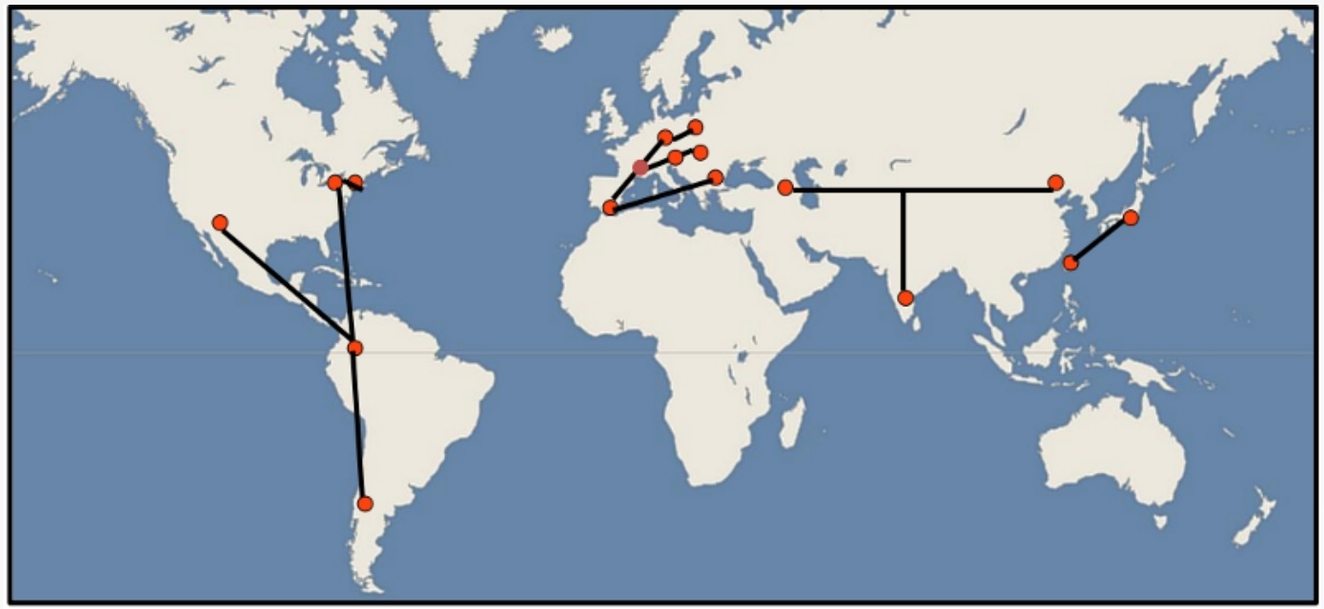


YETI observations of three young open clusters: NGC 869, NGC 884 and IC 4665

Paweł Zieliński
Warsaw University Astronomical Observatory, Poland

Outline

1. YETI network recently (2016-2018)
2. Young planets vs. open clusters studies
3. Observations of three open clusters: NGC 869 NGC 884, IC 4665
4. YETI + OPTICON network

Young Exoplanet Transit Initiative

World-wide monitoring of young open clusters to find young transiting exoplanets

Cooperation of ~20 observatories and institutes in total since 2010, ~10 observatories active recently

Project PI: Ralph Neuhäuser (AIU Jena/Germany)

Thanks to the Co-Is:

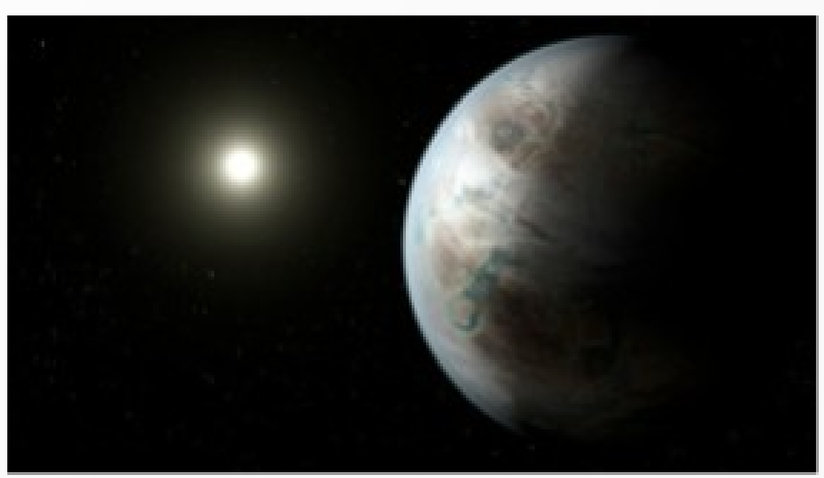
Markus Mugrauer (Jena/Germany), Stefanie Raetz (Tuebingen/Germany), Ronnie Errmann (Hatfield/UK),
Theo Pribulla, Zoltan Garai, Martin Vanko (Stara Lesna/Slovakia),
Gracjan Maciejewski (Toruń/Poland), Zhenyu Wu, Zhou Xu, Yonghao Wang (Xinglong/China),
Jan Janik (Brno/Czech Rep.), Waldek Ogłoza, Marek Dróżdż (Suhora/Poland),
Eda Sonbas (Adiyaman/Turkey), Michał Żejmo (Zielona Góra/Poland),
David Mkrtichian (NARIT/Thailand & CTIO/Chile), Santosh Joshi (ARIES Nainital/India),
Wen-Ping Chen, Po-Chieh Jason Huang (Lulin/Taiwan) and many others...

Young Exoplanet Transit Initiative

Young Exoplanet Transit Initiative

Goals of YETI network

- The main aim is to find young transiting extrasolar planets
- Studying in detail the selected eclipsing binaries, determining the orbital and physical parameters of companions (exoplanets, brown-dwarfs, low-mass stars of late spectral types)
- Investigating of other variability phenomena in selected stars on different time-scales
- Understanding the early life of planetary systems:
  - When do planets form around stars?
  - How many of them survive this early phase?
  - What is the role of environment?
  - How fast do they cool down and contract?
- Long-term goal is to test star and planet formation scenarios

