

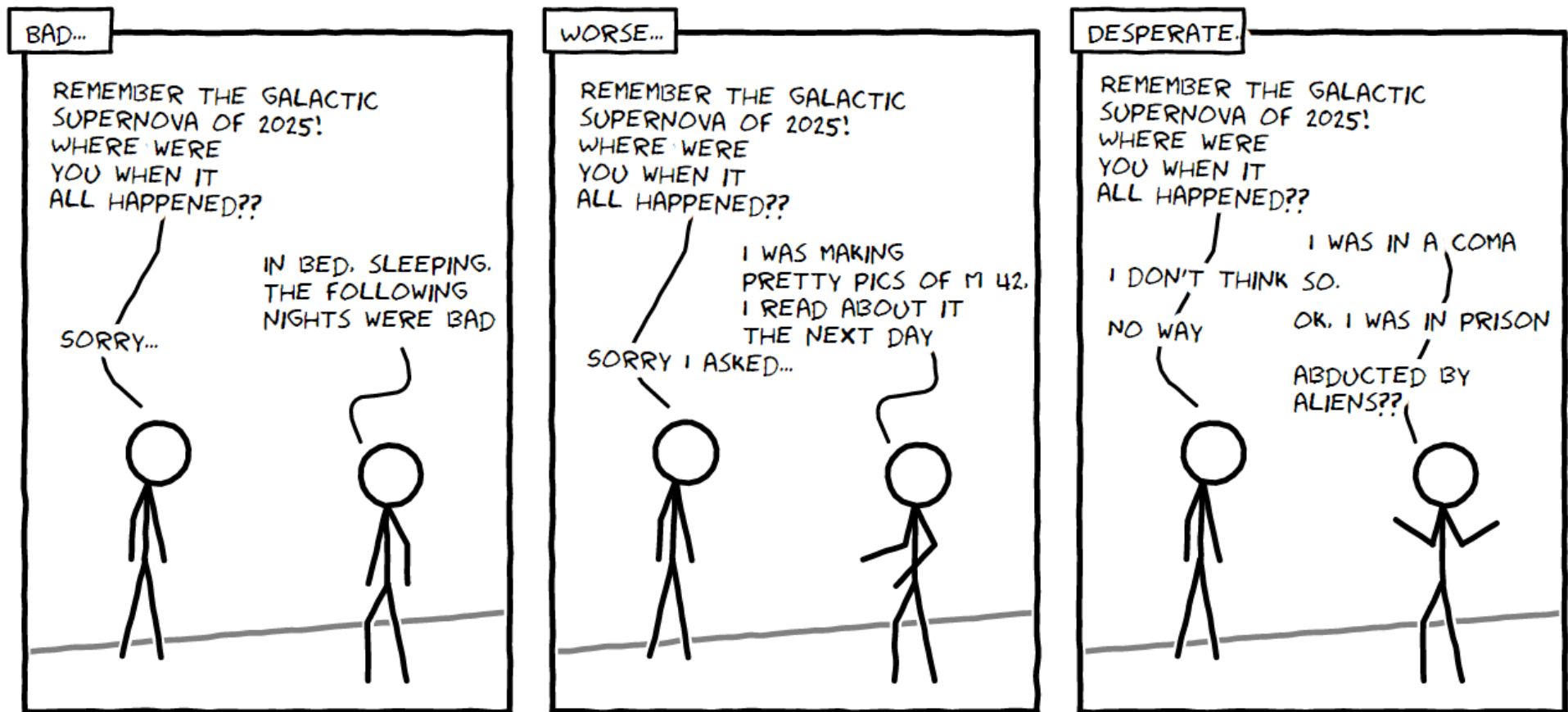
# Public alerts : Amateur Astronomy MMA

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Done with cmx.io . For the real XKCD stuff, go to [xkcd.com](http://xkcd.com)

# Overview

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- Definitions: Amateur astronomy
- **What** could amateurs possibly do for multi-messenger astronomy?
- **How** to connect professional and amateur astronomers?
- **Where** to go from here? Action items.

