活動銀河核アウトフローの多波長観測による比較

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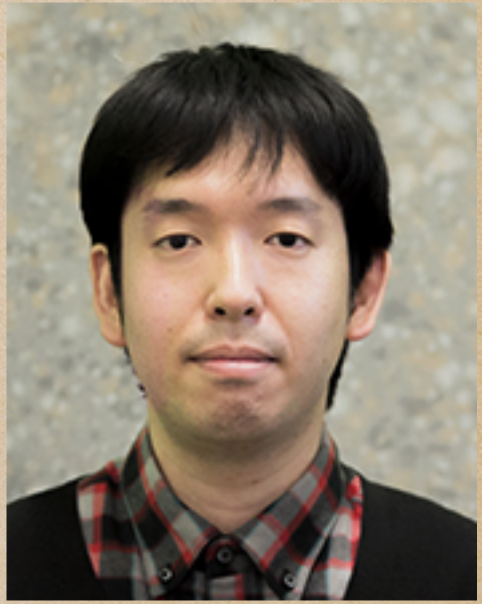
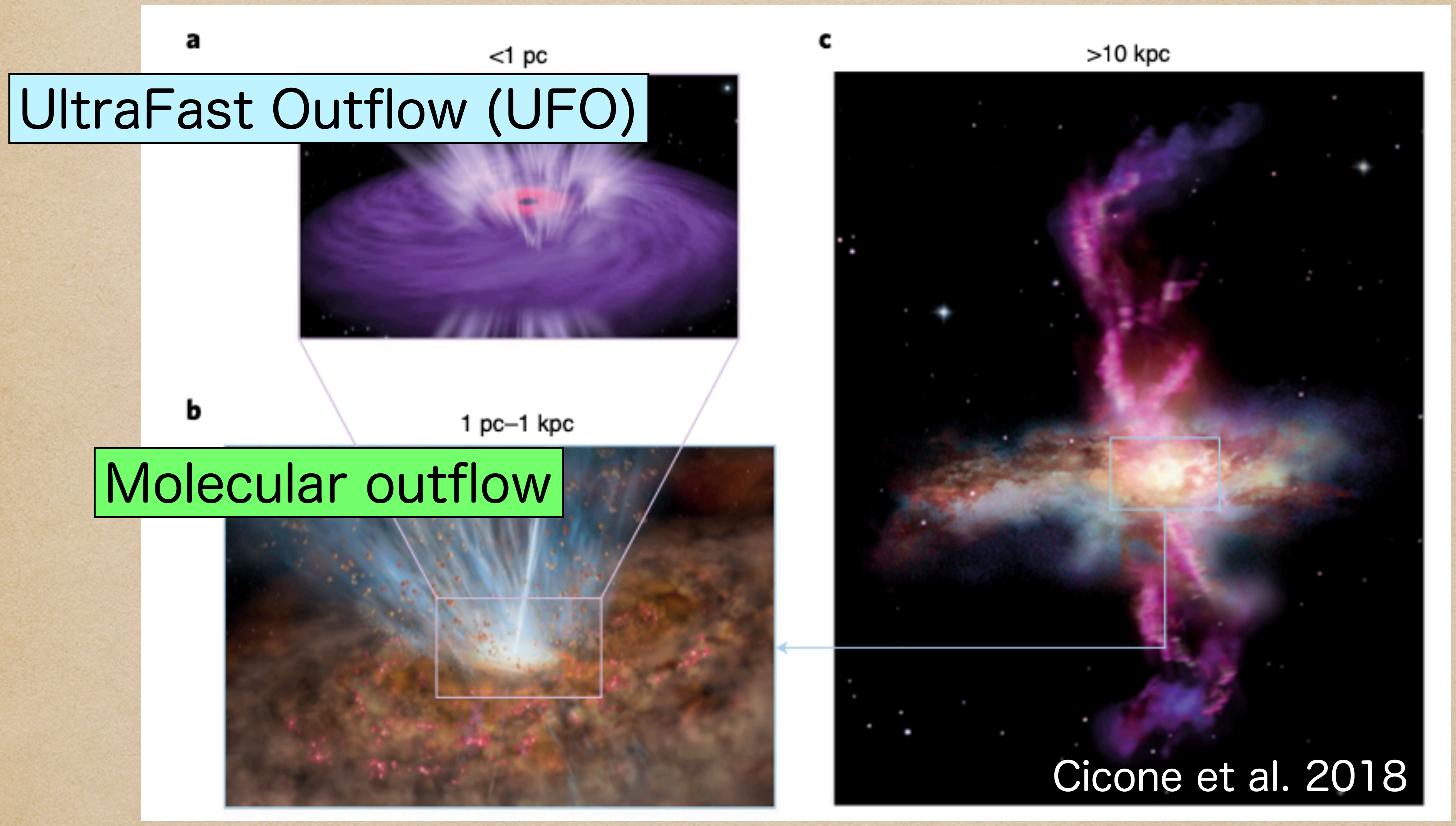