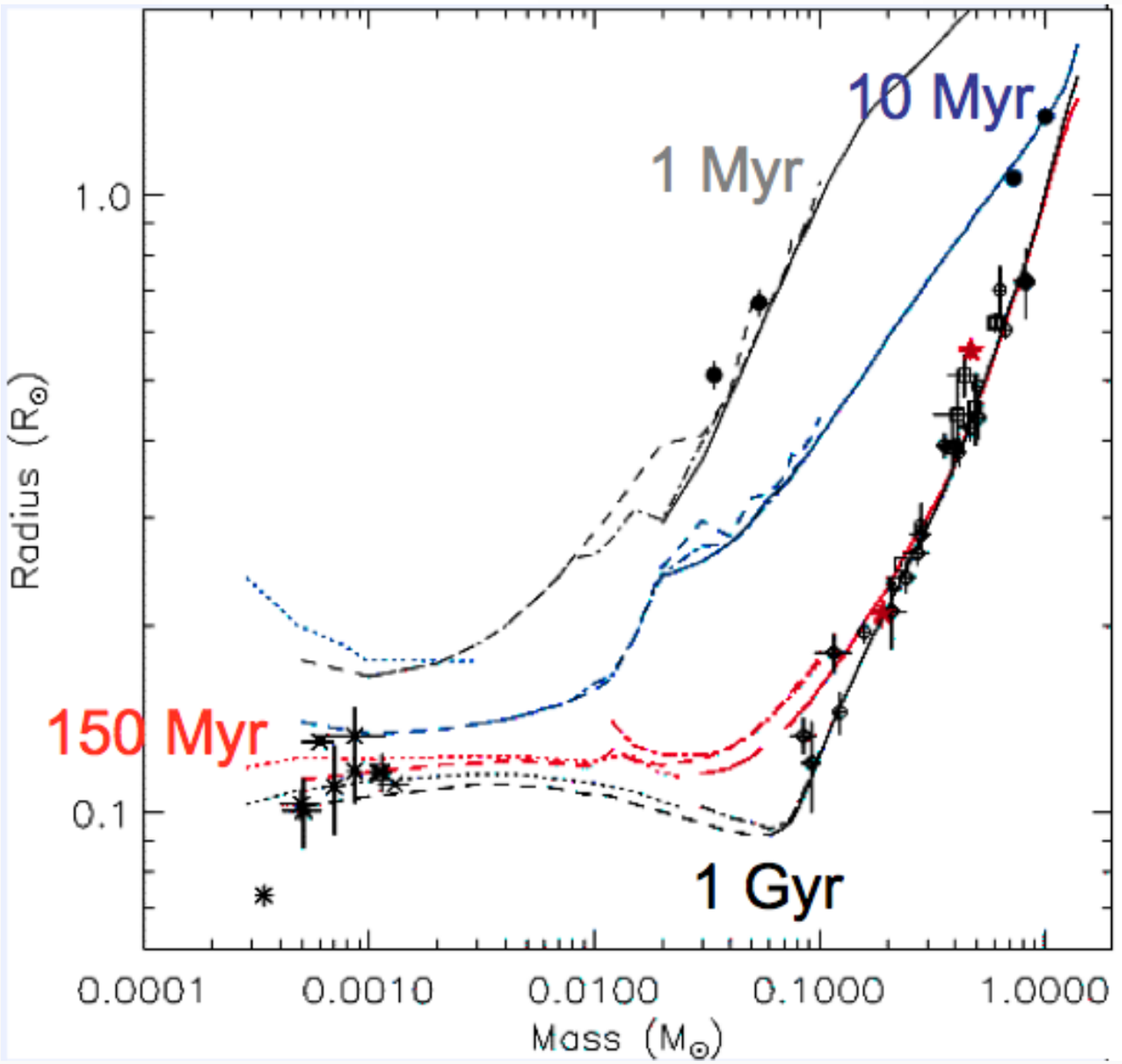


Credit: NASA Ames/JPL-Caltech/T. Pyle

M-R diagram

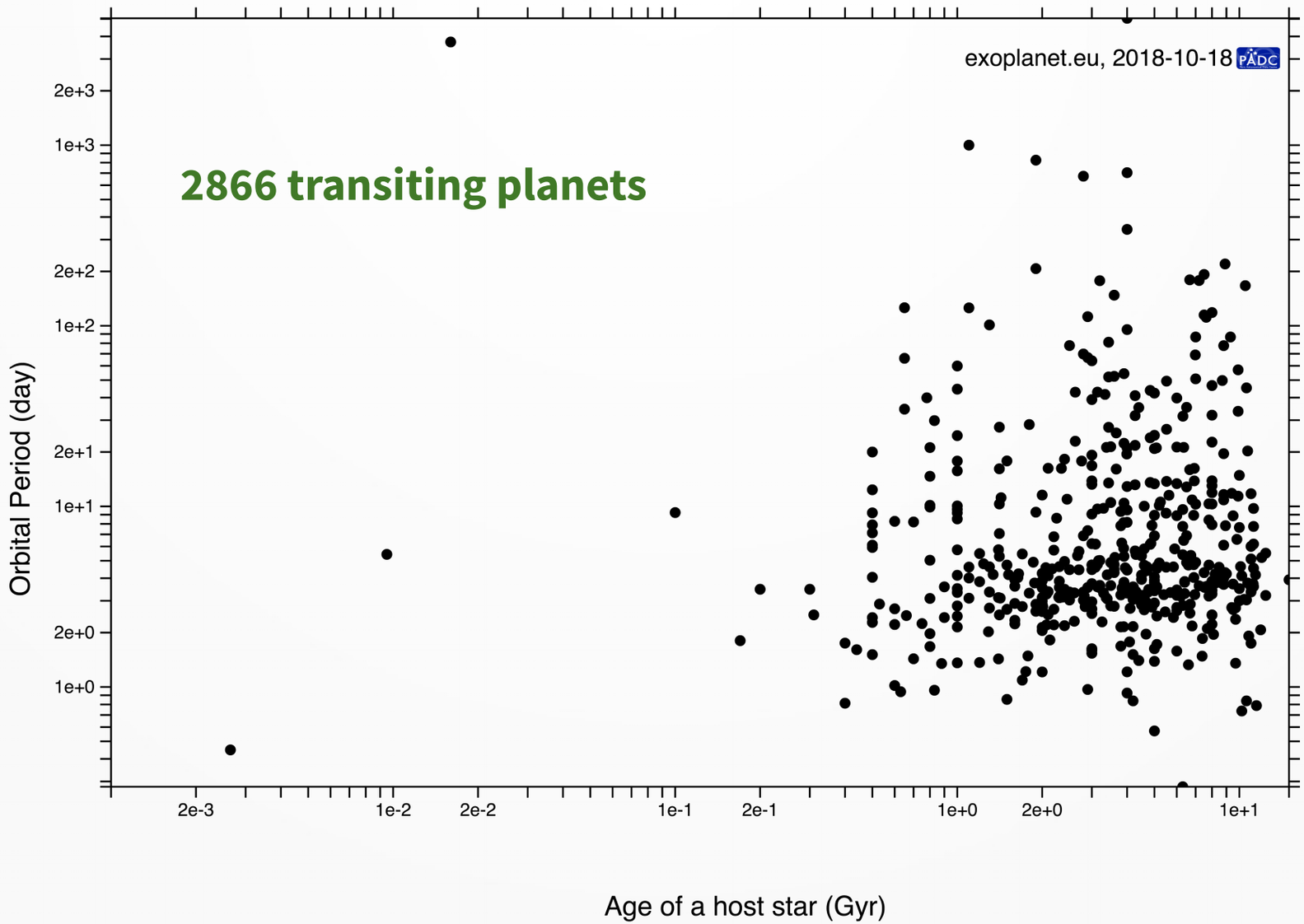
testing the evolutionary models at young ages and low masses

- very few PMS systems
- lack of objects in BD regime
- no young (transiting) planets

