Characterization of high-accretion outbursts in planet-forming YSOs

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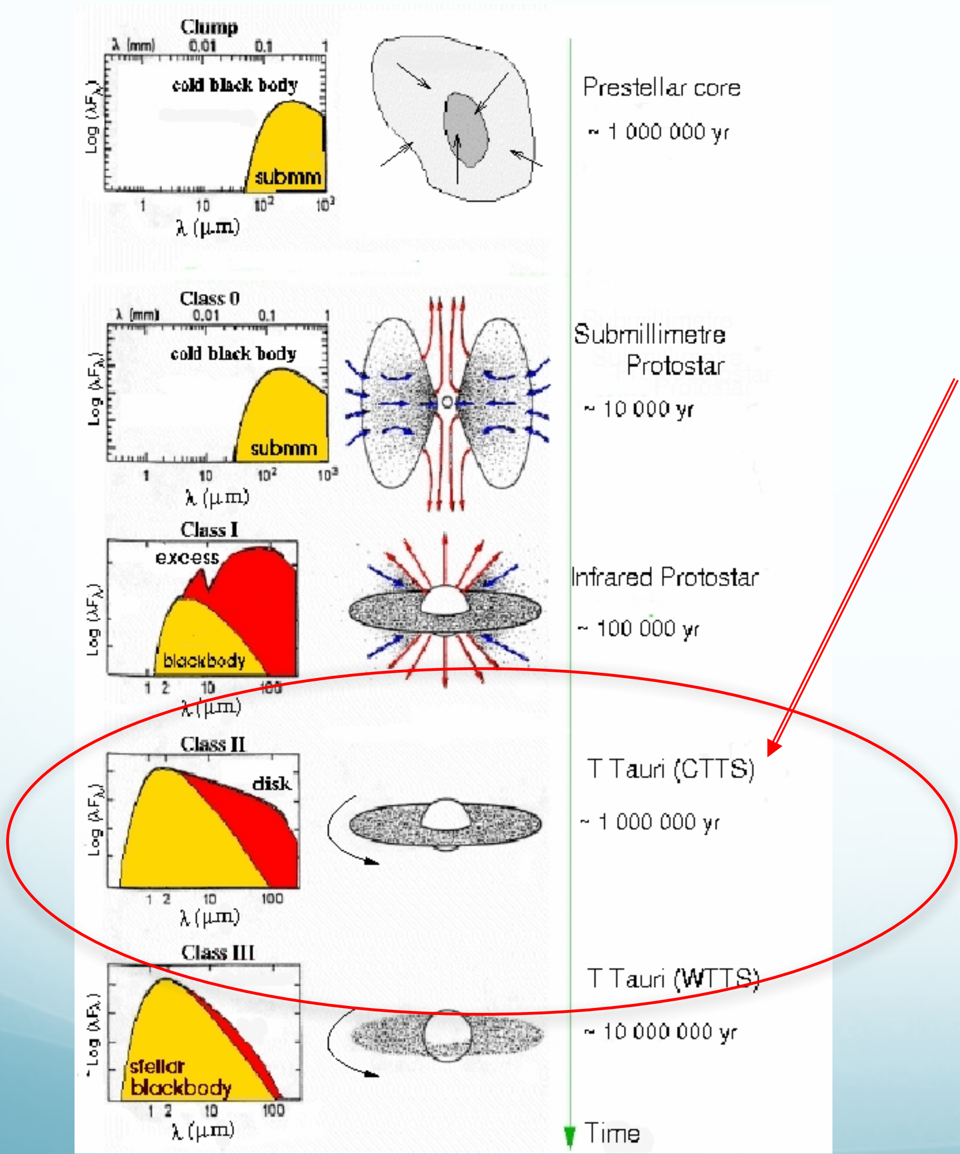
YSO evolution and Planet formation



- Planets form in protoplanetary discs.
- Crucial period for planet formation
  - 1 Myr: First planetesimals formed (Pfalzner 2015)
  - 10 Myr: protoplanetary discs around most stars have dissipated (Bell 2013)

Planet Formation

- The properties of the disc, such as surface density or temperature, play a key role in the formation and evolution of protoplanets.
  - These properties enter into migration rates or determine the location of the snowline, the latter having an impact on the surface density of solids (Cieza et al. 2017, Mordasini 2018).