元論文: Mizumoto, Izumi, Kohno 2019, ApJ, 871, 156

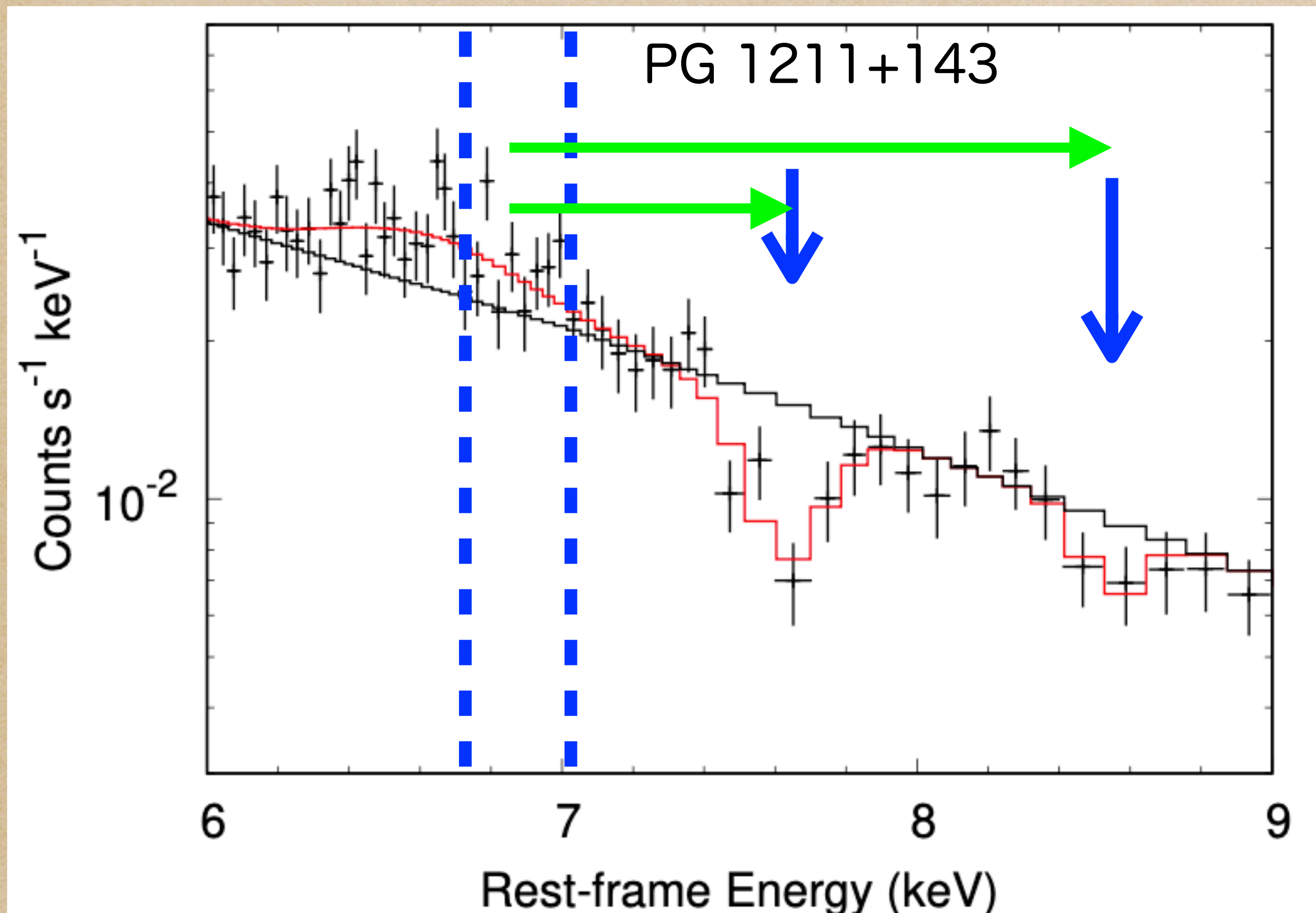
Multi-phase AGN outflow

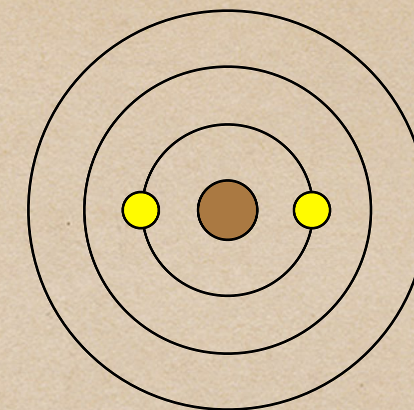


Outflows with different size and different wavelength

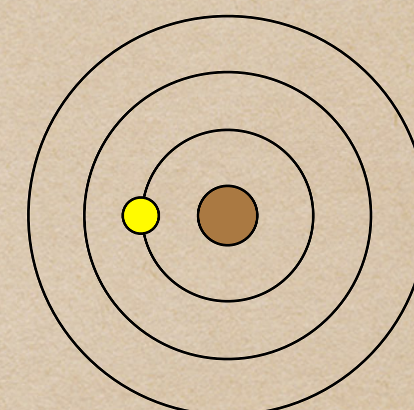
Accretion disc (<1pc)
-> Surrounding ISM (1pc-1kpc)
-> Host galaxy (>10kpc)

