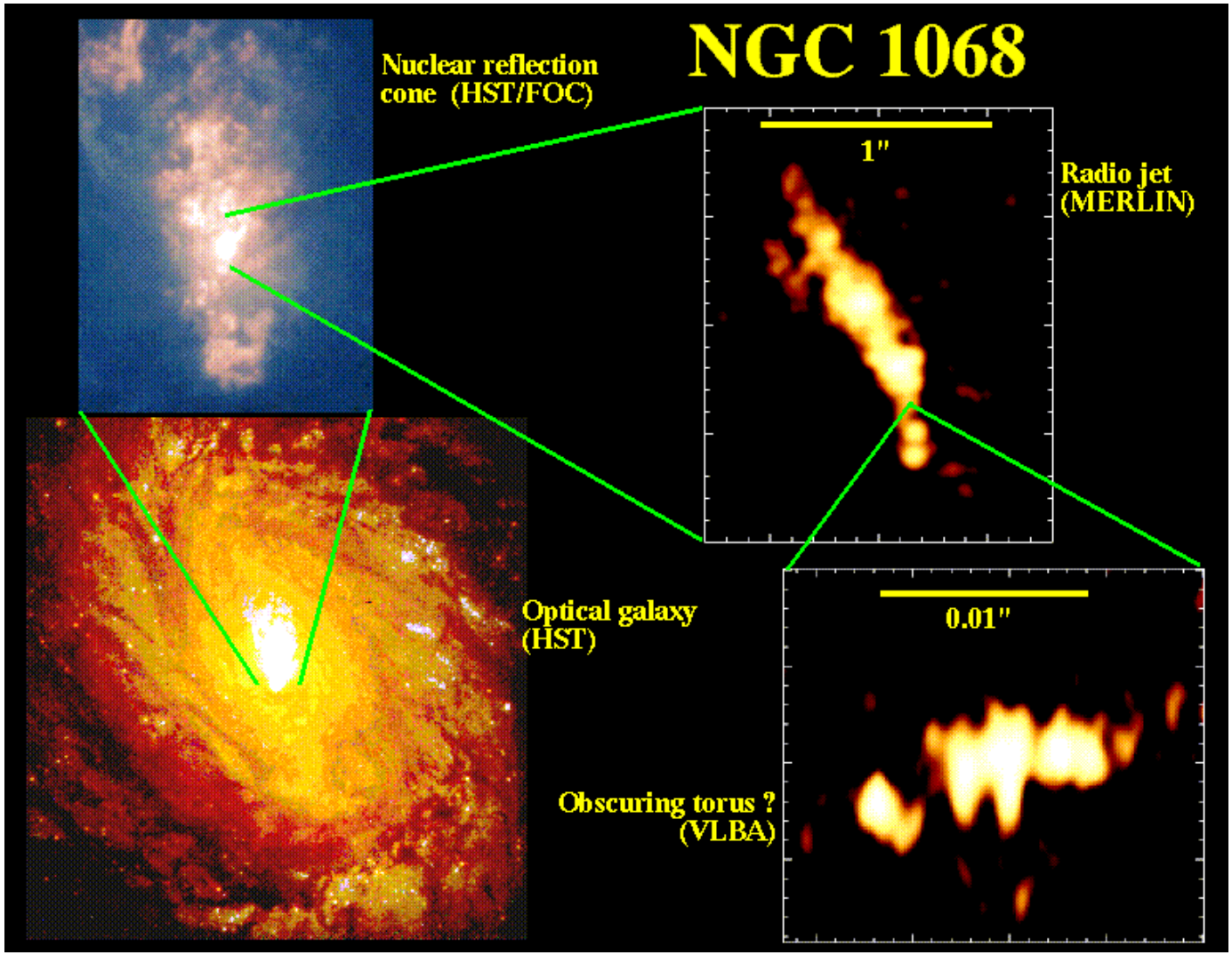
High energy emission and cosmic rays from AGN (wind) feedback

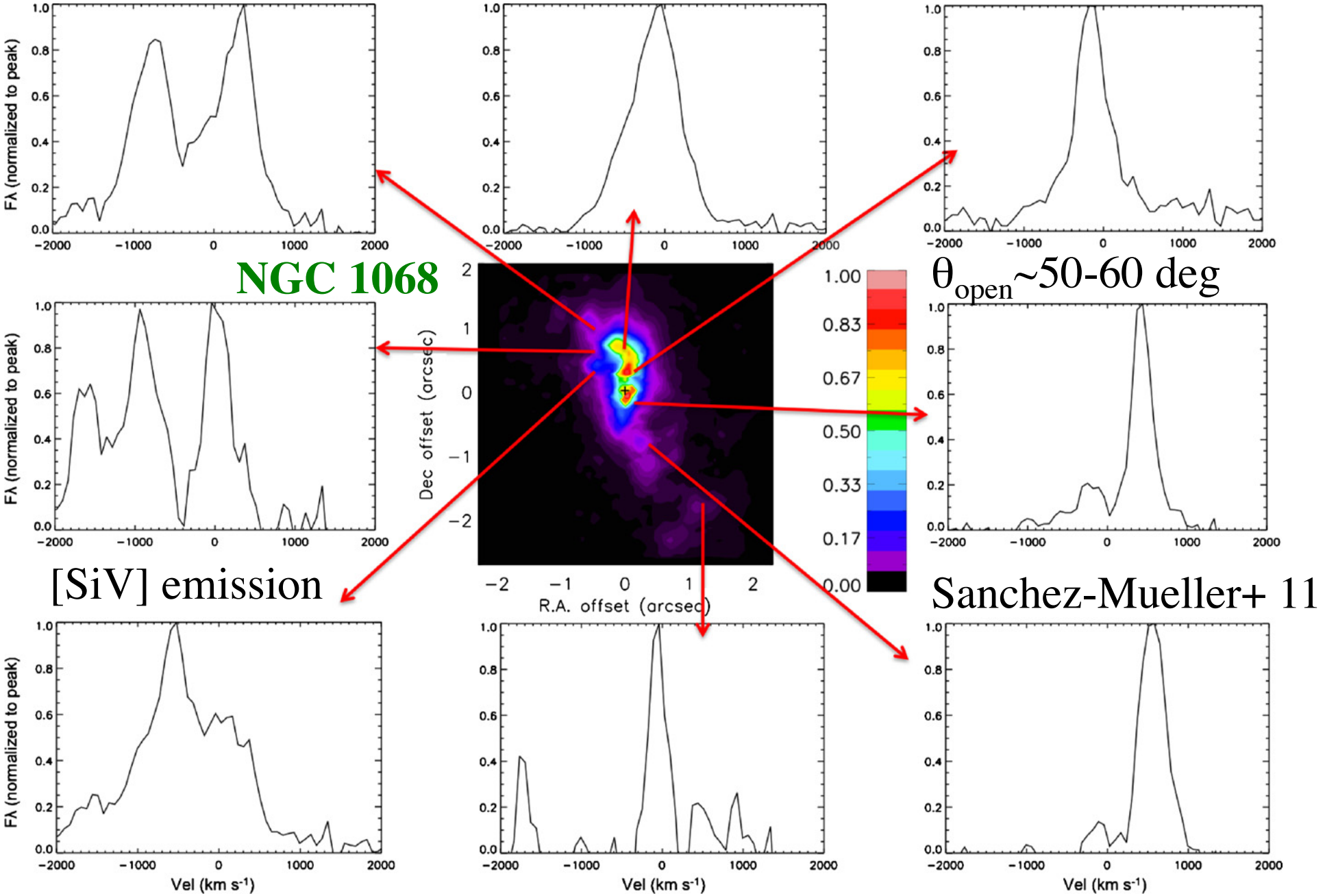
NGC 1068 as AGN-(rather than star-)burst galaxy

Susumu Inoue (RIKEN), Ruo-Yu Liu (MPIK)



AGN winds at subkpc: fast, highly ionized winds

UV/optical/NIR emission/absorption lines -> few 1000 km/s

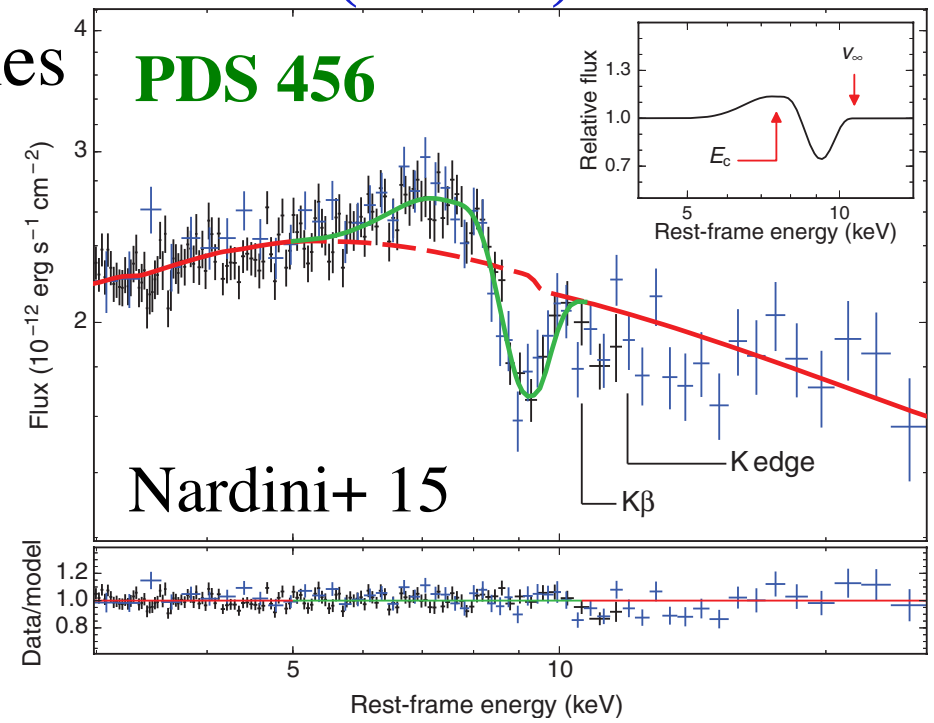


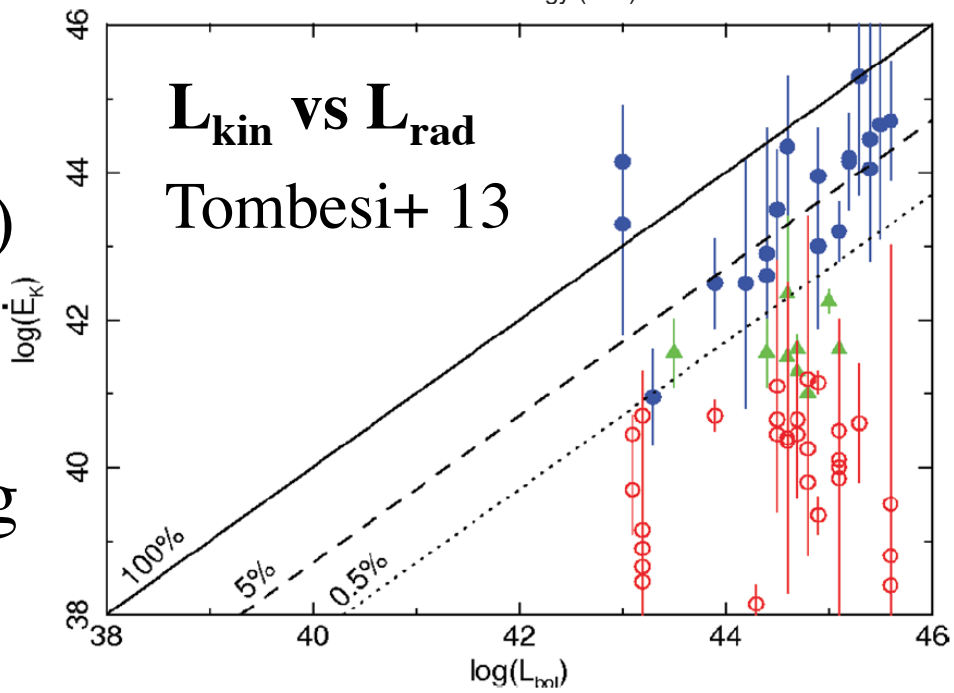
AGN winds at subpc: ultra-fast outflows (UFOs)

