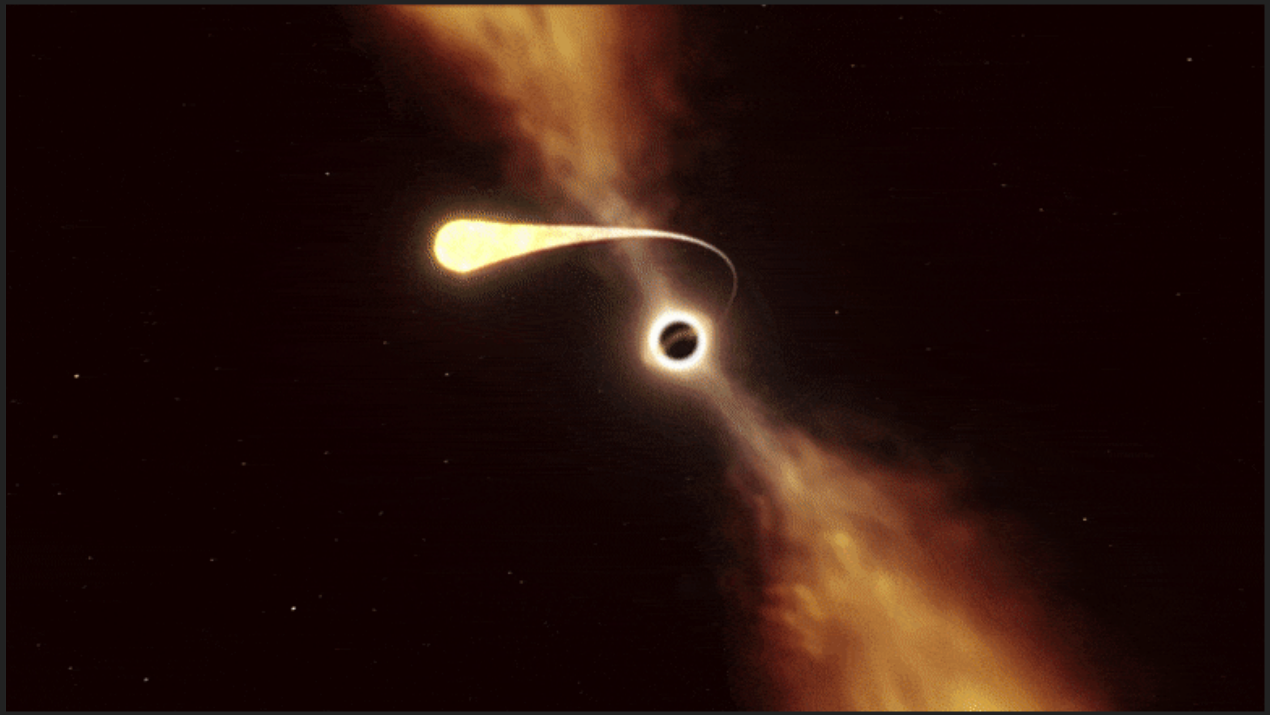

ANDREJA GOMBOC
CENTER FOR ASTROPHYSICS AND COSMOLOGY
UNIVERSITY OF NOVA GORICA
SLOVENIA

STATUS OF SLOVENIAN IN-KIND CONTRIBUTIONS

University of Nova Gorica | University | Study | Research | e-UNG | Search

Center for Astrophysics and Cosmology

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- Research Topics
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- Experimental Collaborations
- Grants and Networks
- Group bibliography
- Gallery

Research

- Origin of the Ultra-High Energy Cosmic Rays
- Astrophysics of transients
- Active Galactic Nuclei
- Dark Matter
- Cosmology with SNIa
- Instrumentation for Cherenkov Astronomy
- Experimental Particle Physics

Event

- CAC Sem
- CAC Wor
- Outreac

SLOVENIAN IN-KIND CONTRIBUTIONS

SLO-UNG-S1 Serving LSST Catalogs from the Slovenia Lite IDAC

SLO-UNG-S2 Science Pipeline Development in the LSST TVS SC

People involved @UNG:
Tanja Petrushevska, Mateusz Bronikowski (SNe) - DESC
Gabrijela Zaharijaš, Saptashwa Bhattacharyya (dark matter)
Mile Karlica, Andreja Gomboc (TDEs) - TVS SC
&
Andrej Filipčič (Lite IDAC)

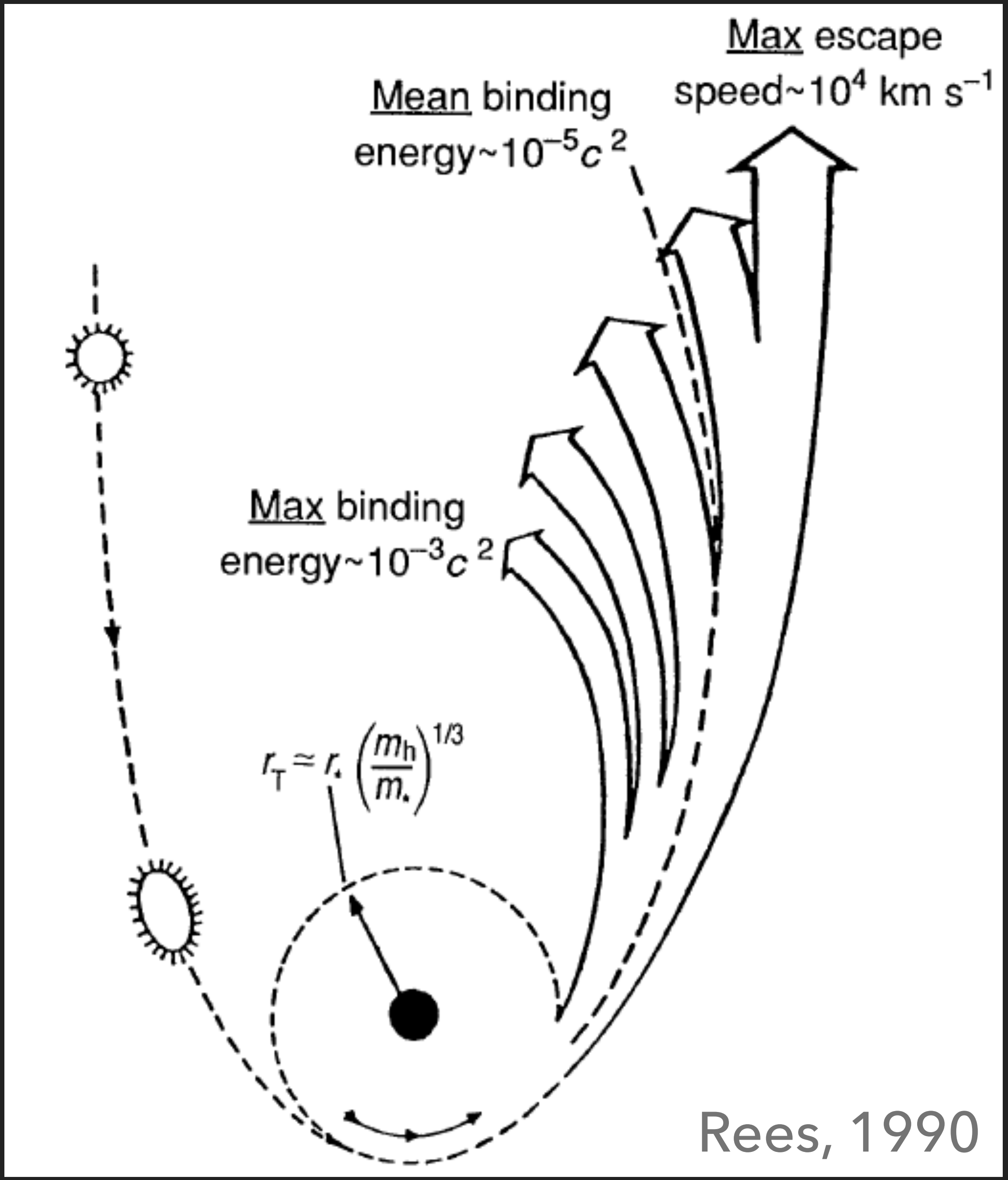
TIDAL DISRUPTION EVENTS

- tidal radius $r_\mathrm{t} = R_* \left(\frac{M_\mathrm{BH}}{M_*}\right)^{1/3}$
- Rees 1988, 1990
- fallback rate:

$$\frac{\mathrm{d}m}{\mathrm{d}t} = \boxed{\frac{\mathrm{d}m}{\mathrm{d}\epsilon}}\frac{\mathrm{d}\epsilon}{\mathrm{d}t} = \frac{1}{3}(2\pi G M_\mathrm{BH})^{2/3}\frac{\mathrm{d}m}{\mathrm{d}\epsilon}t^{-5/3}$$

- luminosity follows the fallback rate:

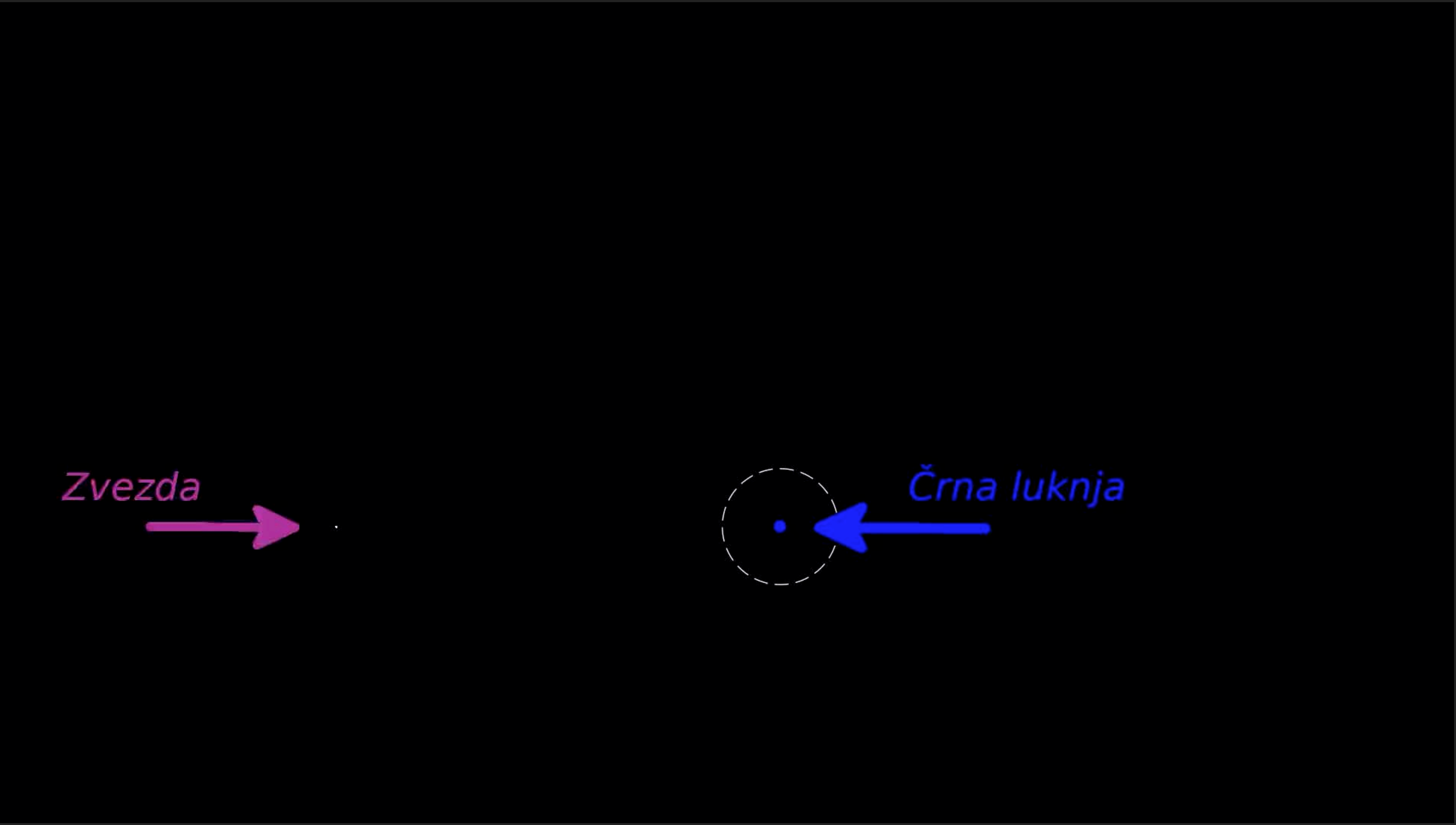
$$L \propto \dot{M}_\mathrm{fallback} \propto t^{-5/3}$$



Rees, 1990

PHANTOM, Solar type star

Vega HPC, Taj Jankovič



OBSERVATIONS

- nuclear transients, rate ~ 100 $\mathrm{Gpc}^{-3}\ \mathrm{yr}^{-1}$,

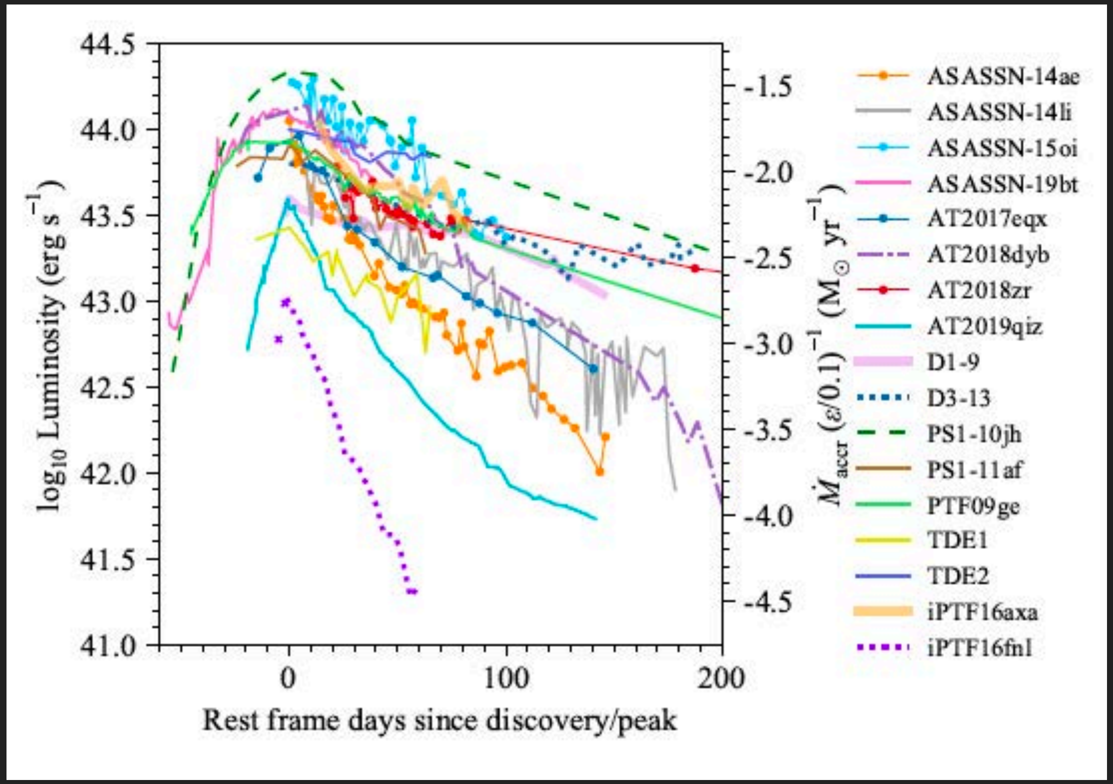
  10^{-4} $\mathrm{galaxy}^{-1}\ \mathrm{yr}^{-1}$

- about 100 TDE candidates, 60 robust (review: van Velzen et al. 2020)

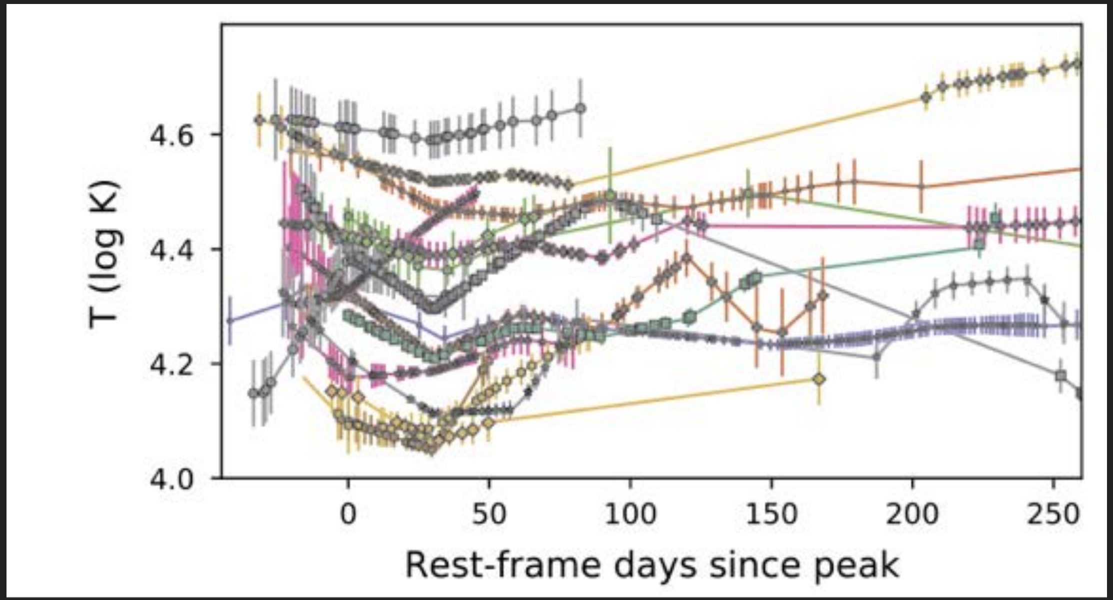
- rise~month, decay $t^{-5/3}$, UV/opt peak ~ -20 mag,