1. X-ray UltraFast Outflow (UFO)

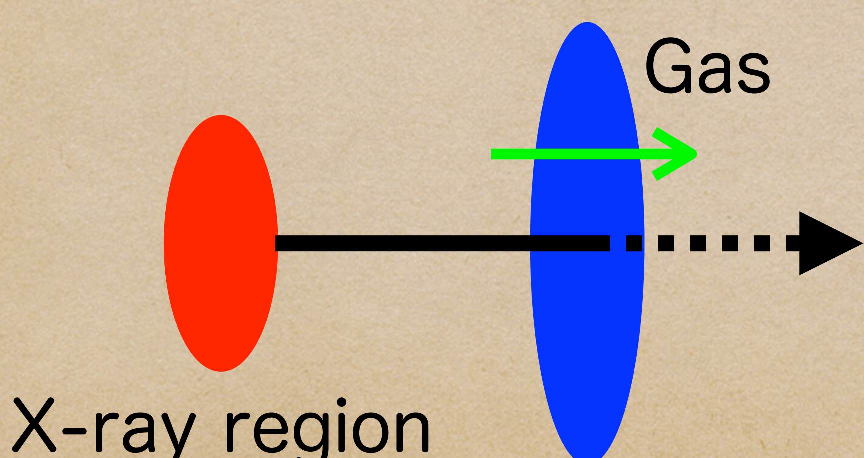




He-like Fe ion (Fe^{25+})
-> 6.7 keV line

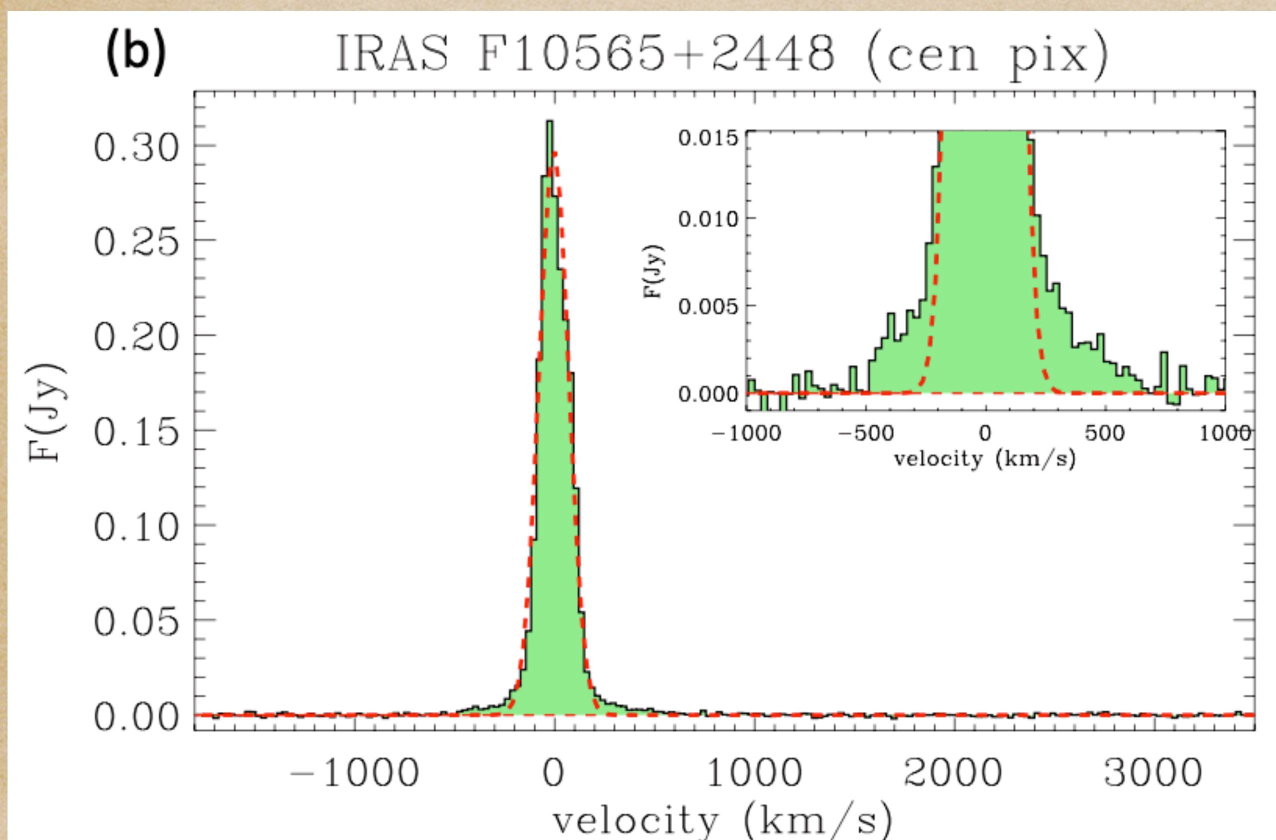


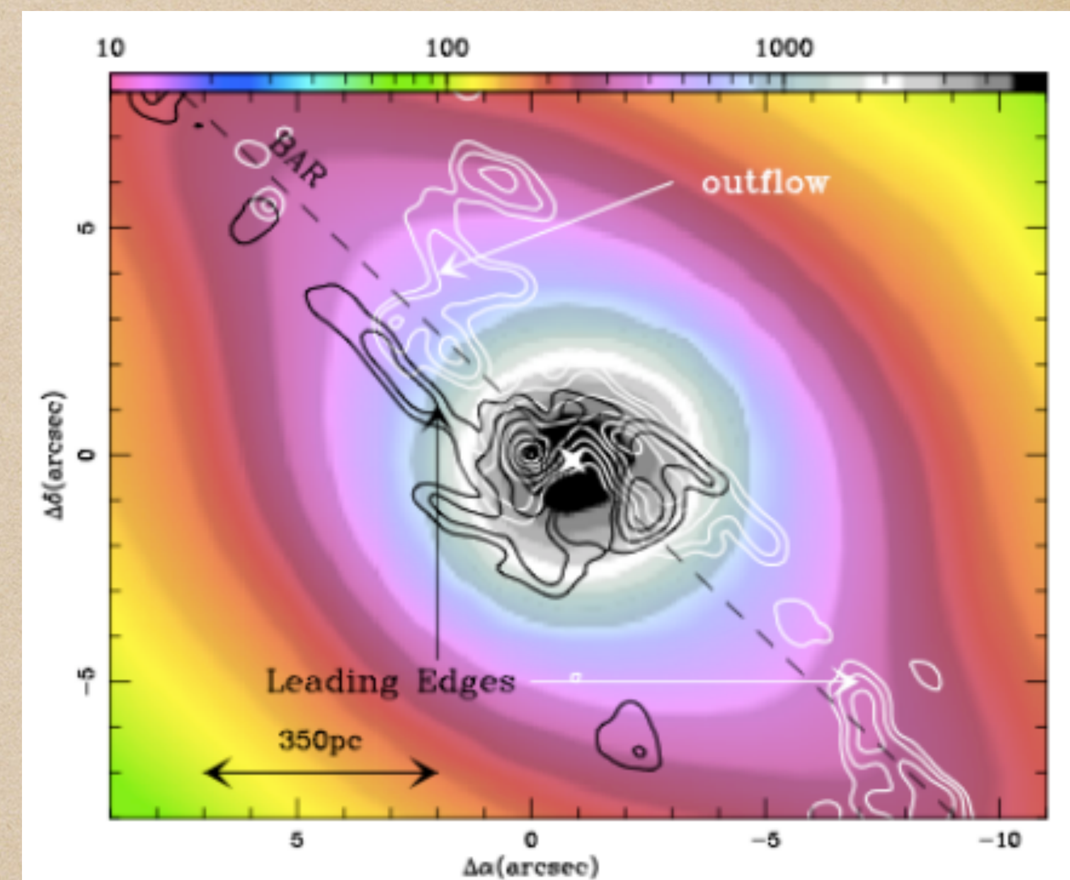
H-like Fe ion (Fe^{26+})
-> 7.0 keV line



v=0.1c-0.3c
r~100-1000R_g (<<1pc)
Kinetic energy ∝ v^2
Carry a lot of energy from AGN to galaxy

2. mm/sub-mm molecular outflow

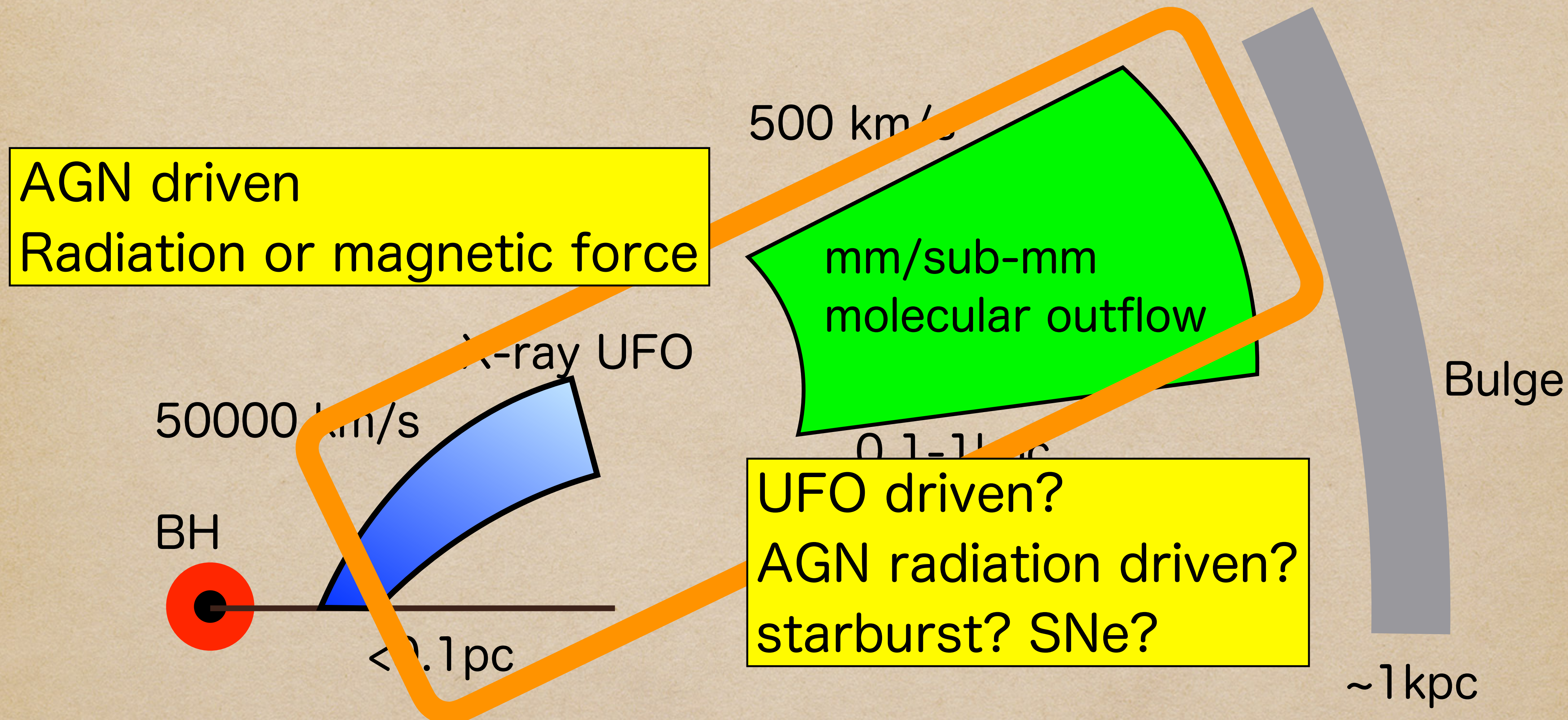




r=1kpc, v=600km/s
CO(1-0), Cicone et al. (2014)

