Contributions to a Galaxy Zoo "oral history" (or following Dali, A decade on the outskirts of citizen-science history)

William C. Keel, May 2020

I started this recollection soon after Chris Lintott noted that a proper history of the Galaxy Zoo project should be done one day but it is still too soon (and that his book *The Crowd and the Cosmos* ended up being rather different, having less to do specifically with Galaxy Zoo, then he first expected). As the chronologically most senior member of the Galaxy Zoo science team, demographics (even before CoViD-19) had me thinking I should write this all down now. My perspective is a bit "from the edge", since I have been involved in forum-based science more than the main statistical thrust of Galaxy Zoo. My aim is for this to have some of the flavor of oral history, maybe with better grammar and dates looked up.

My background and career path

I was the breed of astronomer who started eyeballing the Universe from the back yard. Growing up in the US in the 1960s, space was always in the news for some spectacular new development, so maybe it was socially acceptable. I mowed yards for a summer around 1970 to get a secondhand 6-inch Dynascope Newtonian reflector, whose clear sharp views were a revelation compared to the department store 60mm refractor I had before. By my junior year in high school, I must have been a pest to Doug Hall at Vanderbilt University; my first publication, in the AAVSO Journal, was based on a visual light curve of the eclipsing binary star EG Cephei.

I did my undergraduate work at Vanderbilt in Nashville, where I could commute from home. I did projects with Doug Hall to begin with, on period changes in binary stars, and eventually with Daniel Weedman on galaxies (I was hooked). Some entailed a lot of observations with Dyer Observatory's 61-cm Seyfert telescope. Again, I was hooked.

Between undergrad and starting grad school, I spent much of the summer of 1978 as an NRAO summer student in Charlottesville. I worked there with Thijs van der Hulst on VLA observations of galaxy nuclei - although it had only one arm and about 8 dishes, so it was more like a Pretty Big Array. And there was no AIPS yet. As well as exposure to radio astronomy, this project had a followup 5-7 years later in a large, multiwavelength comparison of interacting and noninteracting spiral galaxies.

I went to grad school at UC Santa Cruz, starting in 1978, largely supported by an NSF fellowship. This was the last time I had a choice of career options; the attraction was telescopes and instruments available to their students. I did lots of photographic

work at the Crossley telescope, including a project on whether some of the apparent excess of bright quasars Arp reported around nearby galaxies could result from what we now call gravitational microlensing by objects in their halos. My dissertation work, advised by Joe Miller, was the first such project on the then-new Nickel 1-meter telescope, using the Wampler/Robinson IDS spectrum scanner to investigate the nature of the galactic nuclei which were shortly to be known as LINERs. That project took something like 70 nights at that telescope and the 1.5m UCSD/Minnesota telescope on Mt Lemmon, Arizona, which was equipped with a clone of the IDS (a theme about observing is becoming more apparent). I was able to supplement these data with narrowband images using the Video Camera on the Kitt Peak 2.1m telescope (for which I was eventually the final instrument scientist, signing its retirement memo as it gave way to lower-noise CCDs).

I started what was at the time a Kitt Peak postdoc in 1982, which ended up lasting 3 years with some observatory-support responsibilities in the final year. I did additional narrowband galaxy imaging, spectroscopy of potential optical jets in galaxies, and was part of a fruitful collaboration on the effects of interactions on AGN and star formation in galaxies from optical, radio, and the far-IR viewpoint just then emerging as the IRAS catalogs were released. (At that time a sample of 160 galaxies seemed huge and statistical). I managed to maintain a connection with Mt. Lemmon by agreeing (with facility directory Dr. Barbara Jones at UCSD) to be available for questions and support on their IDS system - a small price for an annual week of time at the 1.5m telescope, 90 minutes' drive from my apartment. I did a lot of observing while in Tucson - walking in to my 2nd-floor apartment once, I heard someone down the walkway say "See, I told you somebody lives there."

I went on to Leiden for 2 years, in a position which partly filled the gap in their staff left when George Miley was assigned to STScI. He kept trying to extend that leave through launch but that couldn't keep up with project and launch delays. The Dutch community had recently partnered in the Isaac Newton Group of telescopes on La Palma, so bringing optical spectroscopic experience was useful with some of their students (especially working with Rien de Grijp on the then-very hot topic of IR-selected AGN). In hindsight, I am struck by the value of such an experience in connecting with pieces of the astronomical community I would never encounter at observatories or US meetings. One project combining previous experiences while at Leiden was experimenting with deconvolution for optical images, modifying the CLEAN techniques I learned about at NRAO for data where the noise is in the image domain, trying it out on some CCD images taken in my final months at Kitt Peak, using a fine pixel scale to sample the point-spread function very well. Most notably, this let me break down the structure of the M87 jet for better comparison with VLA results, looking at its synchrotron spectral changes.

I have been at the University of Alabama in Tuscaloosa since 1987. Mine was one of a couple of new faculty positions initially supported by the NSF/state EPSCoR program, with the aim of expanding the astronomy group to a critical mass so that it would be self-supporting though the ordinary NSF and NASA funding. (I am proud to

note that we did so and remained so). Initially a postdoc, Ray White III joined the faculty a year later (and is now associate dean). We had discussed computer purchases before I arrived; as soon as I got here, I had to take the lead in setting up a MicroVAX system and IIS image display (since I was most desperate to use them).

Beyond EPSCoR, essentially all my research funding here has been from NASA, whether IUE, Astrophysics Data Program, HST, or other satellite-based programs. This meant that I went into a somewhat scattershot research profile, following enough topics of interest to various facilities to get funding, and pursuing other ground-base programs as funding allowed. This was eased by a UA policy in which 10% of the research overhead from a grant goes into a discretionary research fund for the investigator.

My initial involvement in HST data came from those experiments with optical deconvolution in the Bad Old Days of spherical aberration. I had met Rogier Windhorst in Tucson, and again at the Baltimore IAU General Assembly in 1988. Some time after the announcement of aberration, he called to ask if I'd like to try this technique on some WF/PC images of radio galaxies (and take some grant funding, the summer-salary part of which wound up being a big part of where our home down payment came from). Extending work on the most distant of these radio galaxies, 53W002 at z=2.39, led to our group's finding of compact Lyman α emitters at that epoch, and with some ground-based optical and IR followup, what some cite as an early set of Lyman α blobs.

In the 1990s I was fairly successful at keeping observational research programs going, getting time at Kitt Peak, plus getting on the Lowell visitors list for their 1.1m telescope when Jay Gallagher was director (and they kept me on for a while). I keep telling students that with digital sky surveys, what once took 6 months of observing runs and CCD imaging just to refine the sample for a spectroscopic project can now be done in an afternoon. (OTOH, everyone else can do that too, making database queries an important professional skill). I was fortunate enough to have overlapping NASA grants for HST, IUE, ROSAT, ISO, FUSE, and Chandra projects (recently passing the 30-year mark - thanks, NASA!) Along the way I did committee work (NASA Senior Review a couple of times, MIDEX proposal selection), one byproduct of which was getting an invitation to the "VPs with kids" viewing area for the predawn launch of STS-82. (STS-125 was on my own dime via commercial tour bus, but I really had to see it).

Truth be told, my research career was in a lull circa 2005. It was getting more difficult to get time on national facilities (and my connection to Lowell through former directors was gone), and travel to Chile was prohibitively expensive post EPSCoR anyway. (Close observation will show an acknowledgement to the Delta Sky Miles program for Mauna Kea observations in one paper). I was exploring things like observatory-support jobs, with no local observing opportunities and UA salaries

revealed to have been historically about 22% below the regional average once all the numbers came out.

This changed radically for me in 2005-7. UA installed a new 0.4m DFM telescope at the start of 2005, procurement of which started with Ron Buta handling things and somehow ended up with me doing the purchase orders and commissioning. By negotiating to keep the money from the sealed-bid sale of the old 10-inch J.W. Fecker refractor (to John Allseits, IIRC) we got a 2K x 3K SBIG CCD imager and SBIG SGS spectrograph to go with it. After I'd spent a couple of months working with the system, my wife wondered whether I was planning for Christmas to end any time soon.

The following year, UA joined the Southeastern Association for Research in Astronomy (SARA) consortium, looking ahead to their adding a second telescope at CTIO. This gave us an effective combination for grad student training in particular. They could start on the local telescope, operating from a control room but where it was easy to look around the sky or run upstairs and see what the telescope was doing, so while the interface was different from the remote SARA telescopes, the principles were known. Then, for those grad students going on to use larger facilities for dissertation work, the whole experience was not so unfamiliar. (I might like people to think I planned all this, but it just happened to work out that way). By now SARA has 3 telescopes, not only the 1m Frankenscope at Kitt Peak (made from the not-best parts of two former telescopes) and the former Lowell 0.6m at Cerro Tololo but, in a stretch that paid off, the 1-meter Jacobus Kapteyn Telescope (JKT) on La Palma. (And as it turned out, the standard instrumentation paper on the SARA network was Keel et al. 2017). This has been very fruitful for student training at multiple levels, and a good way to carry out targeted emission-line surveys to supplement the kinds of AGN-ionized clouds whose occurrence in Galaxy Zoo has been very enlightening. Younger Self would never have believed that I could find remote observing comparably fulfilling to going to the mountains, and it's not, but not having to do or pay for the travel, and the extra flexibility, make it a fair trade.

Galaxy Zoo!

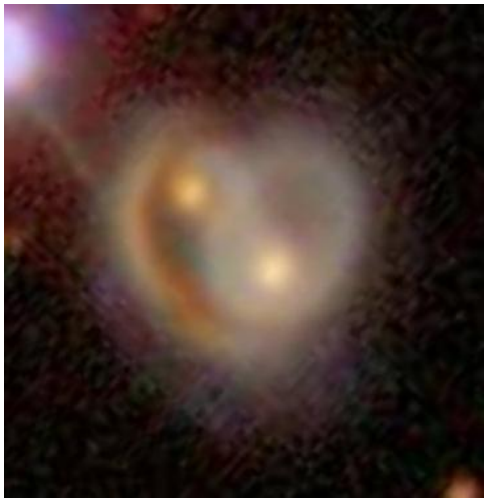
Then came Galaxy Zoo. I'm still not sure where I saw a notice and the link - I thought it was the old Bad Astronomy Bulletin Board or its successor BAUT forum, but was never able to find it again. I probably owe someone a basket of their favorite holiday treats for that. After watching a bit and seeing interesting galaxies being posted, I signed up on the project discussion forum on 1 August 2007. Soon afterward I posted a request for participants (who later started calling themselves Zooites) to keep an eye out for overlapping but non-interacting galaxy pairs, to do the kind of dust-obscuration studies I'd done off and on since 1983. After work with Ray White and Chris Conselice published a couple of years earlier, we had essentially run out of systems that could be identified with the Digitized Sky Survey, and I was quickly

impressed with how many more could be picked out via the added dynamic range of color SDSS displays. (I have kept this up as a major piece of my Galaxy Zoo followup work, but as will become clear, other topics arose which were very exciting and seemed scientifically more urgent. And cool.)

It was only at a 2009 team meeting in Greenwich that I learned this post had made me the first person banned from the Galaxy Zoo forum (then quickly reinstated). Chris Lintott and Kevin Schawinski each blamed the other - they were unsure who this person posting projects was, but Google convinced them I was an actual astronomer capable of contributing to research papers and everything. Then in the following months, I started seeing my name on the science team list - the process was apparently quite informal at that point.