blue-shifted X-ray absorption lines

- ~40 % of all AGNs
  both radio-quiet/radio-loud
- fast outflow: v~0.05-0.3c
- highly ionized: Fe XXV/XXVI
- high column density:
  N_H~10^{22}-10^{24} cm^{-2}
- variable: t_{var}>~ks

- R~0.0003-0.03 pc (~10-10^4 Rs)
- M~0.01-1 $\dot{M}_{sun}$/yr
  L_{kin}~0.01-1 L_{Edd}
- broad opening angle ~<100 deg
- independent of relativistic jet

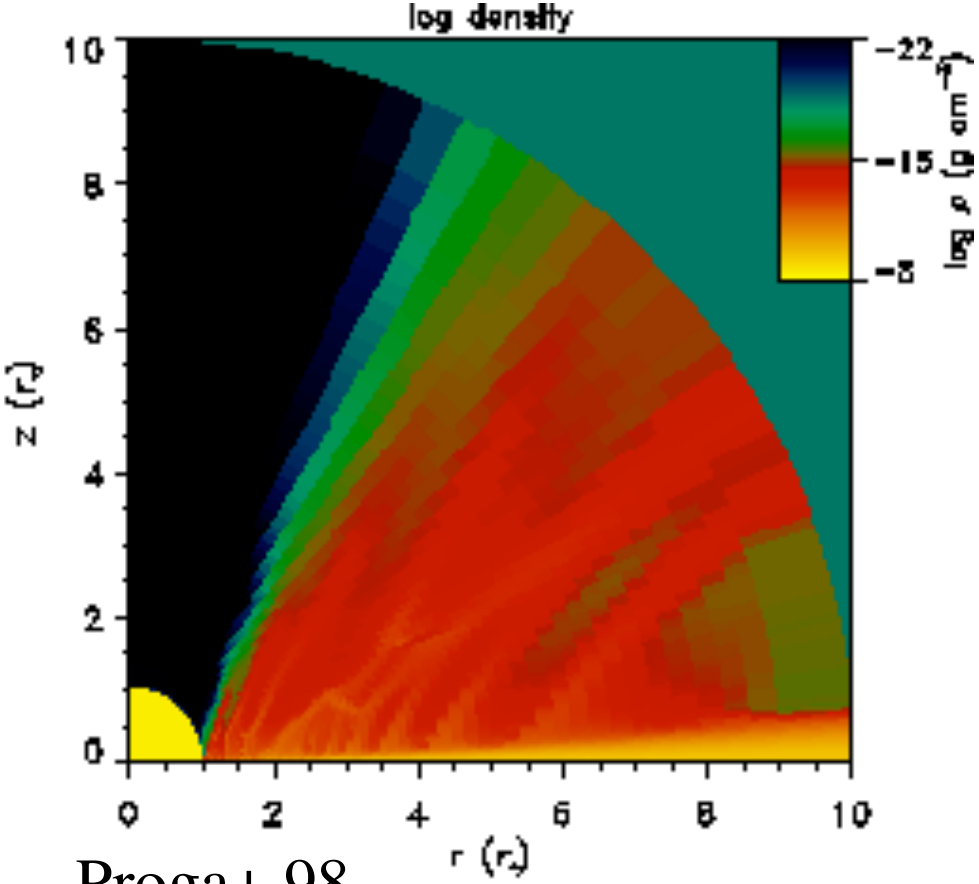




accretion disk winds: formation mechanism(s)

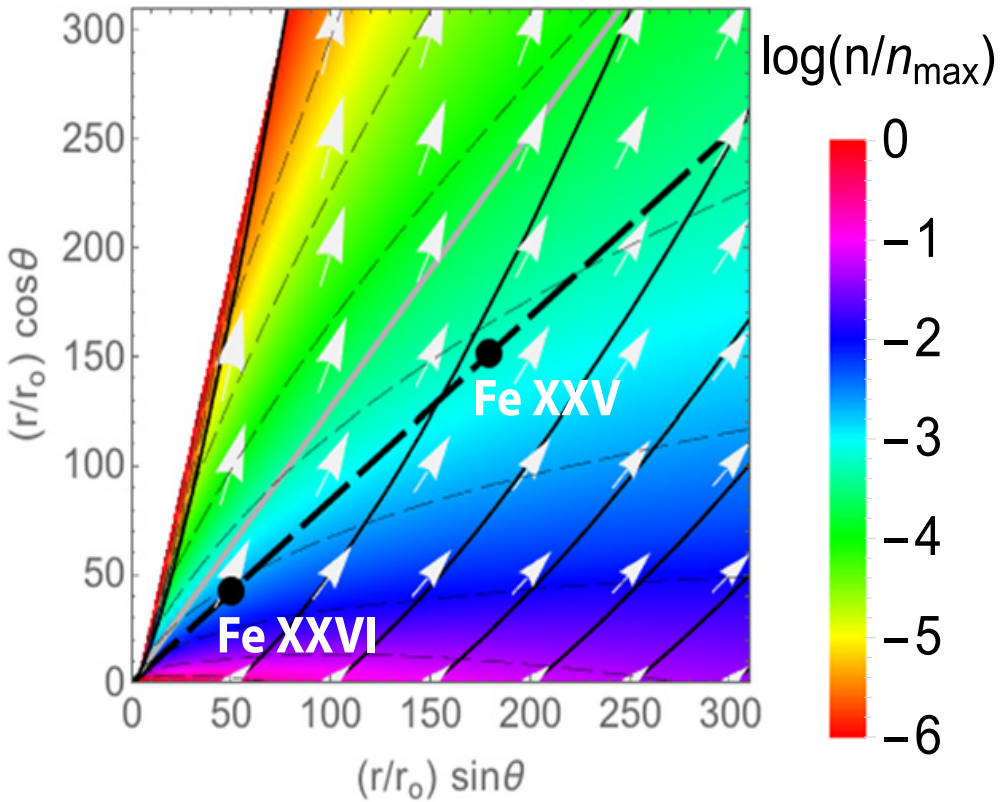
thermal? radiation (continuum or line)? magnetic?
hybrid (thermal+radiation, radiation+magnetic)?...