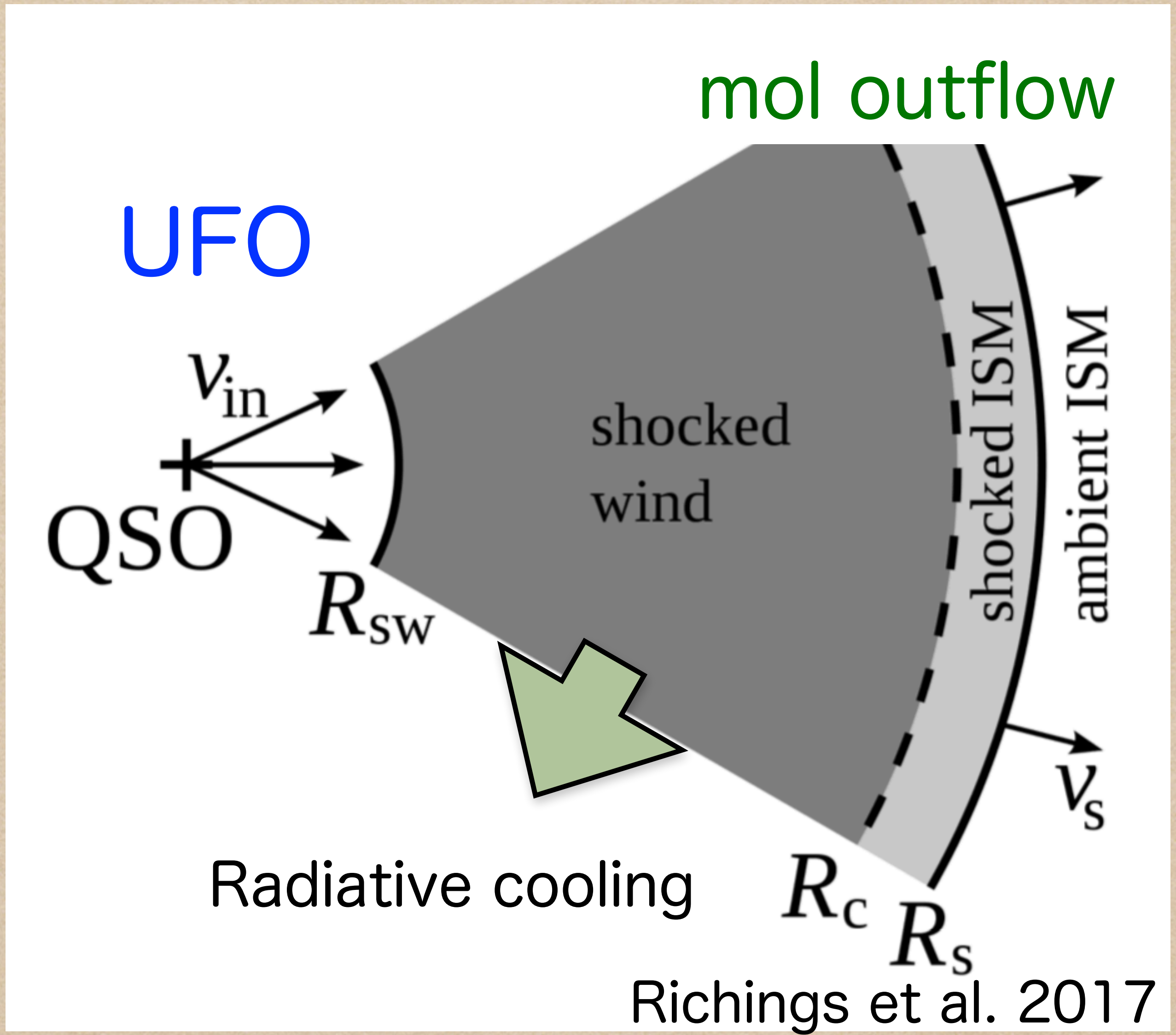
r=400pc, v=100km/s
CO(3-2), NGC 1068
Garcia-Burillo et al. (2014)

Schematic picture



How are these outflows launched?
Are the two outflows physically connected?

