

# Nuclear Transients

Suvi Gezari



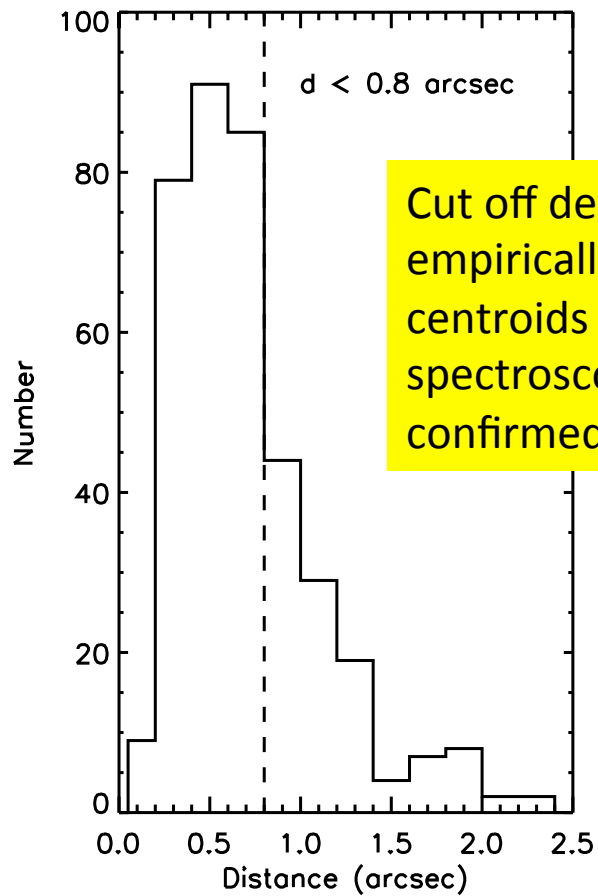
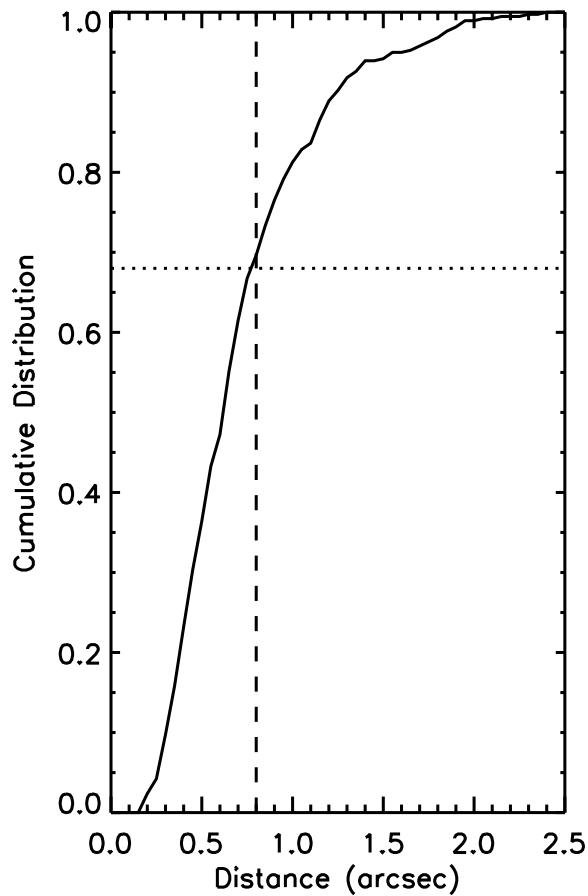
JSI

JOINT SPACE SCIENCE INSTITUTE

iPTF/ZTF Workshop – May 19, 2016

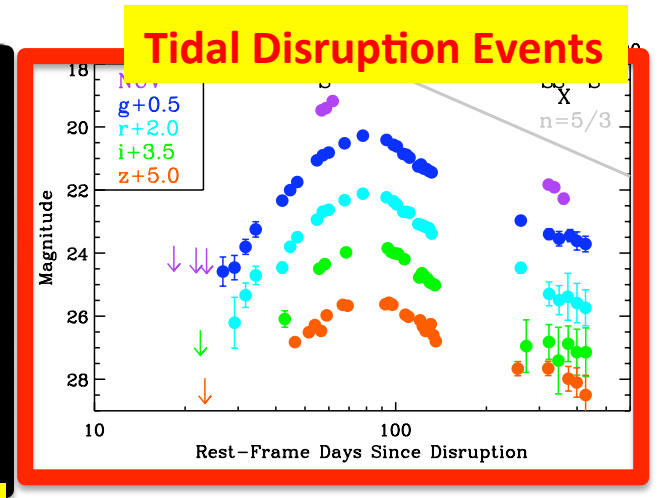
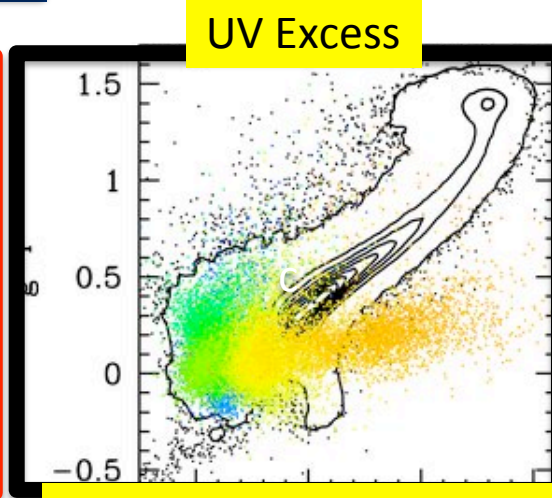
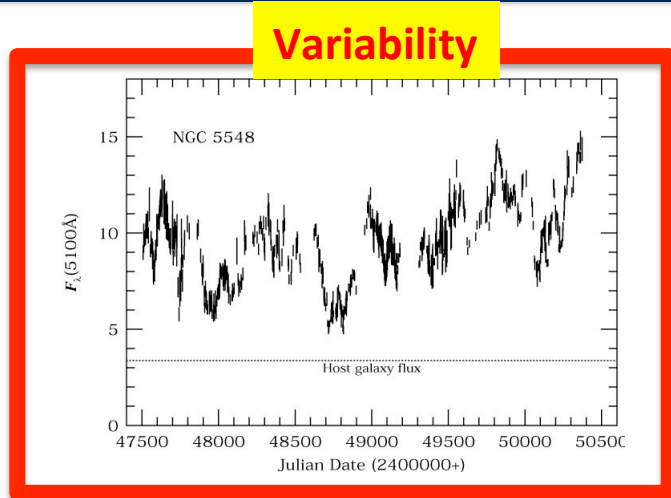
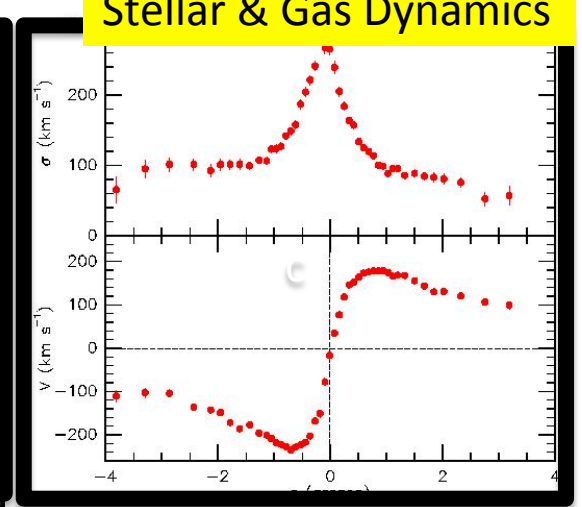
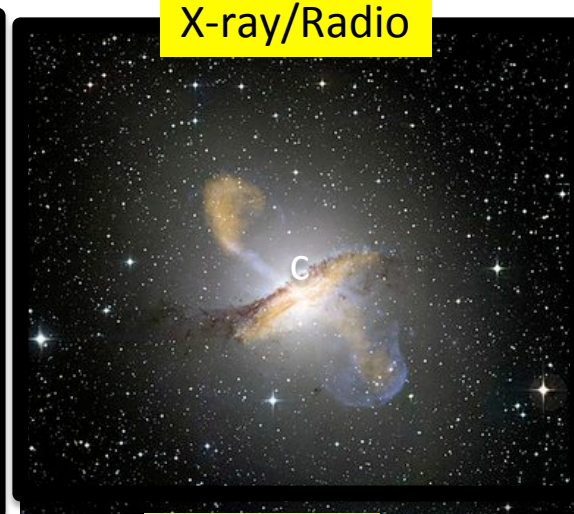
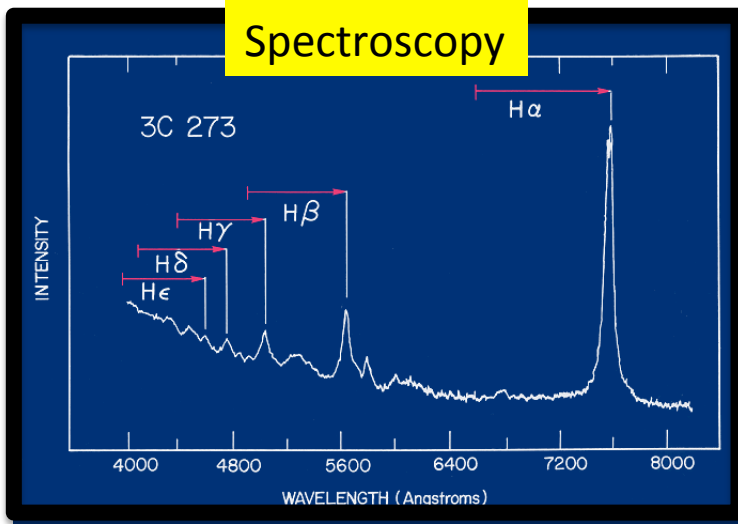
# Technical Definition for iPTF

Transient coincident with a host galaxy center within 0.8 arcsec.



# Scientific Motivation: SMBHs

# How Do We Find SMBHs?



**Time Domain**

# But we want to do more...

We don't just want to use time domain observations to **find** SMBHs in galaxy nuclei.

We want to use time domain observations to **probe** SMBH:

- Demographics (mass, spin, binarity)
- Accretion Physics
- Strong Gravity

# Black Hole GAMES

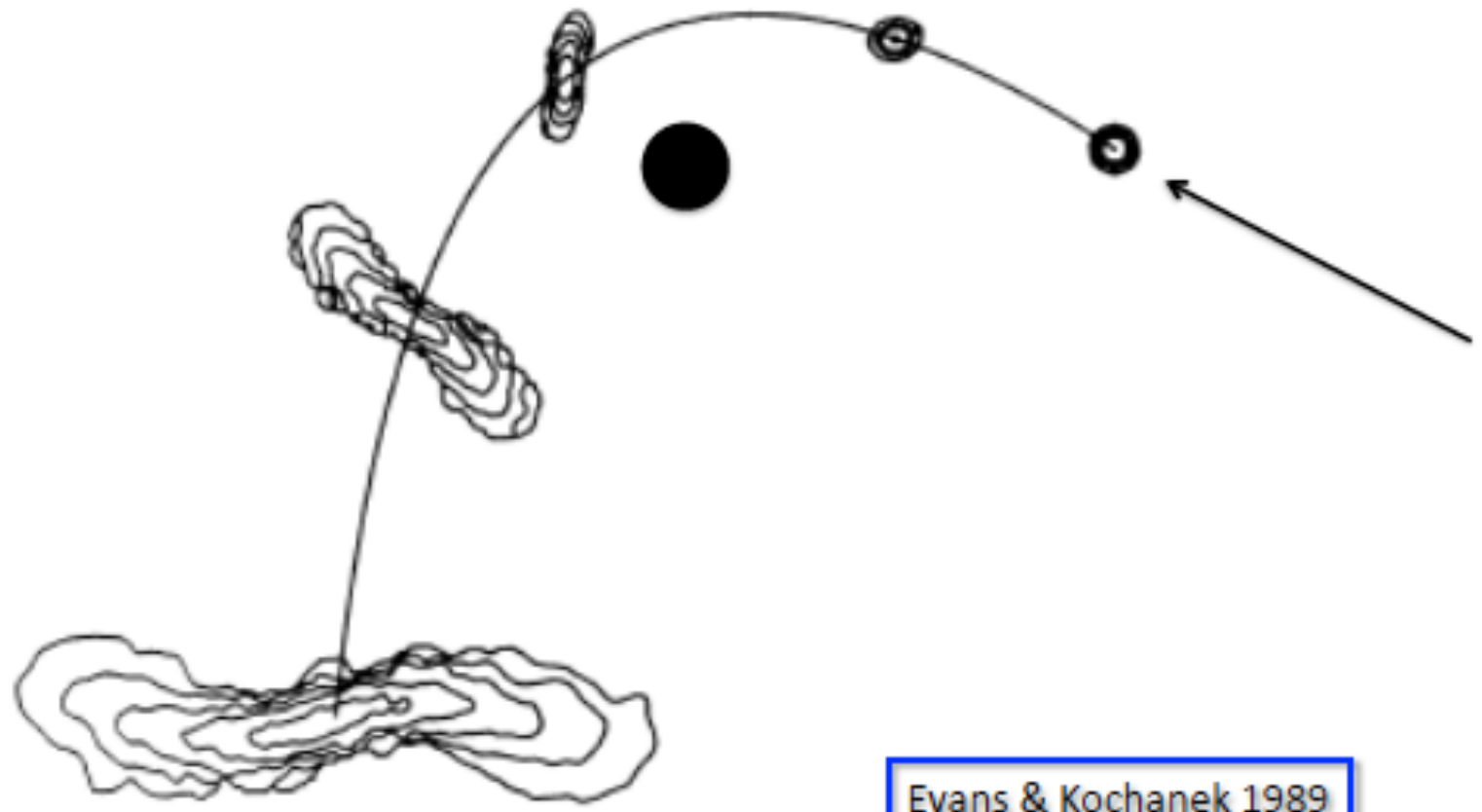
- ✧ **Intermediate mass** black holes
- ✧ **Rapidly spinning** supermassive black holes
- ✧ **Binary** supermassive black holes
- ✧ **Recoiling** supermassive black holes

Interesting phenomena for **black hole physics** as well as **black hole – galaxy coevolution**

# Tidal Disruption of a Star



# Tidal Disruption of a Star



Evans & Kochanek 1989



# Tidal Disruption of a Star



The star is ripped apart when tidal forces overcome the self gravity of the star:

$$\frac{GM R_{\star}}{r^3} = \frac{Gm_{\star}}{R_{\star}^2}$$

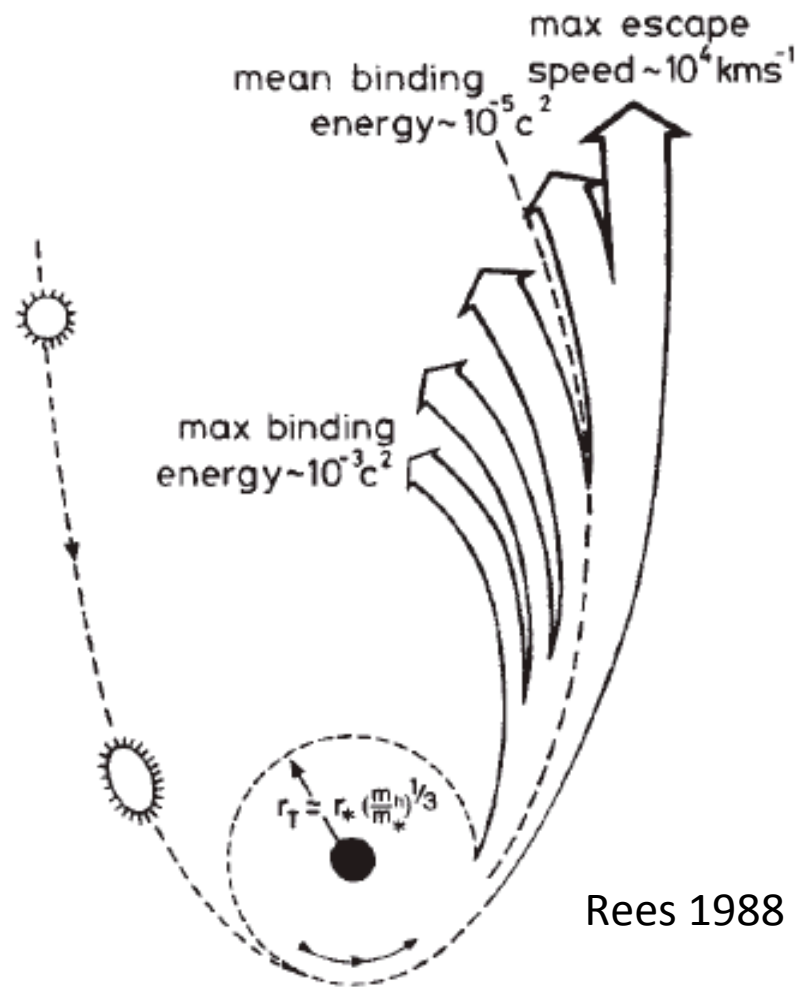
Tidal Force

Self-Gravity

$$r_{\text{T}} \approx R_{\star} (M_{\text{BH}}/m_{\star})^{1/3}$$

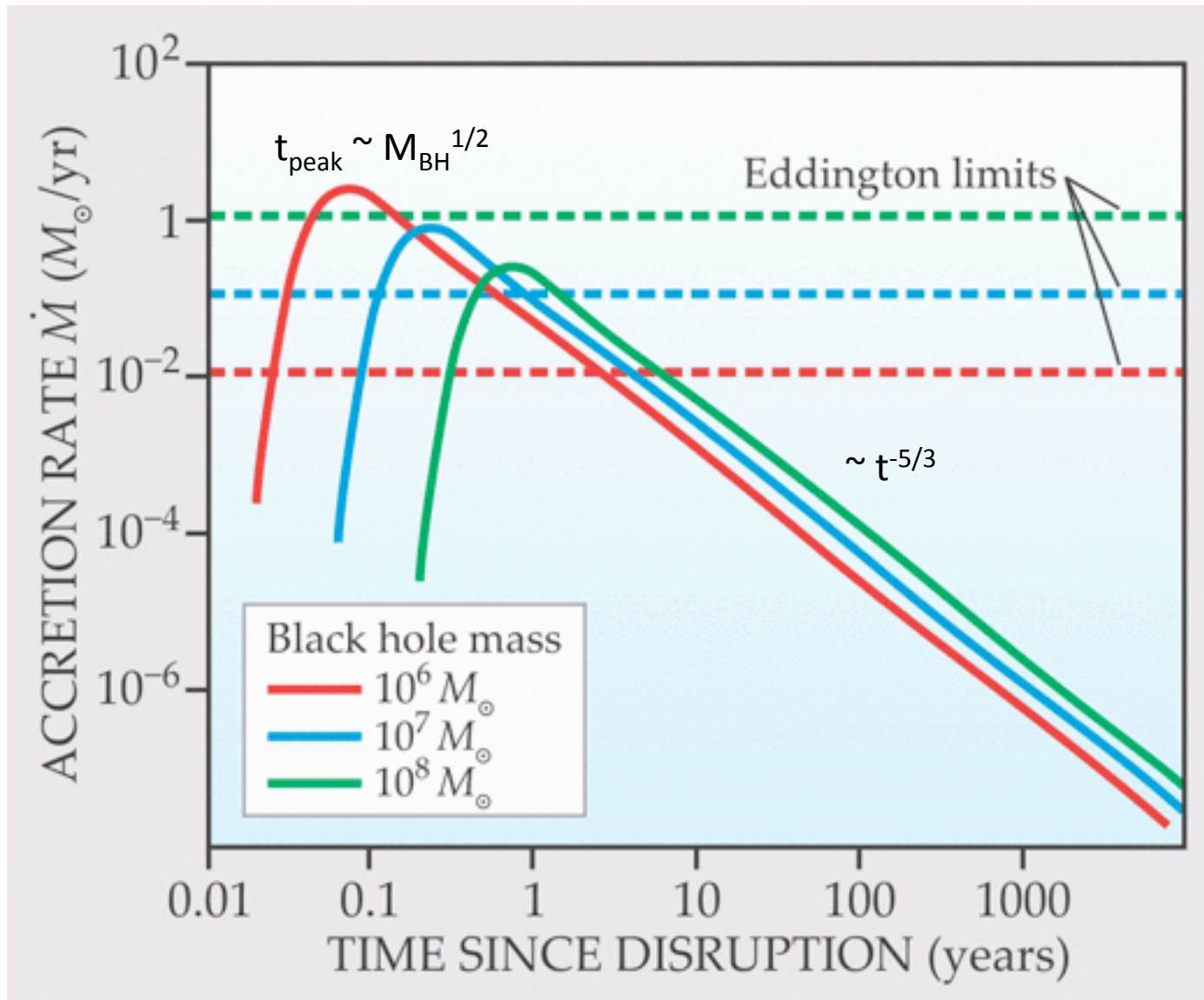
Tidal Disruption Radius

# Transient Signpost for Dormant SMBHs

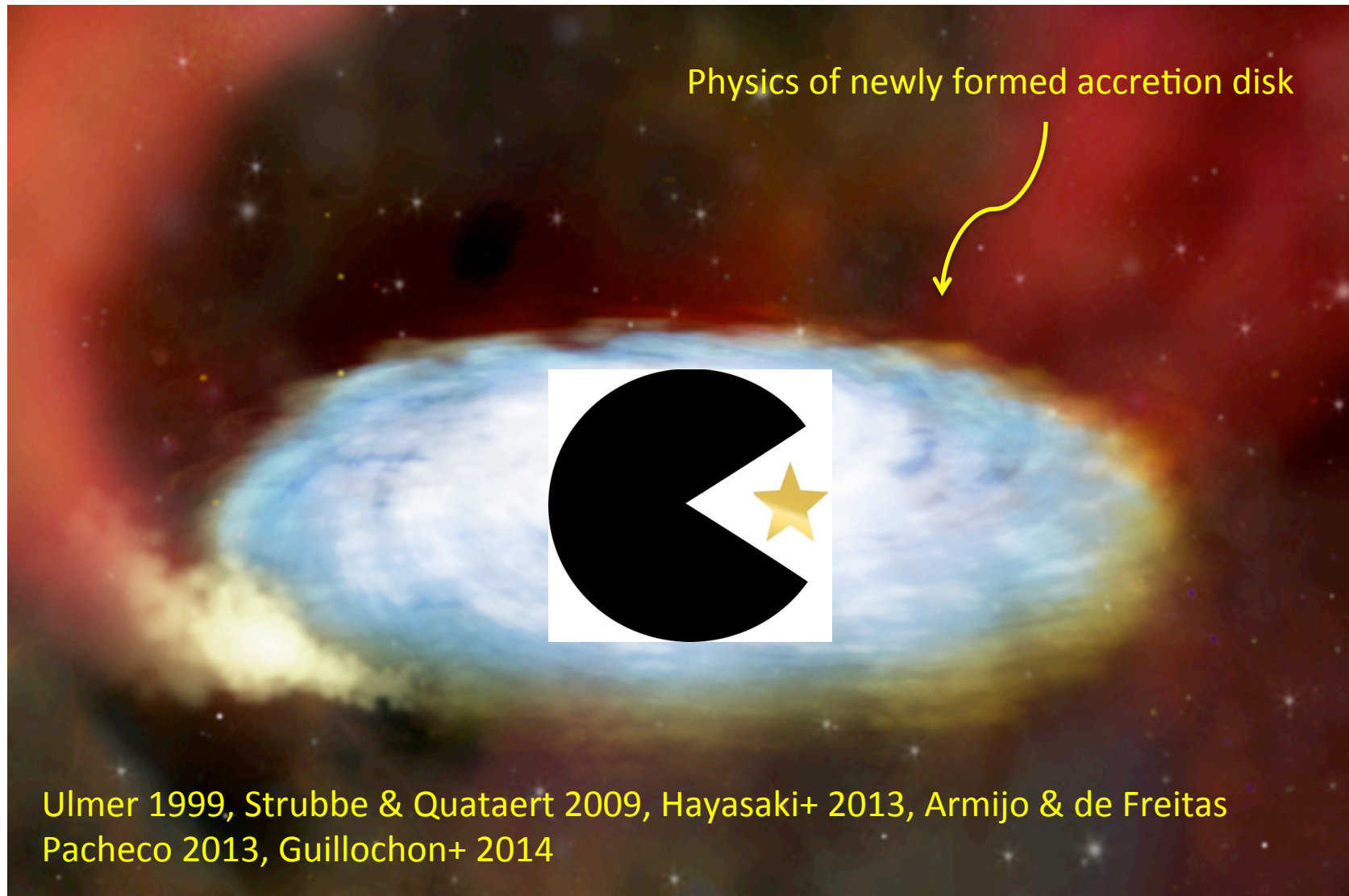


Rees 1988

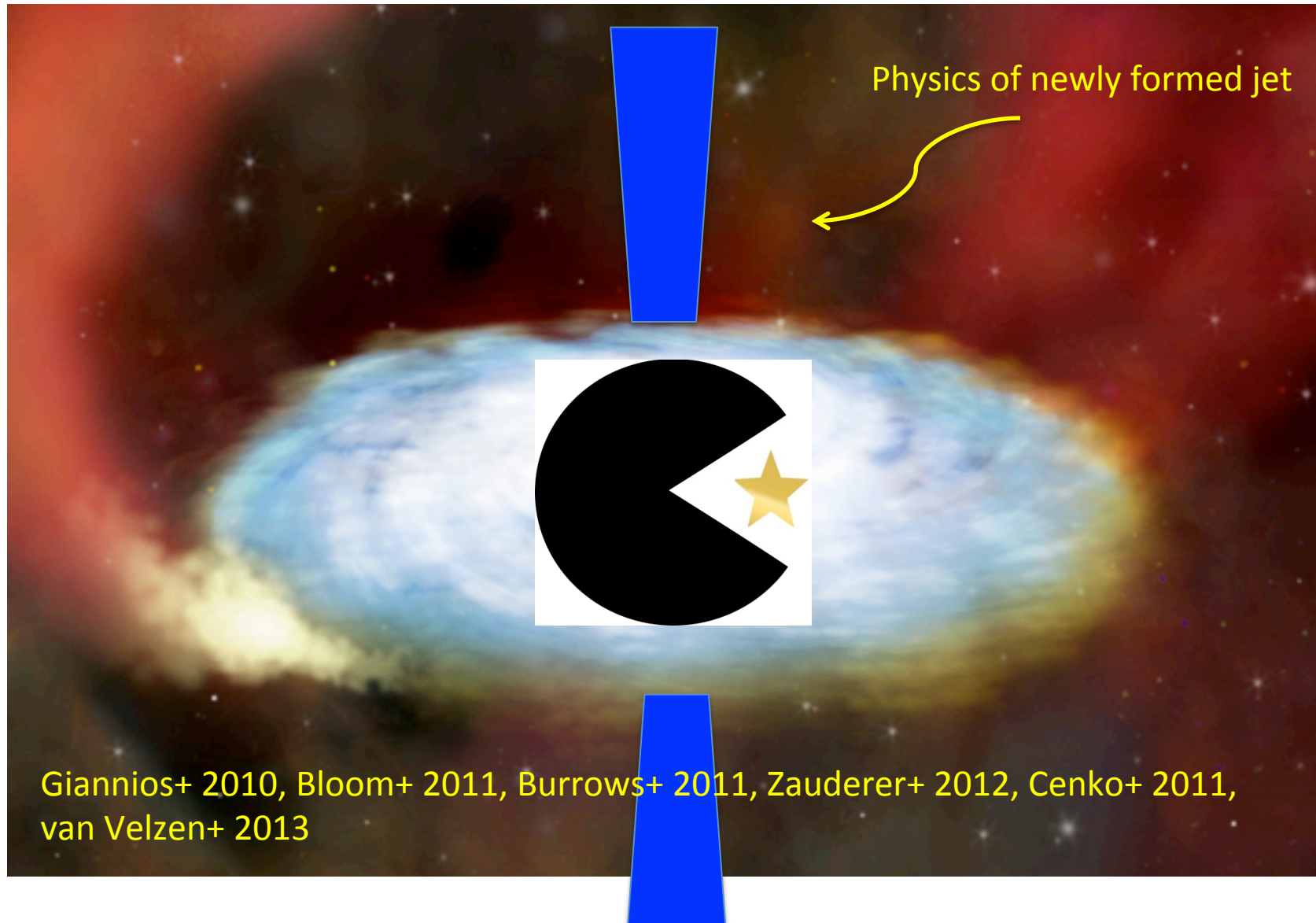
# Tidal Disruption of a Star



# What can we learn from TDEs?

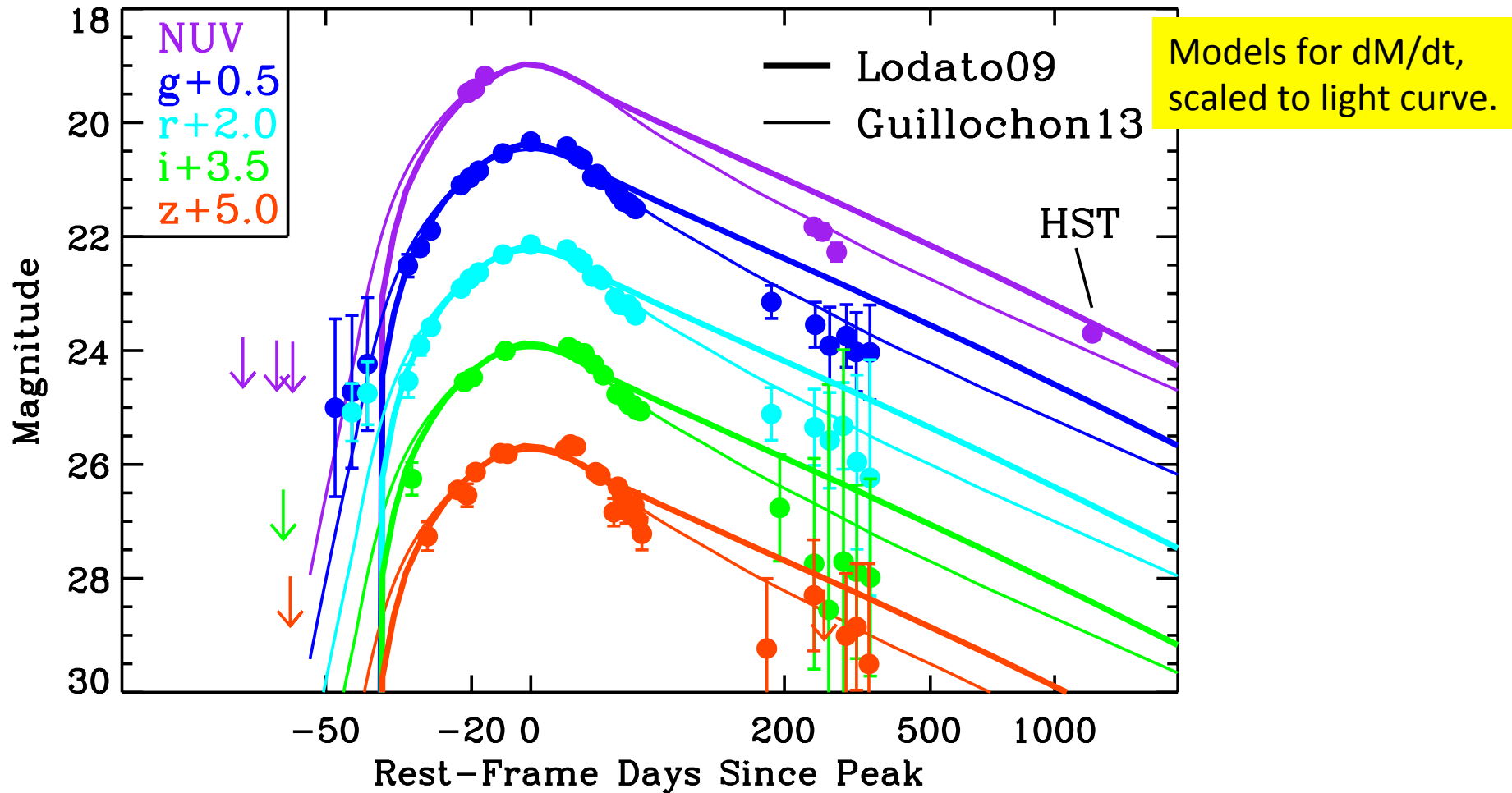


# What can we learn from TDEs?



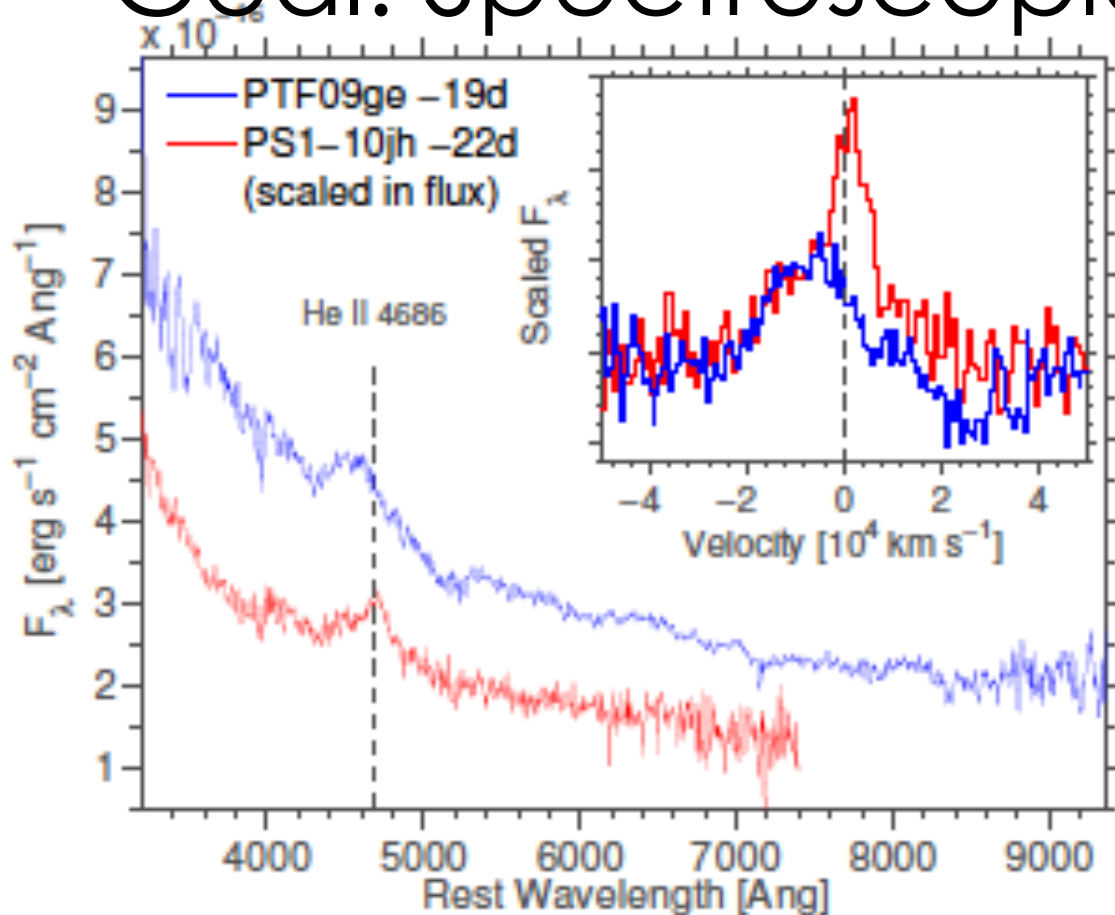


# Goal: Well-Sampled Light Curve



PS1-10jh: Gezari+ 2012, 2015

# Goal: Spectroscopic Follow-Up



PS1-10jh: Gezari+ 2012, 2015  
PTF09ge: Arcavi+ 2014  
ASASSN-15oi: Holoien+ 2016

*He-rich core of tidally stripped red giant star? (Gezari+ 2012)*

*Special photoionization conditions in debris of main sequence star (Guillochon+ 2014)*