radiation (line) -driven model



Proga+ 98

MHD+radiation model

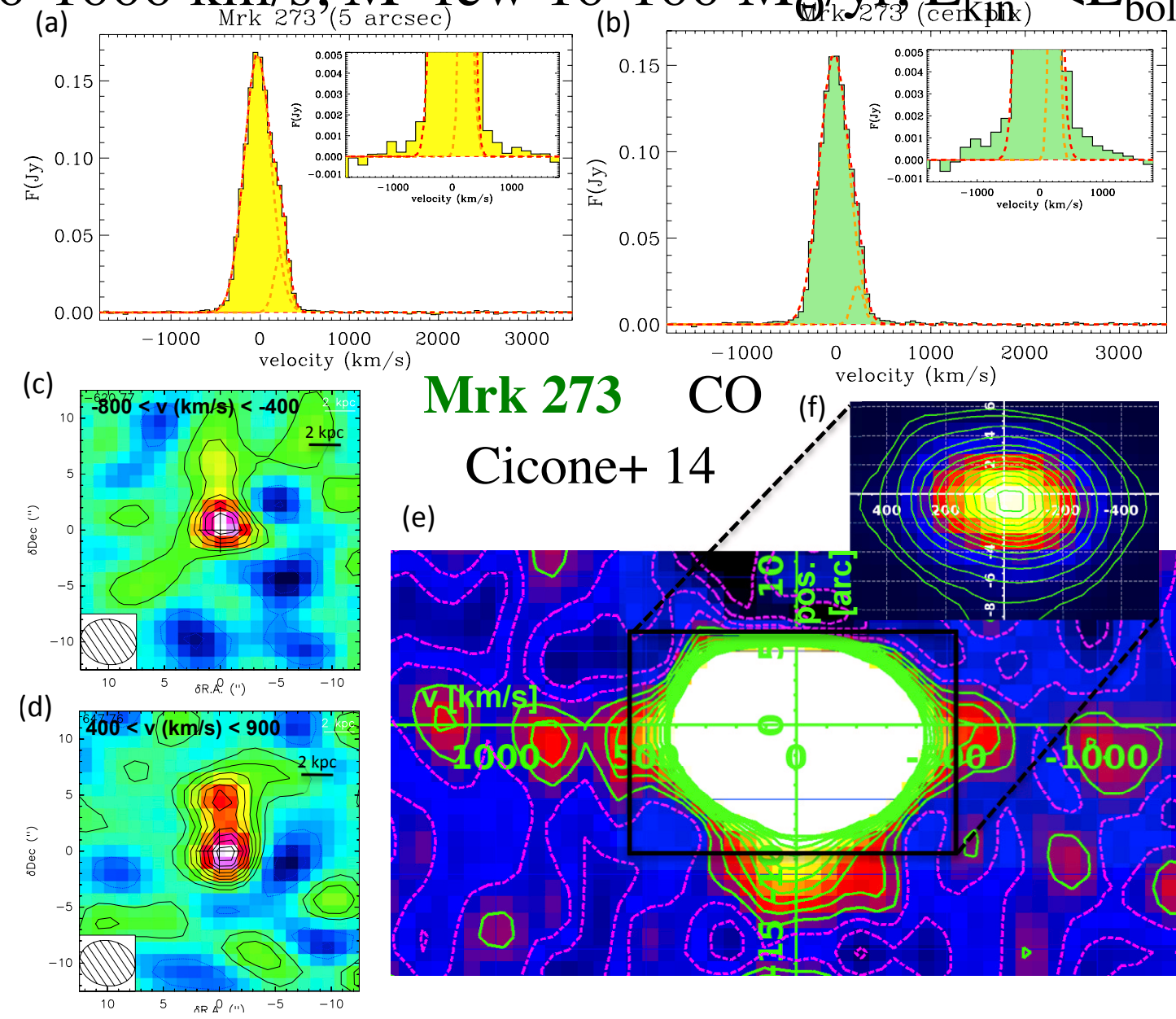


Fukumura+ 15

AGN winds at >~kpc: massive molecular outflows

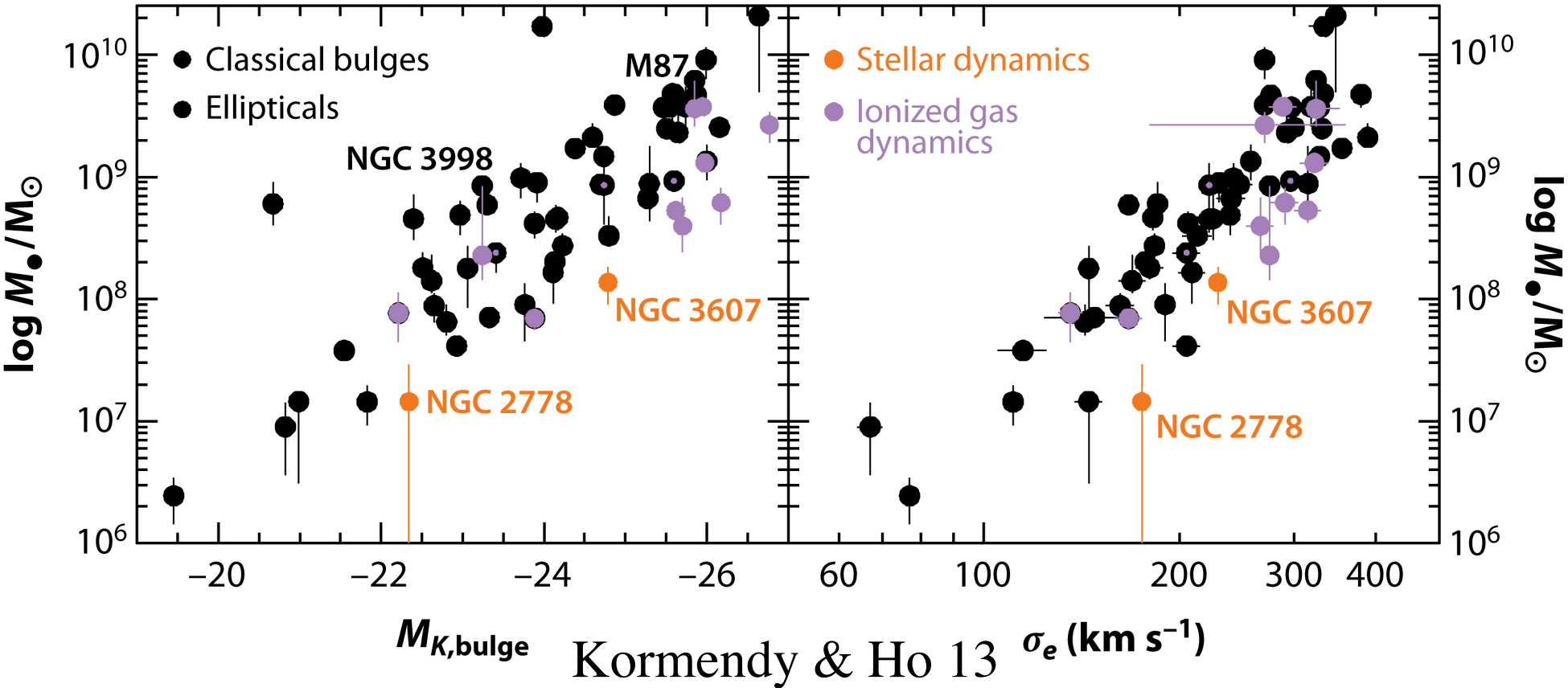
CO, OH etc. emission

-> v~100-1000 km/s, M~few 10-100 $M_\odot$/yr, L_{kin}~<L_{bol}



black hole - galaxy bulge scaling relations

likely consequence of AGN feedback



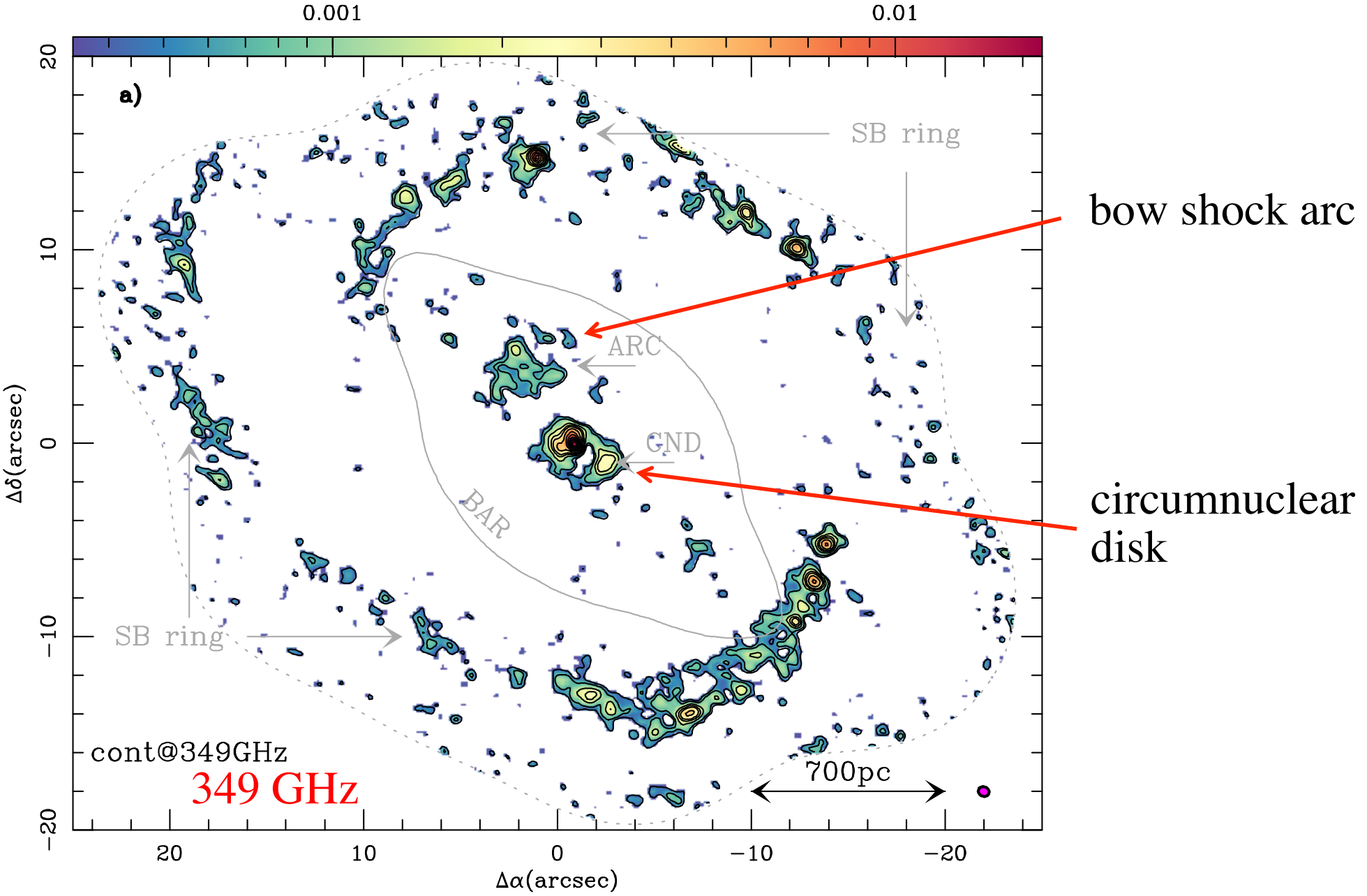
self-regulating mechanical feedback by AGN winds?

Silk & Rees 98, King 03, …

evidence of AGN feedback in action

Garcia-Burillo+ 14

ALMA observations of NGC 1068 D=14 Mpc



bow shock arc

circumnuclear disk

evidence of AGN feedback in action

Garcia-Burillo+ 14

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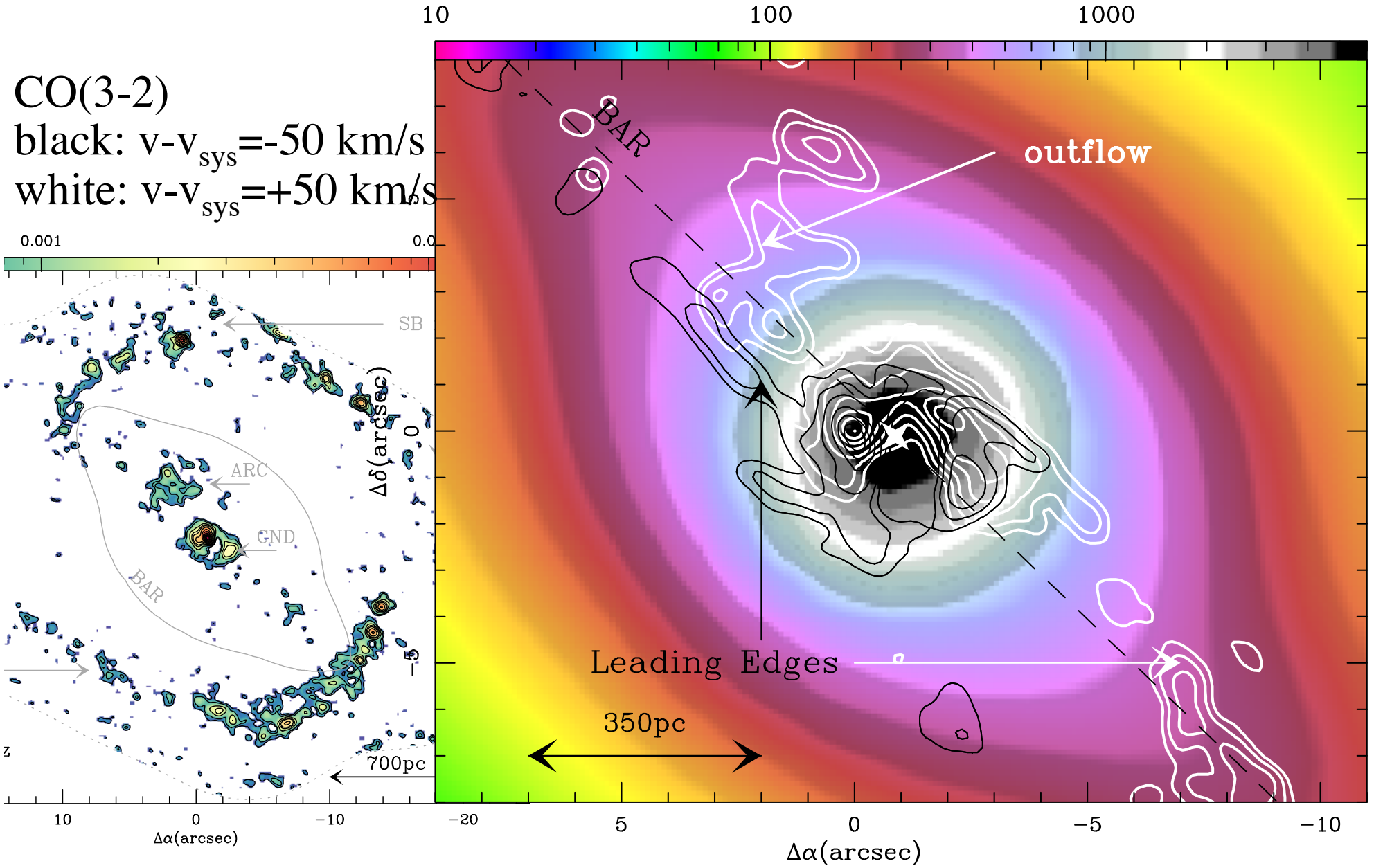