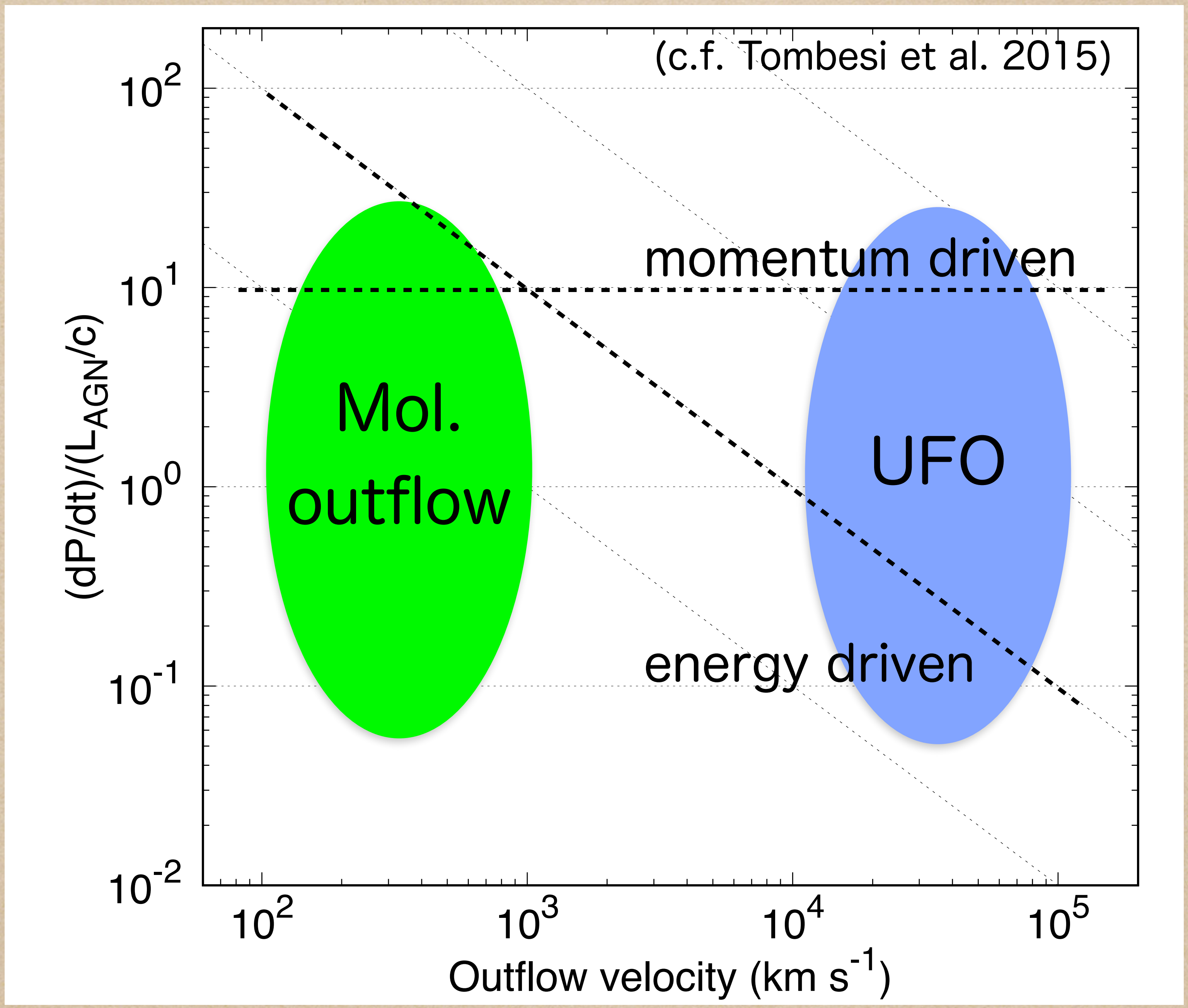
The simplest interpretation



with efficient cooling -> momentum-driven wind
with inefficient cooling -> energy-driven wind

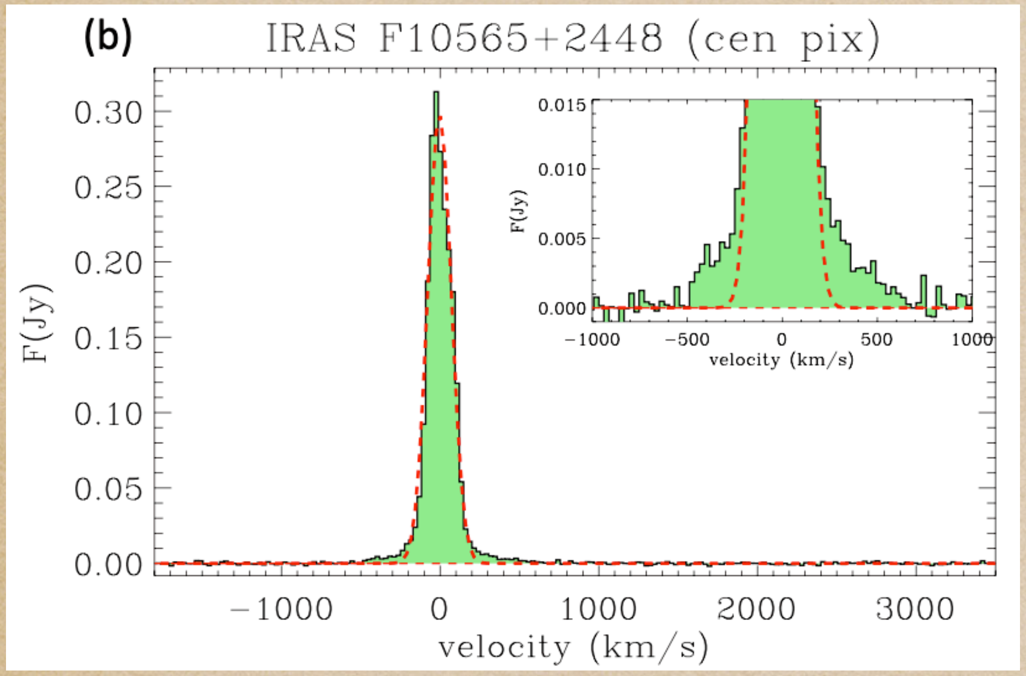
Motivation: Is this picture valid?

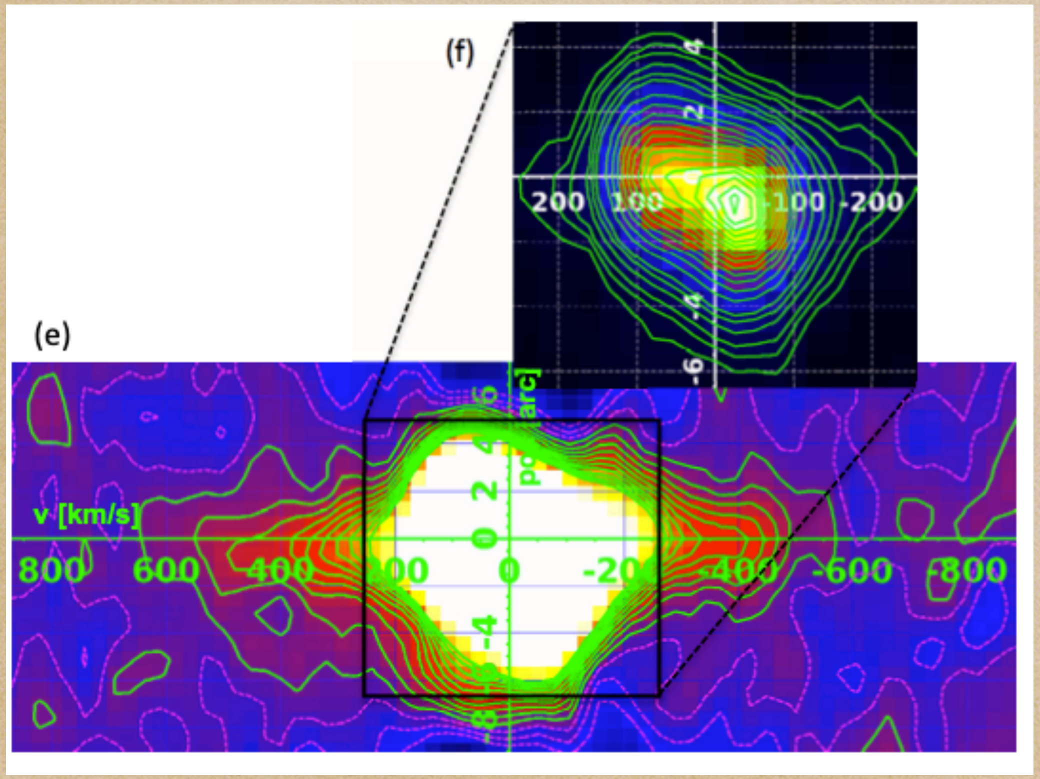
momentum flux vs velocity



Outflow velocity and momentum flux are needed.
I am familiar with X-ray, but not with mm/sub-mm.

