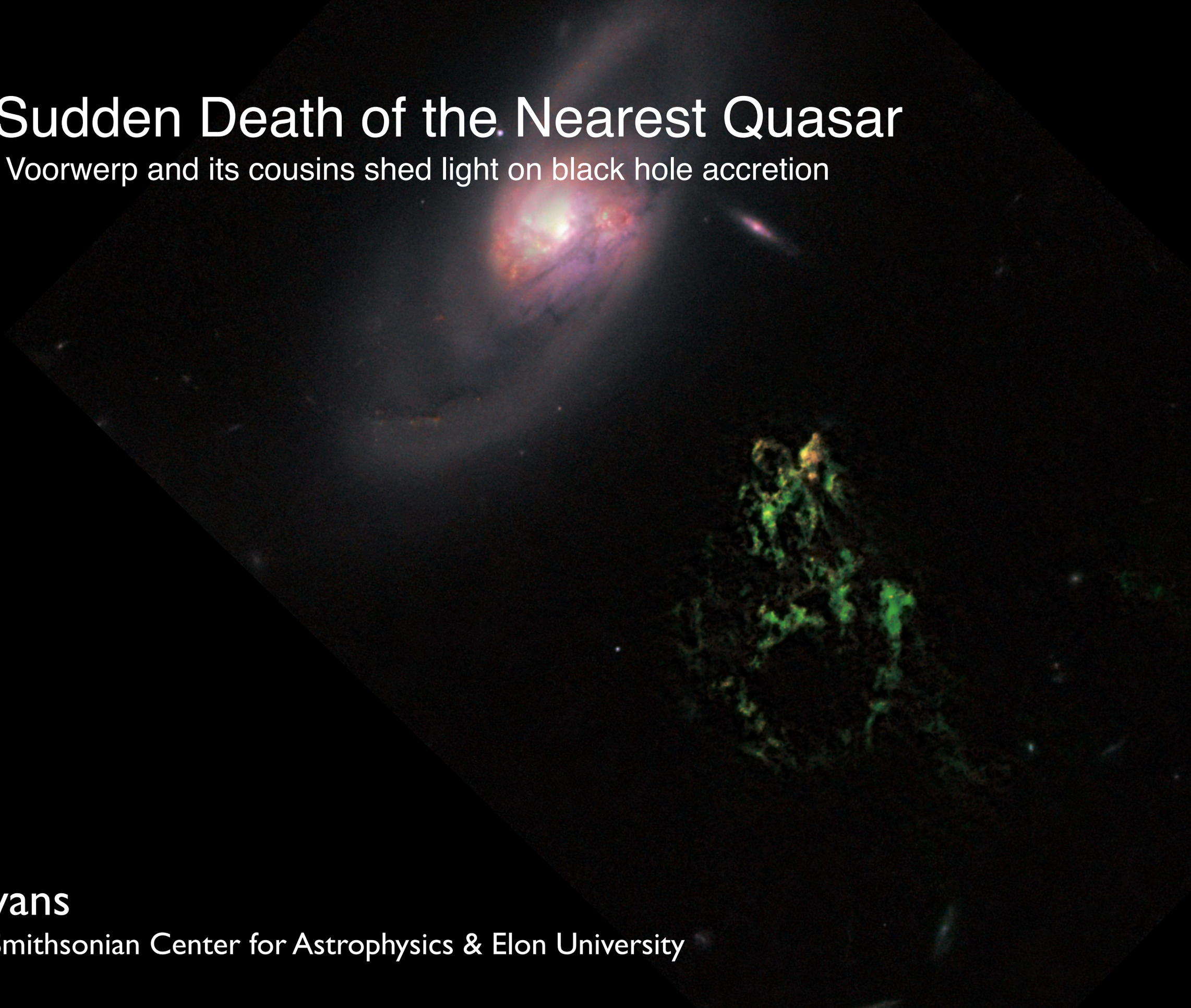
The Sudden Death of the Nearest Quasar

Hanny’s Voorwerp and its cousins shed light on black hole accretion



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Key collaborators:

Kevin Schawinski, William Keel, Meg Urry, Shanil Virani, Chris Lintott, Priyamvada Natarajan

Hanny van Arkel, Richard Proctor, Hannah Hutchins, Elizabeth Baeten, Massimo Mezzoprete, Elizabeth Siegel, Aida Berges, voyager1682002, Caro, Christian Manteuffel...

430,000+ Zooniverse Citizen Scientists

Schawinski et al. 2010, ApJ Letters, **724**, L30

Science Questions

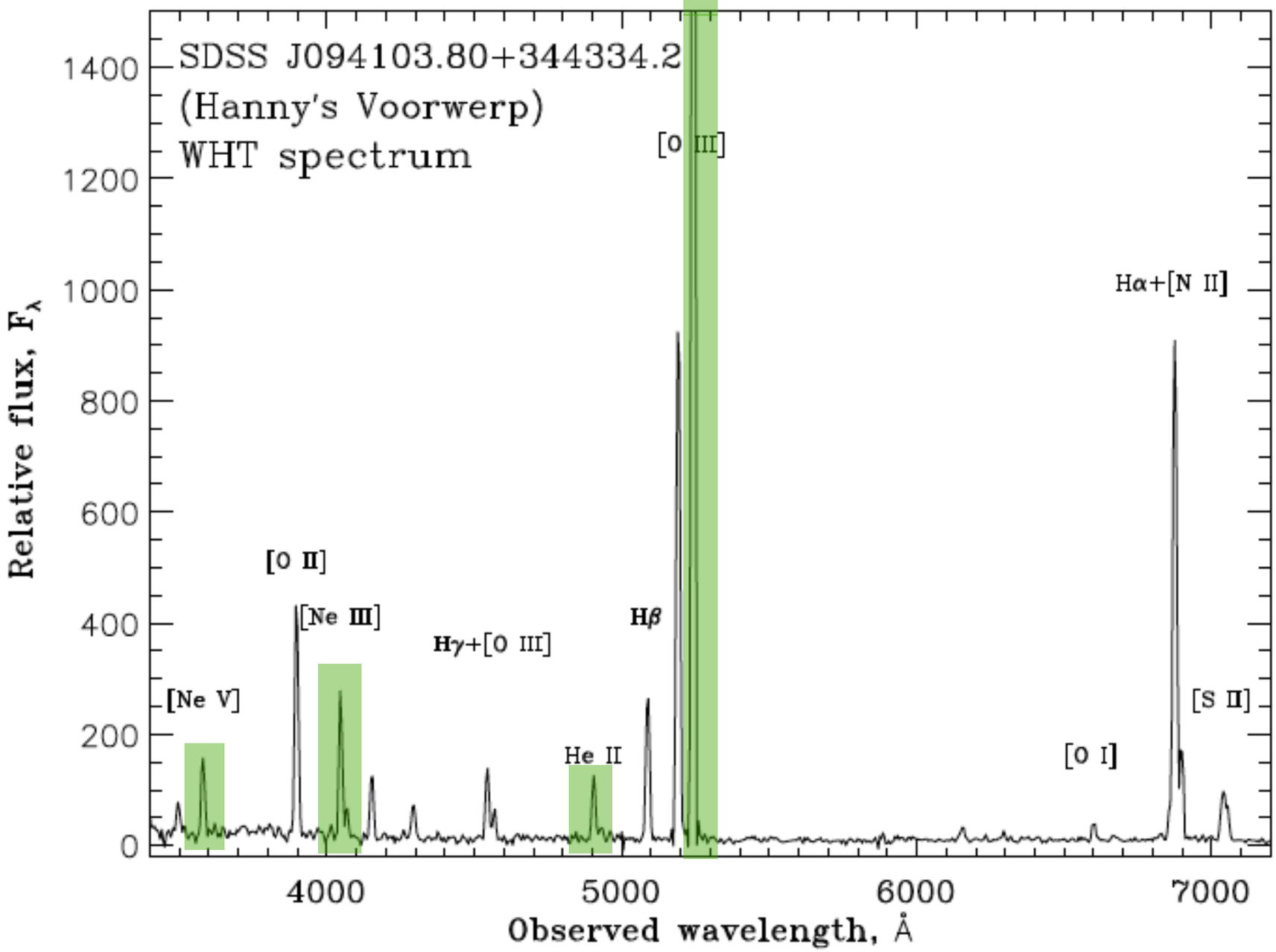
What is the time scale on which quasar phases turn on and off?