- high black body temperatures (T ~2.10^4 K, persists): blue colors

constant blue colors for months after peak are typical for TDEs



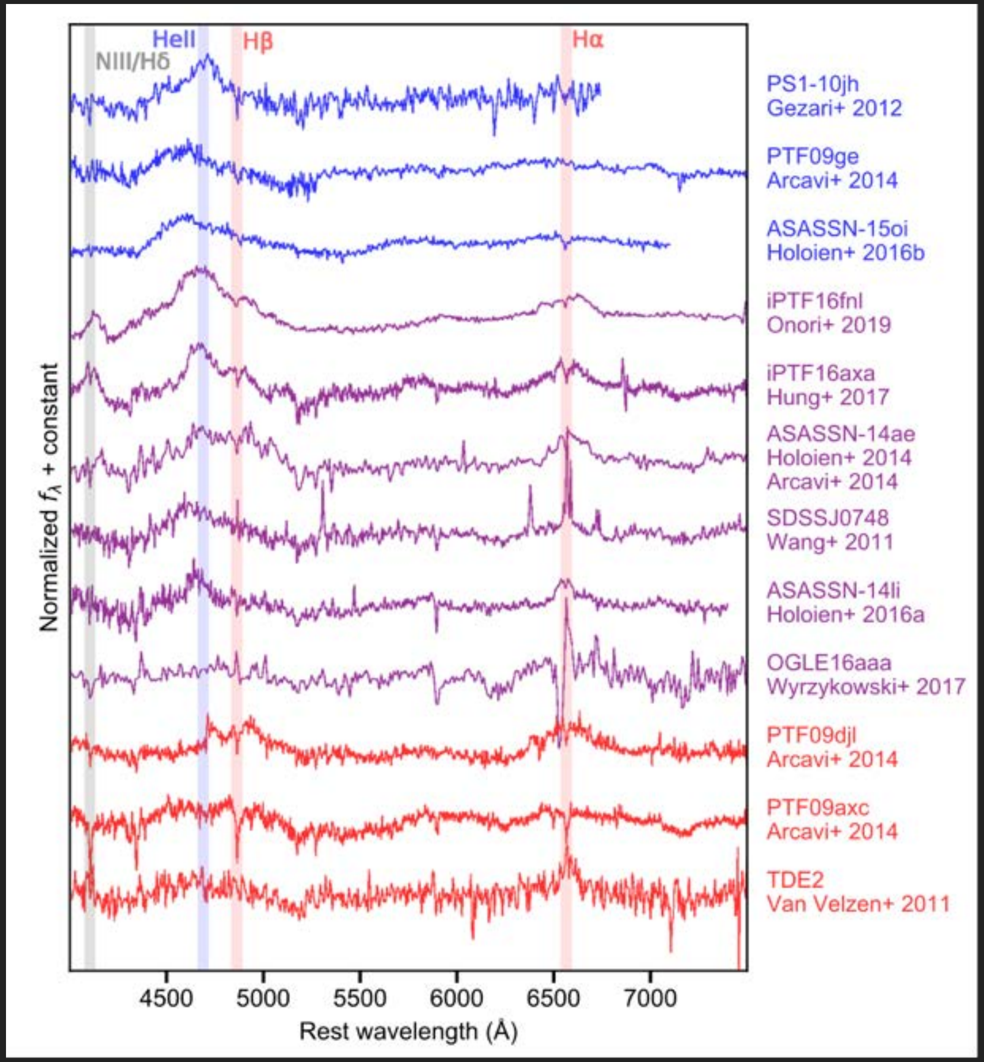
van Velzen et al., 2020



OPTICAL SPECTRA

- broad emission lines superimposed on a strong and consistent blue continuum
- He II λ4684 and/or Hα, Hβ emission lines
- TDE-H, TDE-He, TDE-H+He classes
- majority of H+He TDEs show Bowen fluorescence lines
- N III, O III, N II…
- diversity between spectral types associated with the radius and temperature of the photosphere

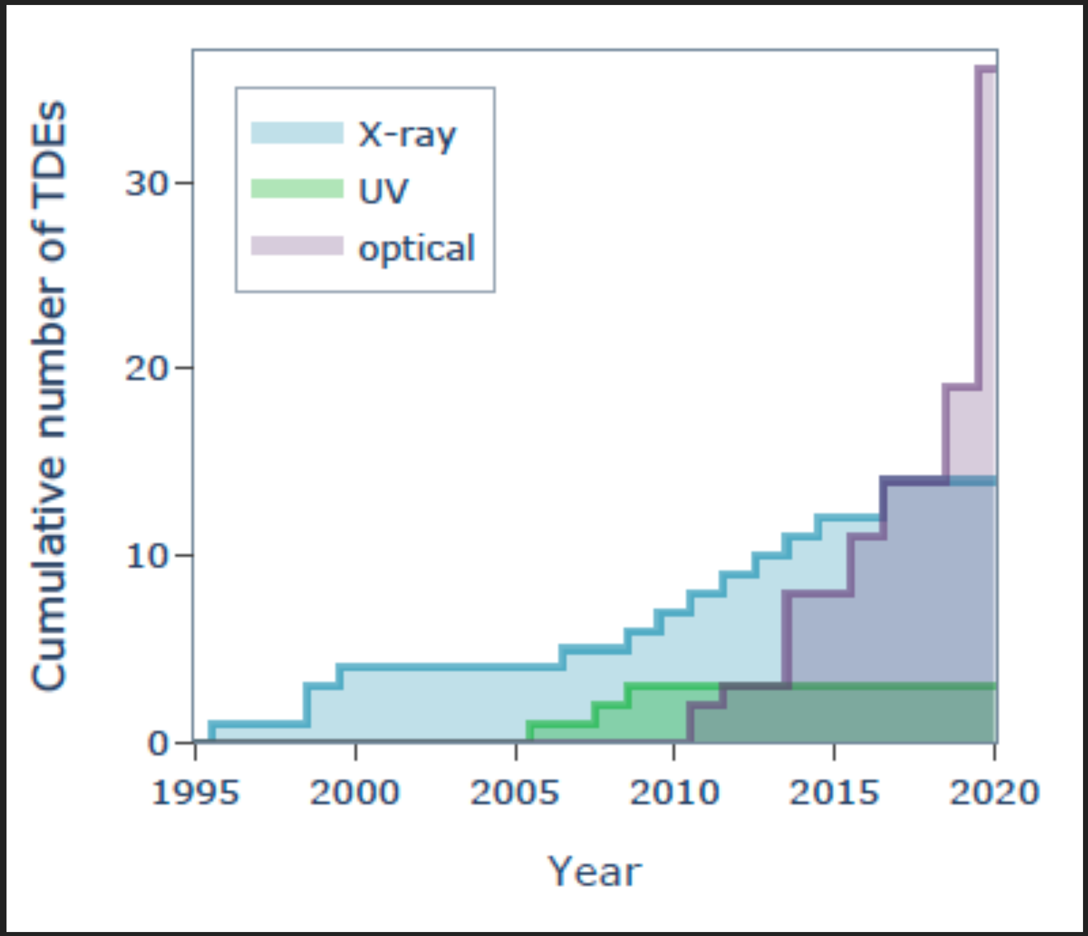
spectra are very important for classification



van Velzen et al., 2020

PROBES

- SMBHs in non-active galaxies
- stellar population and dynamics
- accretion efficiency
- TDE rates with z, host galaxy type
- multi-messanger: neutrinos, comsic rays, GWs
- etc.



Gezari 2021, Bučar Bricman 2021

current discovery rate ~ 10/yr

PROSPECTS OF OBSERVING TDES WITH RUBIN LSST?

- LSST Software Stack
- Operations Simulator (cadence, site conditions, HW and SW…) - used minion_1016 cadence
- added TDEs in Catalog Simulator - using MOSFiT (Guillochon et al. 2018) to calculate SED
- varied impact parameter (1 M_S, parabolic orbit) and BH mass

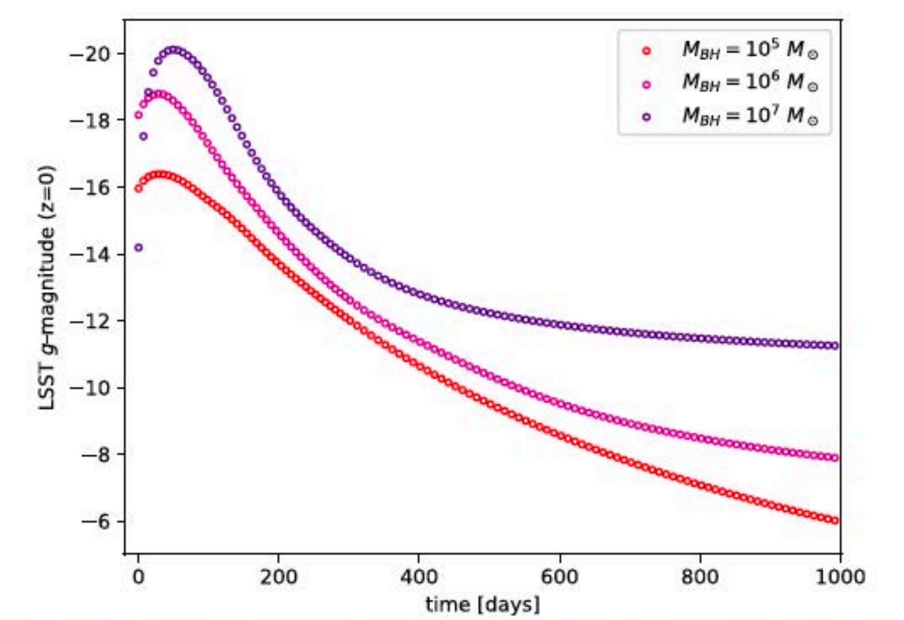
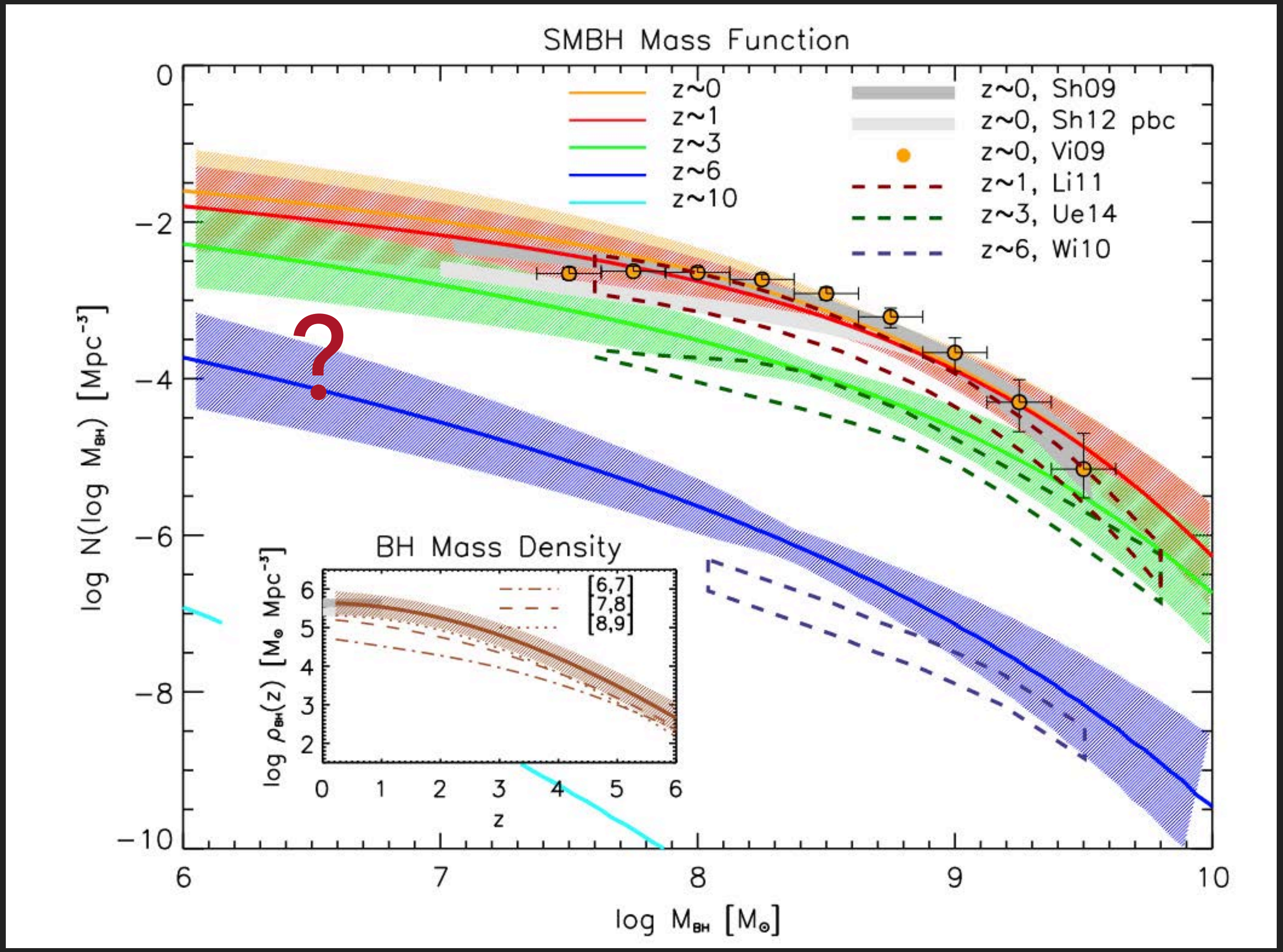