*in an optically-thick, extended envelope? (Roth+ 2015)*

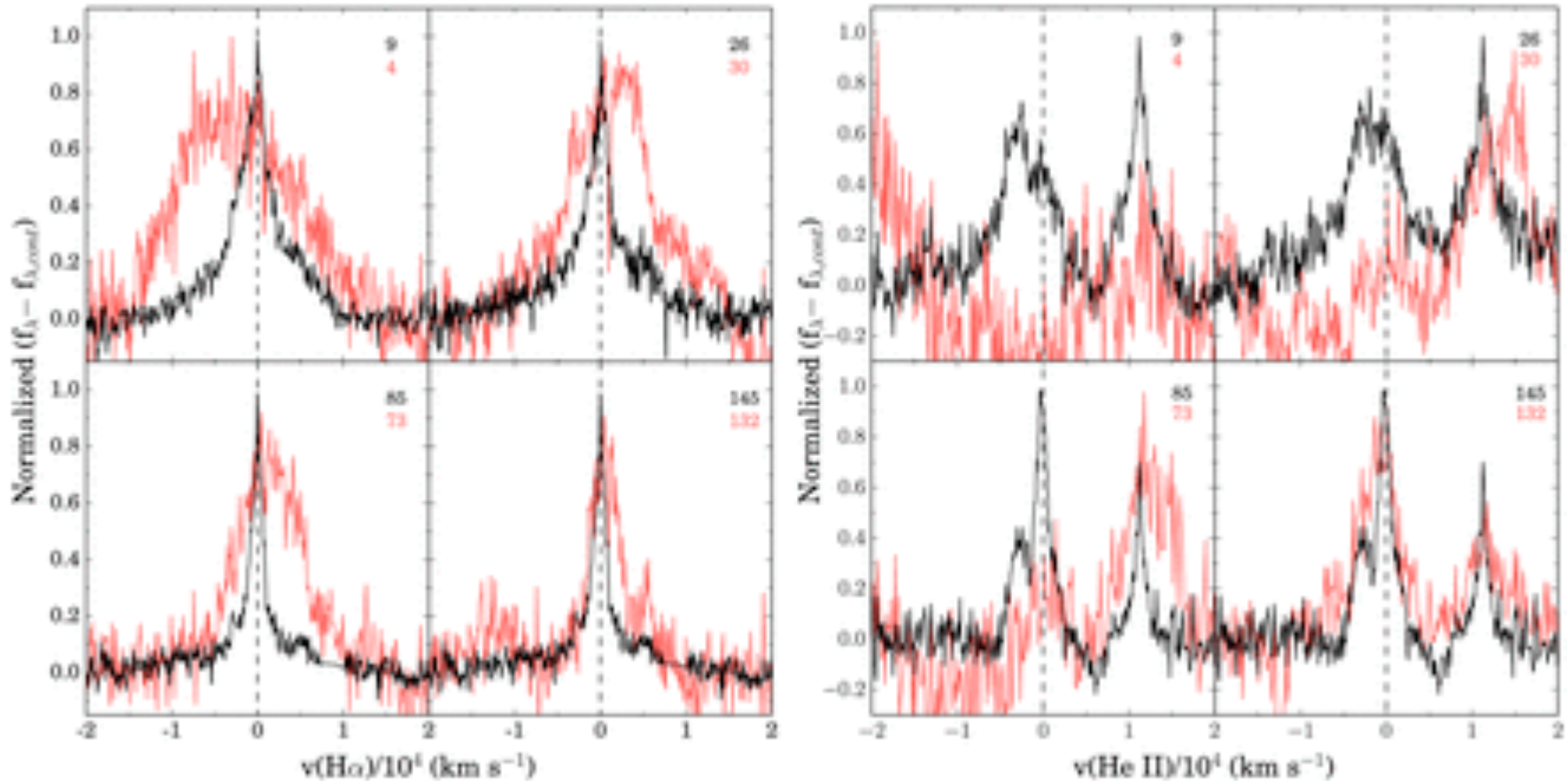
*He-enhanced core of main sequence star due to nuclear burning? (Kochanek 2016)*



# Goal: Spectroscopic Follow-Up

H $\alpha$

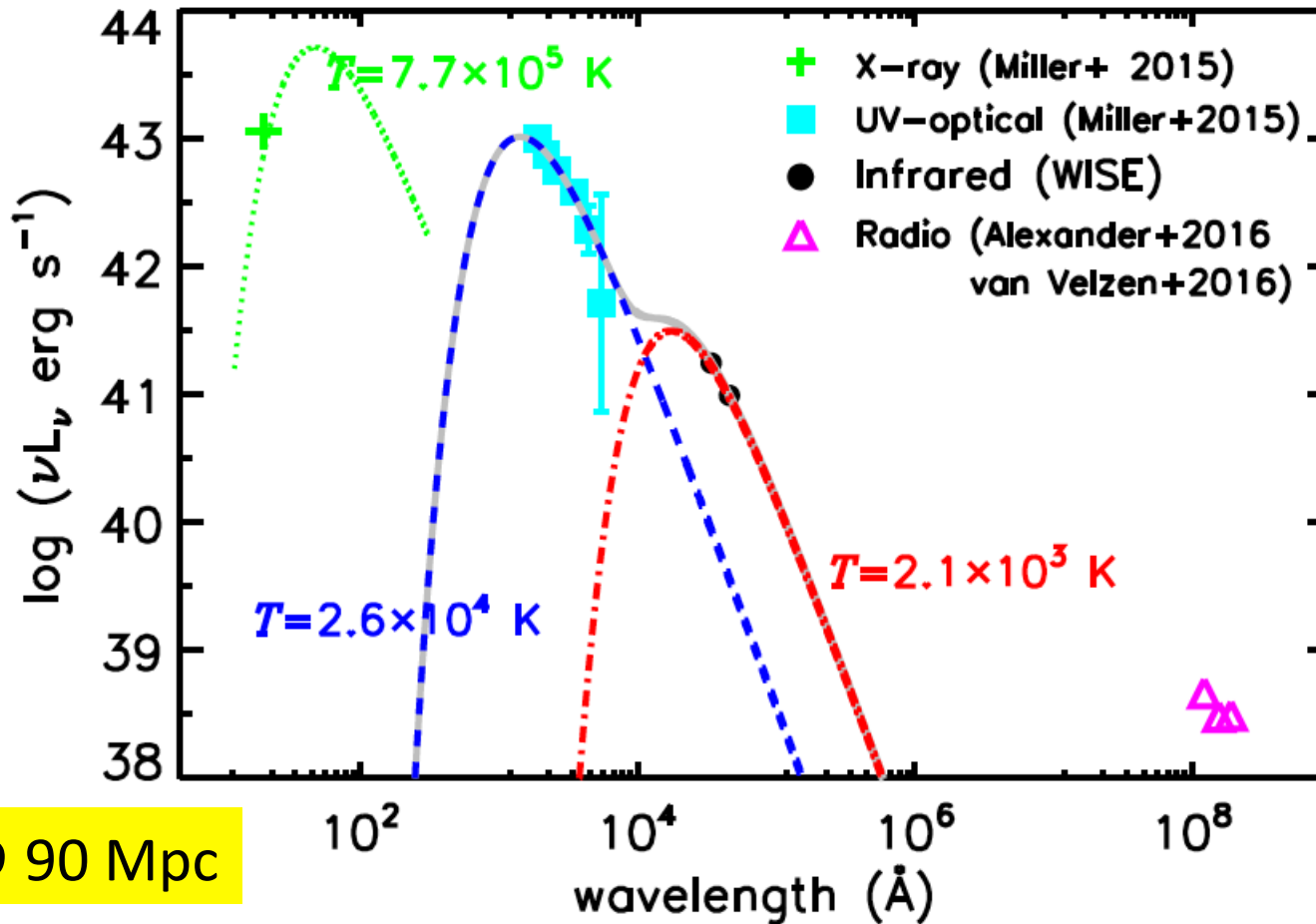
He II  $\lambda 4686$



Dynamical fingerprint of tidal disruption debris!

Holoien+ 2016

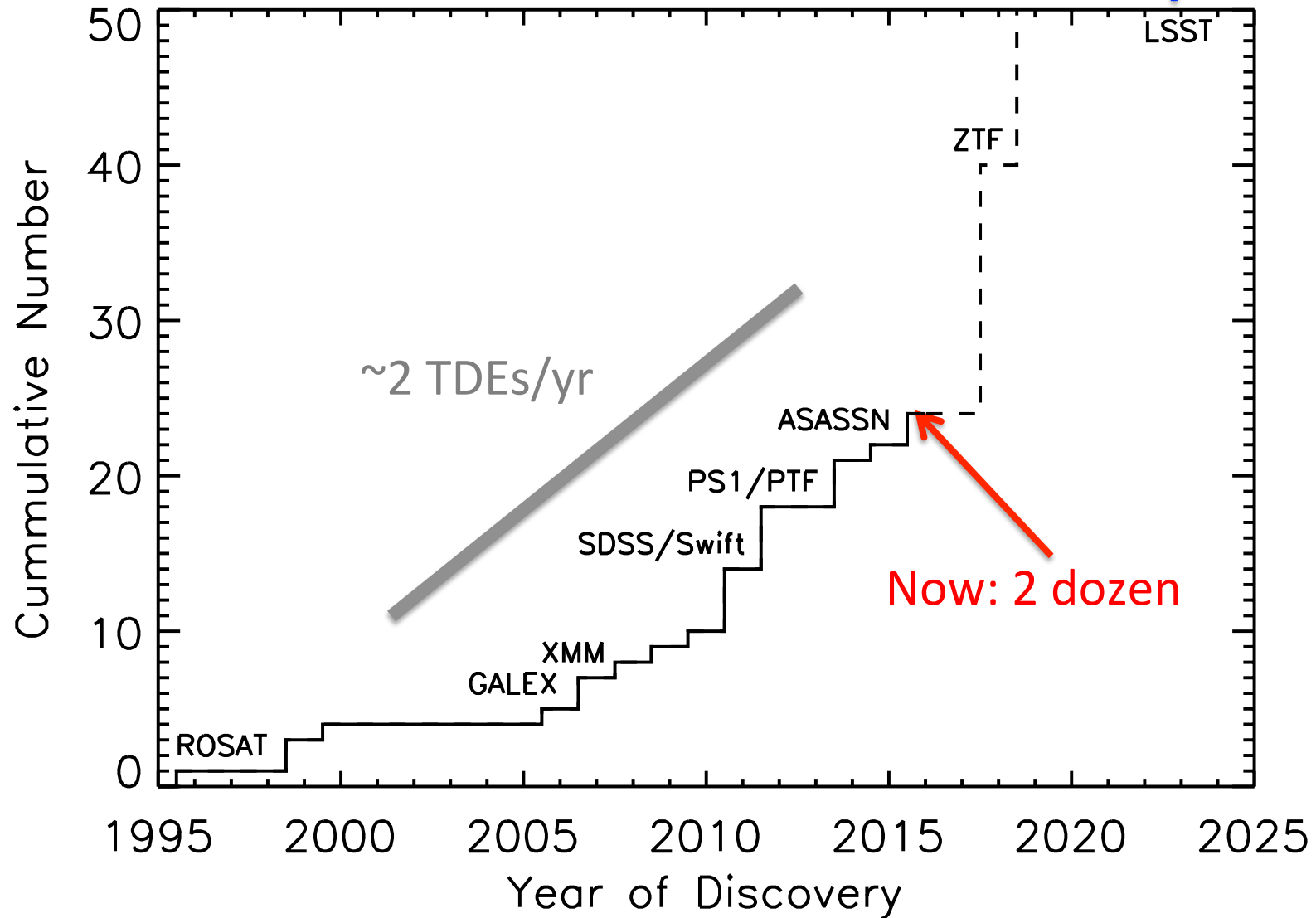
# Goal: Prompt Multiwavelength Follow-Up



TDE @ 90 Mpc

# Rate of Discovery

Future:  
thousands?



