



HOYS-CAPS

CITIZEN SCIENCE

Hunting Outbursting Young Stars with the Centre for Astrophysics and Planetary Science

Dirk Froebrich
Jack Evitts

Alexander Scholz

And numerous other (Amateur) Astronomers

University of
Kent

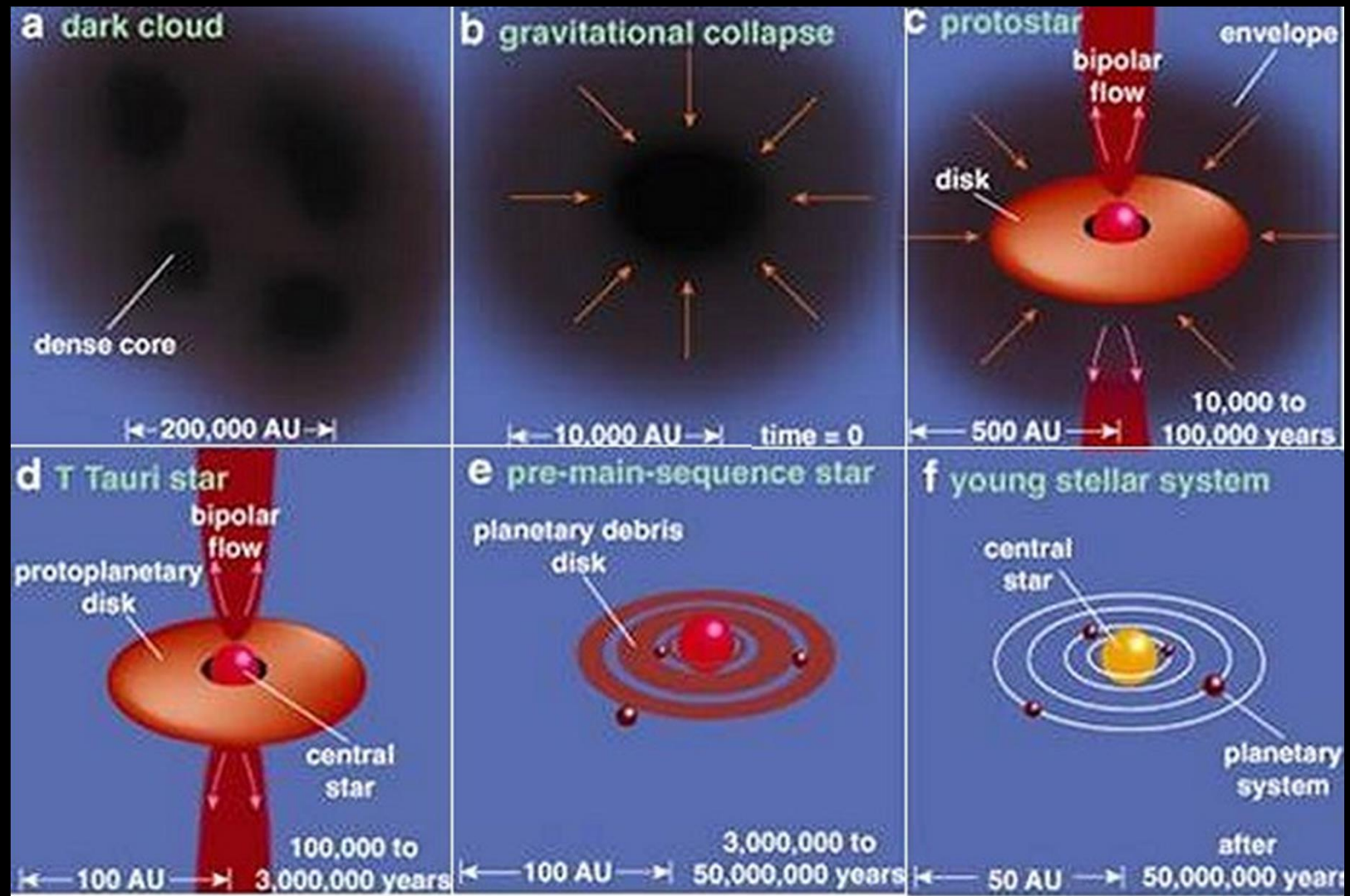
 University of
St Andrews



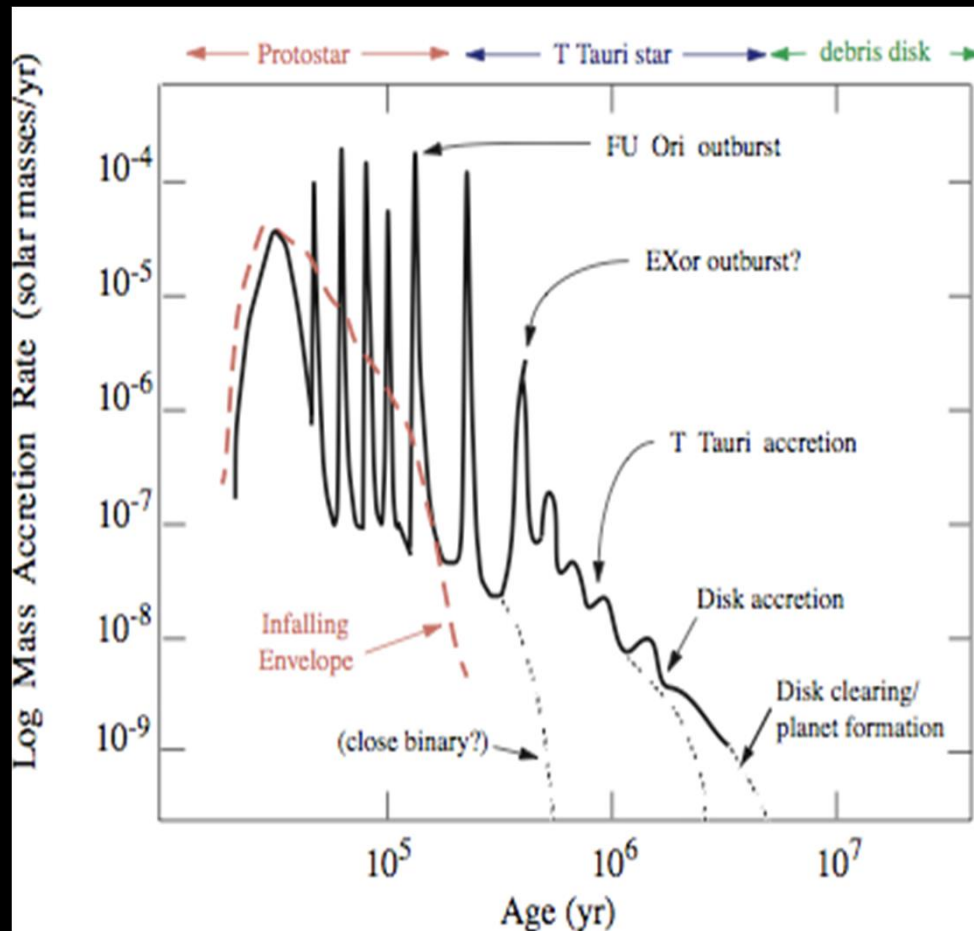
CENTRE FOR ASTROPHYSICS AND
PLANETARY SCIENCE (CAPS)


HOYS-CAPS
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Making Stars and Planets



Young Star Accretion Disk Structure and Accretion Bursts



PROTOPLANETARY DISKS

HD 163296

HL TAURI

HD 169142

RH J1615

HD 135344B

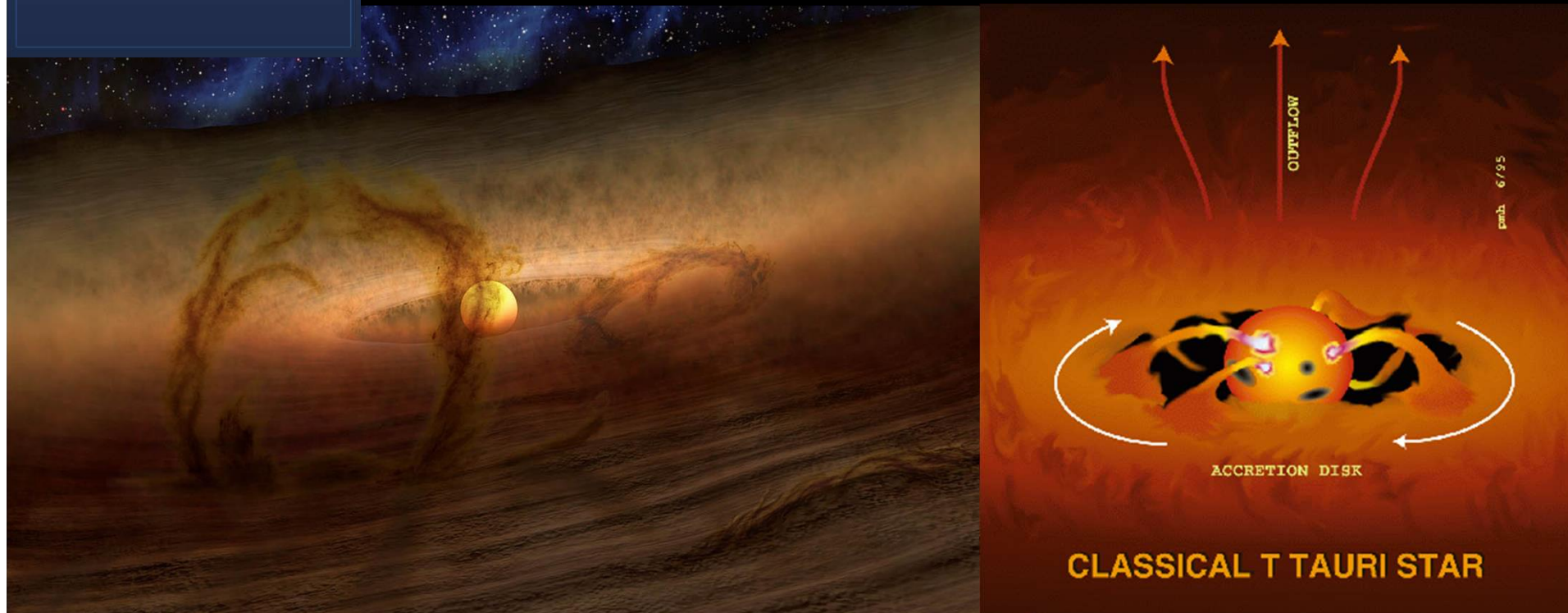
AS 209

TW HYDRAE

ELIAS 2-27

Specimens exhibiting rings, gaps, & spirals

Young Star Accretion Disk Structure and Accretion Bursts



Photometric monitoring of Young Stars can achieve resolution of disk structures down to 0.01AU independent of distance

As well as rotation periods and temperature, size and position of hot/cold spots on YSO surfaces



HOYS-CAPS Goals



Photometric Monitoring

long-term (~25yr)

high-cadence (1...2 observations per day per filter)

multi-wavelength (U, B, V, R, H α , I)

photometric monitoring

of

young (<10Myr)

nearby (d<1kpc)

star clusters and star forming regions (currently 22 regions)

with small or intermediate size telescopes

HOYS-CAPS Targets (selection)