What do rapid “deaths” tell us about black hole accretion physics?

Are “dead” quasars the real culprits in quasar feedback?

Discovered by citizen scientist Hanny van Arkel in 2007
Named by GZ forum members after discoverer

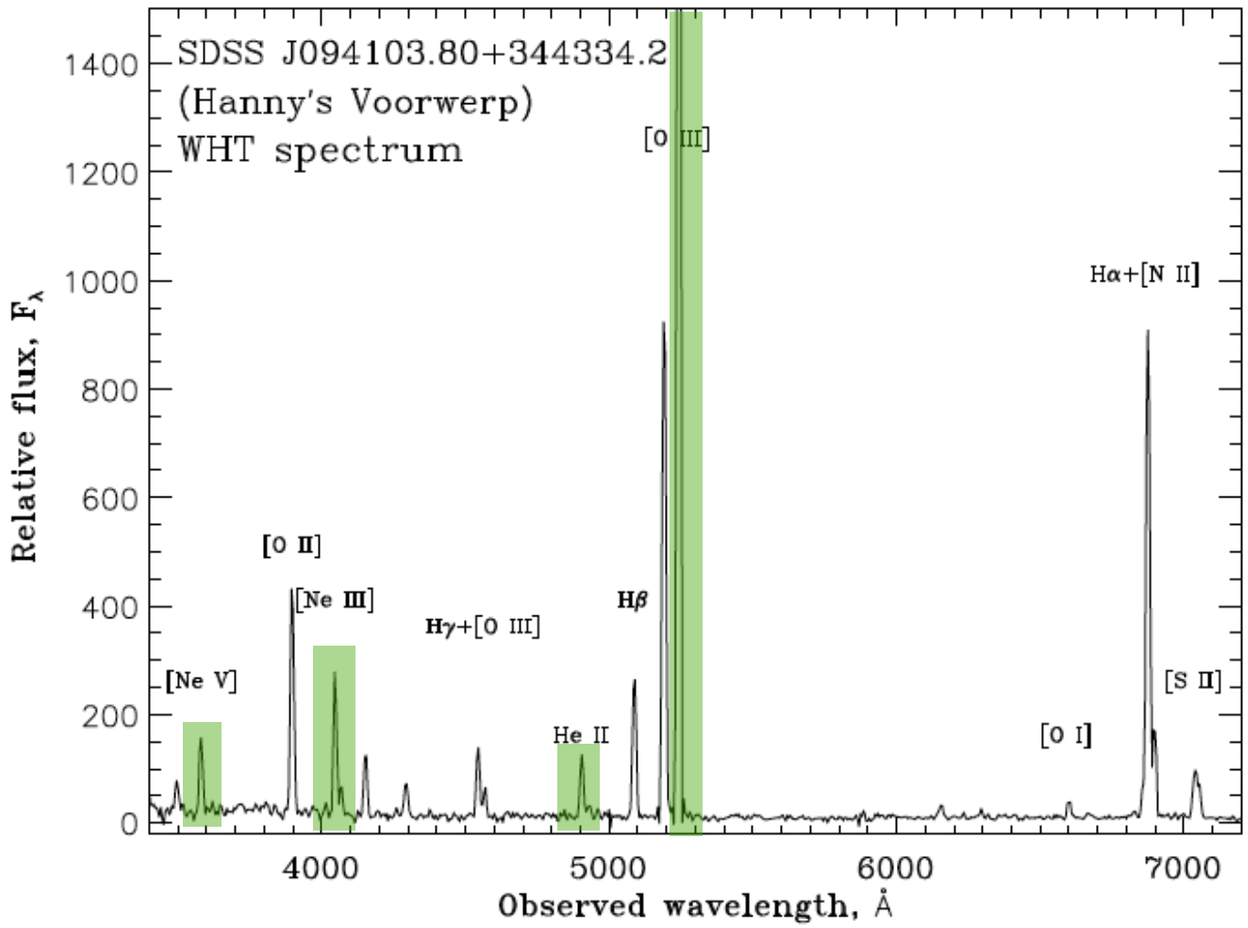
Spectroscopic Properties



z=0.05 - same as IC 2497

Lintott, Schawinski et al. (2009)