Figure 1. MOSFiT-generated light curves of three TDEs with black hole masses: $10^5\ M_\odot$ (red), $10^6\ M_\odot$ (pink), and $10^7\ M_\odot$ (violet). In all three events a solar-type star disruption with $\beta = 1$ was assumed. The absolute magnitudes were calculated in the LSST g band.

Bricman & AG, 2020

SMBH MASS DISTRIBUTIONS

- uncertainties in distribution over BH mass at low mass end



Aversa et al 2015

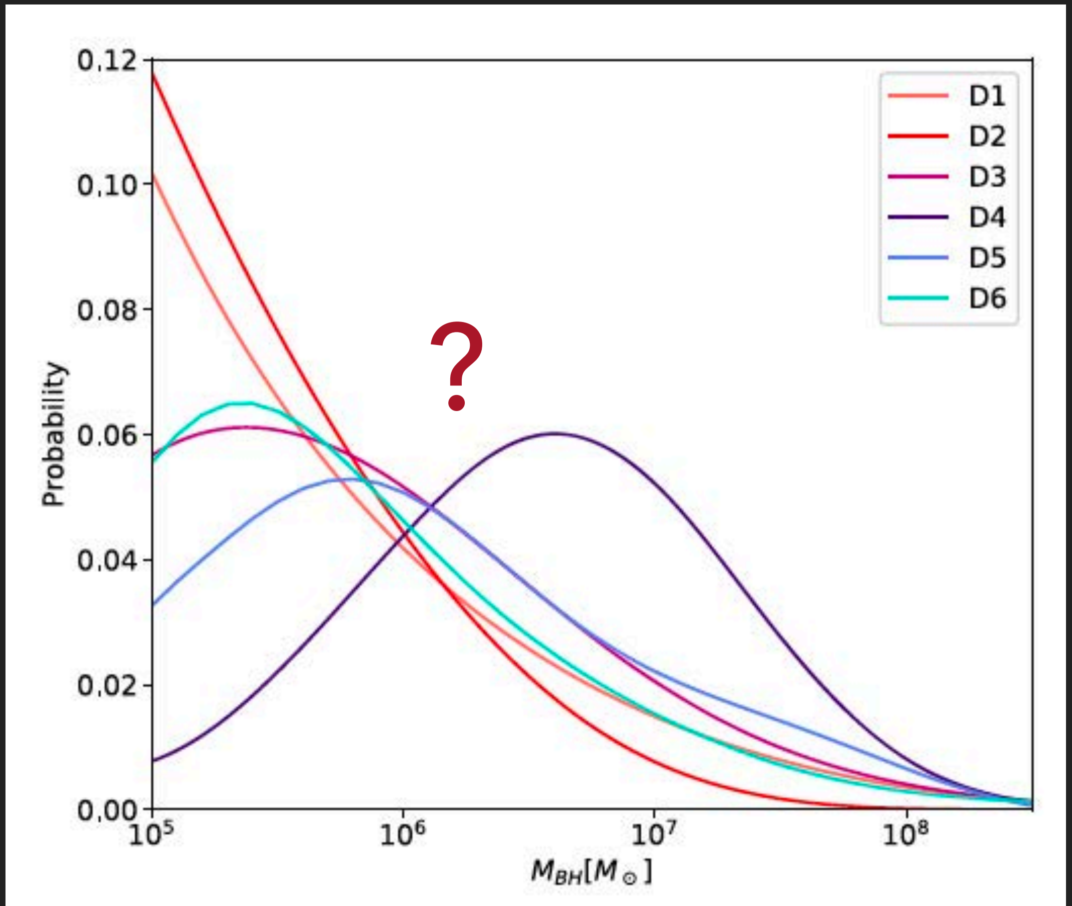


Figure 2. Input SMBH mass probability distributions D1–D6.

20 FIELDS IN THE SKY

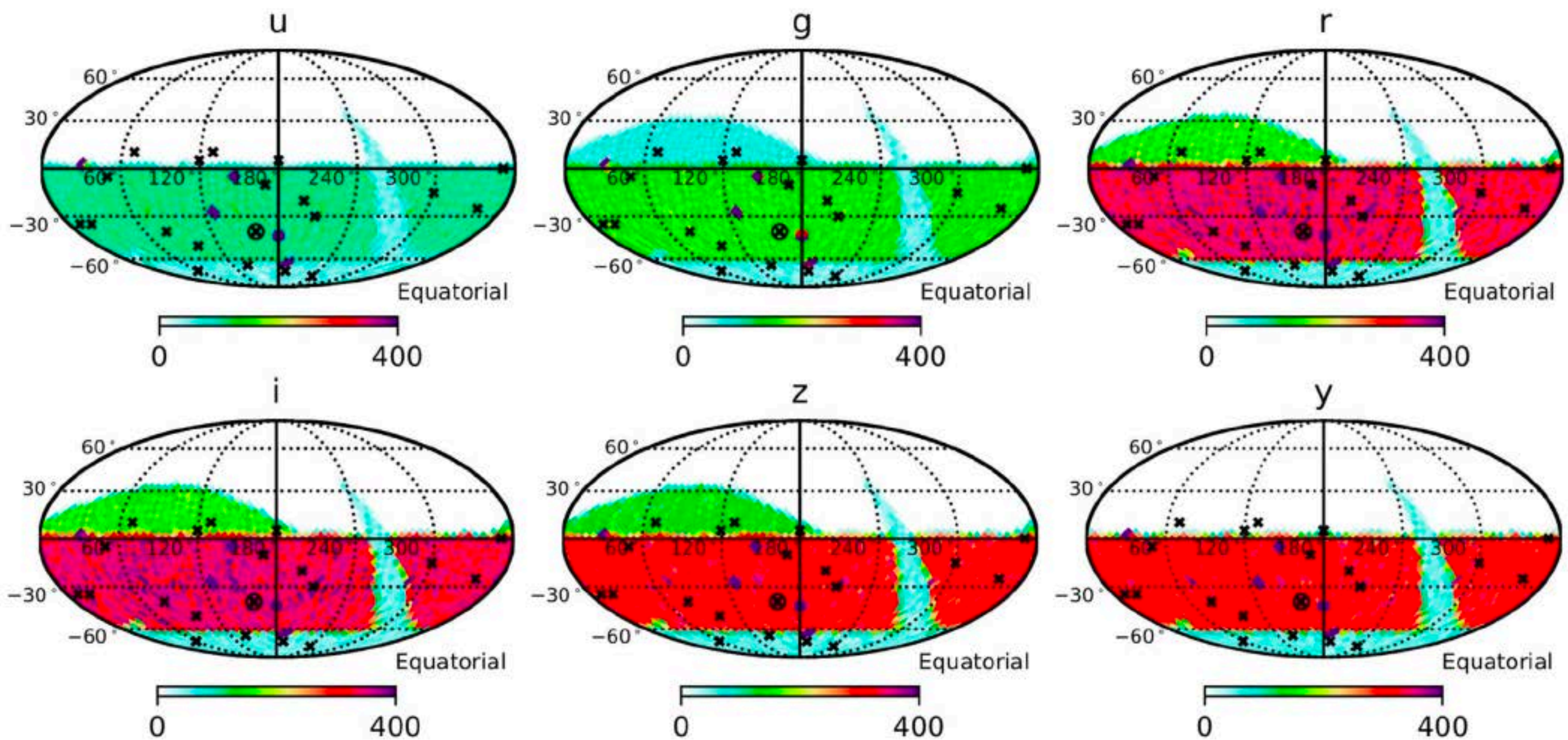


Figure 3. Number of visits (where a visit consists of two 15 s exposures) to a given field on the sky over 10 years of LSST observations in all six bands (*u*, *g*, *r*, *i*, *z*, and *y*) according to the observing strategy `minion_1016`. Observations in the *r*, *i*, *z*, and *y* bands will be more common than those in the *u* or *g* band, which is also apparent from the panels corresponding to each of the bands. The distribution of number of visits on the sky is irregular, as the cadence proposed is also irregular. Black crosses mark the locations of fields on which we simulated TDEs.