Greenwich 2009: Zookeeper Chris and the astronomers of the Round Table

I believe I looked at every galaxy shown in the image threads (tens of thousands) over the lifetime of the Forum - its structure made it straightforward to see what was new. That was the 2-hour highlight of a lot of my workdays. I started to save candidate overlapping-galaxy systems for possible followup; it was life-changing when I found keyboard shortcuts for copy/paste. As often happens, I would have saved more information on date/time posted and which user posted each pair, had I had a clue what the scale of the project and duration of followup would become.
I eventually started collecting especially notable galaxies of other kinds (even if just memorable images such as the Heart double-ringed interacting system SDSS J155308.66+540850.1)



I met Chris Lintott in person at the Austin AAS in January 2008. I was rocking an NGC 3314 T-shirt for recognition (matching my forum avatar, and, later, Twitter handle) - the kind of thing one could find online without being custom-made, complete with the accompanying HST release text and investigators' names on the back. It had chilled that evening a bit faster than I expected, and I did try not to shiver too much.

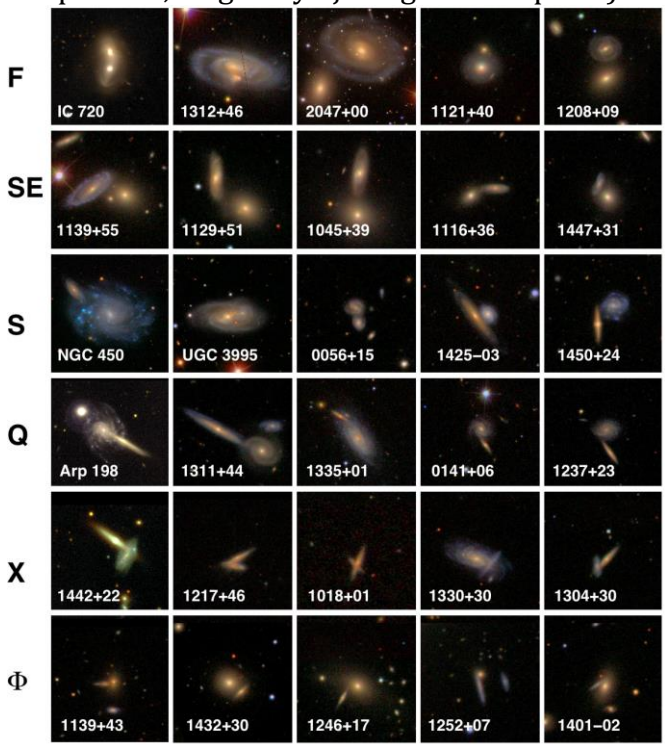
I found myself the senior science team member, perhaps not surprising since Galaxy Zoo was largely founded by postdocs and grad students, so part of the role that emerged was popping in with old history background to things. (It's like I woke up one day in my 50s, then 60s - I have earned the Old Astronomer shtick and will use it without shame). Possibly because my career was more secure, I also settled into a more common presence on the project forum, watching for unusual objects and interacting with participants pretty consistently about a range of science topics. (Currently, a few moderators on Galaxy Zoo Talk will clue me in if I particularly need to drop in to a thread I'm not otherwise following).

Backlit galaxies

The first galaxies that really jumped out at me in perusing the Forum were pairs of overlapping galaxy images, where one appears backlit so we could measure the attenuation produced by foreground dust, no matter its temperature or location in the galaxy. I had addressed this in NGC 3314 and NGC 1275 in a 1983 paper which now seems unutterably primitive, but my interest in this approach was piqued even earlier, around 1977 when I saw a print on Dan Weedman's desk of the galaxy cluster Abell 1060 from plates he had recently taken at Cerro Tololo (which went into a study of the globular-cluster system of the 2 large central galaxies). The idea was revisited again in the 1990s, when Ray White III and I were jointly bemoaning the press attention to a Nature paper by Ed Valentijn which proposed that spiral

galaxies are largely opaque, based on statistics of photographic photometry of ESO-LV galaxies. Our major quibble was that if the conclusion were literally true as stated, we couldn't see out of our galaxy well enough to take the data - and if you allow the dust to be clumpy, everything about the interpretation changes. We set out to find candidate galaxy pairs to do the backlighting test, with what seem, again, very primitive samples (Arp and Arp-Madore atlases plus anecdotes). At least there were now CCDs. We took data from Kitt Peak, Lowell, and Cerro Tololo, appearing in a Nature paper and several ApJ/AJ ones (including one with Chris Conselice when he was our summer student). Chris Conselice spent a good bit of time scouring galaxy-pair catalogs on the digitized Palomar Sky Survey, limited by the dynamic range of the images. Circa 2000, this approach had pretty much been applied from the ground for the 20 or so galaxy pairs known to be suitable and well enough resolved from typical CCD images. We had done a few with HST data (NGC 3314, NGC 1275, AM0500-20, AM1316-241, and Elmegreen and coworkers did NGC 2217), getting a clearer view of the fine structure of dust and showing length scales over which it acted fractal. And there the project sat for about 7 years.

Galaxy Zoo participants quickly found many additional backlit galaxy systems, often because the color information and wide dynamic range of the SDSS composite images revealed structure in what had been blended blobs on the digitized Sky Survey. I started keeping a list of objects and links; in hindsight, I should have realized sooner that this would become a project of some scope and kept more information (including who posted first and when), and tracked repeat reports of a single system as a way to estimate completeness (which I started doing only late in the process; originally I just ignored repeats).



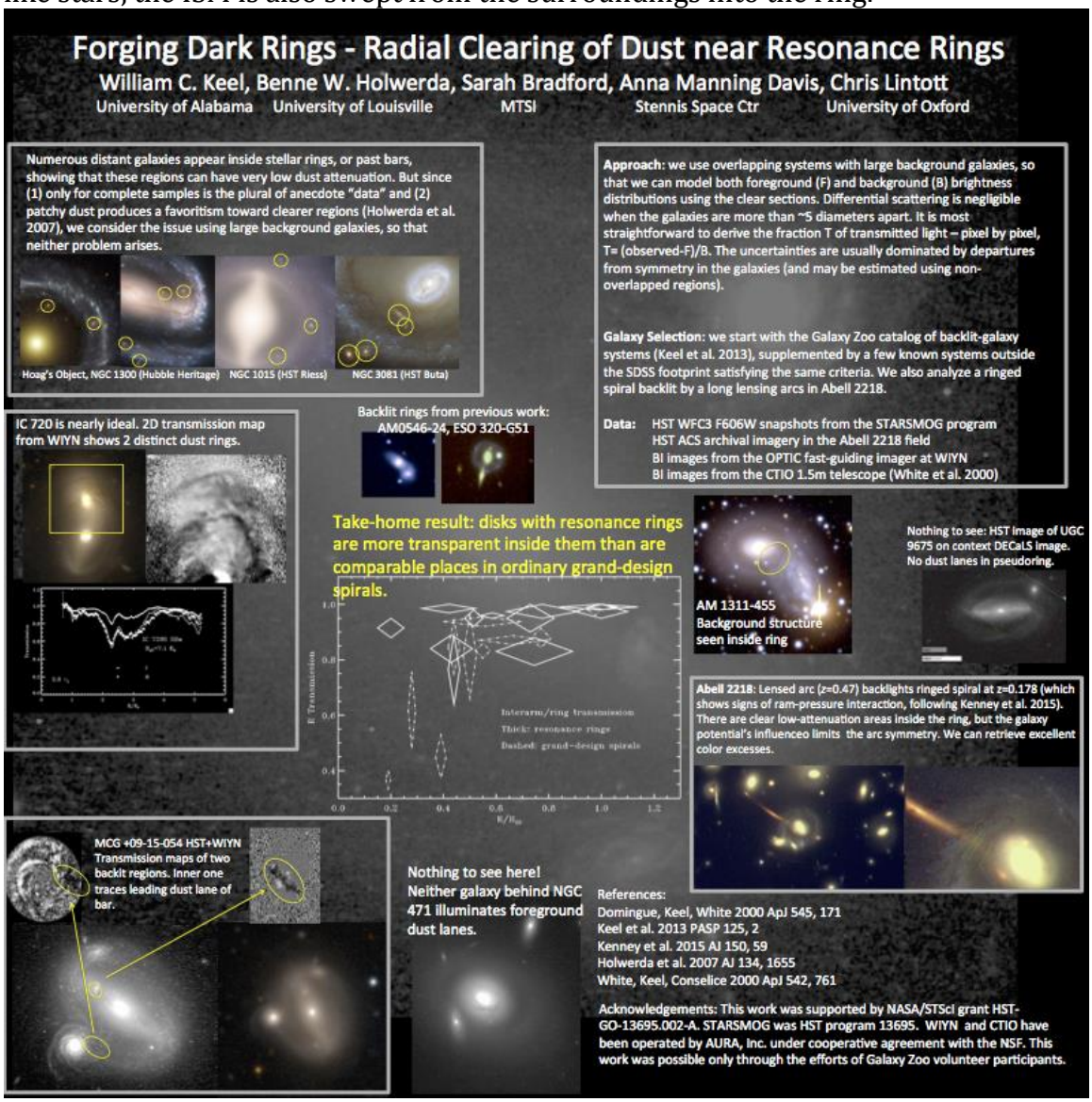
Various kinds of galaxy overlaps, from the PASP catalog paper

Participant Half65 was particularly active in this effort, not only in finding the galaxies but collating their catalog data (he's a coauthor on the catalog paper). We published a list of almost 2000 pairs from this phase, while I've continued to maintain a list of later reports - first as SDSS data releases filled the early gaps in sky coverage, and then as Galaxy Zoo started to work through images from the Dark Energy Camera. The original manuscript included the catalog and a sample of processed galaxies to illustrate our approach and sample results, but the MNRAS referee was unhappy with this combination. So much so that we pulled out the catalog and sent it to PASP. (Because Galaxy Zoo results should be public and easy to find, the catalog in text form is posted on data.galaxyzoo.org along with PDF files of images, coordinates, and other information broken up into RA ranges to be manageable).

One of the first followup observing runs for Galaxy Zoo projects was for backlit galaxies, using the OPTIC fast-guiding CCD system on the 3.5m WIYN telescope at Kitt Peak. UA grad student Anna Manning, Chris Lintott, and I went for the session. It was fantastic to watch the systems appear on deep images, often with subarcsecond image quality. Chris was tracking who first posted each target so we could notify them and maybe send an image. While he was struck at how many of the Kitt Peak staff I knew (because I had only been observing regularly since 1981), we ran into some of his fan club - he was recognized walking around the mountain by a tourist who belonged to an astronomy club which gathered monthly to watch Sky at Night DVD episodes as bound into the magazine and widely available in the US. That project had 2 more observing runs (April and November 2008 and May 2010; I couldn't help noticing that Hanny's Voorwerp crossed the meridian at the start of morning twilight in November, so we got spectacular images that enriched our later Hubble work). Anna Manning did a master's thesis combining these data with GALEX and XMM Optical Monitor data to narrow down the UV extinction of galaxies, a first with this technique (and showing that the Calzetti et al. empirical extinction slope is a pretty good approximation even in the outskirts of spiral galaxies, far from the starburst environments where it was derived).