Pelican Nebula

IC348

Christmas Tree Cluster

Elephant Trunk Nebula

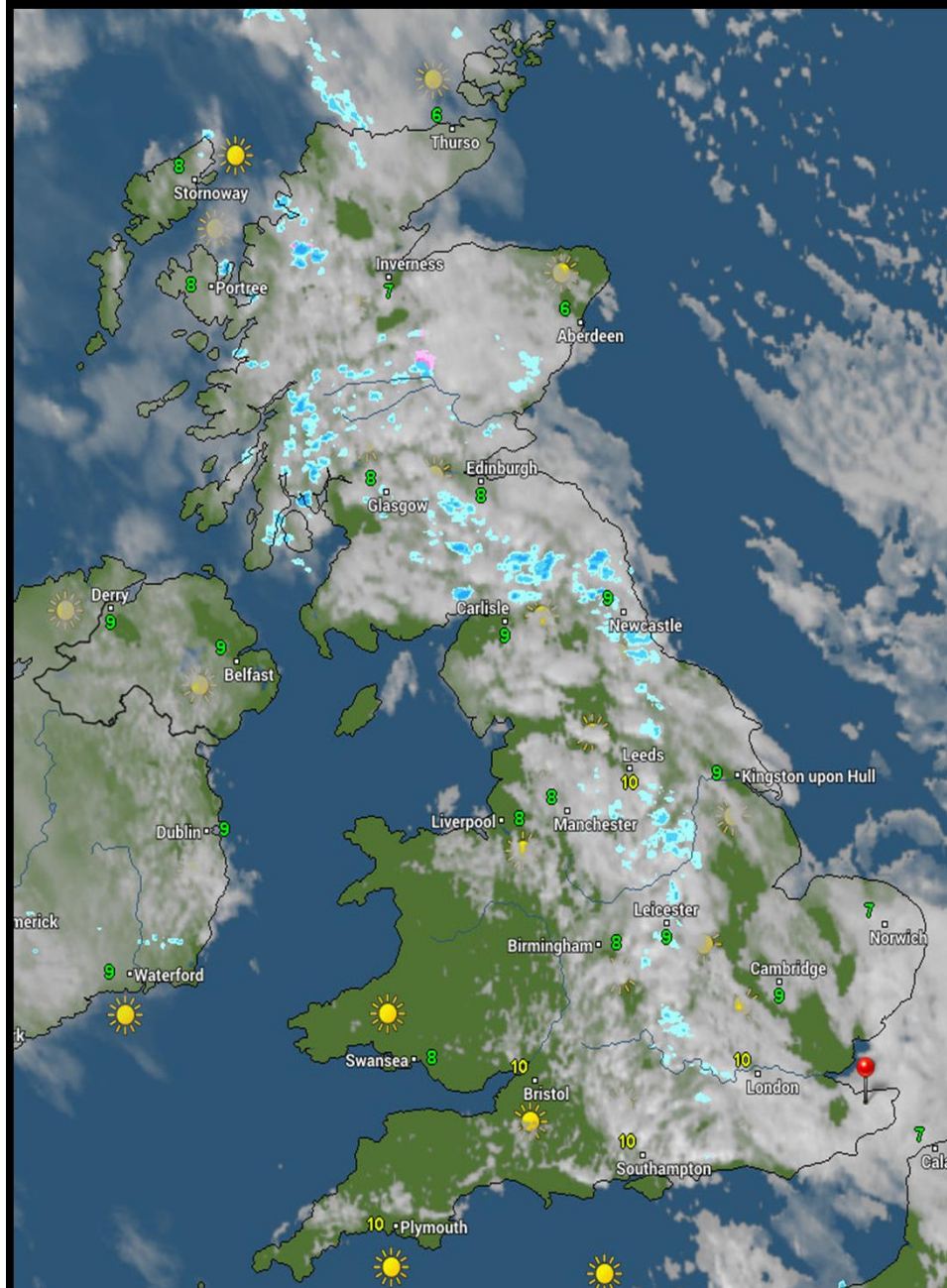
**Rosette
Nebula**

**Cocoon
Nebula**

NGC1333

NGC7129

Typical UK Satellite Image and UK Amateur Astronomy Societies



Making Stars and Planets:

The HOYS-CAPS Citizen Science Project



14243km



1039

#35/45



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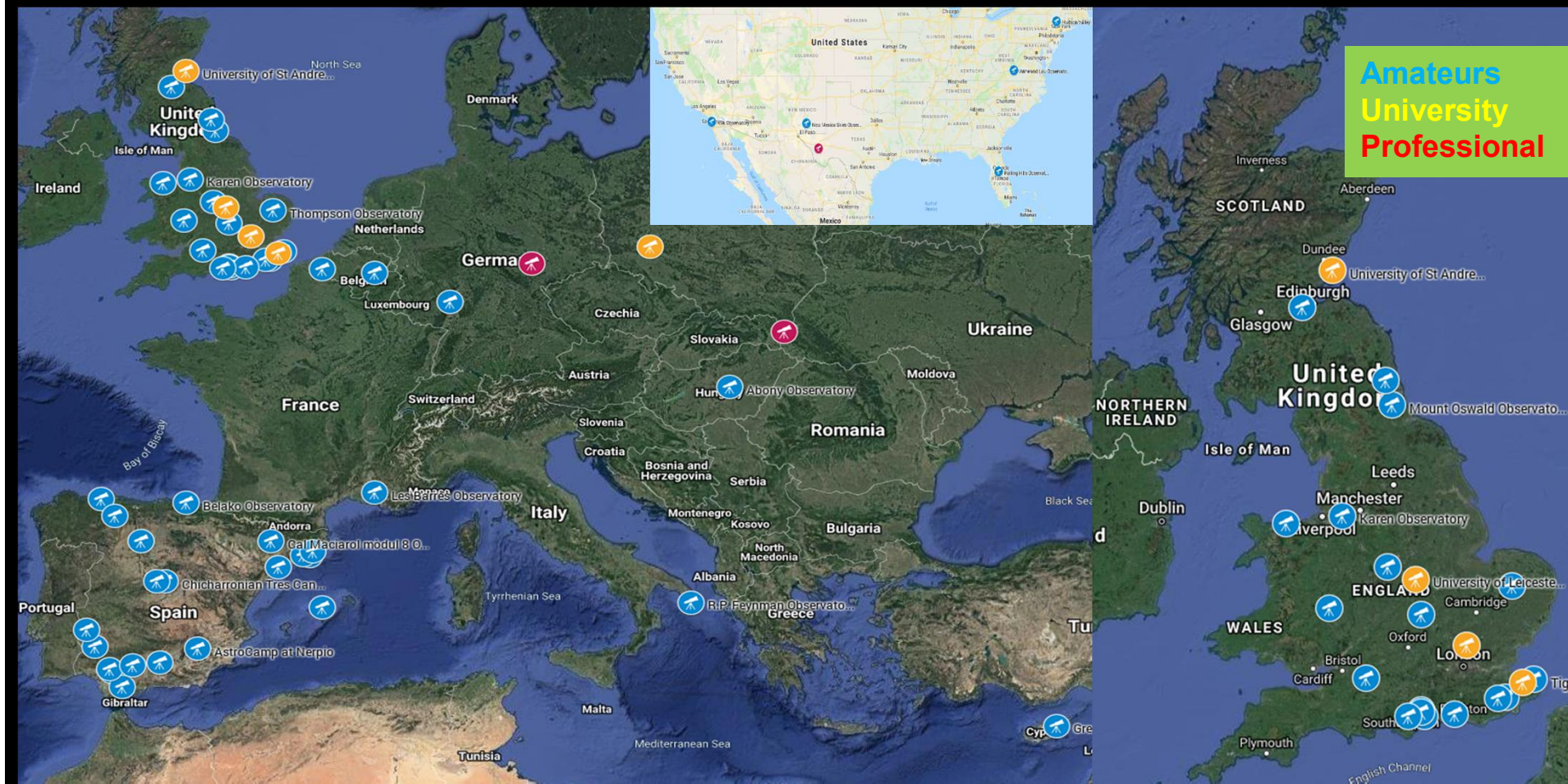
HOYS-CAPS Observatories

~58 active participants, from 11 countries

~12450 images

~600 hrs * m² exposure time

~95million accurate brightness measurements



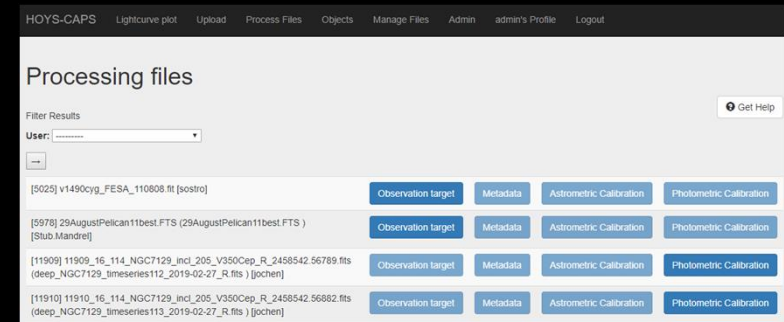
Data Calibration

Initial, User led:

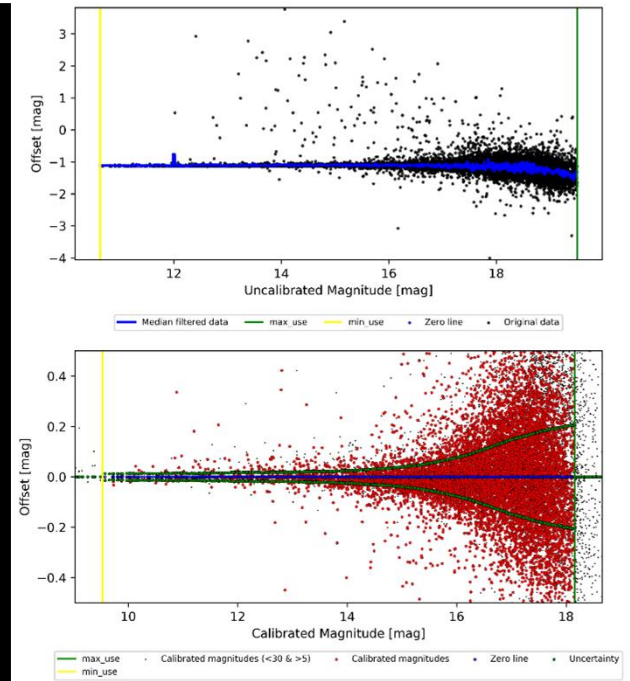
- ID of target region and devise
- Astrometry
- Source Extractor photometry, calibration into reference system via Photofunction and $P_4(m)$

Post-Processing:

- Identification of non-variables via low Stetson index
- Correction of colour terms using $P_2(m) + P_2(V-I)$



$$f(m^i) = A \cdot \log \left(10^{B \cdot (m^i - C)} + 1 \right) + P_4(m^i)$$

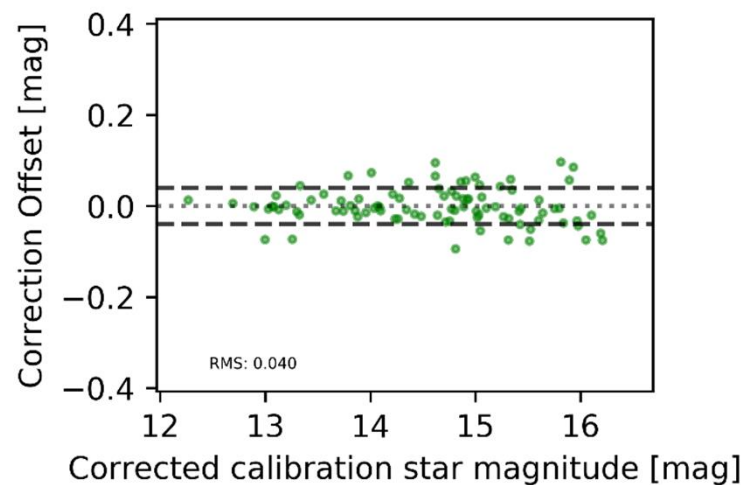
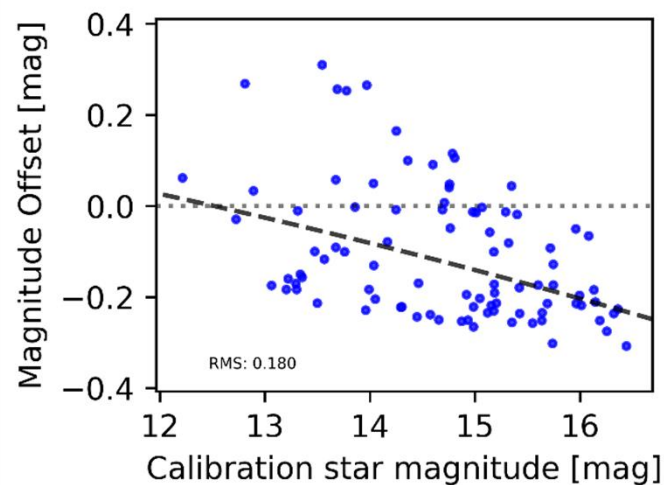
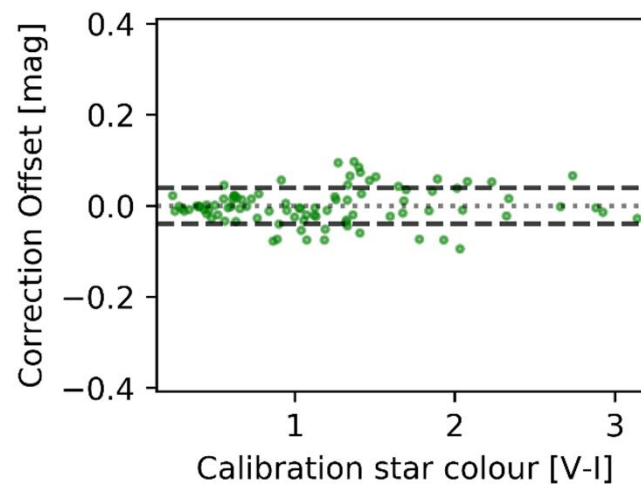
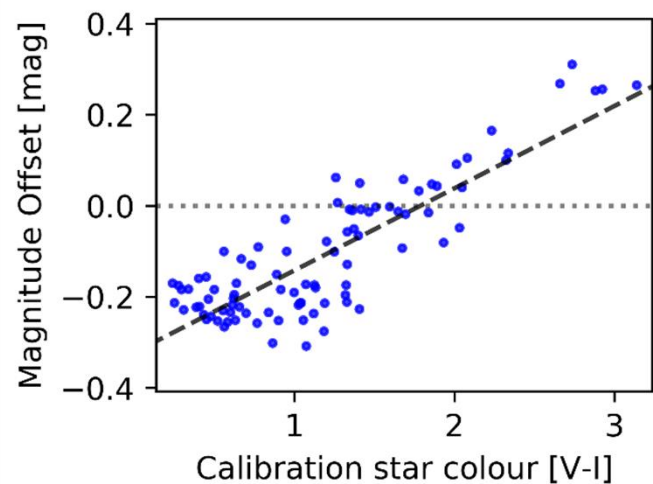


