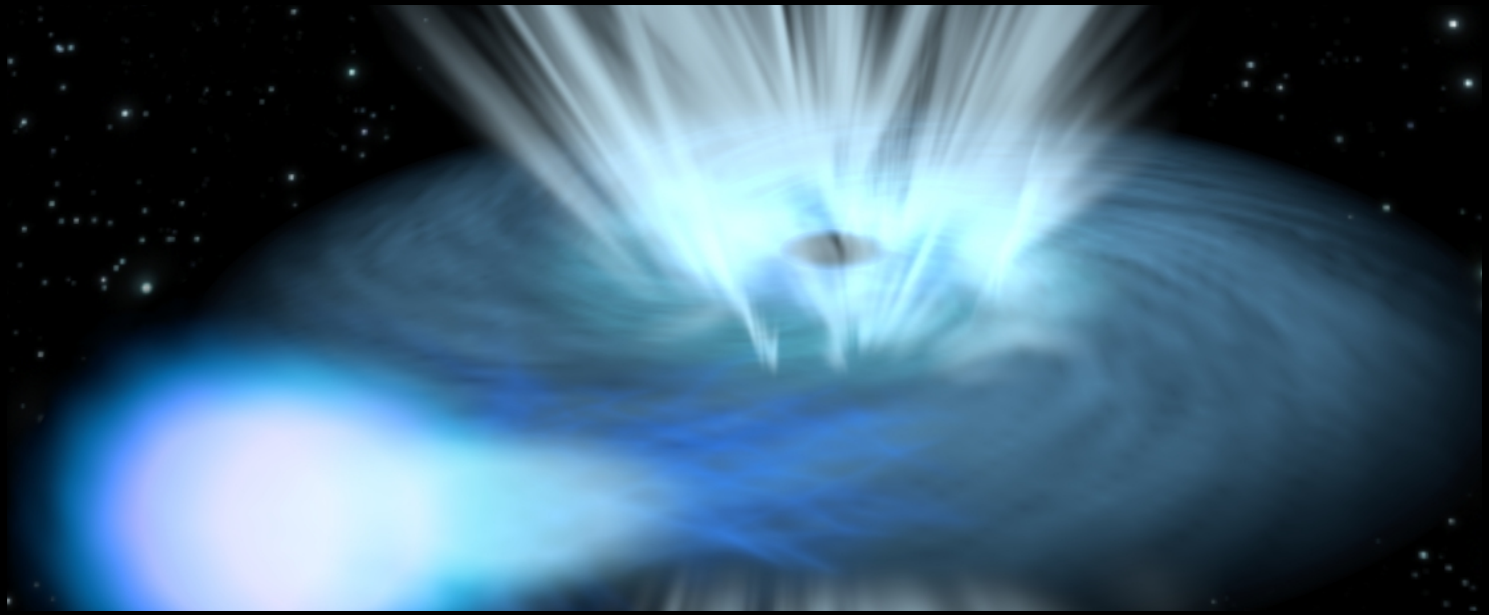
SEAWIND

Super-Eddington Accretion: wind, inflow and disc



INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Ciro Pinto

IASF – Istituto di astrofisica spaziale
e fisica cosmica di Palermo

E. Ambrosi, A. D'Aì, M. Del Santo, S. Paiano, F. Pintore, A. Robba, G. Rodriguez, T. Russell, Y. Xu (IASF-PA), S. Motta, A. Wolter (OAB), A. Belfiore, A. De Luca, N. La Palombara, R. Salvaterra, L. Sidoli (IASF-MI), G. Israel (OA-RO), M. Bachetti (OAC), G. Migliori, F. D'Ammando (IRA-BO), L. Zampieri (OAP), F. Barra, T. Di Salvo, R. Iaria (UNIPA), S. Bianchi, G. Matt, F. Ricci (UNIRO3), P. Esposito, A. Tiengo (IUSS-PA), A. Riggio (UNICA).

A little history ...

Cited by		VIEW ALL
	All	Since 2017
Citations	5104	4169
h-index	42	37
i10-index	97	92

Naples, Italy ('08)

SRON (2008-2012)

Cambridge (2012-2018)

ESA / ESTEC (2018-19)

INAF Palermo (12/2019-)