# Expected TDE Rates in iPTF/ZTF

*Scaling up from SDSS rate (van Velzen+ 2011):*

- $3.25 \text{ yr}^{-1} (2000 \text{ deg}^2)^{-1}$

*Scaling up from ASAS-SN rate (Holoien+ 2016):*

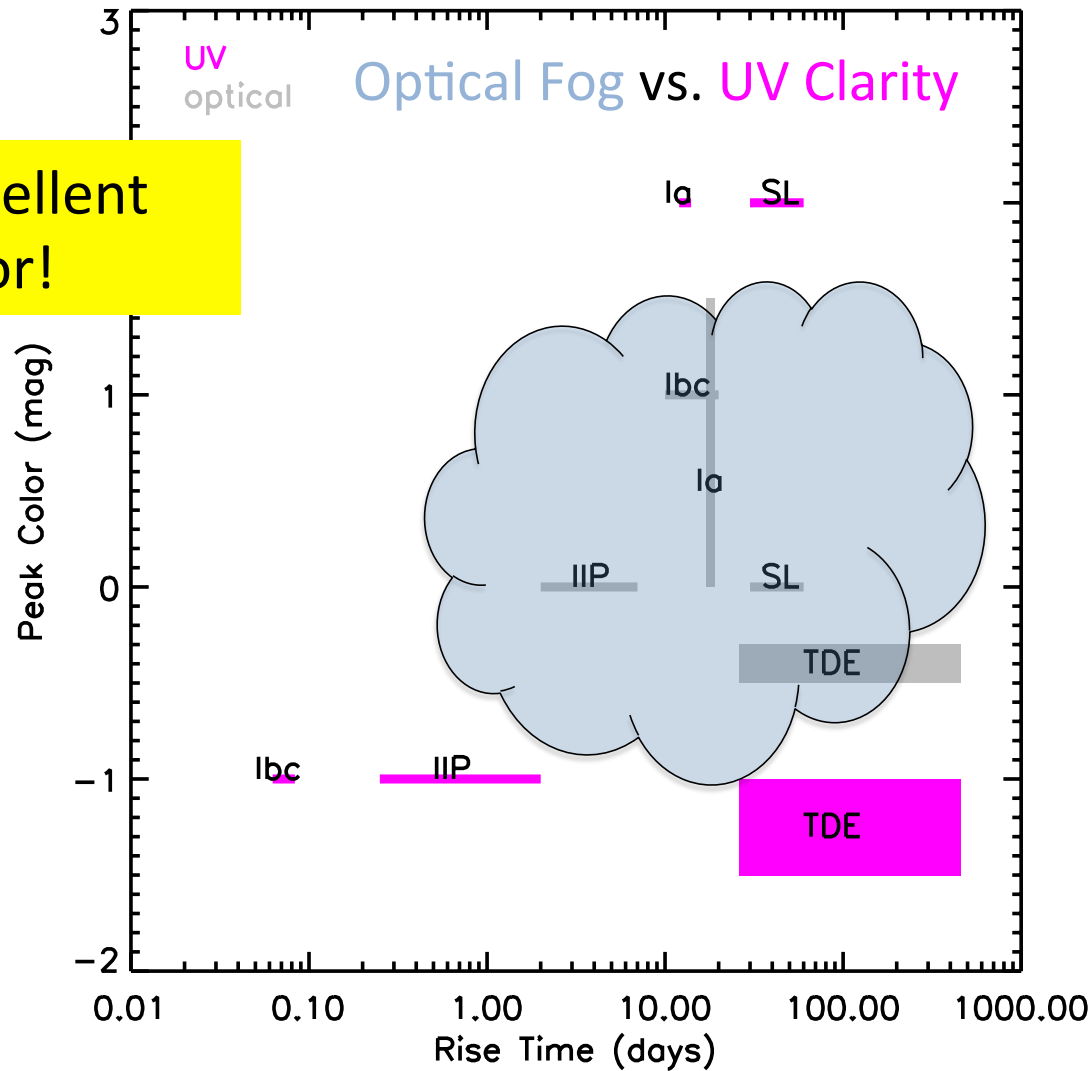
- $1/70 \times \text{SN Ia rate}$



CAUTION: SNe coincident with the nuclei of galaxies may appear as TDEs in your optical survey telescope.

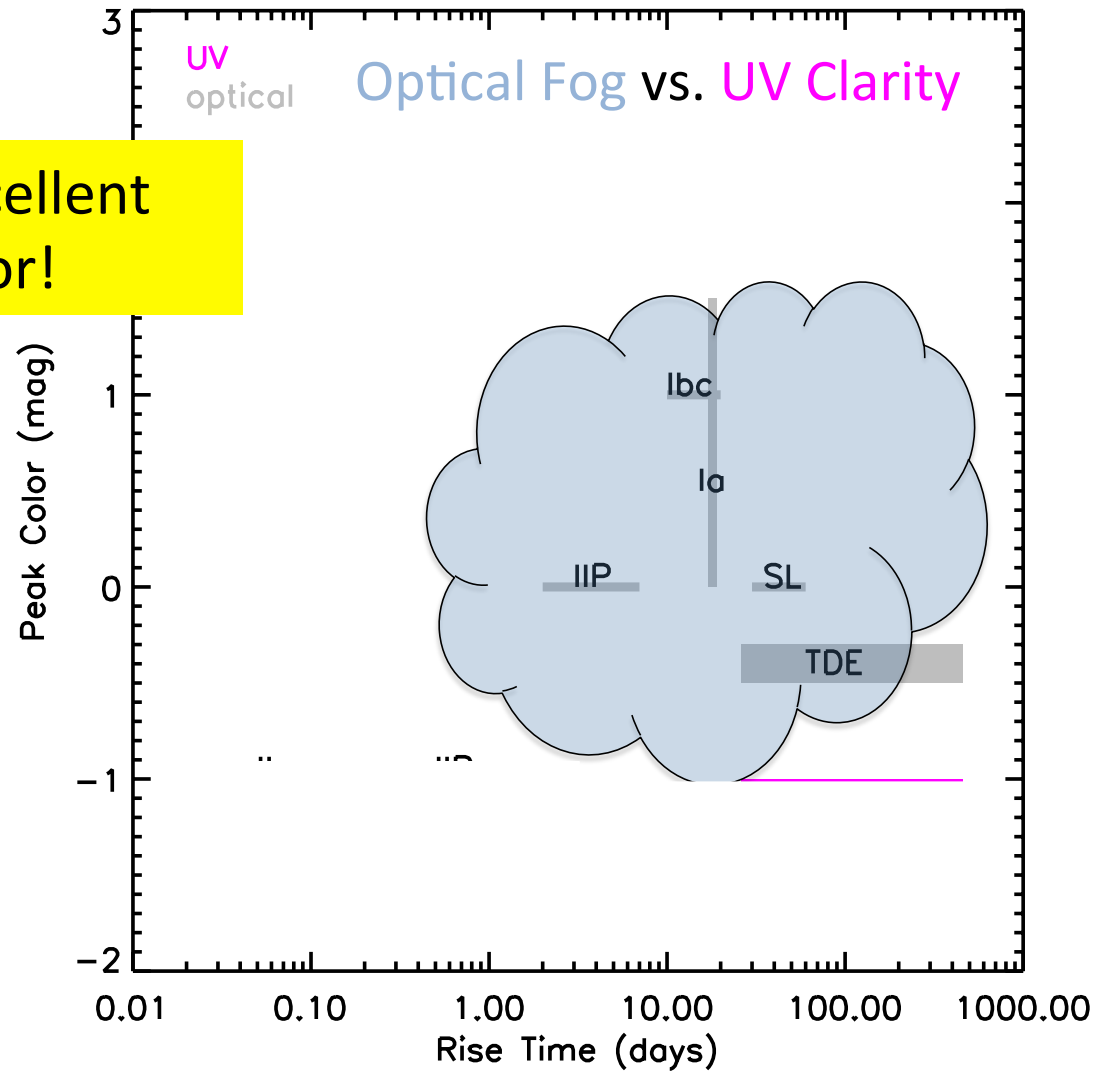
# UV Clears the Fog of SNe

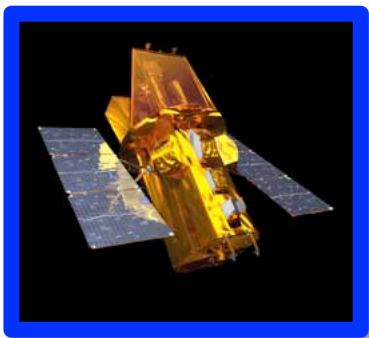
UV is an excellent discriminator!



# UV Clears the Fog of SNe

UV is an excellent discriminator!

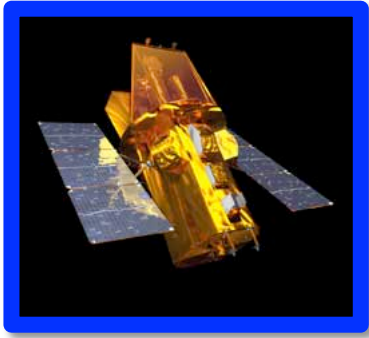




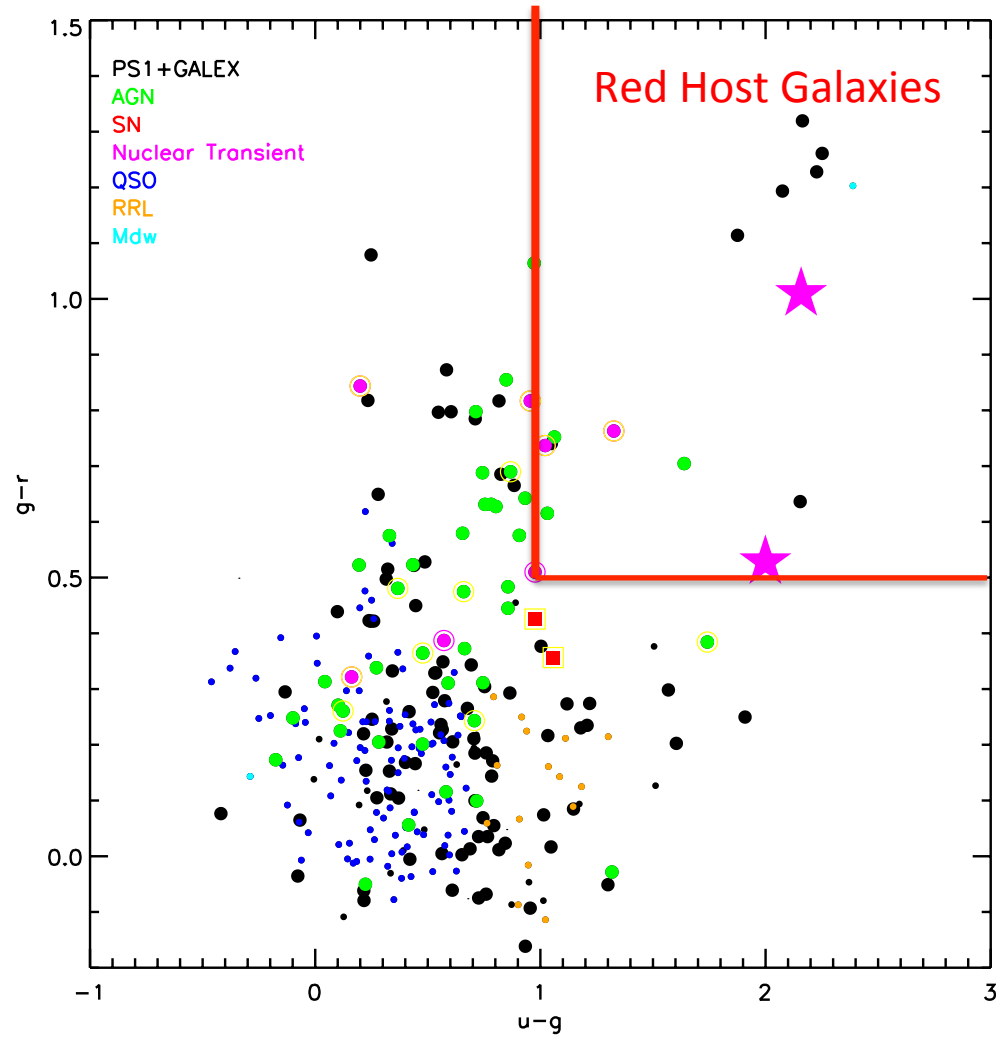
# Swift Key Project

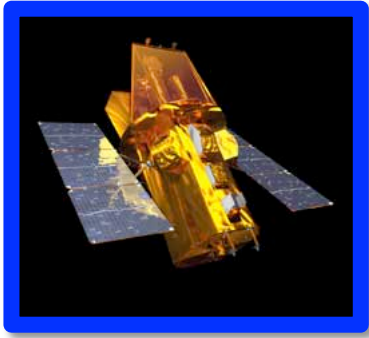
- Swift Key Project approved for Cycle 12 (now in progress) [Gezari, Cenko, Hung, Kulkarni, Yan, Blagorodnova]
- 2 triggers per week, with a second epoch possible 2 weeks later, 1ksec in uvw2 band
- Trigger criteria: nuclear transient in red host galaxy
- Total Swift allocation: 112 ksec
- 2 VLA triggers for spectroscopically confirmed TDEs



