Probing new territory with Gaia: fast optical transients

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Very fast transients

- 10 4.4 s CCD integrations (AF)
- Subsequent FoV transit: 106.5 min
- Time between successive scans: 6 hours
Extending AlertPipe to very short timescales

- Nominal operation of AlertPipe: detection across 2 FOV
- Geared to 'traditional' transients: SN, CV, Novae, ...
- Previous efforts and experience in other surveys
- We know what to expect / what to look for!
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- Very short events (within FOV transit) are likely to be missed
Goal

Detecting and characterizing extremely short astrophysical transient events
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1. Limit the amount of rubbish in alertstream
2. Identify instrumental artifacts / systematics
3. Detect genuine transients
4. Acquire data needed for characterization
Classical picture (taken from LSST science book):
Ground-based efforts?

- Short integration times: noisy data
- Limiting atmospheric effects
- Small area coverage / shallow depth
- Extremely large amount of pixels to get good coverage with reasonable sampling
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- Short integration times: noisy data
- Limiting atmospheric effects
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- Extremely large amount of pixels to get good coverage with reasonable sampling
- Gaia provides high-quality photometry, colors, low res. spectra, all-sky
Rate of rise vs. $t_{\text{rise}}$

Limiting sensitivity for $\Delta \text{mag} = 0.5$
Some examples: TDFs around IMBH

- Star enters tidal radius of BH: differential gravity leads to disruption

Typical timescale for a disruption (Lodato & Rossi, 2011):

$$t_{peak} \sim 41 \times m_{star}^{-1} \times r_{star}^{1.5} \times M_{BH,6}^{1/2} \text{ days}$$ (1)
Some examples: TDFs around IMBH

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(1)

For a 0.6 \( M_\odot \) WD:

- 60 - 1800 sec for \( M_{BH} \sim 100 - 10^5 M_\odot \)

Not visible around SMBH!
Some examples: TDFs around IMBH

TDF of a 0.6 $M_\odot$ WD

- $10^2 M_\odot$ BH
- $10^3 M_\odot$ BH
- $10^5 M_\odot$ BH

$\nu F_\nu$ (erg/s) vs. Time (days)
Some examples: compact binaries

- Double degenerate systems with periods $\sim$ minutes - hours - days
- 3 flavours: interacting (AM CVn) - detached - non-interacting
- Potential GW sources, SNIIa progenitors
- Current population $\leq 100$
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- Double degenerate systems with periods $\sim$ minutes - hours - days
- 3 flavours: interacting (AM CVn) - detached - non-interacting
- Potential GW sources, SNIa progenitors
- Current population $\leq 100$
- Estimated number of detectable systems with Gaia $\sim 10^4$
- Eclipses can be of order 10s of seconds: within single FOV transit
Some examples: compact binaries
Some examples
Instrumental calibration

- Extremely sensitive to instrumental/astrophysical contamination
- Characterization of instrumental imprints on data, such as:
  - Bad column / pixel maps
  - CCD edge artifacts
  - Influence of gating on source detection
  - Moving objects / bright stars / ...
Selection criteria

- Start with restricted parameter space, expand later
- Rise / decay with threshold magnitude / rate of change
- Outlier detection
- External triggers
Characterization of events

- Very short timescale makes follow-up challenging / impossible
- We have extra Gaia info: spectra + colors
- X-matching with multi-wavelength archival data
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- Very short timescale makes follow-up challenging / impossible
- We have extra Gaia info: spectra + colors
- X-matching with multi-wavelength archival data
- Look for other ways of gathering extra information
- E.g. commensal radio / X-ray observations
Potential overlap with CU7 (for e.g. DWD eclipses)

A non-significant fraction will not be detected as periodic variables!
CU7 overlap: defining transient / variable phenomena

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- A non-significant fraction will not be detected as periodic variables!
- What is the definition of a transient event?
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A non-significant fraction will not be detected as periodic variables!

What is the definition of a transient event?

It is good to have some overlap for maximum science return

Coordination / communication is important!
Summary

- Use Gaia to probe (virtually) unexplored phase space in optical
- Known knowns, unknown knowns, unknown unknowns!
- AM CVn, TDF around IMBH, ???
- Create additional filter/class in AlertPipe
- Think about selection criteria, characterization etc.
- Some work needed on instrumental characterization
T. Wevers

Very fast transients

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