UNIPA

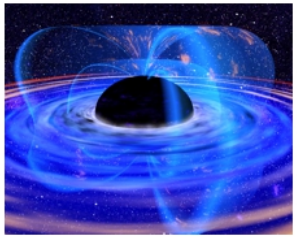
1. Context – Black hole growth

see talk by S. Motta

Accretion / ejection

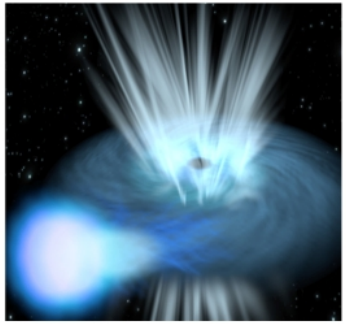
Supermassive Black Hole

$10^6 – 10^{10}$ M_{SUN}



BH Growth

Outflows alter the growth



Stellar-mass Black Hole or Neutron Star

1 – 100 M_{SUN}

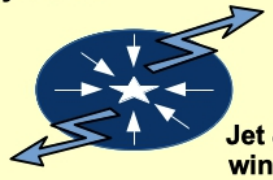
High accretion rates

NLS1, TDEs & quasars

Wind hoovering ISM & accretion disc

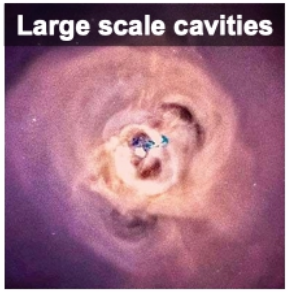
Low accretion rates

Seyfert 1-2

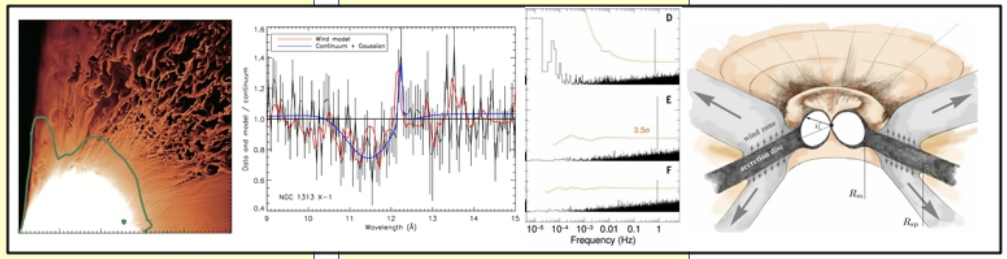


Jets heating the ISM

Feedback

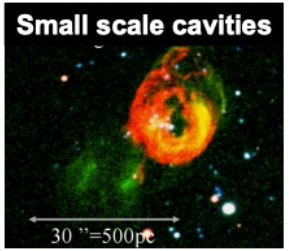


Methods: Theory + Observations



ULXs / transient Galactic ULXs

Classic Galactic XRBs

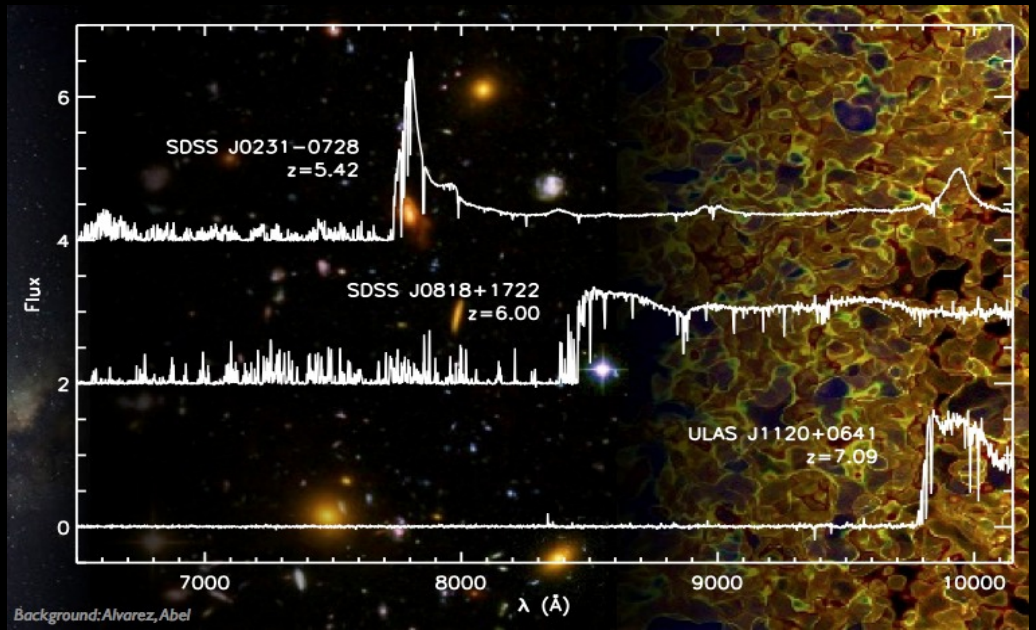


Formation of supermassive black holes

→ Super-Eddington accretion ?

→ Massive black hole seeds ?

→ Black hole (&NS) mergers ?

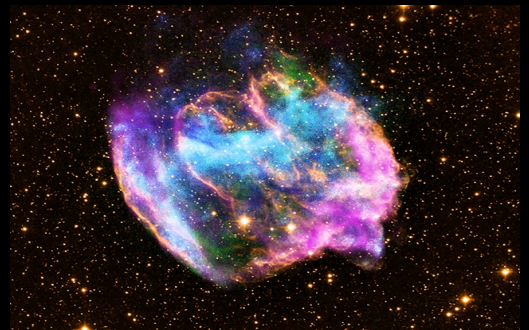


MASS GAP

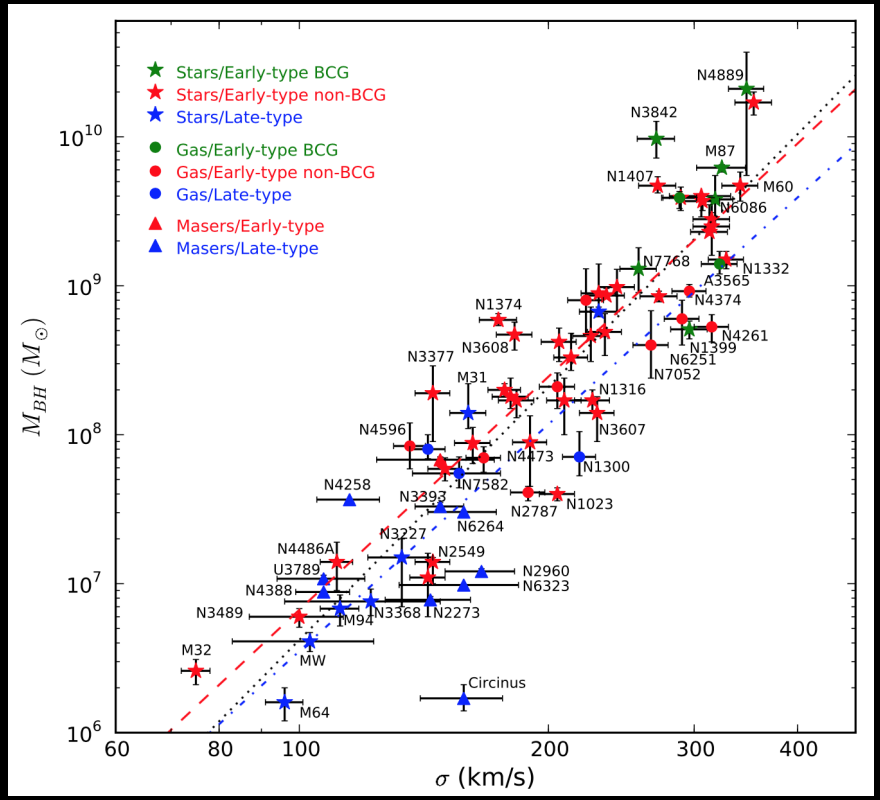
M_{SMBH} (AGN) ~ $10^{5\text{-}10}$ $M_{\odot}$

M_{BH} (XRB) ≤ 25 $M_{\odot}$

(≤ 100 $M_{\odot}$ | $Z<<Z_{\odot}$)

