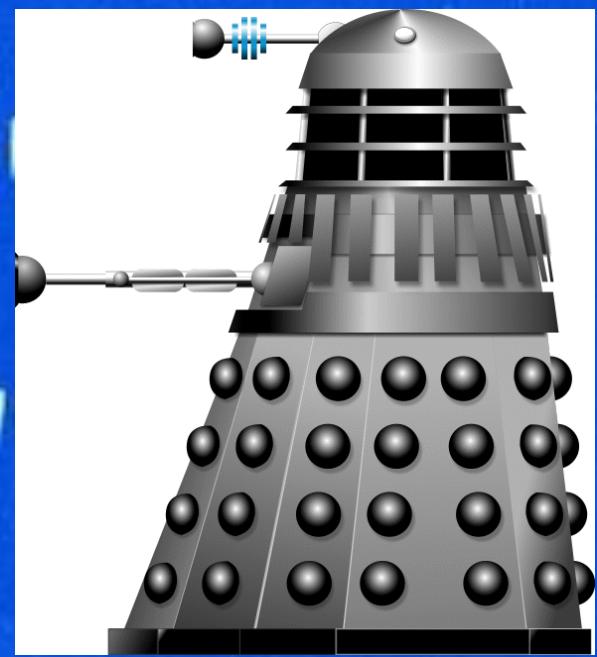
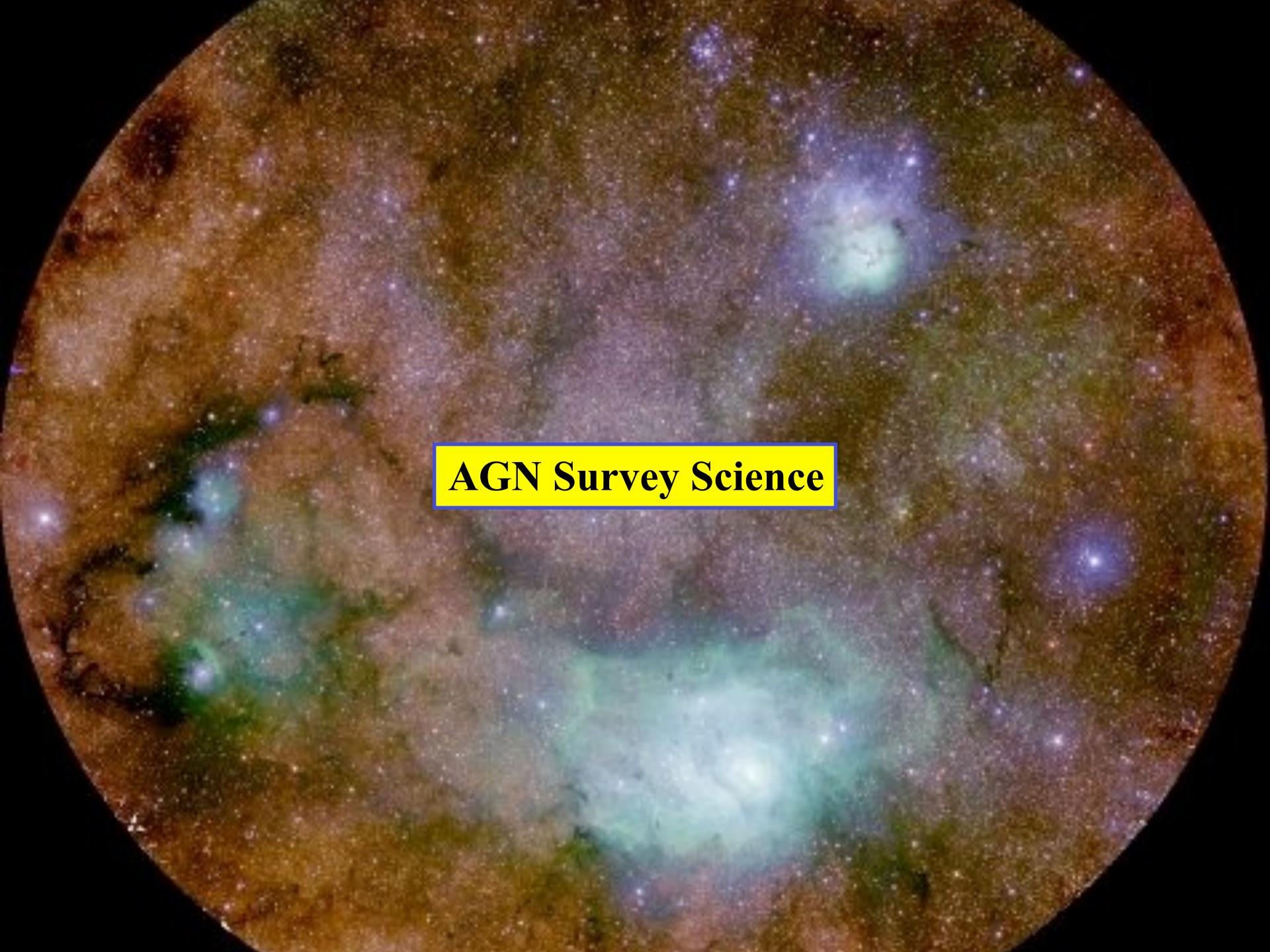


Clues to the structure of AGN through massive variability surveys

Oct 2015
Andy Lawrence
Byurakan



The background image is a circular view of a galaxy or star field. It features a dense cluster of stars of various colors, including white, yellow, and orange. In the center, there is a prominent, diffuse nebula with a mix of blue, green, and purple hues, suggesting the presence of ionized gas and young stars. The overall texture is grainy, typical of a deep space photograph.