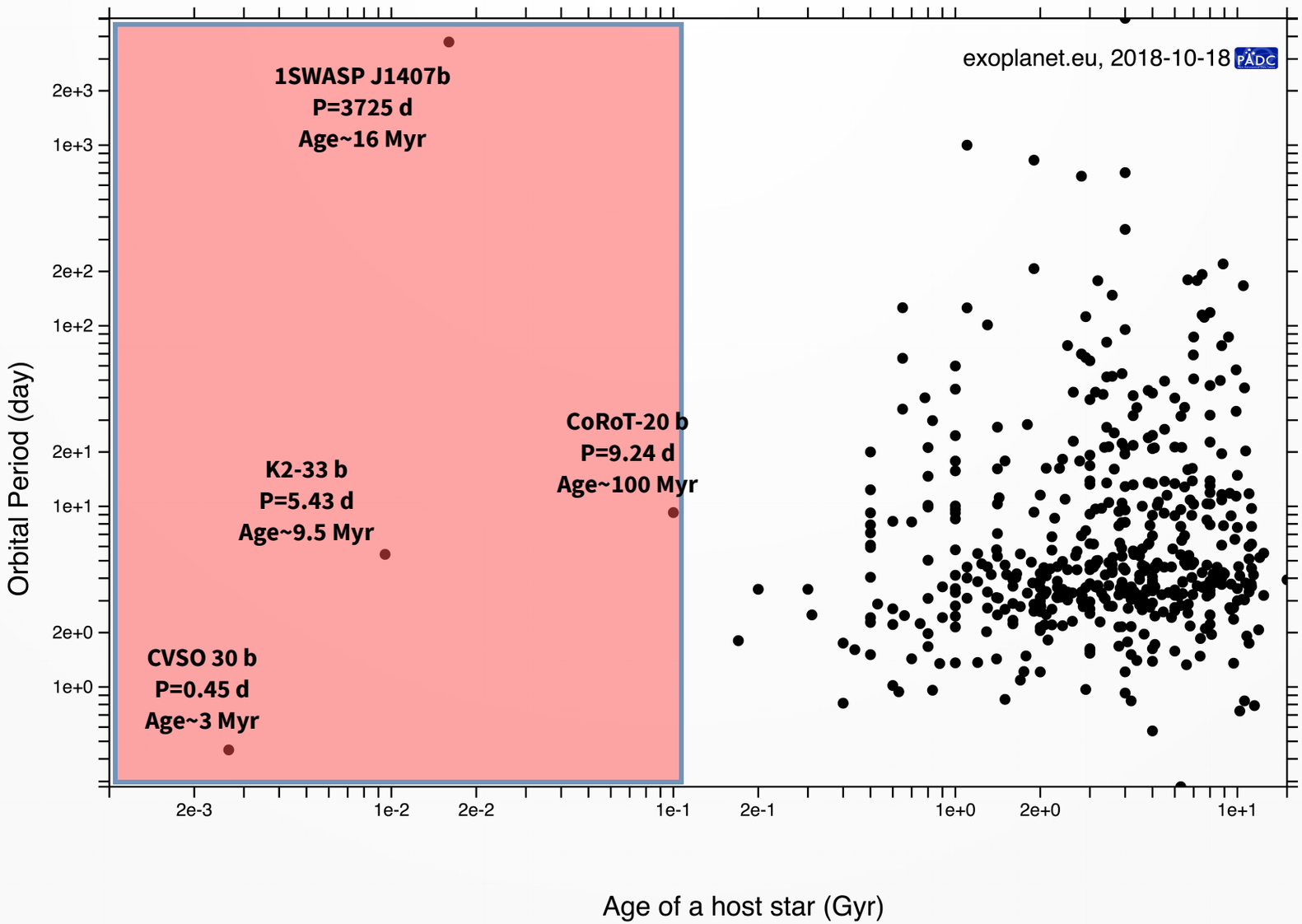


Source: E. Moraux, JENAM 2010 mini-symposium *Star clusters in the era of large surveys*

Transiting exoplanets today

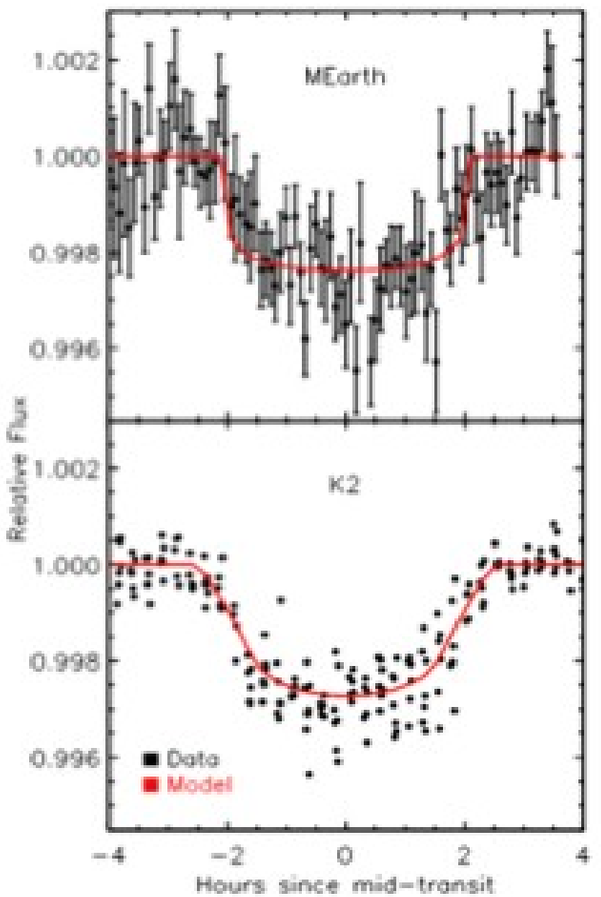


Transiting exoplanets today



Other studies

- **ZEIT (Zodiacal Exoplanets in Time)** since 2014
  Mann, Gaidos et al.
- Targets: open clusters with age of ~10-800 Myr visible for K2 (Upper Scorpius, Pleiades, Hyades, M67, Ruprecht 147 and Praesepe)
- Observations made by Kepler-2
- Results: 14 planetary systems until now



Upper Scorpius OB association (~11 Myr):
K2-33 b, r'=14.9 mag, R=5 Rearth, P=5.4 d

Mann et al. 2016, AJ 152, 61

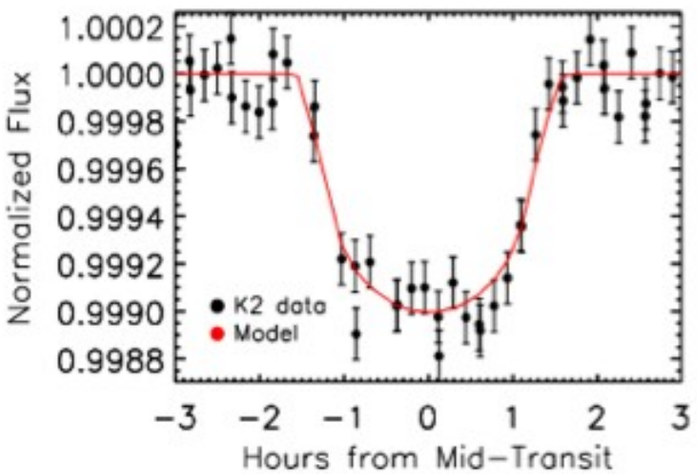


Figure 8. Phase-folded light curve of EPIC 210363145 (black) from K2. The best-fit (highest likelihood) transit model is shown in red.

Pleiades (~110 Myr):
EPIC 210363145, V=12.2 mag, R=2.3 Rearth, P=8.2 d

Gaidos et al. 2017, MNRAS 464, 850

Other studies

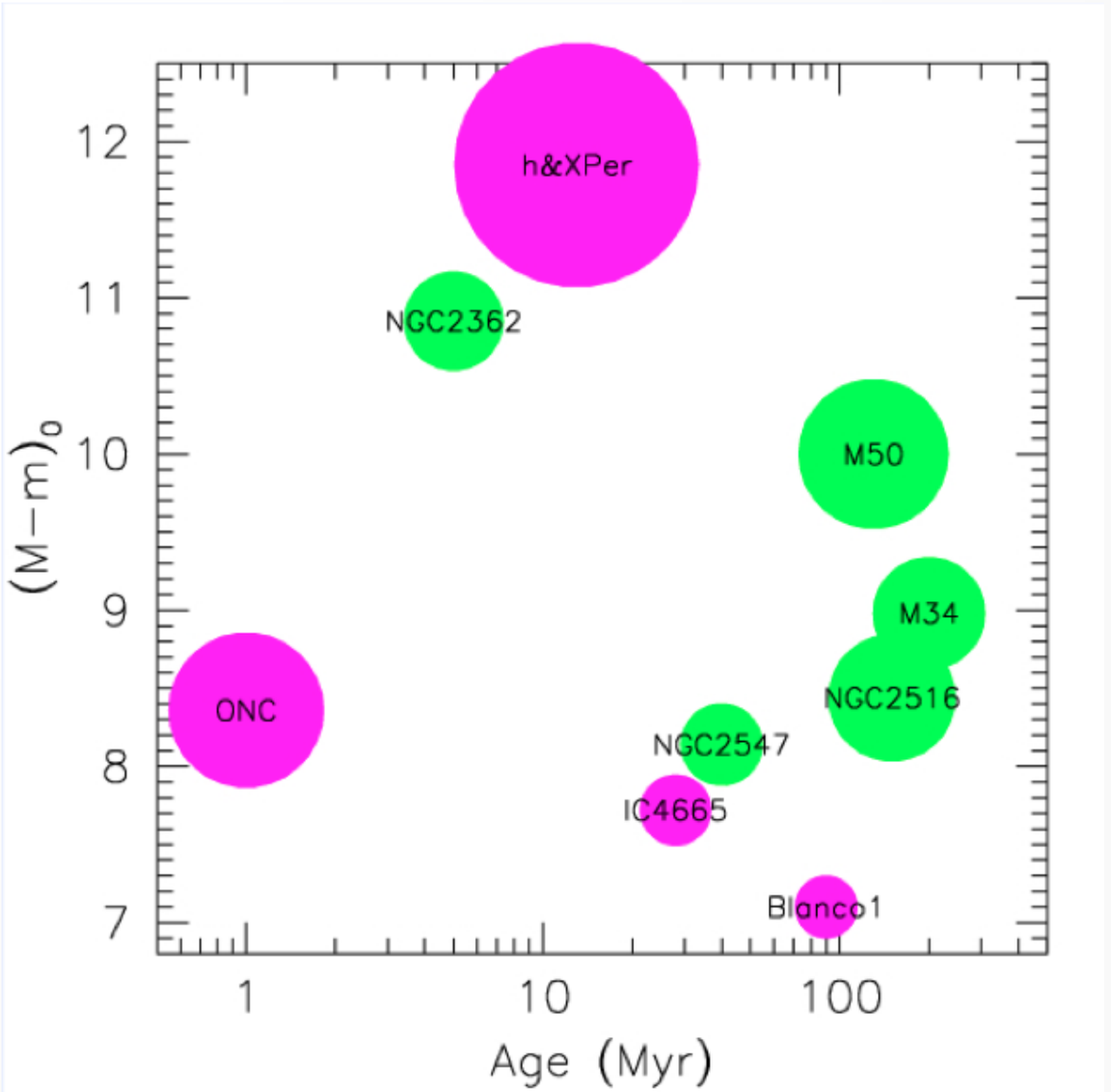
- **Monitor project**
  2005-2013
  Aigrain, Hodgkin, Irwin, Moraux et al.

