

## Accretion in Stellar Systems

Jeremy Drake & Doug Swartz

**Rudy:** Can you organize the summer CXC meeting this year? It will be fun!

**Jeremy:** “Organize a meeting” they said. “It will be fun” they said. Knowing full well that “organize a meeting” and “fun” do not go in the same sentence, except a stingingly negative or sarcastically pejorative one, like “organizing a meeting is as much fun as sticking your head into a vat of boiling oil”, I was adamant I would not get sucked into such a thankless escapade.

**Doug:** I was game to help organize the summer CXC workshop, as long as I got along with the people involved. Since there was only one person at CXC I would not want to work with I was good to go ahead.

**Rudy:** Jeremy has enthusiastically agreed to co-chair on the CXC side.

**Doug:** Count me out.

**Rudy:** Doug is definitely in on the MSFC side!

**Jeremy:** Doug Swartz! He’s a great friend - I knew him back in postdoc days in Austin! Those were the days - I’d always be keeping him out of trouble! No way I’m organizing a meeting with him though.

**Doug:** Back in Austin I spent the whole time trying to keep Drake from getting into trouble. Organizing a meeting with him will be the same all over again—trouble!

**Rudy:** Something on stars. That’s what the meeting should be on this summer. How about accretion?

**Jeremy:** Accretion in stars? Hmm, yes, it could include T Tauri stars, CVs... X-ray binaries. Even the ULXs that Doug likes....

**Rudy:** Right, that was what I was thinking! So glad you can organize it - thanks!

**Jeremy:** What...?

**And thus was the beginning of Accretion in Stellar Systems.** There was actually another reason for Accretion in Stellar Systems, and that was to honour the late Jeff McClintock who passed away in November 2017. We never really had any doubts that we both wanted to do this.

### Hashtag

On the one hand it was insane to attempt to cover all stellar mass accreting objects in the the two and a half days available for the summer workshop. Any one subfield could easily fill a week long conference. On the other, there is that perennial irresistible temptation to unify and see common threads and parallels between the different classes of object. “See, if we plot the mass accretion rate normalized to the Halpha flux to some power of the disk gravitational settling time at the corotation radius against the radiation pressure during the soft high state...”

Choosing the program was then a major challenge. But there was a much bigger problem than that: what was to be the meeting Twitter hashtag? The ideal hashtag has to be snappy, instantly recognizable and unique—a social media fingerprint of the meeting itself. Errr.... #accr2018 why not? And so it was. Apart from a minor clash with the Asian Road Cycling Championships #ACCR2018 it all went well, enough...

After a very interesting AXIS workshop I'm now at the "accretion in stellar systems" Chandra science workshop. And it has an official hashtag: #accr2018! Yay! :)



Felix Fuerst @BIGfalke  
11:40am - 8 Aug 2018

There was the attempt to garner interest from the generally non-accreting stellar systems meeting held across the river at BU the previous week...

As the sun sets on @CoolStars20 #CoolStars20 don't despair at the prospects of a dreary trip home back to the same old dreary routine... stick around for "Accretion in Stellar Systems" #accr2018 next week! All about how stars misbehave when they get too close to each other....  
[twitter.com/cosmodrake/sta...](https://twitter.com/cosmodrake/sta...)



Jeremy Drake @cosmodrake  
1:03pm - 3 Aug 2018

And so, on the morning of 2018 August 8 we began to settle in to the fancy conference room at the Sheraton Commander, Cambridge MA 02138.

### Wednesday

After some tedious boilerplate introductory rambling blather from the local SOC chair, our intrepid observatory directory, Belinda Wilkes, started us off with an encouraging review of the prospects for the next ten years of the *Chandra* mission.

Yes, we do have some challenges with thermal constraints going forward which narrows down the time we can dwell and the area of the sky we can point to at any given time. But there is better news on the contamination - the rate of accumulation is palpably slowing. We look forward to organizing #accr2028!

Invited speakers for the meeting were asked to try and draw parallels between the different types of accreting stel-

lar objects - with of course the motivation of imposing at least some degree of failure and creating good rib poking opportunities during post-session relaxation (“...super-Eddington accretion in T Tauri disks, ha ha...!”).