Molecular outflow





Cicone et al. (2014)
IRAM/PdBI: CO(1-0) emission
-> Constrain outflow parameters of 16 AGNs

Observables:

- Total flux (wing)
- Radius

Assumption #1

conversion factor

H_2 mass

Assumption #2

spherically symmetric

Mass loss rate
Momentum flux

Molecular outflow

velocity

mass loss rate

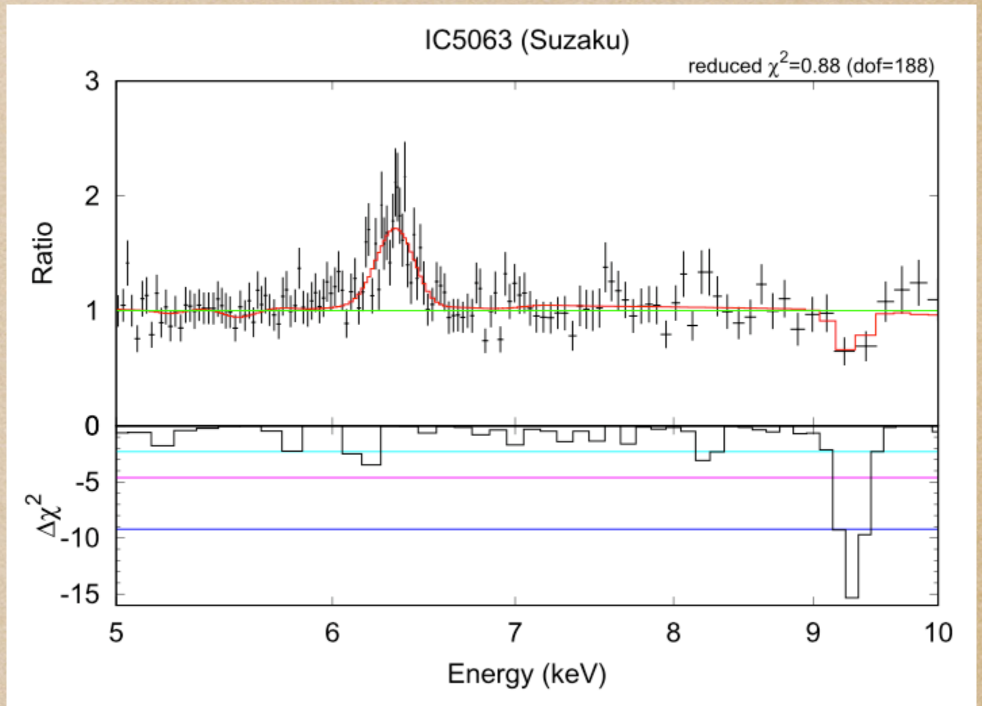
momentum flux

Object (1)	$\log(M_{H_2,OF})^\dagger$ $[M_\odot]$ (2)	$\dot{M}_{H_2,OF}{}^\dagger$ $[M_\odot\ yr^{-1}]$ (3)	R_{OF} [kpc] (4)	$v_{OF,avg}$ $[km\ s^{-1}]$ (5)	$v_{OF,max}$ $[km\ s^{-1}]$ (6)	$\log(\tau_{dep})^\dagger$ [yr] (7)	$\log(P_{kin,OF})^\dagger$ $[erg\ s^{-1}]$ (8)	$(\dot{M}_{H_2,OF}v)/(L_{AGN}/c)^\dagger$ (9)	Refs. (10)
IRAS F08572+3915	8.61	1210	0.82	800	1200	6.10	44.39	35	1
IRAS F10565+2448	8.37	300	1.10	450	600	7.42	43.28	40	1
IRAS 23365+3604	8.17	170	1.23	450	600	7.70	43.04	31	1
Mrk 273	8.24	600	0.55	620	900	6.92	43.86	130	1
IRAS F23060+0505	≤9.56	≤1500	≤4.05	(550)	(1100)	≥7.21	≤44.16	≤14	1
Mrk 876	≤9.48	≤1830	≤3.55	(700)	(1700)	≥6.57	≤44.45	≤35	1
I Zw 1	≤7.67	≤140	(0.50)	(500)	(750)	≥7.41	≤43.04	≤6	1
Mrk 231	8.47	1050	0.60	700	1000	6.71	44.21	26	2
NGC 1266	7.93 - 8.66	33–180	0.45	177	362	7.71–6.97	41.51–42.25	54–300	3
M 82	8.08–8.25	12–18	0.80	100	230	7.56–7.38	40.58–40.75	≥650–≥980	4
NGC 1377	7.29–8.03	14–76	0.20	110	140	7.29–6.56	40.73–41.46	34–190	5
NGC 6240	8.61	800	0.65	400	500	6.96	43.61	25	6
NGC 3256	7.34–7.51	11–16	0.50	250	425	8.64–8.48	41.34–41.50	≥560–≥810	7
NGC 3628	7.36–7.54	4.5–6.7	0.40	50	110	8.88–8.70	39.55–39.72	≥690–≥1030	8
NGC 253	6.32–6.50	4.2–6.3	0.20	50	100	7.53–7.35	39.52–39.70	≥870–≥1300	9
NGC 6764	6.52–6.69	3.1–4.7	0.60	170	280	8.41–8.23	40.45–40.63	59–89	10
NGC 1068	7.26	84	0.10	150	250	7.19	41.77	27	11
IC 5063	7.37–8.10	23–127	0.50	300	450	7.48–6.75	41.82– 42.56	7–36	12
NGC 2146	7.68–7.86	14–22	1.55	150	200	7.78–7.61	41.00–41.18	≥3300–≥4900	13

(Cicone et al. 2014)

X-ray UFO

16 AGNs in Cicone et al. (2015)
-> 8 AGNs have sufficient X-ray photons in the archive data (Suzaku, XMM-Newton)
-> 6 AGNs have UFO features with a 90% significance level