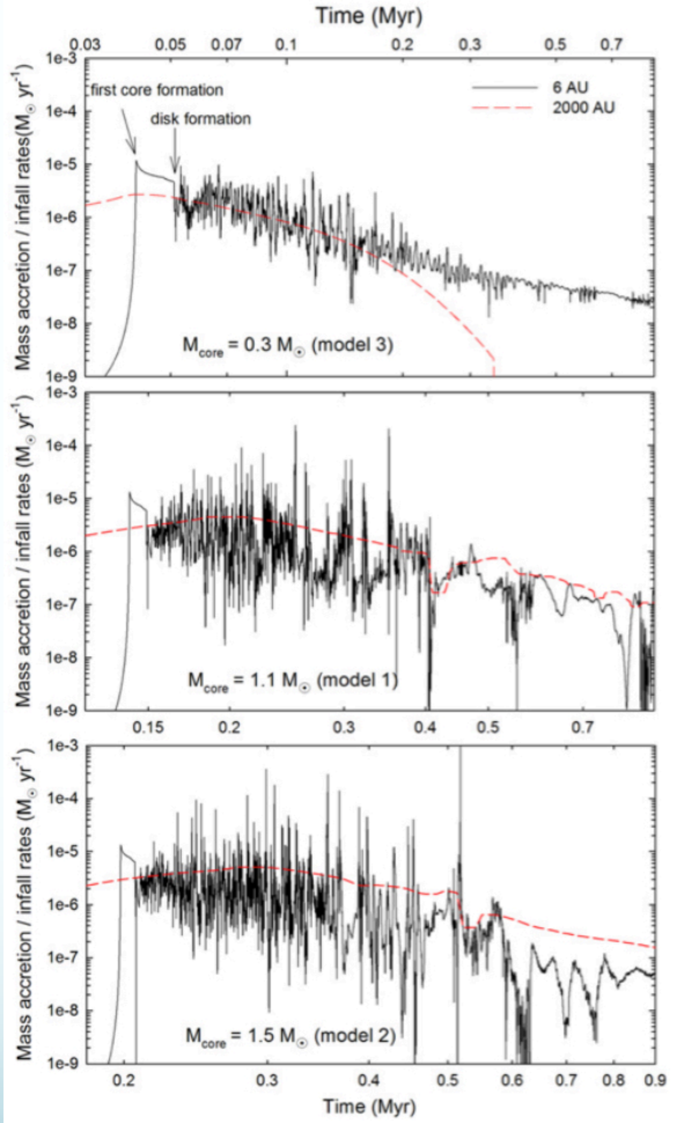
↓

- Depend on the accretion rate from the disc onto the central star.
  - Generally assumed to decrease steadily with time and some models include a dependence with the mass of the central star (Kennedy et al. 2008, Mulders et al. 2015).

Planet Formation

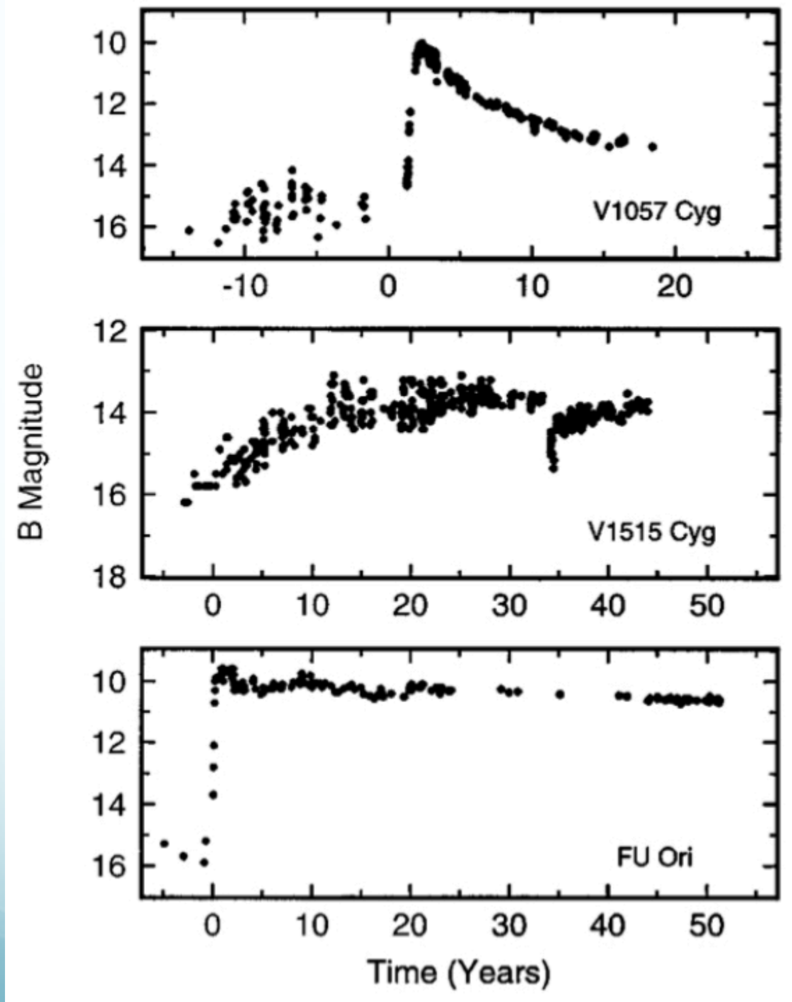
But,

- Accretion onto the central star is unlikely to be a steady process (see e.g. Vorobyov et al. 2015)