First up for the challenge was Matt Middleton, whose talk “ULXs - our window into the extreme”, while masterfully reviewing that comparatively new field and the key role that super Eddington accretion plays, utterly failed to yield to the temptation. Next time Matt. But his concluding bullet point was tremendously uplifting: “Our options for getting more data over the next 5, 10, 20 (?) years are looking pretty good.”

Matt Middleton from @unisouthampton on the empirical definition of Ultra-Luminous X-ray Sources: "always be careful of anything defined empirically because it means we drop-kicked the physics out of the window" #accr2018  
[twitter.com/rudy\\_phd/statu...](https://twitter.com/rudy_phd/statu...)



Jeremy Drake @cosmodrake  
10:10am - 8 Aug 2018

### ..out of the Window into the Extreme, no less.

The session continued with three speakers addressing different aspects of ULXs. Breanna Binder gave us a run-down on NGC 300 ULX-1, a fascinating beastie initially identified as a supernova and now ingloriously known as a “supernova imposter”. Breanna found geometric beaming effects to be minimal and that the ULX-1 system is “one of only a few bona fide ULXs to be powered by accretion onto a neutron star.” Interspersed among the ULXs, Paul Hemphill reprised “The peculiar case of 4U 1626-67”. It is dead simple: loads of neon in the *Chandra* X-ray spectrum of this ultra-compact X-ray binary means an ONeMg white dwarf donor. But, err, there is no Mg. And it was time to roll out the white dwarf physicsy stuff to work out how to hide it.

Konstantinos Kouvlikas pointed out the difficulties of studying individual ULXs and determining the properties of source counterparts and argued for statistical studies of larger numbers of objects. Cross-matching with the Chandra Source Catalog, he reported finding about 900 galaxies that host ULXs. These will be useful for teasing out the ULX luminosity function, and the effects of metallicity and age on ULX behaviour and formation.

Then Yanli Qiu spoke about a Wolf-Rayet ULX in the Circinus Galaxy, arguing that its intriguing dipping and eclipse behaviour are a defining property of this class of super-Eddington HMXBs.

Yes, it was time for coffee and posters. Vladimir Karas made us feel energetic with a paper on acceleration of electrically charged particles and the onset of chaos near a magnetised black hole, while Zhuo Chen raised the interesting physical challenge of including complex equations of state in astrophysical hydrodynamics. Evan Nunez did a show and tell on characterizing the intermediate mass pre-main sequence stars in the Carina complex via their X-ray emission, and Mike McCollough showed phase- and time-dependent HETG spectra of his favourite source of all time—the Wolf-Rayet X-ray binary Cygnus X-3. Just before the bell rang, there was time to take in Norbert Schulz's observations of 400 km/s outflows from Circinus X-1 in the low state, and conjecture that all can be explained by a precessing oblate Be star.

### And round two began.

M31 is where it's at for testing nova evolution and explosion models. In a tour de force of extragalactic nova studies, Martin Henze pointed out that it is much easier to study novae in M31 than it is in our own Milky Way - pesky gas and dust getting in the way of most of the action. One particular highlight is a nova, M31N 2008-12a, with recurrent outbursts every year. Martin emphasised their importance for the single-degenerate channel of Type-Ia supernova progenitors, noting that, in his unbiased opinion, M31N 2008-12a is the best Type Ia SN progenitor system to date

**Martin is a guru on novae and in particular in our nearest spiral galaxy neighbour M31. "I'm 70% and X-ray observer, 30% optical, and I also enjoy hiking and long walks on the beach" @chandraxray #accr2018 [twitter.com/rudy\\_phd/statu...](https://twitter.com/rudy_phd/status/1028111111111111111)**



**Jeremy Drake** @cosmodrake  
11:32am - 8 Aug 2018

Next we heard from Karleyne Silva on Modeling Accretion Columns of Polars, in particular, the AM Her-type CV

**I think Martin Henze wins the quote of the morning: "Sorry I did not have time to show that - I was concentrating more on getting some jokes in." #accr2018 @chandraxray [twitter.com/rudy\\_phd/statu...](https://twitter.com/rudy_phd/status/1028111111111111111)**



**Jeremy Drake** @cosmodrake  
12:36am - 8 Aug 2018

EV UMa. Karleyne brandished some impressive modelling of optical and X-ray data that found a low system inclination with only one extended accretion region that is self-eclipsed works jolly well.