SIMULATED LIGHT CURVES

what counts as a detection?

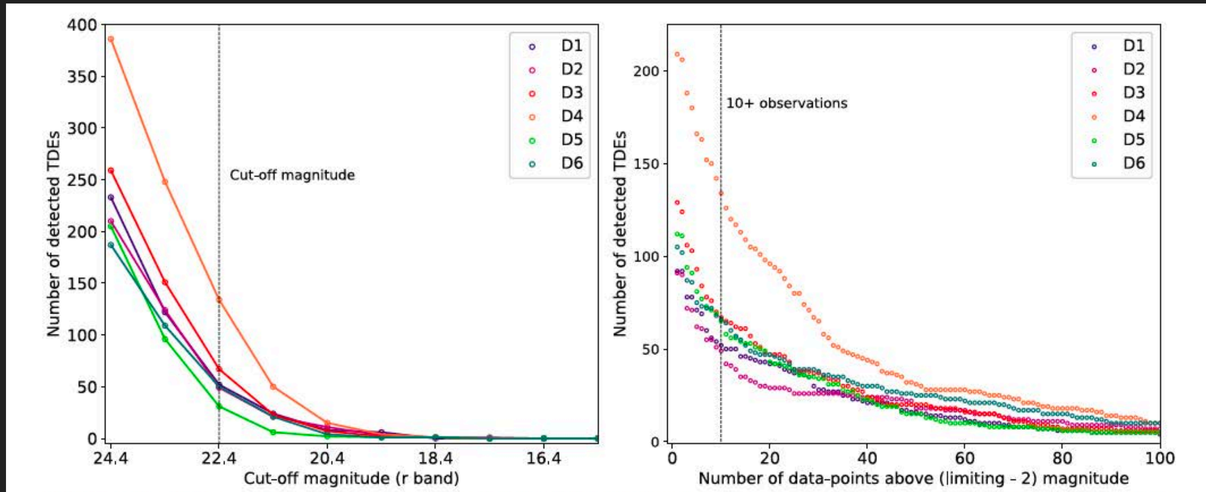
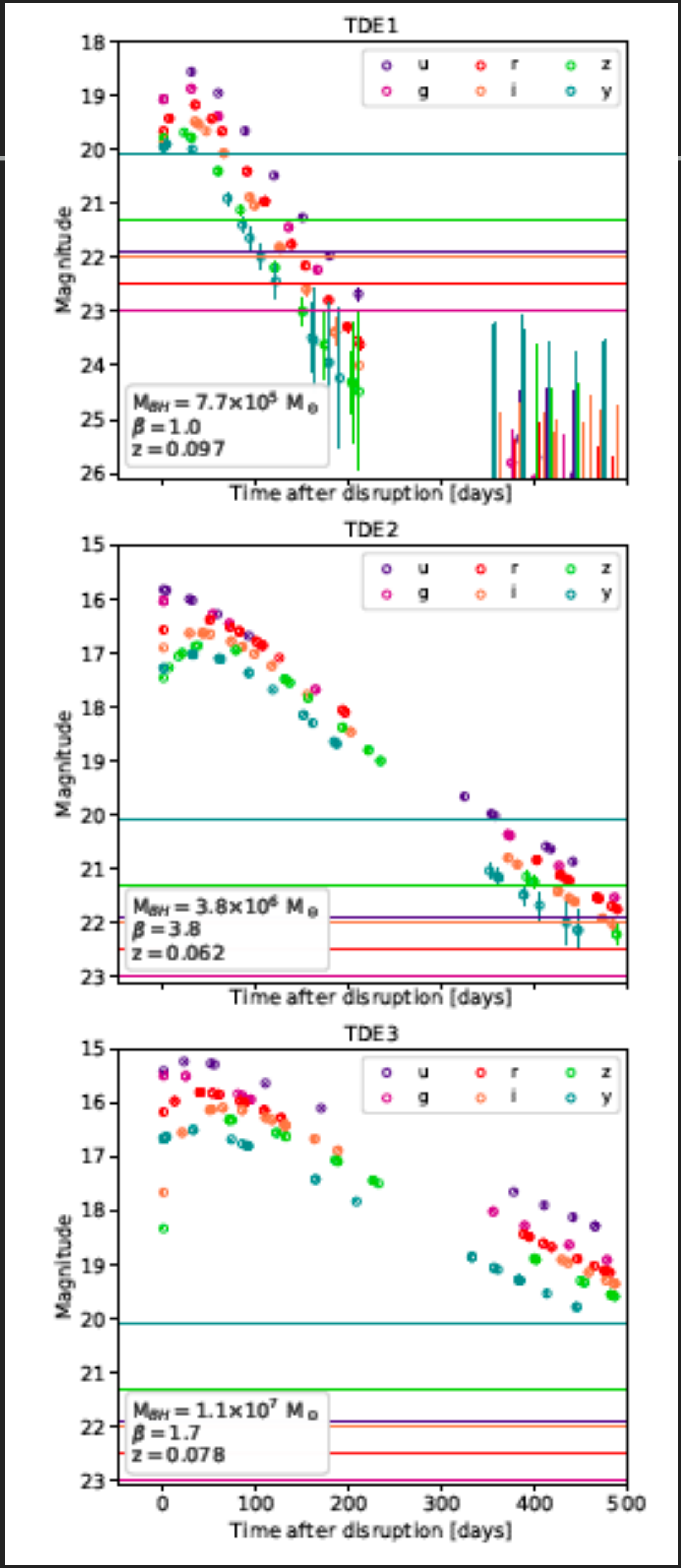


Figure 5. Left: the number of TDEs seen at least once above a certain cutoff r-band magnitude over 10 years of LSST observations on 20.25 deg^2 of the sky as a function of the cutoff magnitude in the r band. The number of detected TDEs decreases as we go to brighter limits. We chose (limiting −2) magnitude to eliminate events close to the limiting magnitudes of each band. Right: the number of detected TDEs over 10 years of LSST observations on a small patch of 20.25 deg^2 of the sky as a function of the number of data points above the chosen cutoff magnitude, (limiting magnitude −2), in all LSST bands together. For a representative number, we assumed 10 observations above the cutoff magnitude as sufficient to classify the event.

10 observations above cutoff magnitude:

u_c=21.5, g_c=22.8, r_c=22.4, i_c=21.9, z_c=21.3, y_c=20.1



NUMBER OF TDES DETECTED

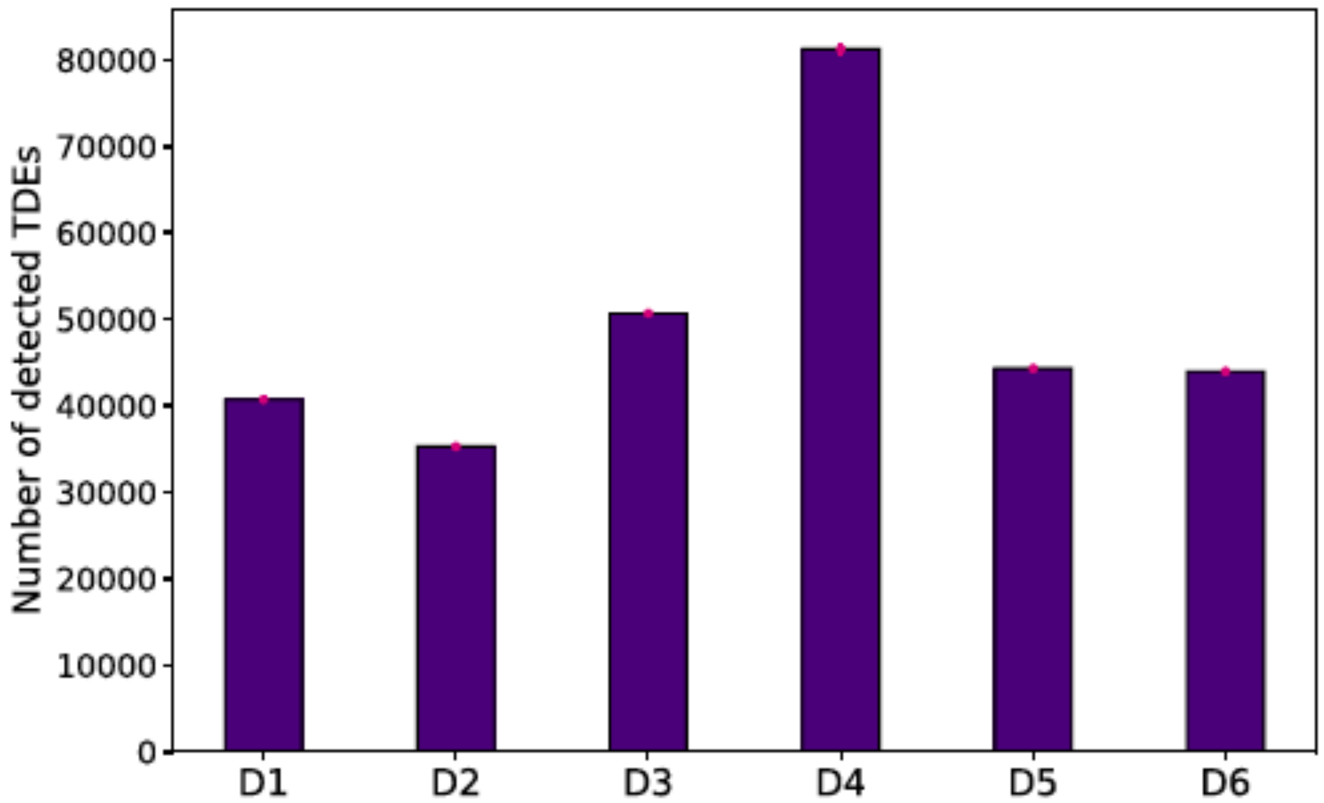


Figure 6. Number of detected TDEs for each of the SMBH mass distributions D1–D6. The number of expected detections is between 35,000 ± 260 and 80,000 ± 400 over 10 years of observations. This corresponds to average values between 10 and 22 TDEs per night.

rate of TDEs: 10^{-5} galaxy^{-1} yr^{-1}

~10 - 22 TDEs/night

identification?