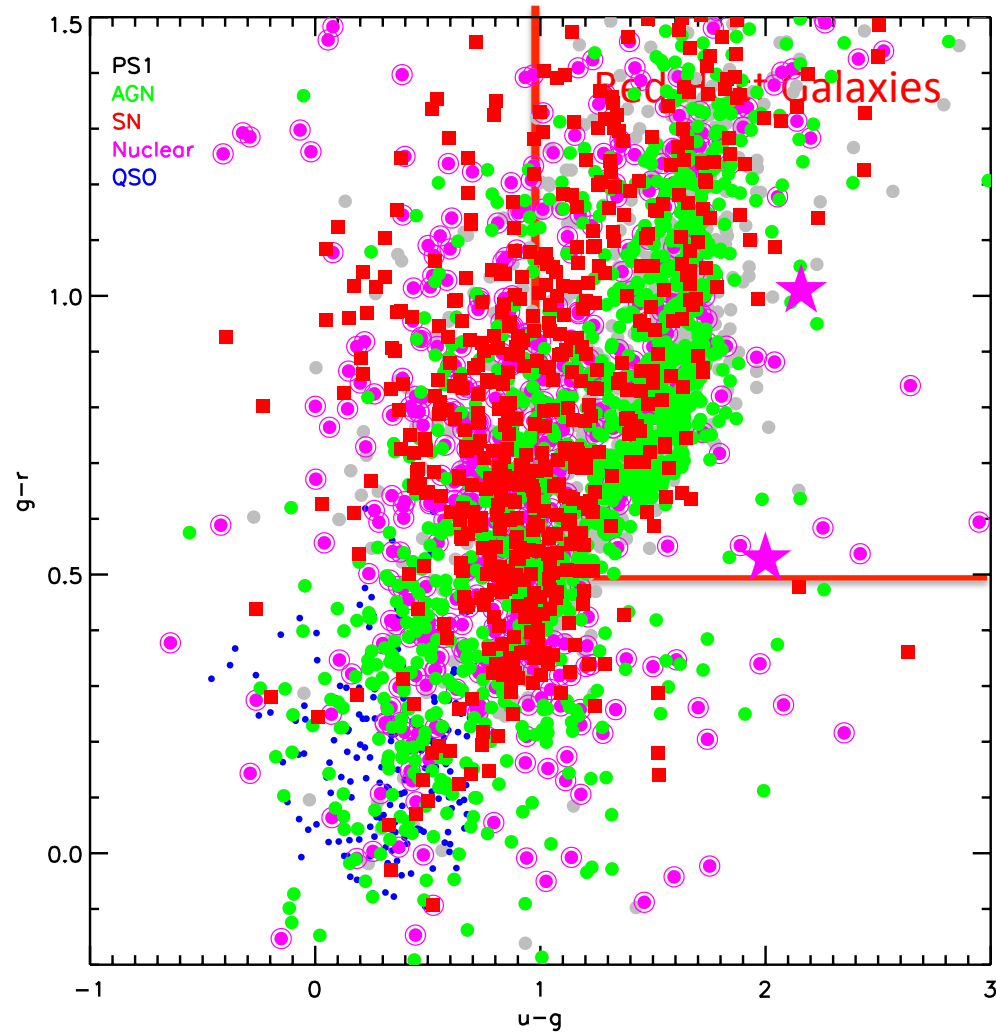


# Swift Key Project

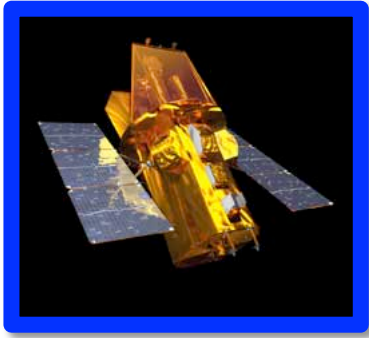




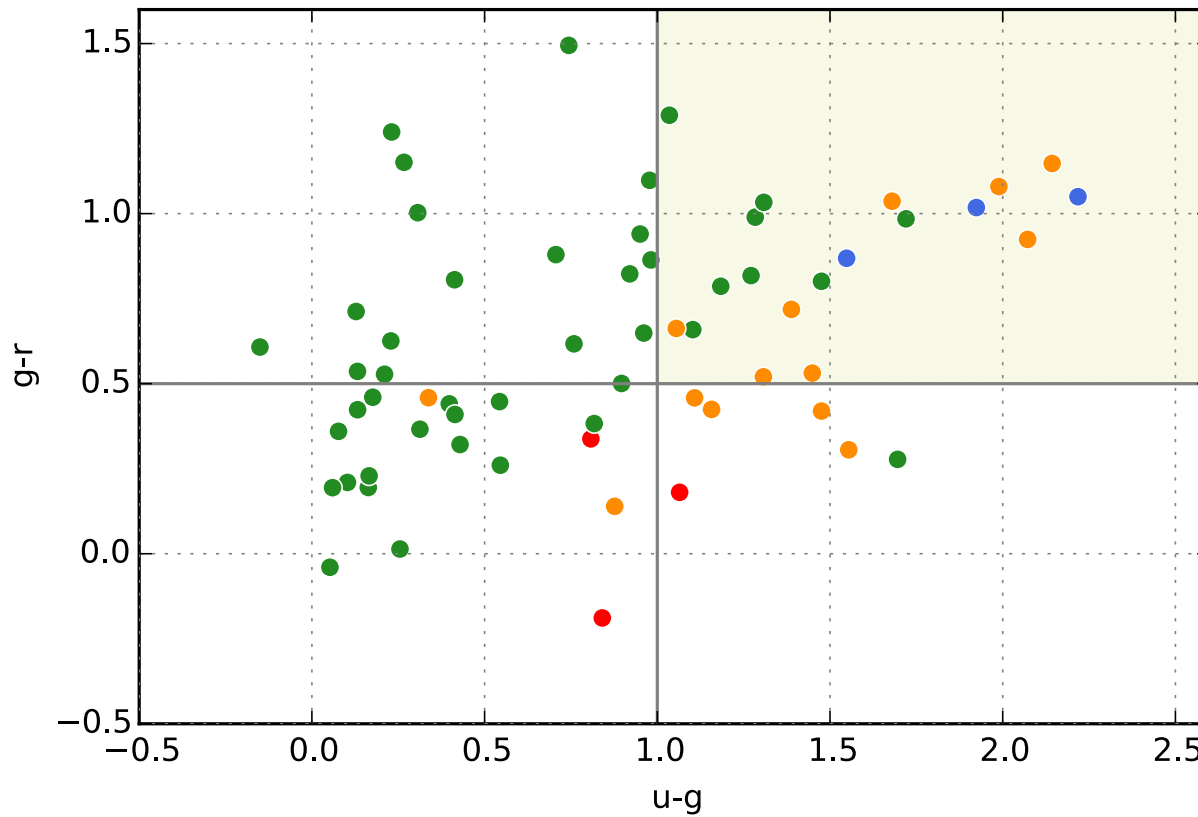
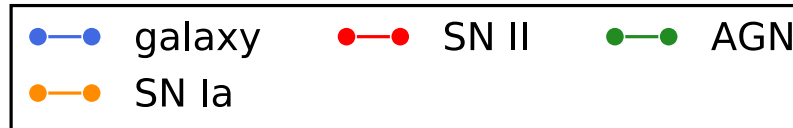
# Swift Key Project