Fred Walter fizzed a salvo of southern nova observations just over our heads. Among other things one does with observations of southern novae, Fred has been trying to establish what happens to the accretion disk in a nova explosion, and how rapidly the disk is reformed. Evidence is there that the disks do reform, but no firm answers on the timescale yet.

Then Felipe Jimenez Ibarra on determining orbital velocities from IR/optical emission lines of LMXB with big and bright disks, which is devilishly tricky, even with GTC-10.4m spectroscopy. Nevertheless, Felipe was able to place strong constraints on the accretion disc opening angle of the neutron star binary Aquila X-1, finding results consistent with theoretical predictions for highly irradiated accretion discs.

And yes! A talk on protoplanetary disks! Both soft X-rays and UV emission in accreting T Tauri stars like TW Hya arise in the accretion columns. That has generally been the story, at least. Showing that these disks can be at least as devilish as those of X-ray binaries, Mark Reynolds found no correlation between the softest X-ray and UV variations in extensive Swift observations, perhaps pointing to a different origin of the coolest X-rays.

### Time for lunch.

Then, in his invited review talk Christian Knigge actually does try and look for parallels and connections between different types of accreting objects! Way to go Christian!

After talking up the universal processes in accretion disks—such as outbursts and jets, he then tries to sell us “GOALS: The Great Observatories Accretion Legacy Survey.” Coming to a review panel near you. He made AAVSO chief, Stella Kafka, happy too by showing an abundance of AAVSO light curves.

Tim Waters then dragged the audience firmly onto theoretical territory with a foray into magnetothermal disk wind modelling. The initial surprise from the modelling of disk winds launched in the high/soft state was that includ-



ing a magnetic field suppressed the thermal wind to some extent - essentially closing down regions of acceleration. But kinetic luminosities at mid-latitudes can be increased, apparently in-line with expectations from observations of the LMXB system GRO J1655-40. Moritz Guenther pulled us back to protoplanetary disks and a bizarre observation of enhanced iron in RW Aurigae.

Following that interlude, it was back to numerical modelling of disks by Daniel Proga, who strapped us in and raced us around thermal winds, radiation driving, enhancements through radiation pressure, and working out where the acceleration takes place - it felt like “everywhere”. At that point, heading out with wobbly legs we needed a stiff beverage, but it was only coffee time. And poster time.

Thanawuth Thanathibodee had a really scary poster title, beginning with “The End of Accretion”! But, phew, it was just for the slowly accreting T Tauri star CVSO 1335. Saeqa Vrtilik pointed to the great promise of identifying point X-ray sources in external galaxies - essentially all of which are accreting objects at current survey sensitivities - while Dipanka Maitra reported on heart-warming observations of the 2015 outburst of V404 Cyg with a 12” telescope. Sibasish Laha went supermassive, probing AGN torus structure using X-ray variability, and David Principe next door was using high resolution X-ray and optical spectroscopy to investigate star disk interactions in T Tauri systems. Valliant SOC member Vallia Antoniou showed us clues about the formation efficiencies of different generations of HMXBs in the Magellanic Clouds before it was time to sit down again.

### And then...

Nathalie Degenaar reviewed outflows in X-ray binaries, navigating the event horizon or not comparison with the agility, speed and precision of a happy gazelle after a double espresso. Among the highlights was a discussion of how X-ray bursts can probe winds and jets, and jet formation in neutron stars with high magnetic fields.

And on to the high resolution spectroscopy master, Jon Miller, whose grist has been anything gravitation-y potential-y enough and bright enough to point the *Chandra* HETG at. Pushing the order envelope by analysing 3rd order spectra, Jon has been finding much faster and more highly ionized outflows that lead to orders of magnitude increases in estimates of the mass outflow rates and kinetic power inferred from disk winds.

While fewer than 1 in  $3 \times 10^6$  Americans attended #accr2018, three out of the 2 million Canary Islands inhabitants attended...