AGN Survey Science

- Discovery
- Population studies
- Rare objects

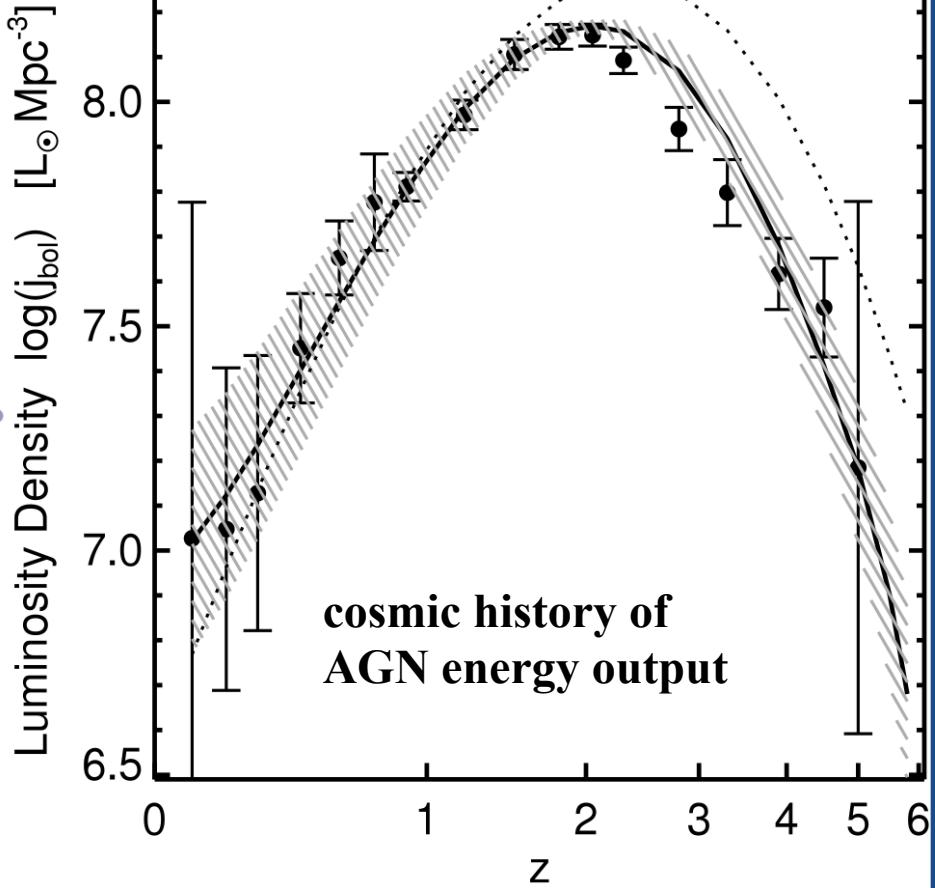
Discovery

Markarian objective prism survey
The beginning of serious AGN studies

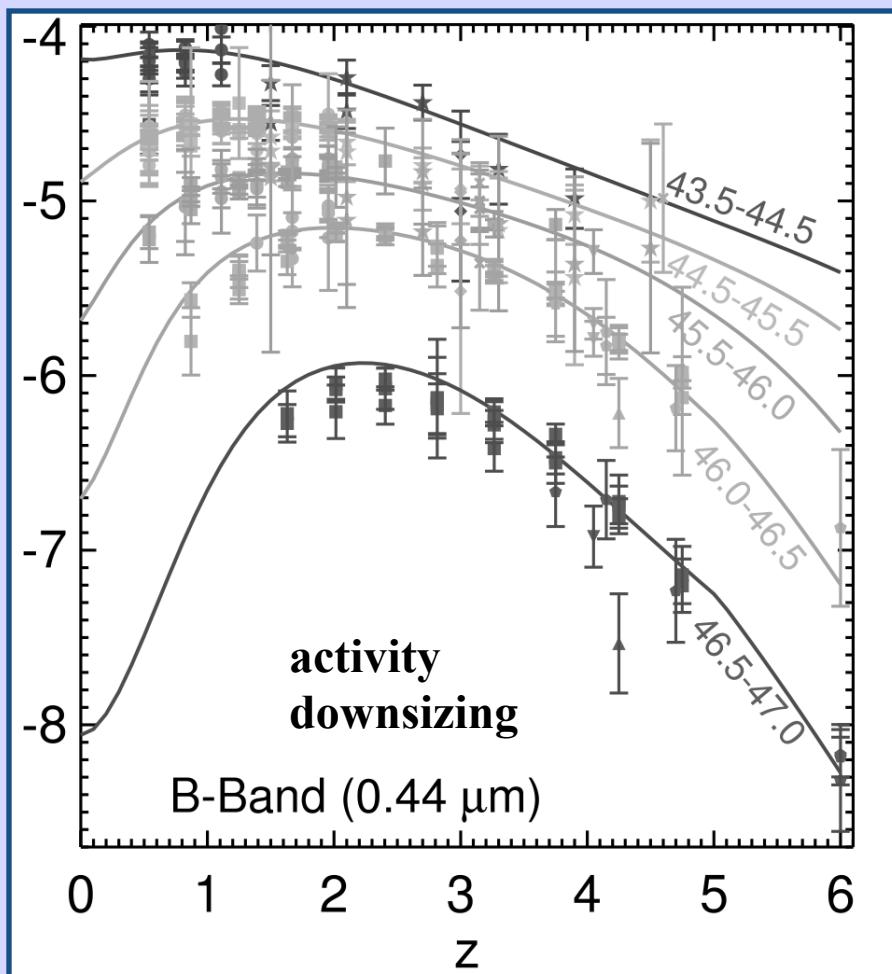


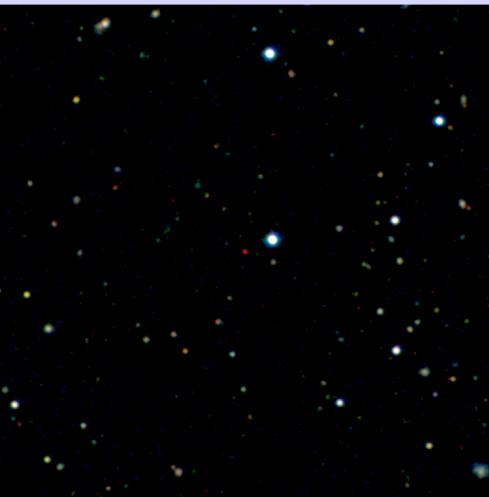
Population studies

Hopkins
et al 2007

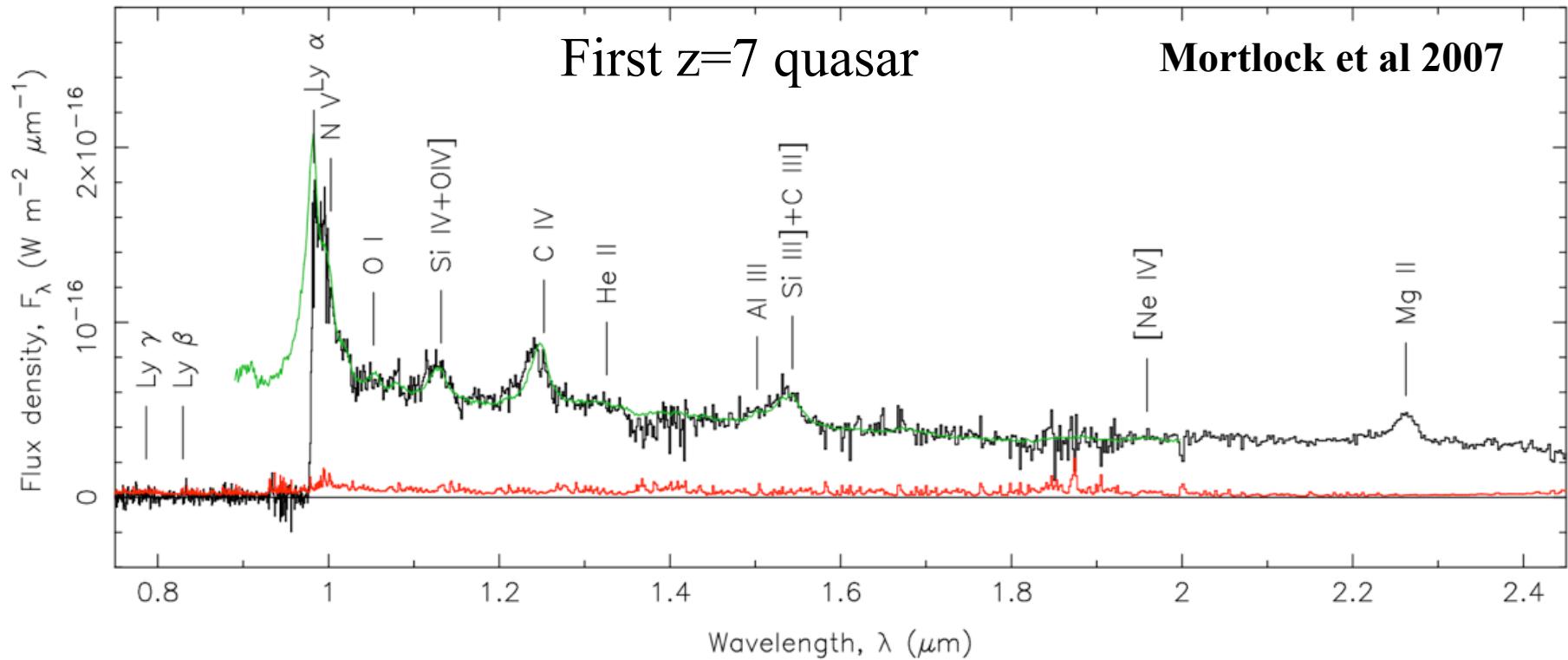


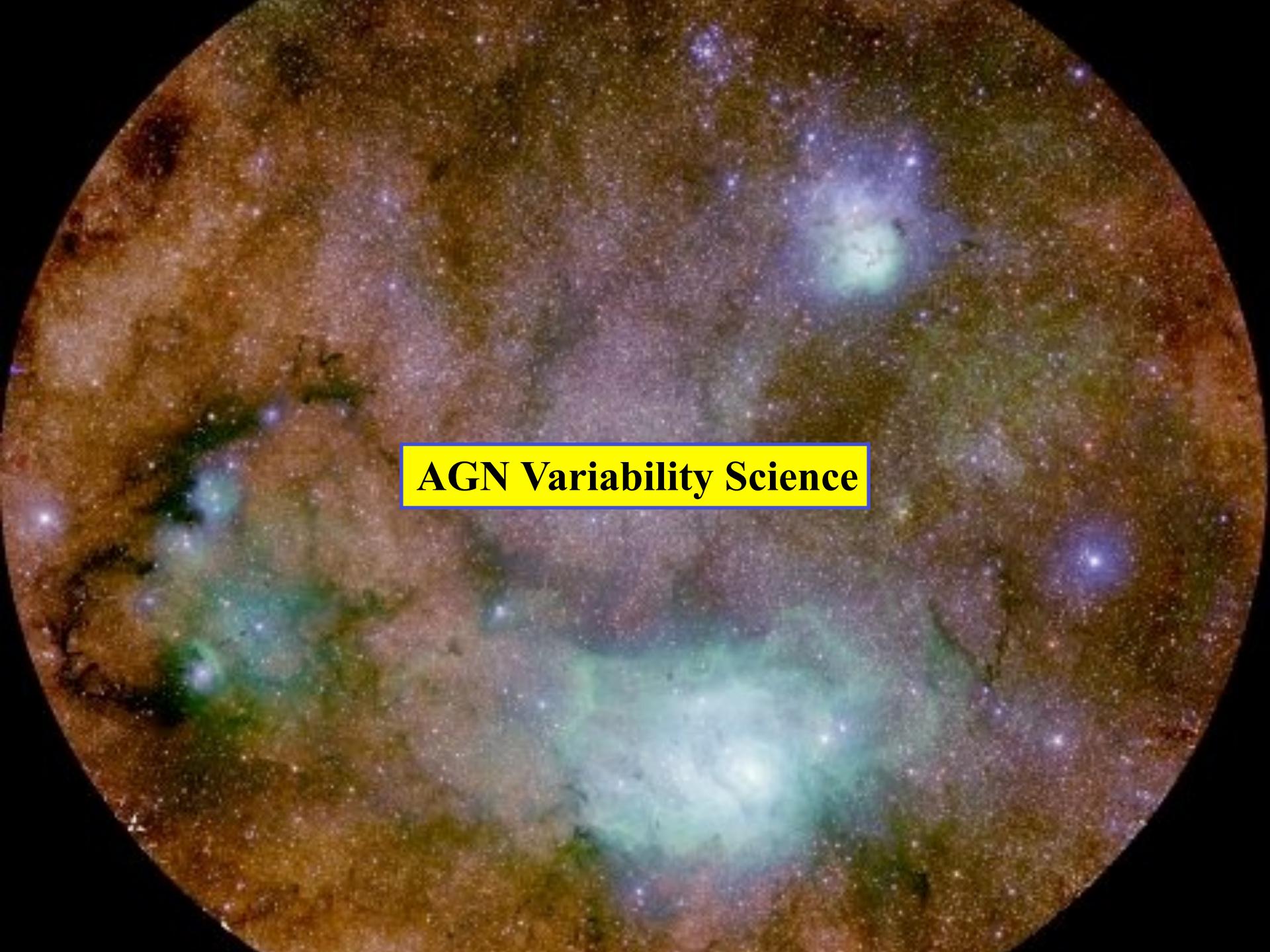
Black hole growth from combining multiple surveys





Rare objects





AGN Variability Science

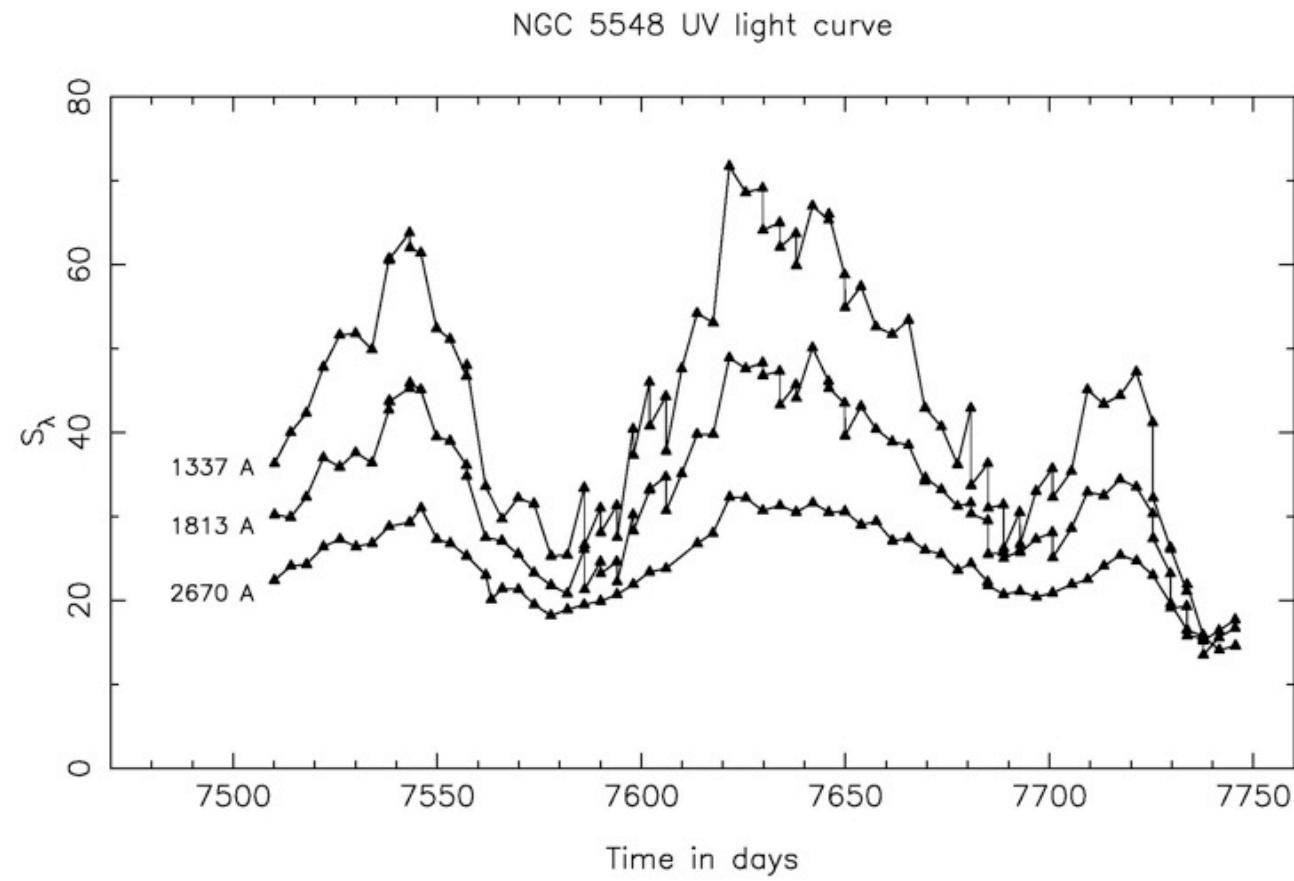
why does AGN variability matter?

For $M=10^8 M_{\text{sun}}$ $D=100 \text{ Mpc}$

	θ	t_{light}	t_{dyn}	
disc	$100R_g$	$1\mu\text{as}$	$13H$	35 days
BLR	$10^3 R_g$	$10\mu\text{as}$	6 days	4.3 yrs
torus	$10^5 R_g$	1mas	1.6yrs	3100 yrs

viscous timescale $\sim 10,000 \text{ yrs}$

optical-UV variability

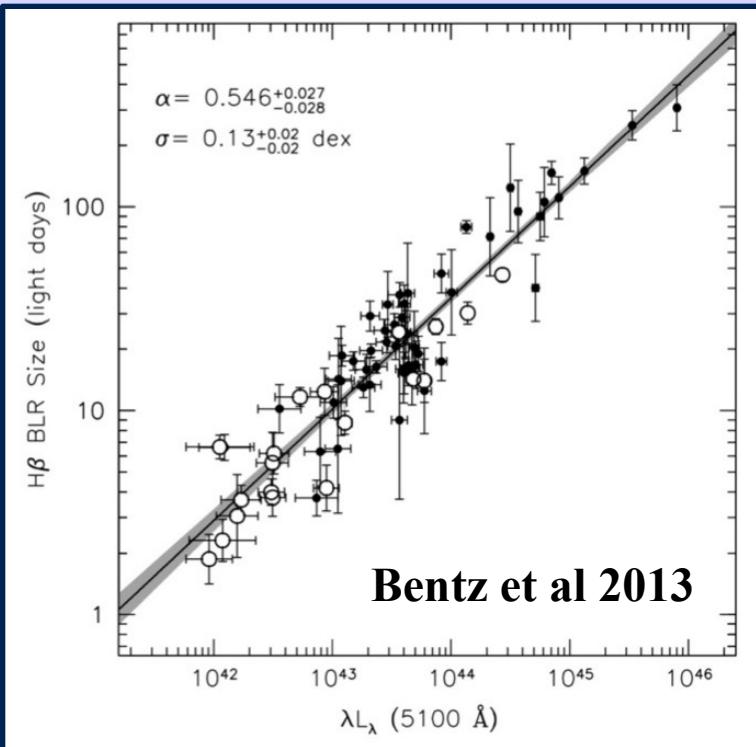
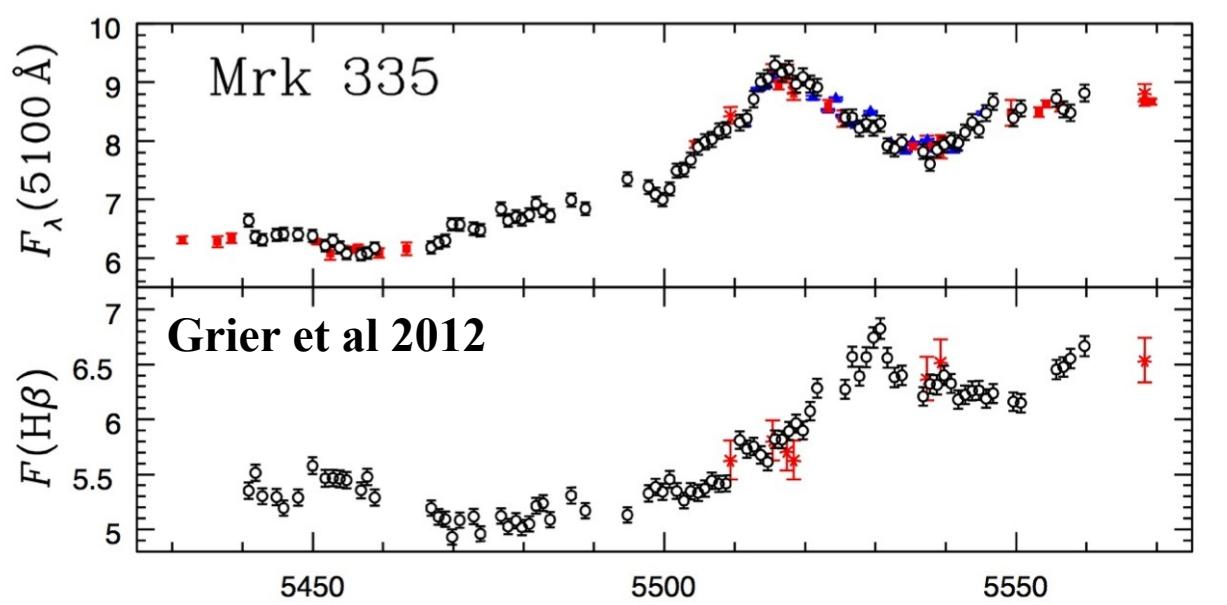