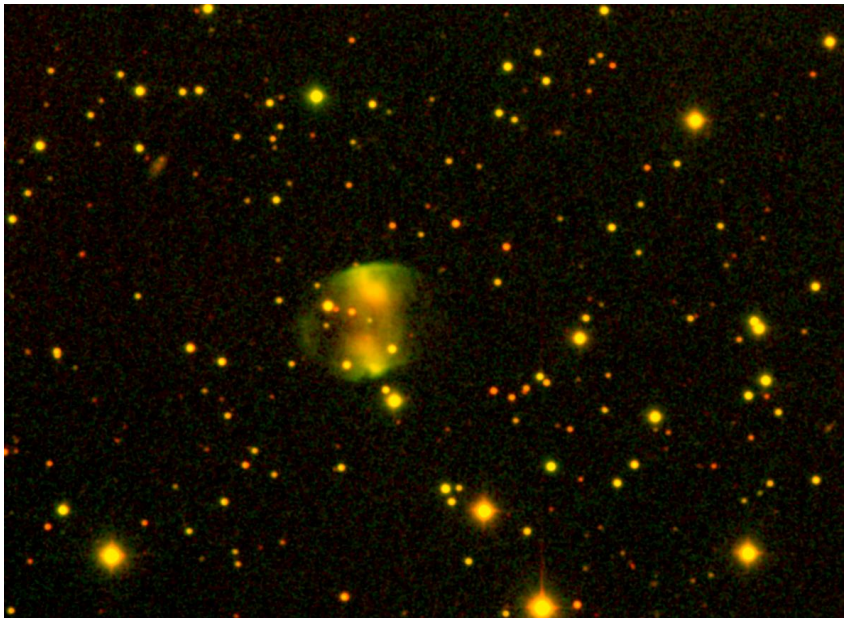
There remains much to learn from this sample and these data. We've probed at subtopics so far. A serendipitous find was literally brought to us at a Seattle AAS meeting while I was talking to Benne Holwerda, who also had background in this area. Julianne Dalcanton walked up and said we both needed to see this - a faint galaxy pair in the background of the stellar halo of NGC 253 from the ANGST HST survey, with distant backlit dust tendrils. This is remarkable - significant dust lanes more extended than the starlight. This put us out to seek more, one of the rationales for an HST snapshot survey we kept proposing of our "gold standard" pairs whose redshifts are so different that we can rule out distortions due to interaction with each other. (The level to which we can demonstrate a galaxy's symmetry is a major piece of the uncertainty budget when we measure attenuation via backlighting). After trying for several years, it finally made the HST schedule as the STARSMOG

project led by Benne. I suspect it did better in review that time not only because Benne produced a memorable acronym, but his centering of its utility to generate priors for supernova extinction in cosmological programs that eventually made it more competitive. UA grad student Sarah Bradford analyzed some of the geometrically best-behaved of the STARSMOG objects in her master's thesis. We continue to add to her results - the dust web of crisscrossing dust lanes in some disks, another very clear case of dust beyond the stellar disk, sharp edges to the extinction in disks, and hints of statistical changes in dust distribution on small scales between galaxies. By 2018, we had enough data for a side project (presented at the galaxy-ring meeting honoring Ron Buta's retirement) demonstrating that resonance rings in galaxies have clearings inside and outside them, suggesting that, like stars, the ISM is also swept from the surroundings into the ring.



We did follow up on the dusty dwarf systems with external dust, through an imaging survey in April and May 2012 that marked my final work at the Kitt Peak 2.1m

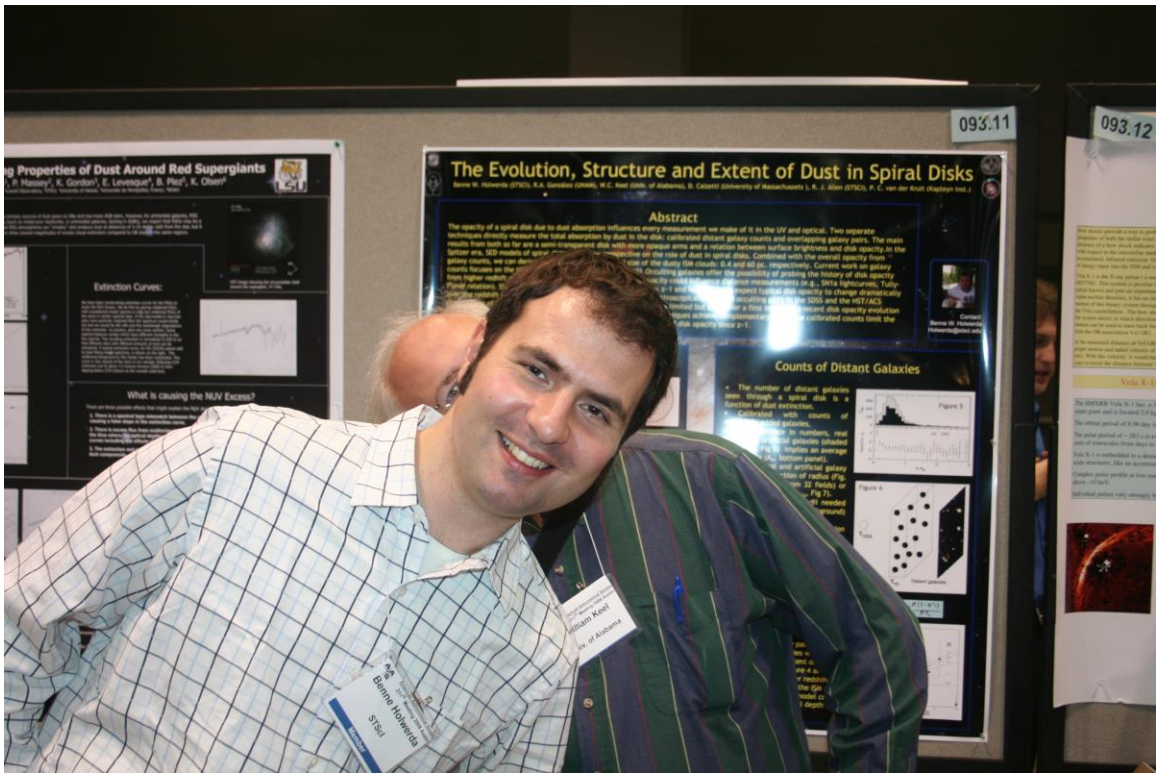
telescope (first encountered at the end of 1981) and led to HST imaging which has confirmed a few more cases. The Kitt Peak observing run, a bountiful 7 nights, was split into two pieces, partly in hopes of having collaborators along for some. That didn't work out - and worse, a planned video visit by Dianne Sawyer and a 60 Minutes video crew, for a story on citizen science, fell through at the last minute due to a personal emergency. (The one time having a 60 Minutes crew in the control room would not have suggested calling a lawyer). They were hoping to have Zooite Jonathan Bennett, IIRC a New York journalist, there for observations of a planetary nebula he came across in the SDSS. Maybe just as well, because it was a poor time of year and we might or might not just have been able to push the telescope far enough east to catch it as morning twilight brightened. (It is a nice Dumbbell-nebula type with very hot central star – we really should do a short paper. Any day now.)



Jonathan Bennett's planetary nebula, in [O III] and Hα filters from the Jacobus Kapteyn telescope.

VV191 is an impressive spiral with elliptical backlighting, found as such in Galaxy Zoo, which is striking enough that Rogier Windhorst offered some of his JWST GTO time for a look. That, in turn, was enough for a proposal led by Benne Holwerda to get UV data with HST, so the goal is to have a composite attenuation curve from 2000 A - 5 microns from a single technique for the same galaxy. Although after the number of Januaries I've awoken at 2 a.m., sat up in bed and said, "It launches NEXT YEAR!", it's like the toast at the end of a Seder. Next year in L2!

While gathering material to share with Benne Holwerda and students in Louisville, I compiled a list of my observations of backlit galaxies, ground- and space-based. With 400 data sets over the years, it may be no wonder that we have yet to generate the Grand Unified Dust Synthesis.



Austin, January 2008: with Benne Holwerda, demonstrating how to measure attenuation of light with the overlap technique. Benne's head is quite opaque.

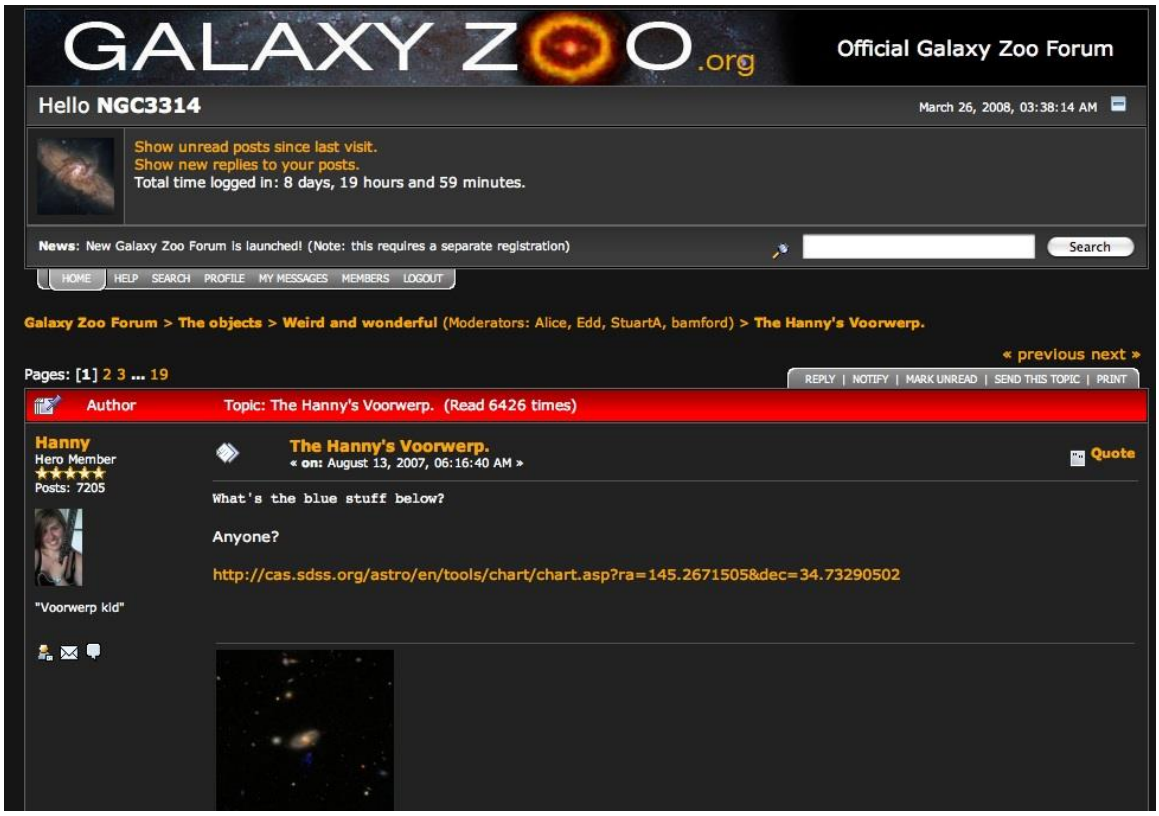
Hanny's Voorwerp

This find, to my mind, centered in many people's minds the value of having more and more eyes looking over sky surveys. Hanny van Arkel, at the time (IIRC) a 23-year-old school teacher in the southern part of the Netherlands, posted a message on the Galaxy Zoo forum on August 13, 2007 with the SDSS image of IC 2497 asking simply,

"What's the blue stuff below?

anyone?"

and the rest became history. This was only about 5 weeks into the Galaxy Zoo project; looking back later, about 12 volunteers had seen the image of IC 2497, and only one other person later posted it on the forum with a similar question before it became well known and instantly recognizable.