Teo Munoz-Darias presented the discovery of an impressive optical wind in the outbursting black hole host V404 Cygni; and perhaps more importantly, evidence that such outflows are common in such systems. These winds appear

One of three speakers from the Canary Islands! #accr2018 @chandraxray  
#CanaryIslands #Canarias  
[twitter.com/AstroRaikoh/st...](https://twitter.com/AstroRaikoh/status/1250000000000000000)



Jeremy Drake @cosmodrake  
5:34pm - 8 Aug 2018

to carry as much material as is accreted. Then Ruchit Panchal went through simulations of light curves of the IC10 X-1 X-ray binary, which has a Wolf-Rayet secondary. Absorption in the wind of the WR star leads to interesting diagnostics of the wind density and acceleration.

Finally, finishing us off, in more ways than one during a blisteringly intense and exhilarating afternoon session, Rozenn Boissay Malaquin sneaked in something a bit more massive than a star. Using *Chandra*/HETGS and NuSTAR observations he found two ultrafast outflows in PDS 456, which, I’m sorry to report, is only quasi-stellar. It was time to leave the meeting and go to the pub - now that was an ultrafast outflow.

### Thursday

Fresh and sprightly, we returned...



The phenomenal physicist Felix Fuerst’s magnificent manifest of the variable cyclotron line energy due to relativistic beaming in GX 301-2 was a good starter. Two separate cyclotron resonant scattering features were inferred, and appear to originate at different heights above the neutron star surface, where they sample different magnetic field strengths. Then, Rene Ludlam explained how NuSTAR and NICER observations of relativistic disk lines in neutron star low-mass X-ray binaries can determine the neutron magnetic field strengths and help place limits on the radius of the compact object itself.

And just when the long-sought solution to the NS equation of state appeared to be within our sweaty grasp, it was

time to return to T Tauri stars, and specifically the closest one we know, TW Hydrae.

Costanza Argiroffi and colleagues have been busy measuring spectral line velocity shifts in *Chandra* high resolution spectra and have been able to deduce that infalling material channeled by magnetic fields impacts the star at fairly low latitudes. Brooks Kinch then presented some nifty Fe K $\alpha$  profile simulations based on general relativistic magnetohydrodynamic simulations using a Monte Carlo method. He asked the question on everyone's mind "Can MHD simulations of disks really predict the light we see?". And they sort of did look a bit like Cyg X-1 in the soft state.

The other question on everyone's mind was whether one of our invited reviewers would take up the challenge today to address how accretion compares in different types of object?

**Xuening Bay explains differences between proto-planetary accretion disks and disks around compact objects. For example, PP disks are dominated by external heating, resulting in a different thermal balance.**

[#accr2018](#)



**Felix Fuerst** @BIGfalke  
10:15am - 9 Aug 2018

It all came over as very sensible too. The rest of Xuening Bay's talk was a stunning rendition of the MHD and microphysics that need to be accounted for in protoplanetary disks. And if you last looked into them some years ago, MRI appears to have been ousted by disk winds as the primary angular momentum loss antagonist.

Break and poster time brought us Matthew Coleman's paper on convection and magnetic turbulence in white dwarf accretion disks, Sergei Dyda's clumpy outflows from 3D line-driven winds and Kristen Dage ULXs in extragalactic globular clusters. Then there was a poster that, ehem, did not show up on the first day from some Drake fellow on the peculiar X-ray/UV accretion rate schism in the dM+DA binary QS Vir.

Reinvigoration by coffee rendered us suitable recipients of the wide range of accretion on offer the next session....

**Now Marat Gilfanov on what luminosity of X-ray binaries tells us about their radiative accretion efficiency. [#accr2018](#)**



**Cecilia Garraffo** @cecigarraffo  
11:16am - 9 Aug 2018

And it gets pretty low for ULXs, dropping sharply for the most luminous objects such that they must lose about 90% of the accreting material in outflows. Silas Laycock drew our attention to massive X-ray binaries in starburst galaxies, asking "What do they look like and how massive are they really?", with special big foam finger pointing at IC10... at which point it was time for an invited review.

Andreas Zezas gave us a Greek epic that especially emphasised the utility of the Magellanic clouds for teasing out environmental factors in binary production.

Leading up to lunch, Dacheng Lin successfully modelled accretion in neutron star low-mass X-ray binaries using a combination of disk and boundary layer models, while Rigel Cappallo presented a method for modelling X-ray pulsars that will be useful for looking at trends and statistics of derived emission region parameters in samples of objects.