OTHER STRATEGIES PROPOSED

- > 200

7 main survey parameters:

- Survey footprint modifications: WFD area from 18, 000 deg^2 to 20, 000 deg^2.
- Exposure time per visit: u-band visit - 1x 50 s exposure, retaining the same overall number of visits in u-band
- Allocation of observing time per band: changes in the filter distributions across visits
- Cadence and revisit times variations : visits in a pair in the same or in mixed filter, or adding an additional visit
- Rolling cadence: sky is split into a defined number of declination bands, receiving a higher number of visits during an “on” season followed by a lower number of visits during an “off” season.
- The footprint of mini-surveys : footprints of GP, North Ecliptic Spur, and South Ecliptic Pole mini surveys, DDFs footprint, location and cadence.
- Twilight observations: changing the cadence and filter distribution during twilight observations

EFFECTS ON TDE OBSERVATIONS?

- TDE metric - with Katja Bučar Bricman, Sjoert van Velzen, Federica Bianco in LSST TVS SC
- TDE impostors: SN Ia, AGNs… photometric identification required
- important to resolve the peak and colour - TDE are (and remain) blue

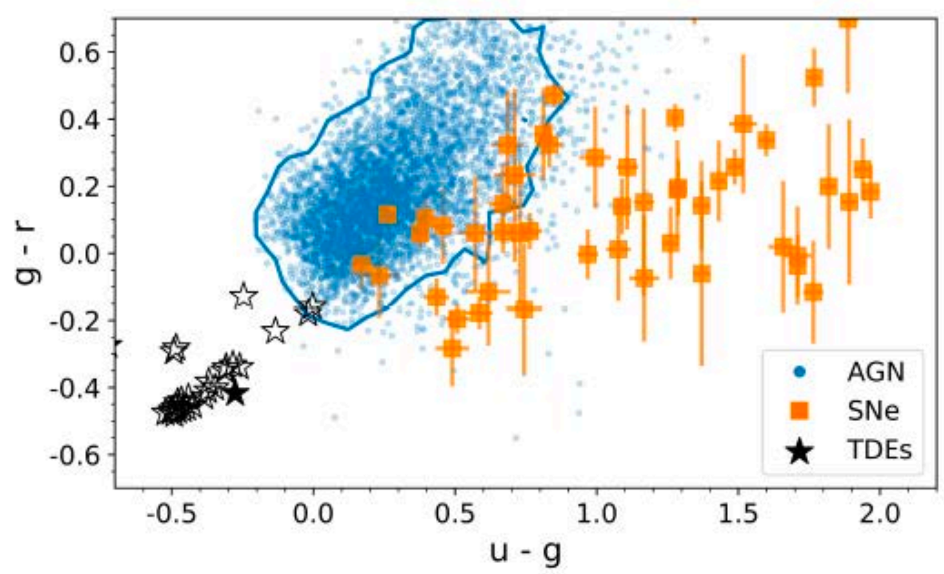


Figure 1: Color-color diagram of nuclear transients: mean $g-r$ color against mean $u-g$ color of the decaying phase of the light curve. TDEs lie in the lower left part of the diagram, with blue mean colors $u-g \sim -0.5$ and $g-r \sim -0.4$, making them clearly recognizable from SNe and AGN. Plot is adapted from van Velzen et al. (2011) and has been updated with recently observed TDEs.

van Velzen 2020

MAIN FINDINGS

- footprint: smaller (with denser sampling) better (classification, young, peak)
- rolling cadence better
- u-band exposure 1x 50 s better than 2x15 s (number of u-visits not decreased)
- photometric classification more important than number of detections
- more u- and g- band (OK for other science cases)

IDENTIFYING TDES – MAIN CHALLENGES

- How to reliably identify TDEs based solely on Rubin LSST photometric data, which may not have ideal time and multi-band coverage (in particular in u-band filter).
- Measure the purity of TDE filter using realistic light curves of the most frequent contaminants: SNe and AGNs.
- How to identify a TDE before the peak in the light curve, i.e. on the order of days to weeks, depending on the time of the first detection.

TDE FILTERING PLANS

SLO-UNG-S2 Science Pipeline Development in the LSST TVS Science Collaboration

We (TVS TDE subgroup led by Sjoert van Velzen, Netherlands)
propose a dedicated TDE filter to run on Rubin LSST Alert stream data on one or more of the broker(s).
It could be developed in stages:

- extracting nuclear flares (from the centers of galaxies),
- photometric feature extraction (e.g. rise-time, color, color evolution, fade timescale),
- photometric typing, including machine learning.

Required data would be the information included in the LSST Alerts: history of an object, full photometric light curve, astrometric data (galaxy cross-match, off-set from galactic center), galaxy photo-z, galaxy color/type.
The TDE filter output would be a stream of nuclear flares with light curve features, including classification labels or probabilities.

LITE IDAC

SLO-UNG-S1 Serving LSST Catalogs from the Slovenia Lite IDAC

led by Andrej Filipčič
Vega/EuroHPC - IZUM, Maribor, Slovenia

EUROPEAN UNION
COHESION FUND

REPUBLIC OF SLOVENIA
MINISTRY OF EDUCATION, SCIENCE AND SPORT

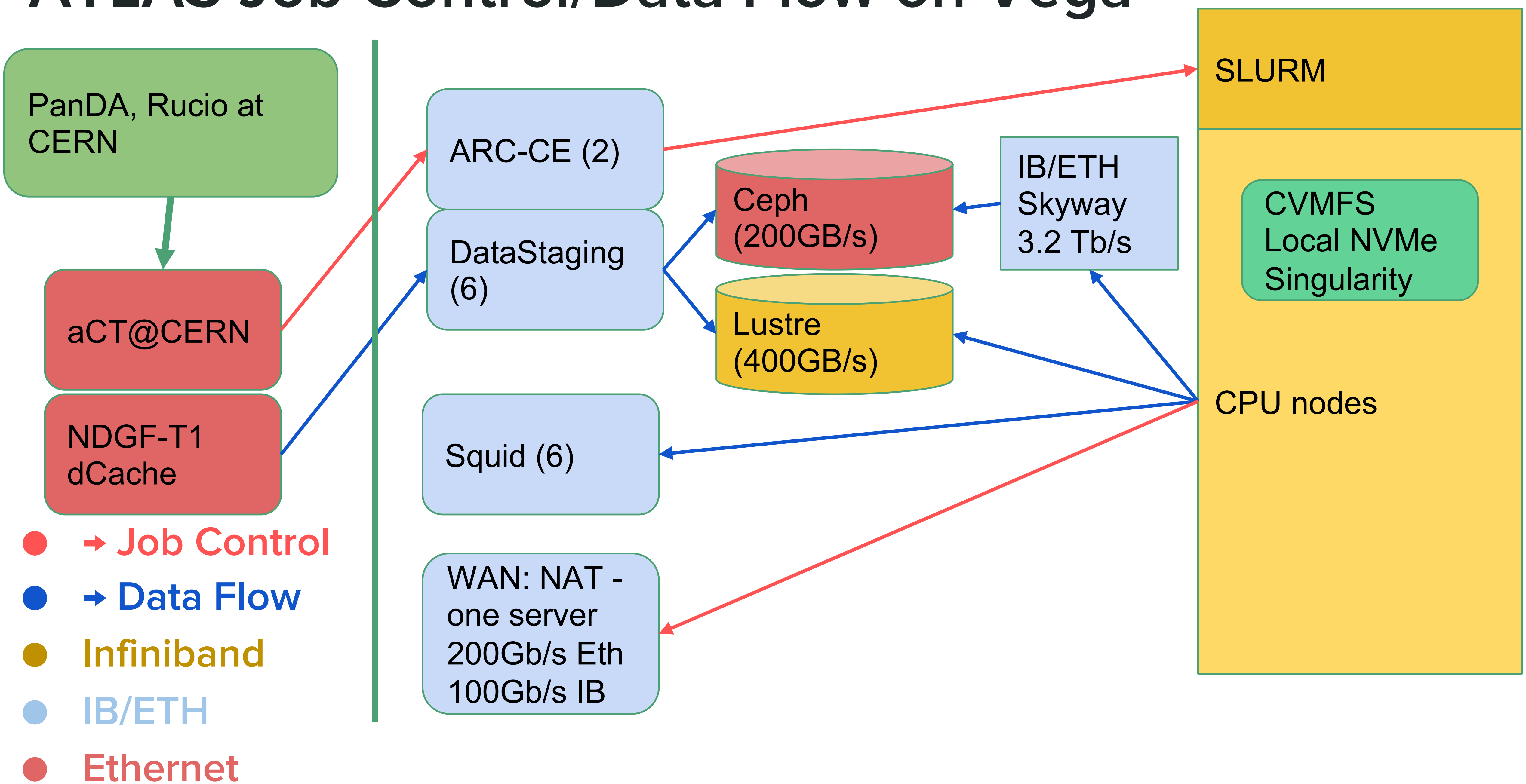
EuroHPC

Number of Nodes	1020
Number of login nodes	4 CPU login nodes and 4 GPU login nodes
Compute partitions	CPU partition: 960 (768 standard CPU nodes and 192 high memory CPU nodes * GPU partition: 60 nodes
Storage capacity	1 PB high-performance NVMe storage, 23 PB raw large-capacity storage (18 PB usable)
Sustained Performance	6,9 petaflops
Peak Performance	10.1 petaflops