Planet Formation

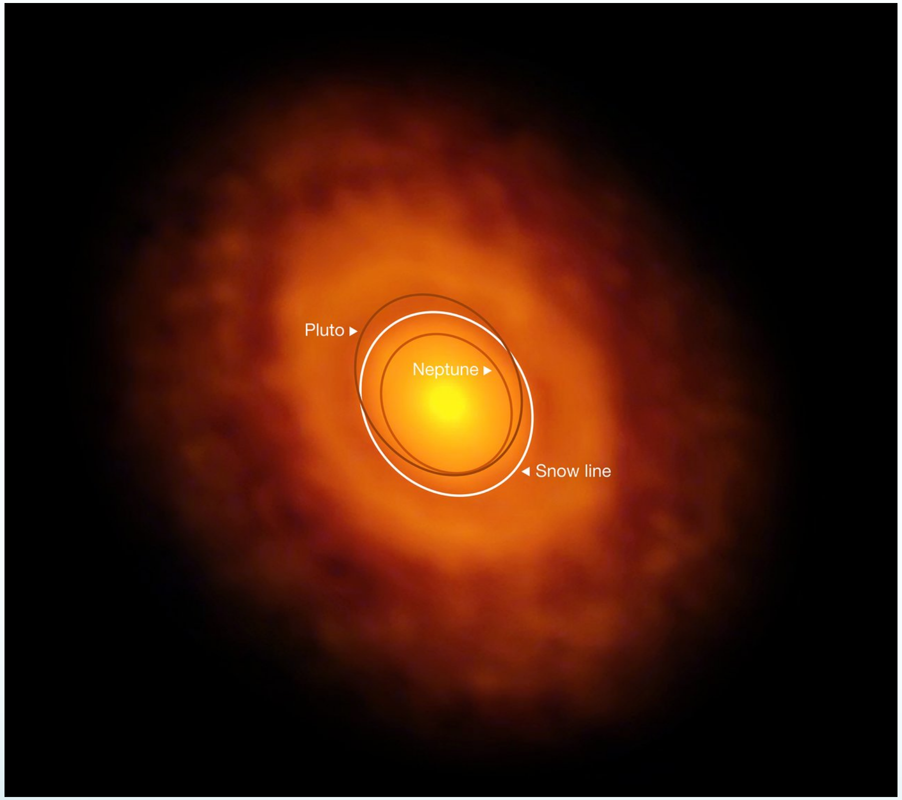
But,



- YSOs are known to go through sudden episodes of enhanced accretion that can last 100 years (e.g. Hartmann & Kenyon 1996, Audard et al. 2014; Contreras Peña et al. 2017).
- Approx. 14 long-lasting outbursts have been recorded in the past 70 years (Hillenbrand et al. 2018) .

Planet Formation

But,

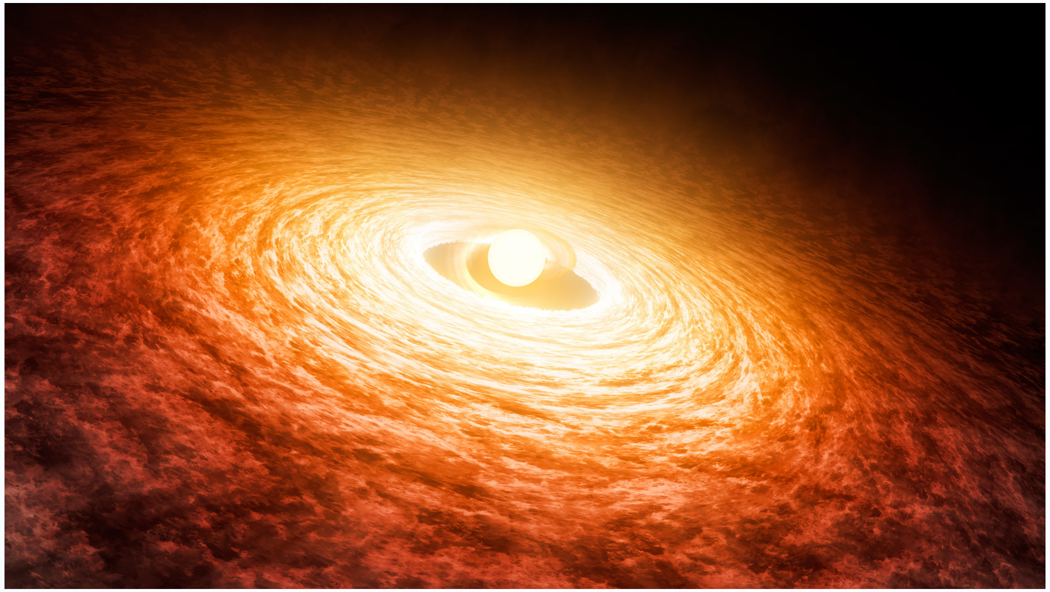


ALMA (ESO/NAOJ/NRAO)/L. Cieza

- Large accretion events allow the in-situ formation of rocky planets even at distances ~1 AU, and will lead to planetary system architectures similar to our own (Hubbard 2017).
- Variable snowlines (V883 Ori, Cieza et al. 2017)

Outbursts

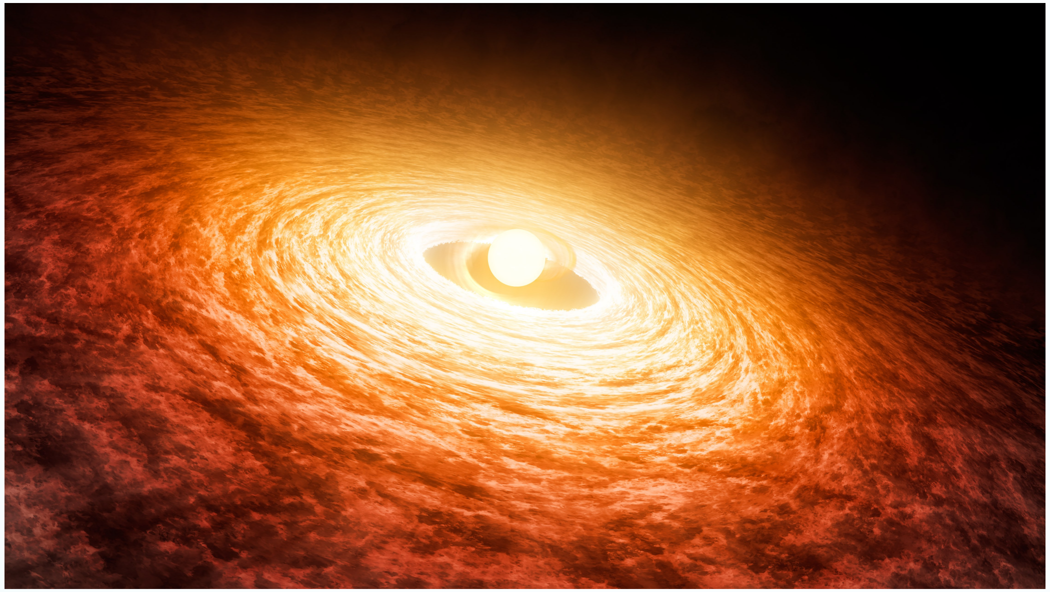
Artist's conception of FU Orionis NASA/JPL