**The problem with a conference focused on a topic you care about a lot is that every talk is interesting and you can never just zone out or skip a session... [#accr2018](#)**



**Felix Fuerst** @BIGfalke  
11:39am - 9 Aug 2018

The scientist with the best name at the meeting, Montserrat Armas Padilla, got us going with a talk on how multi-wavelength analysis of ultra-compact and very faint X-ray binaries can provide us with new insights into accretion physics at low mass transfer rates. Salvko Bogdanov took up the same theme but using transitional millisecond pulsars—compact neutron star binaries that switch between accreting and rotation-powered pulsar states.

And then it was time to dream a little bit as Ann Hornschemeier gave a consummate review on "Future Observations of Compact Objects with Athena and LISA". Enormous credit must go to Ann for resisting the temptation to use the "multi-messenger" cliché in both her abstract and talk, which related the merciless pincer movement that LISA and Athena would enact on the hapless hitherto recondite mysteries of the full gamut of black hole, neutron star and white dwarf binaries.

We could not help but think about [#accr2018](#) again... Before Laura Shishkovsky launched us back into the present with the possibility that black holes could be found in globular clusters, despite there being no convincing candidates yet. Until now perhaps - their MAVERIC survey having dished up a promising one in M62 from VLA observations.

While the VLA has done some nifty things with T Tauri stars, one gets the impression Connor Robinson's druthers would be more for the UV that is formed in accretion columns on T Tauri stars and can reveal accretion rate varia-



tions. He finds that large UV flux, and therefore accretion rate, variations are likely linked to inhomogeneities in the innermost disk, and could have an impact on disk heating and chemistry, as well as planet formation. What, coffee time already? Time to mosey over to the posters.

Rosaria Bonito presented on how observations, simulations and laboratory experiments (a true science trifecta!) can join forces against the mysteries of accretion onto young stars with disks, SOC member Elena Mason presented insights into classical novae from high resolution multi-band spectroscopy, and Eric Schlegel wrapped up with some neat Kepler K2 observations of accretion variations and stunted bursts on the CV AC Cnc.

And it was around the last corner and onto the home straight for Thursday, as Iminhaji Ablimit got us all to think again about SN 1a and in particular the evolution of magnetic white dwarf binaries toward conflagration.

Rosanne Di Stefano then regaled us with tales of hierarchical triple systems as a channel to gravitational mergers. The drift is that a third body in a wider orbit donates mass to a more compact binary, and shortens to the “time to merger” in the process. Cecilia Garraffo instead showed us how cataclysmic variables can go incognito in the CV period gap if the magnetic complexity of the M dwarf secondary increases in the evolution toward shorter periods. Magnetic braking is closed down, and the M dwarf slips back into thermal equilibrium within its Roche lobe and keeps its hands to itself.

Then it was straight into a wonderful treatise on what #accr2018 is really all about: mass transfer and “The story of  $q$  and  $\zeta$ , and, to some extent, of  $\alpha, \beta, \gamma$ ” by Natasha Ivanova. Swirling us about the theory like we were in the accretion disk itself with the most lucid view of the fundamentals. Stable mass transfer appears to be possible even at high mass ratios and should be a more common phase that once thought for some object classes.

**Then..**

**Last talk of the day by Morgan MacLeod on common envelope accretion, and how that transfers the binary and the objects in it.**

**#accr2018**



**Felix Fuerst** @BIGfalke  
5:29pm - 9 Aug 2018

The common envelope phase is a bit like the matchmaker bringing together widely separated stars into a more intimate relationship. Morgan described how accretion during the common envelope phase can modify the masses and spins of compact objects, potentially with observable signatures for gravitational wave detectors like the LIGO-VIRGO network. ANd Thursdays science sessions were over.

It was time to bring our common envelope into the reception room for virtuals and liquid refreshment. We had a more grave, bitter-sweet duty ahead of us for the evening: honouring and remembering the late Jeff McClintock



Eulogies and reminiscences were given by many meeting attendees, as well as several guests who came in especially for the occasion.