Clavel et al 1991
via Lawrence 2012

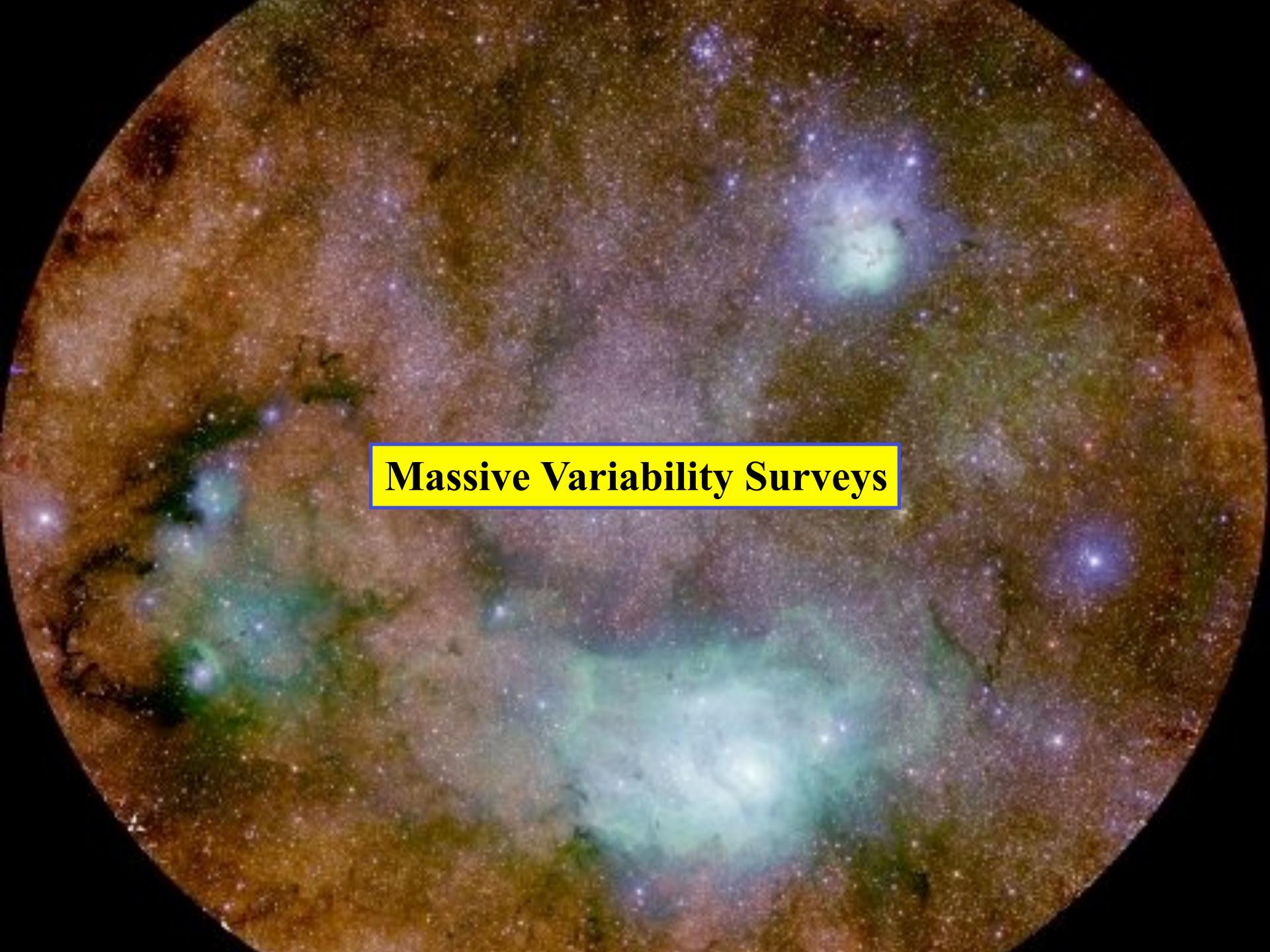
mix variable
blue thing
with constant
red thing?

- varies on dynamical timescale
- bluer when brighter
- simultaneous at all wavelengths

BLR variability



- light travel delay time
- size of BLR
- constant U : physics of BLR

A circular image of a star field, likely a deep-space photograph. It features several distinct nebulae and star clusters. In the upper right, there is a bright, multi-colored nebula with shades of blue, green, and purple. In the lower center, a large, diffuse green nebula is visible. To the left of the green nebula, there is a smaller, more concentrated cluster of stars and gas. The background is a dark, textured space filled with numerous small stars.

Massive Variability Surveys

New frontier is **repeating the sky**

- deep stacking
- moving objects
- transients
- variable objects

Schmidt (eg Hawkins F287)
Ogle, MACHO
SDSS overlaps and Stripe 82

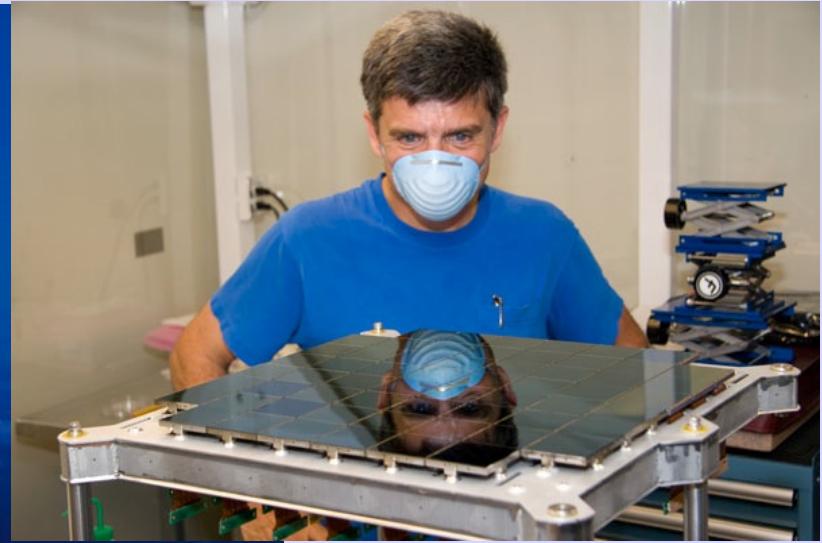
note:
for 0.1" pixels,
sky requires
100TB/band/visit

PanSTARRS

→ LSST



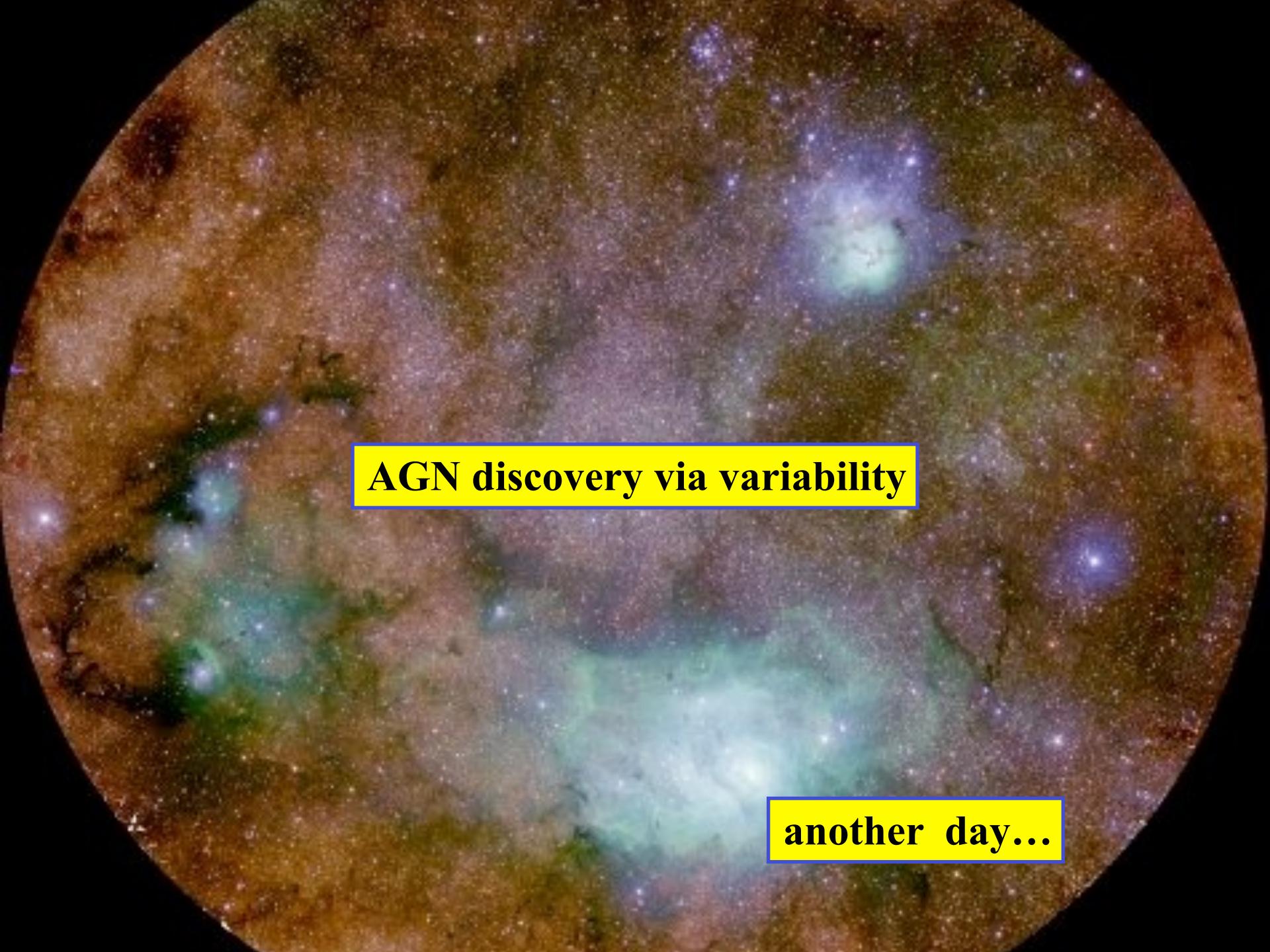
PanSTARRS-1



- 1.8m telescope on Haleakala
- Gigapixel camera
- *grizy* filters
- 7 sq.deg. FOV
- Prototype for PS-4
- Built by Univ.Hawaii
- operated by PS1SC
- survey Mar 2011-2014

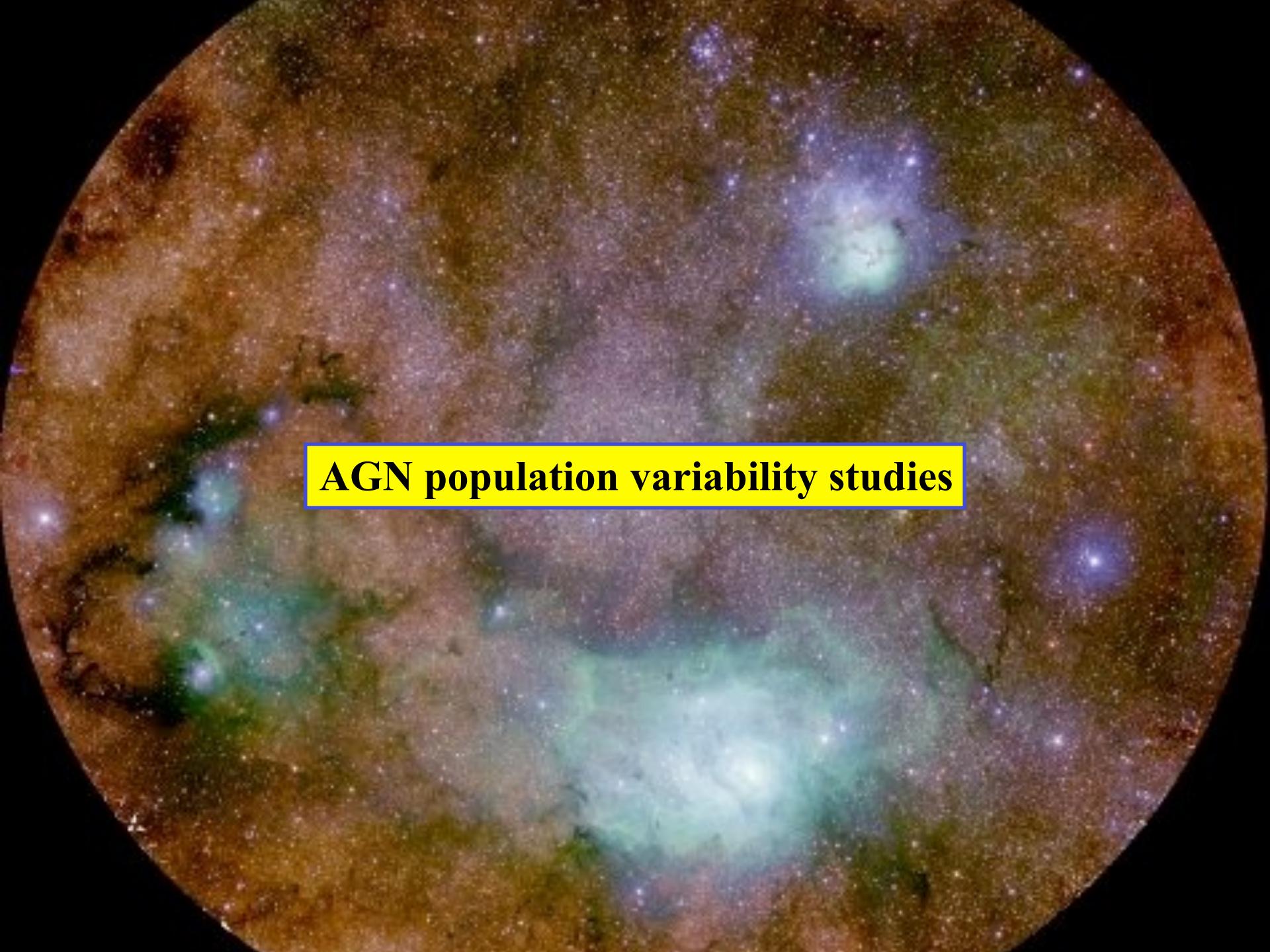
3 π survey:
30,000 sq.deg
4 times/yr/filter

Medium Deep Fields
10 x 7 sq.deg
once every four days

A circular image of a star field, likely a deep-space photograph. It features several prominent nebulae and star clusters. One large, diffuse nebula in the center-right is composed of purple, blue, and green gases. Another smaller, more concentrated nebula is visible in the lower-left quadrant. Numerous stars of varying sizes and colors are scattered across the field, with some appearing as small white dots and others as larger, more luminous points of light.