# Overview

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- **Definitions: Amateur astronomy**
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# Definition: Amateur Astronomer

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I will use the term “Amateur Astronomer” to mean this:  
(others are free to use the term differently)

- *Someone not being paid* for doing astronomy (also not in the process of being trained to become a professional astronomer one day)
- But still following the *scientific method*

The term “amateur” is ***not*** used to classify people based on

- Education
- Type of equipment used
- “Pretty Picture” Amateur Astrophotography  $\neq$  Amateur Astronomy
- “Stargazing”  $\neq$  Amateur Astronomy
- This talk focuses on *observing astronomy*, but data-analysis and data-mining in archival data is astronomy as well!

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# Astronomy Messengers and Amateur observations

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## **As of 2022:**

- Terrestrial observations only
- Electromagnetic spectrum
  - ✓ Optical wavelengths
    - ✓ ~ 350 nm to ~ 1100 nm  
( UBVRI filter passbands )
      - ✓ Photometry
      - ✓ Astrometry
      - ✓ Spectroscopy

# Astronomy Messengers with Amateur observations

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## As of 2022:

- x Obviously not within amateur observation reach:
  - x Neutrinos, gravitational waves, gamma rays, X-rays
- What about radio astronomy?
  - Very few groups, not considered in this talk,  
e.g.  
*Astroteiler Stockert e.V.*  
(25m “vintage” radio dish)



## As of 2022:

- What about radio astronomy?
  - Off the shelf amateur radio telescope e.g. by Radio2Space (Italy)
  - e.g. 3m dish, receiver , 1024 channels, opt. for 1.4Ghz for ca 50.000 €/US-\$
  - But useful for science???
  - (except training perhaps)





## As of 2022:

- What about cosmic rays?
  - A few project ideas on muon detectors:
  - perhaps possible and useful?
  - E.g. “Cosmic Ray Extremely Distributed Observatory (CREDO)” (smartphone cameras as detectors)
  - E.g. cosmic-pi ([cosmicpi.org](http://cosmicpi.org)),
    - reached prototype stage,
    - but currently project is paused
    - Design: scintillator with Si-photomultiplier

# Economics of optical telescopes

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- Scaling of capabilities with budget (rule of thumb)
- Optical, terrestrial telescopes
  - O(0.3k €/\$/£) : toy/recreational,  $D \sim O(100\text{mm})$ , ( $\Rightarrow A : 0.008\text{m}^2$ )  
science: visual photometry
  - O(3k EUR) : modest amateur ,  $D \sim O(200\text{mm})$ , ( $\Rightarrow A : 0.03 \text{ m}^2$ )  
science: digital photometry, time series, very low-res spectroscopy
  - O(30k EUR): ambitious amateur/semi-professional/low end professional, academic (training) equipment  $D \sim O(400\text{mm})$ , ( $\Rightarrow A: 0.13 \text{ m}^2$ )  
science: deep photometry/hi-res spectroscopy
  - O(300k EUR): low to mid size professional, “crazy” amateurs,  $D \sim O(1 \text{ m})$  ( $\Rightarrow A=0.8\text{m}^2$ )
  - O(3 M EUR): observatories with dedicated staff  
....
  - O(3 G EUR): Next generation giant telescope ,  $D \sim 40 \text{ m}$  ,  $A: 1260\text{m}^2$

# Small aperture professional science

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Professional science done with “small” apertures

- TESS (~0.1m aperture per camera)
- KELT (Kilodegree Extremely Little Telescope)  
(Ohio State University, Vanderbilt U., Lehigh U, SAAO)  
0.042 m aperture)
- ASSASN (e.g. “Brutus” & “Cassius”): consumer-off-the-shelf Nikon telephoto lens, 0.14m aperture

# Amateur equipment: The CCD/CMOS revolution

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- Let's see what a relatively low cost CMOS astronomy camera can do (random example, no recommendation):
- (ZWO ASI 294mm-pro, all specs according to manufacturer)