*Jack Steiner, one of Jeff's students and mentees, speaks at a special evening session dedicated to his work and memory.*

**Friday**

Our final sessions were to be more focused on topics of especial interest to Jeff—black holes. Ramesh Narayan's talk on advection-dominated accretion flows, and how they naturally lead to the jets that are observed, was mesmerizing, profound, magnificent.

**Its going to be tough to beat Ramesh Narayan's quote "X-ray data imply that black holes really are really black!"**

**#accr2018**



**Jeremy Drake** @cosmodrake  
9:28am - 10 Aug 2018

Shane Davis' "Giving Spectral Modelers an f" followed. Unfortunately, it was not a cue for all the observers to rib the theorists, but an exposé of the correction term applied to pseudo-blackbody models used to model accreting sources. Shane, one of the creators of the BHSPEC XSPEC model finds  $f \sim 1.4-2$ , but  $f < 2$  for photon-starved disks at accretion rates much below the Eddington limit.

Joey Neilsen showed some really NICER new data on GRS 1915+105, revealing how winds change on timescales as short as a second in response to X-ray variability and the implications for the inner and outer accretion flow. Jerome Orosz then gave a lucid mini-lecture on how Jeff's interest in measuring black hole spin was realised by obtaining independent distances and applying stellar models to constraint system geometry. Conspicuous was the palpable sense of suspense Jerome left us with, noting the many near-future distances to X-ray binaries that should come from Gaia.

Coffee punctuated the proceedings, followed by Jack Steiner's moving talk on his work with Jeff on measuring black hole spins. In addition to being intrinsically fascinating, Jack showed how spin is crucially important for how black holes form and the mechanism by which relativistic jets are launched. Javier Garcia made the natural progression to "Probing the innermost region of accreting compact objects" with some gratifyingly physics-y modelling of disk reflection spectra.

I think Javier Garcia @jaj\_garcia is now winning the quote of the day - both scientific and heartwarming! "I was so proud of these model fits that I put the plot on my grandma's fridge" #accr2018  
[twitter.com/BIGfalke/statu...](https://twitter.com/BIGfalke/status/1018111111)



Jeremy Drake @cosmodrake  
11:54am - 10 Aug 2018

And it was time for Josh Grindlay's much anticipated talk on.... Josh? Time dilation effects within the strong gravitational field of Josh's office apparently having skewed his schedule, Charles Bailyn stepped up to report on 20 years of observations of the dynamically-confirmed black hole candidate A0620-00, and an overall trend toward increased disk luminosity. Charles explained how we might be witnessing a gradual build-up of the disk as the source progresses toward its next outburst. #accr2028

Jonathan Grindlay on BH populations: why is there only one Cyg X-1 in the galaxy?  
 #accr2018



Cecilia Garraffo @cecigarraffo  
12:29am - 10 Aug 2018

Speaking of outbursts, Josh arrived! Josh is a prime instigator of the Digital Access to a Sky Century @ Harvard project to scan all the Harvard plates. He gave a wonderful overview of estimating the population of black hole X-ray binaries in the Galaxy and how DASCH can help tease them out.

And we were at an end, uplifted and inspired as by a moving spiritual ceremony... And all wanting to ditch our current tedious research projects and study black holes.

So, that's the end of #accr2018! It was a really great meeting, thanks to @chandraCDO, @cosmodrake, @rudy\_phd, and all the other people involved! I learned a lot and had a great time! Now, back to science and white paper writing ;-)



Felix Fuerst @BIGfalke  
3:02pm - 10 Aug 2018

In addition to the two authors of this article, the long-suffering SOC of #accr2018 who put together the science program, were Vallia "Another HMXB Survey" Antoniou, Rosanne "Mine's a Triple" Di Stefano, Catherine "Proto-planetary" Espaillat, Elena "New Star" Mason, Jon "High Res" Miller, Roberto "Ultra-Luminous" Soria and Jack "Black Hole" Steiner. Local arrangements and logistics were blended smoothly by Jason Conry, Karla Guardado, Ray Hemond, Lauren Robbins and Aldo Solares.

No meeting at all would have happened without the supreme stewardship of Rudy "Can We Fix It? Yes We Can!" Montez. No talk of revenge or anything, bygones being bygones, forgive and forget, all friends together, but, dear reader, why not hit him up sometime for... SOC chair? #accr2028.