Hosts of PS1  
transients



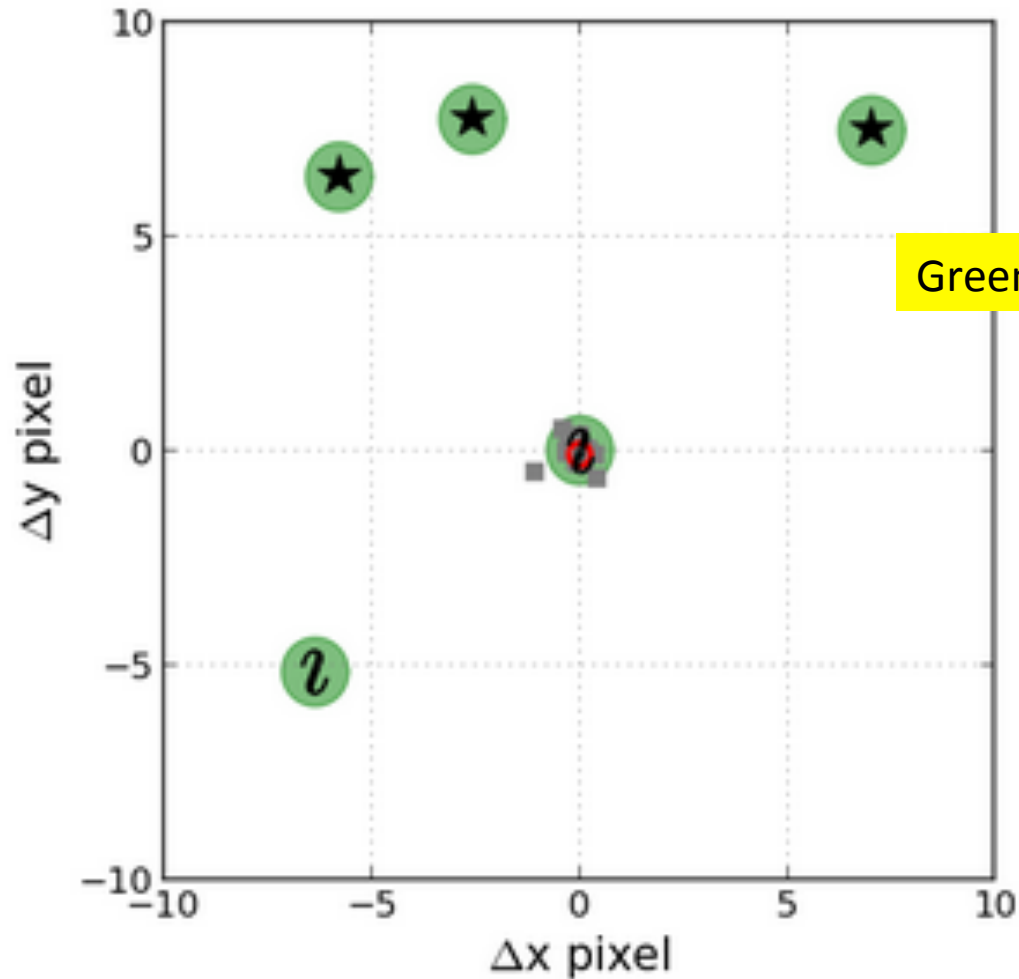
# Swift Key Project



Hosts of iPTF transients

# Offset Plots on Marshal

Offset Plot



Courtesy of Tiara Hung

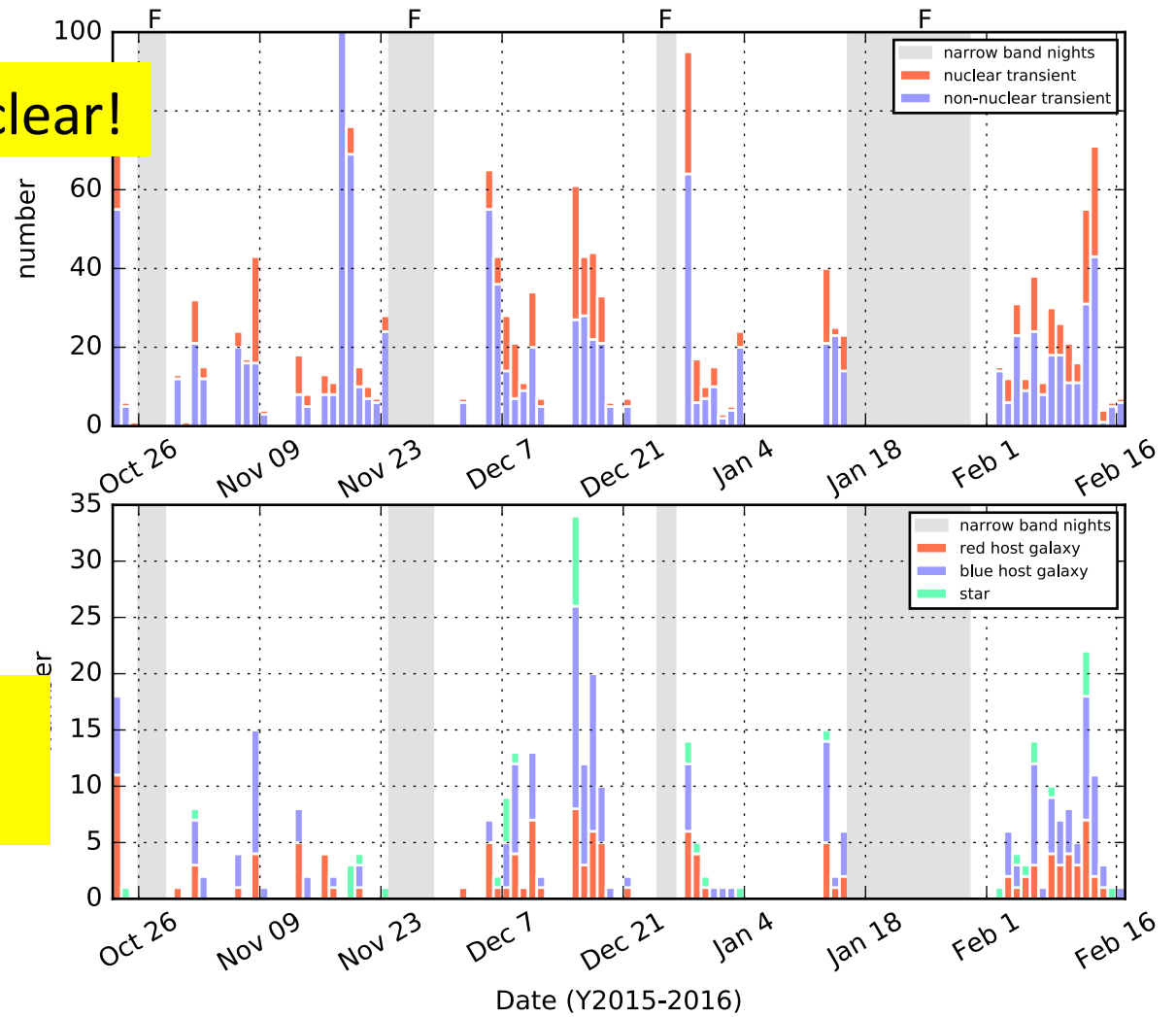
# iPTF Nuclear Transient Rates

iPTF Winter Survey 2015-16

1/3 of transients are nuclear!



1/3 of nuclear transients are in red hosts!



Date (Y2015-2016)

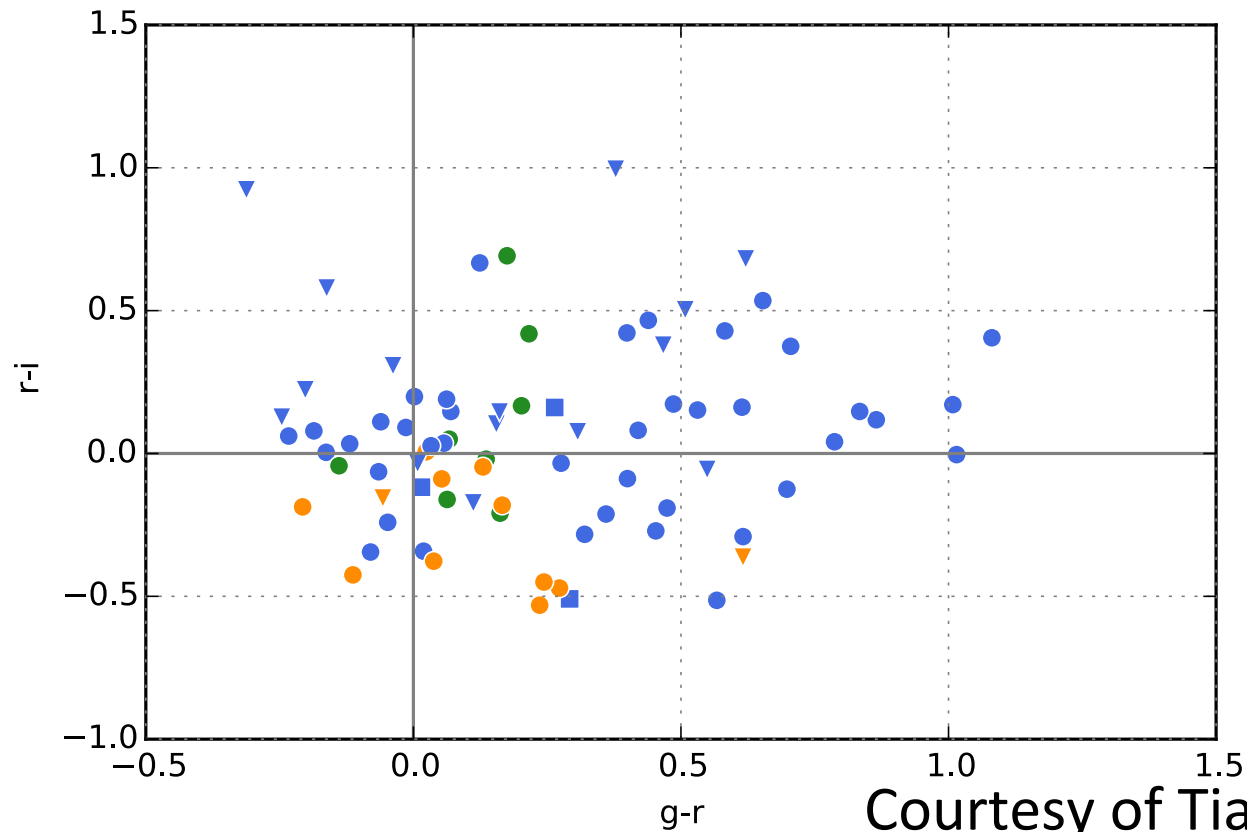
Courtesy of Tiara Hung

# Need Filtering Criteria

*Need to cut down sample to 1-2 per week:*

- P60 colors of nuclear transient with  $g-r < 0$   
(filter out most supernovae and AGN)
- Large flux change relative to host galaxy  
(filter out most AGN)
- Light curve history?  
(avoid AGN)
- Absolute magnitude?  
(avoid SNe Ia)
- Other ideas?

# P60 Colors of iPTF Nuclear Transients



# Nuclear Transients Table

Nuclear transients follow up

Home Swift CC plot Menu 3

Date range:   delm<0.5  absm<19.0

Show 25 rows Column visibility Search:

Name	peak	offset	absm	delm	transient	Host class	P60stat	g-r	comment	iPTF spec	Date
<a href="#">16ath</a>	20.05	0.43	-19.14	-1.23			ACTIVE	99	<a href="#">✎</a>	✖	2016-05-12 03:06:12
<a href="#">16atf</a>	20.55	0.34	-20.72	-1.94			ACTIVE	0.03	<a href="#">✎</a>	✖	2016-05-12 02:43:22
<a href="#">16ate</a>	19.77	0.3	-19.16	-0.56			ACTIVE	0.28	<a href="#">✎</a>	✖	2016-05-12 02:38:55
<a href="#">16ata</a>	18.67	0.24	-19.84	-1.15				99	PTFIDE shows no detection	✖	2016-05-12 01:56:36
<a href="#">16asv</a>	20.28	0.72	-20.43	-2.12			ACTIVE	99	<a href="#">✎</a>	✖	2016-05-12 00:48:26
<a href="#">16art</a>	19.68	0.45	-19.18	-0.63			ACTIVE	0.43	<a href="#">✎</a>	✖	2016-05-11 00:23:47
<a href="#">16aqg</a>	18.96	0.39	-19.2	-0.5		GALAXY	EXPIRED	0.47	red transient	✖	2016-05-05 02:10:42
<a href="#">16aoq</a>	19.74	0.34	-19.18	-0.78			EXPIRED	0.36	red transient, nuclear SN?	✖	2016-05-03 04:33:55
<a href="#">16anw</a>	19.59	0.67	-19.79	-0.67		GALAXY	EXPIRED	99	a little off the nucleus.	✖	2016-05-03 00:30:28
<a href="#">16anu</a>	19.89	0.41	-20.23	-1.47	SN Ia		ACTIVE	99	<a href="#">✎</a>	✔	2016-05-03 00:29:09
<a href="#">16anc</a>	19.83	0.48	-19.85	-1.08	SN Ia		EXPIRED	99	<a href="#">✎</a>	✔	2016-05-02 07:42:27
<a href="#">16amv</a>	19.05	0.28	-19.17	-0.58		GALAXY	EXPIRED	99	<a href="#">✎</a>	✖	2016-05-02 07:38:38

Courtesy of Tiara Hung



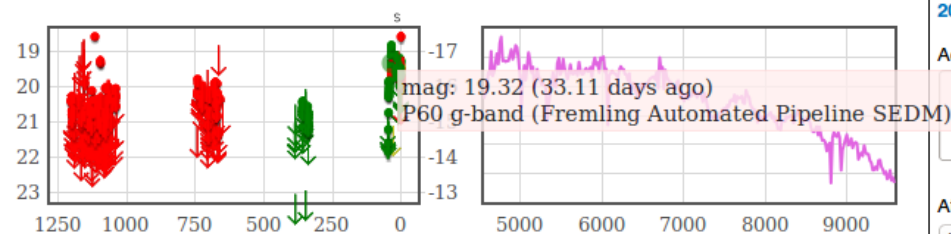
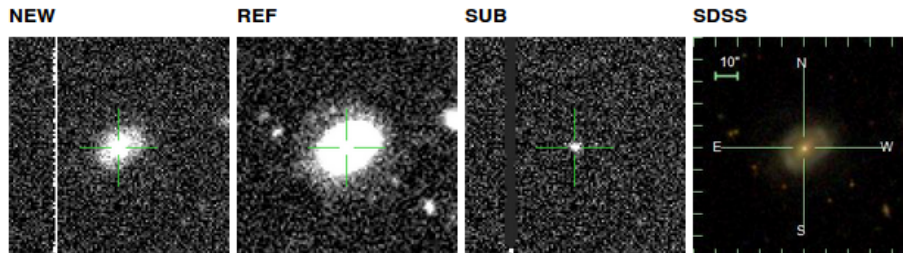


# 16ahe

16:28:37.32 +39:41:56.3  
247.155497 +39.698960

View

OVERVIEW PHOTOMETRY SPECTROSCOPY OBSERVABILITY FINDING CHART NERSC EXAMINE IPAC EXAM



r >20.2 (0.1 d) | Upload New Photometry

z = 0.0313 | Upload New Spectroscopy  
DM (approximate) = 35.63

### ADDITIONAL INFO

[NED](#) [TNS](#) [SNEx](#) [SIMBAD](#) [VizieR](#) [HEASARC](#) [SkyView](#) [PyMP](#) [MPChecker](#) [Extinction](#)  
[CFHT](#) [IPAC](#) [DSS](#) [WISE](#) [Subaru](#) [VLT](#) [FIRST](#) [CRTS](#) [Variable Marshal \(Search\)](#) [ADS](#)

### CURRENT FOLLOWUP REQUEST

Requester	Start Date	End Date	Program	Priority	Filters	Cadence	Search	Status
tiara	2016-04-14	2016-04-22	Tidal Disruption Events	5	g,r,i	2.0		
tiara	2016-05-06	2016-05-14	P60 Transient Vetting	5	g,r,i	2.0		
rsw	2016-05-10	2016-05-11	P60 Transient Vetting	5	IFU	1.0		

### ADD P60 FOLLOWUP

Select an observing sequence below.