Price tag: ~ 1500 EUR/\$



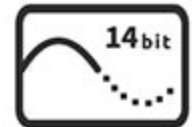
Sensor  
IMX492



4/3"  
19.1\*13.0mm



Resolution  
4144\*2822



ADC  
14bit



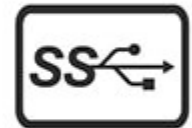
Read noise  
1.26-8e



Cooling Tempe  
35°C



DDR3 Buffer  
256MB



USB  
3.0



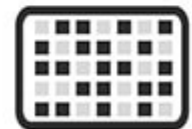
FPS  
16.3



Full Well  
66ke



QE  
about 90%



Pixel Size  
4.63µm

# Amateur use of data reduction software

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- Big change in the past several years:
  - Move away from obscure and semi-obscure packages like IRAF
  - Democratization of pipelines: open data/open software
  - Python and Jupyter notebook
  - Also good homegrown s/w by amateurs like LesvePhotometry, Peranso (period analysis for time domain photometry)
- Cloud-driven tools usable by amateurs
  - Photometry: VPHOT by AAVSO
  - Astrometry: [nova.astrometry.net](http://nova.astrometry.net)
  - CDS Catalogs
  - ...

# Case Study: GW170817/GRB170817A/ AT2017gfo

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- First multi-messenger-observed Binary Neutron Star merger (GW,  $\gamma$ , optical, X-ray, radio...)
- Timeline [1]:
  - **2017-08-17 12:41 UTC**: gravitational wave merger time
  - Ca 1.7s later: GRB trigger time
  - First “good” sky localization from three GW detectors: **17:54:51 UTC**
  - Optical counterpart imaged in NGC 4993 (const. Hydra): **Aug 17, 23:50 UTC with a 40 cm aperture telescope (a bit earlier also by a 1m telescope)**
  - No other observations of NGC 4993 at sufficient depth available for several nights before that.

[1] Multi-messenger Observations of a Binary Neutron Star Merger,  
B. P. Abbott et al, 2017 ApJL 848 L12

# Case Study: GW170817/GRB170817A/ AT2017gfo

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- Amateur Astronomers' contributions to this effort:

NONE

- Why? Because there was no public alert!
- NGC 4993 was still up at ~ 40deg altitude in the night sky at time of skymap ~~publication~~ distribution in western parts of Southern Africa
- **Missed chance? We will never know.**

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# Example: Kilonova-Catcher project

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- Gravitational wave triggers are now public.
- How to get amateurs to help find their optical counterparts?  
<http://kilonovacatcher.in2p3.fr/>



**KILONOVA** CATCHER

THE GRANDMA CITIZEN SCIENCE WEBSITE ON GRAVITATIONAL WAVE ASTRONOMY.  
SUPPORTED BY [GRANDMA](#) AND [UNIVERSITÉ DE PARIS](#).

# Example: Kilonova-Catcher (KNC) project

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JOURNAL ARTICLE

## GRANDMA observations of ZTF/*Fink* transients during summer 2021

V Aivazyan, M Almualla, S Antier, A Baransky, K Barynova, S Basa, F Bayard, S Beradze, D Berezin, M Blazek, D Boutigny, D Boust, E Broens, O Burkhonov, A Cailleau, N Christensen, D Cejudo, A Coleiro, M W Coughlin, D Datashvili, T Dietrich, F Dolon, J-G Ducoin, P-A Duverne, G Marchal-Duval, C Galdies, L Granier, V Godunova, P Gokuldass, H B Eggenstein, M Freeberg, P Hello, R Inasaridze, E E O Ishida, P Jaquierey, D A Kann, G Kapanadze, S Karpov, R W Kiendrebeogo, A Klotz, R Kneip, N Kochiashvili, W Kou, F Kugel, C Lachaud, S Leonini, A Leroy, N Leroy, A Le Van Su, D Marchais, M Mašek, T Midavaine, A Möller, D Morris, R Natsvlishvili, F Navarete, K Noysena, S Nissanke, K Noonan, N B Orange, J Peloton, A Popowicz, T Pradier, M Prouza, G Raaijmakers, Y Rajabov, M Richmond, Ya Romanyuk, L Rousselot, T Sadibekova, M Serrau, O Sokoliuk, X Song, A Simon, C Stachie, A Taylor, Y Tillayev, D Turpin ✉, M Vardosanidze, J Vlieghe, I Tosta e Melo, X F Wang, J Zhu

*Monthly Notices of the Royal Astronomical Society*, Volume 515, Issue 4, October 2022, Pages 6007–6022, <https://doi.org/10.1093/mnras/stac2054>