- Targets: 10 open clusters younger than 200 Myr

- Observations made by 2-4 m class telescopes:
  2.5 m INT, 4 m Blanco/CTIO, 3.6 m CFHT, 4 m Mayall/ KPNO

- Results:
  several transit-like signals but with no planetary confirmation, several low-mass eclipsing binaries, detailed rotation period studies for cluster stars

- Data partly published



What can we detect?

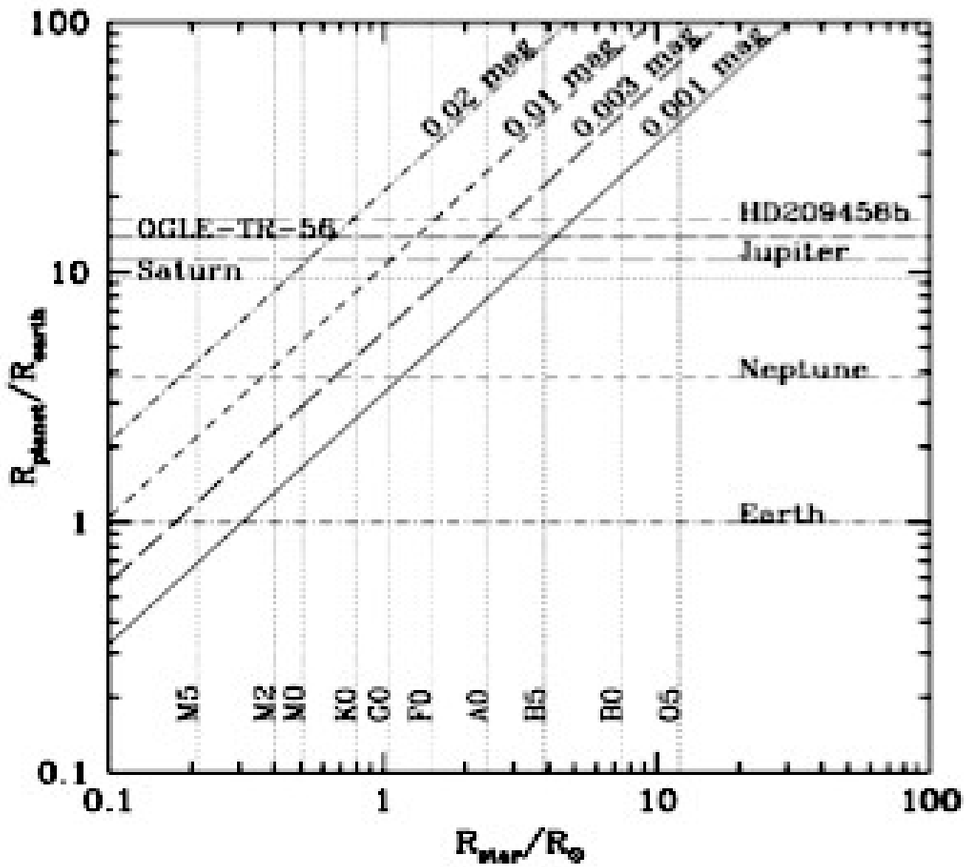


FIG. 1.—Depth of transit signal for transiting planets with different radii as a function of MK spectral type and corresponding stellar sizes (from Cox 2000) based on geometric arguments only. The diagonal lines indicate the amplitude of the transit signal in the light curve of a given planet-star combination. For instance, a Jupiter-sized planet would cause a 0.01 mag dip in the light curve of a G0 star, but only a 0.003 mag dip in the light curve of an A0 star.

von Braun et al. 2005, PASP 117, 141

List of YETI clusters

Open cluster	RA [h:m:s]	Dec [° : ’ : ”]	Monitoring dates (start - end)	Age [Myr]	D [pc]
Trumpler 37	21:39:00	57:29:24	2009 Aug - 2011 Sep	~4	870
25 Ori	05:24:45	01:50:47	2010 Oct - 2013 Feb	7-10	323
IC 348	03:44:34	32:09:48	2012 Sep - 2014 Nov	~2	316
Collinder 69	05:35:06	09:56:00	2012 Nov - 2015 Feb	~5	400
NGC 1980	05:35:24	-05:54:54	2013 Feb - 2015 Feb	4-5	400
NGC 7243	22:15:08	49:53:54	2013 Aug - 2015 Nov	~76	750
NGC 869	02:19:00	57:07:42	2016 Oct - 2018 Jan	12	2079
NGC 884	02:22:18	57:08:12	2016 Nov - 2018 Feb	11	2345
IC 4665	17:46:18	05:43:00	2017 May - 2018 Jul	43	352

Selected targets

Open cluster name	Central coordinates J2000.0 RA [h : m : s]	Dec [° : ’ : ”]	Age [Myr]	Distance [pc]	V [mag]	Angular radius of the cluster [deg]	No. of member stars
h Per (NGC 869)	02:19:00	+57:07:42	12	2079	4.9	1.75	~3000
χ Per (NGC 884)	02:22:18	+57:08:12	11	2345	5.7	1.75	~2300
IC 4665	17:46:18	+05:43:00	43	352	4.2	1.00	382