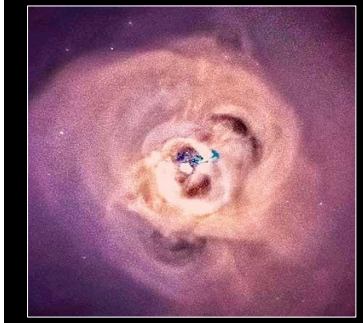


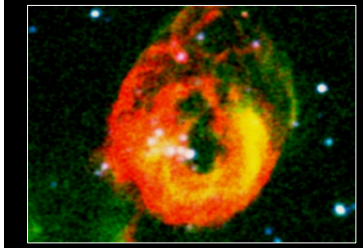
Feedback onto the surrounding medium



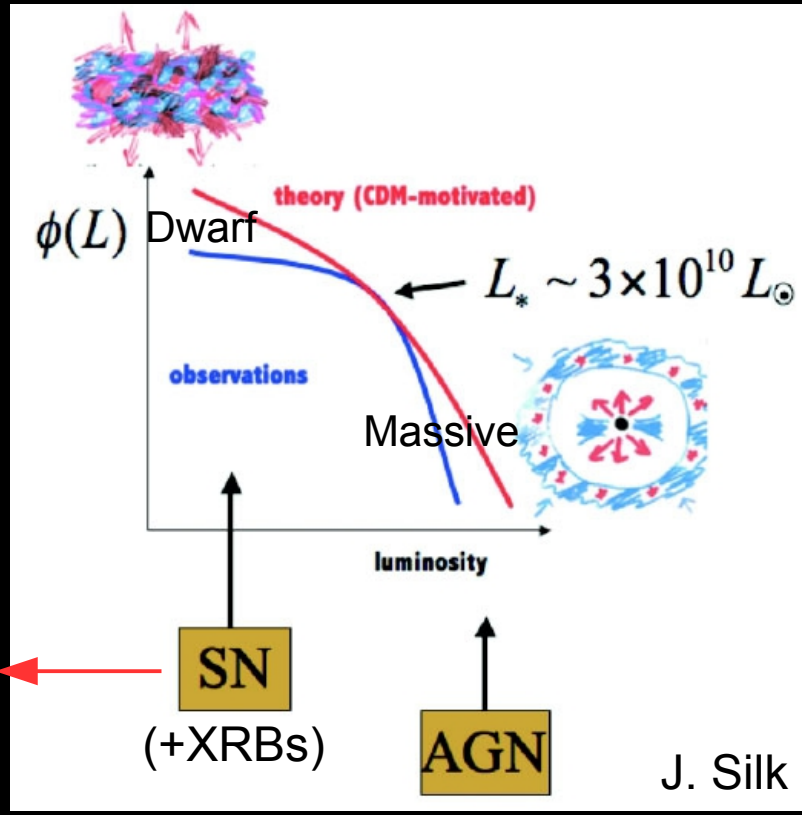
McConnell & Ma'13 (also *Kormendy* relation)