# Example: Kilonova-Catcher project

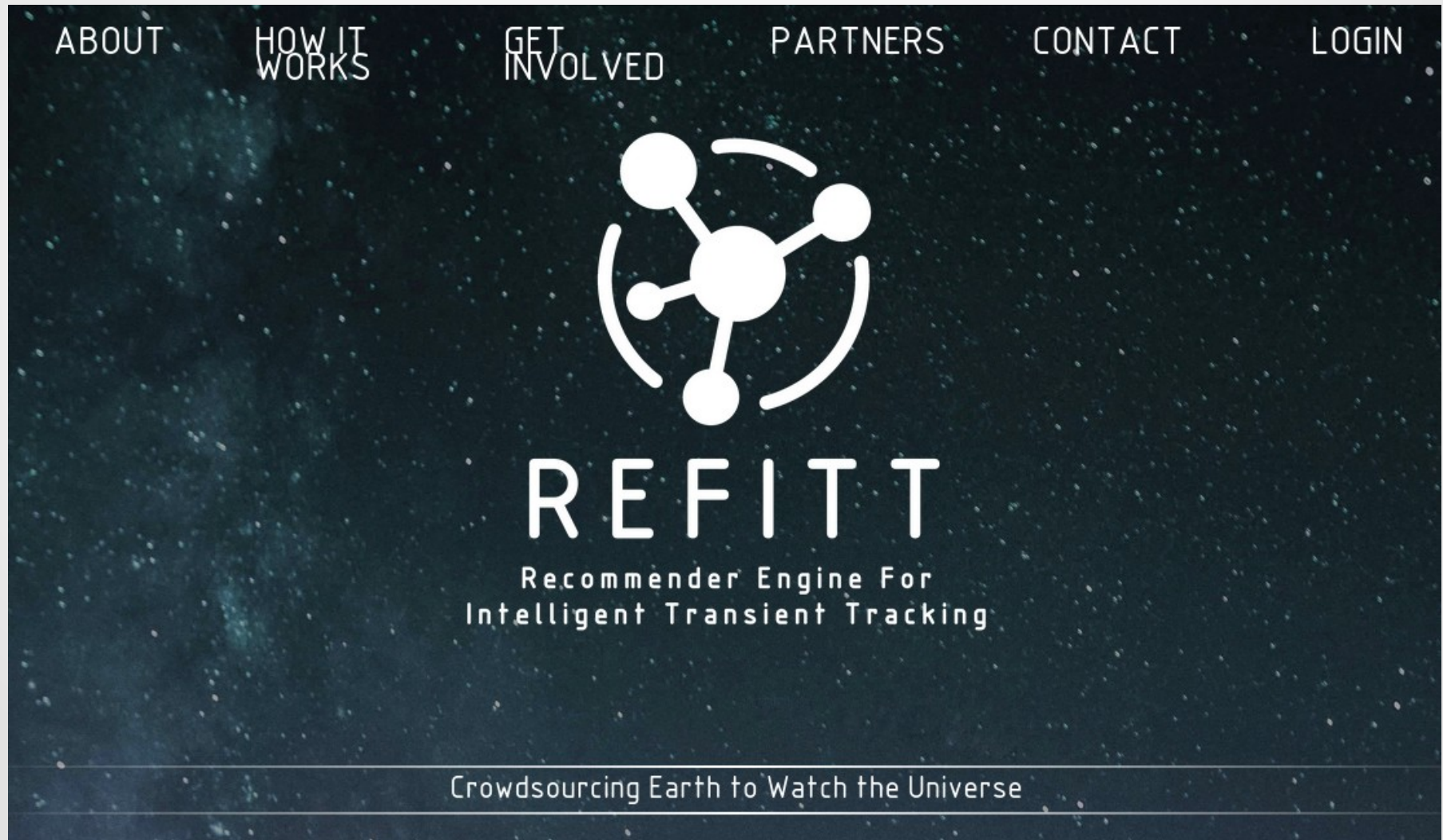
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- Highlights:
- Practice run: use candidates identified by Fink broker
- Alerts communicated via emails and Slack channel
- Observers upload calibrated/stacked images
- KNC then uses professional survey images of galaxies to subtract background from amateurs' images
  - Challenge: often different filters