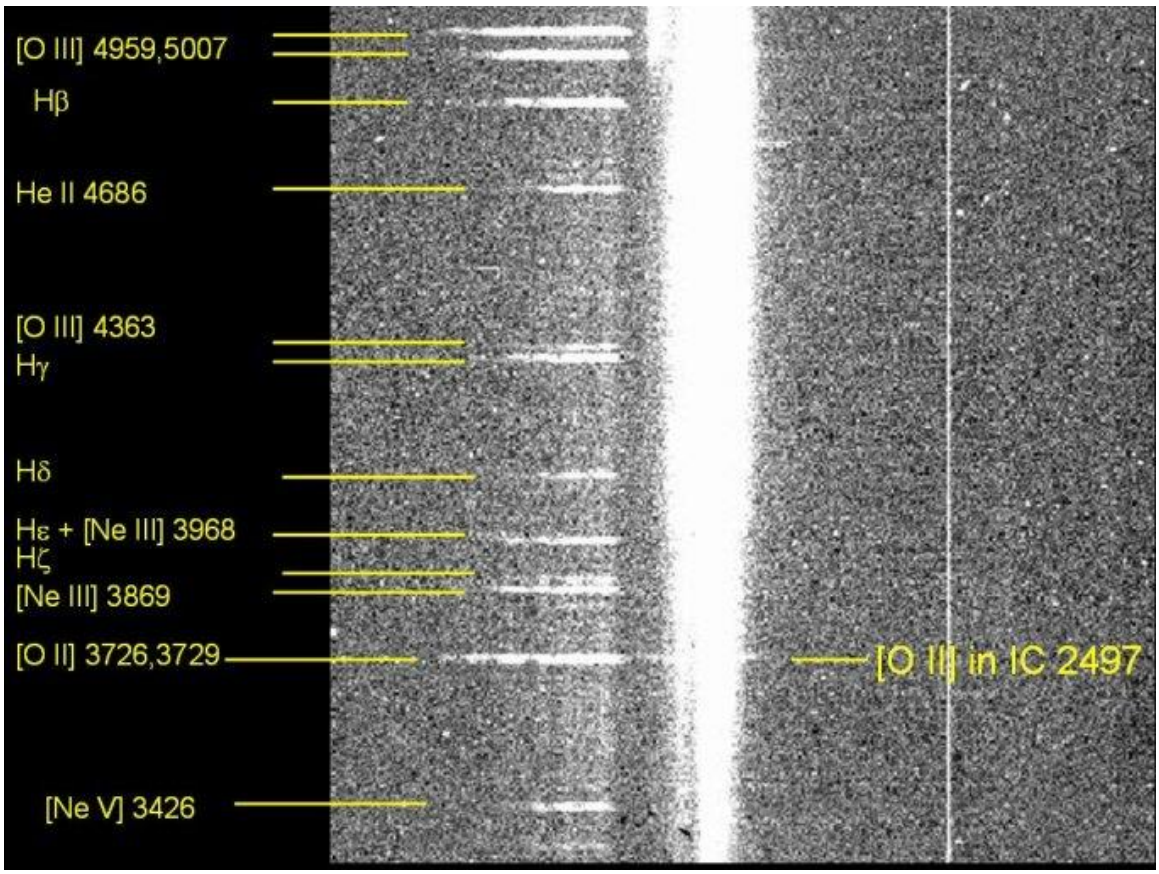


For some reason, I don't recall the science team members being very interested until near the end of 2007, when people started looking at various sky surveys. On December 30/31, I did images in BVR filters with the SARA 1-meter remote telescope at Kitt Peak, confirming the object and slightly narrowing down where a strong spectral peak had to be in wavelength in order to match the extreme colors (it had to be in both *g* and V filters).

We wouldn't really know what it was until somebody got a spectrum. For all we knew, it could be a foreground nebula or enormous Lyman α blob at redshift z=3.3. So we started looking at online telescope schedules, to see whether someone we knew, had gone to school with, or ever worked with had upcoming time on a telescope with long-slit spectrograph. Eventually, I got in touch with Gabriela (Gaby) Canalizo, who I knew as a former student of Alan Stockton and fellow participant in an informal group of Christians in astronomy who would meet over lunch at AAS meetings. Gaby, in turn, passed the target along to her then-postdoc Vardha Bennert, who was shortly observing at the Lick Observatory 3m Shane telescope with the Kast double spectrograph (which had been designed by Joe Miller, my thesis advisor from 25 years earlier). In parallel, the Oxford-based Galaxy Zoo people (my circuitous way of saying either Chris Lintott or Kevin Schawinski, I know not which) had been in contact with Matt Jarvis's group, shortly observing on the 4.2m William Herschel Telescope on La Palma with a similar double spectrograph, whose interest was piqued because they had been working on Lyman α blobs. (Jarvis' group also got a series of excellent images, including one in He II which happens to redshift into

a filter band used for low-redshift Hβ. I got the image data through a circuitous route, which resulted, to my continued shame, in my utterly screwing up the image credits when a composite was used for Astronomy Picture of the Day. I sent Bob Nemiroff a correction that day, which I still managed to mess up.)

The WHT data were obtained first, Jan 8 2008 UT, as I learned while (IIRC) still at the Austin AAS meeting. They initially emailed a screenshot JPEG of the reduced data, sort of "OK, smart guy, figure those out". When I worked out the spectral range, it led to one of the very few career moments when the hair stood up on the back of my neck. The spectrograph slit was set to cross the nucleus of IC 2497 and much of the cloud. The cloud showed emission lines throughout, at close to the same redshift as the galaxy. The emission-line ratios matched, not star-forming regions, but gas ionized by an active galactic nucleus. In particular, He II and [Ne V] emission lines were prominent all across the cloud, out to a projected distance of 40 kiloparsecs from the nucleus of IC 2497, which the spectrum showed to have activity at such a mild level that it could not account for the quasar-level ionization of the surrounding gas.



About 6 weeks later (observations February 8/9 of 2008) we got FITS files from Vardha, giving similar results at lower signal-to-noise but better spectral resolution. These provided an additional key piece of information by placing a limit on the

density through the ratio of the red [S II] emission lines (largely blended together in the WHT data).

Vardha Bennert (center) and then-student observers Chelsea Harris and Anna Pancoast at Lick 3m Shane telescope.

By this time, the possibilities were narrowed down to either an AGN which is very strongly obscured from our direction, but not toward Hanny's Voorwerp, or, in a possibility which we later learned had been briefly discussed earlier but never identified in the sky, an AGN which had faded during the extra time it took its light to reach the gas, then be reradiated in our direction. I started keeping copies of the team email exchanges to illustrate the process, but soon was overwhelmed. (One classic was from Chris Lintott - "That makes no sense. Excellent."

The discovery paper had, I thought, very thorough discussion of the archival data, new optical spectra and images, and even UV imagery and an X-ray nondetection from the Swift rapid-response program (which was strong support of the fading-quasar picture). The referee apparently didn't believe something but never said just

what, so we went through an extraordinary number of rounds. The referee at one point asked to see the raw data FITS files plus a full narrative of our data reduction - then complained that the narrative, illustrated and in PDF format for their eyes only, was too long. I did learn to look closely at key data even from close associates - neither of the main programs on the telescopes needed to carefully track the intensity calibration across the handover between red and blue channels of the spectrographs, where dichroic filters have large ripples in transmission versus reflection, and this happened to affect the important [O III]/Hβ line ratio in both data sets. The numeric value shifted significantly when I redid all the data processing more carefully across this spectral range, even though not changing the conclusions of the work because the energy mismatch (between that required to light up the cloud and what we see from the galaxy nucleus) is so large. The referee quibbled that we could not really demonstrate a factor 1000 mismatch, not much greater than 100 in their view. Fine. Point made. I remain surprised how well this interpretation has held up with later developments. At the time, theorists seemed uncomfortable with the idea of AGN accretion changing much on 10,000-year timescales - but with the growing number of "changing-look" AGN found to show strong variations in only a few years, this is not where the frontier in interpretation lies any more.

Partly because of the refereeing delays, ours was not the first refereed paper dealing with the properties of Hanny's Voorwerp. Along the way, the name had come into use starting when an English-speaking zoo volunteer looked up the Dutch equivalent of "object" and pulled out Voorwerp (though this is not the most common translation one would pick for this context). In hindsight for consistency and to avoid diminutives, we might today have pushed for van Arkel's object. But because of the public nature of Galaxy Zoo, and our use in blog entries, the name was already out in the wild (we knew it was out there when NED understood it as an object designation). The first formal paper dealt with radio observations. As then-director of ASTRON (the Netherlands Foundation for Radio Astronomy) Michael Garrett described it, he heard about Hanny's Voorwerp in a podcast (possibly the Jodcast from Jodrell Bank, where Garrett is now director) while driving to a meeting. He said the meeting was so boring that it retroactively erased Hanny's Voorwerp from his memory until it was jogged by another mention, at which point he applied for some of his own director's discretionary time at the Westerbork Synthesis Radio Telescope to investigate it. The data, published by Josza et al., gave two major new bits of information - Hanny's Voorwerp is an ionized section of a huge arc of neutral hydrogen, with nearly 10 billion solar masses of gas arcing around IC 2497; and there are extensions to the galaxy radio emission suggesting an outflow, if not a jet, in its direction. (This didn't really qualify as being scooped, since the WSRT team had the grace to include several of us among the coauthors).

The open questions surrounding Hanny's Voorwerp prompted, among other things, a proposal for HST observations. This included narrowband emission-line images in [O III] and Hα+[N II], UV and near-IR imaging to seek embedded star formation, and