Perseus cluster core





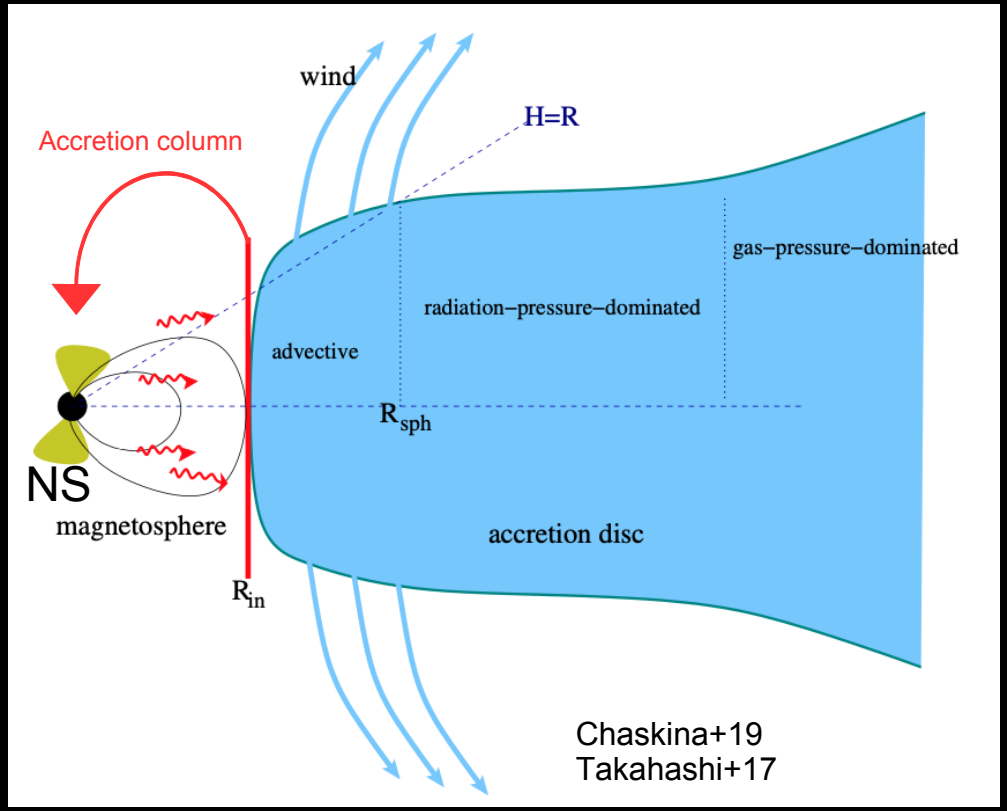
Ho IX ULX-1

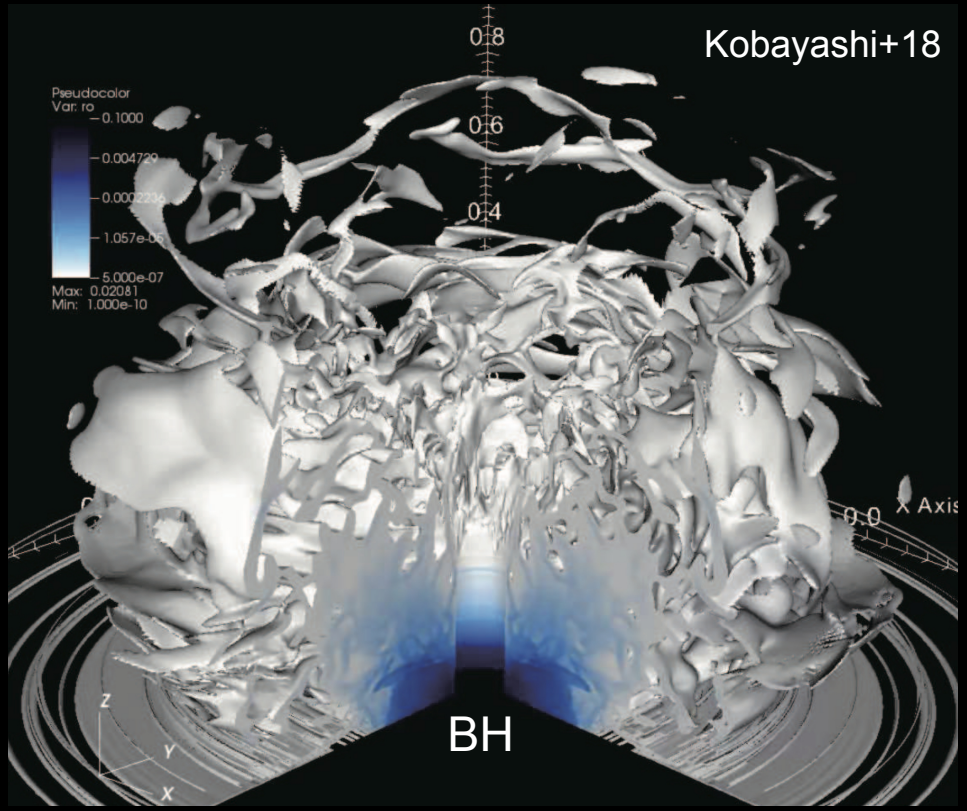


Shortage of galaxies due to energy release

Super-Eddington accretion

The radiation pressure inflates the disc and launches a wind : funnel geometry

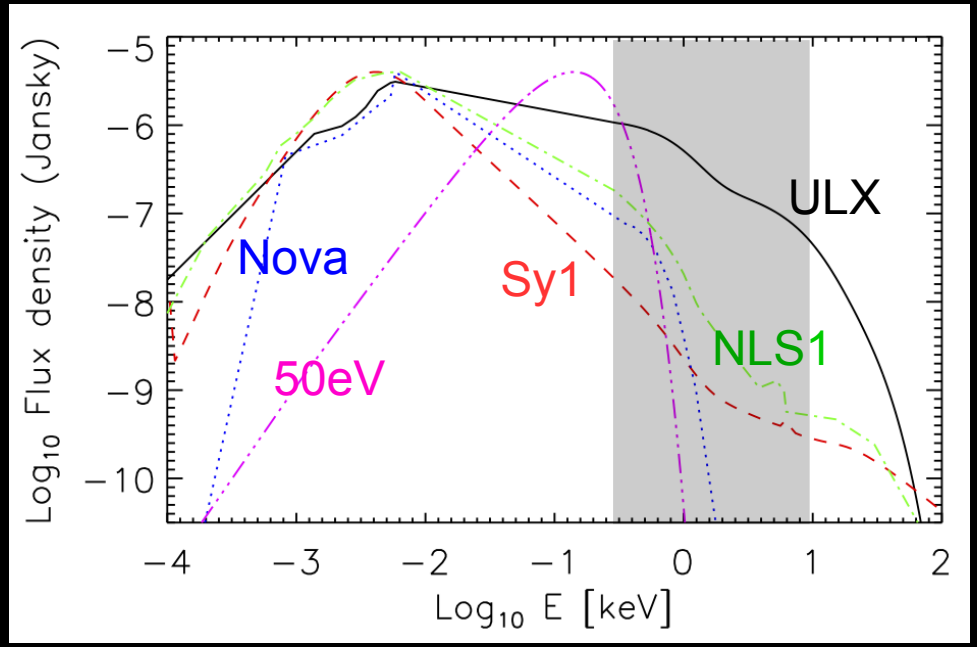




Super-Eddington Accretion Top Indicators

Narrow-Line Seyfert 1 (NLS1) AGN

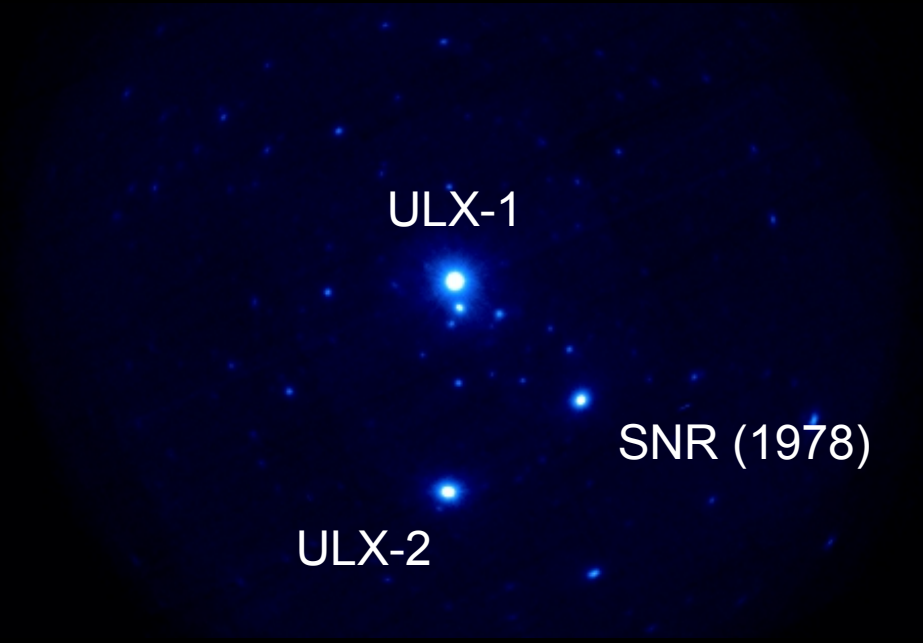
"Lower-mass" supermassive black holes accreting @ or above the Eddington limit



CP+2020a,b

Ultra-Luminous X-ray sources (ULXs)