Spectroscopic Properties

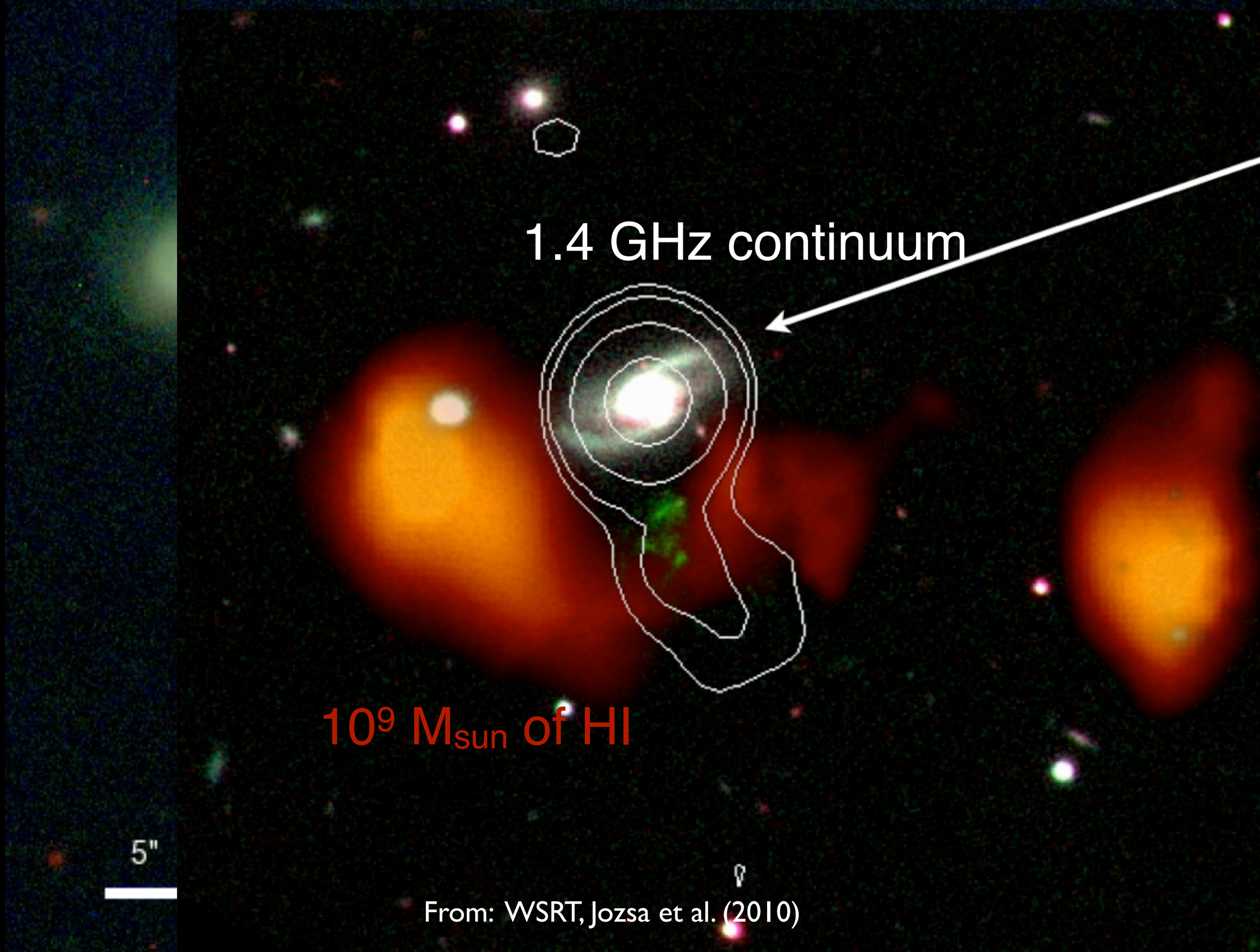


Low Density Gas:
[S II] λ6717/6731 ratio is density sensitive and lies in the low density limit ($n_e < 50$ cm^{-3})

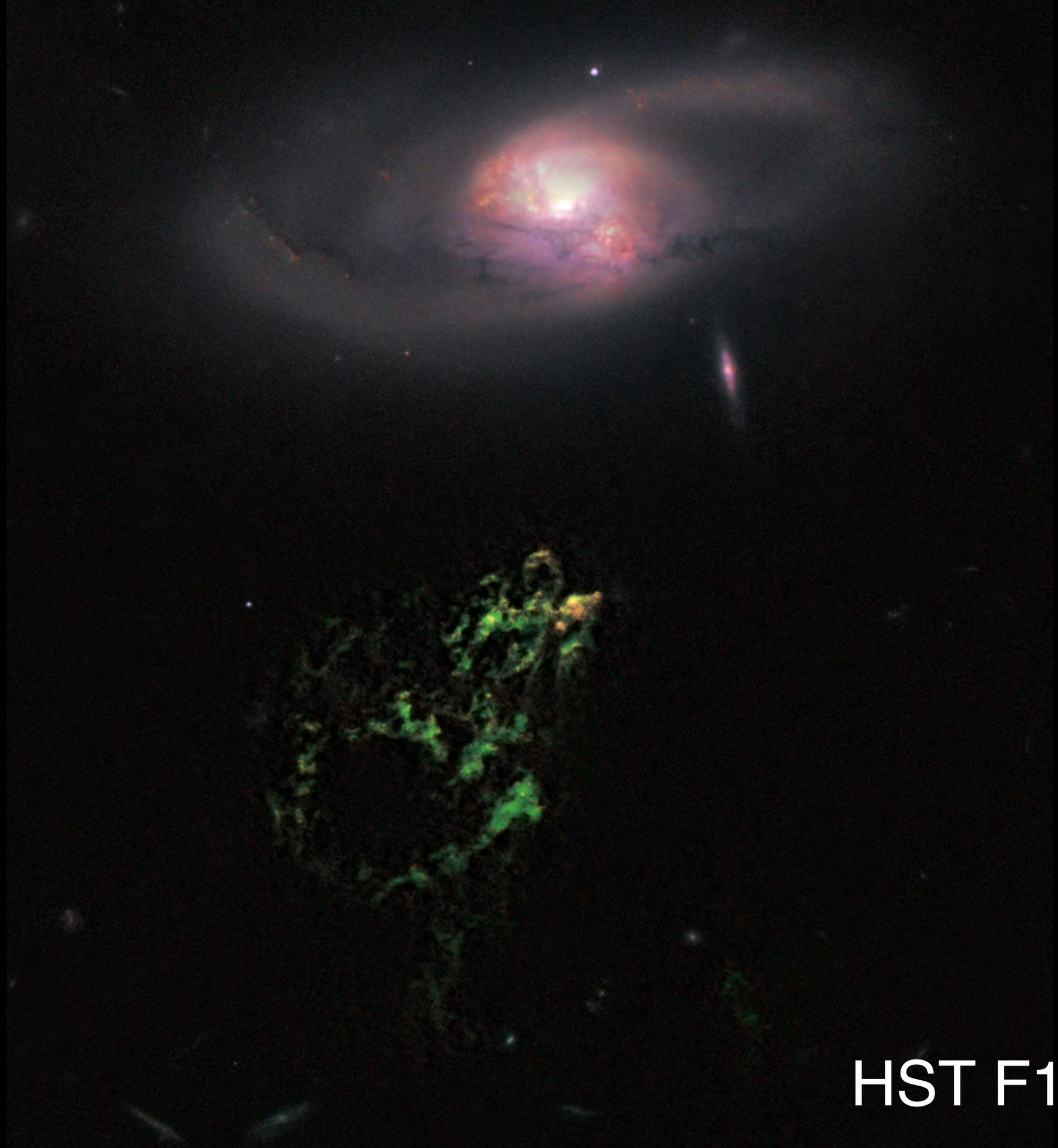
AGN Photoionized:
He II λ4616 and [NeV] λλ3346,3426 + [OIII] imply high ionization parameter, log U = –2.2 (need v ~ 400km/s to get lines due to shock)

Low Metallicity:
[N II]/Hα and [S II]/Hα indicate low metallicity of ~0.1-0.2 Z_{solar}

Lintott, Schawinski et al. (2009)



From: WSRT, Jozsa et al. (2010)


HST F184W

How luminous?