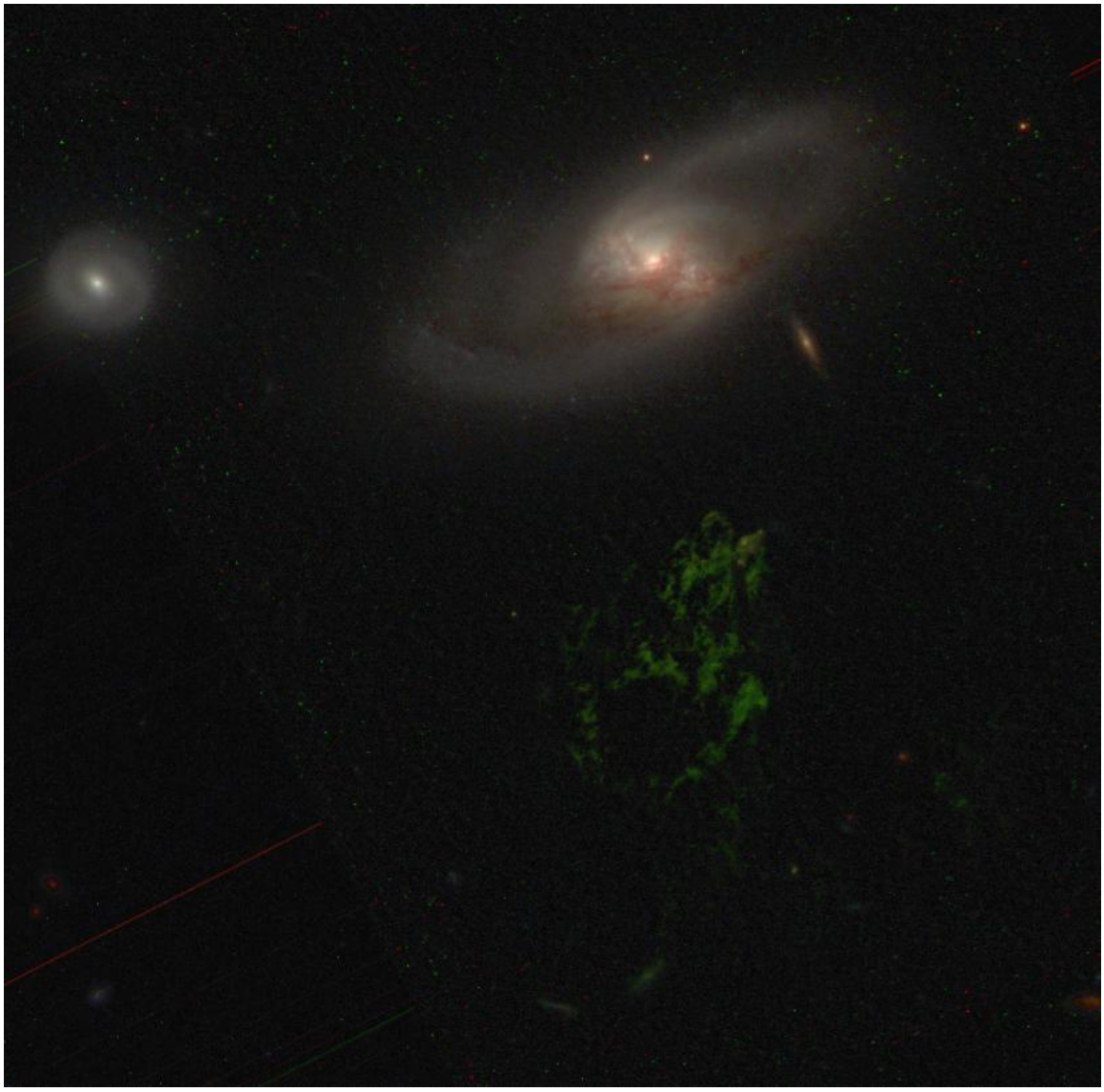
spectra near the nucleus to see whether there were clouds of gas "now" seeing a more luminous AGN than appears from our direction. The message announcing approval of the proposal was sent out, appropriately, on Hanny van Arkel's 25th birthday. These observations were all dependent on the success of the final HST servicing mission, STS-125 (launched 11 years ago as I write this, I see from a Tweet by one of the crew). When the proposal was submitted, one of the instruments required was still in a clean room on the ground, and two more were in orbit but sidelined by electronics failures. Of course, as we know now, the mission was a stunning success. Noticing that a delay put the launch just after our spring final exams in 2009, I bought a tour ticket and jumped in the car for Orlando, then took the tour bus to the causeway south of the pad to provide moral support. (I sent before and after Galaxy Zoo blog entries from the hotel room back in Orlando - as soon as the shuttle went out of sight, I tried to call home to convey my excitement but was too choked up to get more than a few words out).

The Hubble review panel feedback noted that, because of the human as well as scientific interest in the object, we were encouraged to apply for one of the education/public outreach (EPO) grant supplements to help disseminate the results. The product was a webcomic (eventually also available in print), Hanny and the Mystery of the Voorwerp. The idea came from Pamela Gay at SIUE Edwardsville, at the time part of the Galaxy Zoo outreach team (this was before the extremely ugly divorce between parts of the team at SIUE and at the Adler Planetarium in Chicago, about whose details I do not know enough to render moral judgment, but I am grateful that everyone involved respected my continuing to work with both teams). After review of submitted portfolios, an artist and colorist were selected, both SIUE students. (As Pamela remarked, had we known the 2008 recession was coming, we could have gotten "name" comic artists for that amount). The text was produced from a timeline and notes we provided, by attendees at CONVergence in Minneapolis, following the Galaxy Zoo tradition of broad participation. This was interesting, and widely disseminated, and opened my eyes to things of which I had been blissfully unaware. One was how underfunded EPO projects are; certainly Pamela and I put in a great deal more time over a compressed period than was reflected in the budget. Hanny was unhappy that the wrong kind of guitar was pictured on the cover, and the wrong kind of laptop (and then, that the schedule did not allow time for everybody to review everything). This was when Chris reminded me to roll with it, that we didn't get to choose our discoverers. (I think I relayed that back to him a few years later). Still, at one point I was losing sleep about the possibility that the whole thing might fall apart because of this, and I might be responsible for paying $20,000 back to STScI. Looking back, this was one of the times I was struck at how much the way we work differs from the image of science many people bring from elsewhere (movies and other media, I suspect). We did not work fast enough and could not immediately bring the resources to bear on questions that some volunteers expected, and became rather demanding about. To some extent, I think we were competing with every Bond villain in decades of movies. (One of the most vociferous complainers, who could be downright demanding about us exercising a duty of care to data curation and volunteers, was

Jean Tate. One of the handful of "super-Zooites", she has gone on to play a key role in the Zoo Gems HST project and is likely to be first author on a research paper soon. She now understands more about why it can take what seems like an unconscionably long time to get papers out.)

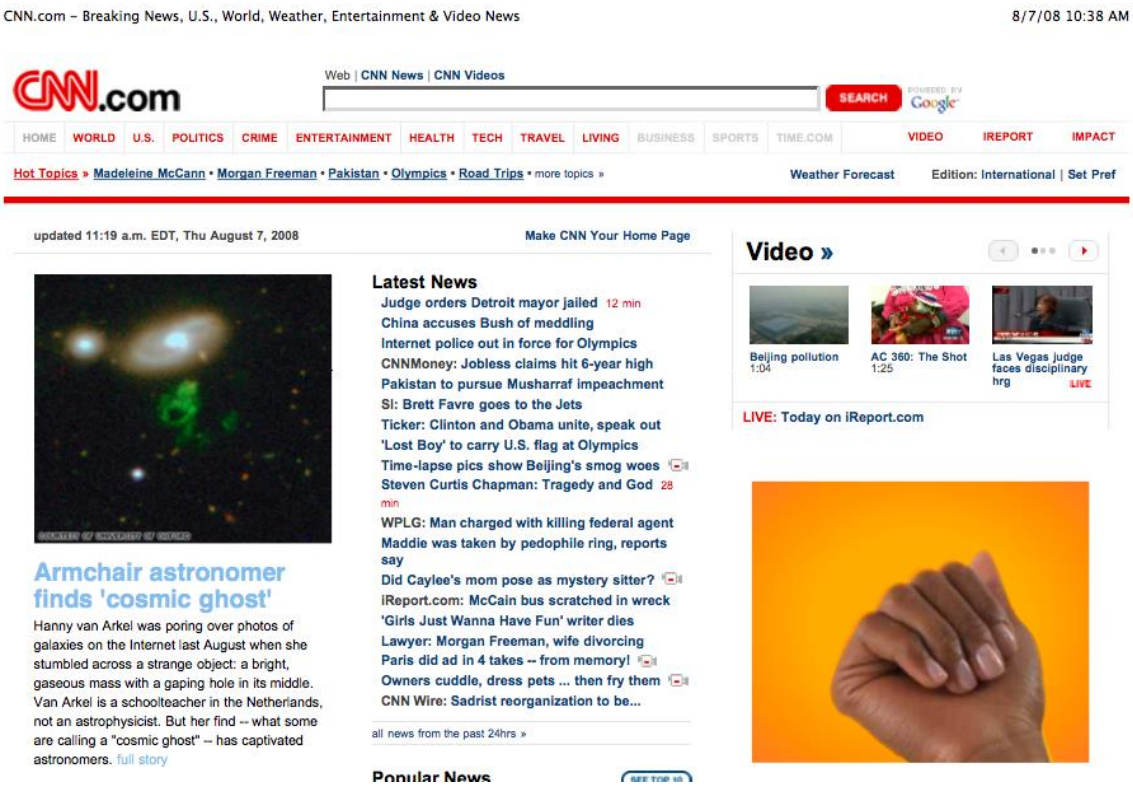
The webcomic (and print edition) premiered at DragonCon in Atlanta, where I've done science outreach talks annually since 2005. Since there are programming tracks for science, space, new media, and comics, it was an opportune venue. The event started at 11 p.m., prime time at the Con; Hanny was awake and chipper at 3 a.m. in the Netherlands, appearing on the big screen via Skype. I met the artist and colorist (and had a chance to thank them for dramatically improving on my actual hair). The comic was discussed on the Embargo Watch blog, because (as space journalist and Twitter gadfly Daniel Fischer posted out) one of the HST science results (embedded star formation in the Voorwerp) was mentioned in the comic, which was released several months before the paper on HST results. The blog did say it was well worth a read, with a subplot about being scooped, so there's that.

We tried to be as public about the HST data as we could, while also wanting to preserve the wide impact of an STScI press release that would accompany acceptance of the paper or presentation at a meeting. This included a blog post showing a spiral galaxy in one corner of the WFC3 image, illustrating how much better resolved it was than seen in the Sloan survey. The real public unveiling came at the Seattle AAS meeting in January 2011. Hanny was flown in to be introduced at the press conference. Unknown to us, because they like to keep things under wraps before embargos lift, STScI had prepared a nice set of artist's conceptions of stages in the inferred history of the object – so our presentations were enlivened instead with a set of our own amateurish PowerPoint cartoons. I also remember utterly failing in an attempt to do a radio interview in Dutch, becoming confused enough to have to start over in English. That night, after a round of interviews (including IRA FLATOW FROM NPR!) and trying to catch more meeting sessions, I dropped into bed. This had me miss the guest appearance of the Hanny's Voorwerp HST image as part of a sketch on the David Letterman show, where a kid wiped it off the screen and carried a frog away while the announcer described it. The next day, UA writer Chris Bryant asked how it felt to know that, right then, my career had peaked.



IC 2497 and Hanny's Voorwerp from HST WFC3 and ACS, with color balance improved adding WIYN OPTIC data

At one point I thought I could check Google to see how widely our press release had percolated (and engendered additional stories). I knew, I knew, it was a bad idea because, as our 4-year-old next door neighbor in Leiden giggled in 1985, "Bill Keel" in Dutch sort of means "butt throat", but I did it anyway - googled "Keel Voorwerp" This turns out to be the Dutch medical phrase for "throat obstruction", so I got pages and pages of first-response instructions from Amsterdam and Rotterdam. Still, the story was so interesting that we got wide coverage, including finding ourselves slashdotted (plus being top story on CNN.com for 15 minutes, enough time for me to get a screenshot and one of my sisters to see it, decide I must not be involved, and scroll on).



I happened to have much of the right mix of training for this project. The UV data, first from Swift then GALEX, drove me to pieces of my course notes from Don Osterbrock's class on the interstellar medium that I never thought I'd need in a galaxy context (much of the UV continuum from these clouds come from recombination - and especially the 2-photon decay of the metastable hydrogen state). And had we gone looking, Vardha Bennert would have been a great team addition just based on her dissertation topic, though we sort of happened to get connected for this through her onetime supervisor Gaby Canalizo. Little did I know at the start that this science thread would dominate my research (and funding) for the following decade. Hanny's Voorwerp and IC 2497 have been observed with the European VLBI network, Chandra, XMM-Newton, NuSTAR, and briefly with the Gemini GMOS integral-field spectroscopy mode (as the result of a school contest for things to look at!). Rumor has it there were Keck data, but obtained under indifferent weather conditions.