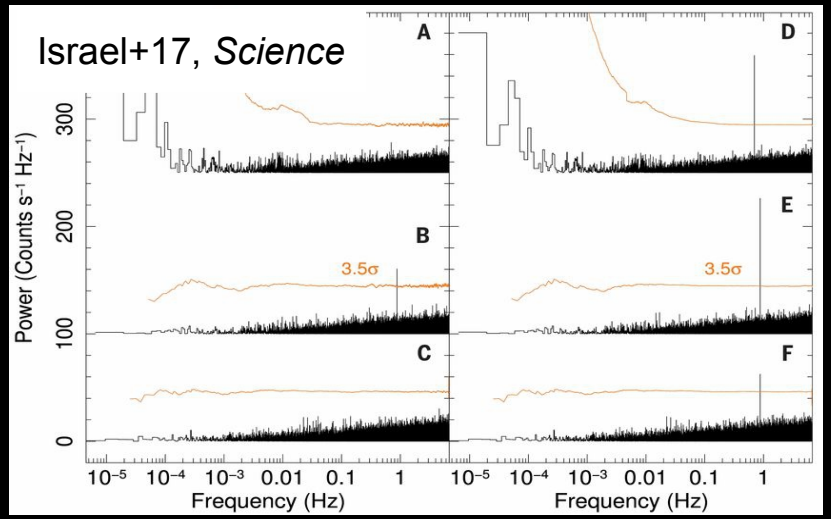
X-ray binaries brighter than 10 $M_{\odot}$ black hole accreting @ Eddington limit (10^{39-42} erg/s)



NGC 1313 galaxy (X-rays / XMM-Newton)

2. A few highlights (stellar-mass regime)

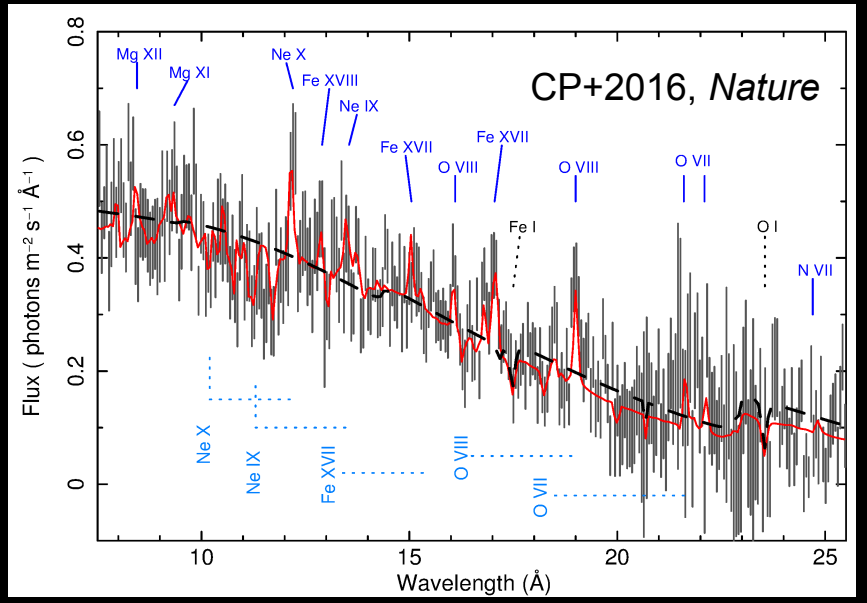
NGC 5907 ULX-1 ~ 10^{41} erg/s ~ 500 x L_{Edd}



Advanced timing techniques e.g. correcting for (super-)orbital motions discovered pulsations: neutron stars in 10+ (t)ULXs

Bachetti+2014, Israel+17a,b, Fürst+16, Carpano+18, Tsygankov+18, Sathyaprakash+19, Rodriguez-Castillo+20, Vasilopoulos+20, Quintin+21

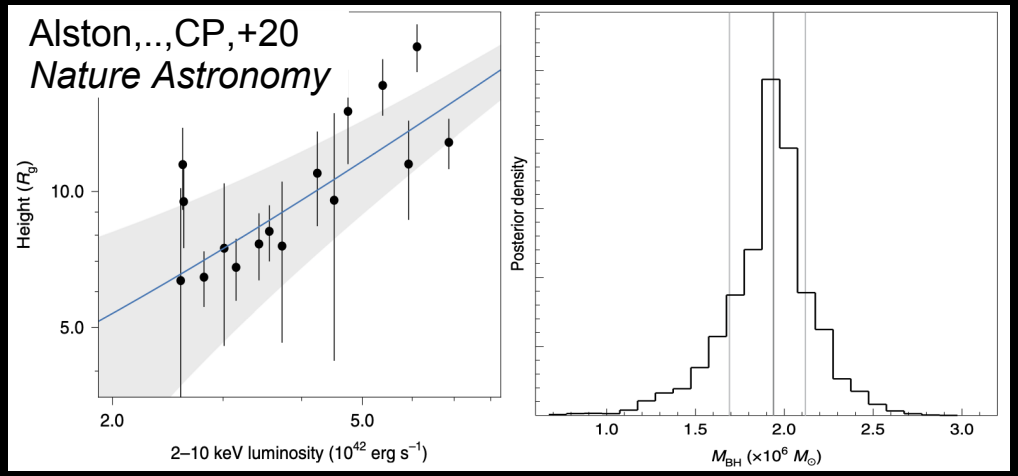
Advanced spectral techniques e.g. Monte Carlo plasma codes discovered winds at 20-30% light speed in 10+ ULXs



CP+2016,**17**,**20ab**,21, Walton+17, Kosec+18-21, Koliopanos+18, Wang+19, Belfiore+20 *Nat.Astr.*

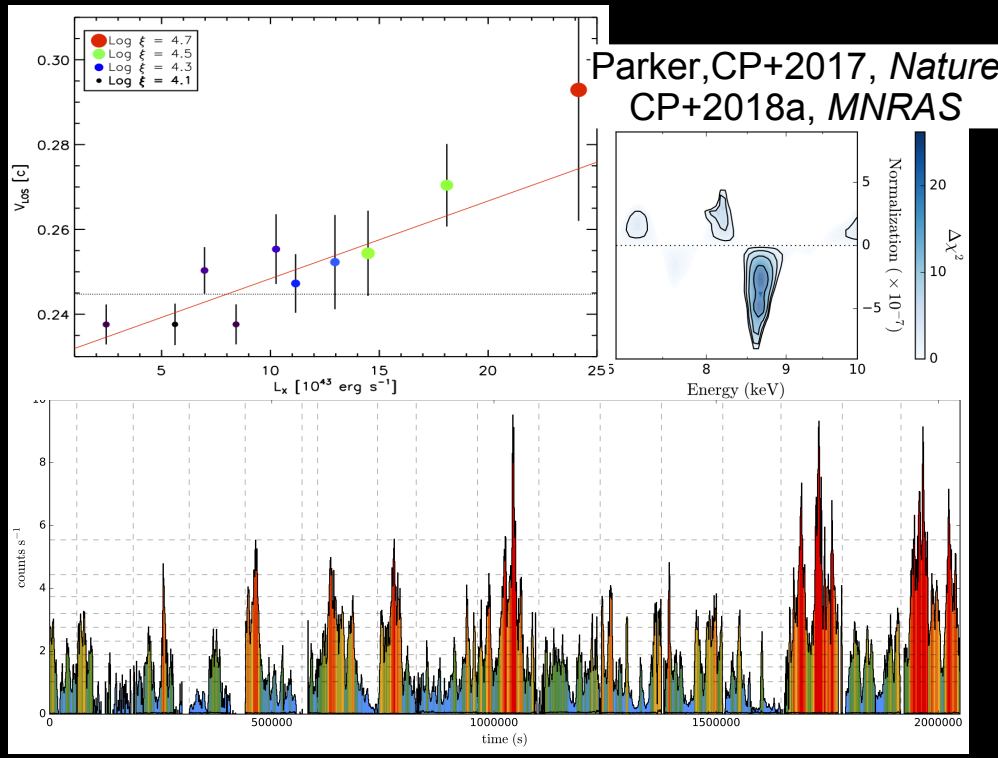
2. A few highlights (supermassive regime)