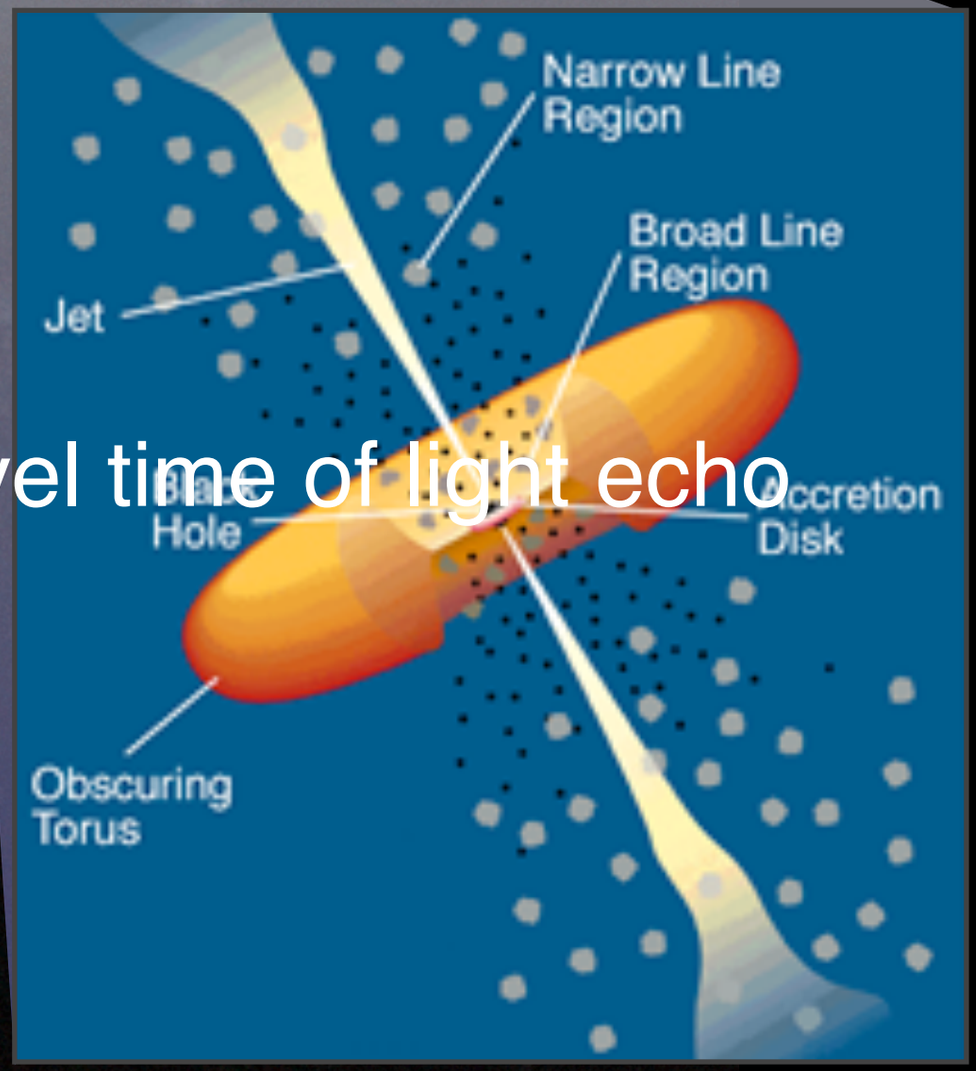
- Template SED from Elvis et al. (1994)
- Scaled SED to match the minimum UV luminosity to ionize the Voorwerp
- Find $L_{bol} \sim 10^{46}$ erg/s
- $L_{2\text{-}10\ keV} \sim 8 \times 10^{44}$ erg/s

Quasar - $L_{bol} \sim 10^{46}$ erg/s!

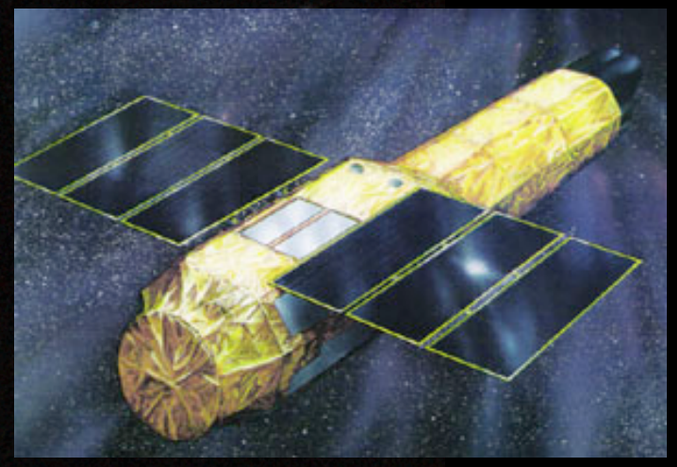
Why don't we *see* a quasar?

1. The quasar is highly obscured

2. The quasar has shut down (travel time of light echo around 70,000 years)

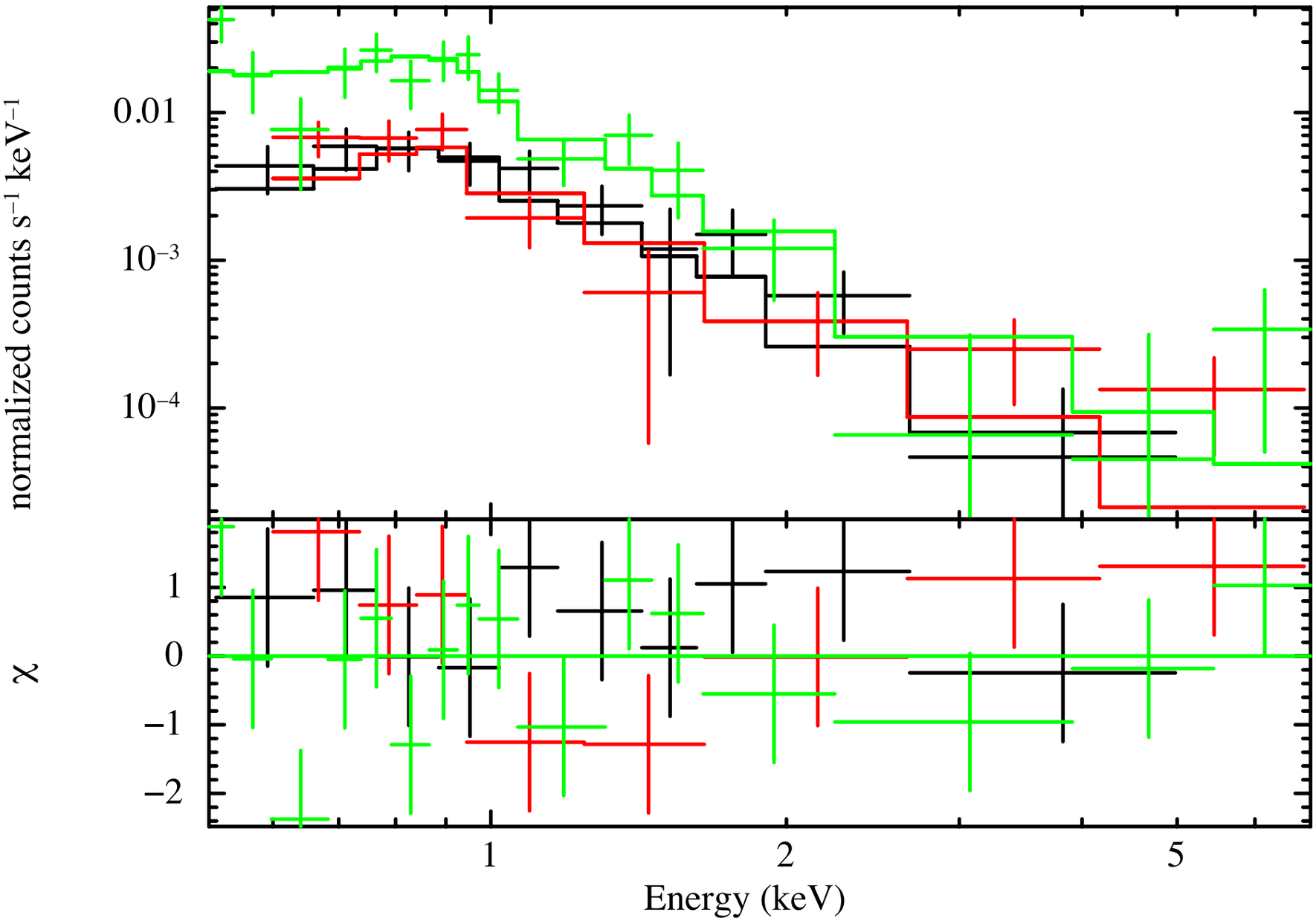


XMM-Newton
(37 ksec)



Suzaku
(75 ksec)

