

# Stellar variability in IC 348

## *YETI Observations*

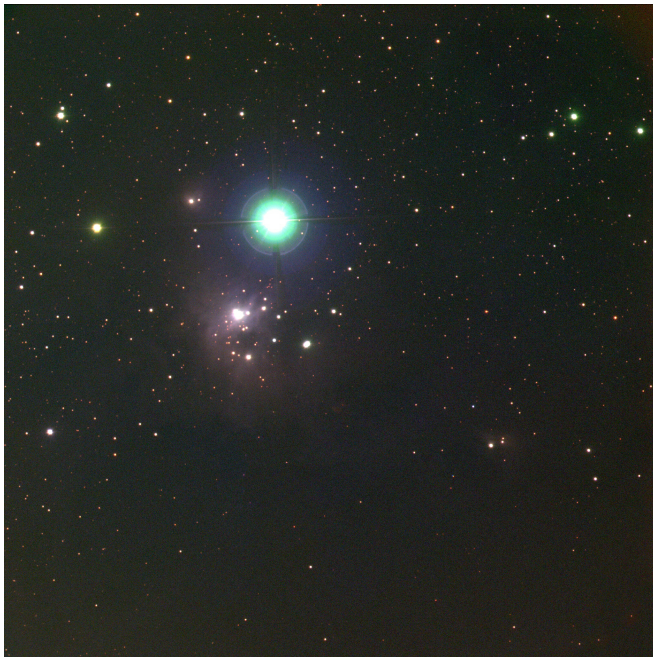
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19 October 2018

# Outline

- 1 The Open Cluster IC 348
- 2 Observations and Time Series Analysis
- 3 Results
- 4 What we have learned

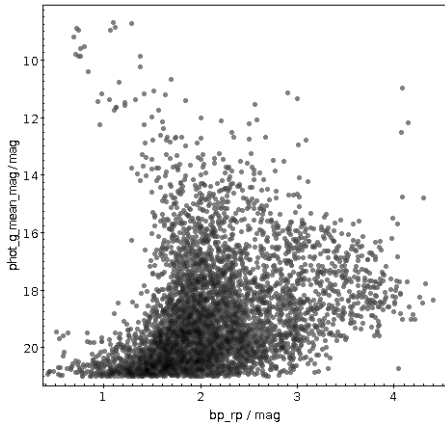


(AIU/M.Mugrauer)

# Basic Facts on IC 348

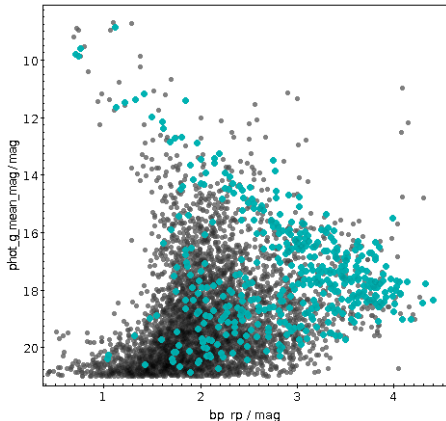
- ▶ Located in the Perseus molecular cloud ( $03^{\text{h}} 44^{\text{m}} 34^{\text{s}}$ ,  $+32^{\circ} 09' 45''$ )
- ▶ Median age between 2 Myr and 6 Myr (Luhman+ 2003, Bell+ 2013)
- ▶  $\approx 470$  members including several brown dwarfs (Luhman+ 2016)
- ▶ Distance: 316 pc (Herbig 1998)
- ▶ Several photometric surveys in the literature.  
(Herbig 1998, Cohen+ 2004, Littlefair+ 2005, Nordhagen+ 2006)
- ▶ 143 stars are periodically variable or candidates (Cieza & Baliber, 2006)

# Colour-Magnitude-Diagram of IC 348



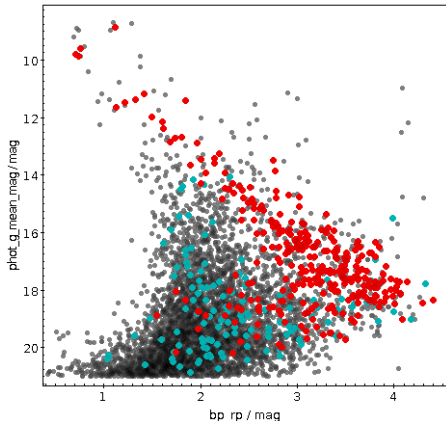
► CMD from *Gaia* DR2

# Colour-Magnitude-Diagram of IC 348



- ▶ CMD from *Gaia* DR2
- ▶ Selection based on proper motion

# Colour-Magnitude-Diagram of IC 348



- ▶ CMD from *Gaia* DR2
- ▶ Selection based on proper motion
- ▶ Refine cluster membership based on parallax.
- ▶ recovers 220 members from Luhman+ (2016)