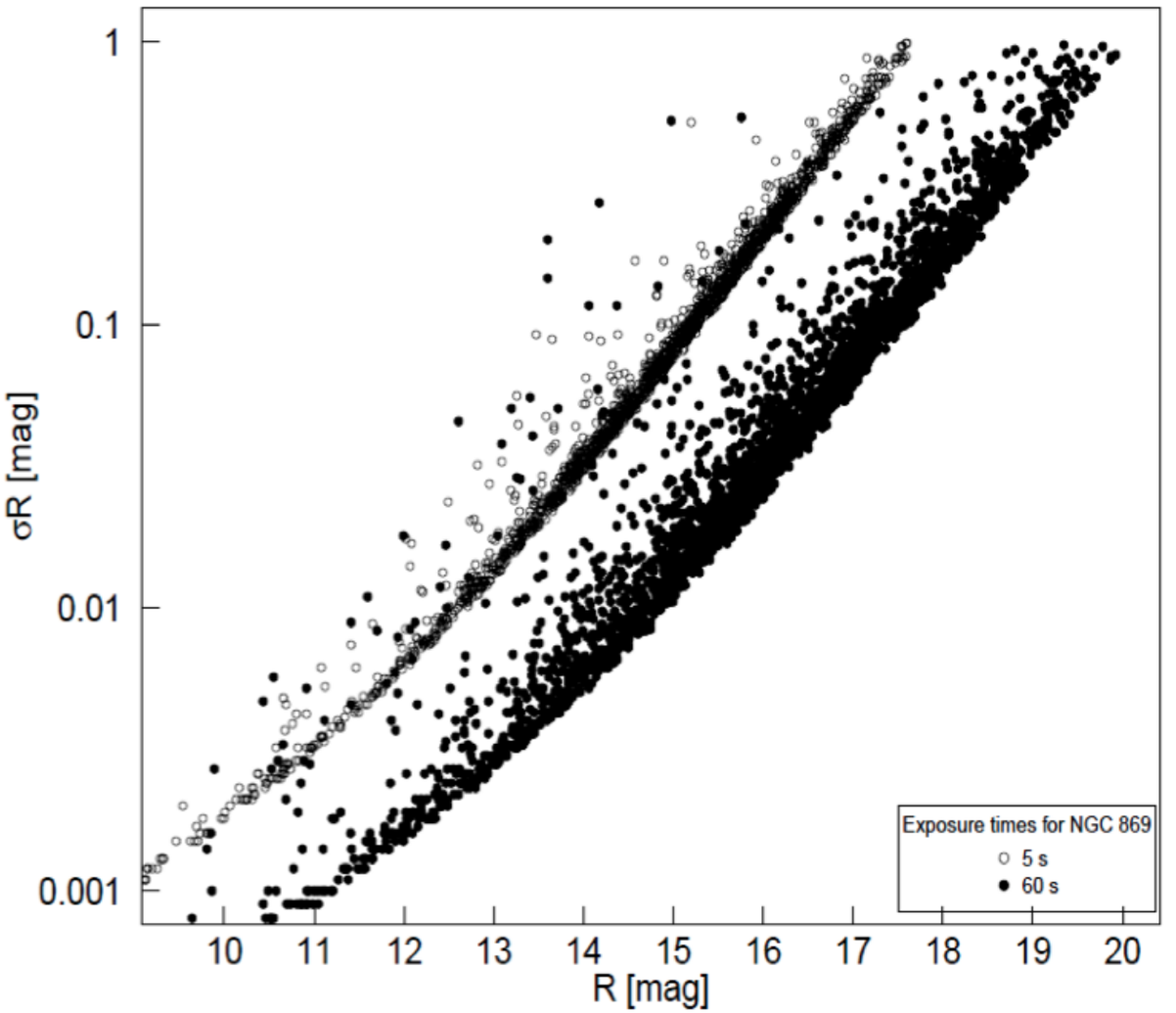
Credit: V. Wendel, J. Popsel, S. Binnewies

Credit: DSS

Observational strategy

- **Photometric monitoring:**
- By using YETI network facility – 1 meter-class telescopes (enough observing time guaranteed)
- 2-3 runs per year per cluster, two weeks long
- CCD observations only with R filter, also in UBVI bands outside campaigns
- Alternating short and long exposures to accommodate bright and faint stars in the clusters
- Aperture and differential photometry
- Analysis of variable objects –

  we are able to detect of any transit with a depth of at least ~5 mmag rms down to R = 14 mag, and ~50 mmag rms down to R = 16 mag stars



Data from 0.6 m telescope at Mt. Suhora Observatory

Summary of observations

NGC 869		
Telescope	**N nights**	**Volume GB**
Jena 0.9 m/STK	36	177,48
Jena/CTK-II	51	27,01
Suhora 0.6 m	27	36,45
Toruń 0.6 m	2	1,16
Stara Lesna 0.6 m	14	21,05
Adiyaman 0.6 m	17	10,74
Lulin 1 m	4	7,03
TOTAL	**151**	**280,92**

Campaign	Dates
C1	21.10-04.11.2016
C2	21.01-04.02.2017
C3	12-26.10.2017
C4	10-24.01.2018

Summary of observations

NGC 884		
Telescope	**N nights**	**Volume GB**
Jena 0.9 m/STK	36	177,48
Jena/CTK-II	51	27,01
Suhora 0.6 m	20	18,91
Toruń 0.6 m	4	3,39
Stara Lesna 0.6 m	10	14,44
Adiyaman 0.6 m	25	18,05
TOTAL	**146**	**259,28**

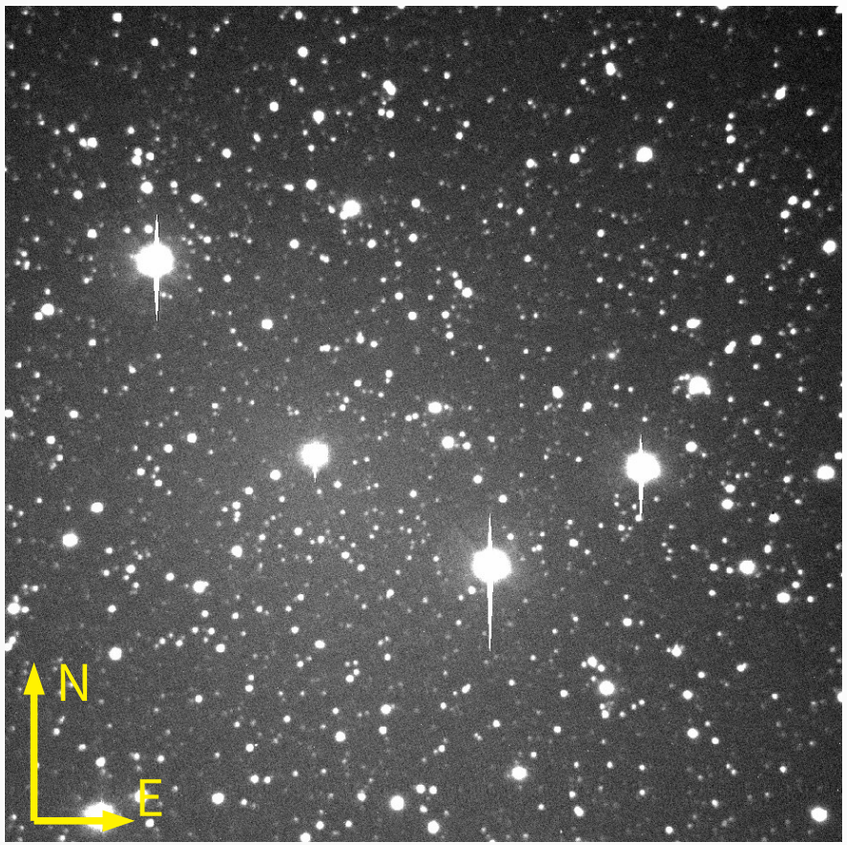
Campaign	Dates
C1	20.11-04.12.2016
C2	19.02-05.03.2017
C3	13-27.09.2017
C4	11-25.11.2017
C5	08-22.02.2018