- It is not clear whether all stars go through episodes of enhanced accretion during their evolution (see e.g. Hartmann & Kenyon 1996).
- The frequency and amplitude of the outbursts is not well constrained.
  - Scholz et al. 2013 compared WISE vs Spitzer photometry and determine an outburst rate between 5-100 kyr.
- There is controversy as to whether the very largest outbursts are associated with the Class II planet building phase at all, or are just limited to the pre-planet-forming (Class 0/I) phase (c.f. Sandell & Weintraub 2001, with Miller et al. 2011).

Outbursts

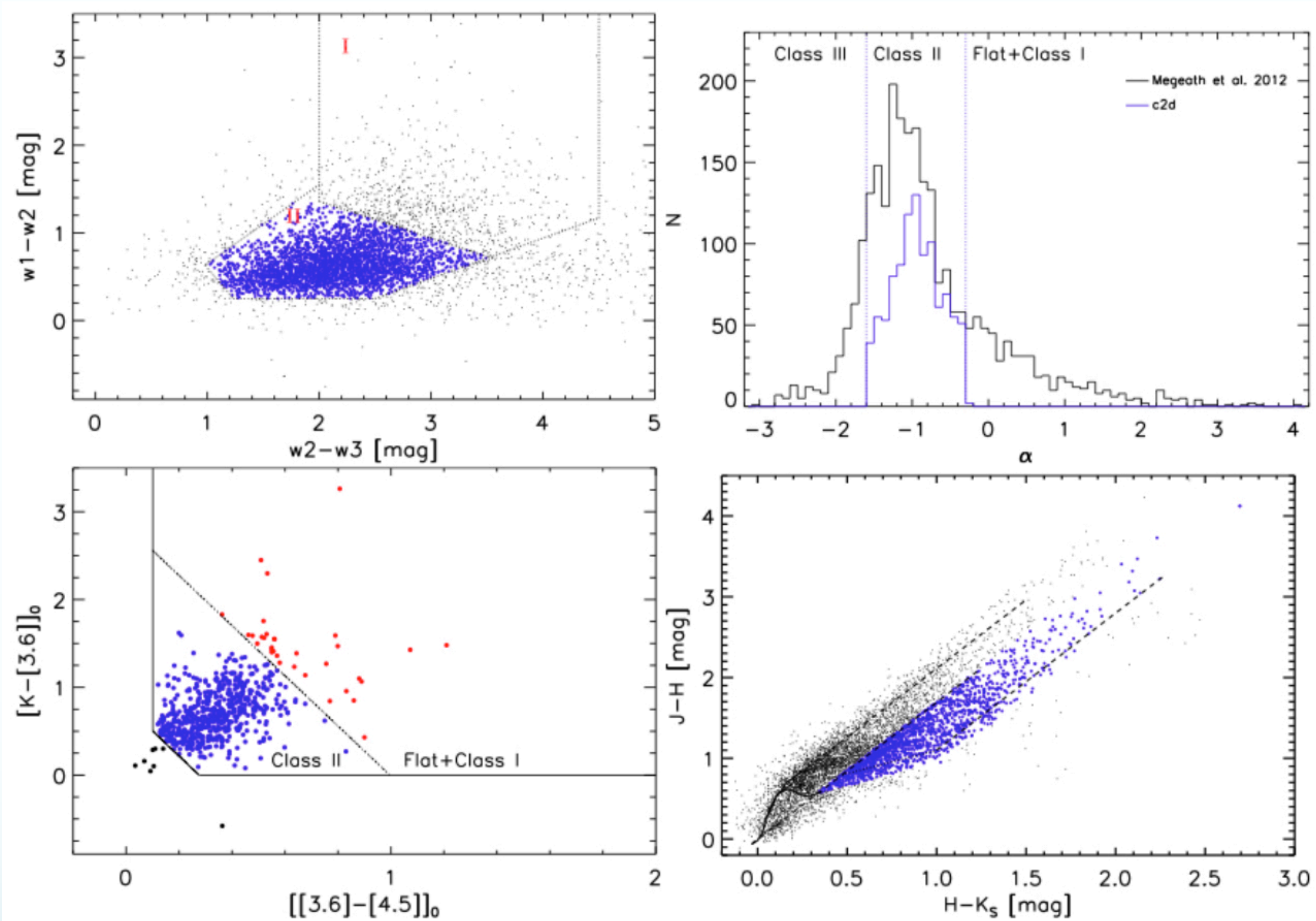
Artist's conception of FU Orionis NASA/JPL



To determine the outburst rate, we need to maximise both the time baseline and the number of YSOs surveyed (see e.g. Hillenbrand & Findeisen 2015).