# REFITT project

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- <https://refitt.physics.purdue.edu>



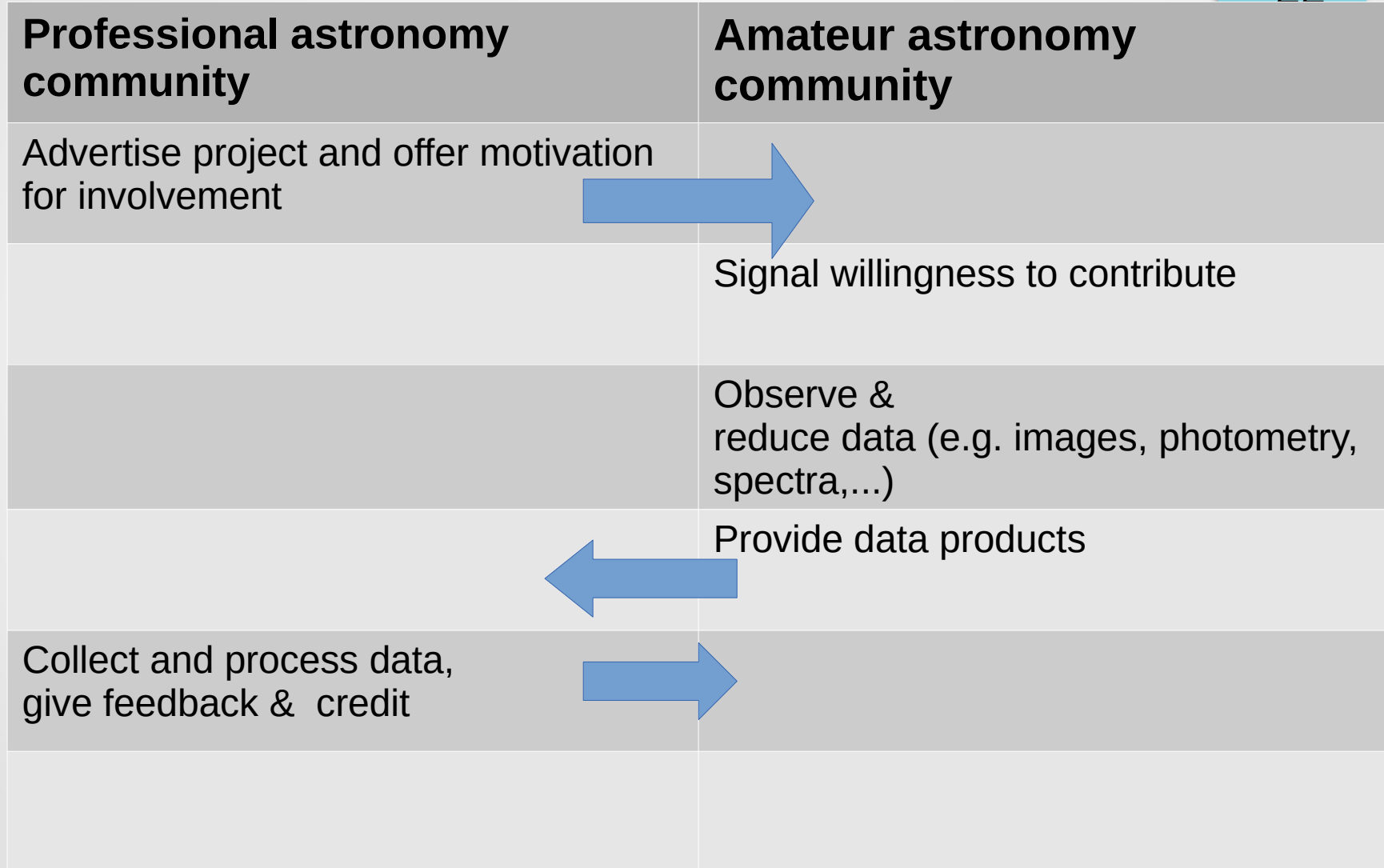
# REFITT project

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- <https://refitt.physics.purdue.edu>
- Amateur Astronomers register with details about their equipment and observation sites
- REFITT ingests data from ZTF (later probably Vera Rubin Obs.) to identify interesting objects
- Based on **obs. capabilities, site, weather forecasts & predicted light curve**, registered observers get recommendations for observations via email for a given night
- Observers upload calibrated images to REFITT platform, & optionally report magnitudes
- REFITT then performs photometry