Data Calibration

Before Colour Correction:
RMS=0.180mag

After Colour Correction:
RMS=0.040mag

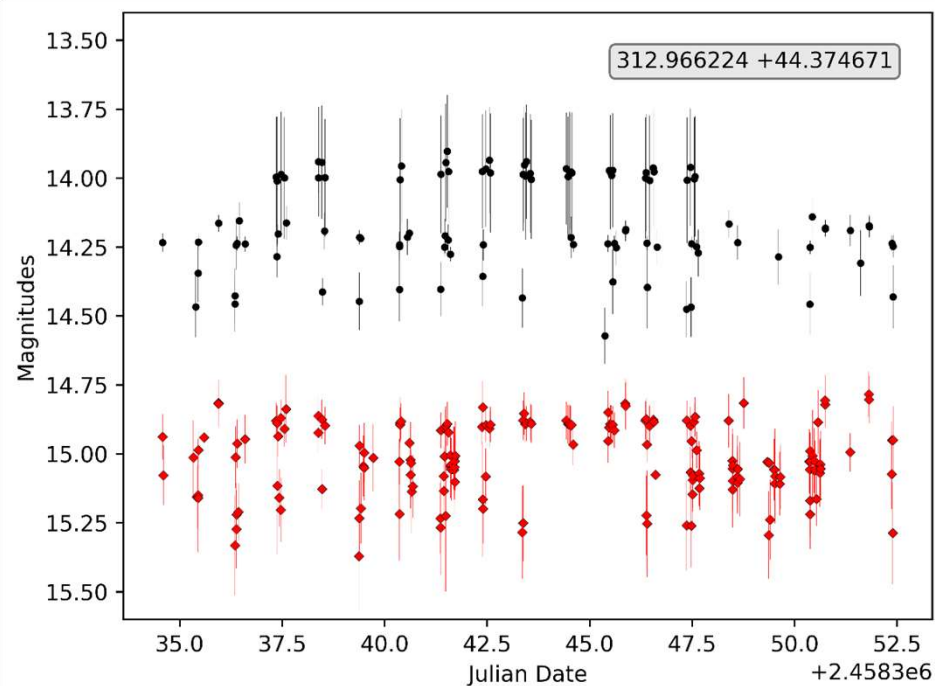
Example:
IC5070,
I-Band,
User #16



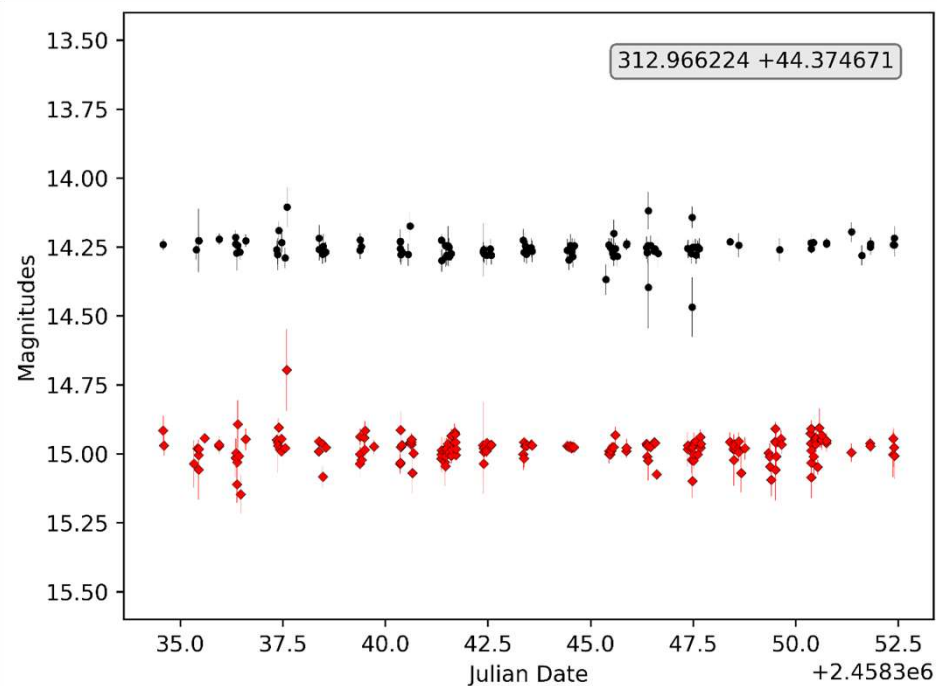
Data Calibration

Example, 2MASS J20515188+4422274

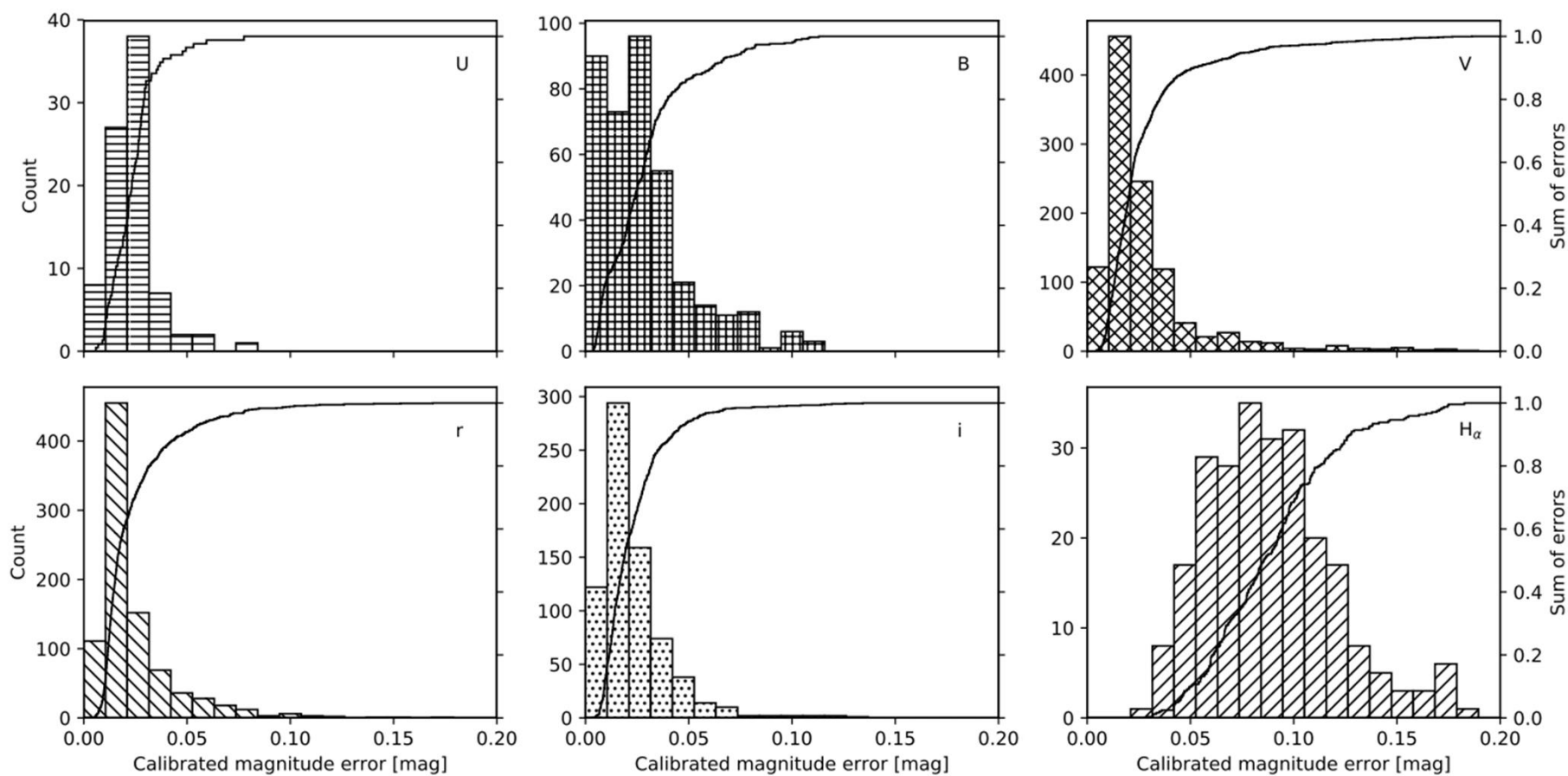
Before Colour Correction



After Colour Correction



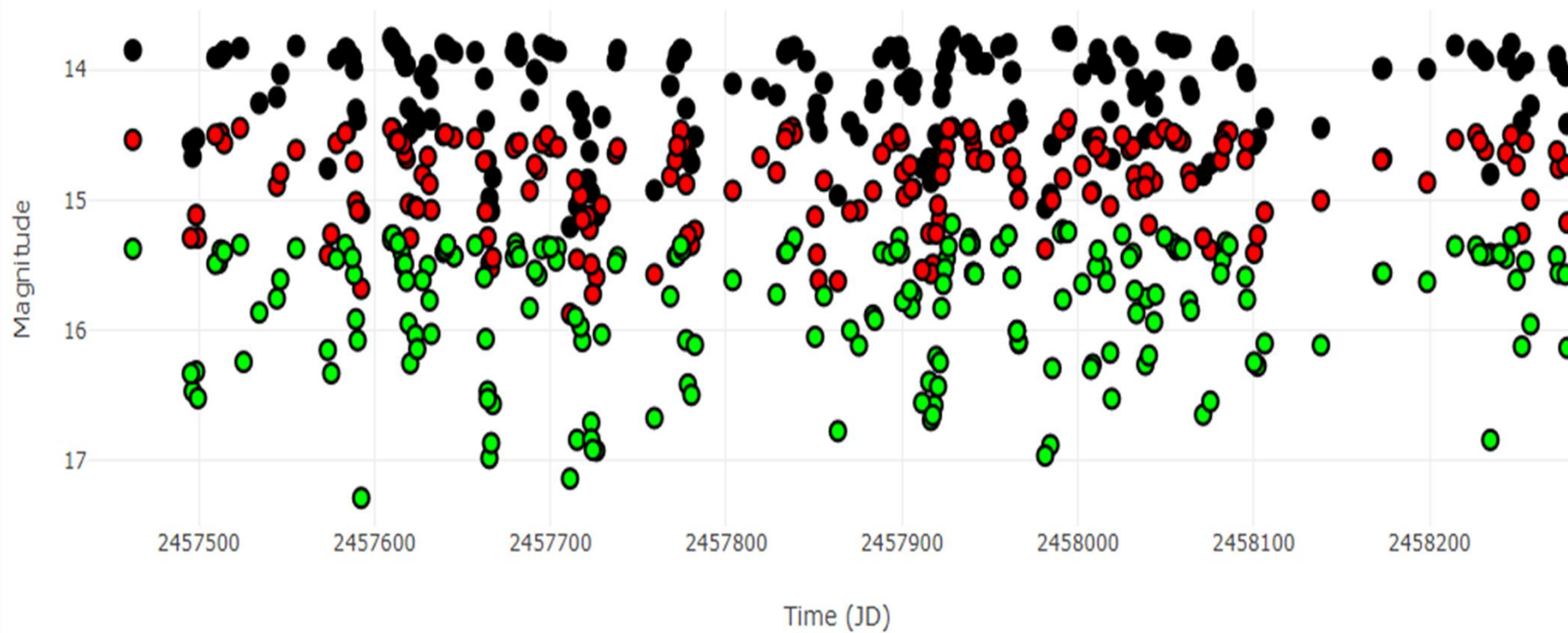
The YSO V1490Cyg



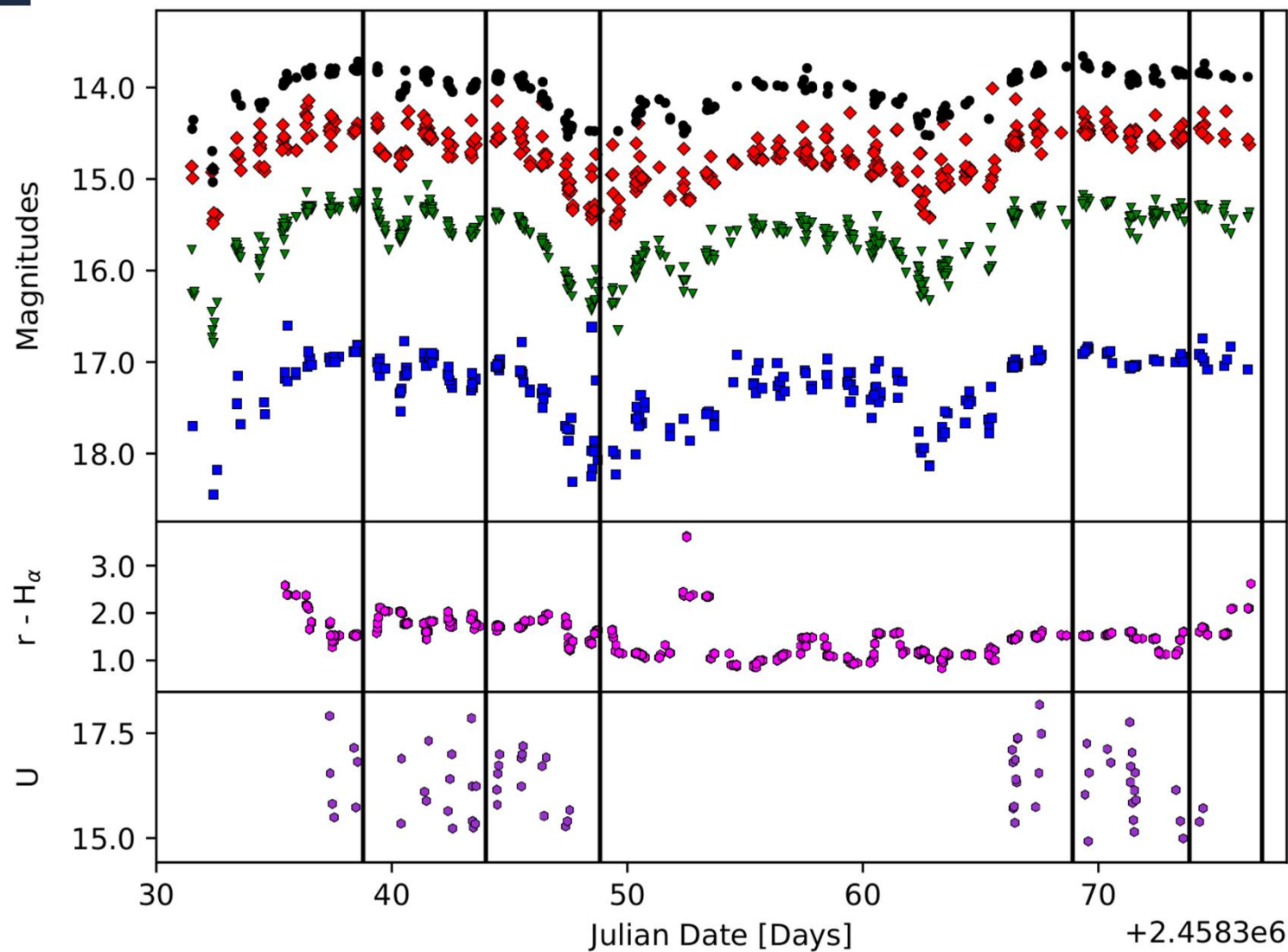
The YSO V1490Cyg



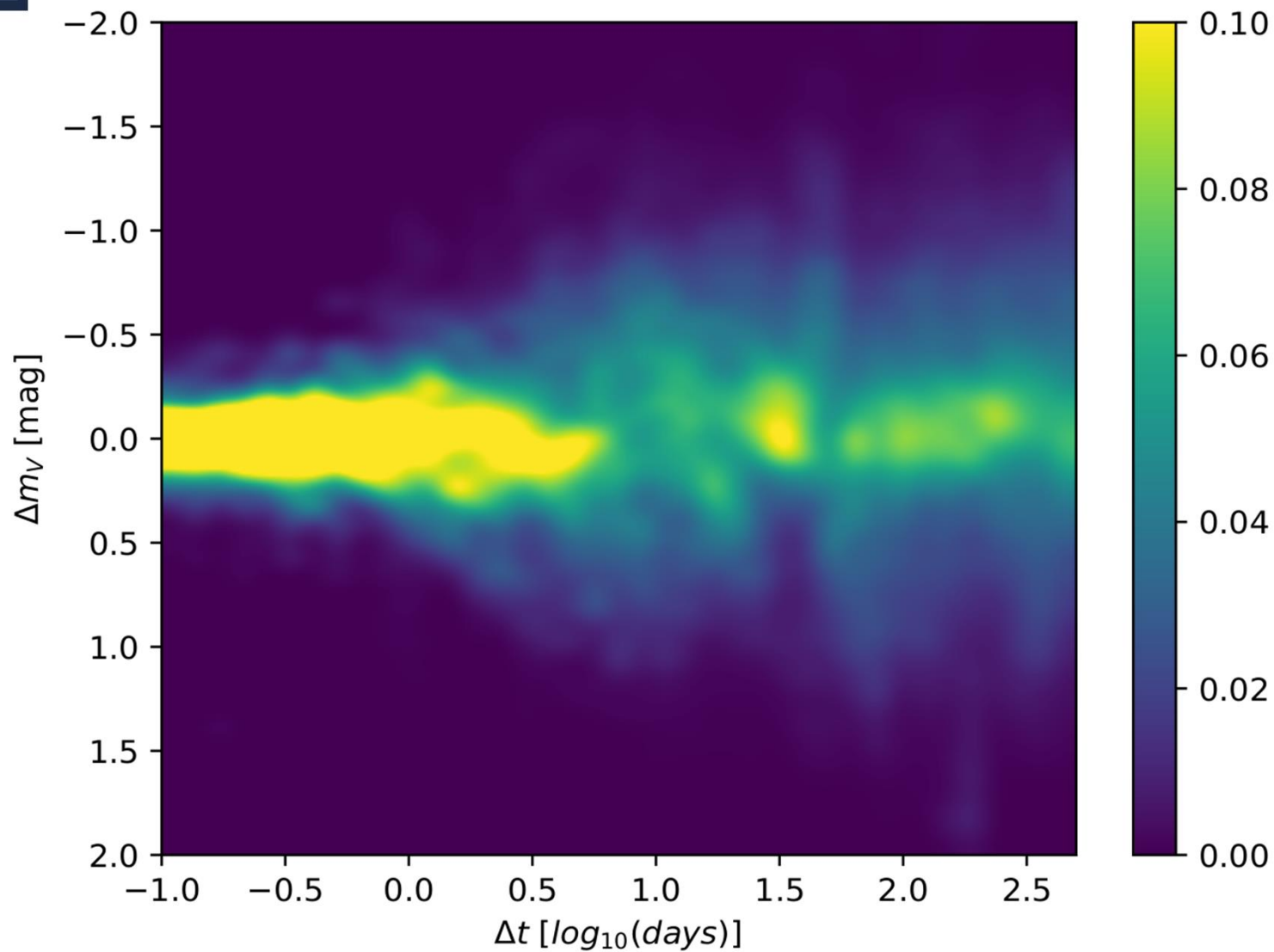
Lightcurve Plot



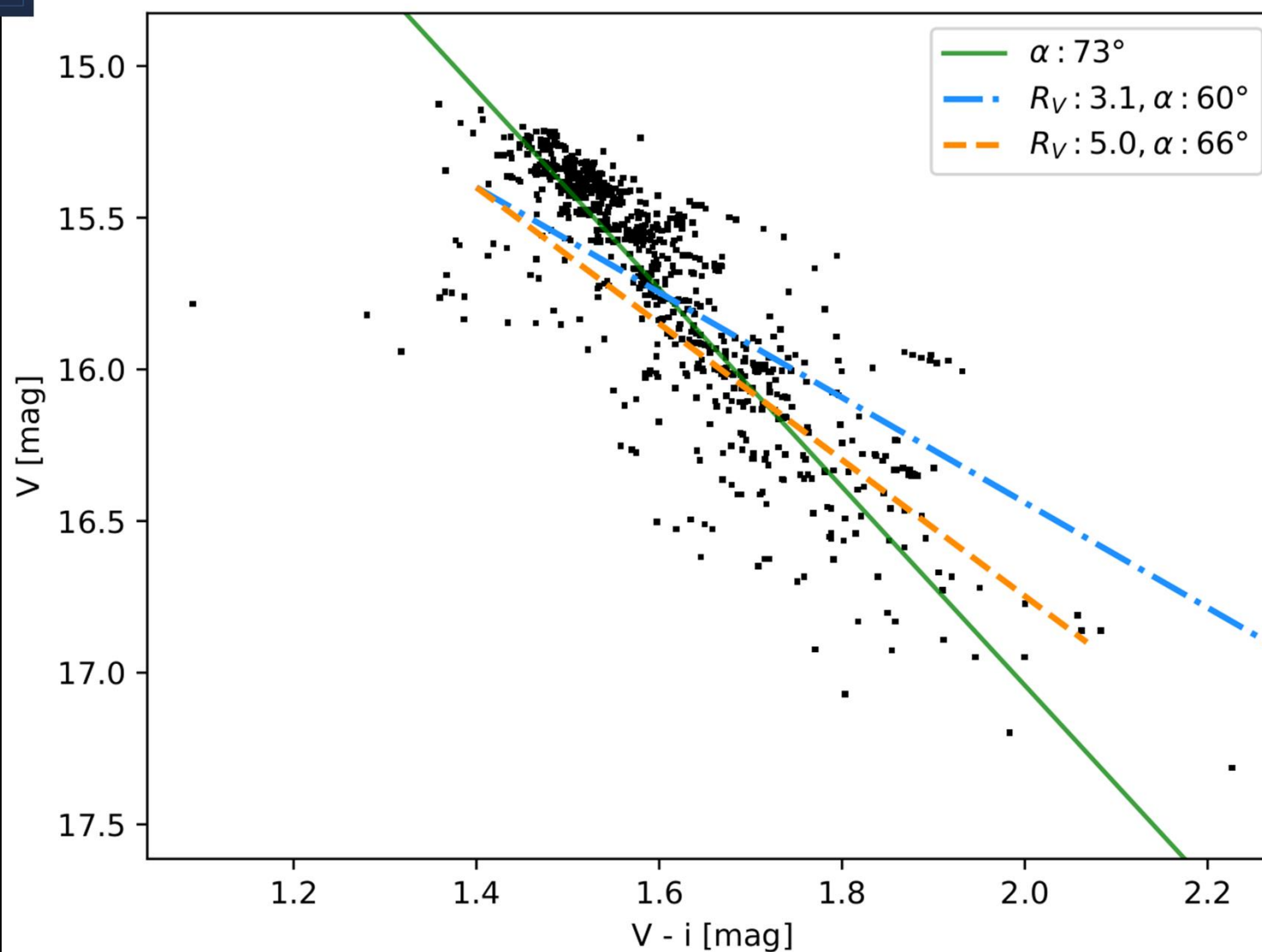
The YSO V1490Cyg



The YSO V1490Cyg



The YSO V1490Cyg



Preliminary Burst and Dipper Statistics



lightcurves of ~2000 known YSOs in V, R, I

- better than 0.2mag photometry
- >50 datapoints per filter
- in at least two filters