See Contreras Peña, Naylor & Morrell, 2019, arXiv:1904.04068 (Accepted for publication in MNRAS)

Sample

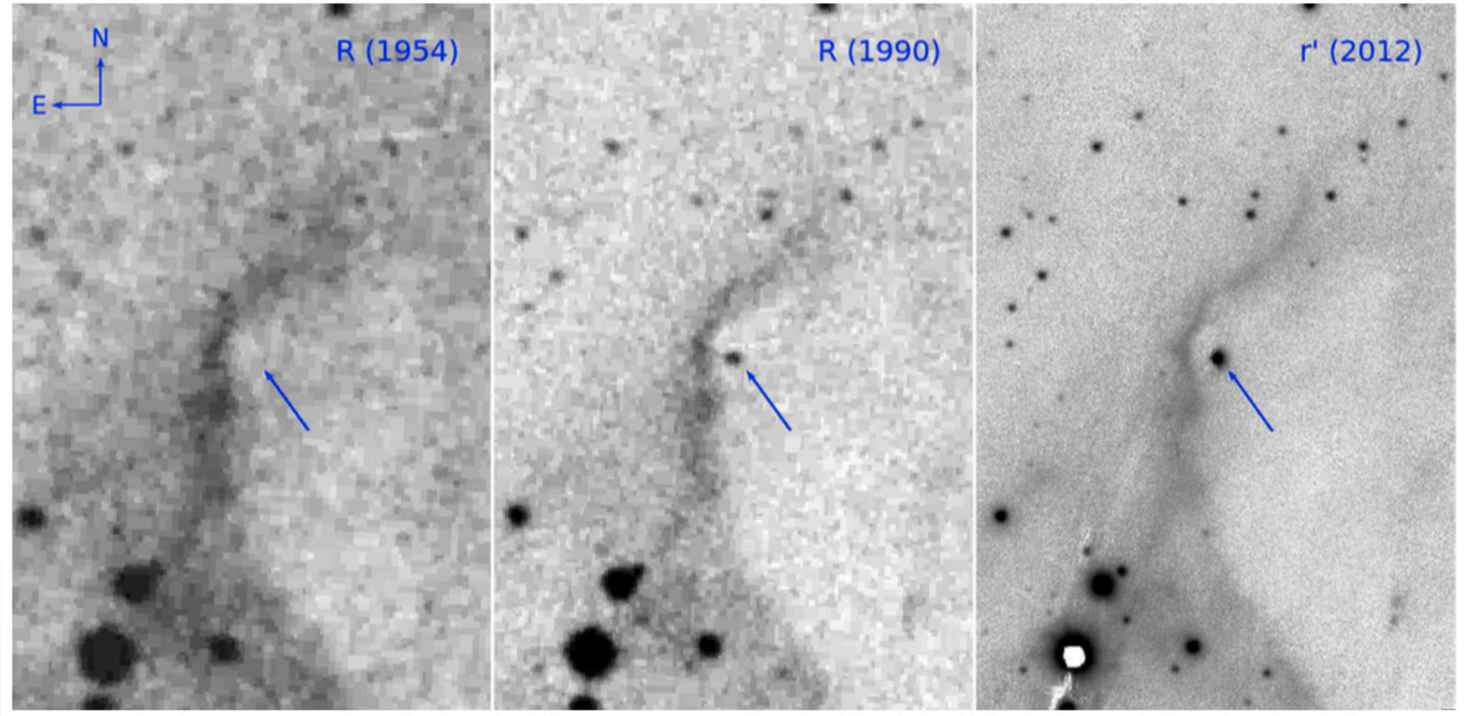


- We have constructed a sample of 15400 class II YSOs from SIMBAD (pMS, TTau, FUor, etc).

Time Baseline

- Comparison of Gaia DR2 magnitudes with those obtained from digitised photographic plates (B, R and I) by SuperCOSMOS (SSS, Hambly 2001) provided a mean baseline of 55.6 yrs.