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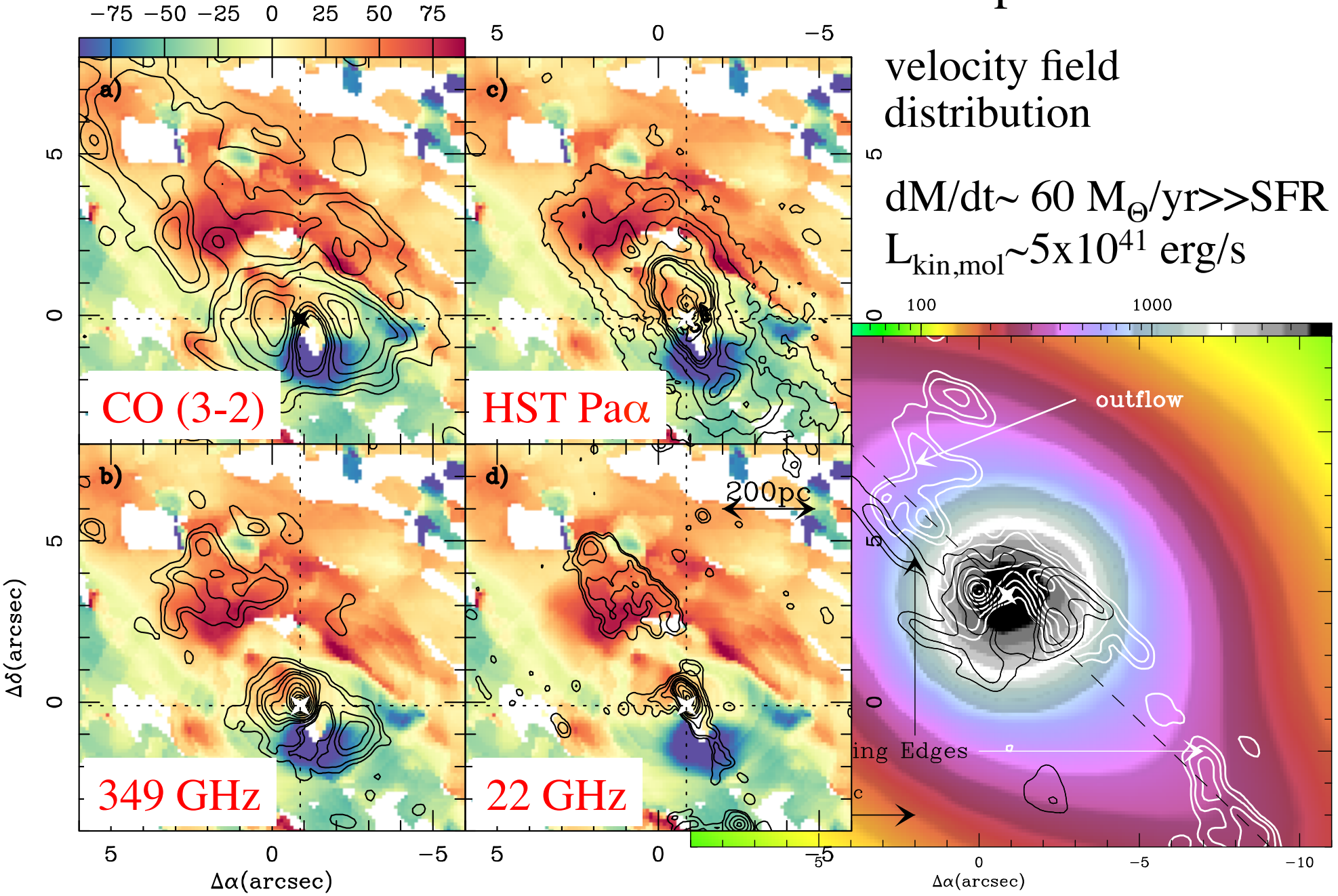