XMM-Newton Spectrum



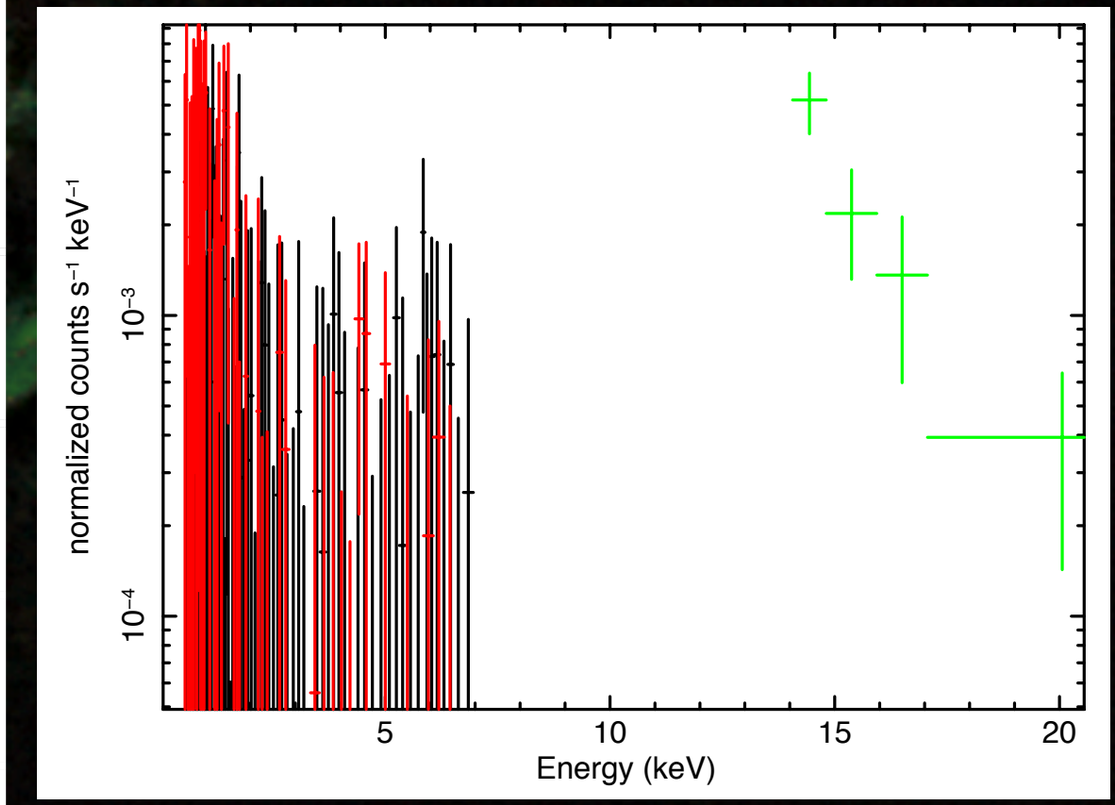
Collisionally ionized plasma (hot gas), kT = 0.78 (+0.18,-0.14) keV

Power law (AGN?) w/ Γ= 2.5 +-0.7, $L_{2\text{-}10\ keV} = 4.2 \times 10^{40}$ erg/s

Schawinski et al. (2010)

Marginal hard-X-ray detection with Suzaku PIN

N_H (cm^{-2})	15-30 keV luminosity (unabsorbed)
10^{22}	$< 4.0 \times 10^{40}$
10^{23}	$< 1.3 \times 10^{41}$
10^{24}	$< 3.5 \times 10^{42}$
10^{25}	$(4.2 \pm 2.3) \times 10^{43}$



Detection highly dependent on choice of background cornorm.

Marginal hard-X-ray detection with Suzaku PIN

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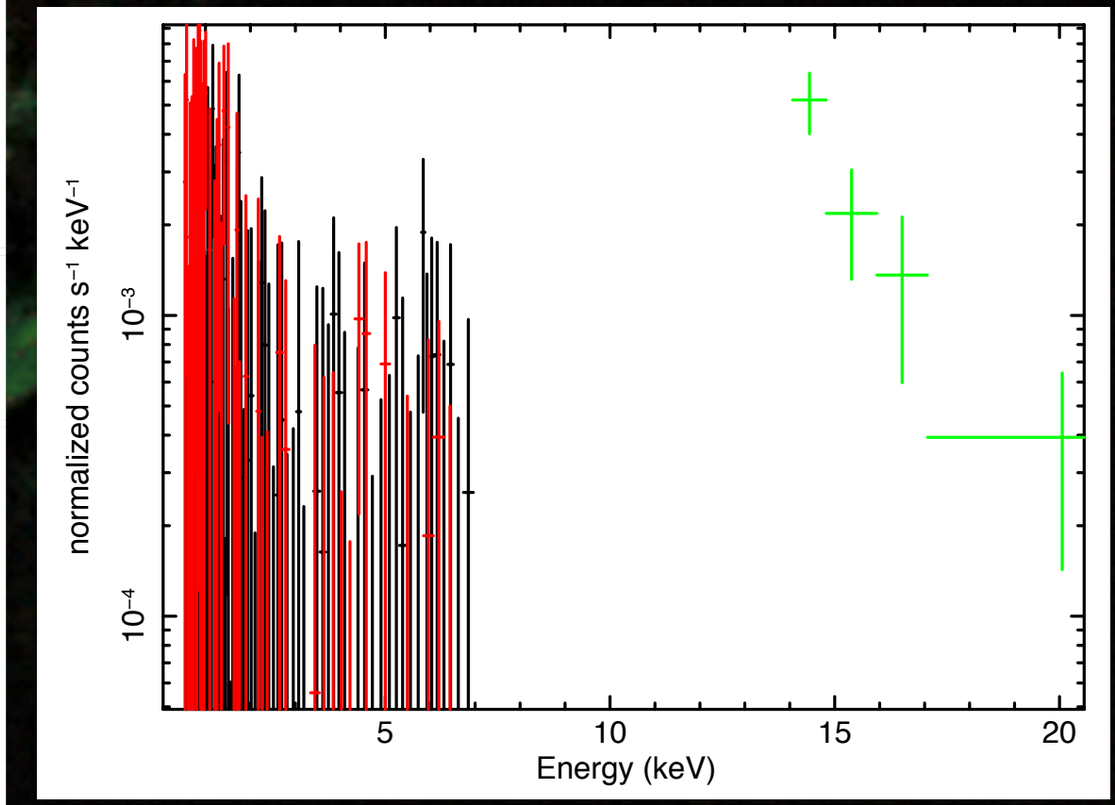
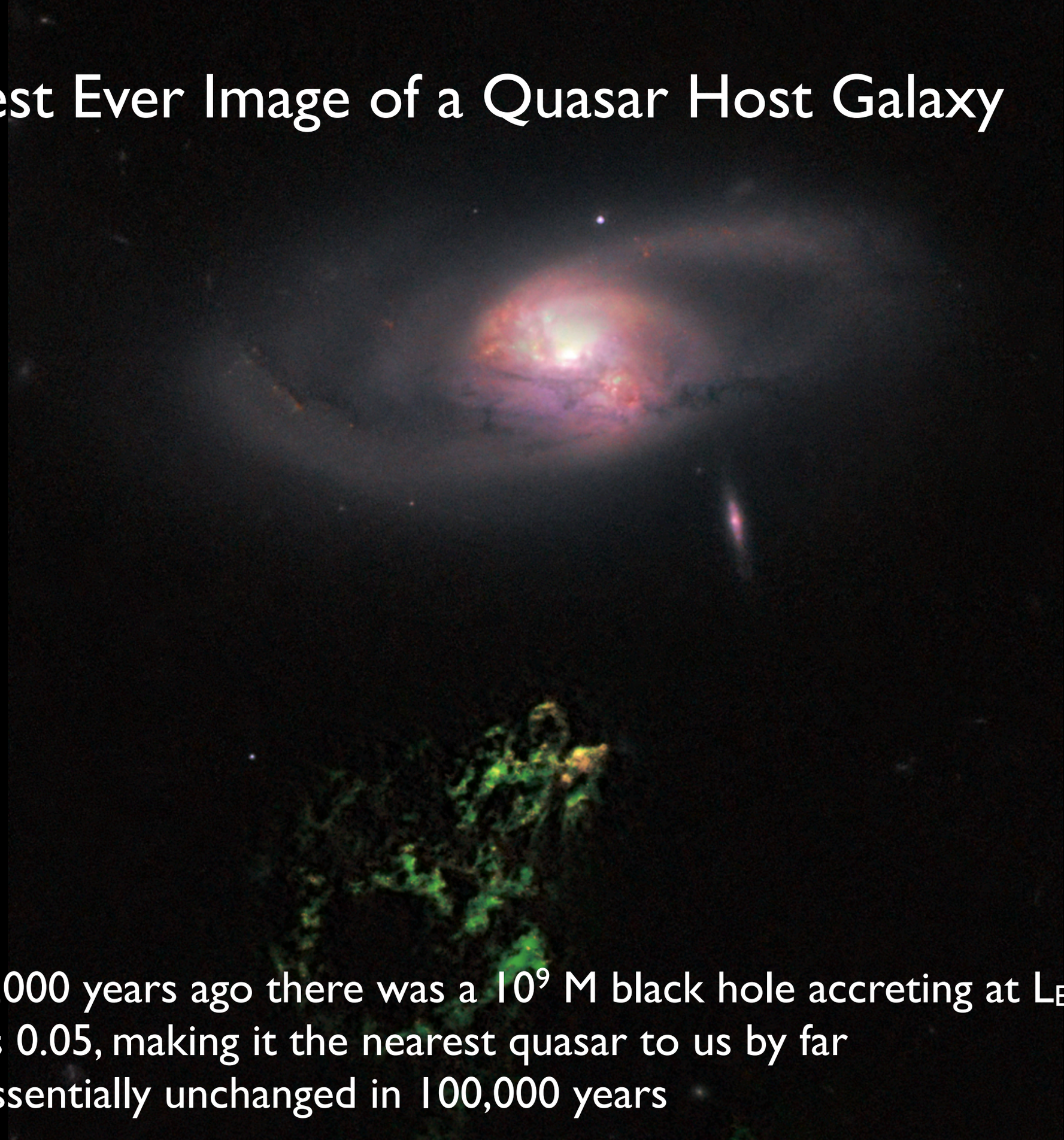