Program:

Observing Group:

(1=low, 5=high)

### COMMENTS

- 2016 May 10 tiara [info]: Swift observation on 4/24 detected extended UV emission from host galaxy by the transient.
- 2016 May 06 avishay [redshift]: 0.0313
- 2016 May 06 avishay [comment]: more accurate va
- 2016 May 06 avishay [redshift]: 0.032
- 2016 May 06 avishay [comment]: Absorption lines Hbeta, Na D, Mg I 5175
- 2016 Apr 16 lair [SDSS\_specz]: 0.03121
- 2016 Apr 15 iyan [info]: sdss\_specz=0.03
- 2016 Apr 14 treasurer [nndist]: 0.04 arcsec. Nucle event!
- 2016 Apr 14 anders [type]: Nuclear

Add a Comment:

Attach File:  No file selected.

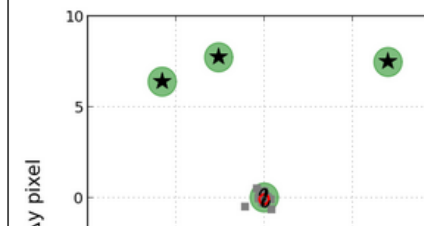
### SEND AN ALERT

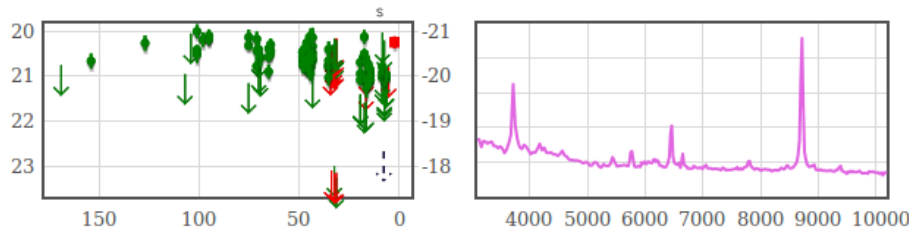
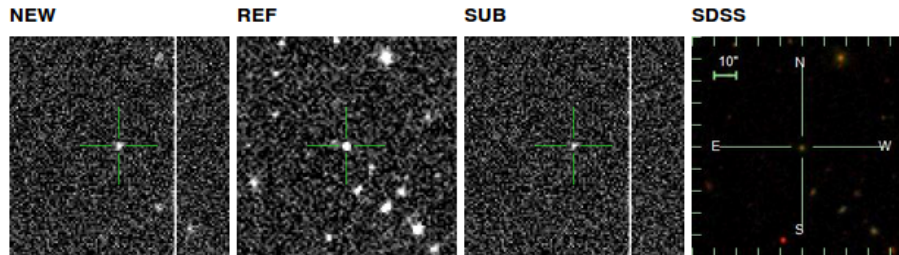
- Soft Alert (email iptftransient)
- Hard Alert (email + SMS)

### PERSONALIZE

- Add to Favorites
- Subscribe to this Target (daily digest)
- Subscribe to this Target (immediate alerts)

### Offset Plot





r = 20.3 (2.1 d) | Upload New Photometry

z = 0.327 | Upload New Spectroscopy  
DM (approximate) = 41.20

### ADDITIONAL INFO

### CURRENT FOLLOWUP REQUEST

Requester	Start Date	End Date	Program	Priority	Filters	Cadence
tiara	2016-05-10	2016-05-18	P60 Transient Vetting	5	g,r,i	2.0

### ADD P60 FOLLOWUP

Select an observing sequence below.

Program: <- Select Program ->

Observing Group: No Follow Up

1 (1=low, 5=high) +

### ASSIGNMENTS

### COMMENTS

- 2016 May 16 nadia [redshift]: 0.327
- 2016 May 16 nadia [classification]: AGN
- 2016 May 11 tiara [SDSS\_specz]: 0.327
- 2016 May 11 tiara [Info]: Swift triggered
- 2016 May 04 amiller [Info]: Saved From IPAC scanning pages
- 2016 May 04 tanja [type]: Transient
- 2016 Apr 04 treasurer [nndist]: 0.21 arcsec. Nuclear event!
- 2016 Apr 04 paul [type]: Transient

Add a Comment:

Attach File: Browse... No file selected.

info Save Comment

### SEND AN ALERT

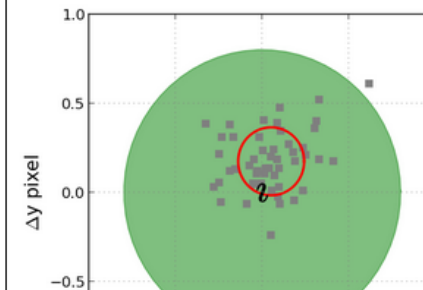
- Soft Alert (email iptfttransient)
- Hard Alert (email + SMS)

Send Alert

### PERSONALIZE

- Add to Favorites
- Subscribe to this Target (daily digest)
- Subscribe to this Target (immediate alerts)

### Offset Plot



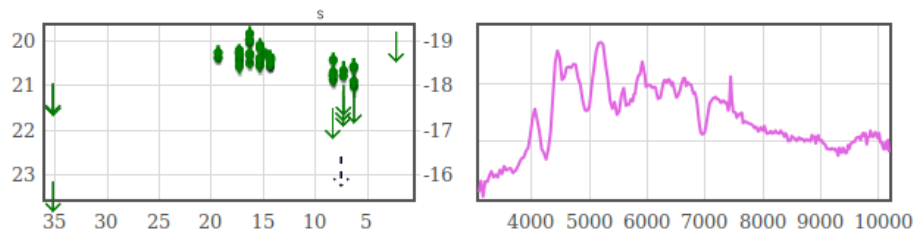
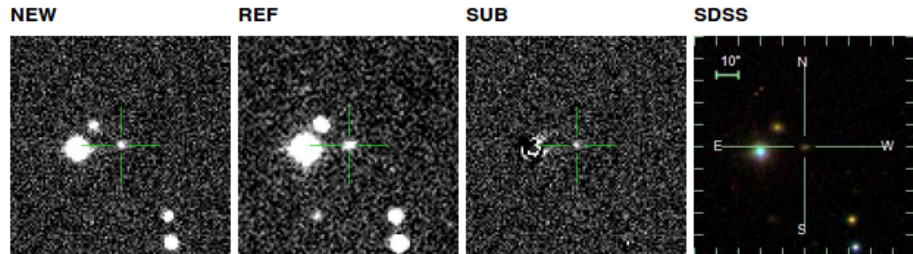


# 16anu SN Ia

12:25:38.79 +05:00:33.4  
186.411608 +5.009276

View ar

OVERVIEW PHOTOMETRY SPECTROSCOPY OBSERVABILITY FINDING CHART NERSC EXAMINE IPAC EXAMI



$r > 20.6$  (473.1 d) | Upload New Photometry

$z = 0.135$  | Upload New Spectroscopy  
DM (approximate) = 39.02

### ADDITIONAL INFO

### CURRENT FOLLOWUP REQUEST

Requester	Start Date	End Date	Program	Priority	Filters	Cadence
tiara	2016-05-10	2016-05-18	P60 Transient Vetting	5	g,r,i	2.0

### ADD P60 FOLLOWUP

Select an observing sequence below.

Program:

Observing Group:

(1=low, 5=high)

### ASSIGNMENTS

### COMMENTS

- 2016 May 16 Joeljo [redshift]: 0.135
- 2016 May 16 Joeljo [classification]: SN Ia
- 2016 May 11 tiara [Info]: Swift triggered
- 2016 May 03 treasurer [nndist]: 0.41 arcsec. Nuclear event!
- 2016 May 03 emir [type]: Nuclear

Add a Comment:

Attach File:  No file selected.

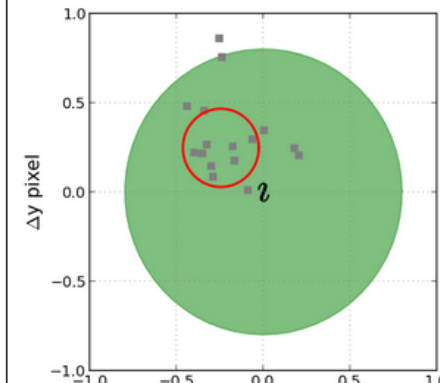
### SEND AN ALERT

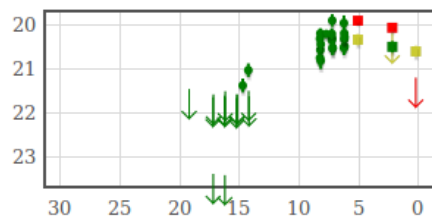
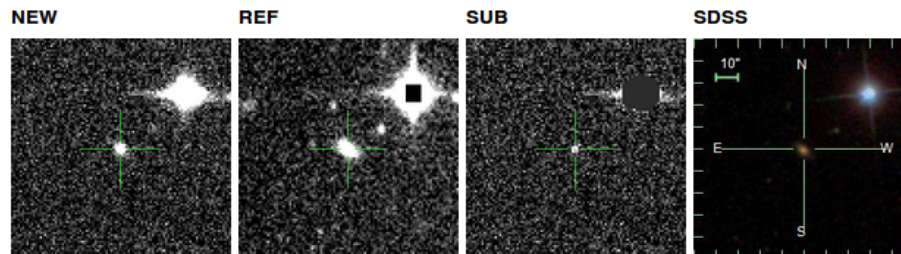
- Soft Alert (email iptftransient)
- Hard Alert (email + SMS)

### PERSONALIZE

- Add to Favorites
- Subscribe to this Target (daily digest)
- Subscribe to this Target (immediate alerts)

### Offset Plot





r > 21.2 (0.2 d) | [Upload New Photometry](#) [Upload New Spectroscopy](#)

### ADDITIONAL INFO

[NED](#) [TNS](#) [SNEx](#) [SIMBAD](#) [VizieR](#) [HEASARC](#) [SkyView](#) [PyMP](#) [MPCChecker](#) [Extinction](#)  
[CFHT](#) [IPAC](#) [DSS](#) [WISE](#) [Subaru](#) [VLT](#) [FIRST](#) [CRTS](#) [Variable Marshal \(Search\)](#) [ADS](#)

### CURRENT FOLLOWUP REQUEST

Requester	Start Date	End Date	Program	Priority	Filters	Cadence
tiara	2016-05-11	2016-05-19	P60 Transient Vetting	5	g,r,i	2.0

### ADD P60 FOLLOWUP

Select an observing sequence below.

Program: <- Select Program ->

Observing Group: No Follow Up

1 (1=low, 5=high) +

### ASSIGNMENTS

### COMMENTS

- 2016 May 13 tiara [Info]: Swift triggered
- 2016 May 11 treasurer [nndist]: 0.31 arcsec. Nuclear event!
- 2016 May 11 anders [type]: Transient

Add a Comment:

Attach File: [Browse...](#) No file selected.

[info](#) [Save Comment](#)

### SEND AN ALERT

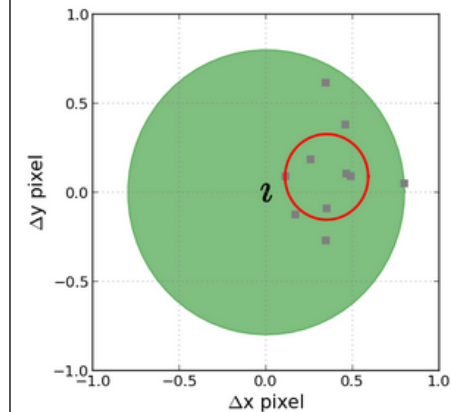
- Soft Alert (email ipfttransient)
- Hard Alert (email + SMS)

[Send Alert](#)

### PERSONALIZE

- [★ Add to Favorites](#)
- [📧 Subscribe to this Target \(daily digest\)](#)
- [🚨 Subscribe to this Target \(immediate alerts\)](#)

### Offset Plot



# Results So Far...

*4 nuclear transients triggered with Swift:*

- 16ahe – extended UV emission from host: SN?
- 16aao – no UV detection: AGN (Keck)
- 16anu – no UV detection: SN Ia (Keck)
- 16art – observed yesterday

# Let's Discuss!

What infrastructure do we need to promptly classify TDEs with ZTF?

How complete can we be with P60 follow-up?

How do we avoid nuclear SNe Ia?

What science can we do with outbursting AGN?