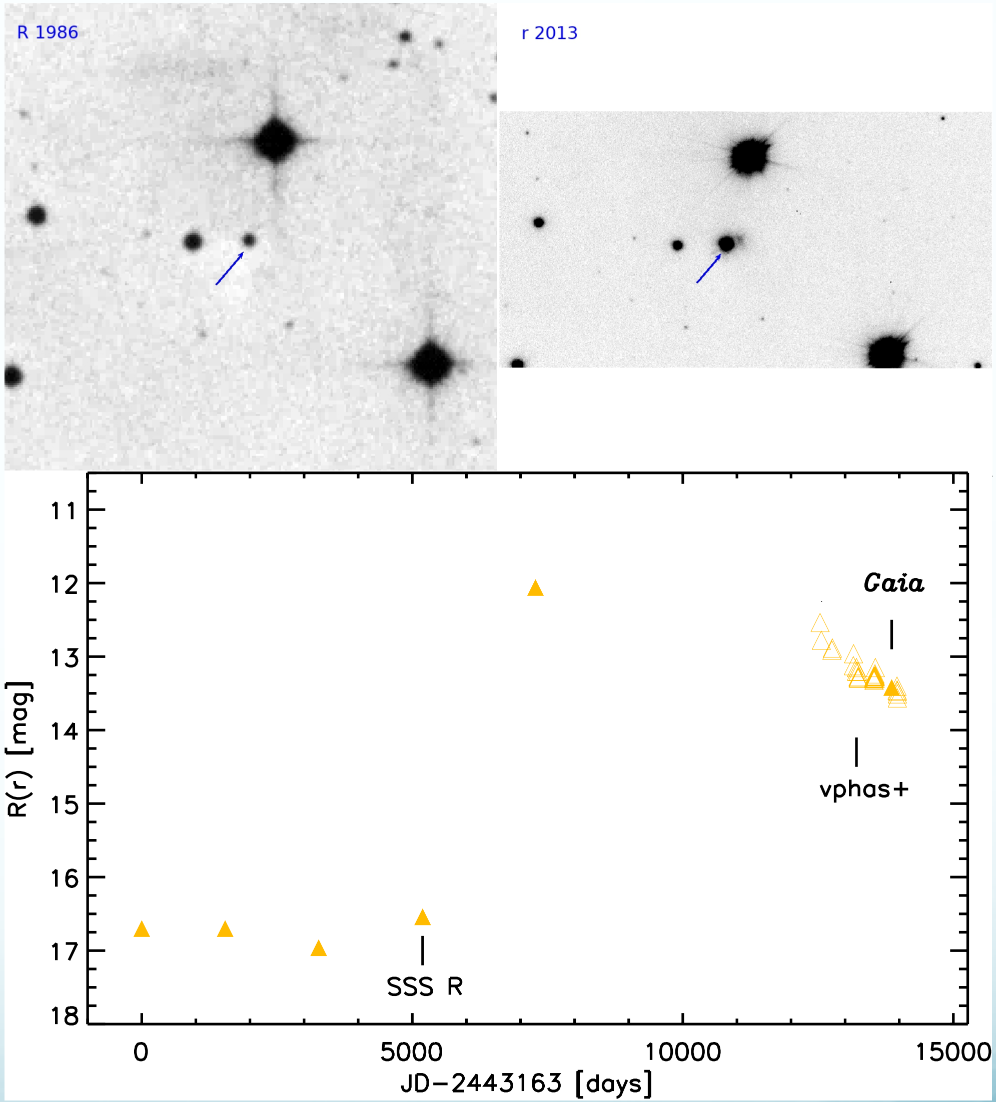
V2492 Cyg



SuperCOSMOS POSS-I E (1954) and POSS-II R (1990) R plate images, and Pan-STARRS r′ (2012)

Outbursts

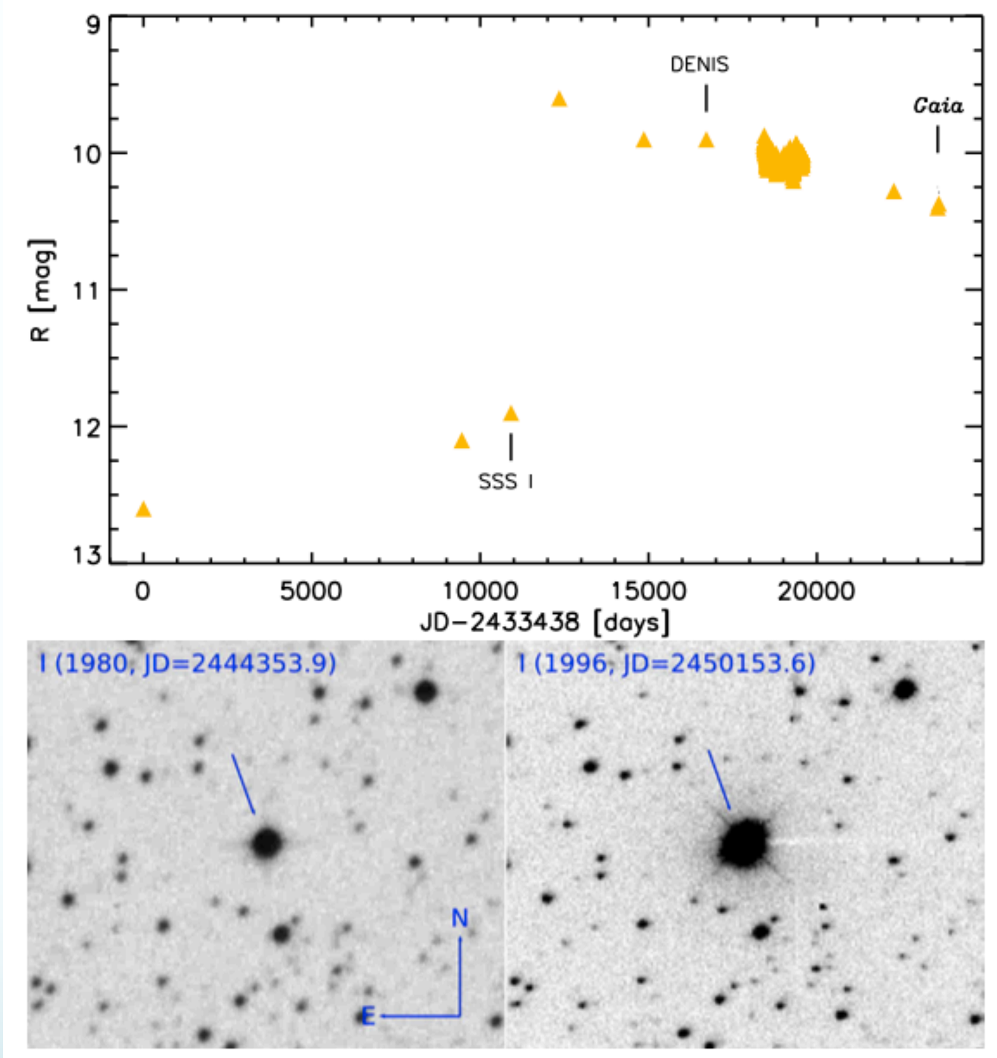
- We classify 6 objects as long-lasting class II outbursts (3 known, 3 new).