NLS1 IRAS 13224-3809



Spectral-timing techniques broke model degeneracy, measuring SMBH geometry & mass

Advanced spectral techniques discovered winds response to the source luminosity!
→ launching mechanism



3. Building a great team: SEAWIND

1) What % of matter do black holes and other compact objects accrete or expel via outflows?

2) Are outflows powerful enough to affect the surrouding interstellar medium (bubbles/SFR)?

Research Team

Duties legend
Organisation et al.
X-ray Spectroscopy
X-ray Timing
Multi-wavelength
Theory of accretion

IASF PA
C. Pinto, M. Del Santo, A. D'Aì, A. Robba, Y. Xu, F. Pintore, G. Rodriguez, S. Paiano. T. Russell, E. Ambrosi

OAC, UNICA
A. Riggio, M. Bachetti

OAR
G. Israel

IASF MI, OAB, OAPD
P. Esposito, A. Tiengo, A. Wolter, L. Sidoli, N. La Palombara, S. Motta, A. De Luca, L. Zampieri, A. Belfiore, R. Salvaterra

PI: Pinto (IASF PA)

UNIPA
T. Di Salvo, I. Iaria

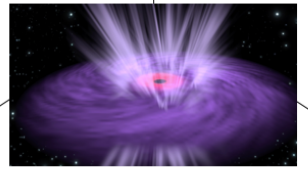
ROMA 3
S. Bianchi, G. Matt, F. Ricci

IRA BO
F. D'Ammando, G. Migliori

Working packages

Ejection
C. Pinto, A. Robba, Y. Xu, L. Sidoli, I. Iaria, F. Pintore, F. D'Ammando, G. Migliori, A. Belfiore, T. Di Salvo

Accretion
P. Esposito, A. Tiengo, N. La Palombara, G. Matt, G. Israel, G. Rodriguez, A. Riggio, M. Bachetti, R. Salvaterra, E. Ambrosi



Coupling
S. Bianchi, A. Wolter, M. Del Santo, A. D'Aì, S. Motta, A. De Luca, T. Russell, S. Paiano, F. Ricci, L. Zampieri

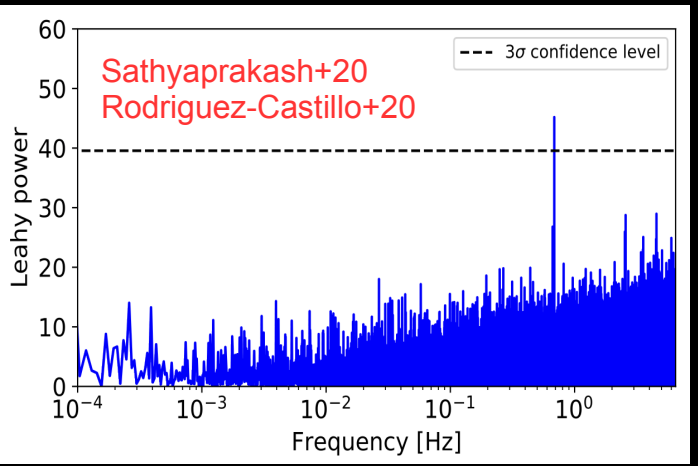
Main international partners:
A. Fabian, M. Parker, C. Reynolds, D. Walton (Cambridge), T. Roberts, R. Sathyaprakash (Durham), M. Middleton (Southampton), M. Guainazzi, W. Alston, F. Fürst, J. Ness (ESA), D. Barret (IRAP), R. Soria (NAO/UCAS), H. Earnshaw, L. Mallick (Caltech), P. Kosec, E. Kara (MIT), M. Mehdipour (STScI)

SEAWIND

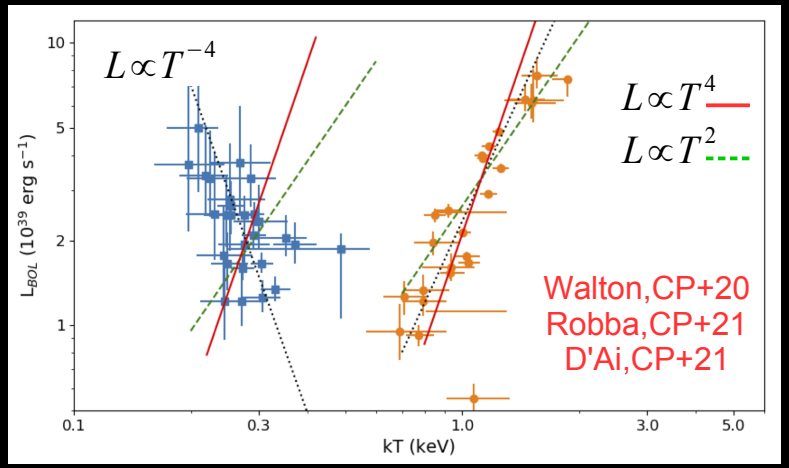
- Super-Eddington Accretion: Wind, INflow and Disc
- Research programme for RSN4 (secondary: RSN1)
  - Compact objects
  - AGN-galaxy coevolution
  - High-energy astrophysics
  - Non-thermal processes
  - Strong gravity
  - Space telescopes
  - Outreach
- 30 members (20 INAF + 10 associates)
- 7 INAF institutes, 4 universities
- 18.1 FTE in total from 2020 (10.9 INAF, 10.7 TI)
- 2 PhD students (highly active) + 2 postdoc (low FTE, other projects)
- XMM-Newton, Chandra, Swift, NUSTAR, XRISM, Athena, eXTP, IXPE, eROSITA, Theseus, Hubble Space Telescope (HST), Fermi (FGST), MAGIC, Cherenkov Telescope Array (CTA), AMI-LA, MeerKAT, ALMA, VLBA