$\dot{M}_{wind} = \Omega b r^2 m_p n(r) v_{wind}$

Ω: Solid angle of the wind

b: Filling factor

$\dot{M}_{wind} = \Omega m_p N_H v_{wind} r$

$\dot{M}_{wind} = 2GM_{BH} \Omega m_p N_H (v_{wind})^{-1}$

$\dot{M}_{wind} = 3.2\pi GM_{BH} m_p N_H (v_{wind})^{-1}$

$\dot{P}_{wind} = \dot{M}_{wind} v_{wind}$

Assumption #1

$N_H = \int n(r)dr \sim bn(r)r$

↑ constant n(r) from r=0 to r

$r = r_{min} = 2GM_{BH}/v_{wind}^2$

Assumption #2

↑ Escape velocity = wind velocity

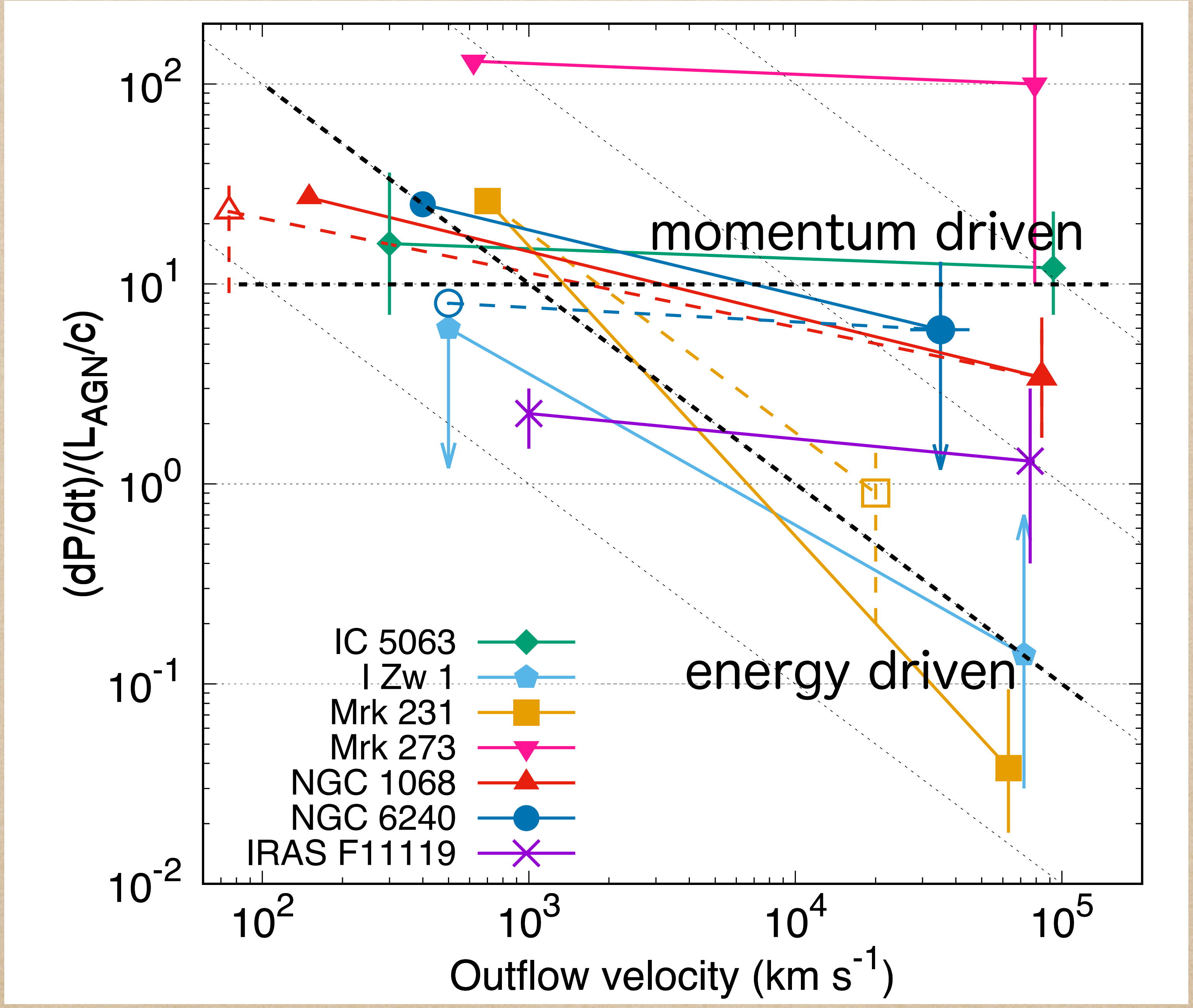
$\Omega/4\pi = 0.4$

Assumption #3

↑ UFO detection rate

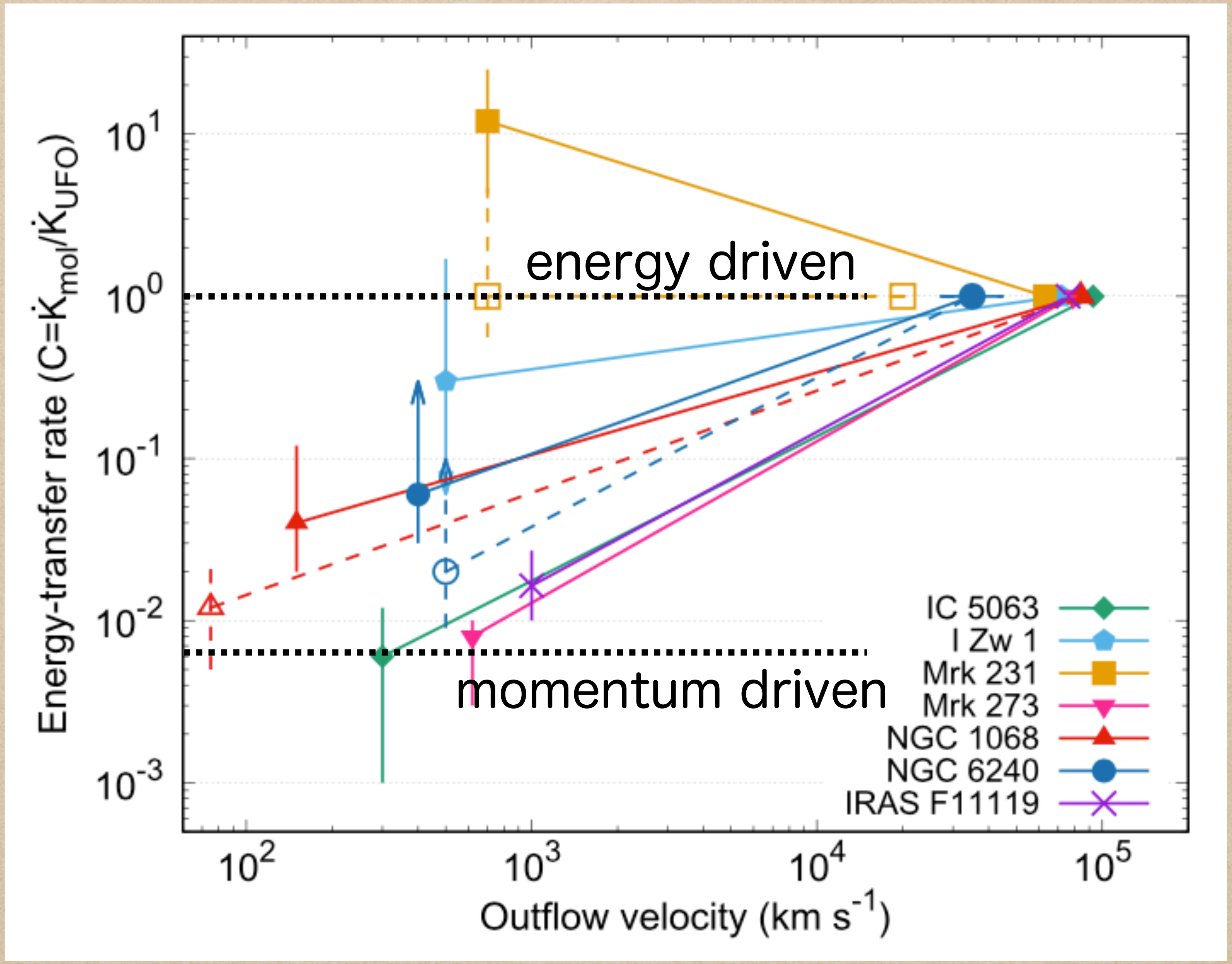
(see Gofford et al. 2015)