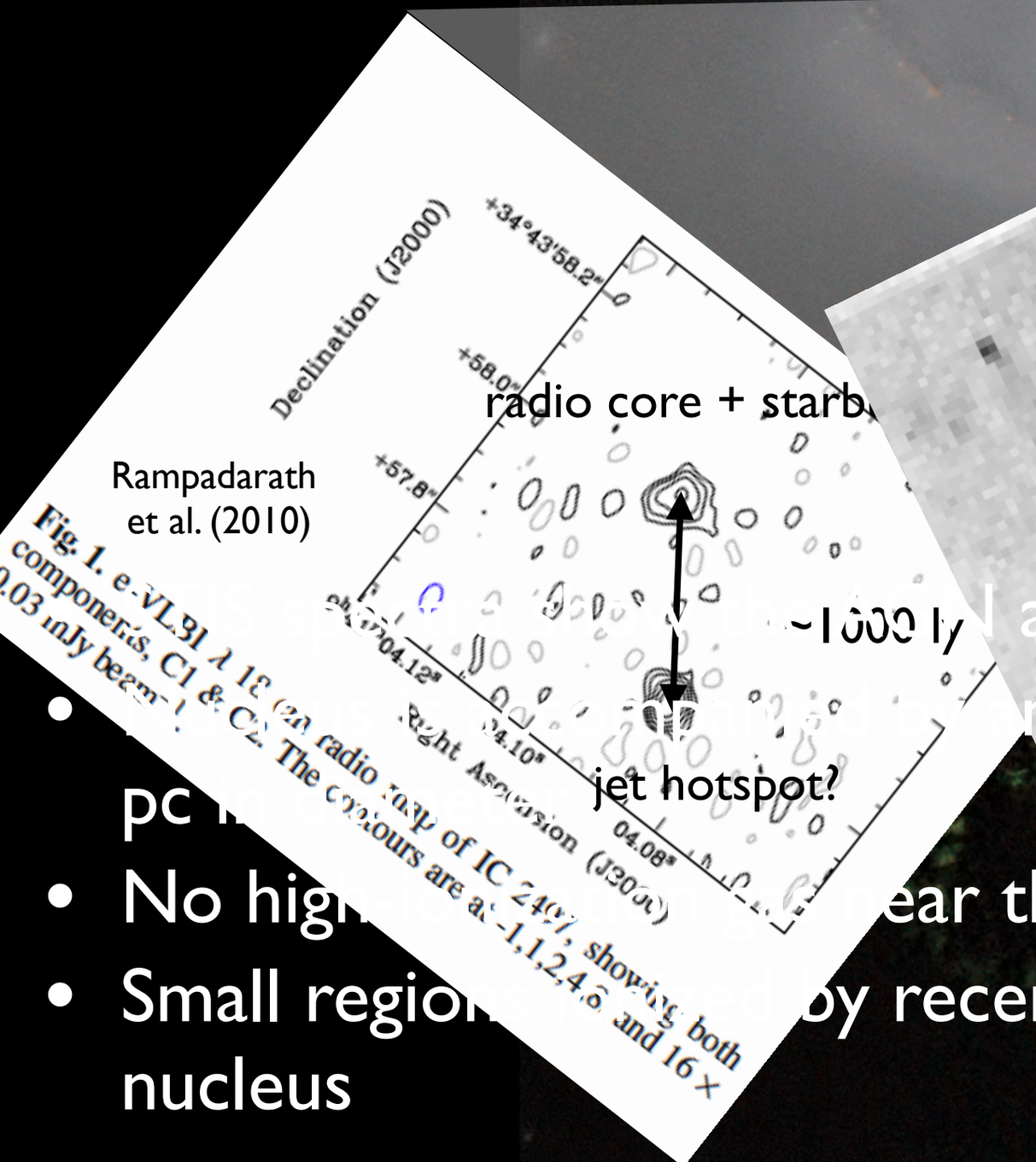
Quasar is likely to have shut down.

The Best Ever Image of a Quasar Host Galaxy



- Less than 100,000 years ago there was a 10^9 M black hole accreting at L_{Edd}
- The redshift is 0.05, making it the nearest quasar to us by far
- Host galaxy essentially unchanged in 100,000 years