V9 (2MASS J08410676-4052174)

Inter-outburst interval

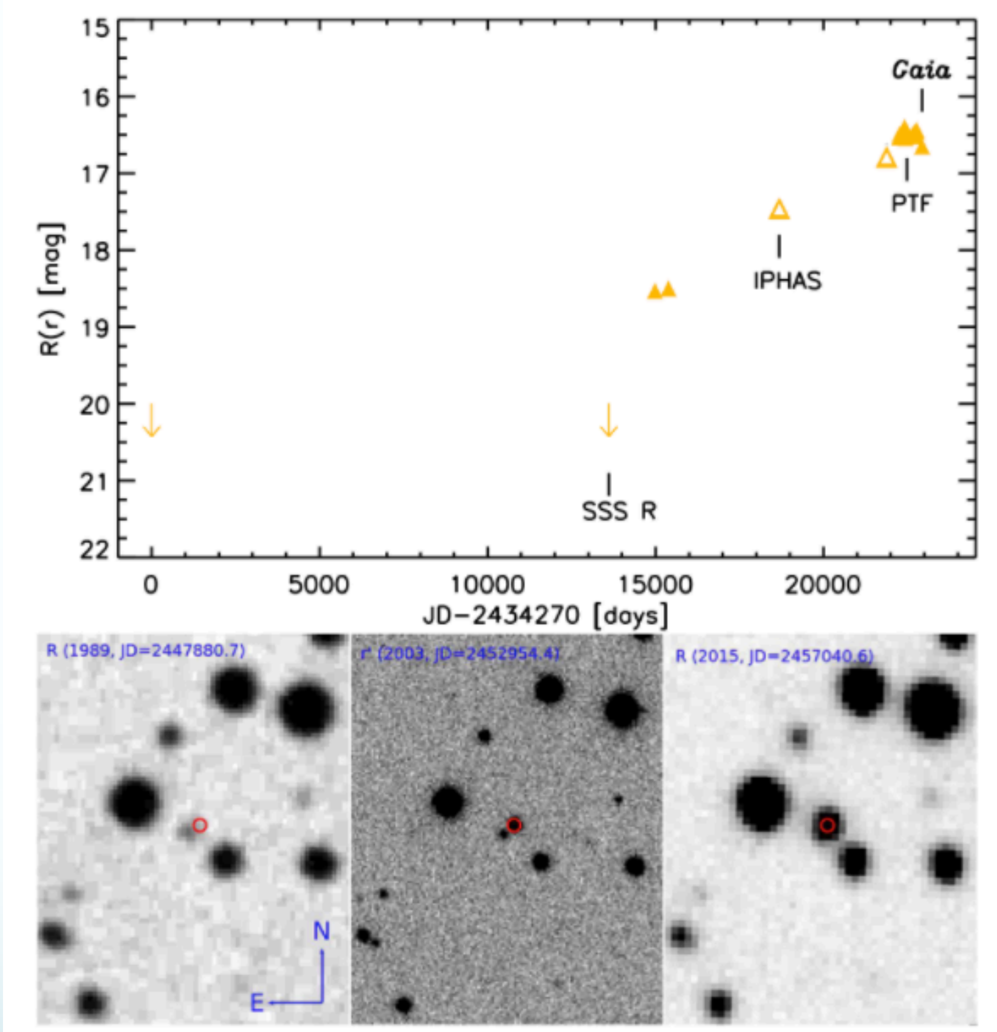
- We determine, for the first time, that class II YSOs do in fact undergo large and long-lasting accretion events, with 74 to 180 kyr inter-outburst intervals.
- From the re-analysis of the Scholz et al. 2013 WISE vs Spitzer variability sample we estimate an inter-outburst interval of 3-30 kyr for the class I stage.



V51 (Wray 15-488)