We cover so far in:

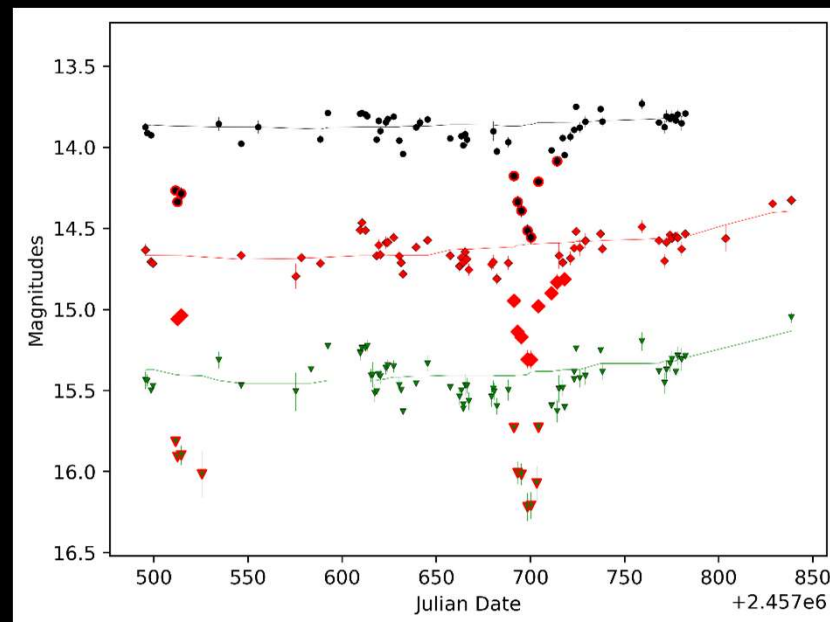
V-Band: 3700yrs

R-Band: 5200yrs

I-Band: 6500yrs

Lightcurves median smoothed with 150d

Dip Detection Example



Dips/Bursts identified as more than 2.5σ outliers in magnitude with at least 2 datapoints in at least two of the filters.

Preliminary Burst and Dipper Statistics



lightcurves of ~2000 known YSOs in V, R, I

- better than 0.2mag photometry
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V-Band: 3700yrs

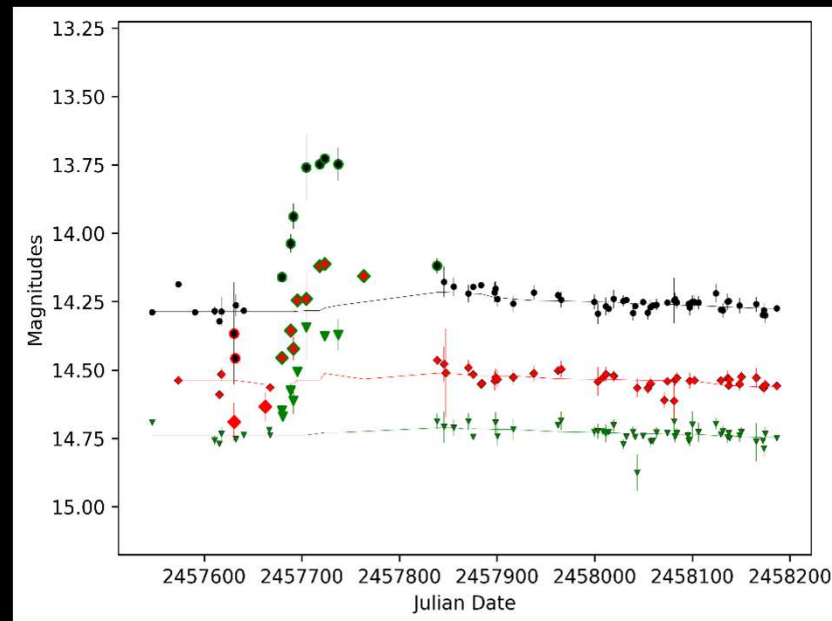
R-Band: 5200yrs

I-Band: 6500yrs

Lightcurves median smoothed with 150d

Dips/Bursts identified as more than 2.5σ outliers in magnitude with at least 2 datapoints in at least two of the filters.

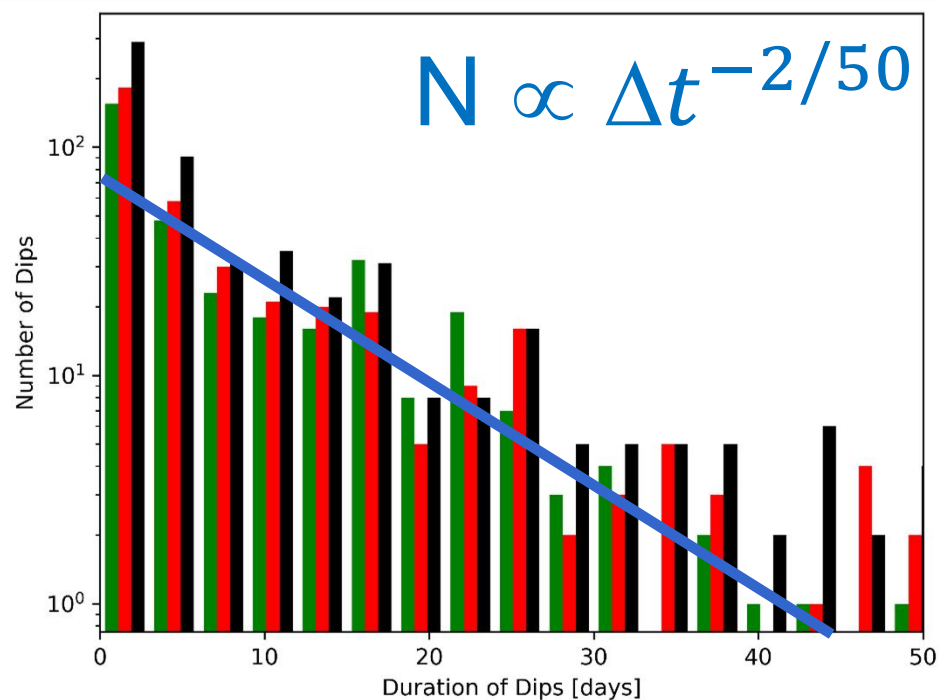
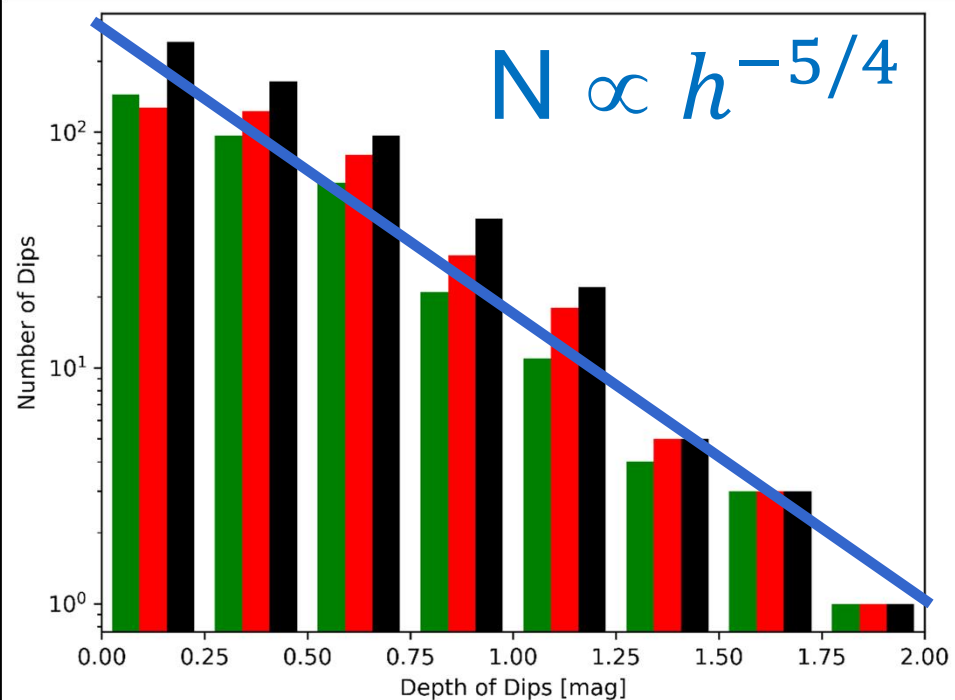
Burst Detection Example