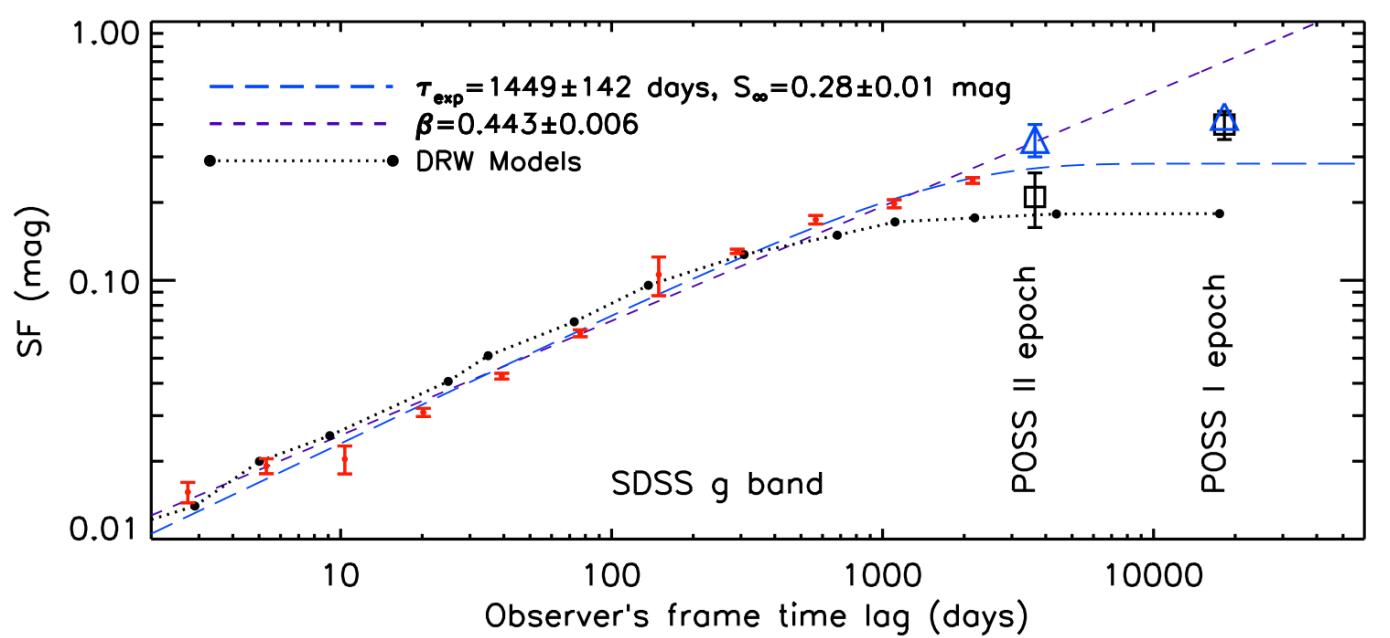
AGN discovery via variability

another day...



AGN population variability studies

33,000 SDSS
quasar repeats

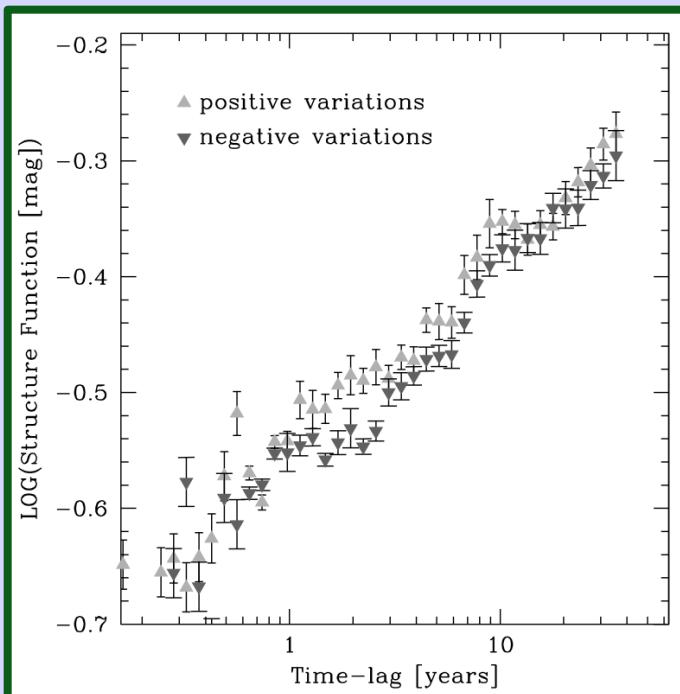


de Vries et al 2005

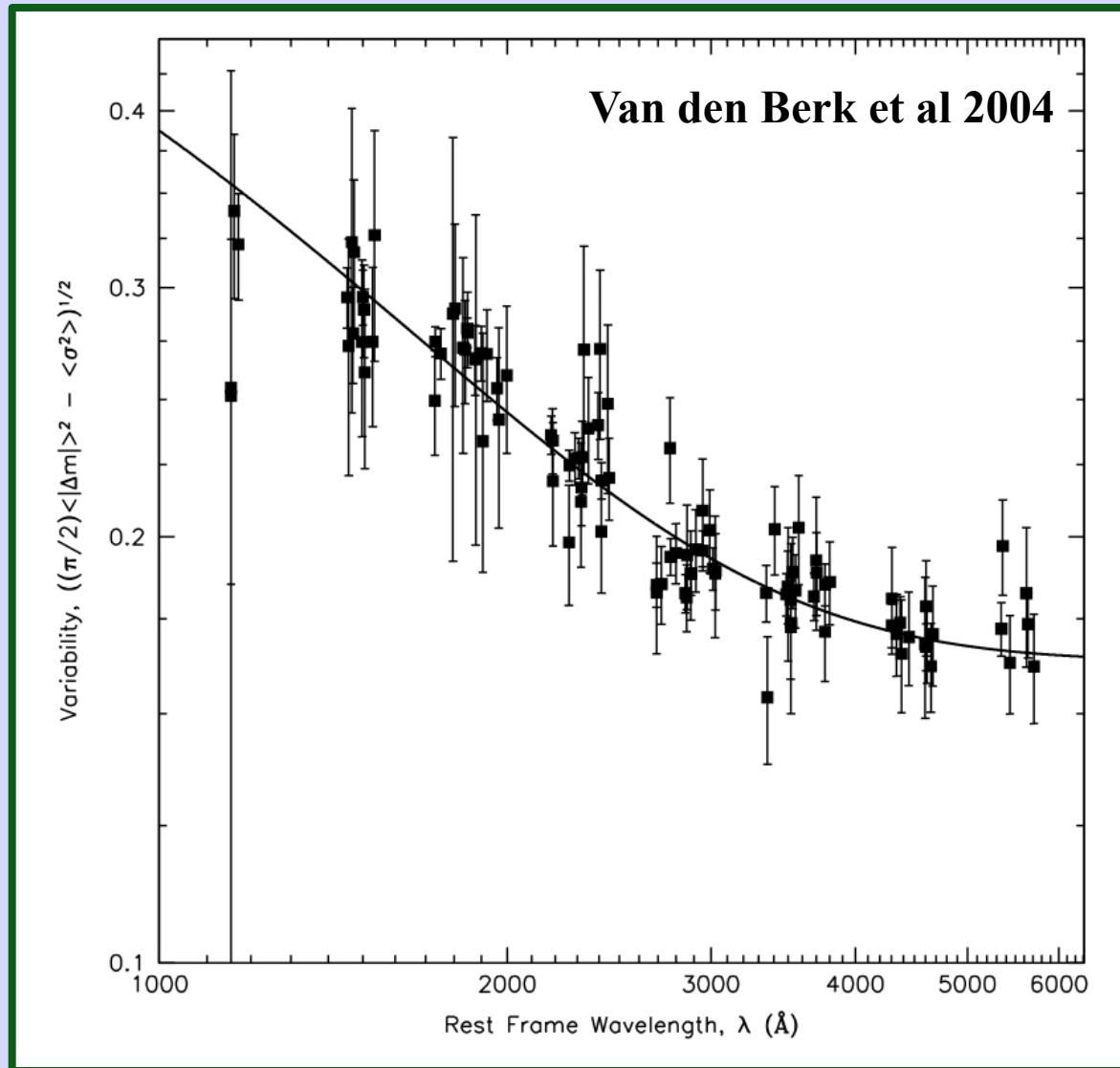
quasars show ~30% flickering
that is random walk-like

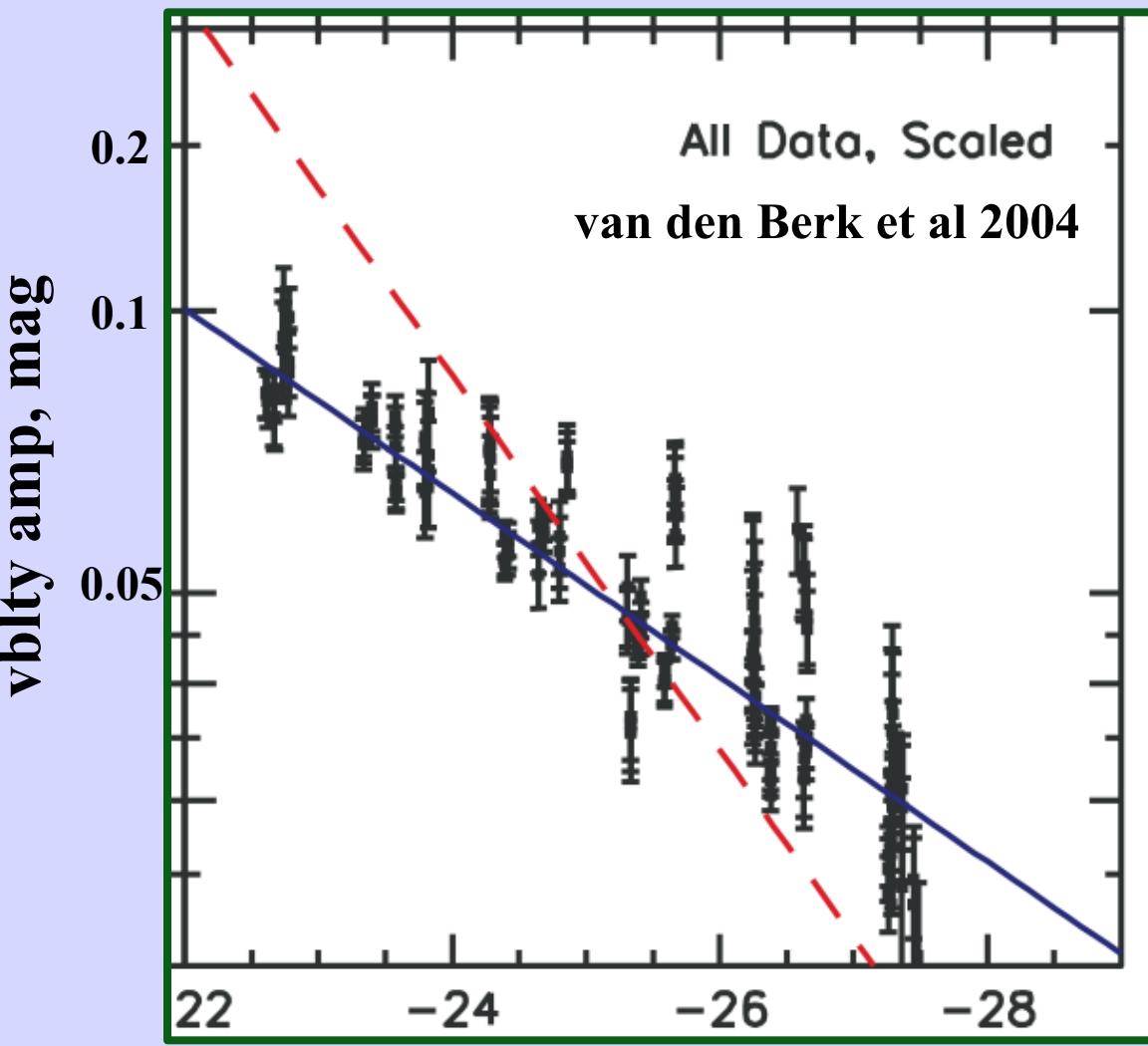
there *may* be a characteristic
timescale of ~2 years

vibrations are
statistically
asymmetric



variations are strongly
dependent on wavelength



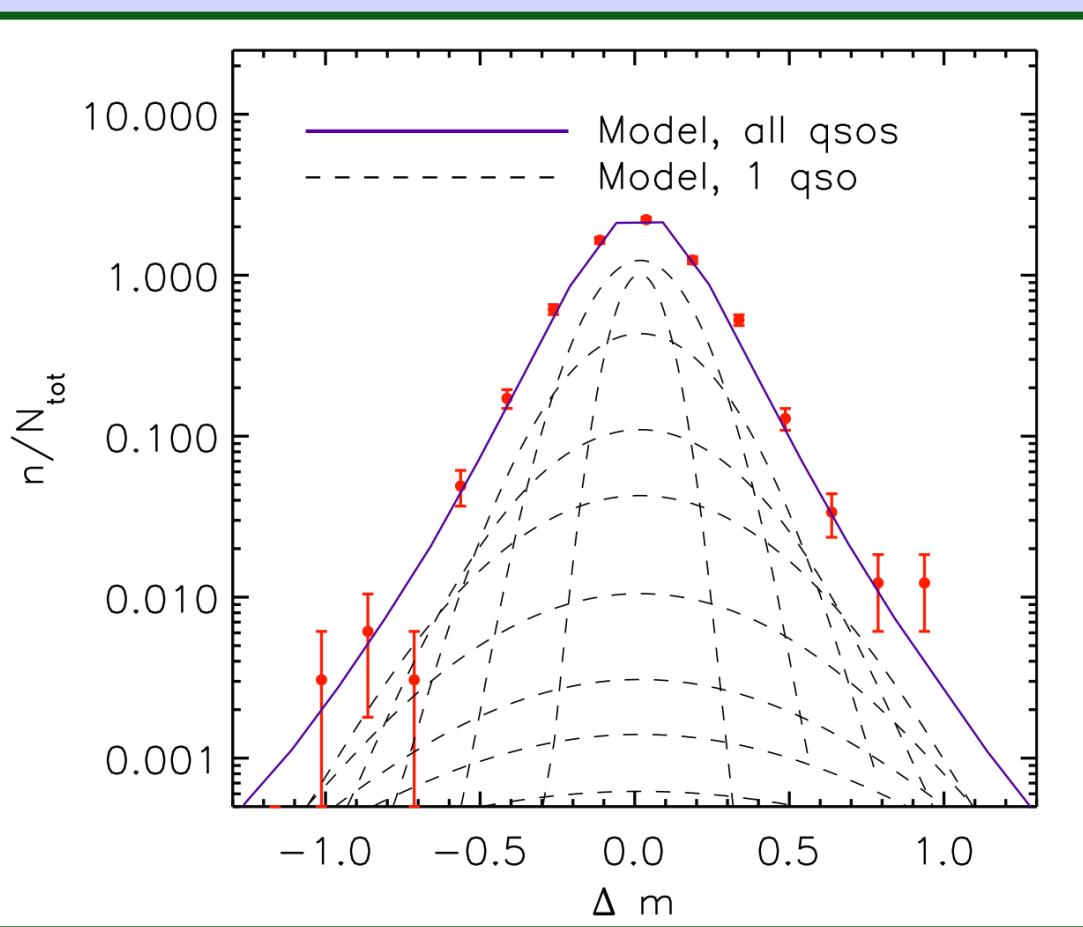


subtle luminosity effect

quasars 100 times more
luminous vary by 6%
instead of 15%

abs.mag

MacLeod et al 2004



high amplitude variables rare
but could be important..