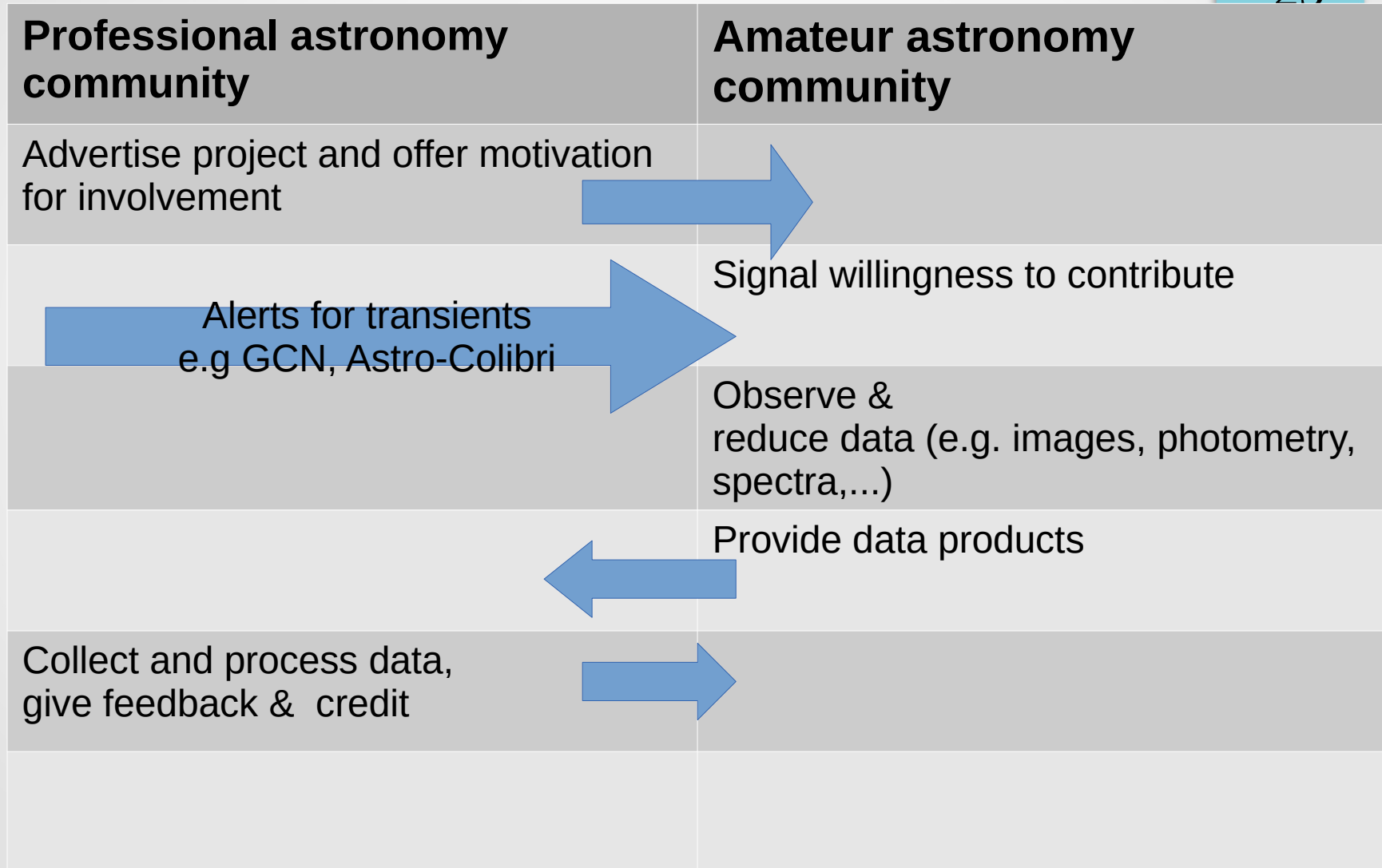
# A common pattern for projects

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# A common pattern for projects

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# AAVSO

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- American Association of Variable Star Observers



- Est. 1911. HQ in Boston, Mass., USA
- “The AAVSO is an international non-profit organization of variable star observers whose mission is to enable anyone, anywhere, to participate in scientific discovery through variable star astronomy.”