More AGN clouds - the Voorwerpjes

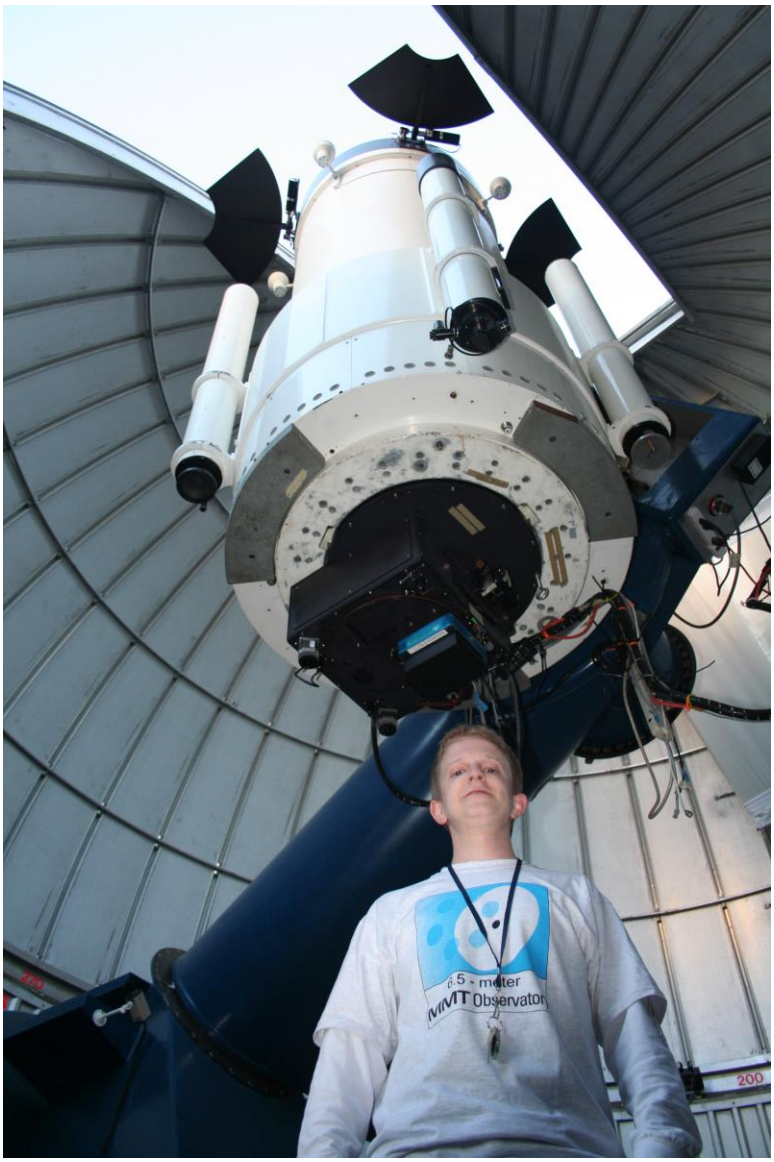
As the nature of Hanny's Voorwerp became clearer, it also became clear that volunteers were posting additional galaxies with oddly colored clouds which might be related. Among the first to show up was SDSS J143029.88+133912.0, which

Kevin Schawinski named the Teacup because of its handle-like loop of emission (albeit a handle 5 kpc across). This offered the possibility of a wide, systematic search. We took two strategies, because the most interesting AGN clouds would have little or no evidence for an AGN in the spectrum of the galaxy nuclei. Accordingly, I put a request on the Forum for volunteers to report possible AGN-ionized clouds - diffuse regions, blue in the SDSS *gri* composite images, and not part of normal galaxy structures such as spirals and rings. In addition, we carried out a targeted search of 16,000 potential AGN hosts, from a union of SDSS spectroscopic classifications and AGN hosts in the literature (even if they did not have an SDSS spectrum). Volunteer Richard Proctor (user name Waveney, whose day job was running an IT consultancy) did the IT structure for this search almost overnight, downloading the SDSS JPEG preview images. (This is the sort of thing that now could be done quickly with the Zooniverse Project Builder framework, as I learned in setup for the Zoo Gems program). In this task, participants (self-selected from Galaxy Zoo volunteers) were asked to vote on each galaxy as definitely, perhaps, or not having such clouds. Within 6 weeks, there were 11-12 votes for all the galaxies. Six people looked at all 16,000 within this 6 weeks.

Chris Lintott later mentioned that I was probably the only team member who could have managed this, with a stable job and tenure so the career risk was not there in case nothing interesting turned up. (Looking back, the science interest turned out to justify followup observations with HST - ACS WFC3, and STIS - and GMOS at Gemini-North, plus both long-slit spectra and imaging Fabry-Perot observations at the 6-meter BTA in Russia. Further looking back, this was true of many of the things I could do, sort of around the edges of Galaxy Zoo). In fact, the galaxies aligned for this project on what I started calling Voorwerpjes - the resulting 2012 MNRAS paper is one I like more and more as I need to refer to it in doing followup work. Within less than a year, we were able to do the imaging selection, a week's worth of blue long-slit spectroscopy from the Kitt Peak 2.1m telescope[1] intermingled with training of SARA REU students, fast reduction by REU student and collaborator Drew Chojnowski, and sending the resulting set of high-priority cloud candidates to Vardha Bennert for red+blue spectroscopy a month later at the Lick 3-meter Shane telescope. In submitting the paper, we learned that the editors would allow us to thank 200 people in the acknowledgements (they had drawn the line at 585 for the overlapping-galaxies paper, so that list is given as a web link). In checking through that list, we had only Zoo handles for some people, and I was just as happy that we didn't end up having to thank "Buddy Christ" or something worse. I was bemused to see that AGN astronomer Anuradha Koratkar had participated in the voting on potential AGN clouds (and verified her identity by email. I can't make too much fun, being well known for my own inability to "leave it in the dome".

[1] For the first time in my memory, the hydraulics of the observing platform, used to access the instruments and instrument rotator, broke, and were only fixed at the end of this observing run. It turned out that I was the only observer tall enough to reach the clamps and cranks while atop the rolling ladder, to rotate the spectrograph for each new object. I don't know how my knees, eventually recognized as badly arthritic, tolerated that. Maybe the excitement overcame that. A further note - this spectrograph was decommissioned and the telescope "divested" not long after this, so the project

would have been much more difficult then. This is pretty much what's happening with my deeper TELPERION survey - I can do the imaging with the SARA telescopes, but spectroscopic confirmation is a slow patchwork.

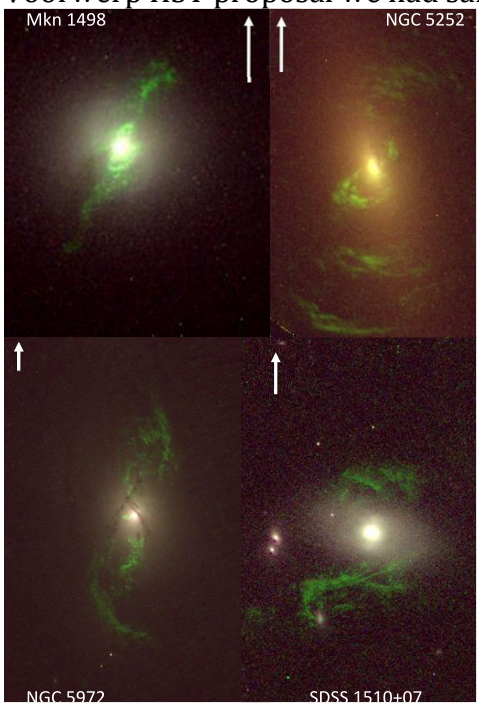


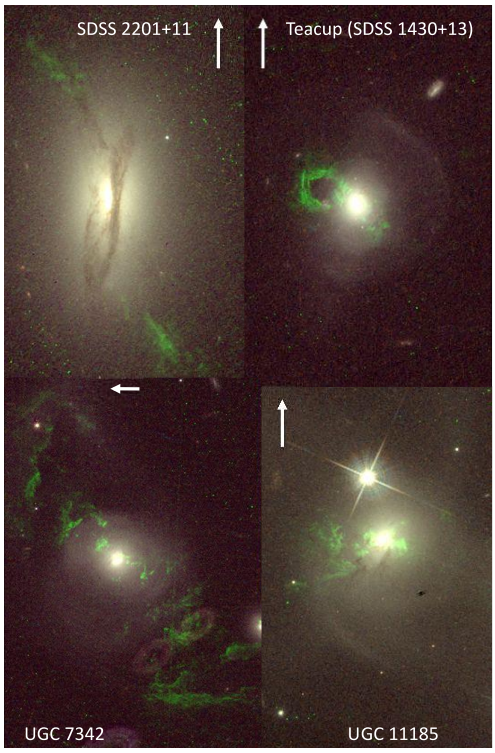
Drew Chojnowski at 1m SARA telescope on Kitt Peak

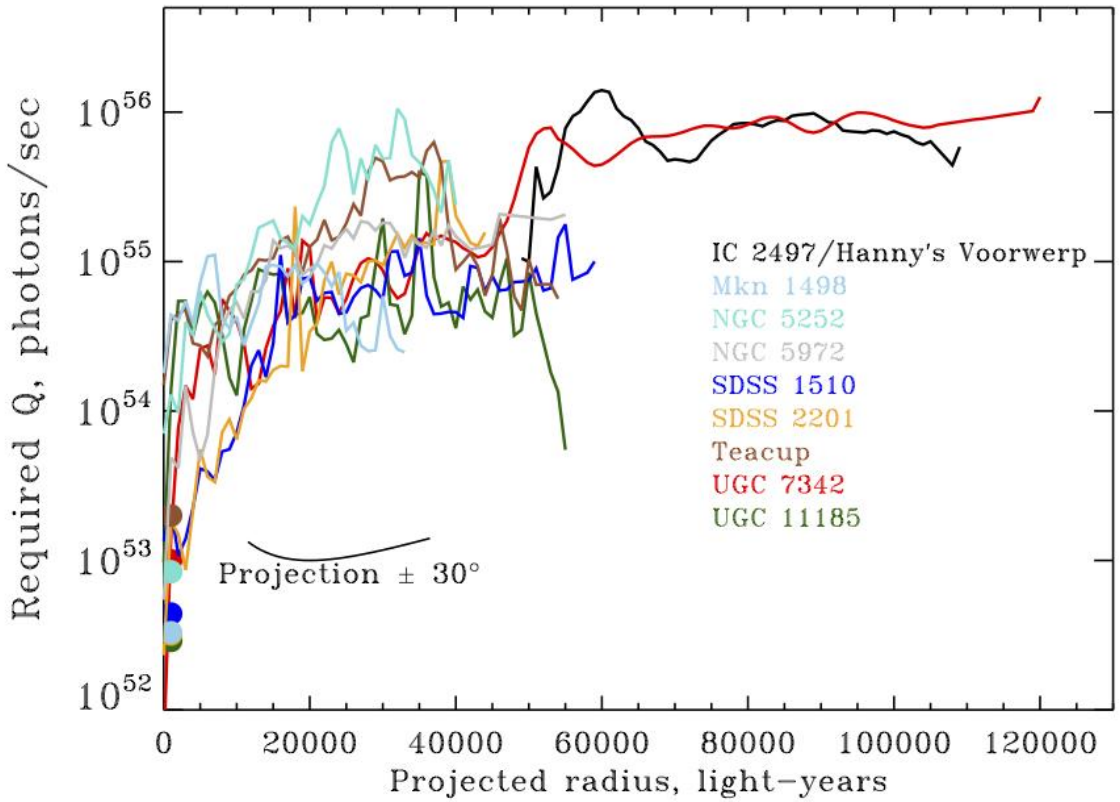
The first spectroscopy of one of these new AGN clouds came about because Michael Crenshaw from Georgia State University was the external member on the master's thesis committee for one of our students. While he was in Tuscaloosa for the defense, I showed him the SDSS data on the Teacup. He called their student Justin Gagne who was using a long-slit spectrograph at the Lowell 1.8m telescope that night. Justin went on to get multiple slits across the clouds, and did a CLOUDY analysis of the whole set of ground-based spectra to provide more detailed information on the energy shortfall. (He politely declined my suggestion that he

repeat this using the 700 or so independent integral-field spectra from Gemini-N, and has gone into other research specialties now).