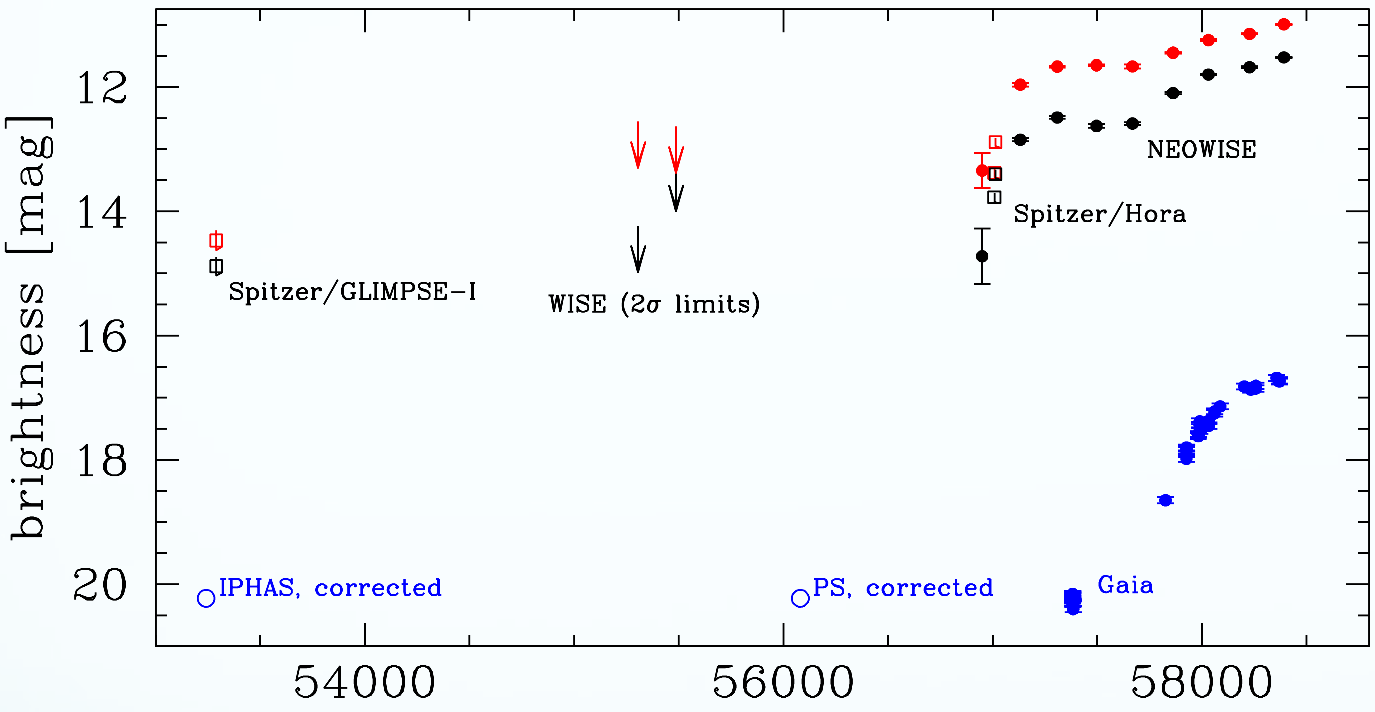
Mechanism

- Reservations - this is an average, perhaps over many mechanisms.
- Gravitational instabilities e.g. Vorobyov & Basu (2015), ApJ 805, 115, produce Class I but probably not Class II interval.
- Planet "daming" – maybe 10^4 years; Lodato & Clarke (2004), MNRAS, 353, 841.
- Combined MRI/GI instabilities – maybe, e.g. Bae et al (2013), ApJ 764, 141.



V4 (2MASS J02335340+6156501)

LSST

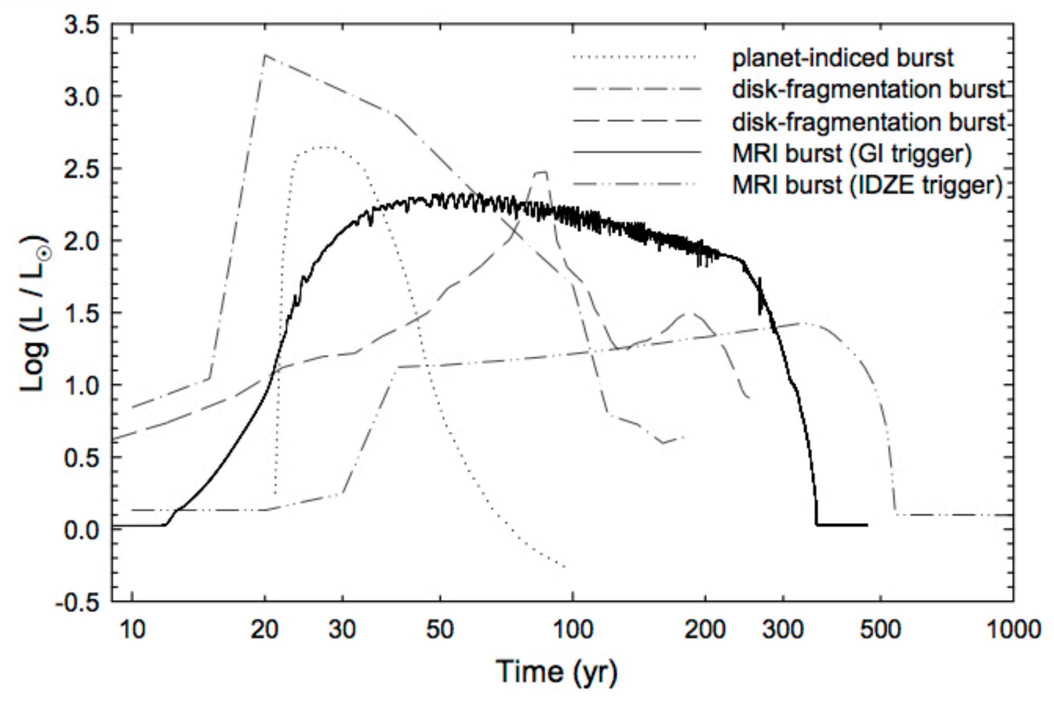


Gaia17bpi (see Hillenbrand , Contreras Peña, et al. 2018, ApJ, 869, 146)

- LSST single exposure depth *r*=24.5, corresponds to *G*=25. Maybe 32x bigger sample?
- This would imply 4 class II YSO outbursts per year (as well as ~10 class I outbursts per year).
- 1 year of LSST observations would provide the current number of YSO outbursts.

LSST

- LSST will provide a unique opportunity to characterize YSO outbursts.
  - Ideal experiment requires high-cadence observations in 2 filters.



Audard et al. 2014,
Protostars & Planets VI

Rise times are slower for inside-out outbursts (Hartmann & Kenyon et al. 1996).

Decay times can constrain the viscosity parameter α (Cannizzo & Mattei 1998, Cannizzo, Chen & Livio 1995).

Thank you!