Preliminary Burst and Dipper Statistics



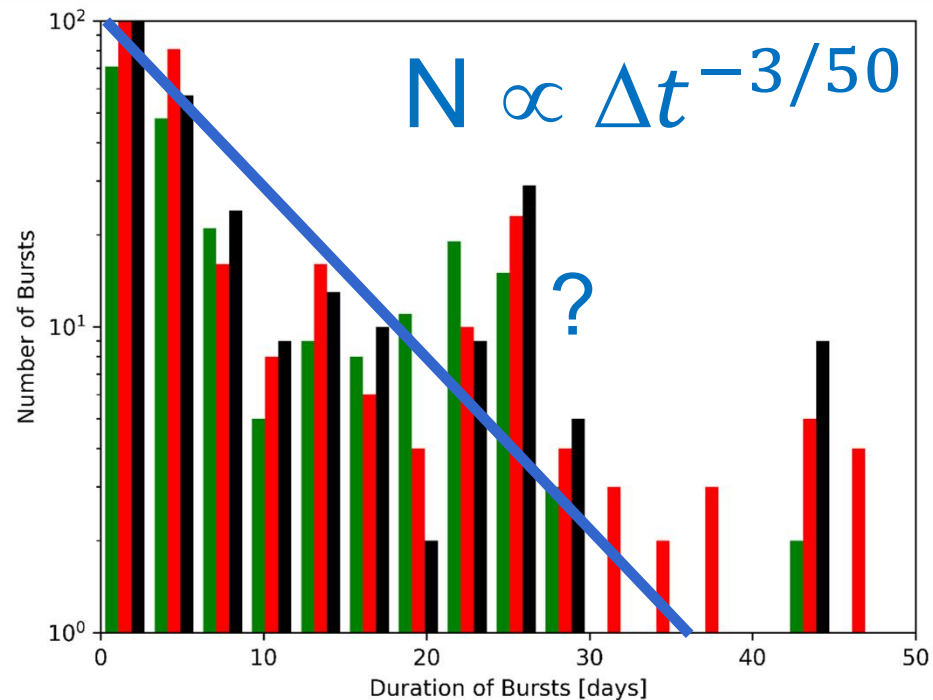
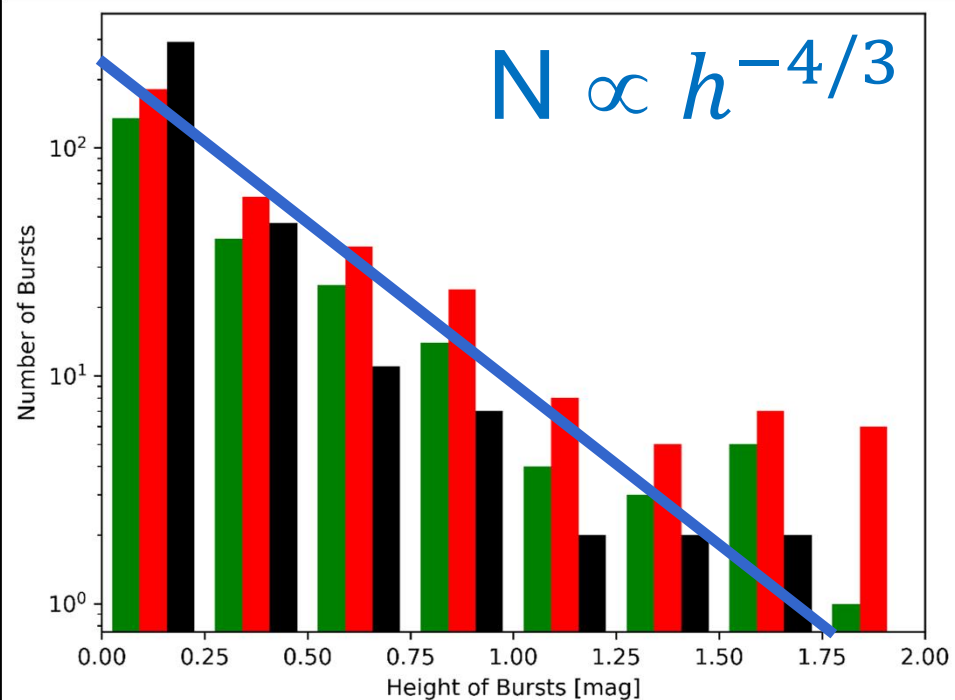
Dip Depth and Duration



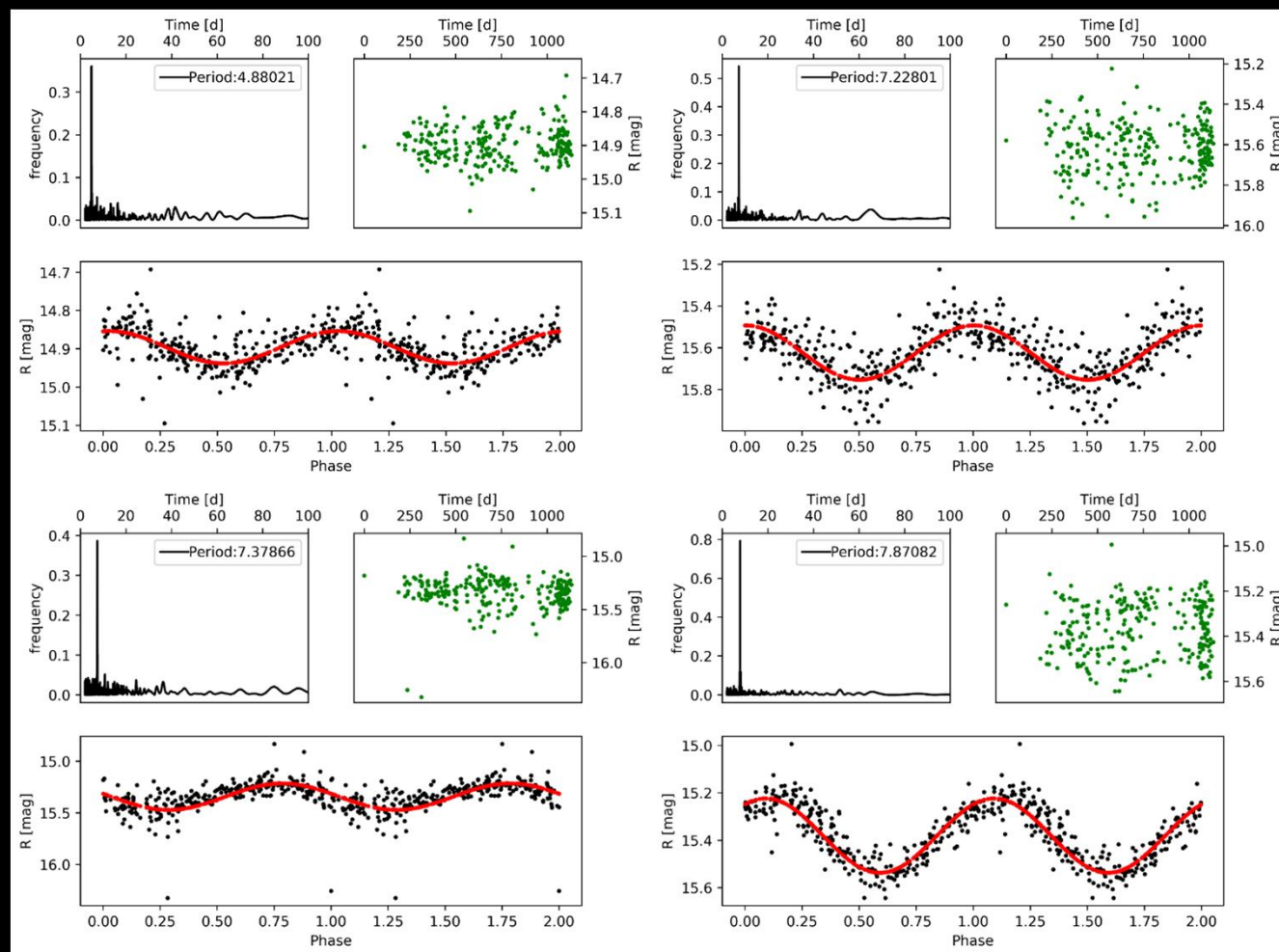
Preliminary Burst and Dipper Statistics



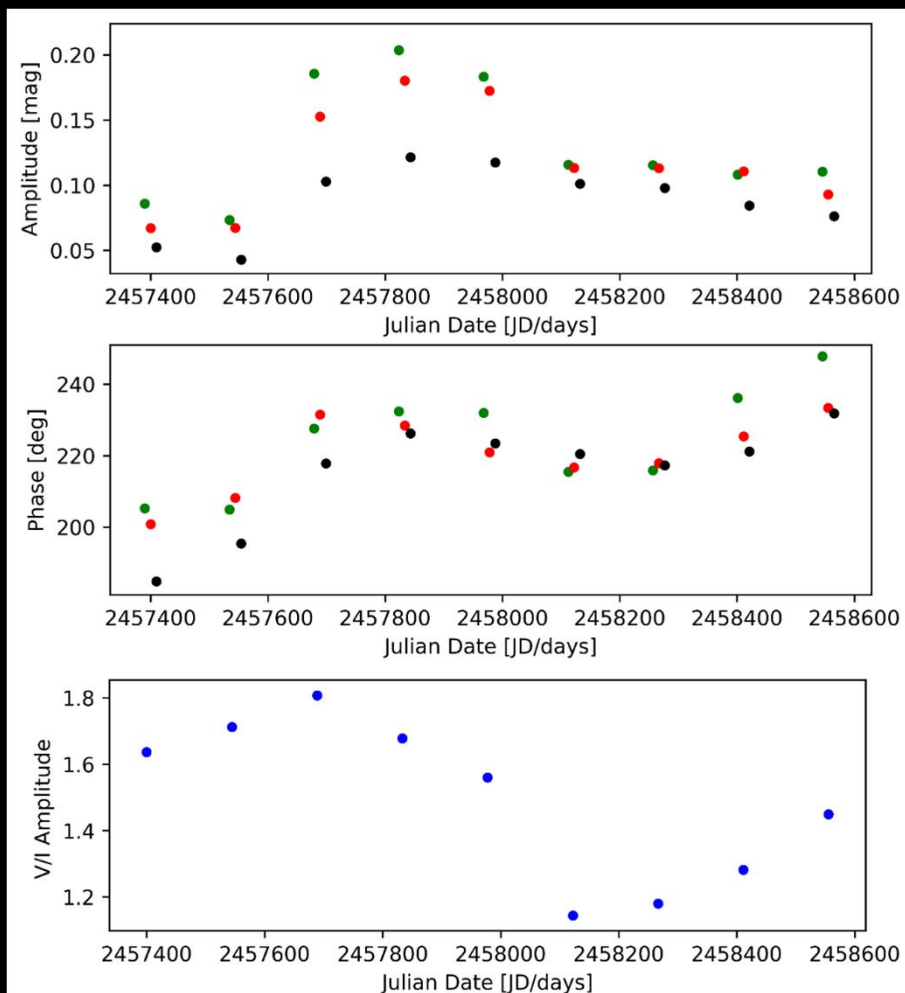
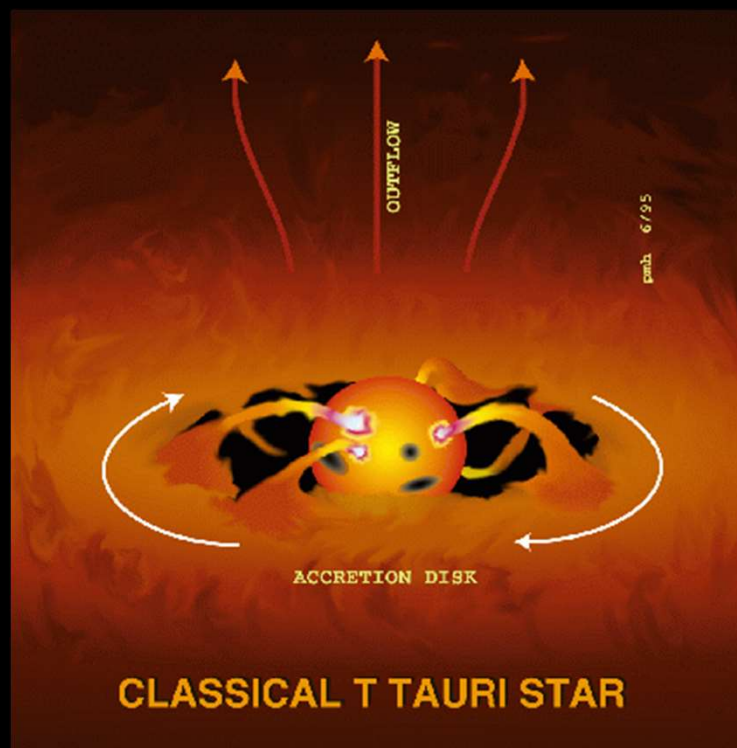
Burst Height and Duration