The Voorwerpjes also led to a successful HST proposal, for narrowband imaging in [O III] and Hα with the near-magic ramp filters on ACS. This revealed a stunning variety of gas structures, and let us take a first shot at the composite history of these fading AGN. This was particularly gratifying because all the way back to the Voorwerp HST proposal we had said such an analysis might be possible.



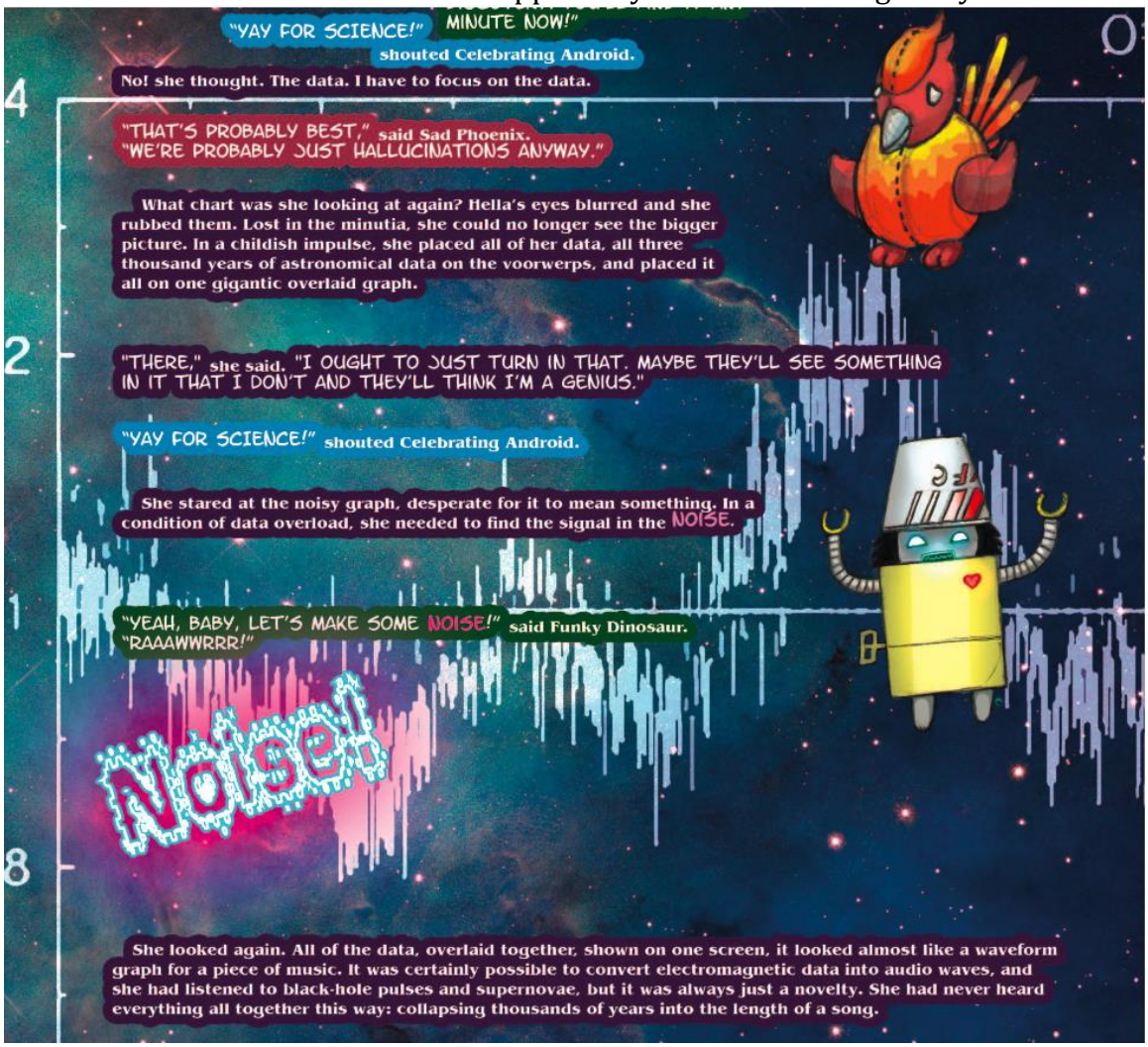




Again, we applied for and got the $20,000 EPO supplement to the HST funding. Pamela Gay came up with a followup to the webcomic, reflecting the diversity of

objects in this program - a web anthology (albeit also printable, freewifionmars.com). It included:

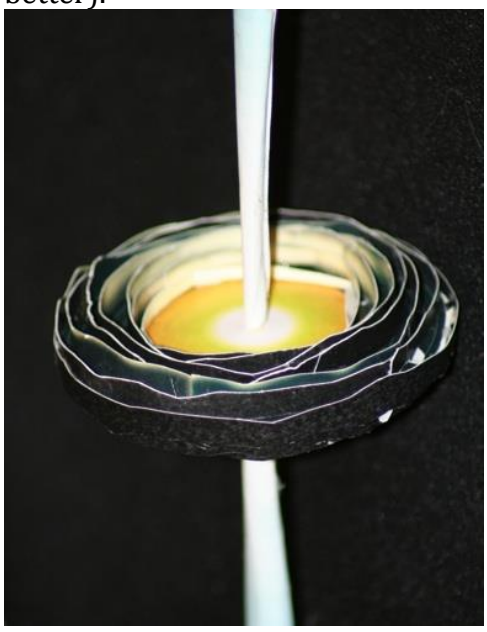
- short-short stories by professional science fiction writers, written in front of an audience at a writer's slam at a Con. Apparently zombies were big that year.



- word-search puzzles, laid out in a font consisting of SDSS galaxies (a Galaxy Zoo byproduct; there are web interfaces which will turn typed text into galaxy font). Some of the puzzles were crowdsourced via the Galaxy Zoo forum.

- hidden versions of the HST images. This was a little funny if STScI image releases were planned, because the timetable to complete the EPO project was shorter than the typical completion time for analysis and publication.

- templates for a print-and-glue paper model of an AGN accretion disk. This began on a paper-modelers' forum, and when I asked, designer Thorsten Brand improved his design and let us distribute it. (Printing the PDF on thick card stock works better).



Because giant AGN-ionized clouds, whether the nucleus is fading or not, are so rare, we've encouraged Zoo participants to keep looking for candidates. Especially as Legacy Survey data are assessed, the sample is growing - we had followup observations from the Australian Advanced Technology Telescope, Magellan, and the BTA within the last year. Participants are getting very sophisticated - Talk posts from some of them now don't just show the galaxy, they post any data from the HST archive, and some check the ESO MUSE archive and will tell me whether there is spatially extended He II emission.

Vardha Bennert, Chris Lintott, and Peter Maksym at a data-analysis meeting in Tuscaloosa. I had just shown them some of the incoming Voorwepje data for the first time.

I've extended this work through a search for extended clouds with redshifted [O III] filters the northern-hemisphere SARA telescopes, starting with Erin Darnell Kneses Master's thesis on H I-mapped AGN hosts. Several new cloud systems have turned up this way, including the first one I actually found. Complementing them, UA set up a single-element Dragonfly clone (Crimson Dragon) based on the Canon 400mm f/2.8 low-reflection lens, which I'm slowly using for [O III] and Hα imaging of the fields of very nearby galaxies (starting with systems known to have extended H I as an ionization screen). But Chris Mihos still found the giant Hα cloud near M51 first.

Crimson Dragon visiting Kitt Peak. Plastic mascot is just visible behind tripod leg, helping to hold cables neat.

Zookeepers and Zooites

Interacting with the volunteers (who came to call themselves Zooites, making at least some of the science team members Zookeepers) has been a major part of the Galaxy Zoo experience - enlightening, exhausting, inspiring, helpful, sometimes all at once. At the outset, I could have believed the breadth of interest and participation, by now with hundreds of thousands of people having taken part at one time or other. But I would have had more trouble with the depth of interest - not just how many people have done large numbers of classifications (up to and including the

entire original DR7 main galaxy sample), but the relative handful of people who have dug very deep, and become genuine collaborators.

Some examples: Half65 (Massimo Mezzoprete in Rome) became interested in our search of overlapping galaxy images. He set up a Perl script to parse the length discussion thread for these in the Forum, parse it for any of the kinds of SDSS object identifiers, used SQL to query the SDSS SkyServer for positions and magnitude information plus thumbnail image, and output a PDF with one page per object collecting this information for reference. He was also very good at find galaxy overlaps. He's a coauthor on the catalog paper - fair is fair.
Or c_cld (Claude Cornen in France). I blame him for my own SQL skills being so primitive ("cute" in the words of a younger and more skilled colleague). Among the Zooite most active in the discussion interfaces, he also has mad skills with SQL, often before I think to ask anyone. Soon after the overlap-catalog paper was submitted, a new SDSS data release came out, and I figured it would be two weeks before I could finish merging in new redshifts from that data release to the 2000-item table. Less than a week later, I get email from Claude saying in case this is useful, here is a listing of all galaxy redshifts within 2 arcminutes of any of the catalog positions which were new in that data release. Or in putting together the list of potential targets for possibly the last Forum science paper on AGN companions, out of the blue he sent a list of all SDSS galaxies satisfying redshift cuts, within a given projected separation in kiloparsecs from an object whose SDSS spectrum was classified as one of the AGN types. I didn't even know you could do all that at once.

We were sometimes fighting expectations which seemed to have come out of a science fiction movie, about the resources at hand or the speed of response. Early on, no one was actually being paid to work on Galaxy Zoo science full-time (Brooke Simmons may have been the first astronomer in that position as an Oxford postdoc). Most of the initial team were pretty junior, weighted to postdocs and grad students. Later on, first, many team members were trying to keep up with wrangling the Zoo data, and now had other responsibilities. There seemed to be sort of a cumulative shock for Zoo volunteers when most of the original team moved from being postdocs to jobs whose requirements gave them less time, in particular to interact with the volunteers. To an extent this was offset by the continued cycling of new team members in, again with a strong dose of students and postdocs.

Partway through the initial Galaxy Zoo classifications, a straightforward way showed up to address whether evidence for a tiny, but statistically significant, excess of S-shaped spirals over the opposite winding reflected the sky or people. In the "bias study", some images were randomly mirror-imaged to see how consistently this caused a changed in the clockwise/counterclockwise sorting of spirals. Good plan, sound scientific practice - but at this point with the site design and low rate of people reading email newsletters, there was no reliable way to inform everybody that this was happening. There were myriads of bug reports as people clicked through to the SDSS Explorer pages (a useful feature from the

beginning) and saw the image differences. And from some participants, there was a near-revolt. They felt they were being served adulterated data, which meant being lied to, they were part of an unauthorized study with human subjects, and so on. Later web interfaces were richer with information (in some cases telling participants when they had identified a simulation, as in the Andromeda Project using simulated star clusters to quantify detection threshold). Still, blogs, information links on the project pages, and email newsletters don't manage to get to everybody. I think of this as one of the topics in *Chris Lintott's Book of the Psychology of Citizen Science* which he can never actually write without individuals being identifiable.[2]. At one meeting, a member of the team contrasted Galaxy Zoo to simulation projects by saying "our computer can get mad at us".