# Observations and Data Analysis



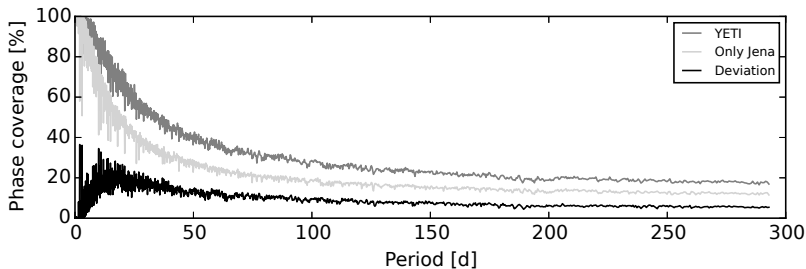
# The Observations in Numbers

- ▶ 2.4 year timebase
- ▶ 8 involved observatories
- ▶ 125 nights of observations
- ▶ 17 846 frames obtained
  - ▶ 10 808 frames from Jena
- ▶ 1001 stars in the field of view analysed



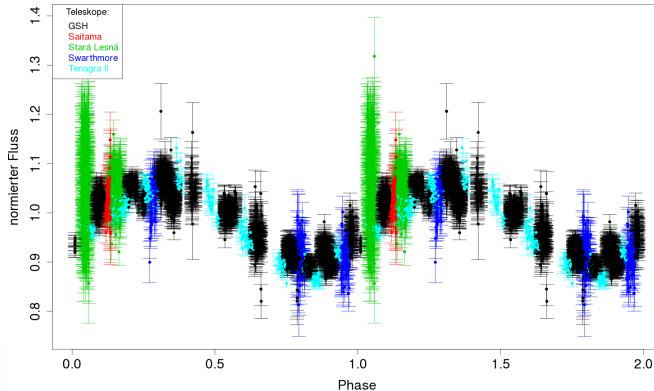
# The Advantage of YETI

- ▶ Better phase coverage for any given period
- ▶ Advantage for periods that are multiple of 1 d  
→ reducing alias



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# Time-Series Analysis

## Three methods were deployed

- ▶ Generalised Lomb-Scargle periodogram (Zechmeister & Kürster 2009)
- ▶ Gregory-Loredo Bayesian periodogram (Gregory & Loredo 1992)
- ▶ String-length algorithm (Dworetsky 1982)

## Common properties of the methods

- ▶ Work on arbitrary spaced data
- ▶ Use predefined trial periods

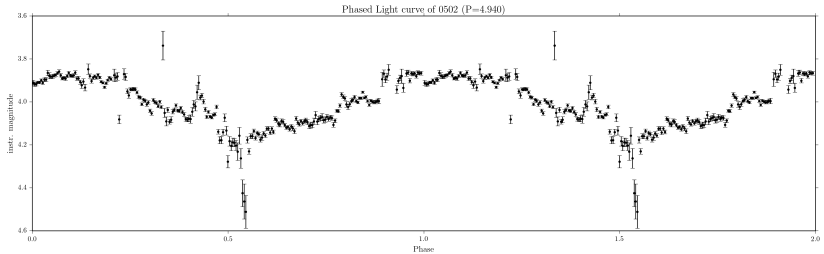
# Workflow of Period Determination

- 1 Independent application of methods to light curve (LC)
  - 2 Two of three should give same period within 10% margin
  - 3 Search within 10% range with finer grid
  - 4 Agreement on 1% level
- Accept period after manual inspection of LC.