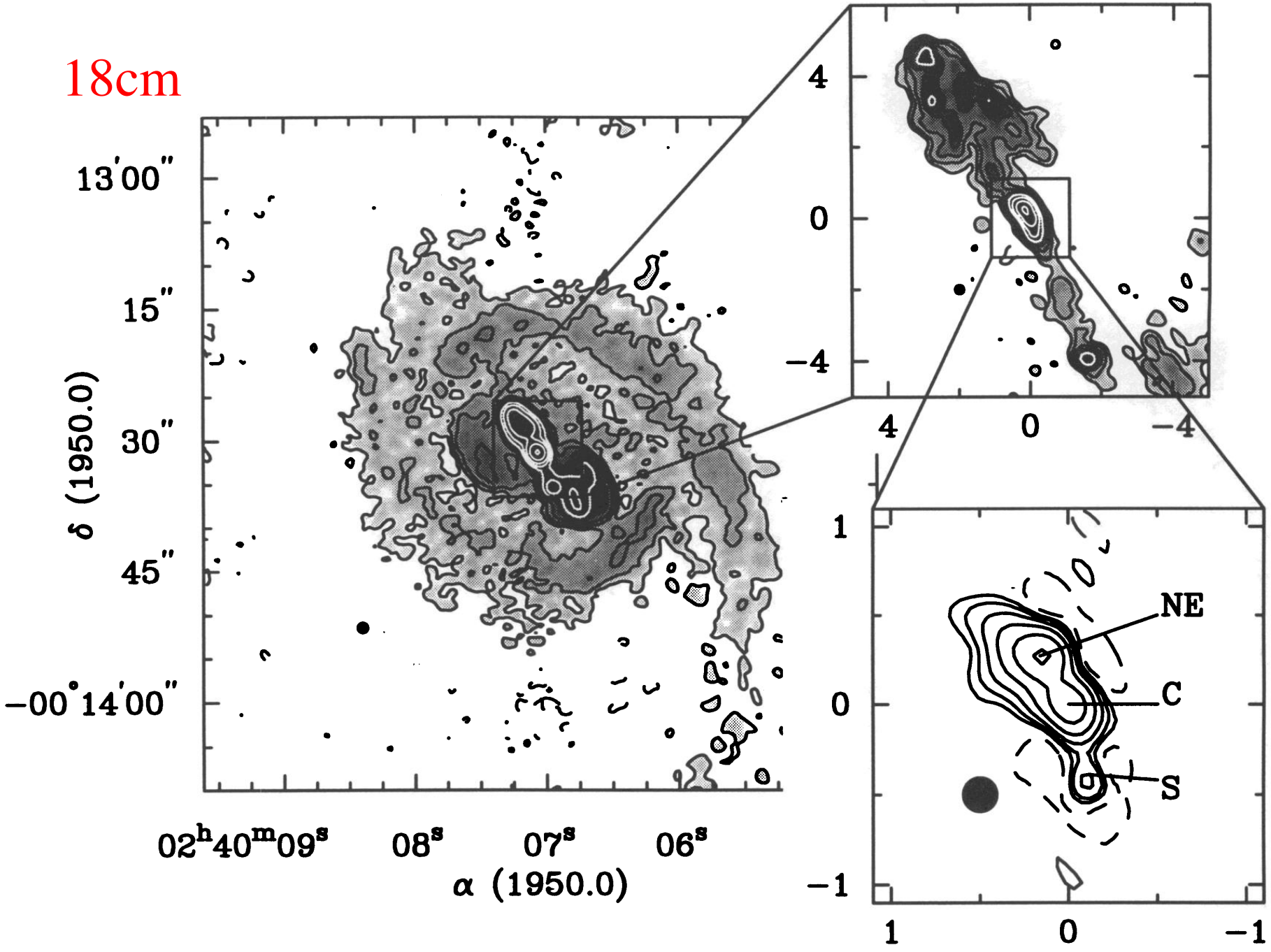
velocity field distribution

$dM/dt \sim 60\ M_\Theta/yr >> SFR$

$L_{kin,mol} \sim 5 \times 10^{41}$ erg/s

kpc-scale radio "jet" in NGC 1068

Gallimore+ 96



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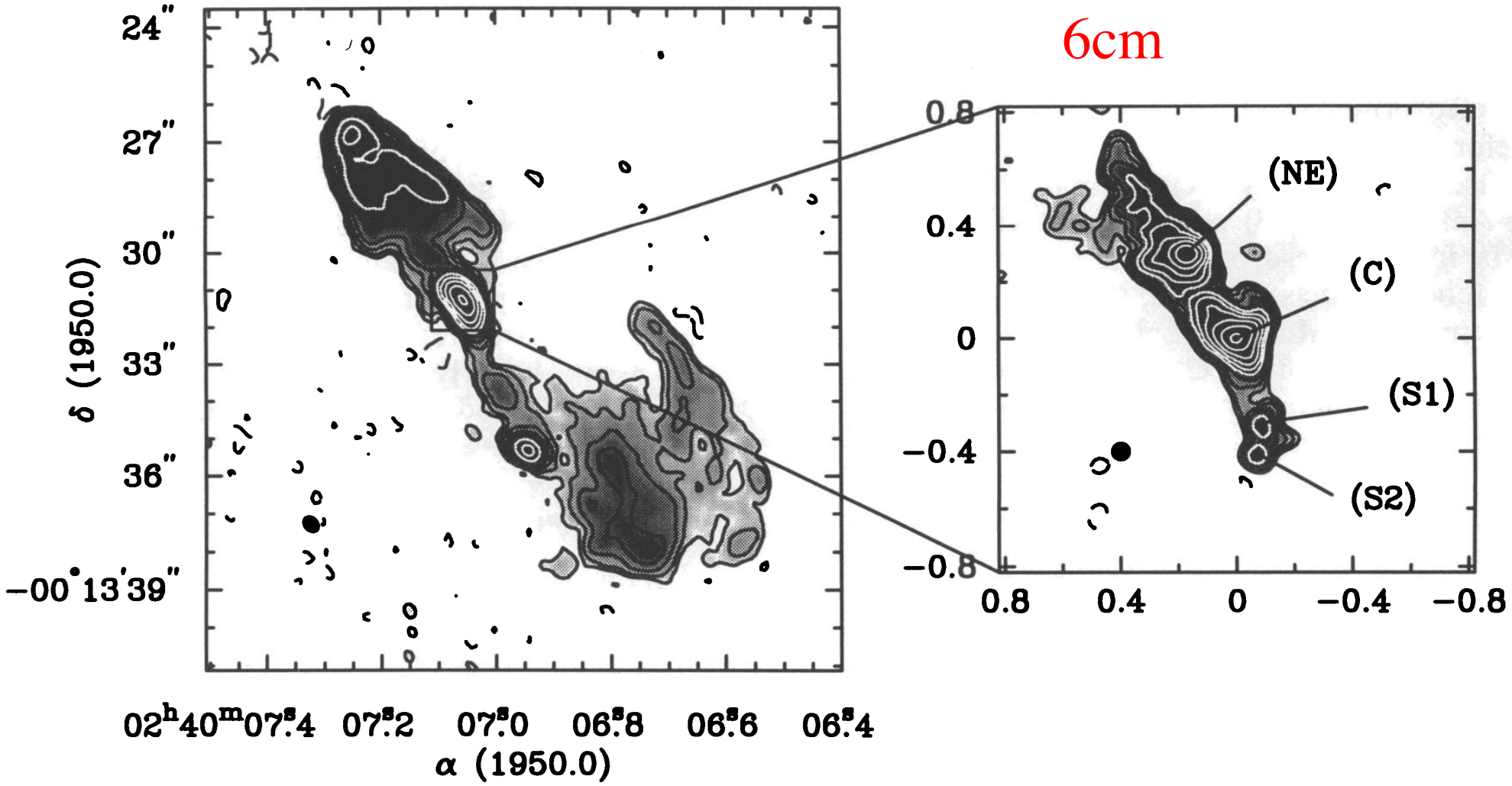