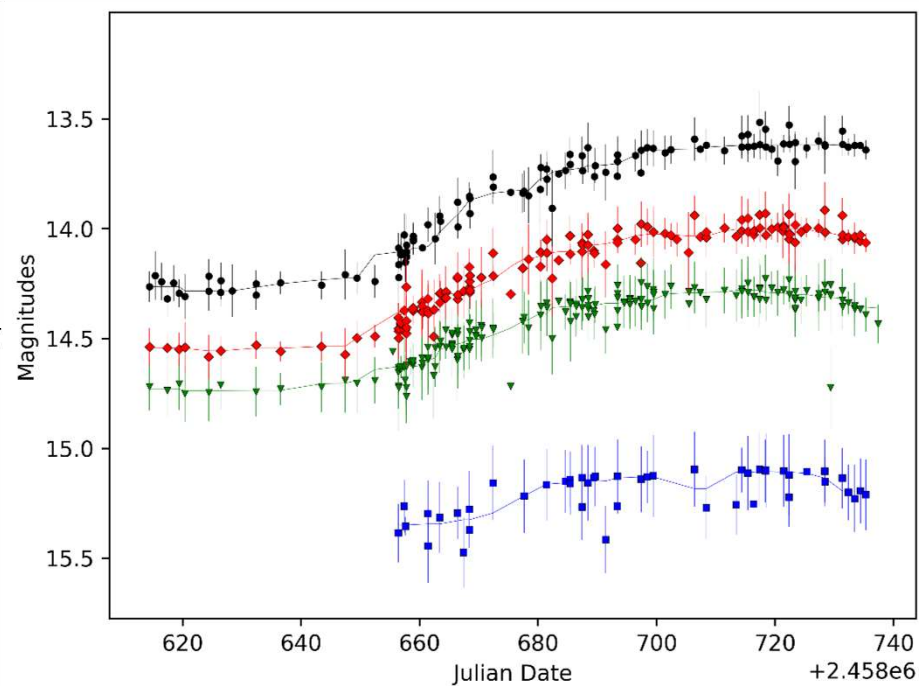
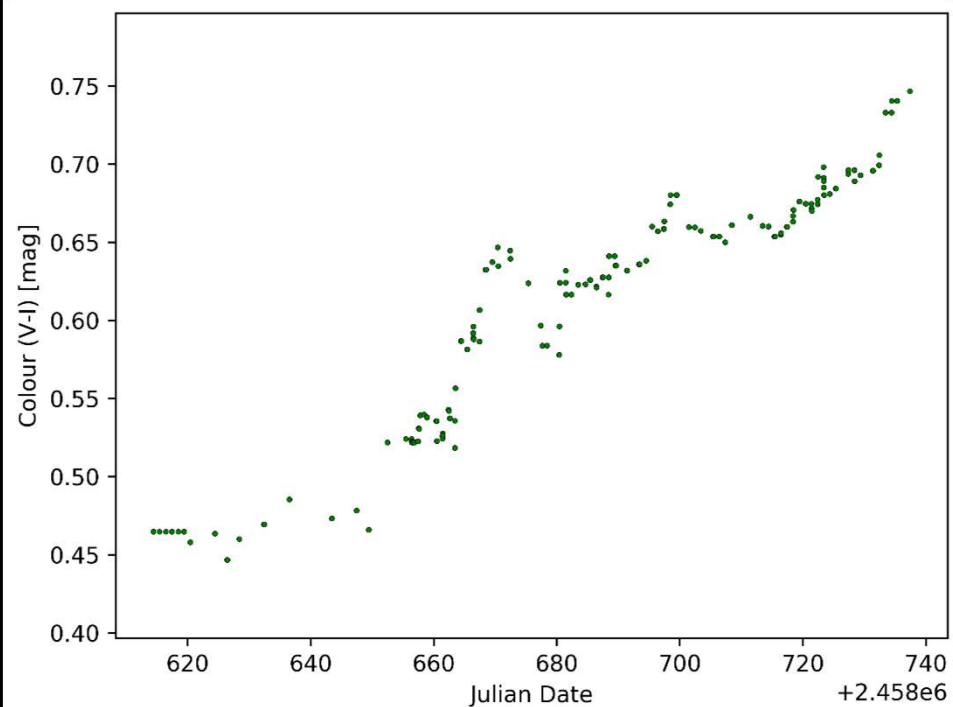
YSO Rotation Periods



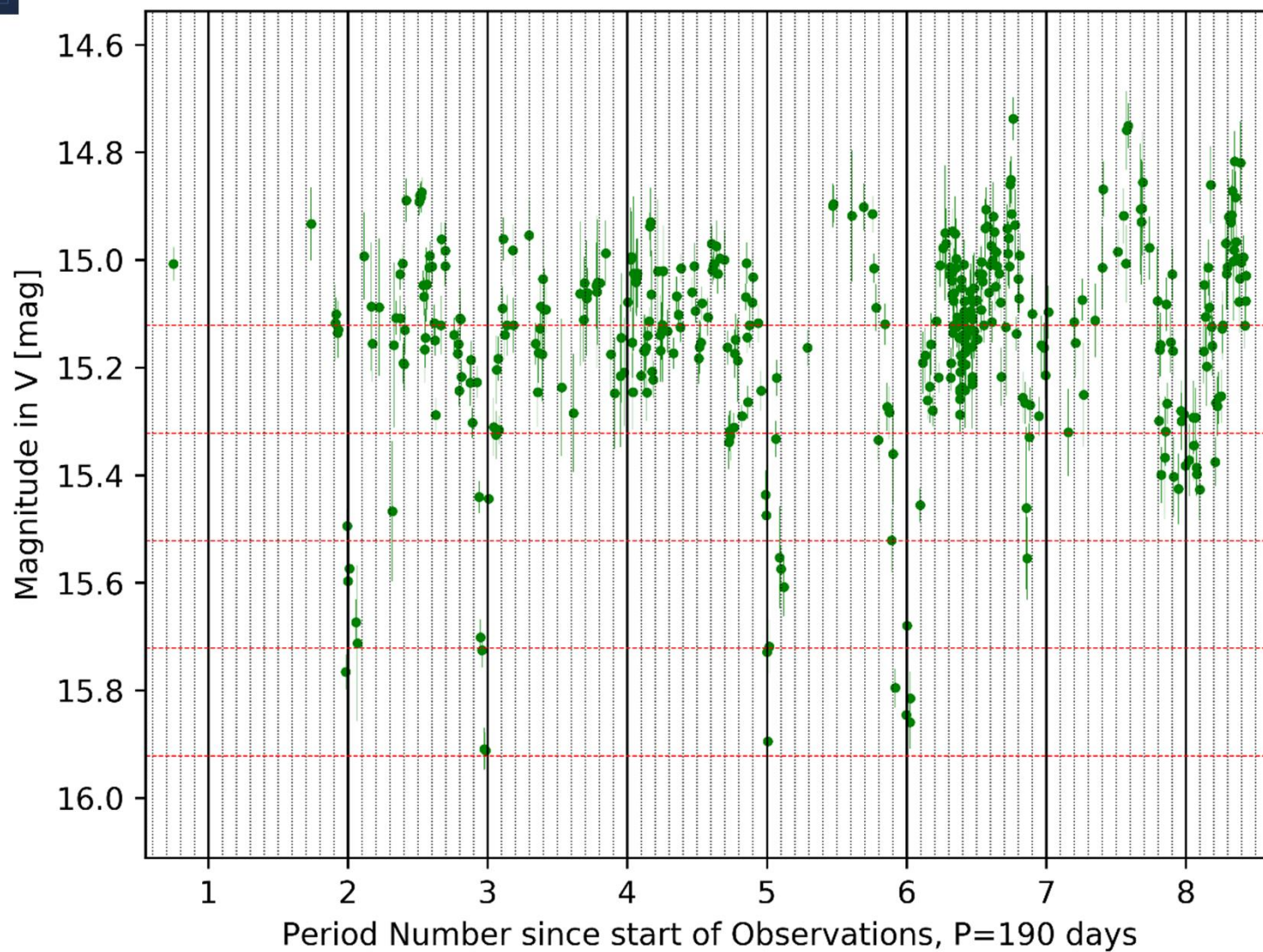
YSO Rotation Periods



The Weired and Wonderful



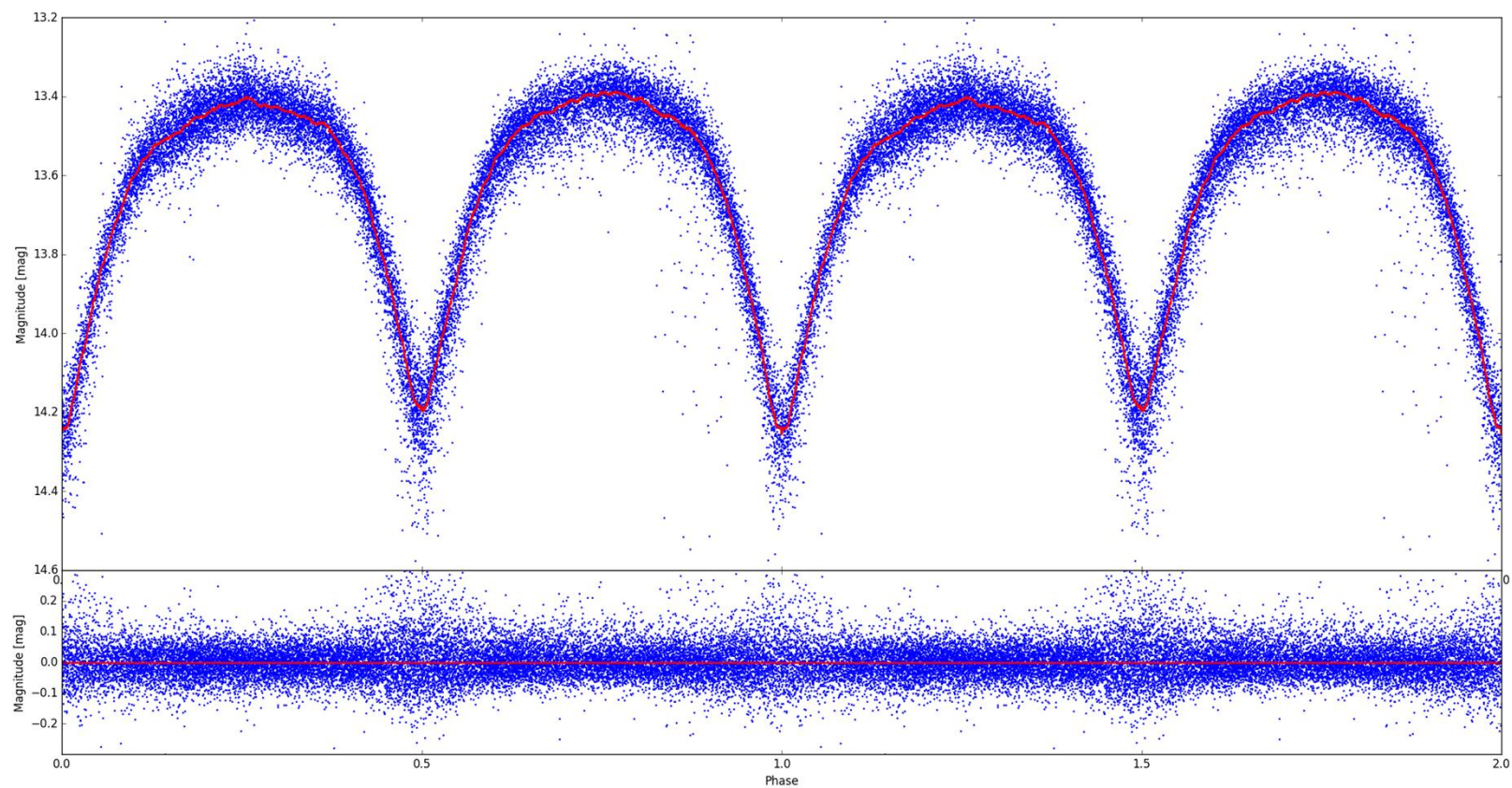
Accreting Planet?