Summary of observations

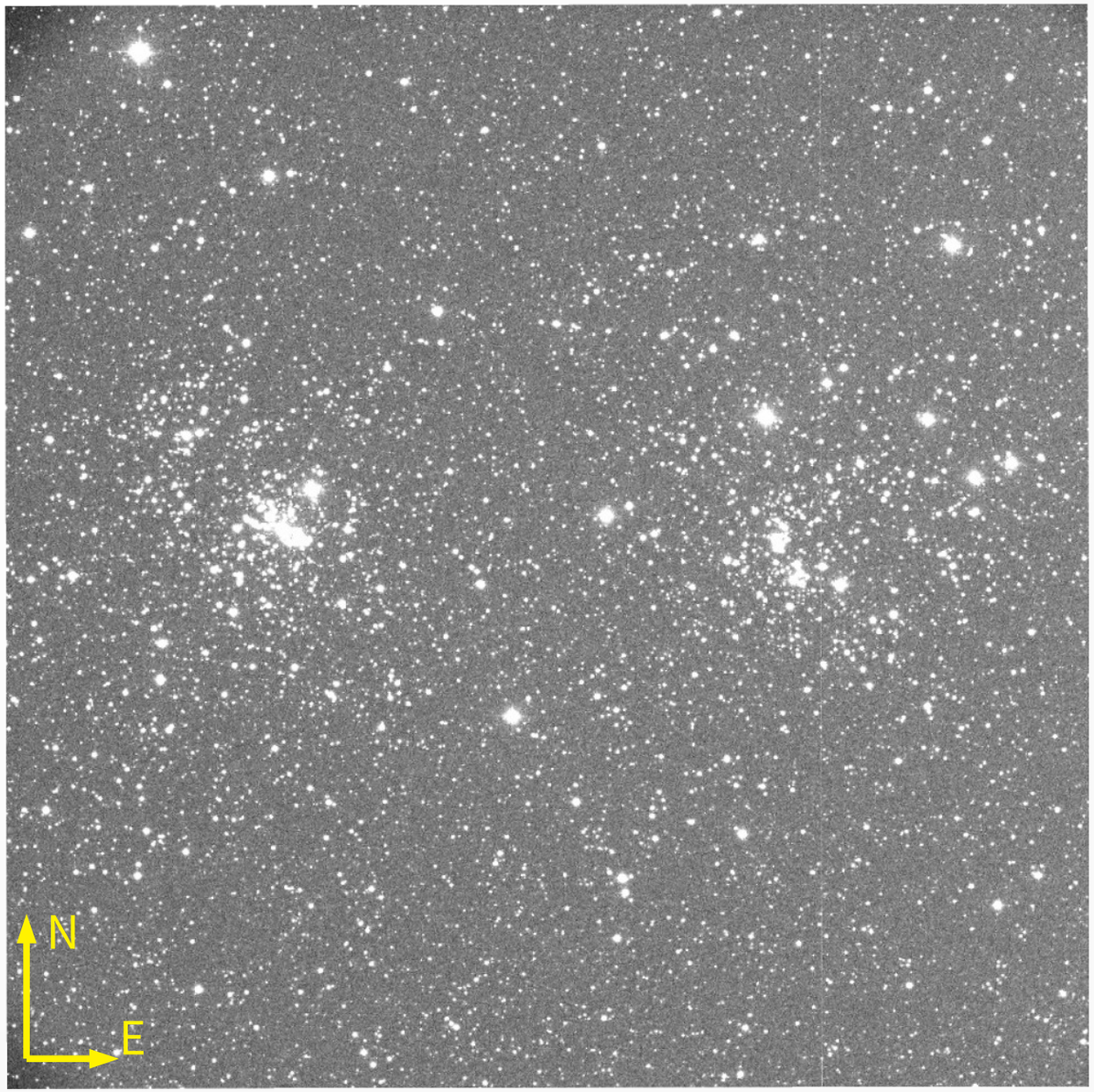
IC 4665		
Telescope	**N nights**	**Volume GB**
Jena 0.9 m/STK	71	108,59
Jena/CTK-II	61	18,15
Suhora 0.6 m	39	10,93
Stara Lesna 0.6 m	18	14,43
Adiyaman 0.6 m	49	26,31
CTIO/Prompt8 0.6 m	7	28
Nainital 1.3 m	1	1,53
Xinglong 0.9 m	14	65,04
TOTAL	**260**	**272,98**

Campaign	Dates
C1	18.05-01.06.2017
C2	17.06-01.07.2017
C3	16-30.07.2017
C4	08-22.05.2018
C5	06-20.06.2018
C6	06-20.07.2018

Summary of observations



IC 4665, Suhora 0.6 m telescope, FoV = 11x11 arcmin

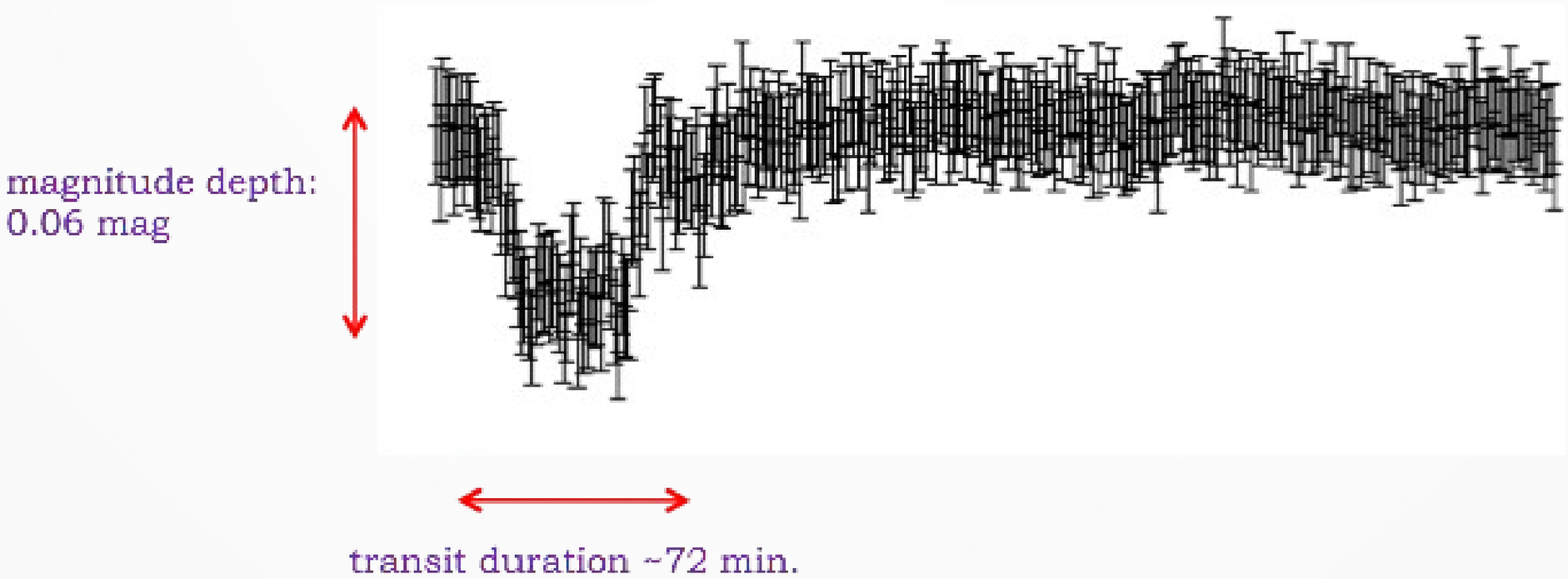


NGC 869 & NGC 884, Jena 0.9 m telescope, FoV = 53x53 arcmin

Some promising candidates...