momentum flux vs velocity



MM+19

Energy transfer rate



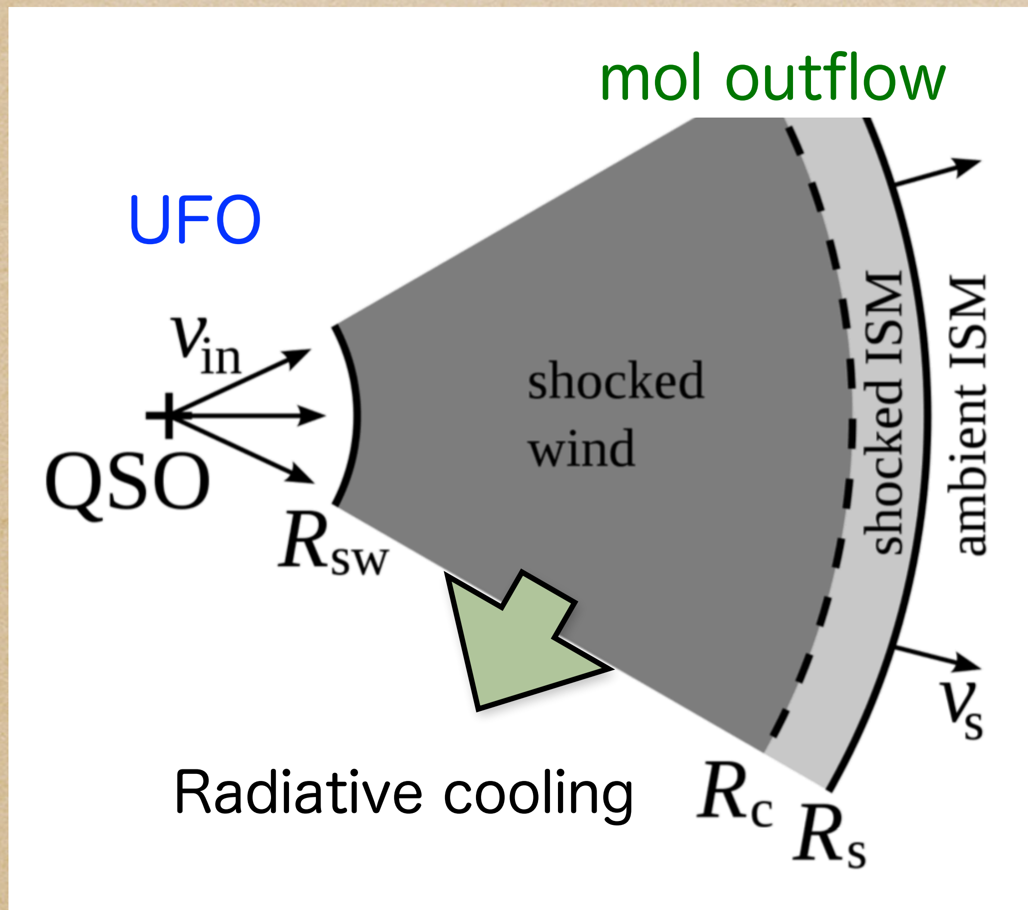
MM+19

C=1 for energy-driven wind

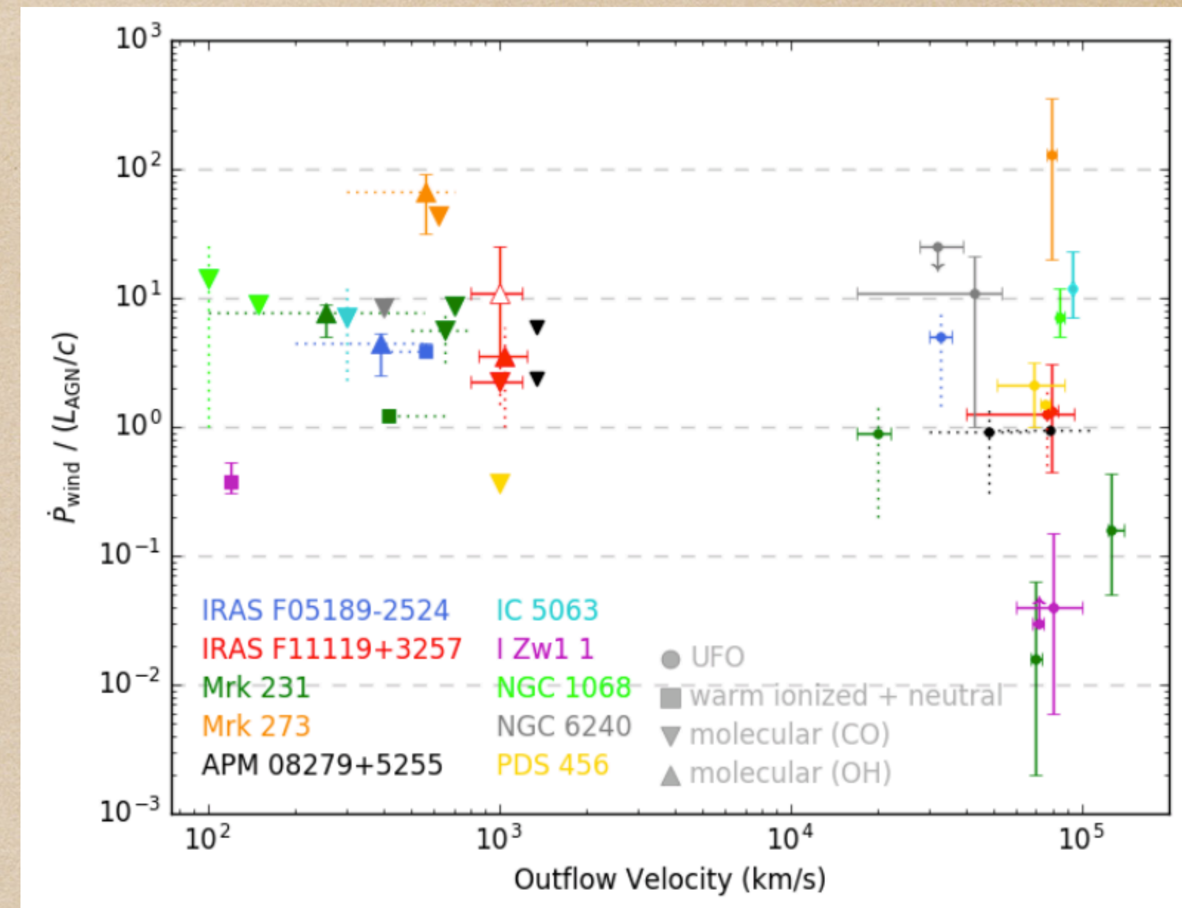
C=(v_{mol}/v_{UFO})~0.007 for momentum-driven wind

Within C=0.007-1 !!

Summary & Future work



Richings et al. 2017



Smith et al. 2019

- The simplest interpretation (UFO sweeps up the ISM and makes the molecular outflow) holds.
- Future work
  - Increasing samples (IRAM/NOEMA, ALMA...)
  - Conflicting with the theoretical studies: "Momentum-driven solutions do not easily occur" (Costa et al. 2020)

私が多波長研究を進めた時の方法（個人差があります）

- 自分がよく知らない方の波長の専門家に頼る
- 手っ取り早く論文の値を使えないか調べる
  - どんな方法で，どんな仮定の下で得られた値で，どの程度の不定性があるかは理解しておかないといけない
- （以後，今やっていること）
- データが足りない分はアーカイブデータを調べて自分で解析をする and/or プロポーザルを出す
- テクニカルな細かいことは専門家に聞いて，自分はサイエンスに集中する，というのが一番効率的に回る気がします

突発天体をクイックに見たいという場合は別で，自分でデータを見れるようにしないといけないと思います。

X線のデータ使いたいんだけど，という人がいれば是非ご連絡を