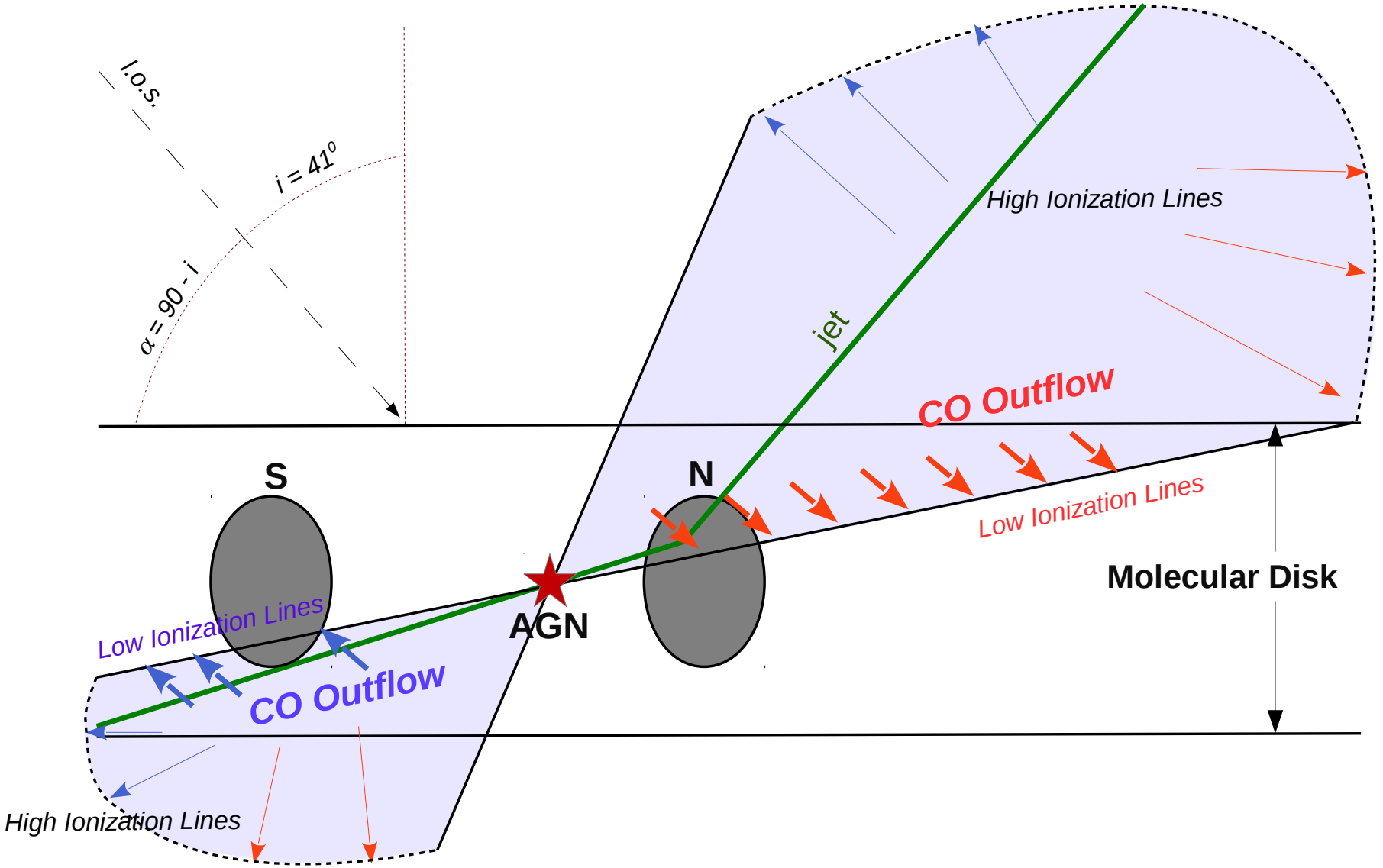
no measurement of velocity or power

estimate from L_{rad}-L_{kin} correlation -> L_{kin}~10^{42}-10^{43} erg/s

evidence of AGN feedback in action

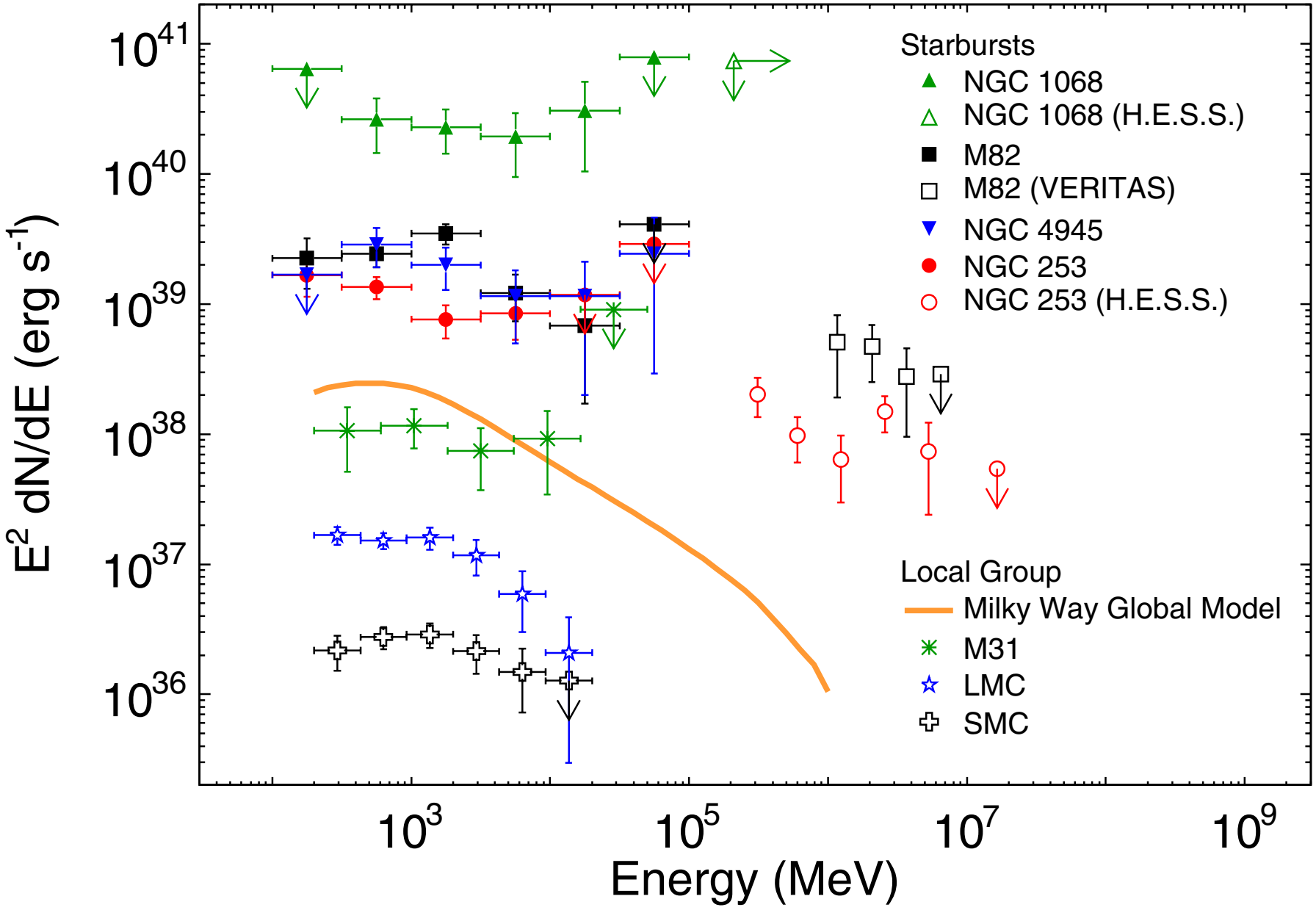
Garcia-Burillo+ 14

ALMA observations of NGC 1068 D=14 Mpc



Fermi observations of "starburst"+normal galaxies

Ackermann+ 12



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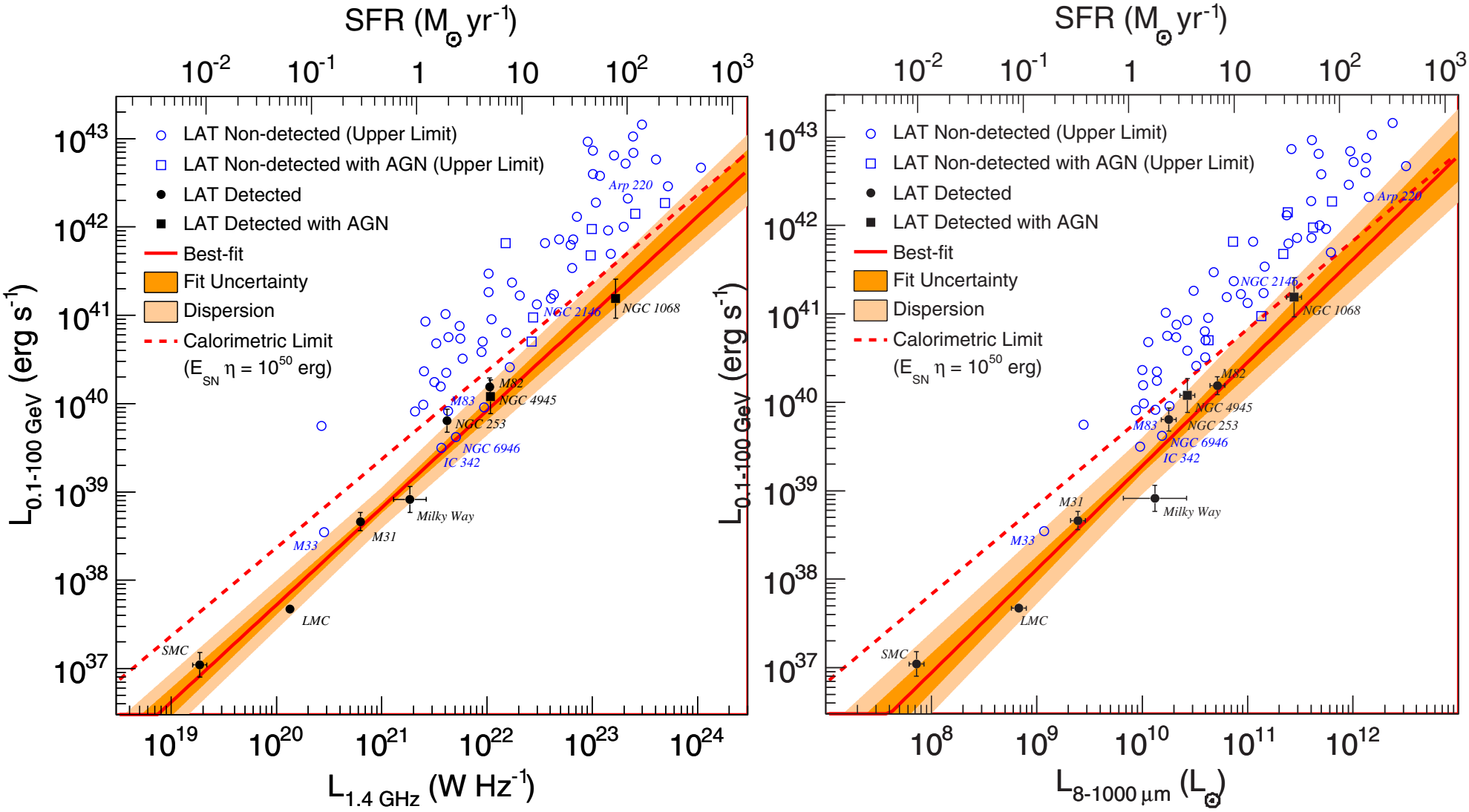
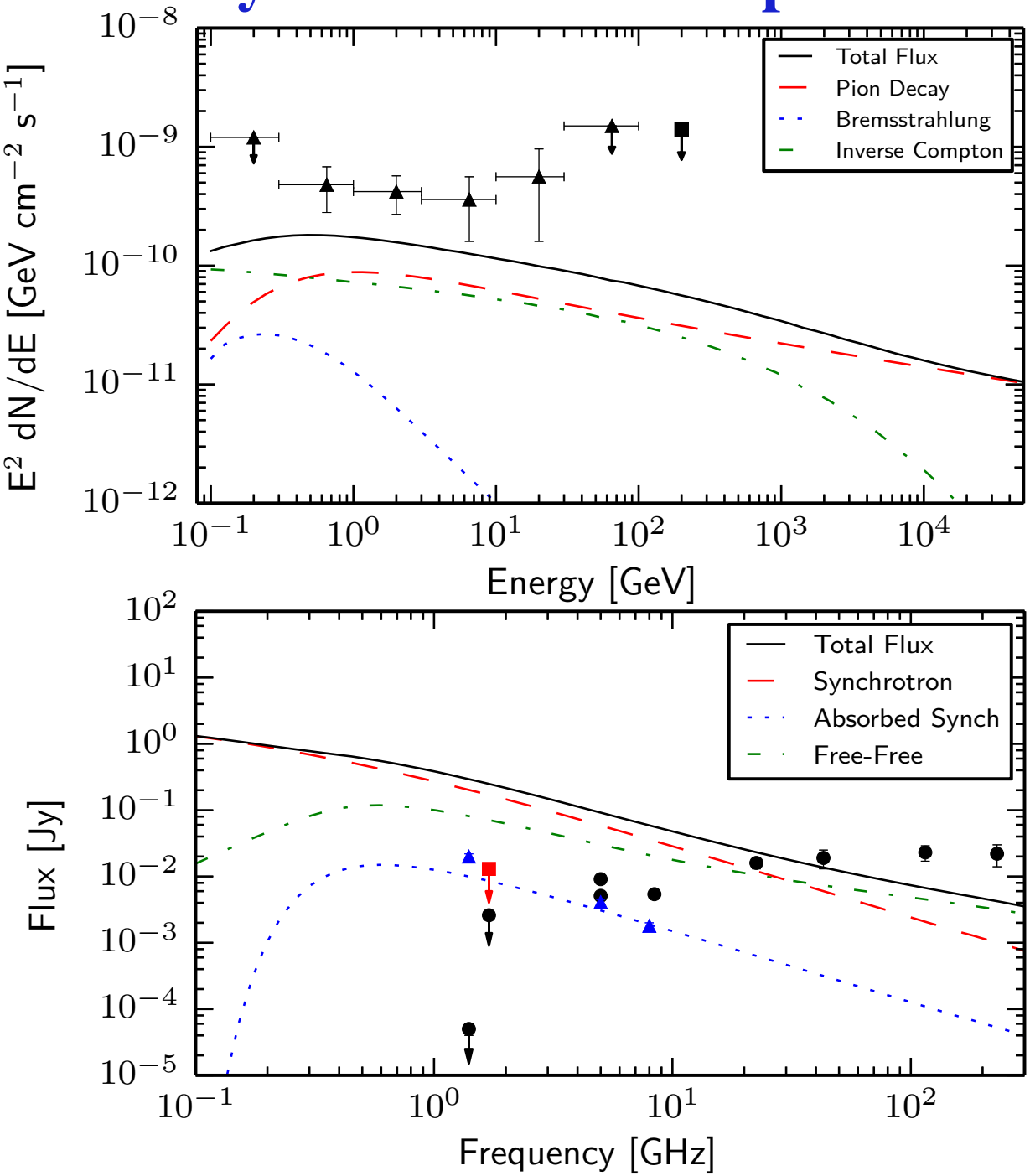


difficulty of starburst interpretation

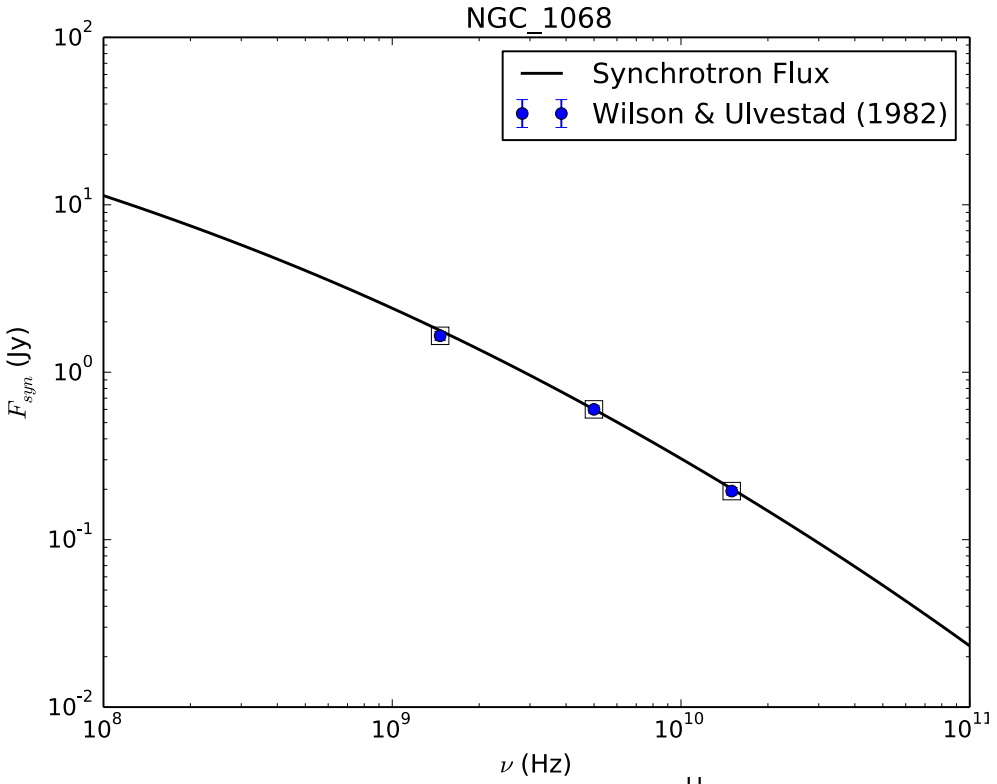
Yoast-Hull+ 14

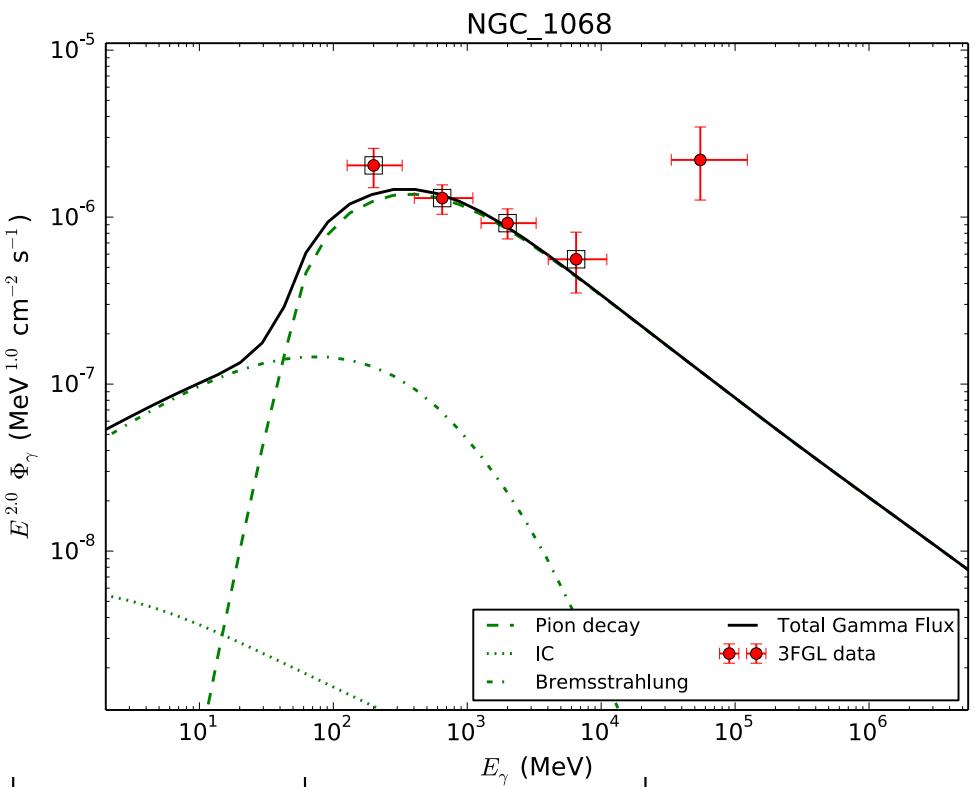


Abstract:
…our starburst model consistently underestimates the observed γ -ray flux and overestimates the radio flux for NGC 1068; these issues would be resolved if the AGN is the primary source of γ -rays.