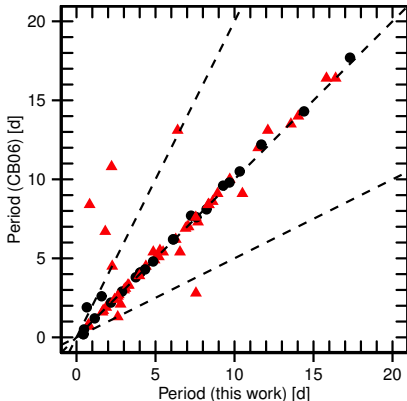
# Results

# Stellar Rotation of PMS stars

- ▶ Rotational variability observable due to star spots.
- ▶ Young stars have large spots → easier to detect
- ▶ Found 87 periodic stars in IC 348, including 33 new
- ▶ Well studied cluster, finding new periods still possible



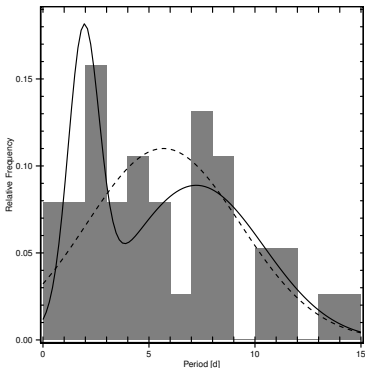
# Comparison with Previous Work



- ▶ Comparison with prior work of Cieza & Baliber (2006) shows:
  - ▶ Most previously found periods have a ratio of 1:1, 1:2, or 2:1
  - ▶ few periods diverge without a proper reason
  - ▶ 24 periods could not have been recovered



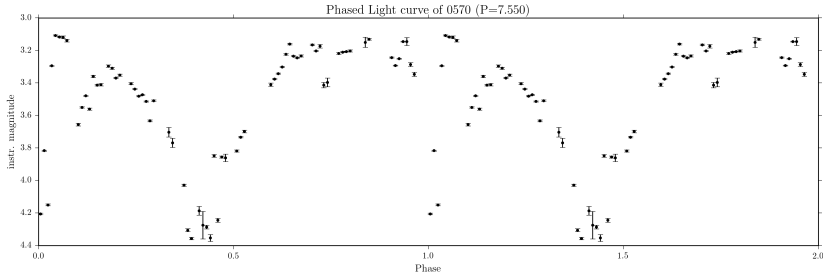
# Bimodal Period Distribution in IC 348



- ▶ Stars in young OC are either fast or slow rotators
- ▶ Discovered in ONC (Herbst 2000)
  - ▶ Bimodal distribution with  $P_{\text{rot}} \approx 2 \text{ d}$  and  $P_{\text{rot}} \approx 8 \text{ d}$
  - ▶ Two populations due to accretion history (Meibom+ 2013)
- ▶ Not statistically significant in our data

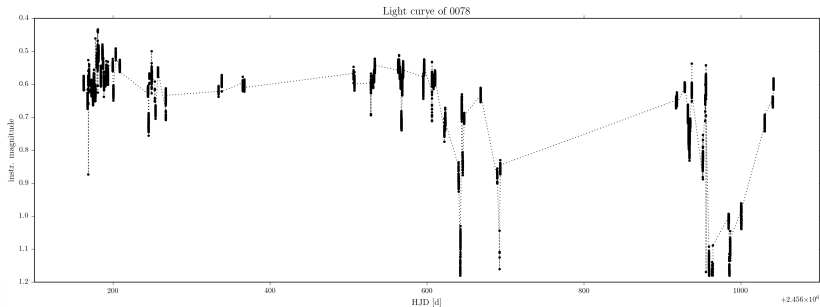
# V695 Per – An AA Tauri System

- ▶ Magnetic interactions of the disc's inner edge with the star
- ▶ Inner edge of the proto-planetary disc is warped
- ▶ Periodic occultation of the star ( $P = 7.55$  d, orbital period)



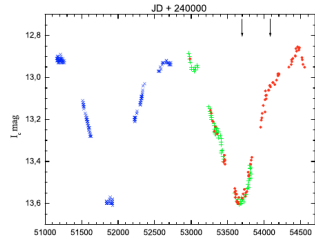
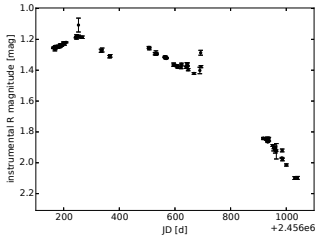
# V909 Per – An UX Orionis System

- ▶ Clumps in proto-planetary disc occult the star
- ▶ Different clump sizes → varying shape and depth
- ▶ Fading of 0.6 mag in a few days
- ▶ Two other stars in IC 348 show this behaviour (Barsunova+ 2013)