quasars not all the same

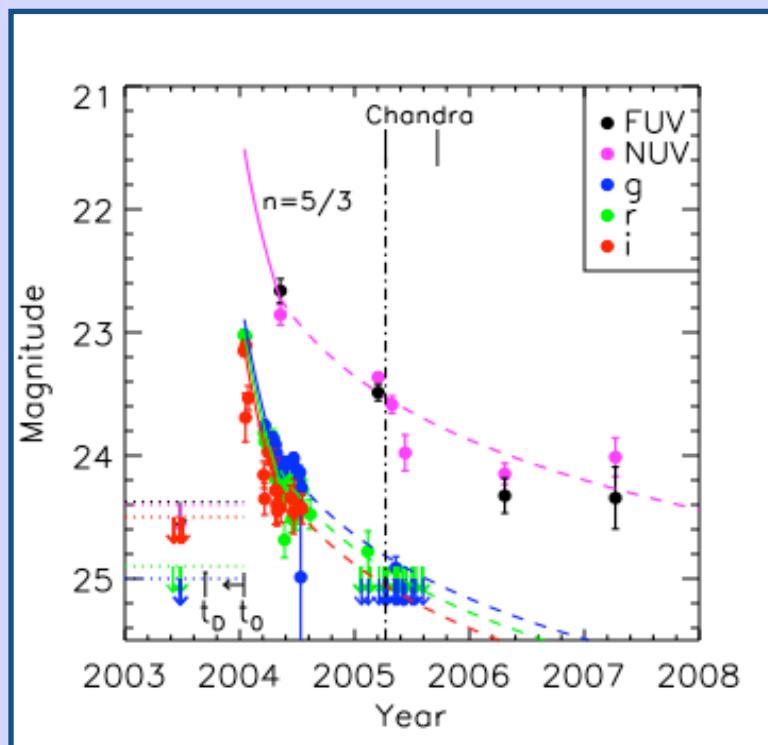
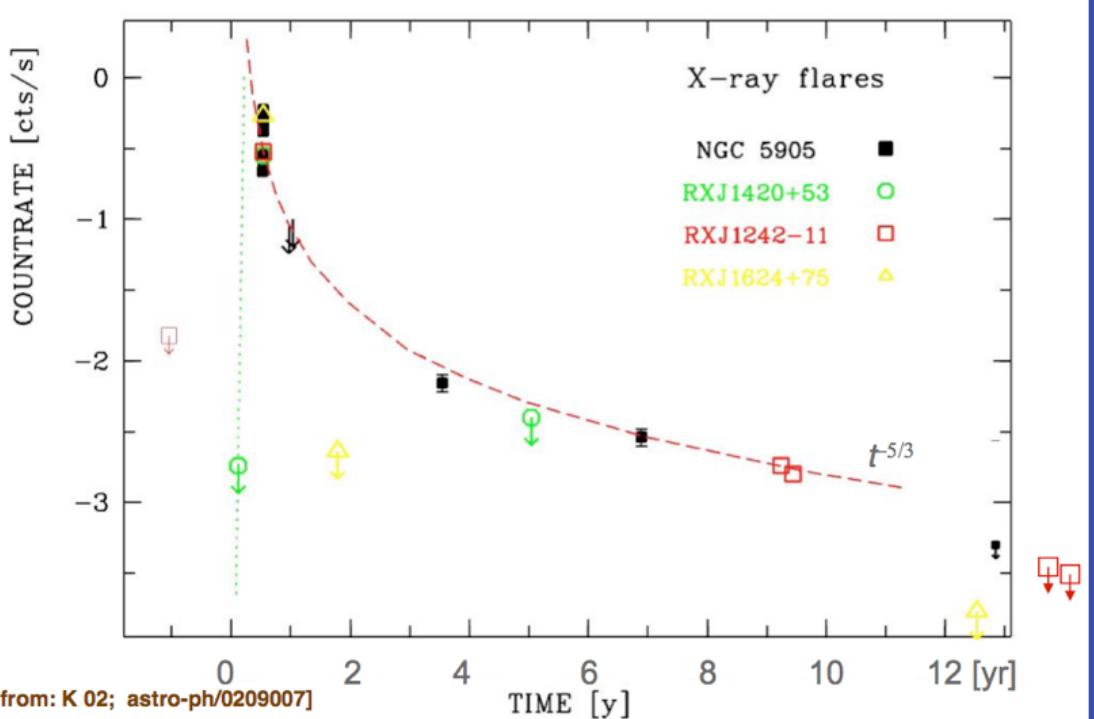
some more variable
than others

distbn exponential rather
than naively expected
Gaussian

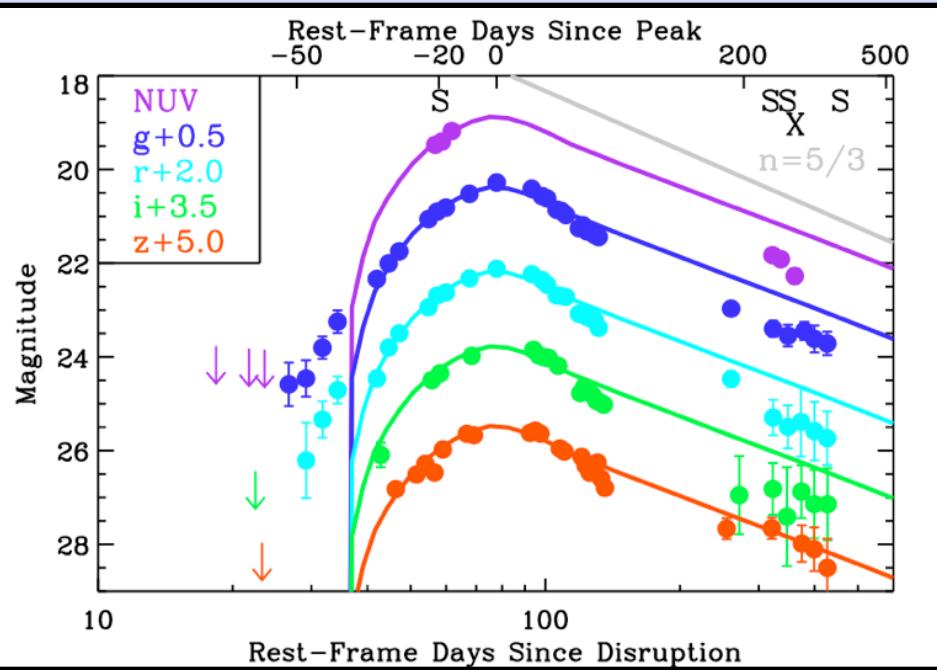
rare objects: TDEs



previous X-ray claims
from ROSAT and XMM
eg Komossa et al 1999,2009
Esquej et al 200x



previous opt-UV claims
from SDSS and GALEX
eg Gezari et al 2008,9
Van Velzen et al 2011

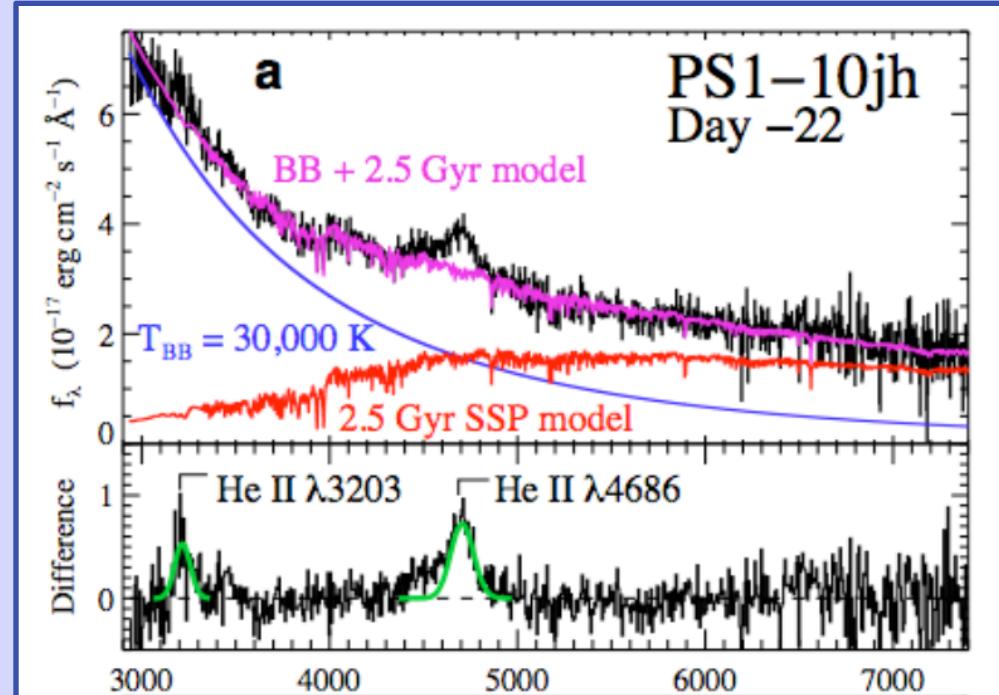


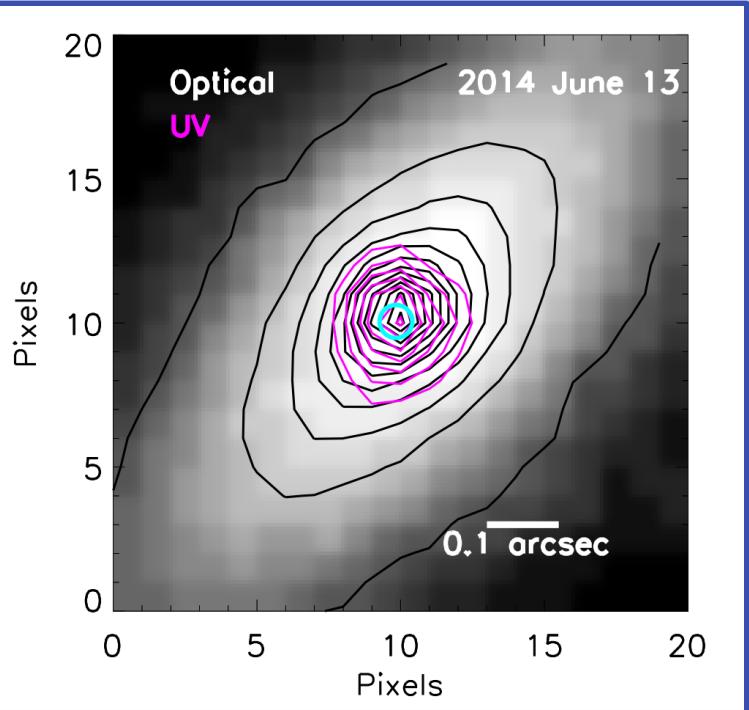
PS1-10jh
 caught by PanSTARRS
 medium deep field programme
 ... every four days
 ... first proper light curve

Gezari et al 2012

spectrum near peak shows
 Helium lines only!