The Best Ever Image of a Quasar Host Galaxy

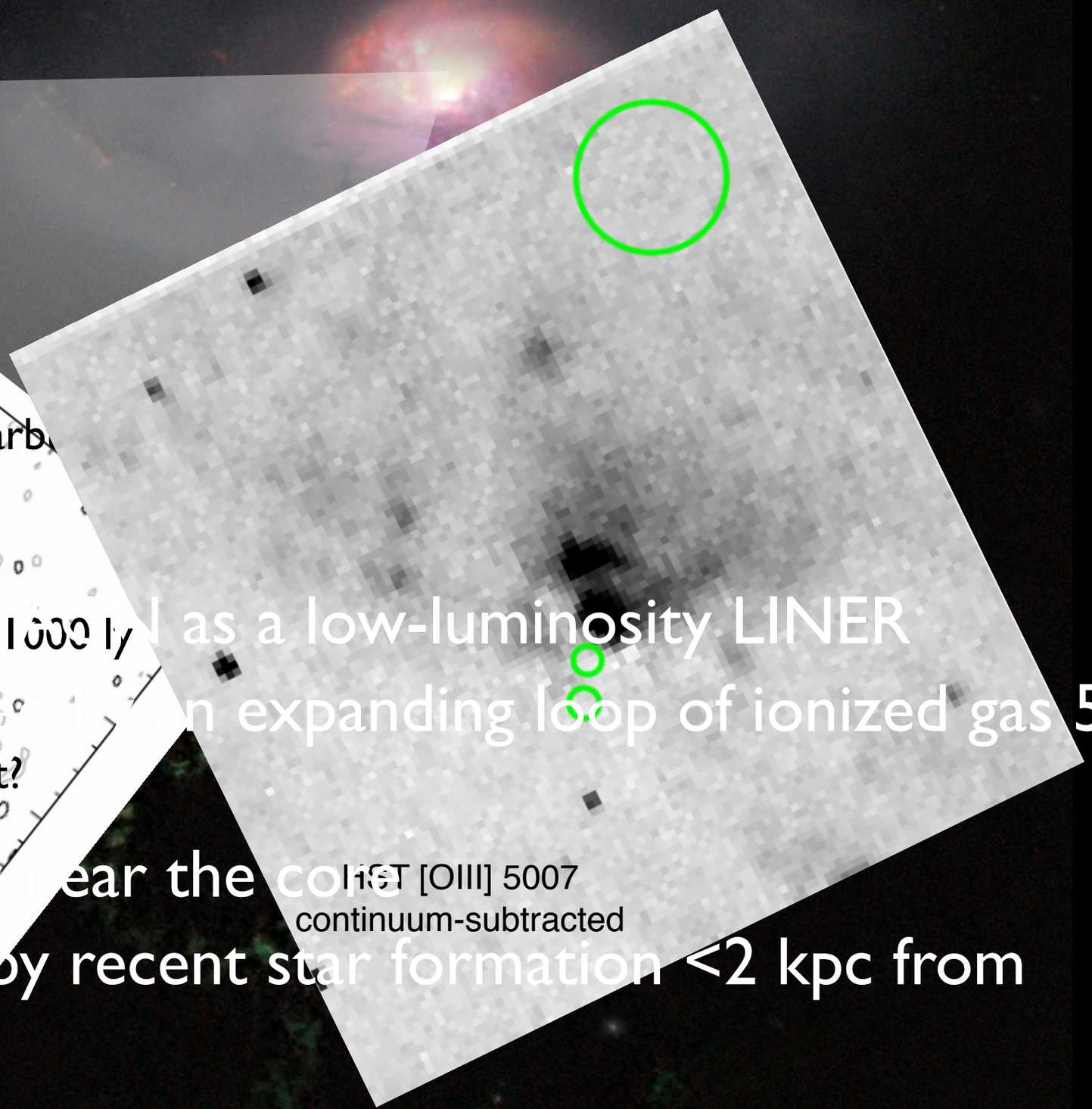


Rampadarath et al. (2010)

radio core + starb

~1000 ly

jet hotspot?



HST [OIII] 5007 continuum-subtracted

- [illegible] as a low-luminosity LINER
- [illegible] an expanding loop of ionized gas 500 pc
- No high [illegible] near the core
- Small region [illegible] by recent star formation <2 kpc from nucleus

State Transitions and Universality of Black Hole Accretion

IC 2497 may have transitioned from a classical quasar in a high state to a radiatively inefficient state.

Galactic X-ray Binary GRS 1915+105, 10 M_{sun} changes in ~1 hour. Scale up to 10^9 M_{sun} yield 10,000 yrs.

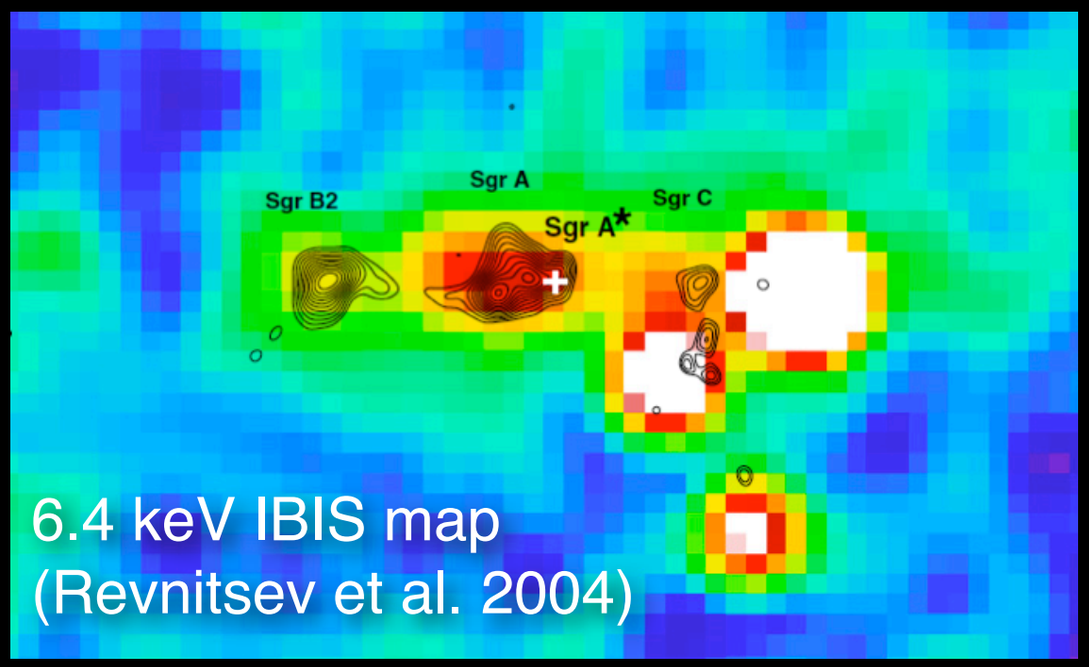
More complex calculation (Done & Gierlinski '05) yields ~10,000 - 100,000 yrs.

However, large luminosity changes in XRBs take several days, as the cooling wave must propagate through the disk in XRBs (Chen et al. 1997, Dubus et al. 2001). Scaled up = 300,000 years.

Analogy not perfect!

Another AGN Shutdown: The Galactic Center

6.4 keV Suzaku XIS map (see talks by T. Tsuru and M. Nobukawa this afternoon)



6.4 keV IBIS map (Revnitsev et al. 2004)

- 300-400 years ago Sgr A* was a LLAGN ($L \approx 1.5\times10^{39}$ erg s^{-1} at 2-200 keV) (e.g. Revnitsev et al. 2004 - Sag B2)
- Present day X-ray luminosity ~2×10^{33} erg s^{-1} (e.g. Baganoff et al. 2003, Muno et al. 2004)

Are there more “Voorwerps”

or

Is this state-switching common behaviour in AGN?

SDSS Query Results

http://cas.sdss.org/astro/en/tools/search/x_sql.asp

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Your SQL command was:

```
SELECT TOP 10
 p.objid,p.ra,p.dec,p.u,p.g,p.r,p.i,p.z,
 p.run, p.rerun, p.camcol, p.field,
 s.specobjid, s.specClass, s.z,
 s.plate, s.mjd, s.fiberid
FROM PhotoObj AS p
 JOIN SpecObj AS s ON s.bestobjid = p.objid
WHERE
 p.g-p.r = 'purple-bluish haze or fuzzy stuff'
```

SQL returned the following error:
Error converting data type varchar to real.