# AAVSO resources

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## Resources



(VSI) Variable Star Index

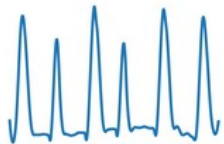
### Pick a Star

Star name here

- ▶ Plot a light curve
- ▶ Check recent observations
- ▶ Create a finder chart

# JAAVSO

The Journal of the AAVSO



Submit and Access Data



Tools and Observer  
Resources



Observing Sections



Education  
CHOICE Courses, Manuals, Videos



AAVSO In Press



Membership and Support

# AAVSO statistics, FY 2020/2021 [1]

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- 4.034.117 observations submitted to AID
- By 941 observers (US: 294, Belgium: 27, China: 5 (!) )
- From 58 different countries

also (submissions/database) [2]:

- 14.486 : Solar database
- 3.612 : Spectroscopy DB
- 429 : Exoplanet DB

and

- 35 Alert Notices published

[1] [https://www.aavso.org/sites/default/files/annual\\_report/Observation\\_Totals\\_FY20-21.pdf](https://www.aavso.org/sites/default/files/annual_report/Observation_Totals_FY20-21.pdf)

[2] [https://www.aavso.org/sites/default/files/annual\\_report/AAVSO\\_Impact\\_Report\\_20-21\\_E.pdf](https://www.aavso.org/sites/default/files/annual_report/AAVSO_Impact_Report_20-21_E.pdf)

# AAVSO: example campaigns/alerts

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Example: optical amateur observation in sync with other messenger observations

## Alert Notice 792: R Aqr photometry and spectroscopy requested in support of Chandra observations

**”Dr. Margarita Karovska (Center for Astrophysics|Harvard & Smithsonian) requests the assistance of AAVSO observers in monitoring the symbiotic binary (Mira + white dwarf) R Aqr in support of upcoming Chandra observations.**

**The Chandra observations are scheduled for September 26, 2022 UT.**

**Starting now, Dr. Karovska requests photometry (UBVRIH, mid-IR if at all possible), high speed photometry (UB), and spectroscopy. Visual observations are welcome. The cadence requested is nightly from now through September 26, then twice a week through October 10.**

**R Aqr has a V range of 5.2 - 12.4. The most recent magnitudes from the AAVSO International Database show R Aqr at magnitude 9.32 V +/-0.006 on 2022 September 19.9033 UT and 10.832 B +/-0.009 on September 19.9042 UT (S. Dufoer, Brussels, Belgium)....”**

# AAVSO: example campaigns/alerts

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- Example: optical amateur observation in sync with other messenger observations