disruption of Red Giant core
 can't be accretion disc flare up

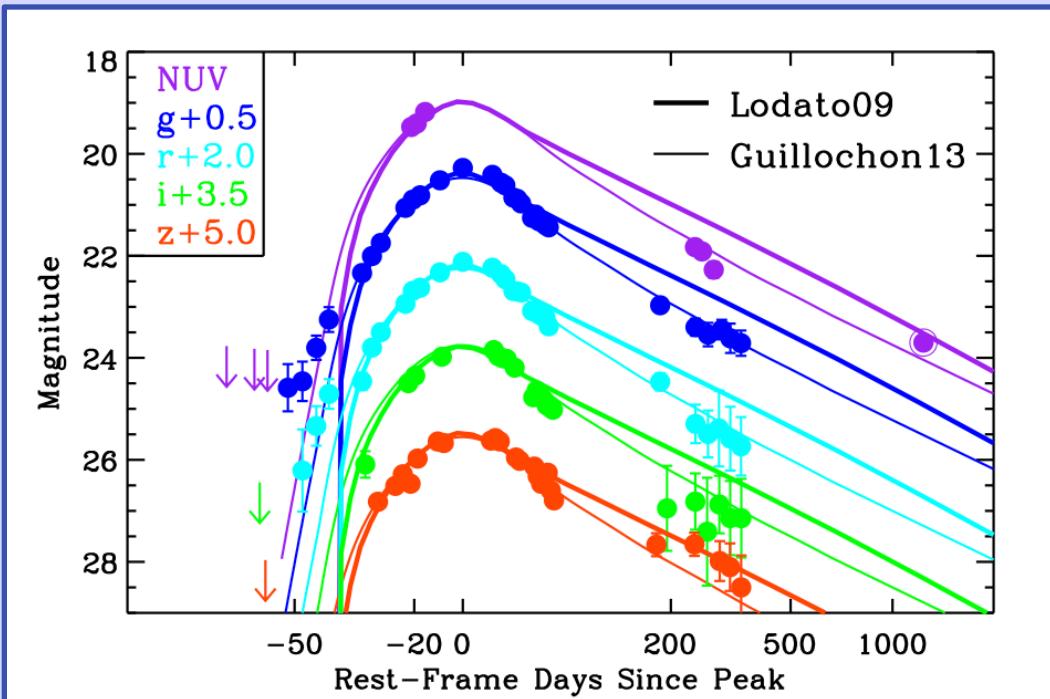


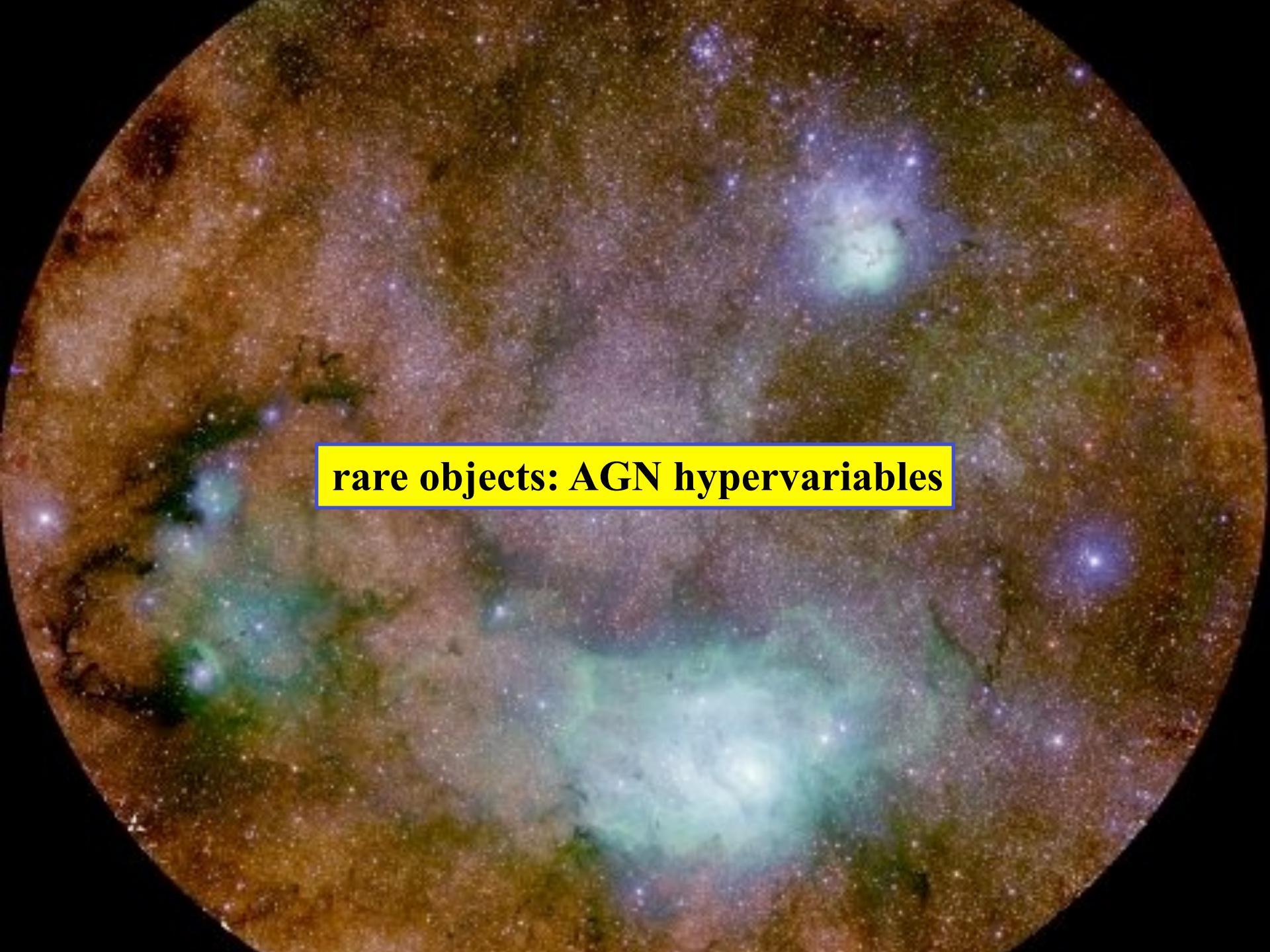


HST sees very faint
nuclear UV source
three years later

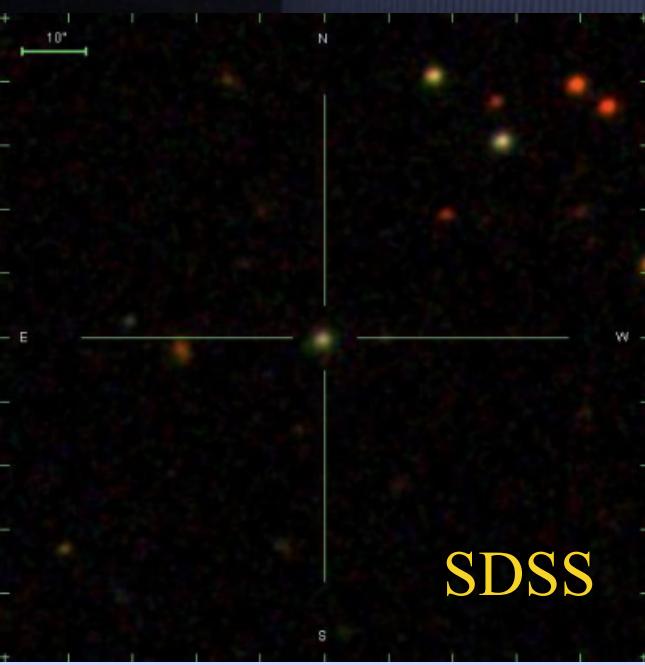
Gezari et al submitted

late time flux
reasonable fit to naive
“fall-back” prediction



A circular image of a star field, likely a deep-space photograph. It features a variety of celestial objects, including several galaxies of different sizes and colors (blue, white, yellow), numerous stars of varying brightness, and several nebulae, some appearing as wispy clouds and others as more solid, glowing regions. The overall composition is a dense, colorful cluster of astronomical features.

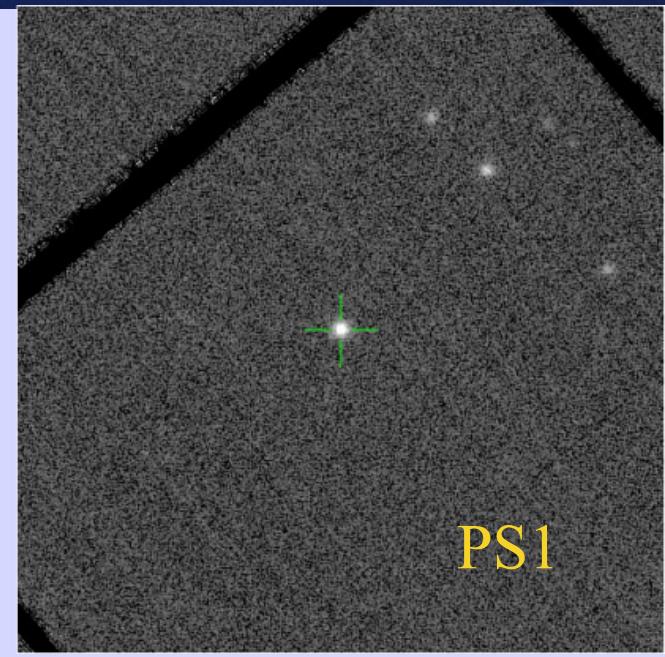
rare objects: AGN hypervariables



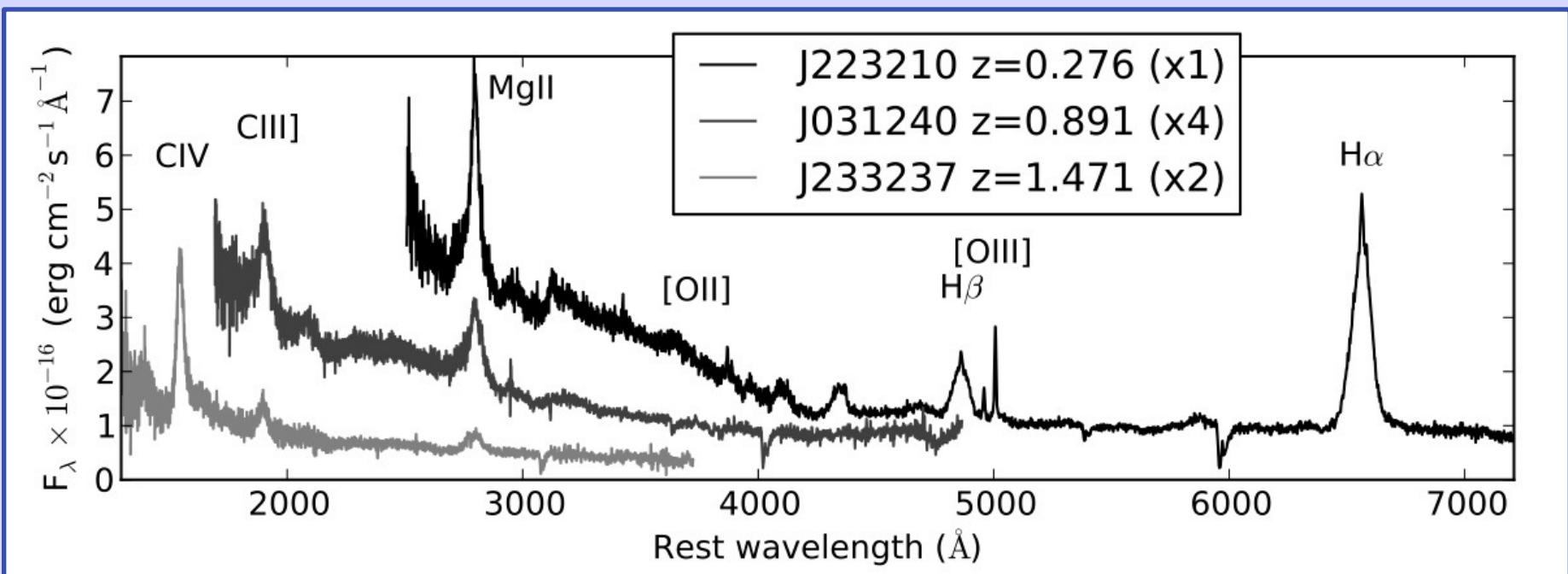
Transient selection:

$$\Delta m > 1.5 \\ \text{in g/r/i}$$

within 0.5" of
SDSS galaxy



some supernovae
some blazars
some flare stars
but most quasars at $z \sim 1$



Lawrence et al 2015

68 examples so far

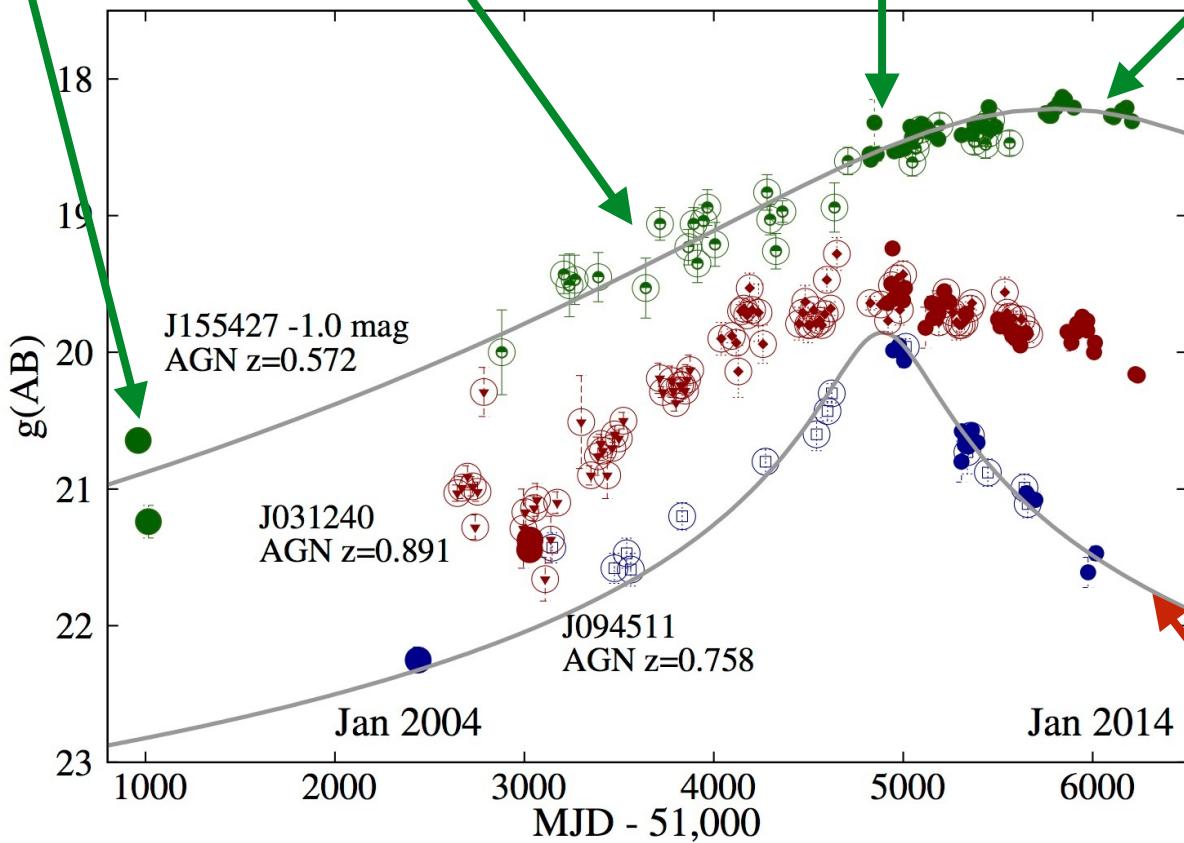
SDSS

CRTS archival
data

PanSTARRS
discovery

Liverpool Telescope
monitoring

smooth fifteen
year outbursts

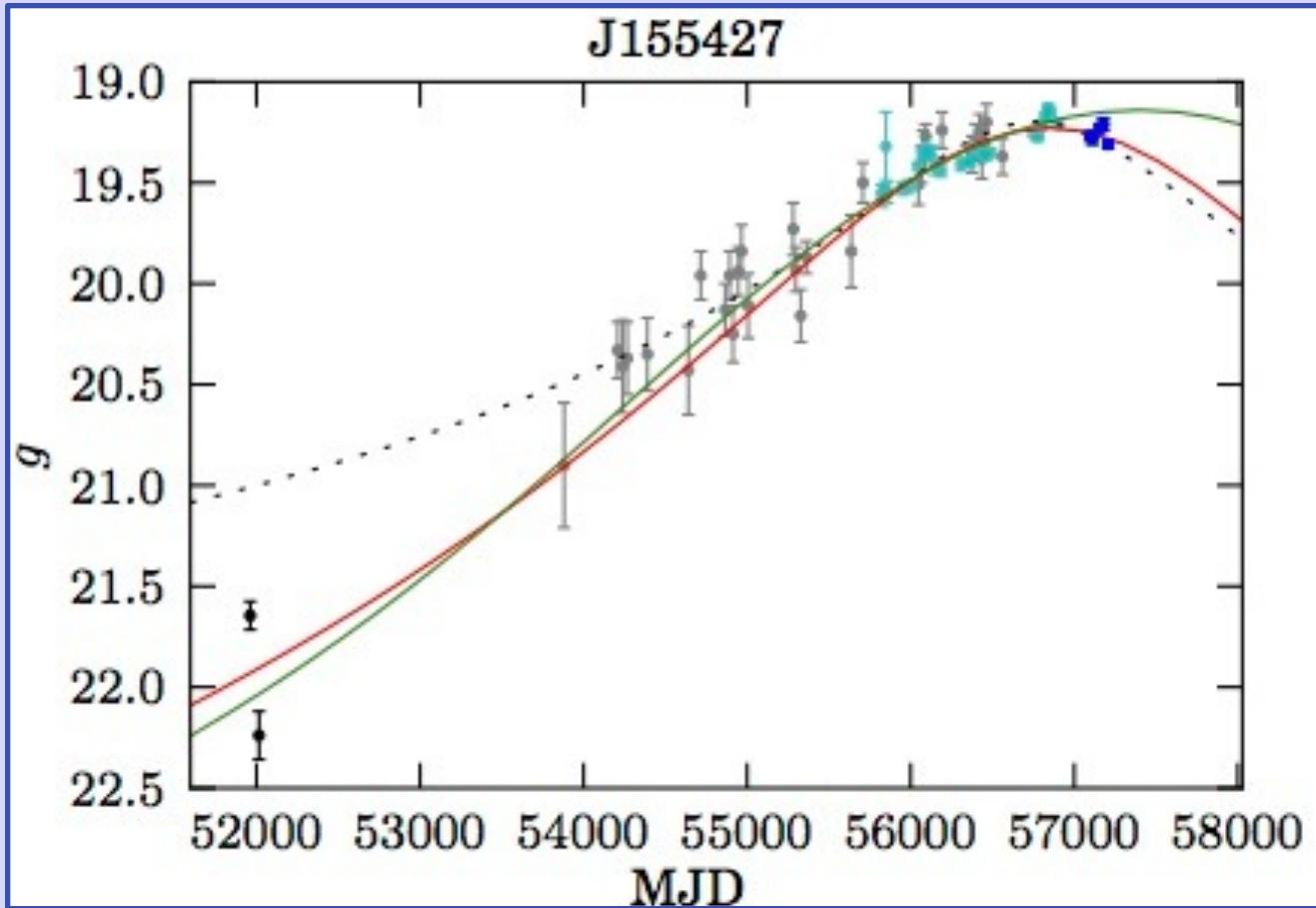


microlensing
model fits

$M=10^8 M_{\text{sun}}$

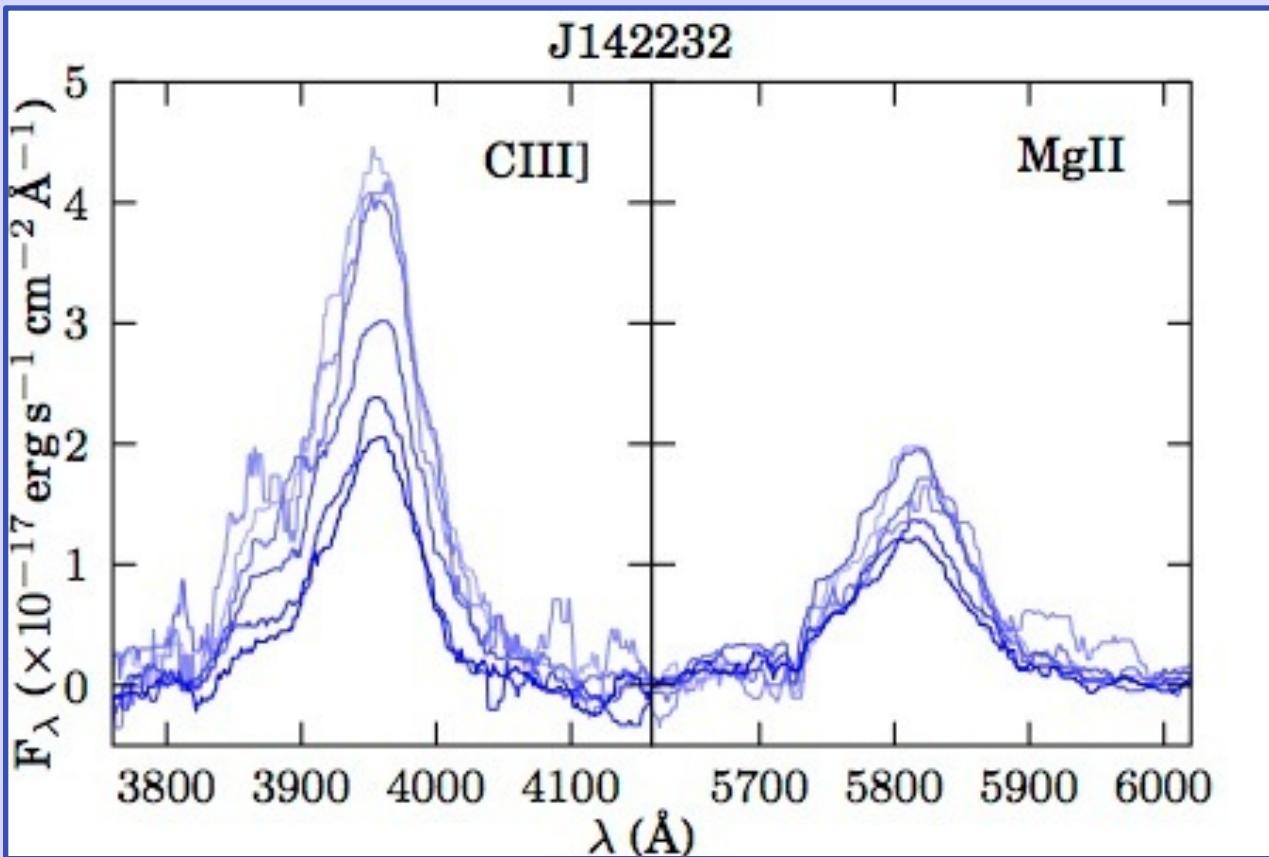
$$R_{1/2} = 400 R_g$$

$$R_{1/2} = 100 R_g$$



A few sources do not fit a
point source model

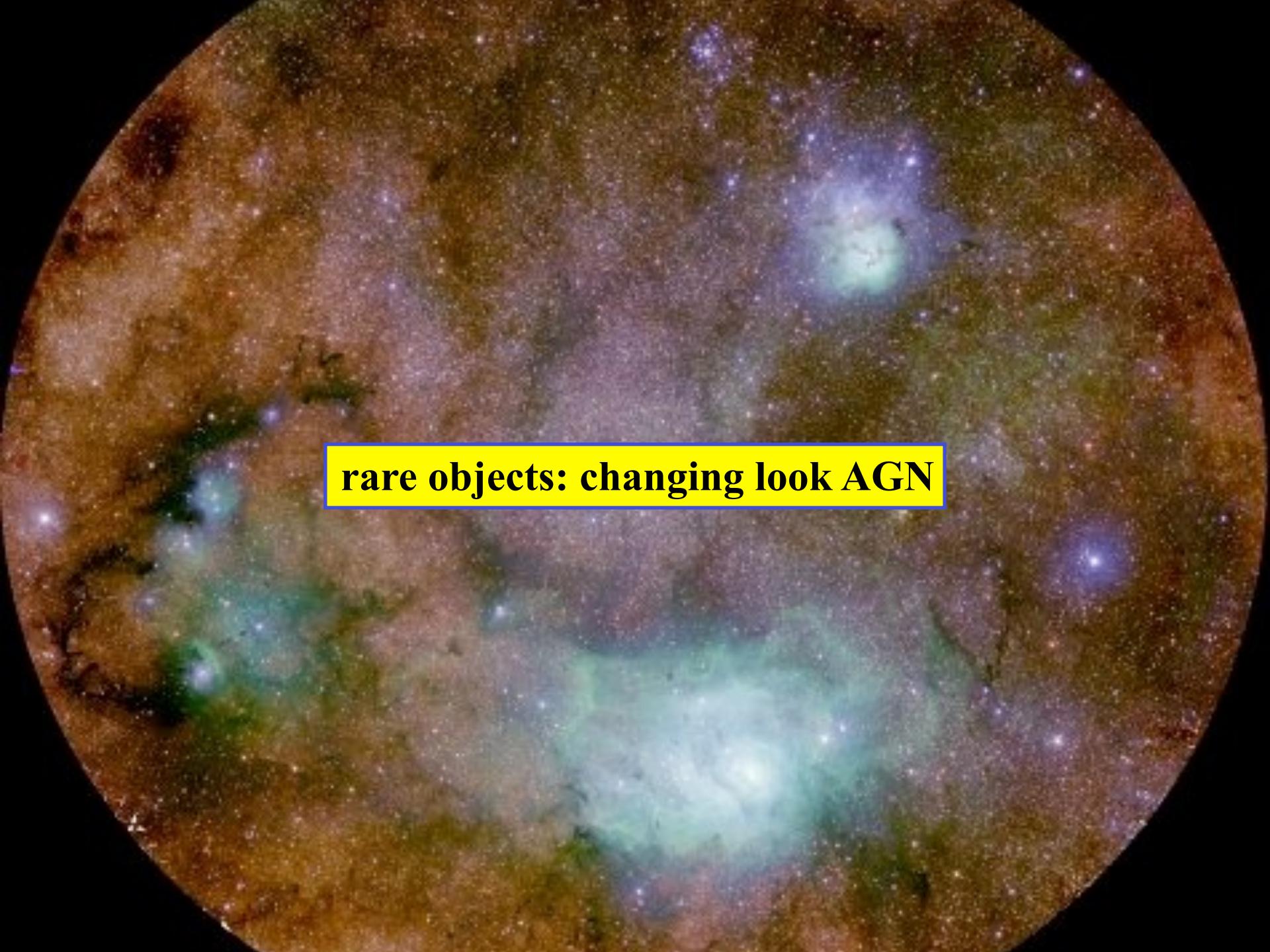
Spectroscopic monitoring



Bruce et al in prep

MgII barely changes
CIII] tracks continuum
- and changes profile!

==> MgII extended, CIII/CIV compact (<7 light days)



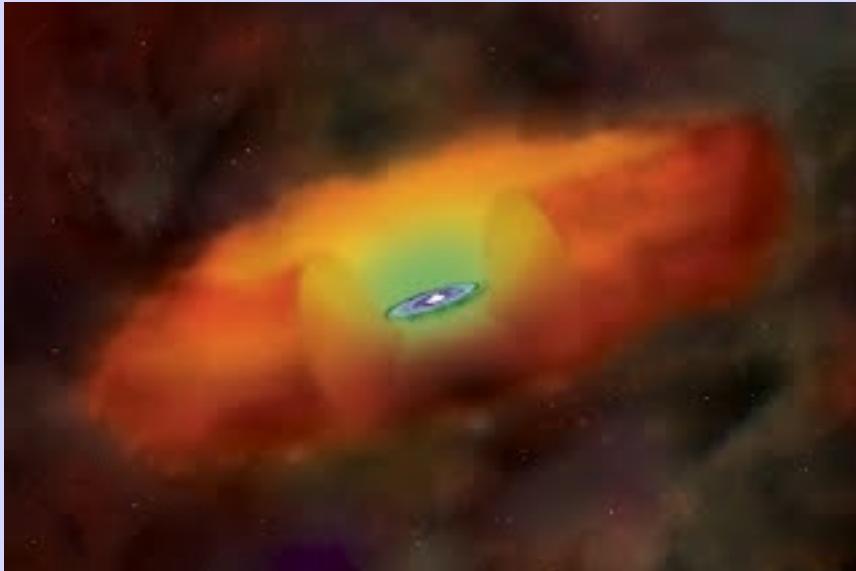
rare objects: changing look AGN

First division into Type I vs Type II

A SPECTROSCOPIC STUDY OF LUMINOUS GALACTIC NUCLEI*

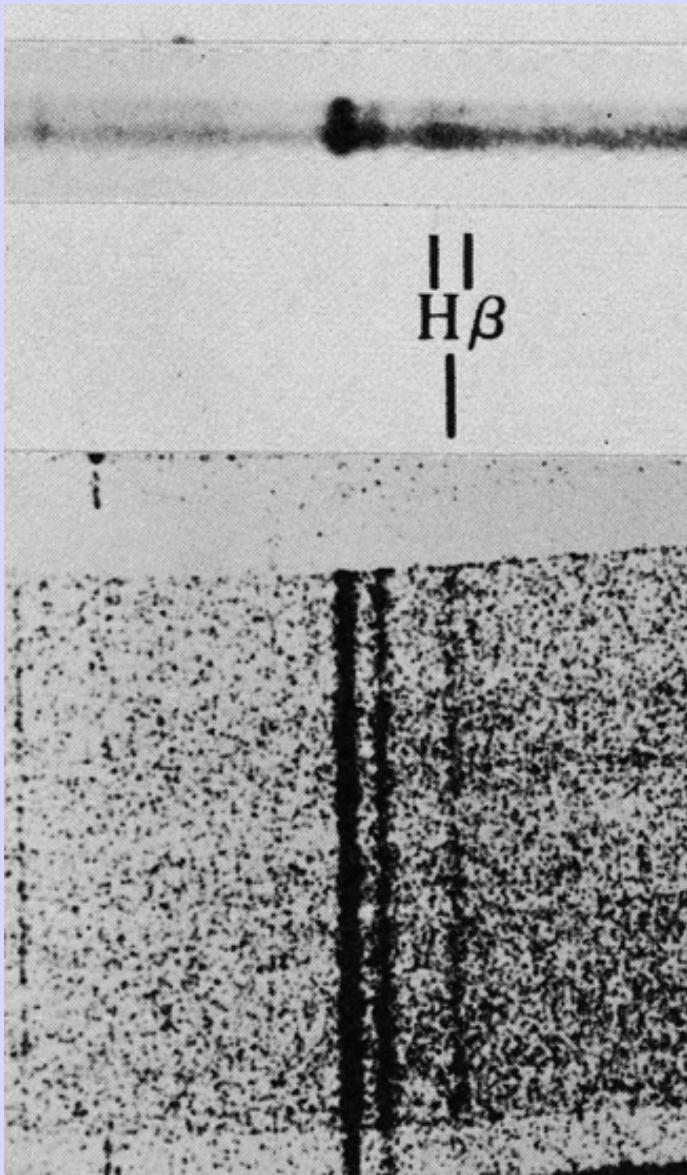
É. Ya. Khachikyan and D. W. Weedman†

Spectroscopic observations of a sample of galactic nuclei from the lists of Markaryan and Seyfert are presented in order to consider the nature of nuclei with broad emission lines. It is found from photographic spectrophotometry and emission line profiles that such galaxies can be consistently classified into two classes: objects like NGC 5548 that are found to have small, dense nuclei containing low velocity gas and objects like NGC 1068 with larger nuclei containing gas of lower density but higher velocity. The observational data favors broadening by electron scattering for the Balmer lines in the first class, and the absolute luminosity in $H\beta$ is generally greater in the first class than in the second. From the extreme spectroscopic and morphological similarity of all galaxies in the second class, it is concluded that the outflow of gas from the nucleus has affected the structure of the entire galaxy.