4. Results (2020- highlights among 35 papers)

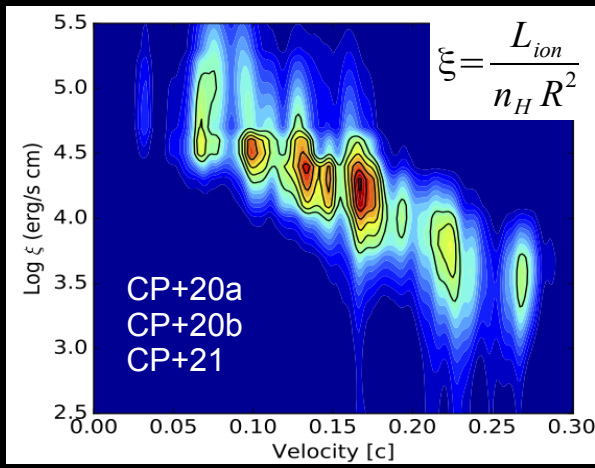
1) Pulsations in more ULXs



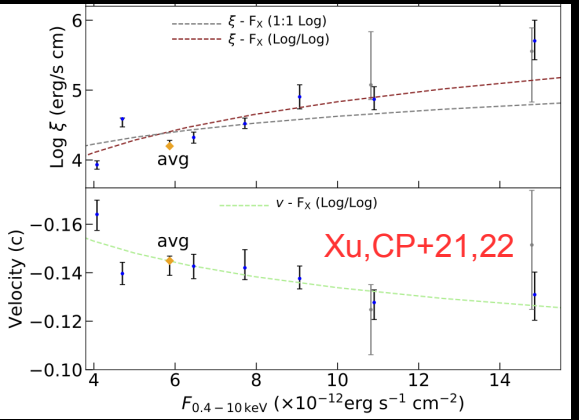
2) Disc spectral evolution ULXs/XRBs

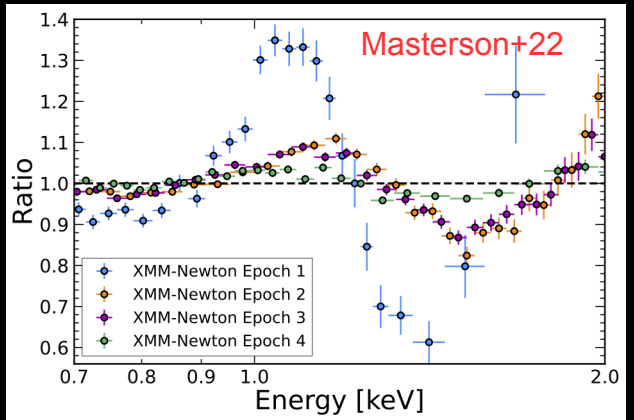


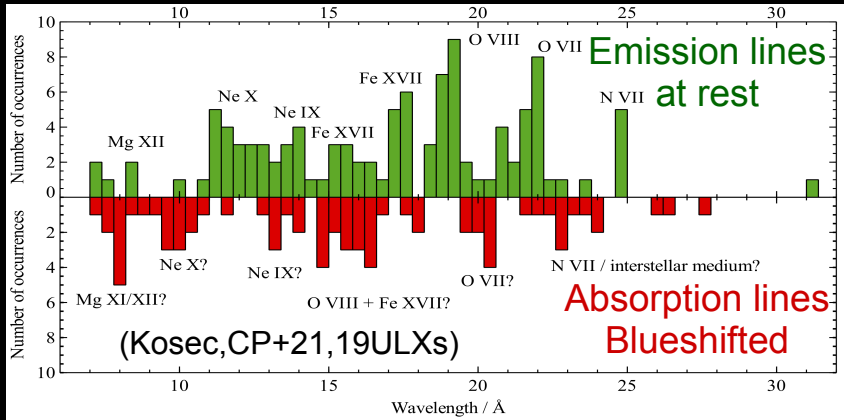
3) Winds in more ULXs



4) Wind responce, strafication & transience in AGN







Leadership

Excellence science requires TOP expertise, data, models & collaboration

- PI and co-Is provide top expertise (discovery of pulsations & winds / INAF world leader)
- Papers published in high-impact scientific & multidisciplinary journals
- Dissertation via press releases, local outreach & Media INAF
- Data collected by ESA & NASA facilities with INAF roles (XMM, NUSTAR, ...)
- Optimise strategies of future missions with INAF roles (eXTP, ATHENA, ...)
- Strengthening the collaboration between different space agencies and countries

5. Critical issues

Excellence science requires TOP expertise, data, models & collaboration

- Limited labour force available: need for at least 2 postdocs (AdR)
- Limited travel funds: need for funds for the most active members
- Project still young (~2 years): need support for outburst
- Not awarded: PRIN INAF 2019. Pending: MUR FIS 2021, PRIN MUR 2022
- PRIN MUR 2020 evaluated SEAWIND 95.7, 8/63, ex aequo with last awarded
- New missions challenge need proper investigation (XRISM, eXTP, ATHENA, ..)

A huge amount of data

Table 1 Black : PI propriety data Blue : Co-PI propriety data Red : PI only partly published data