## Alert Notice 750: T CrB photometry and spectroscopy requested for HST and XMM-Newton observations

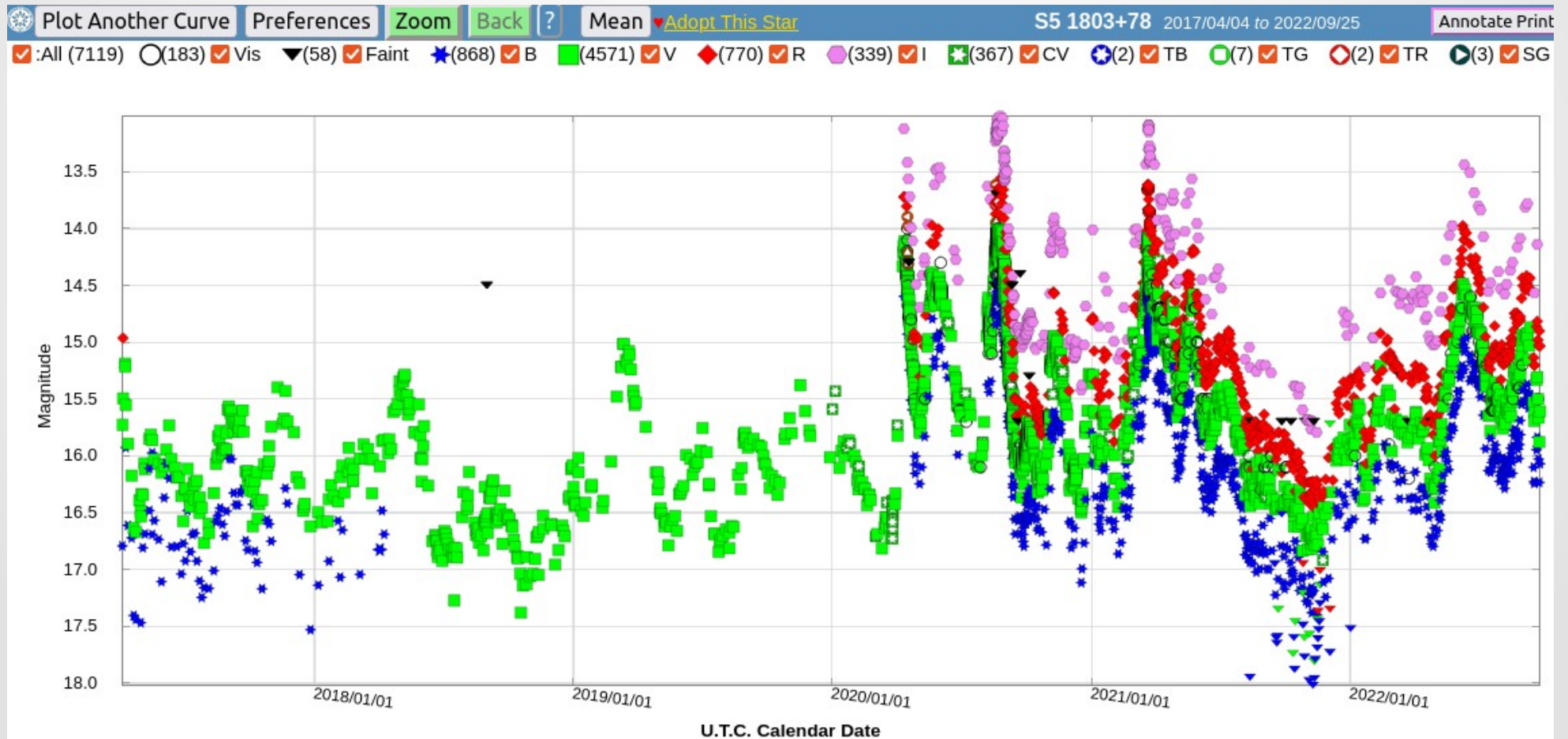
**”Dr. Koji Mukai (NASA-GSFC, University of Maryland) and colleagues have requested AAVSO observers' assistance in monitoring the symbiotic recurrent nova T CrB in support of multiwavelength observations currently scheduled with HST (August 26) and XMM-Newton (to be determined) in August and September.**

- 
- **Dr. Mukai writes: “[Our] HST and XMM-Newton observations of the symbiotic recurrent nova, T CrB ... are part of our ongoing campaign to the current active state that started in 2016, and perhaps leading to its next nova eruption that might happen within the next 5 years or so. ...”**

# AAVSO: example campaigns/alerts

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- Example: Longtime monitoring of an AGN after flare, here S5 1803+78



# Interlude: Amateur Astronomer demography



1916

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- Predominantly male
  - Older than average population
  - Predominantly pink-ish skin color
- ==> we have a (diversity) problem



2019

# Overview

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# Where to go from here: general thoughts

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- Expedite & modernize information flow between Pro and Am Community
- Tools: e.g. Astro-Colibri , (new generation) GCN?
- Keep in mind AM community demographics. Support other languages than English in tools?
- Please help us to improve amateur diversity (visibility for role models that are not necessarily male and have pink skin)



# Where to go from here: hackathon ideas

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- Next Generation (Kafka-Based) GCN integration
- “Back-channel” how to send triggers from AM to PRO community without chasing too many hot-pixel false alerts? Vetting etc.
- Make host galaxy background subtraction (Hotpants etc) accessible for amateurs
- future SNEWS 2.0 integration for Astro-Colibri
- Make alert apps really loud for “very important” events: ignore do-not-disturb, override volume setting, vibration etc
- Interface to robotic systems ( VOevents ?)

Thank you!

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Questions, please :-)