today always
explained by
viewing angle
towards a thick
dusty structure

Khachikian and Weedman 1971b
MKN6

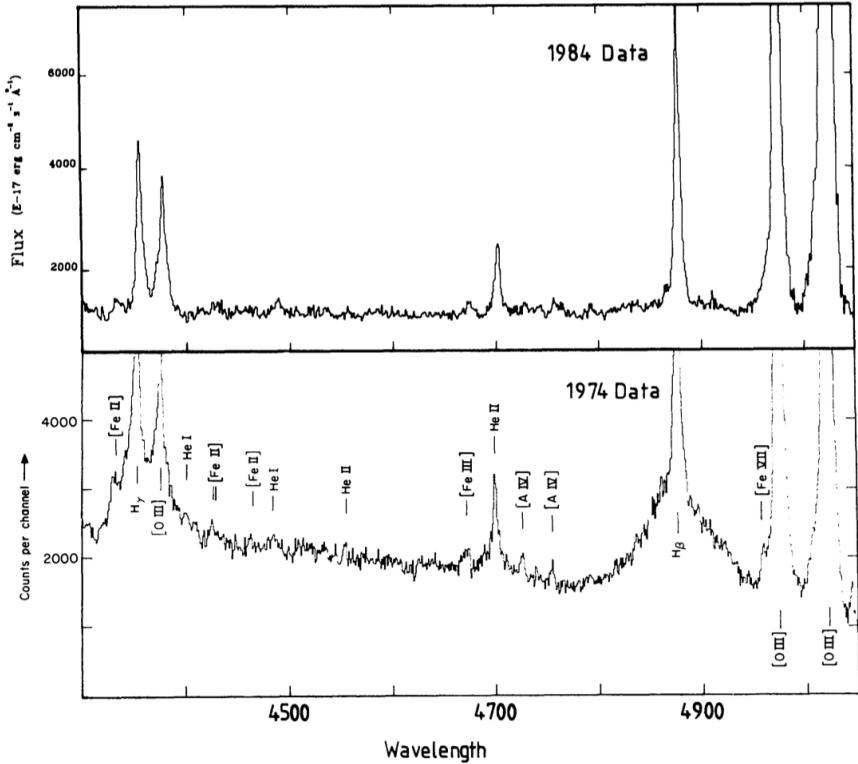


1970 broad and narrow H β

1967 narrow H β only

AGN can change type

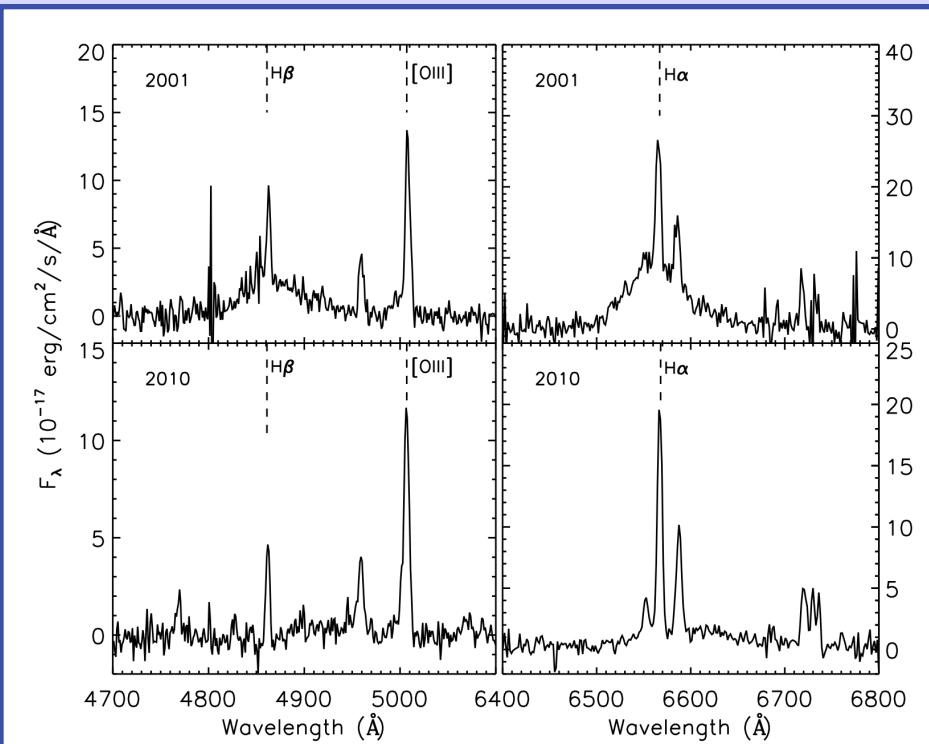
NGC 4151



Penston and Perez 1984

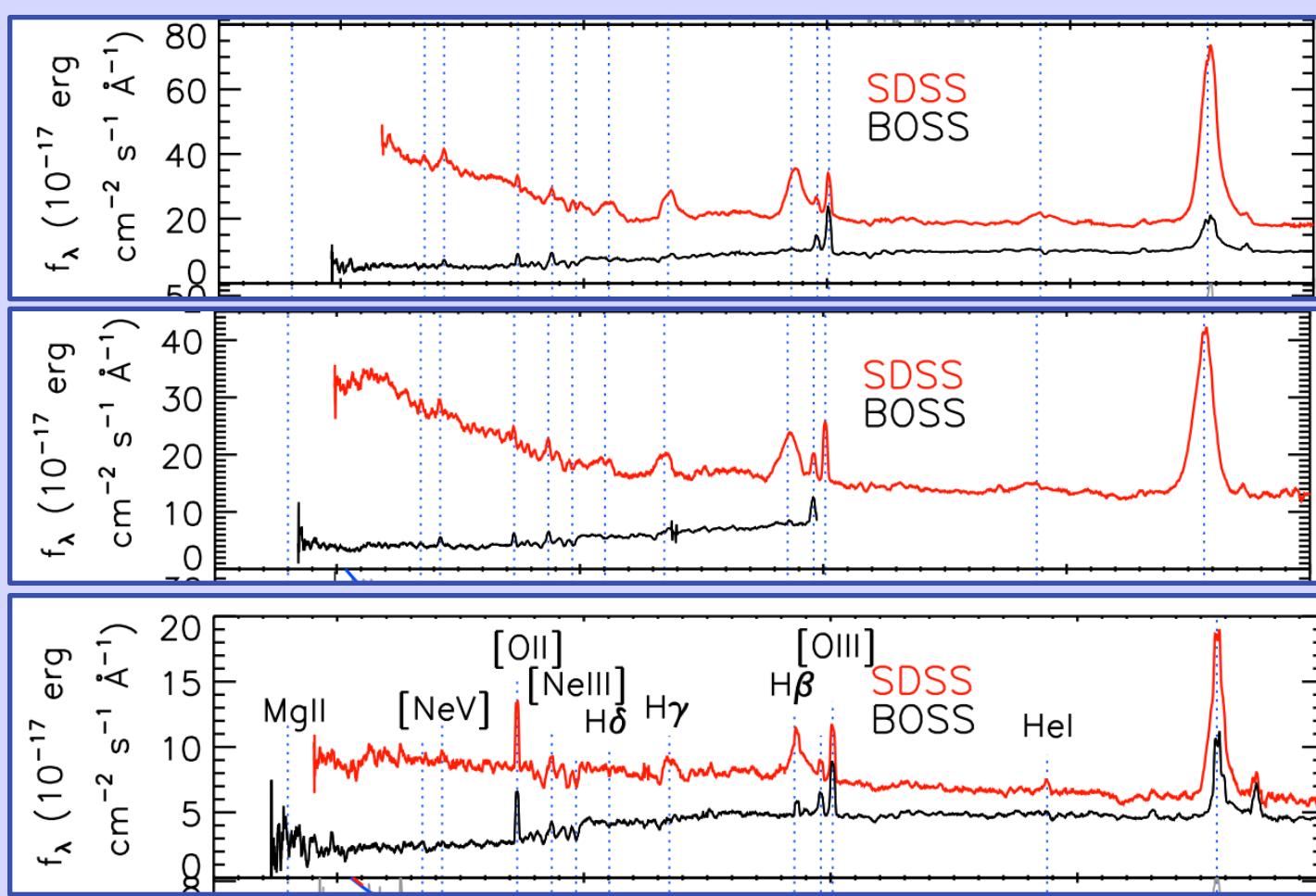
A handful of other cases have emerged

LaMassa et al 2014



but now we can search for them systematically

MacLeod et al 2015



SDSS vs PS1 : 105,783 quasars

15% have repeat spectra with BOSS

6% have $\Delta g > 1.0$ over a decade

→ 1011 potential CLQs

→ 10 found

c.f. BLR dynamical timescale of years

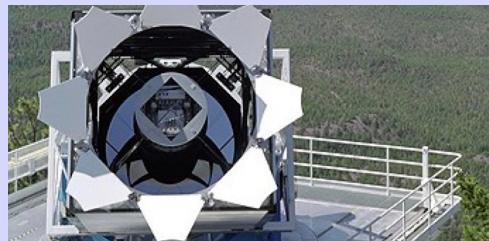


where next?

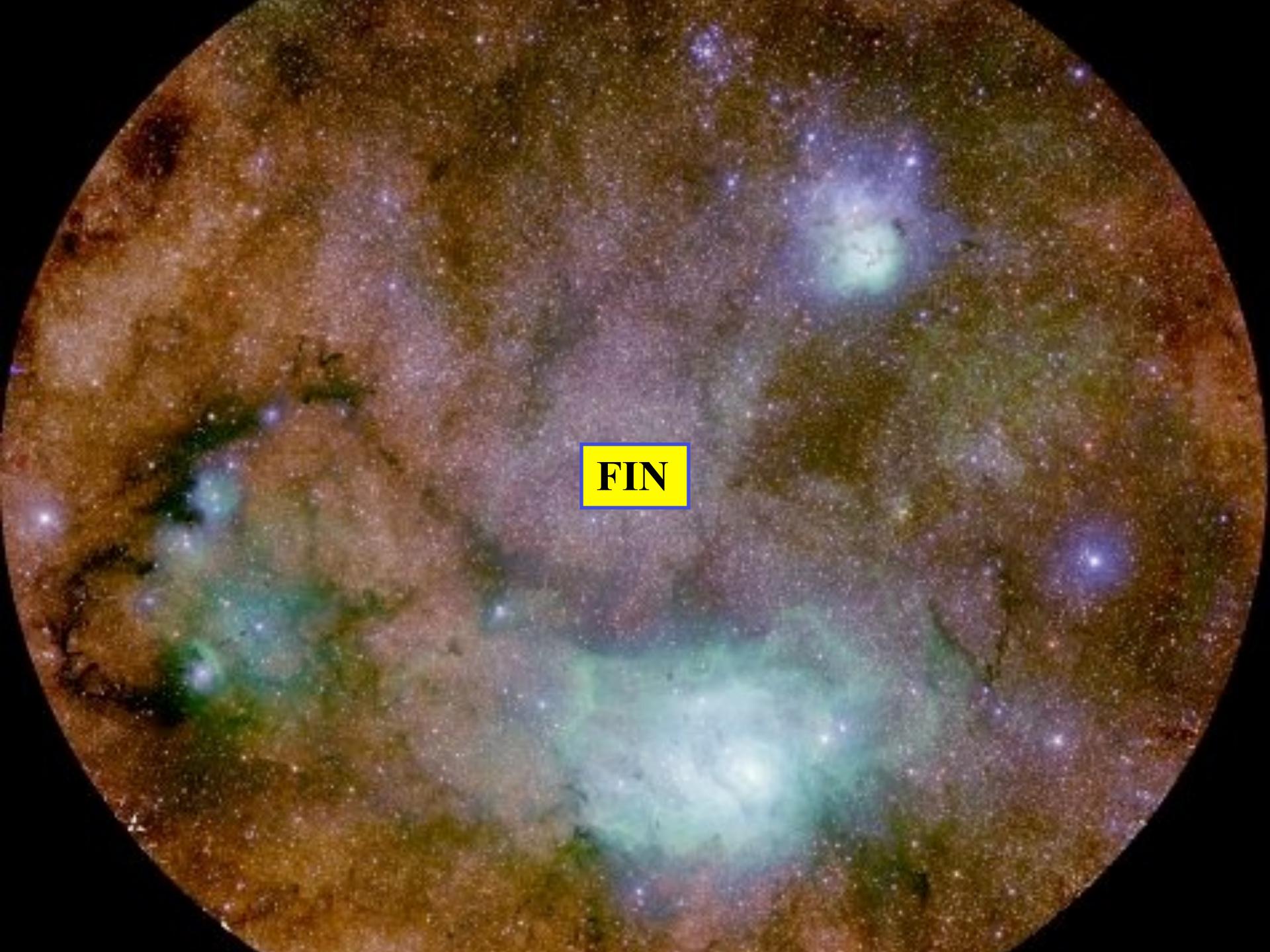
LSST
wider, deeper, faster



TDSS
systematic spectroscopic
survey of variable objects



massive spectroscopic variability survey
??



FIN