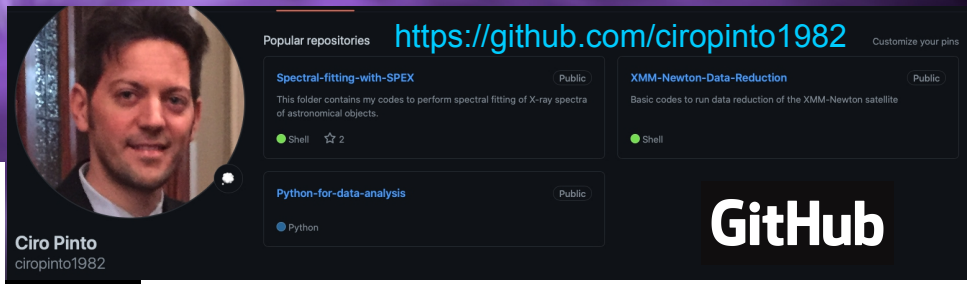
PI	Target	Facility	t (ks)	Notes	PI	Target	Facility	t (ks)	Notes
Pinto	NGC 247	XMM Large	800	1 ULX	Israel	M 51	XMM L	400	8 ULXs
Pinto	NGC 1313	XL+ Chandra	1250	2 ULXs	Walton	NGC 5055	XMM+NUSTAR	133	1 ULX
Pinto	NGC 55	XMM L	380	2 ULXs	Walton	NGC 5907	XMM	63	1 ULX
Pinto	NGC 4559	XMM	130	3 ULXs	Amato	NGC 4190	XMM	123	1 ULX
Pintore	NGC 7456	XMM	130	5 ULXs	Fuerst	NGC 7793	XMM	105	3 ULXs
Motta	NGC 3621	XMM	125	2 ULXs	Mackenzie	Transient ULX	XMM	96	1 ULX
Motta	GRS 1915+10	XMM	40	+ Radio	Salvaggio	3 galaxies	Swift	180	9 ULXs
Xu	PG 1448	XMM	250	NLS 1	Ambrosi	NGC 247	Swift	100	1 ULX
Pinto	NGC 55	Swift	150	2 ULXs	Alston	RE J1034+396	XMM L	950	NLS 1
Pinto	NGC 247	Swift	70	1 ULX	Fabian	1H 1934-063	XMM+NUSTAR L	760	NLS 1
Pinto	NGC 5204	Swift	40	1 ULX	Masterson	1E 1927+654	XMM+NUSTAR	107	NLS 1
Pintore	NGC 4559	Swift	150	3 ULXs	Mehdipour	Transient AGN	Multi-wavelength	100	AGN
Pintore	NGC 7456	Swift	120	5 ULXs	Mallick	SDSS J0228	XMM	123	AGN
Paiano	AGN sample	Swift	120	+ Fermi	Nardini	J2349 / J0609	Swift	60	2 AGN
Total								7055	

BLOSSOM – Black hOle Swift fOrMation

INAF – Large Grant

SEAWIND members with FTE ≥ 0.2

1) Ciro Pinto (PI)	(FTE/year: 0.4)	Coordination & plasma studies	(code development)
2) Melania Del Santo	(FTE/year: 0.2)	XRB multi-wavelength studies	(interpretation)
3) Fabio Pintore	(FTE/year: 0.2)	X-ray spectral-timing studies	(code development)
4) Antonino D'Aì	(FTE/year: 0.2)	XRB X-ray spectral variability	(observations)
5) Simona Paiano	(FTE/year: 0.2)	AGN multi-wavelength studies	(observations)
6) G. Rodriguez	(FTE/year: 0.2)	XRB X-ray timing	(code development)
7) Sara Motta	(FTE/year: 0.2)	AGN X-ray timing	(observations)
8) Anna Wolter	(FTE/year: 0.2)	XRB population studies	(interpretation)
9) Paolo Esposito	(FTE/year: 0.2)	XRB X-ray timing	(interpretation)
10) Stefano Bianchi	(FTE/year: 0.2)	AGN multi-wavelength studies	(interpretation)
11) Yerong Xu PhD student	(FTE/year: 0.4)	AGN wind searches and studies	(observations)
12) A. Robba PhD student	(FTE/year: 0.3)	XRB spectral-timing studies	(observations)
13) Assegnista / Post Doc 1	(FTE/year: 1.0)	XRB time modulation search	(observations)
14) Assegnista / Post Doc 2	(FTE/year: 1.0)	XRB wind search	(observations)

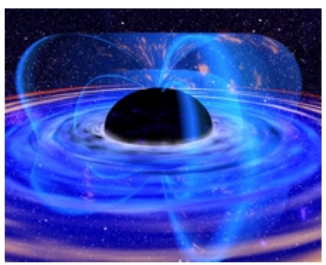


Item	Year 2022	Year 2023
Personnel	70000 Euro	70000 Euro
Equipment	4000 Euro	0 Euro
Travels	27000 Euro	27000 Euro
Consumables	1000 Euro	1000 Euro

Activities Product Tree

Supermassive Black Hole

$M_\bullet = 10^6 - 10^{10}\ M_{SUN}$



Stellar-mass Black Hole or Neutron Star

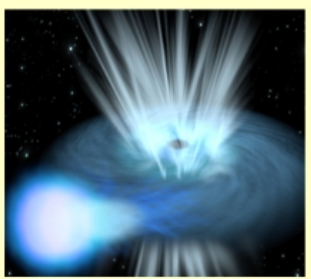
$M_\bullet = 1 - 100\ M_{SUN}$

1) Collect multi-wavelength data for the AGN & XRB samples

2) Build broadband spectral energy distribution

3) Calculation of ionisation balance & plasma models

4) Search for temporal modulations and energy lags



5) Search for winds via high-resolution X-ray spectroscopy

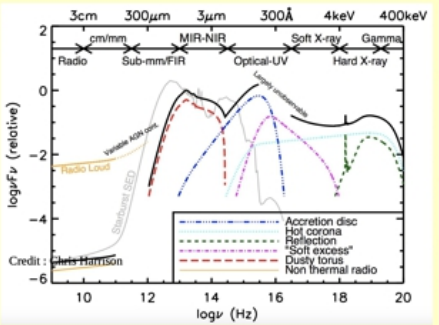
6) Retrieve jet properties in the samples

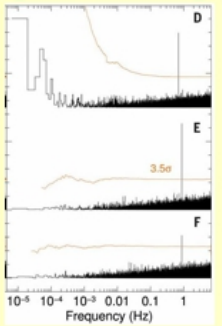
7) Compare wind, jet and disc properties

8) Estimate of outflow and net growth rate

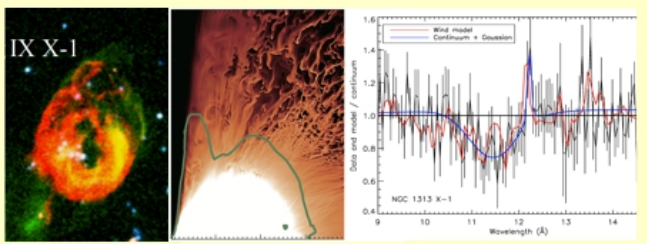
Forecast (at least) 10 high-impact refereed papers

Accretion: Multi-wavelength & timing





Ejections : wind, jets & feedback



Coupling inflow-outflow