difficulty of starburst interpretation

Eichman & Becker Tjus
arXiv:1510.03672





	NGC 253	M 82	NGC 4945	NGC 1068
ν_{SN} [yr^{-1}]	4	3	28	649

Abstract:
…Another important result is that supernovae can not be the dominant source of relativistic particles in NGC 4945 and NGC 1068…

wind shocks: electron & proton acceleration

SI & Liu
in prep.

main parameters

$v_{out}, L_{nuc}, n_{ext}$: observed

$L_e, L_p < L_{kin}$: obs. constrained

R_s: few R_g- R_{bulge}

B_s ($\varepsilon_B = B^2/8\pi$ / $L_{kin}/4\pi R^2 v_{out}$), $D_{ext}(E)$

dynamical time $t_{dyn}=R/v_{out}$, $t_{lc}=R_s/c=500$ s

acceleration time $t_{acc} \sim 10 (v_s/c)^{-2} E/ceB$

external radiation field follows Ghisellini & Tavecchio 09

accretion disk+broad line region+dusty torus

electron loss time

$t_{esyn}=3 m_e^2c^3/4\sigma_T u_B E_e$

$t_{eIC}=3 m_e^2c^3/4\sigma_T u_{ph} E_e$ $u_{ph} \sim u_{ext}$

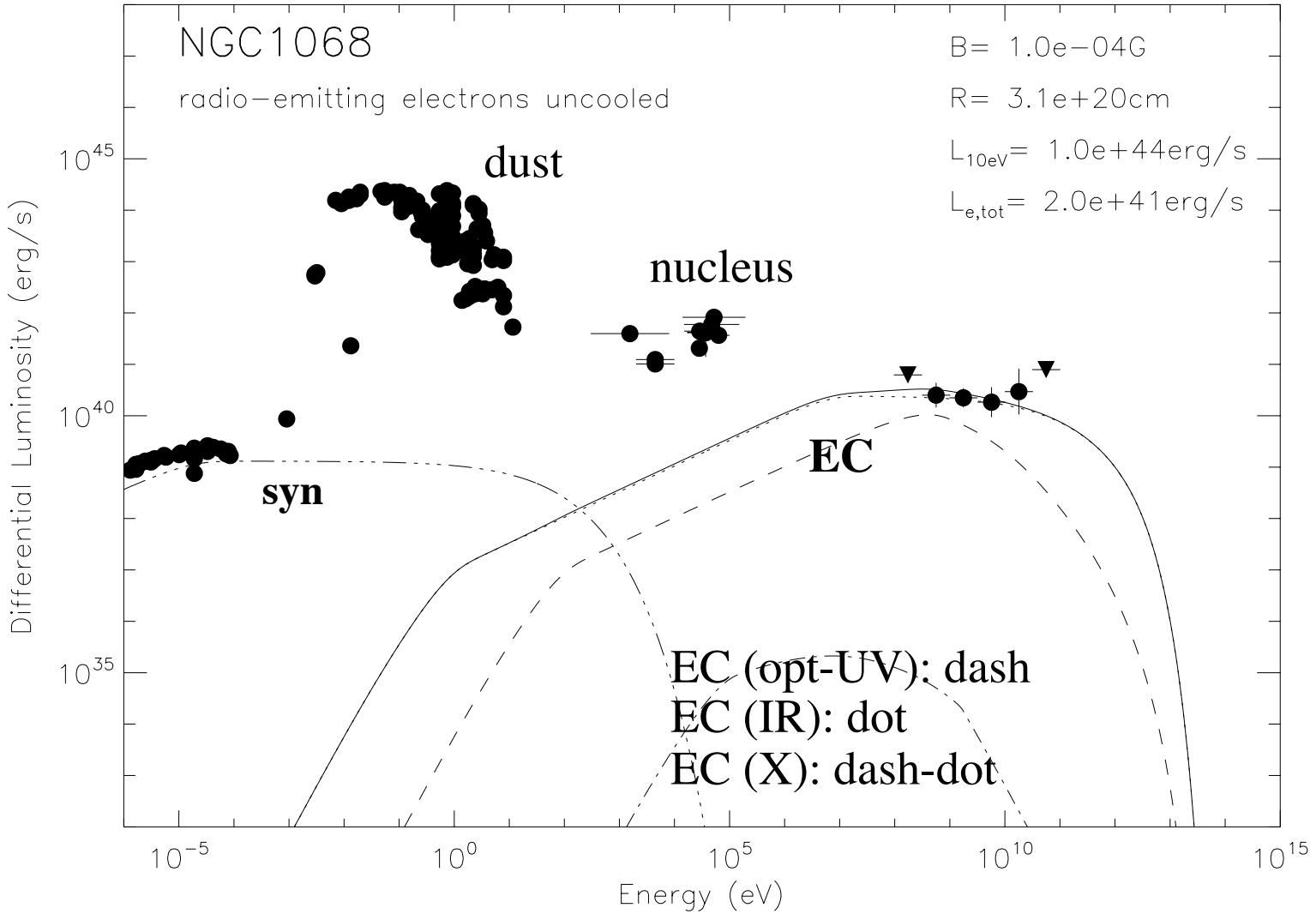
proton loss time

$t_{pp}=(\kappa_{pp}\sigma_{pp}n_p c)^{-1}$

$t_{p\gamma} \propto \int \kappa_{p\gamma}(x)\sigma_{p\gamma}(x)x\, dx \int n_{ph}(x)dx)^{-1}$ $x=h\nu/m_e c^2$

leptonic model R=100 pc, v=1000km/s, B=100μG, p_e=2
$L_e=2\times10^{41}$ erg/s, $L_{nuc}=10^{44}$ erg/s