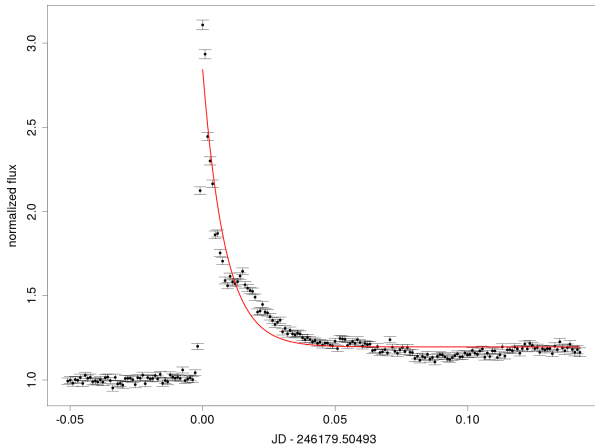


# V718 Per – An Unusual System

- ▶ Long-lasting eclipse of 3.5 yr (Nordhagen+ 2006)
- ▶ "Stable, extended, dusty structure" (Grinin+ 2008)
- ▶ Period: 4.7 yr → eclipse lasts for 75% of a cycle



# Non-periodic Variability



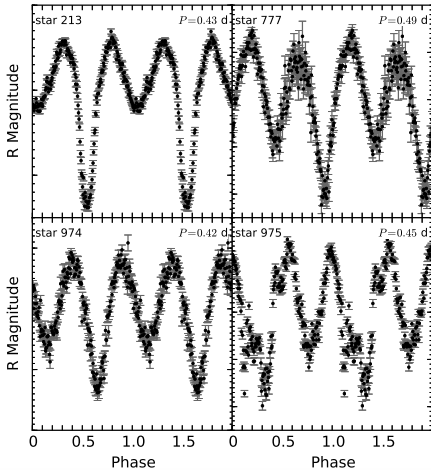
$$\Delta m \approx 1.2 \text{ mag}$$

$$\tau_{\frac{1}{2}} \approx 8.4 \text{ min}$$

# Variability Among the Field Stars

– Periodic Variability is not Limited to Open Cluster –

# W UMa Binaries and Other Variables



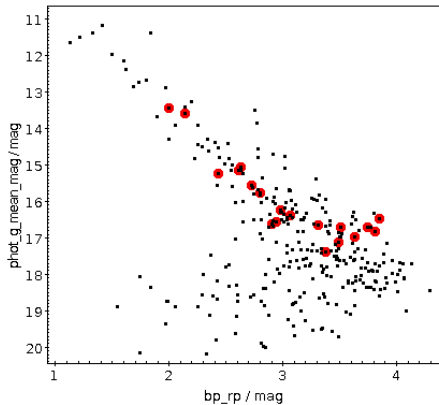
- ▶ Four contact binaries in the field identified
- ▶ All have a similar period and are background stars

# Additional members of IC 348

- ▶ Some *field* stars show fast rotation ( $P < 10$  d).
- ▶ May be additional members of IC 348.

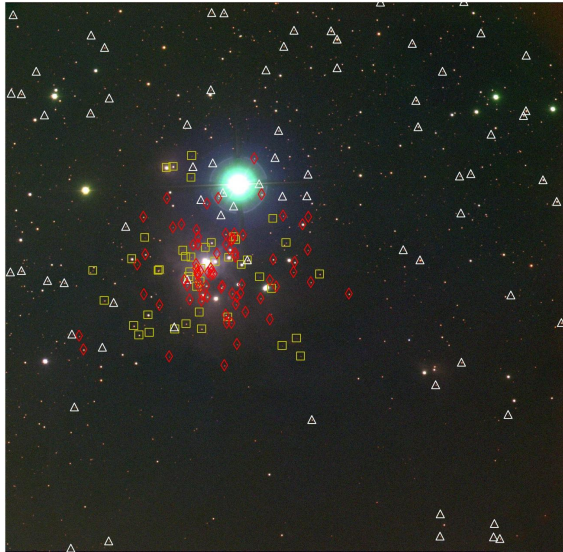


## Additional members of IC 348



- ▶ Some *field* stars show fast rotation ( $P < 10$  d).
- ▶ May be additional members of IC 348.
- ▶ *Gaia* confirms those stars as possible members.

# A Visual Summary



# Conclusion

- ▶ YETI improves the phase coverage for all periods.
- ▶ 87 periodic stars in IC 348 identified (33 new).
- ▶ Wide range of photometric variable objects detected.
- ▶ Rotation periods can identify member candidates.

# Thank You for Your Attention!

Monthly Notices

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MNRAS **462**, 2396–2417 (2016)  
Advance Access publication 2016 July 28

doi:10.1093/mnras/stw1797

## Long-term photometry of IC 348 with the Young Exoplanet Transit Initiative network

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Accepted 2016 July 20. Received 2016 July 20; in original form 2016 June 28