Data from 0.6 m telescope at Stara Lesna Observatory

σR ~0.01 mag

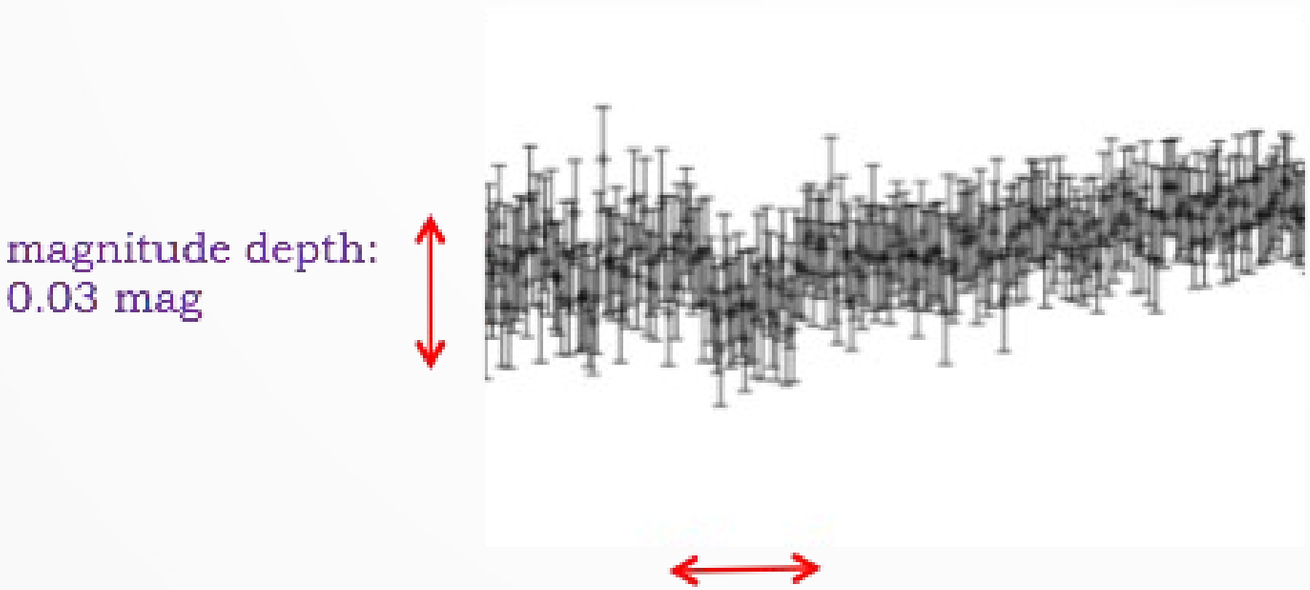


Star 197 in NGC 869

Some promising candidates...

Data from 0.6 m telescope at Stara Lesna Observatory

σR ~0.015 mag



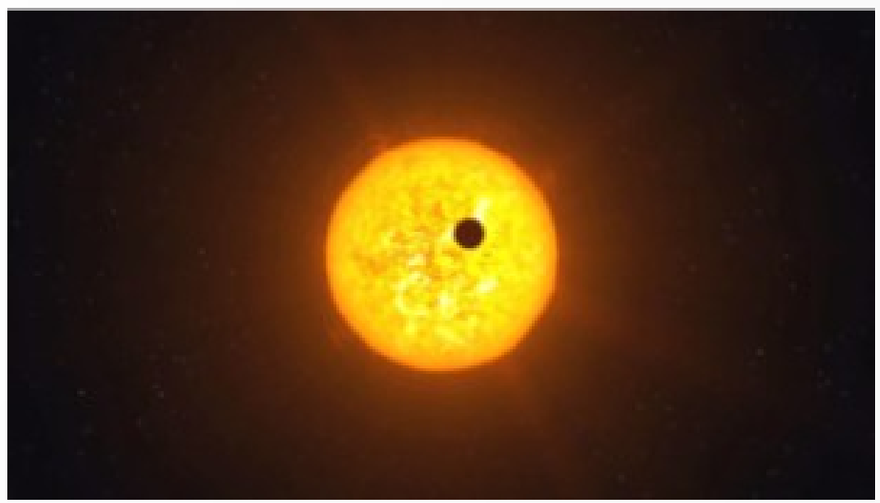
Star 223 in NGC 869

To do list...

- Work in progress!!!
- A few interesting targets visible, but periods not known yet
- Finishing data reduction from all observatories
- Using archival data for clusters – Białków Observatory (Poland), Monitor project etc. (???)
- Period analysis, modelling of light curves
- Preparation of final list of planet candidates as well as other interesting objects
- Multiband photometric observations of selected candidates to improve light curve and orbital periods
- Follow-up spectroscopy in low-resolution (classification) and high-resolution (RV variations), and AO imaging (to exclude brightness changes from other sources within PSF)
- Some other ideas?

Expected results

- **at least 3 new young transiting planet candidates** (Neuhäuser et al. 2011, AN 332, 547)
- **several eclipsing brown dwarf or low-mass star candidates in each cluster**
- **photometric precision for the typical 1 meter-class telescope of the YETI network allows for transit detection of Jupiter-size planets at close-in orbits with periods up to ~30 days**
- **hundreds of new variable and active stars, study of rotation periods distribution**
- **only for Trumpler 37: 400 new variables including eclipsing binaries, flaring stars, tens of rotating and pulsating stars with periods between 1h – 300 d, many T Tauri stars, irregular variables, etc.** (Errmann et al. 2014, AN 335, 345)



Credit: ESO/L. Calçada

YETI + OPTICON network

- Optical Infrared Coordination Network for Astronomy

  Horizon 2020

- http://www.astro-opticon.org/

OPTICON – Time Domain Astronomy

- Networking Activity WP13: Time Domain Astronomy
- networking (workshops)
- coordination of scientific goals in time domain
- support in observations and data processing
- observing trips
- robotic telescopes in TNA support

OPTICON follow-up network

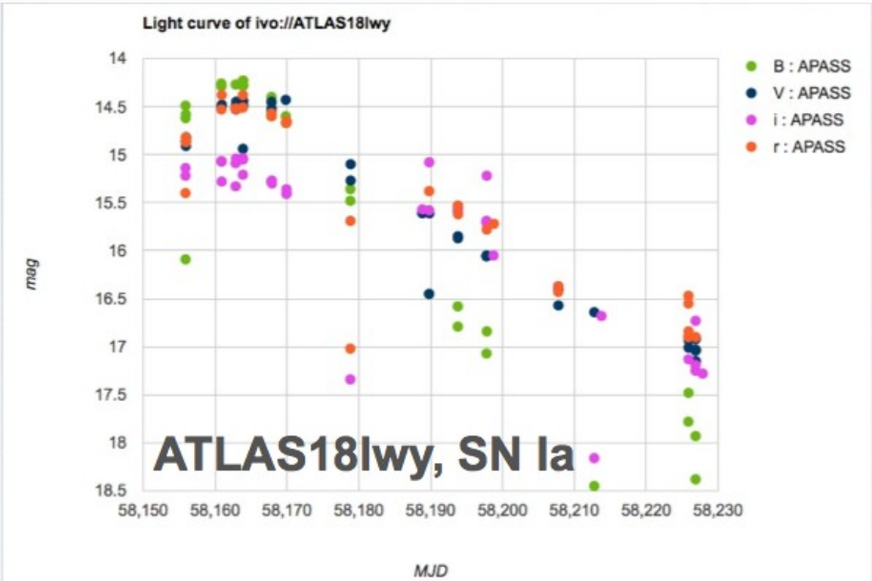
How does it work?

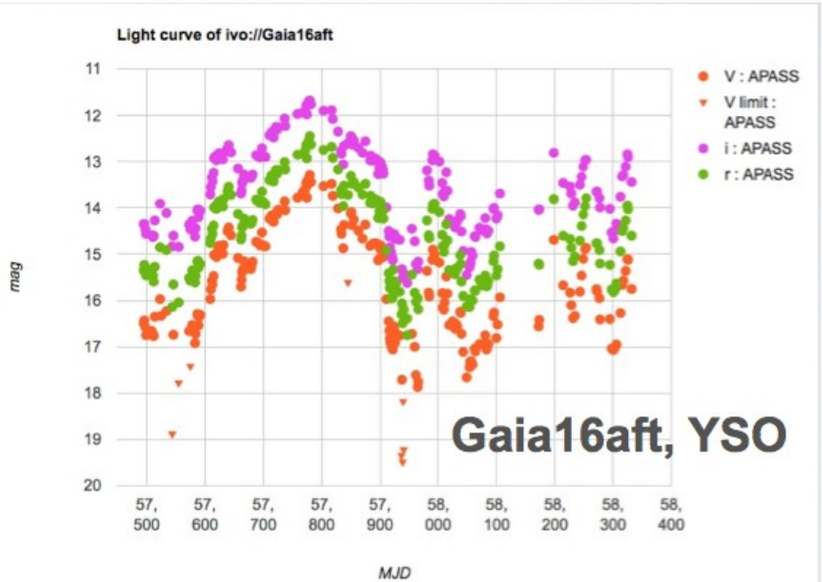
- data from Gaia, ASAS-SN arrives, alert candidates published
- interesting targets identified (microlensing, TDEs, SNe, CVs, transiting planets?, etc.)
- information on the mailing list:

