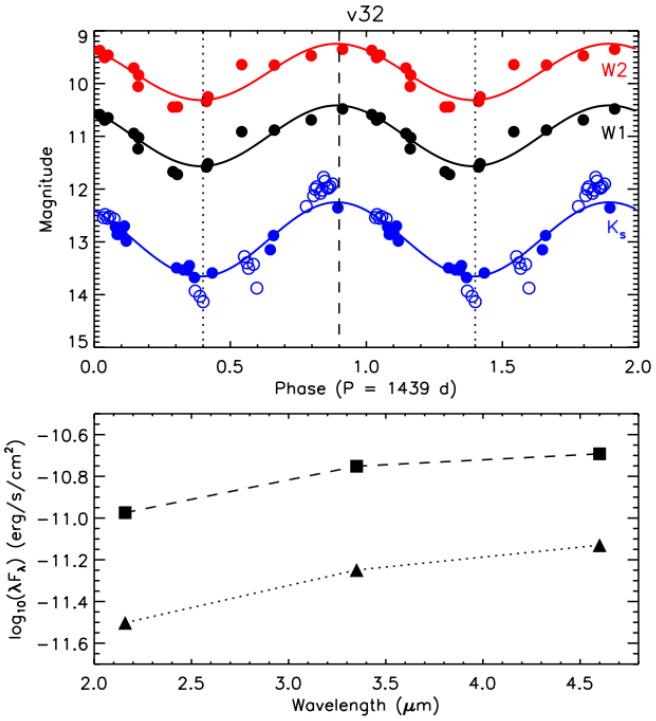
Periodic accretion burst (V347 Aur, EC 53)

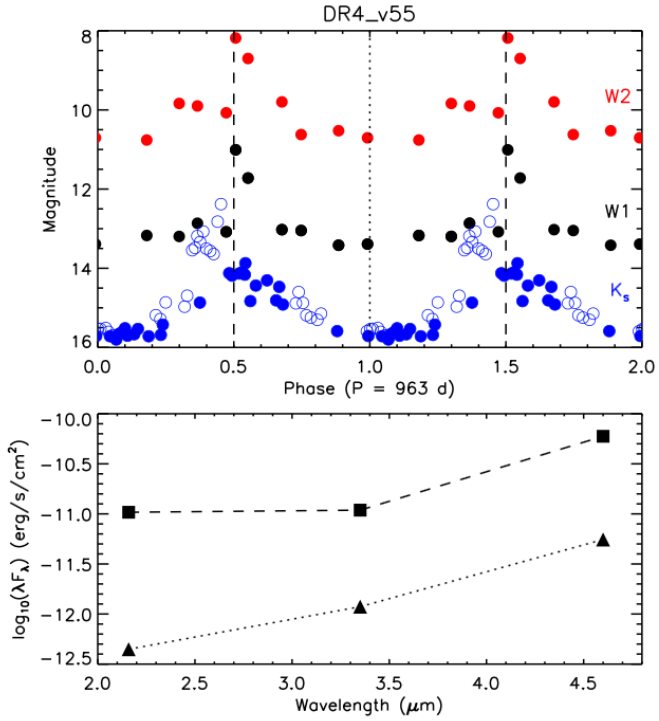
- Companion modulation?
- Magnetic gate? (D'Angelo & Spruit 2010, 2012)

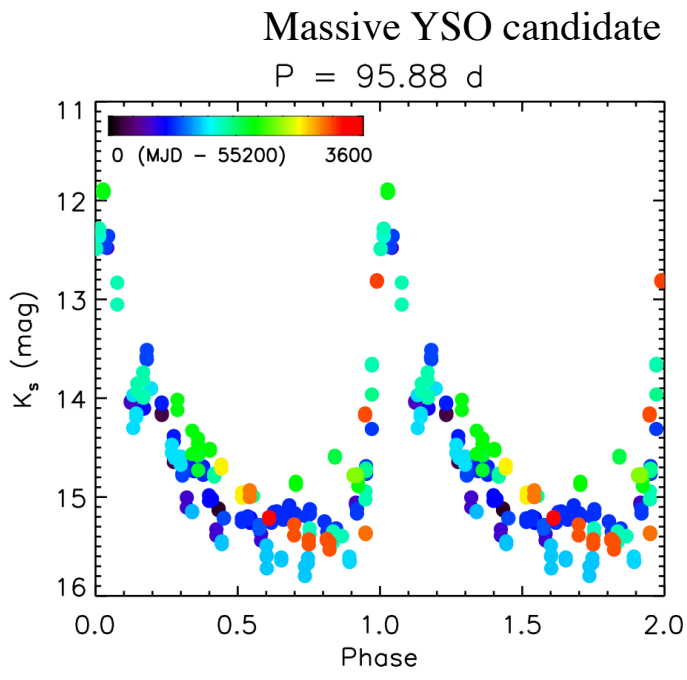



4 periodic and 12 quasi-periodic variables in our follow up studies

10-15% variable YSOs in the VVV



# Summary

Decade-long NIR survey is suitable to find eruptive protostars

Spectroscopic follow ups of VVV eruptive

-> FUors: deeper absorption when the star is brighter

-> FUors are rare and only have long timescales

-> Emission line objects are more common on all timescales

-> What is the boundary between accretion modes?

Periodic accretion bursts

-> not so rare (10% YSOs)

-> theoretical models?