VEGA & LSST

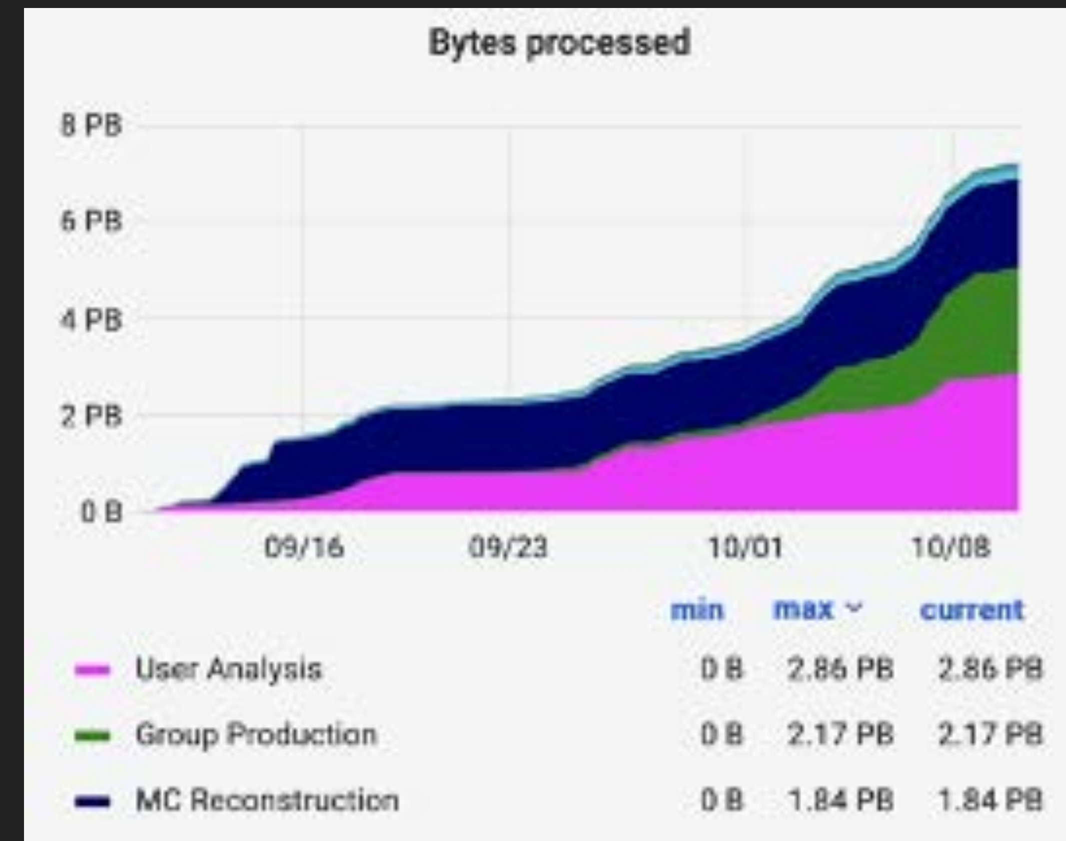
- Pledged resources, though not used yet
  - 2000 cores
  - 1PB of storage
  - Vega EOL is 2026, new HPC is planned and will take over
- Access:
  - Direct (ssh), posix access to Lustre (high throughput) or CephFS (high capacity) filesystems
  - Remote job management (ARC-CE)
  - Remote data management (dCache storage with https and xrootd protocols)
- Custom services:
  - Virtual Environment on Proxmox
  - Dedicated virtual machines on demand for community services, eg data transfers, databases…

ATLAS Job Control/Data Flow on Vega



OPPORTUNISTIC USAGE

- ATLAS can use up to 200k cores when not used by EuroHPC or Slovenian users
- Remote data processing, up to few PB a day on 200Gb/s WAN connection



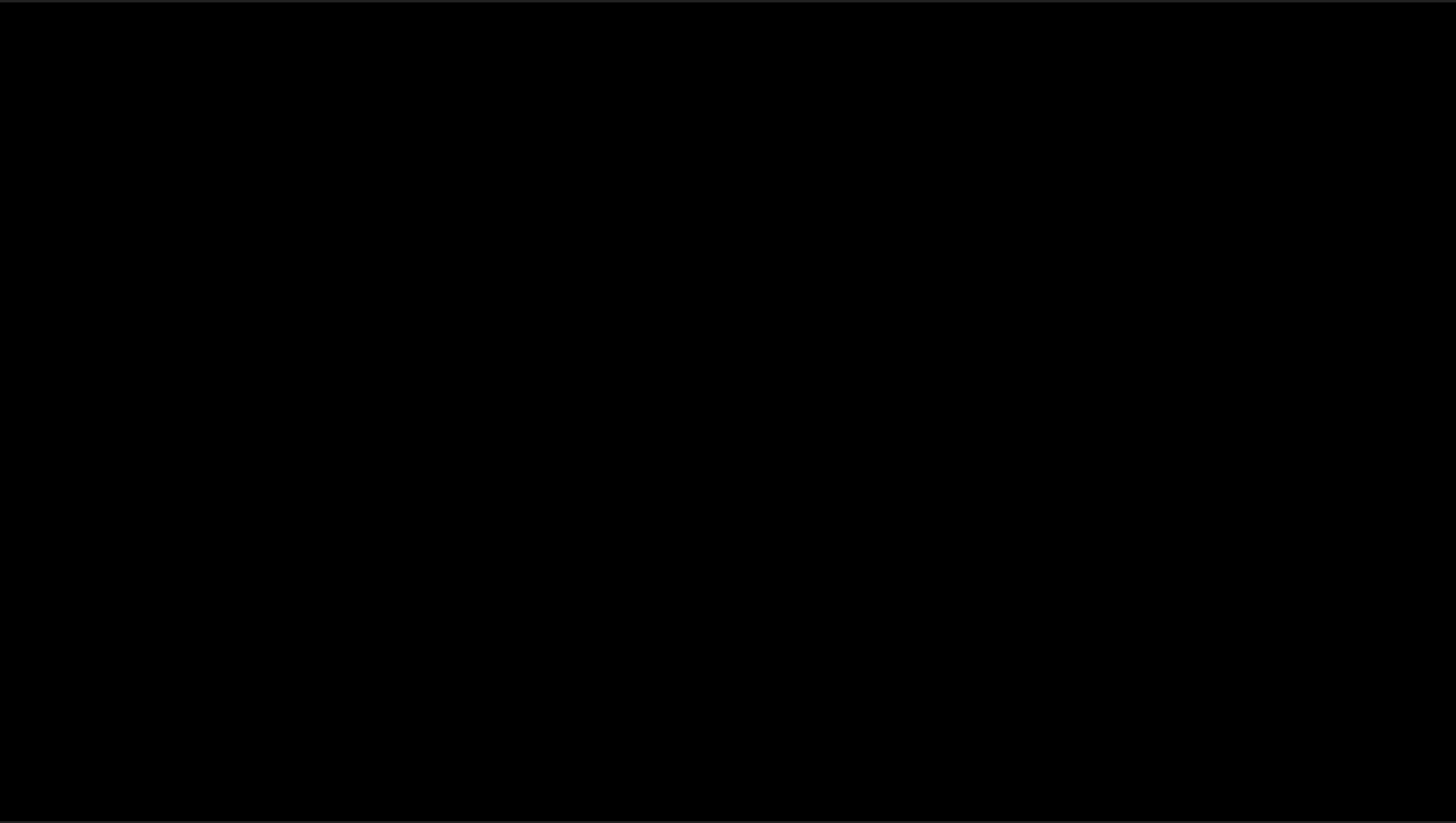
WHAT WOULD VEGA BE USED FOR LSST?

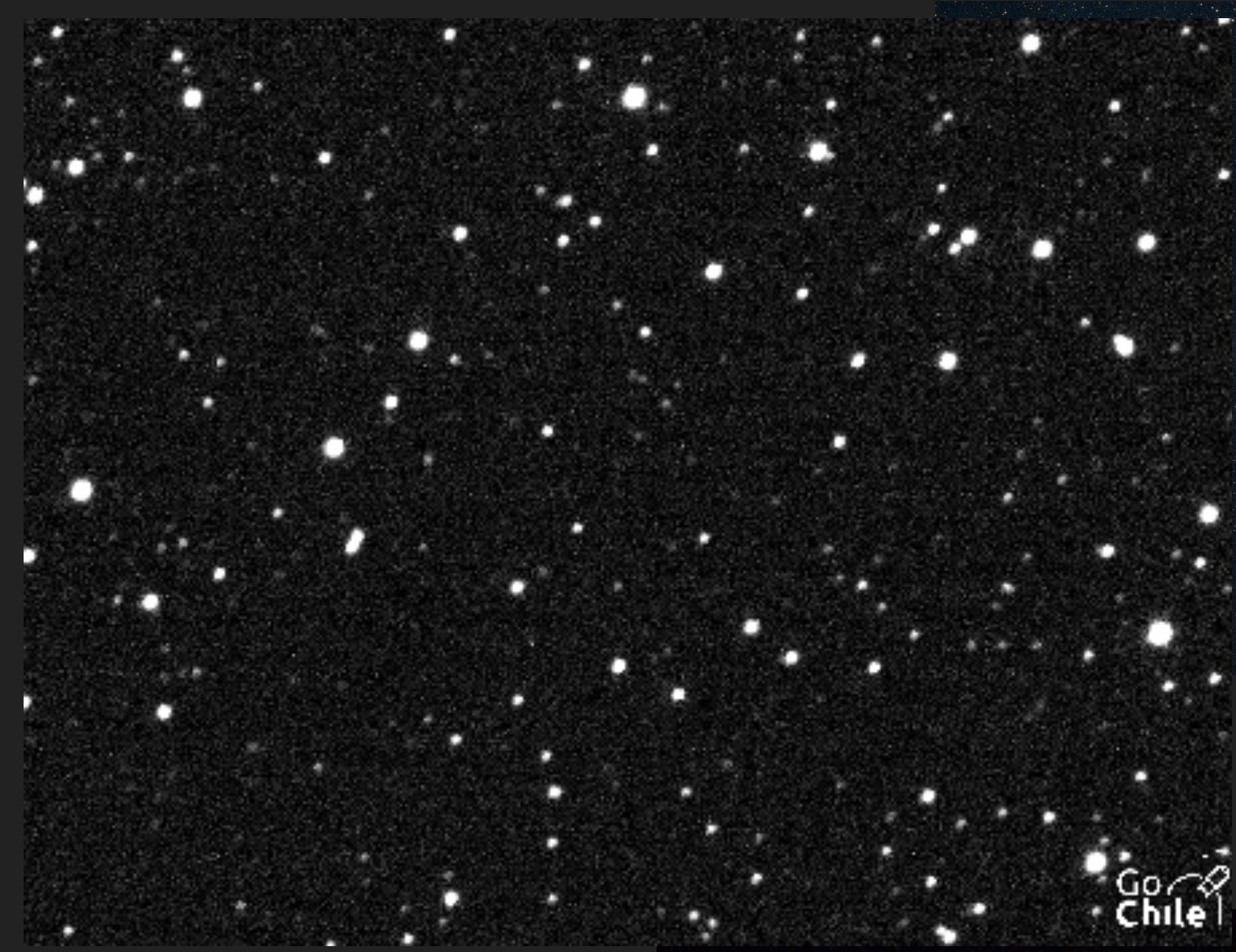
- preferably related to TDEs
- suggestions welcome!