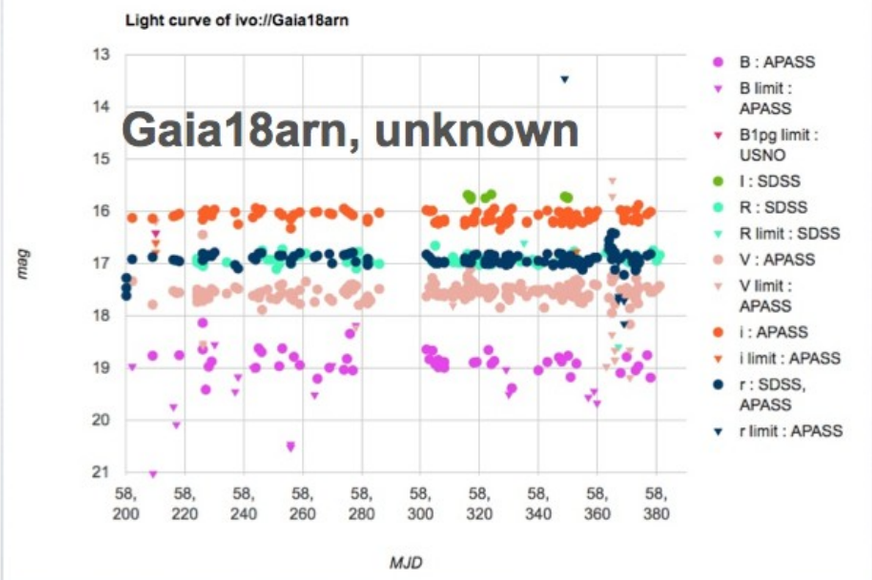
  Gaia Science Alerts Working Group #10 - Photometric Follow-up

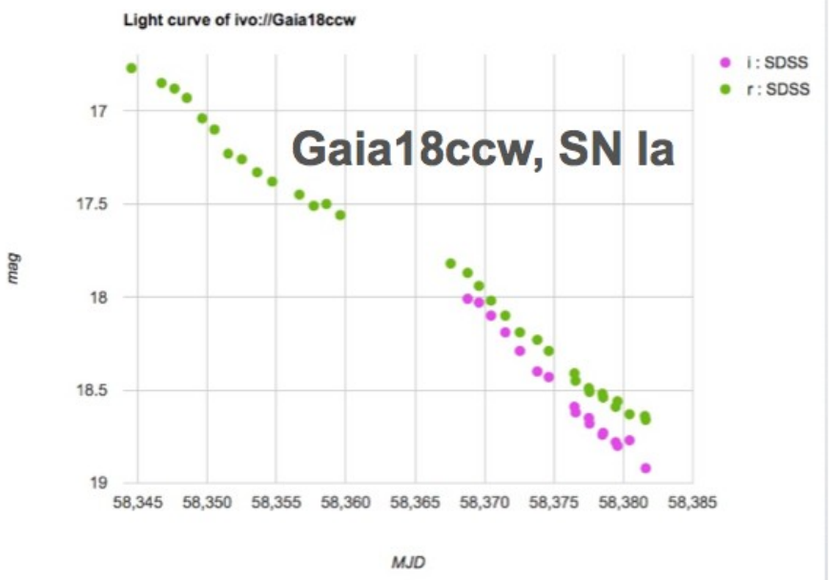
- observers monitor the targets
- follow-up observations going to the Cambridge Photometric Calibration Server

How does it work?

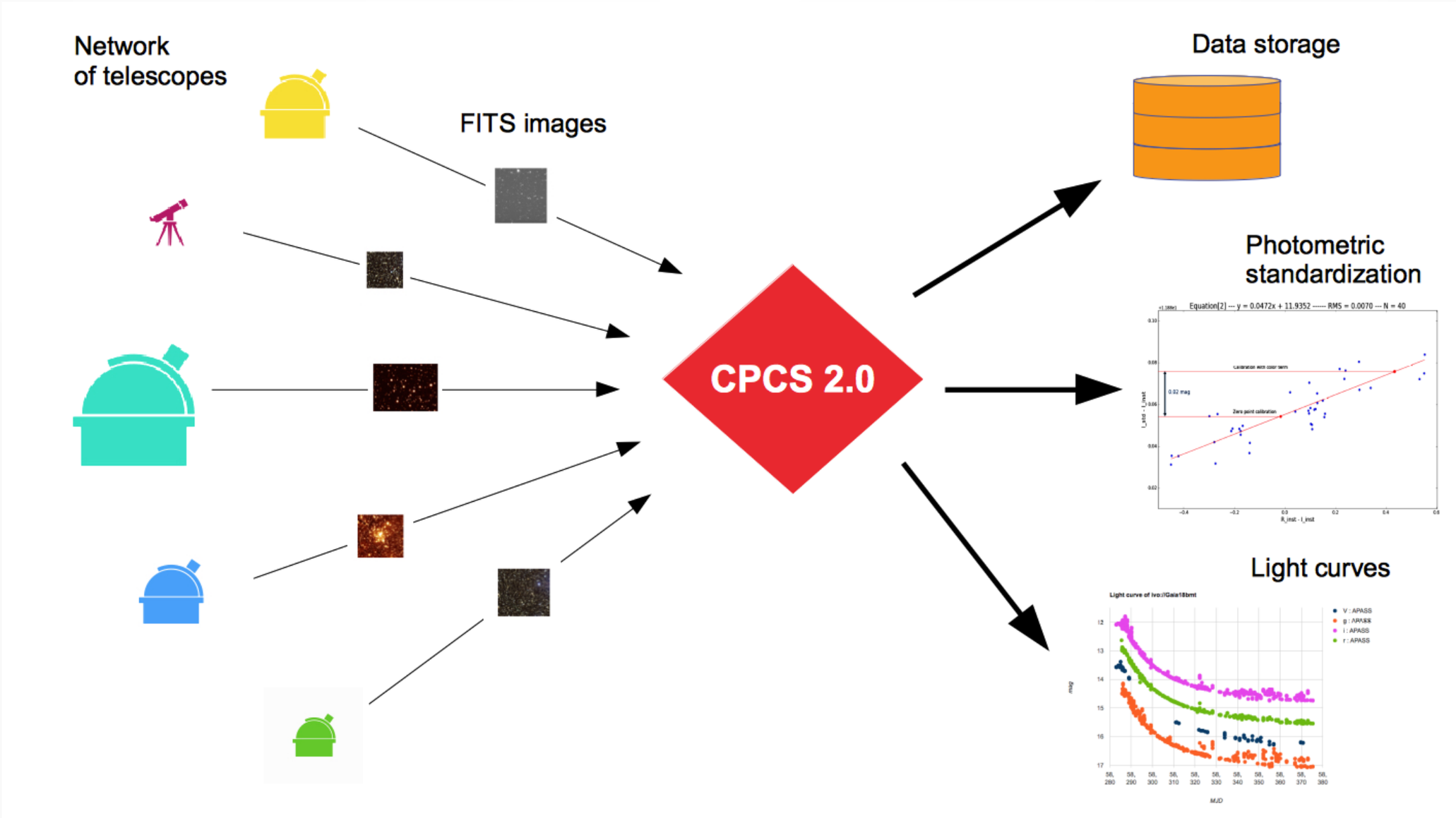








Cambridge Photometric Calibration Server 2.0



YETI + OPTICON network

- Follow-up of planet candidates (photometric and spectroscopic)
- Photometric calibration of observations by using CPCS 2.0 (differential photometry for transit-like signals)

- Feel invited to cooperation in the follow-up network!

- Join our mailing list GSAWG#10 - Photometric Follow-up

contact **Łukasz Wyrzykowski**: lw@astrouw.edu.pl

- You can use it for your own research independently!

Thank you!

Paweł Zieliński
pzielinski@astrouw.edu.pl