[2] Not even getting into the literal handful of Zooites who threatened team members, reported imagined breaches of ethics in venues which required an administrative investigation merely from receiving a report, or made repeated accusations of nationalistic bias, one repeated in a proposal to the NSF demanding limits on the nationality of officials handling the proposal. I know this because the affected official called me to describe the proposal to see whether I could review it, and since I almost certainly recognized who it must be from, someone with no particular bent to actual research that I could see but sure we were all idiots, I had a conflict of interest anyway. I was the first person banned from the Forum but not the last, and some of the later ones were for truly vile behavior.

I was apprehensive on meeting my first group of Zooites at Greenwich in mid-August of 2009, in a gathering timed to coincide with a team meeting.[3] What if I made a bad impression and affected the project? I was struck at the range of people and backgrounds - I met people ages 14-85, from all walks of life. (Most, given the venue, were from the UK, which has always been heavily represented in the project participants).

[3] I could afford that trip only through a Dean's Leadership Board faculty fellowship from the UA College of Arts and Sciences, which provided, $3000/year for 3 years in discretionary research funds, with the only actual responsibility being a science talk to the sponsoring board. My schedule took shape late enough that airfares had started going up, resulting in my having to fly from London-Atlanta and drive the four hours home for the first class meeting the next morning. I do not recommend this.

Greenwich 2009: 0.02% of Galaxy Zoo

The project forum fostered the creation of a real community, going beyond astronomy. Pictures of the day were cycled among selectors, Zooites as well as scientists, and provided interesting opportunities for outreach. People also found time to chat about pets, recipes, and experiences. [4] Several came together when one organized a thread of astrophotos by participants, every day for a year.

[4] I later learned that this is where Hanny van Arkel let some other worried Zooites know that we were OK except for lacking power and water after the mammoth Tuscaloosa tornado of April 27, 2011. I had to drive an hour to get WiFI to get email out. This was OK, because I was slated to speak at the Mid-South Stargaze in Mississippi the following night; the rest of the family was interested in this guesthouse reservation which included electricity and water. I drafted a quick response sitting in a restaurant along the road and copied it to the 50+ people who had emailed asking whether we were OK.

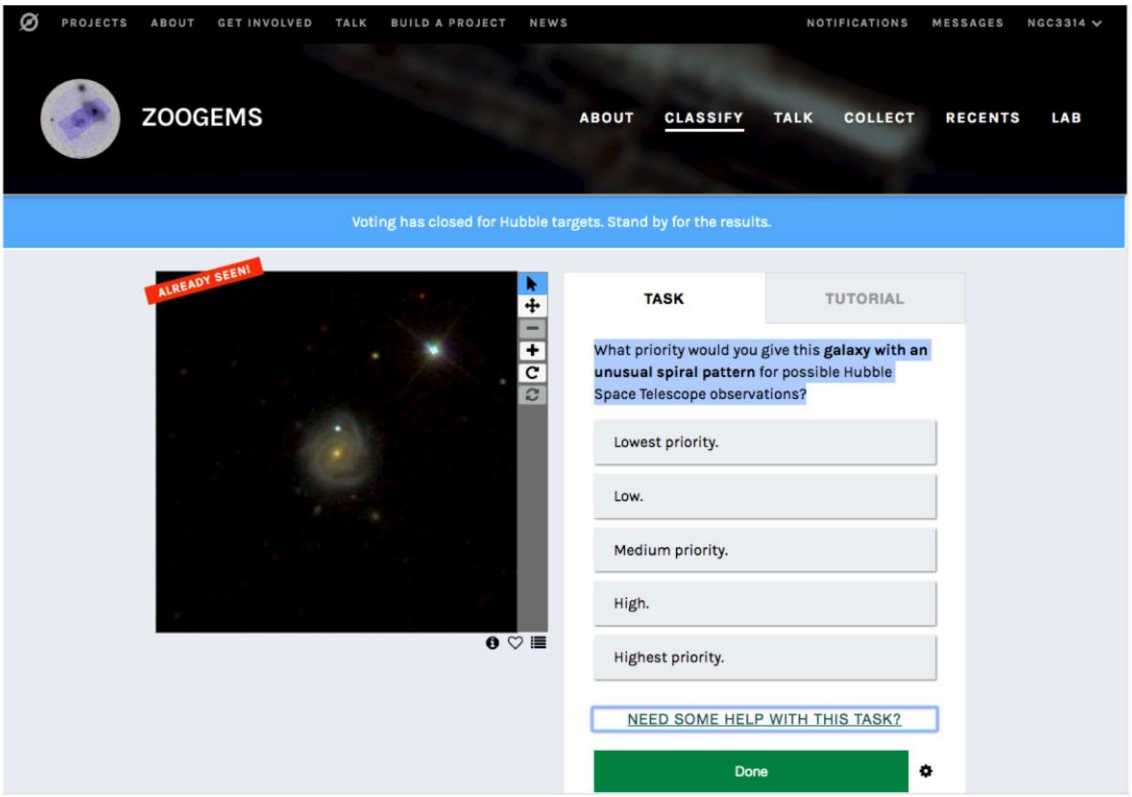
Eventually the time came to freeze the forum and migrate discussion to the new Talk interface. I continue to be surprised by how fast a piece of software goes from "completely functional" to "no longer maintainable". This was probably exacerbated in this case by a small number of posters who regularly said things just short of accusing my whole profession of fraud, theft, and other immorality. Just a few, but it made my daily image browsing a chore for the first time. Despite that, I was probably the Forum's last fan on the science team, so I did get some warning (and on the day it was frozen and archived, acquired moderator superpowers in case later cleanup or organization was needed).

The last forum-science project as such that I know of was our search for instances of what we termed cross-ionization - gas in companion galaxies ionized by radiation from an AGN. Detecting this would give a new way to trace the emerging radiation pattern in time and direction, no longer biased by sampling regions of gas in the structure of the same galaxy. Our paper showed up in 2019 in MNRAS. So of course right after that we found some excellent examples of the process, for example in making Fabry-Perot maps from the 6-meter BTA in Russia showing gas associated with a companion of the galaxy we were targeting.

Zoo Gems

In September 2017, STSCI announced a new proposal opportunity in a broad email (not a usual call for proposals) They had found that short schedule gaps were still going unused, with the snapshot proposals intended to use these being weighted toward longer gaps. After a trial program showing the number of gaps long enough for 10-minute observations (more precisely, 674 seconds), they called for short 2-page descriptions of possible projects. This call for projects was really close to what Chris Lintott mentioned in his book, "we found an unusual thing and want to look at it". It might have been custom designed for the kind of Galaxy Zoo weirdness follow up we had daydreamed about for years. Our proposal was “Gems of the Galaxy Zoos”, now usually shortened to Zoo Gems. We combined Galaxy Zoo and the newer Radio Galaxy Zoo (hence the plural). We were, of course, pleased to learn (at first indirectly, having a program coordinator assigned before we were notified of acceptance) that ours was one of 3 gap-filler projects accepted, being allocated 300 targets. The acceptance notice also mentioned that STScI would especially like to see public participation in selecting the target list, a facet we had in mind from the outset.

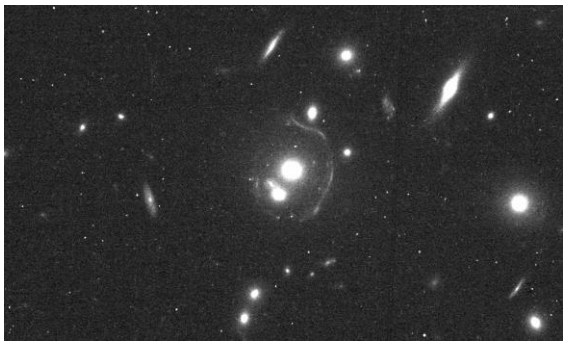
The acceptance decision arrived in mid-December, with a deadline in February to get the complete observation details submitted. With the usual holiday breaks, time was a bit short to winnow a potential 1100 objects into a list of 300, respecting the multiple science cases we planned to address with various subsets (because it was Galaxy Zoo and saw all the galaxies). As it happened, Jean Tate managed the Radio Galaxy Zoo selection, among galaxies with potential resolved emission-line clouds and possible spiral host galaxies. I took over the Galaxy Zoo selection. Both pieces of the process using the Zooniverse Project Builder to show images, comparison of other objects in that science category, and allow voting on a 5-point scale. I sort of made command decisions that sparse categories (<10 available galaxies) would be included “as is”, decided how many of the other categories (Green Peas, backlit galaxies, mergers, rings, etc.) to include, and the balance between GZ and RGZ targets. We coordinated with the STScI social-media accounts (less successfully than I had hoped, I think because of timing and their pre-planned content) to announce the voting opportunity, collecting votes for about 3 weeks.

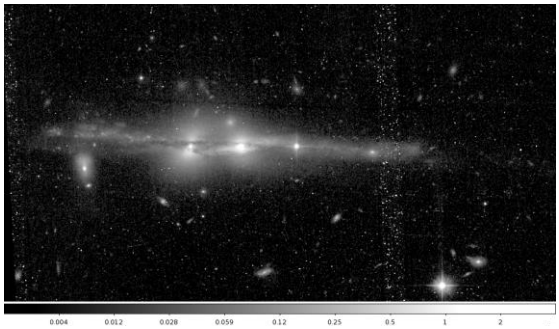


Layout of voting interface for Zoo Gems target selection

During final preparation of the so-called Phase II proposal (specifying coordinates, filters, offsets, and so on) we benefited from the eyes of curious Zooites in finding duplications (since some objects entered in more than one category by different names). We also found there was potential duplication with objects in the Arp-atlas program led by Julianne Dalcanton, so the two of us kept in touch on object lists (if they wanted to do one from our list, that was fine - it still had the same odds of being observed, the data were public immediately, and we could put another one on our list) and observing strategies (in some cases on Saturday nights using Twitter direct messages, because this is 21st-century astronomy).

Two years in, the Zoo Gems program has had 75 observations (25% of the total) and is still on the schedule. It has turned up an excellent gravitationally-lensed arc over 180 degrees in extent with an inflection from another galaxy, shown spiral structure in all the blue early-type galaxies observed, resolved all but one Green Peas into substructures, and turned up what I think of as an Escher galaxy system - which one you see as in front depends on just which dust lane you look at. On the Radio Galaxy Zoo side, we see some certain spiral hosts for double radio sources, rarities whose demographics may shed light on how radio jets escape gas-rich hosts, and intricate structures in the ionized gas of other AGN hosts.





Zoo Gems images: top, lensed ring 1331+5134. Bottom, UGC 7064A.

Working with the changing cast of young faculty, postdocs, and students in Galaxy Zoo puts me in mind of our eldest cat, Arwen, who has been with us for over 15 years (long enough to have sat on my logbooks when I first started observing with SARA telescope in 2006). She can certainly act distinguished, but since we took in Houdini (age 5) and Shadow (18 months) as kittens, Arwen can still run around and leap onto desktops or shelves with the best of them. Keeping up with the youngsters has been very good for her, and for me too. (But my SQL is still terrible - I blame the Zooites who send me results for these projects before I think to ask for them).

12 May 2020, Year of the Pandemic Quarantine