GALAXY ZOO FORUM

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There is one member awaiting approval.
June 27, 2011, 06:51:16 AM

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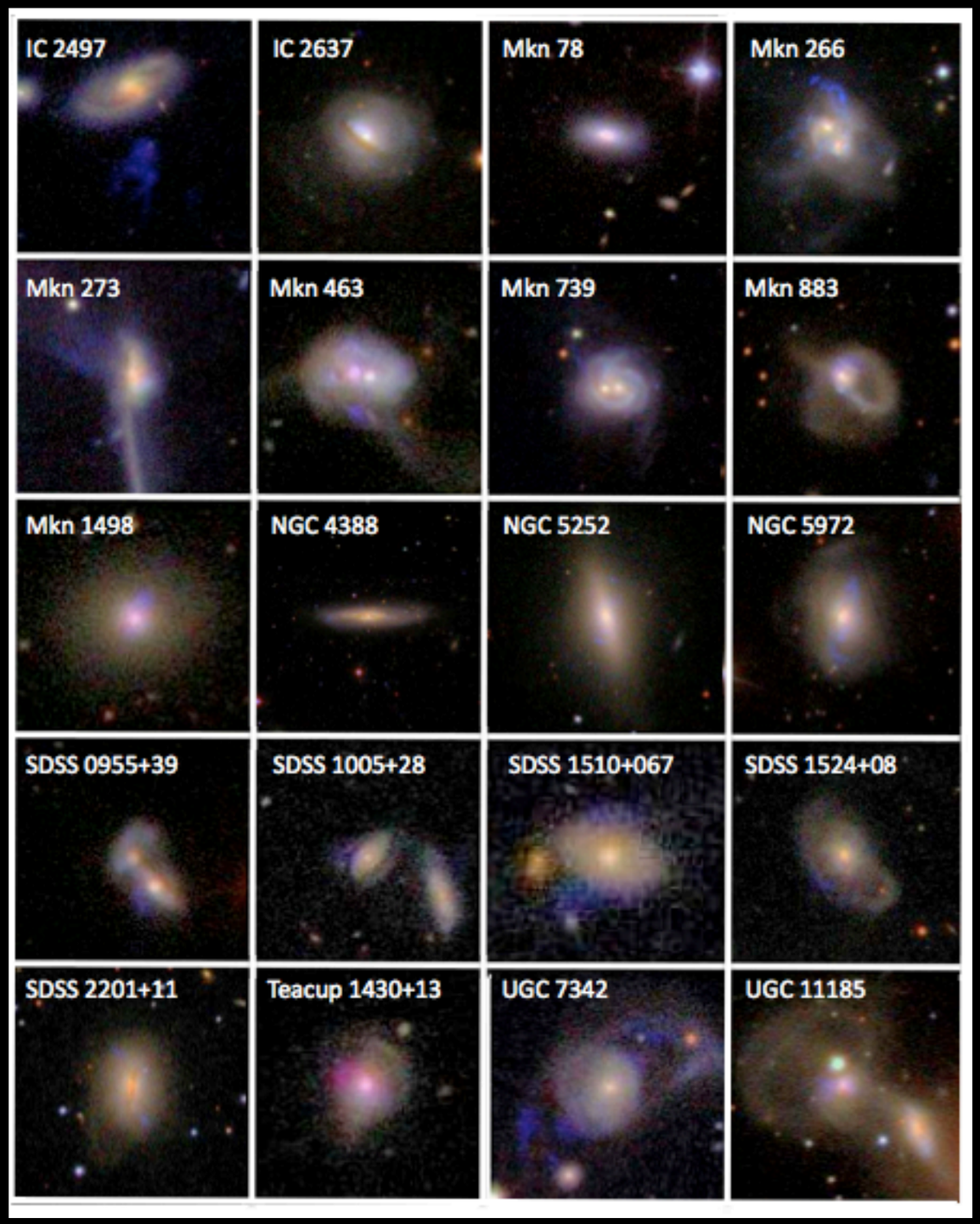
Possible strong gravitational lenses new Started by zookeeperKevin « 1 2 3 ... 413 »	6180 Replies 158248 Views	June 24, 2011, 10:48:59 AM by Budgieye
Gotta love these blues new Started by galaxybabe « 1 2 3 ... 261 »	3901 Replies 111352 Views	June 23, 2011, 09:44:52 PM by RandyC
Active galaxies with ionized gas clouds - more denizens of the Zoo new Started by NGC3314 « 1 2 3 ... 109 »	1632 Replies 27560 Views	June 23, 2011, 09:17:53 PM by RandyC
Could this be a Hanny's Voorwerp as well? new Started by Hanny « 1 2 3 ... 46 »	679 Replies 30526 Views	June 20, 2011, 06:23:17 PM by s4murai
The Galactic Faces Thread new Started by Vanny « 1 2 3 ... 65 »	970 Replies 39328 Views	June 17, 2011, 12:26:11 AM by StephanieC
Give peas a chance! new Started by Hanny « 1 2 3 ... 183 »	2735 Replies 93061 Views	June 06, 2011, 06:36:45 AM by mitch
Galactic Alphabet new	1186 Replies	May 27, 2011, 06:20:24 PM

Top Voorwerpjes (little Voorwerps)



Keel et al, in prep.

- SDSS color search by Galaxy Zoo volunteers
- [OIII] follow-up
- XMM observations of best candidates
- 114 ks Chandra observation of Hanny's Voorwerp

The Sudden Death of the Nearest Quasar

IC 2497 at z=0.05 is the most nearby $L_{bol} \sim 10^{46}$ erg/s quasar and Hanny's Voorwerp is its light echo. It was The Local Quasar.

Suzaku and XMM show it decreased its radiative output by 4 orders of magnitude less than 70,000 years ago. First measurement of the shutdown time of an individual quasar.

Since the quasar is gone, we have a 100% clear view of the Host Galaxy. Does the State Change indicate Feedback??

Quasars can change state much more rapidly than previously observed. Analogy to X-ray Binaries intriguing...

PIN cornorm	$N_{\rm H}$ ($\times 10^{22}$ cm^{-2})	XSPEC 1 keV normalization	15–30 keV luminosity (unabsorbed)	χ^2/ν
0 (0σ)	1	$< 6.3 \times 10^{-6}$	$< 4.2 \times 10^{40}$	112/75
	10	$< 2.0 \times 10^{-5}$	$< 1.3 \times 10^{41}$	112/75
	100	$(3.9 \pm 3.3) \times 10^{-4}$	$(2.6 \pm 2.2) \times 10^{42}$	108/75
	1000	$(1.3 \pm 0.3) \times 10^{-2}$	$(8.6 \pm 2.0) \times 10^{43}$	77/75
0.03 (1σ)	1	$< 6.1 \times 10^{-6}$	$< 4.0 \times 10^{40}$	70/75
	10	$< 1.9 \times 10^{-5}$	$< 1.3 \times 10^{41}$	70/75
	100	$< 5.2 \times 10^{-4}$	$< 3.5 \times 10^{42}$	69/75
	1000	$(6.3 \pm 3.5) \times 10^{-3}$	$(4.2 \pm 2.3) \times 10^{43}$	61/75
0.09 (1σ)	1	$< 5.9 \times 10^{-6}$	$< 3.9 \times 10^{40}$	52/75
	10	$< 1.6 \times 10^{-5}$	$< 1.1 \times 10^{41}$	52/75
	100	$< 1.8 \times 10^{-4}$	$< 1.2 \times 10^{42}$	52/75
	1000	$< 9.0 \times 10^{-4}$	$< 6.0 \times 10^{42}$	52/75