Surprise datasets



Stan Waterman's Data



The 2014-2017 outburst of the young star ASASSN-13db:

A time-resolved picture of a very low-mass star between EXors and FUors

A. Sicilia-Aguilar^{1,2}, A. Oprandi^{3,2}, D. Froebrich⁴, M. Fang⁵, J. L. Prieto^{6,7}, K. Stanek^{8,9}, A. Scholz², C.S. Kochanek^{8,9}, Th. Henning¹⁰, R. Gredel¹⁰, T.W.-S. Holoien^{7,8}, M. Rabus^{11,10}, B. J. Shappee^{12*}, S. J. Billington⁴, J. Campbell-White⁴, and T. J. Zegmott⁴

A&A, 2017, 607, 127

A survey for variable young stars with small telescopes: First results from HOYS-CAPS

D. Froebrich^{1*}, J. Campbell-White¹, A. Scholz², J. Eisloffel³, T. Zegmott^{1†}, S.J. Billington^{1†}, J. Donohoe^{1†}, S.V. Makin^{1†}, R. Hibbert^{1†}, R.J. Newport^{4†}, R. Pickard^{5†}, N. Quinn^{5†}, T. Rodda^{5†}, G. Piehler^{6†}, M. Shelley^{7†}, S. Parkinson^{5†}, K. Wiersema^{8,9†}, I. Walton^{5,10†}

MNRAS, 2018, 478, 5091

Variability in IC 5070: two young stars with deep recurring eclipses*

DIRK FROEBRICH,¹ ALEKS SCHOLZ,² JUSTYN CAMPBELL-WHITE,¹ JAMES CRUMPTON,¹ EMMA D'ARCY,¹ SALLY V. MAKIN,¹ TARIK ZEGMOTT,¹ SAMUEL J. BILLINGTON,¹ RICKY HIBBERT,¹ ROBERT J. NEWPORT,³ AND CALLUM R. FISHER¹

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(Received July 2, 2018; Revised July 2, 2018; Accepted ?)

Submitted to RNAAS

RNAAS, 2018, 2, 61

Optical brightness and colours of V2492Cyg before, during and after the recent record peak in brightness

ATel #10259; Dirk Froebrich (University of Kent), Justyn Campbell-White (University of Kent), Tarik Zegmott (University of Kent), Samuel J. Billington (University of Kent), Sally V. Makin (University of Kent), Justin Donohoe (University of Kent)

on 12 Apr 2017; 17:56 UT

Credential Certification: Lynne Hillenbrand (lah@astro.caltech.edu)

Subjects: Optical, Young Stellar Object, Pre-Main-Sequence Star

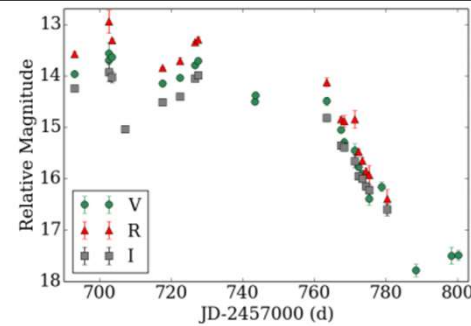


Fig. 4. Lightcurve from the Beacon Observatory. The magnitudes are relative to the data from JD=2457717.594. The data show the rapid decrease of the source flux during January-February 2017 and stabilization from February-March 2017.

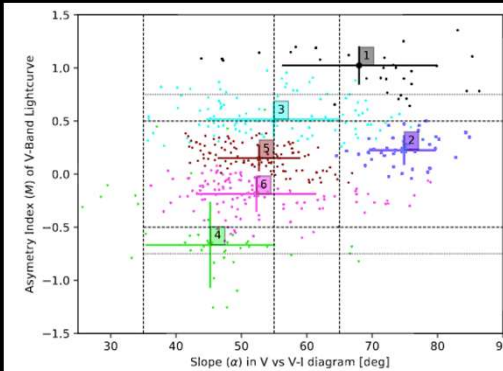


Figure 4. Figure showing the slope α in the V vs V-I diagram and the asymmetry index M for the YSOs in our sample. The larger symbols and error bars indicate the mean and rms of all stars in the different groups. The group number is also indicated. All outliers (summarised in G 7) are not shown as they are partly outside the parameter space of the plot (e.g. at negative slope values). The colours and symbols are the same as in Fig. 3. The dashed horizontal lines separate the dippers (top) from the symmetric light-curves (middle) and the bursters (bottom). The thin dashed horizontal lines separate the most extreme bursters and dippers. The dashed vertical lines indicate the three regions for α discussed in the text.

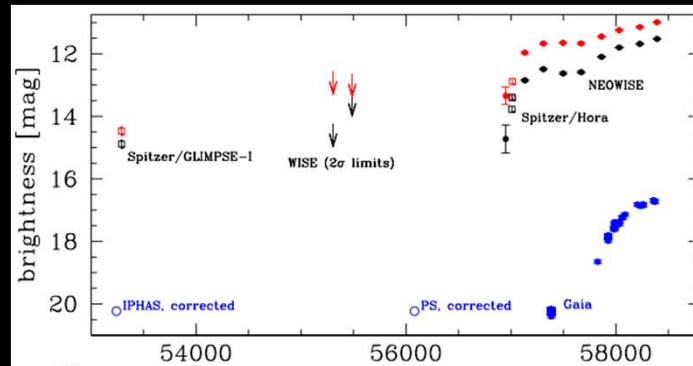
ATel, 2018, 10259

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paper...**

Gaia 17bpi: An FU Ori Type Outburst

LYNNE A. HILLENBRAND,¹ CARLOS CONTRERAS PEÑA,² SAM MORRELL,² TIM NAYLOR,² MICHAEL A. KUHN,¹
ROC M. CUTRI,³ LUISA M. REBULL,³ SIMON HODGKIN,⁴ DIRK FROEBRICH,⁵ AND AMY K. MAINZER⁶

ApJ, 2018, 869, 146



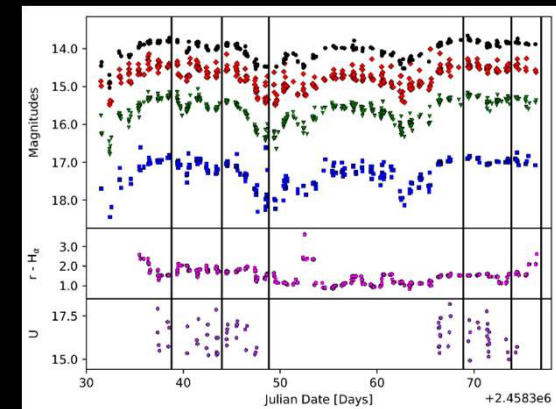
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A survey for variable young stars with small telescopes: II - The periodically dipping YSO V 1490 Cyg analysed by HOYS-CAPS

Jack J. Evitts¹, Dirk Froebrich¹★, Aleks Scholz², Jochen Eisloffel³,
Justyn Campbell-White^{1,4}, Will Furnell^{1,5}, Thomas Urtly⁶†, Roger Pickard⁶†,
Klaas Wiersema^{7,8}†, Pavol A. Dubovský⁹†, Igor Kudzej⁹†, Ramon Naves¹⁰†,
Mario Morales Aimar^{10,11}†, Rafael Castillo García^{10,11,12}†, Tonny Vanmunster^{13,14}†,
Erik Schwendeman¹¹†, Francisco C. Soldán Alfaro^{10,11}†, Stephen Johnstone^{6,11}†,
Rafael Gonzalez Farfán¹⁰†, Thomas Killestein^{6,7}†, Jesús Delgado Casal¹⁰†,
Faustino García de la Cuesta^{10,15}†, Dean Roberts¹⁶†, Ulrich Kolb¹⁶†, Luís, Montoro¹⁰†,
Domenico Licchelli¹⁷†, Alex Escartin Perez¹⁰†, Carlos Perelló Perez^{10,18}†,
Marc Deldem¹¹†, Stephen R.L. Fletcher^{6,19}†, Tim Nelson¹⁹†, Shawn Dvorak¹¹†,
Dawid Moździerski²⁰†, Nick Quinn⁶†, Krzysztof Kotysz²⁰†, Katarzyna Kowalska²⁰†,
Przemysław Mikołajczyk²⁰†, George Fleming⁶†, Mark Phillips²¹†, Tony Vale^{6,22,23}†,
Franky Dubois^{24,25}†, Ludwig Logie^{24,25}†, Steve Rau^{24,25}†, Siegfried Vanaverbeke^{24,25,26}†,
Barry Merrikin¹⁹†, Esteban Fernández Mañanes¹⁰†, Emery Erdelyi^{11,27}†,
Juan-Luis Gonzalez Carballo¹⁰†, Fernando Limon Martinez¹⁰†, Tim Long[?]†,
Adolfo San Segundo Delgado¹⁰†, José Luis Salto González^{10,28}†, Luis Tremosa Espasa¹⁰†,
James Crumpton¹‡, Samuel J. Billington¹‡, Emma D'Arcy¹‡, Sally V. Makin¹‡,
Lord Dover¹‡, G.Piehler[?]†, L.Phillips[?]†, andrew[?]†, A.Timar[?]†, sefida[?]†,

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²SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK



Summary



HOYS-CAPS UBVRIH α monitoring of YSOs with Amateur data is very successful and very simple to take part in

We can accurately ($\sigma=0.01-0.03\text{mag}$) calibrate the inhomogeneous photometric data (variety of filters, cameras and observing conditions)

We can establish accretion burst and dip properties including knowledge of detection biases

We can measure rotation periods at several wavelength and establish time dependent amplitudes and phases



Any Questions?



df@star.kent.ac.uk



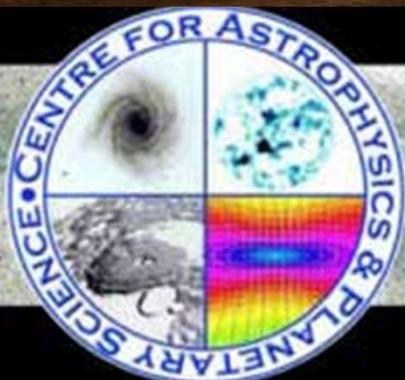
astro.kent.ac.uk/~df/hoyscaps/index.html



HOYS-CAPS Citizen Science Project



HOYS-CAPS



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