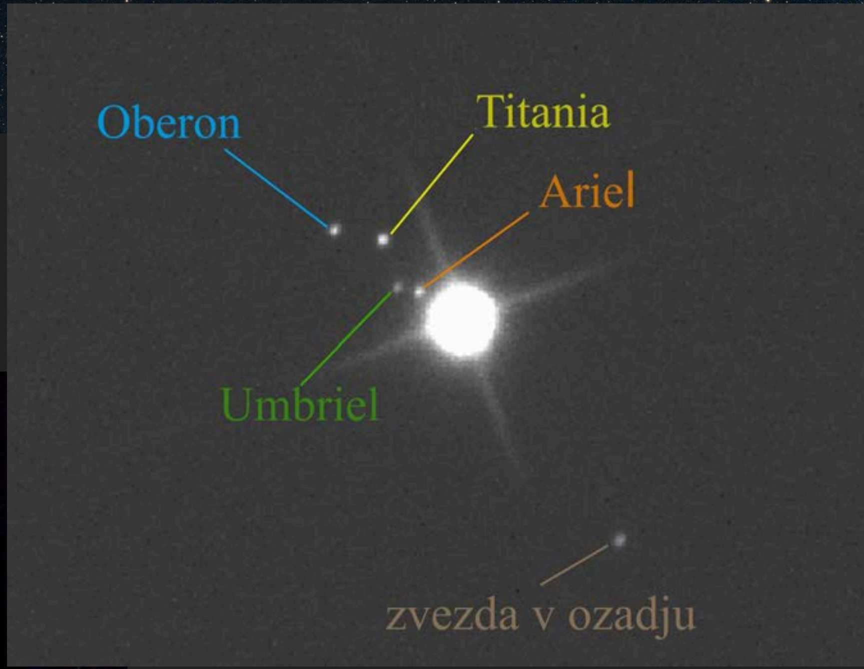
GOCHILE

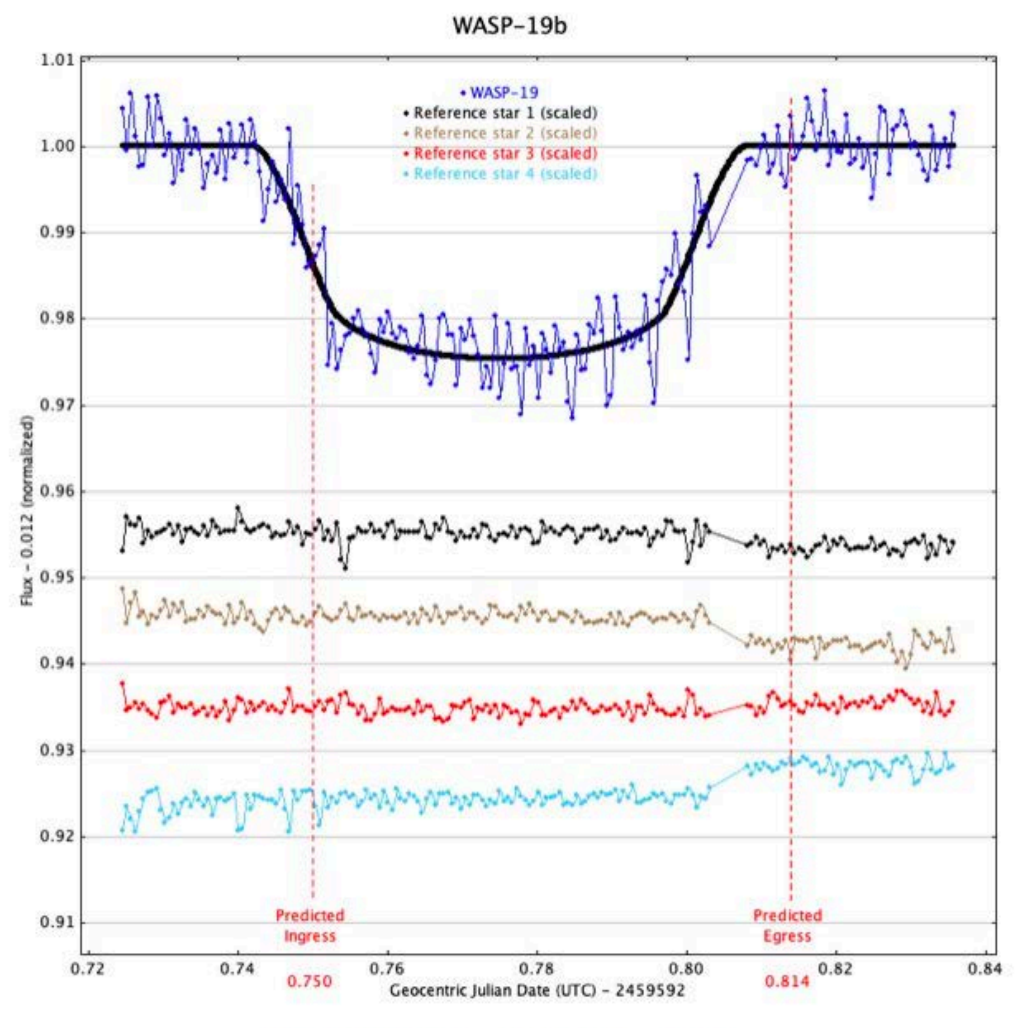
- University of Nova Gorica
- Astronomical magazine Spika

STUDENTS...

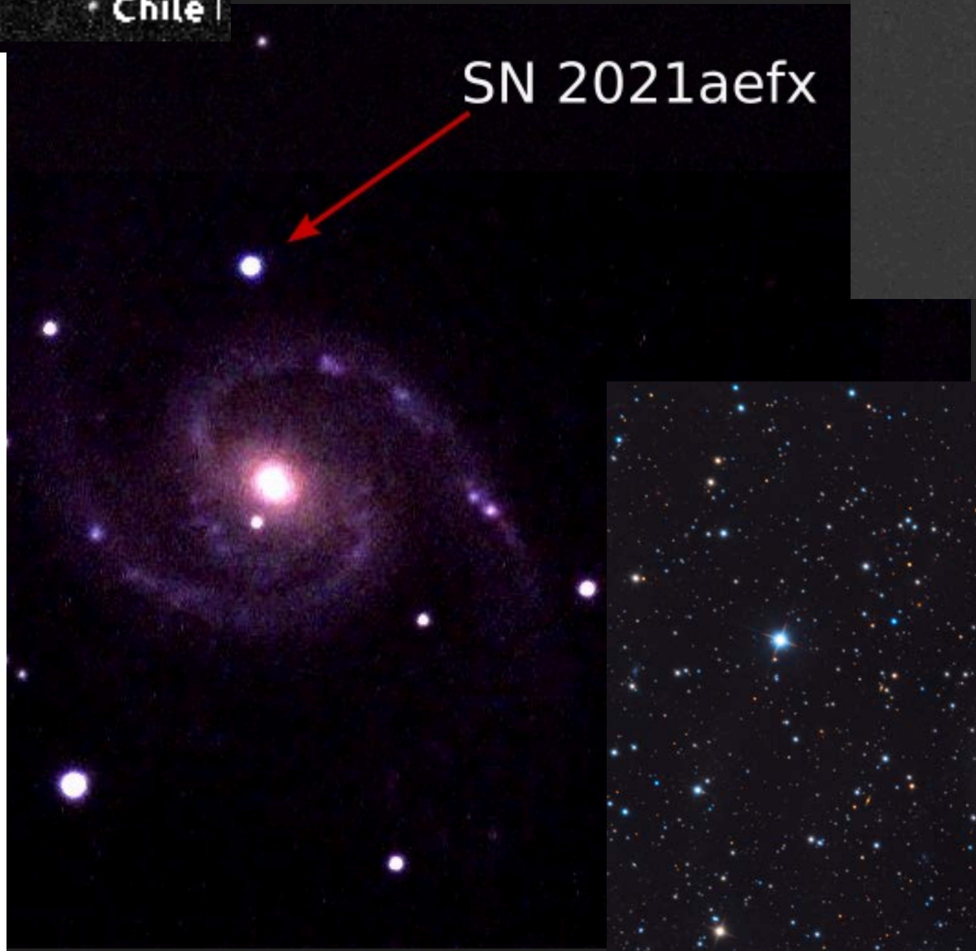








Graf 1: Svetlobna krivulja za prehod eksoplaneta WASP-19b



THANK YOU