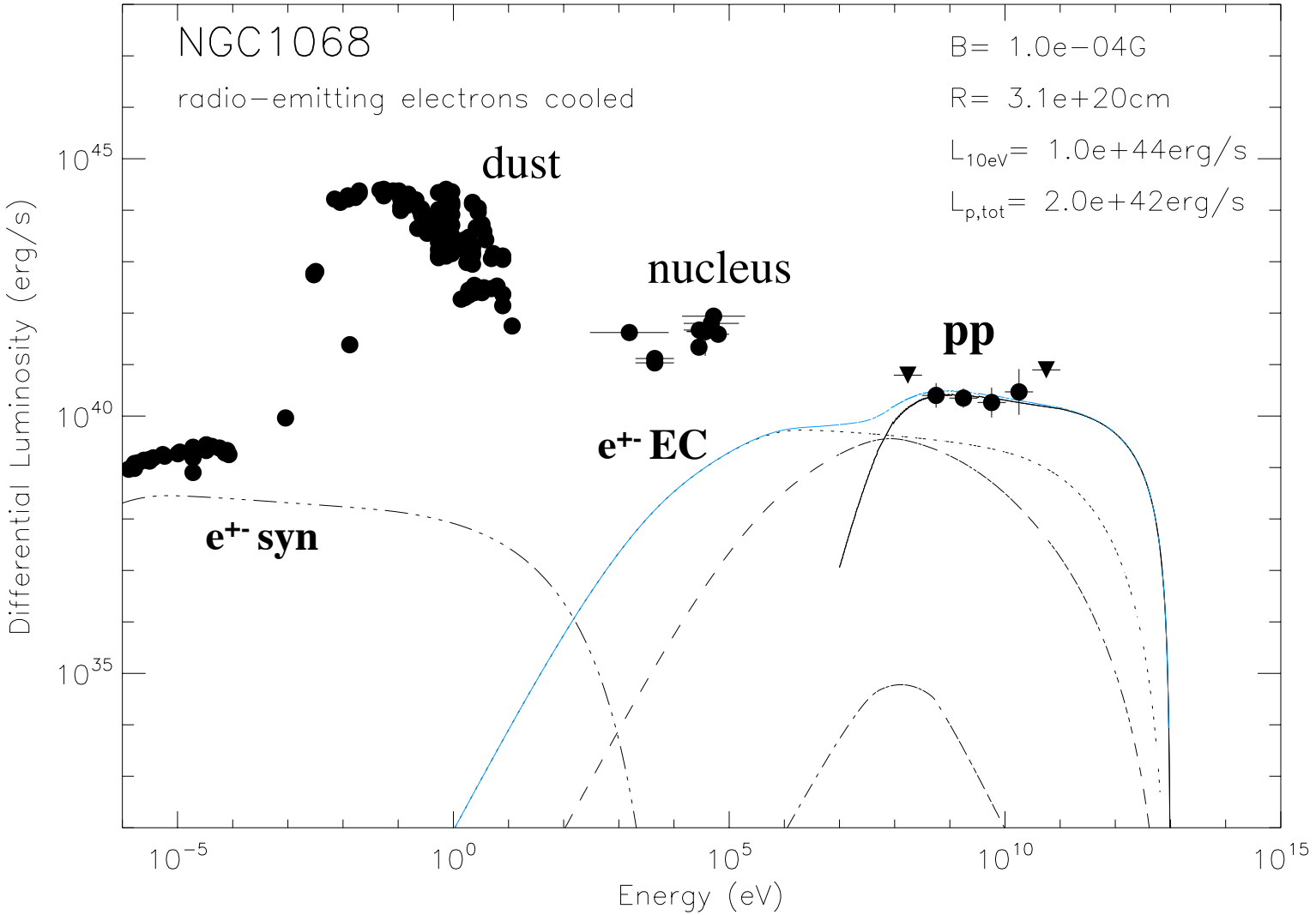
NGC 1068



EC of opt+UV (BLR) dominant over SSC
cutoff at >~300 GeV

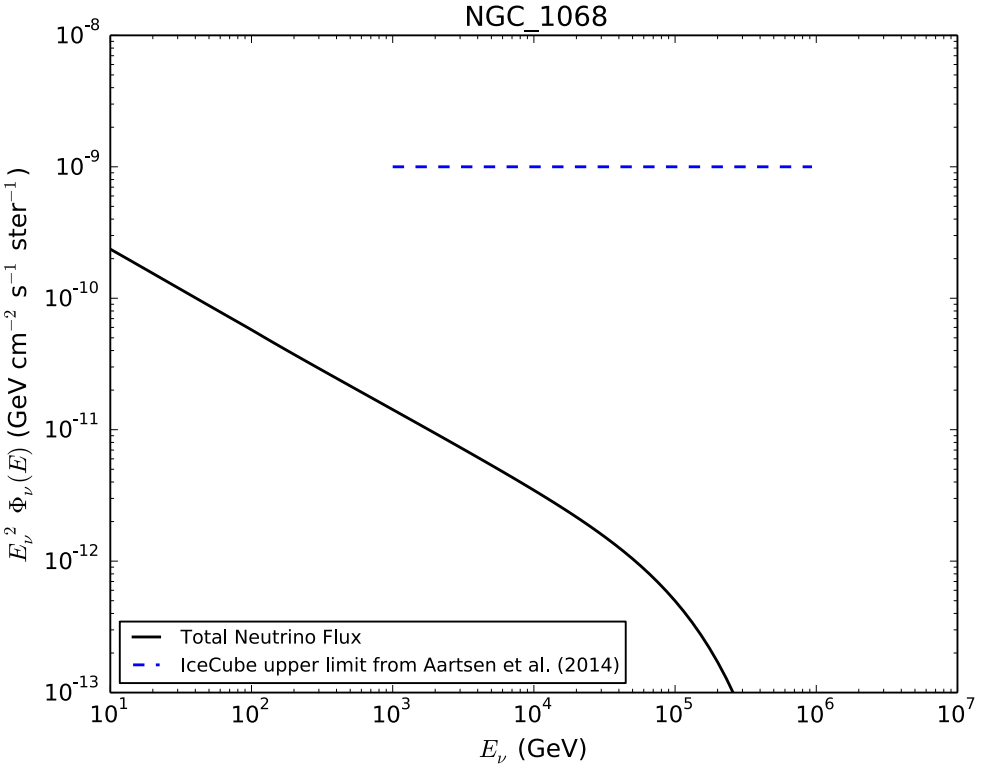
hadronic model R=100 pc, v=1000km/s, B=100μG, p_p=2.2
$L_p=2x10^{42}$ erg/s, $L_{nuc}=10^{44}$ erg/s

NGC 1068
$n_{ext}=250cm^{-3}$
$D_{ext}(GeV)=10^{27}$ cm^2/s



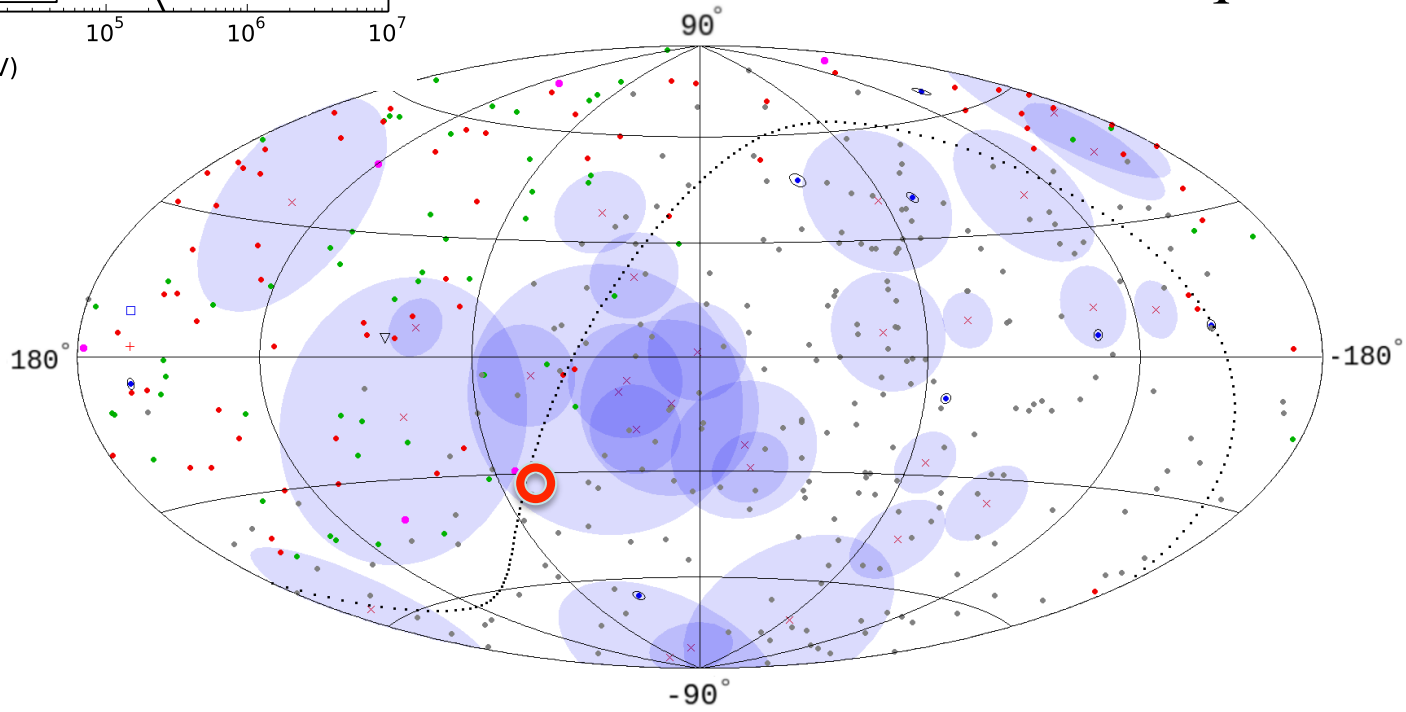
π^0 bump, hard extension to ~10 TeV -> CTA!
syn+EC from secondary e+- important

UHECR, neutrinos?



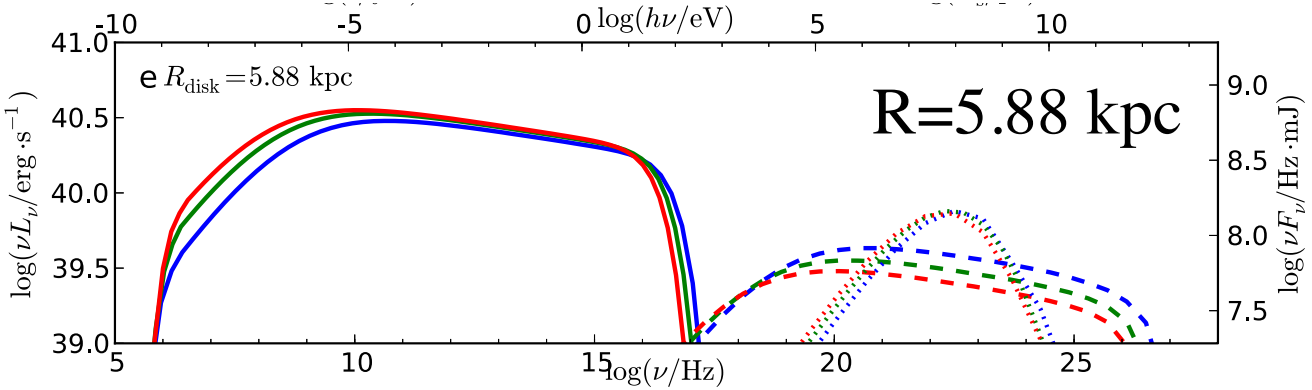
Eichman & Becker Tjus

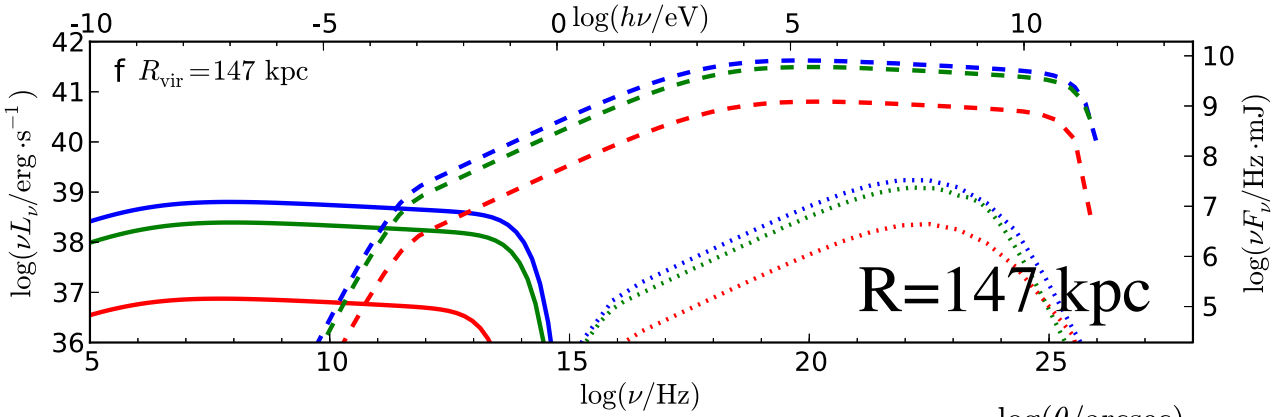
Moharana & Razzaque 15



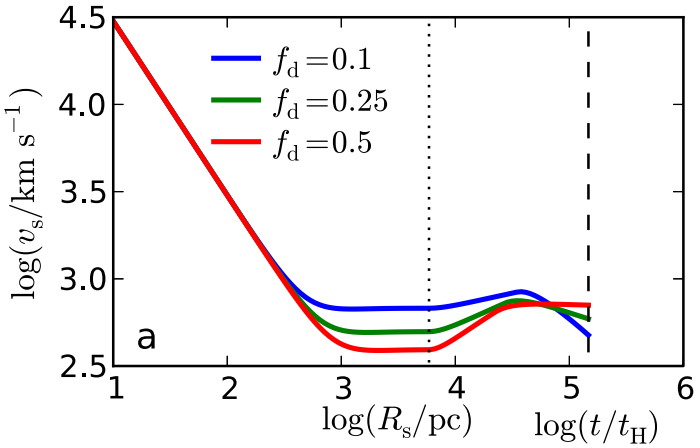
observable signature of AGN wind feedback

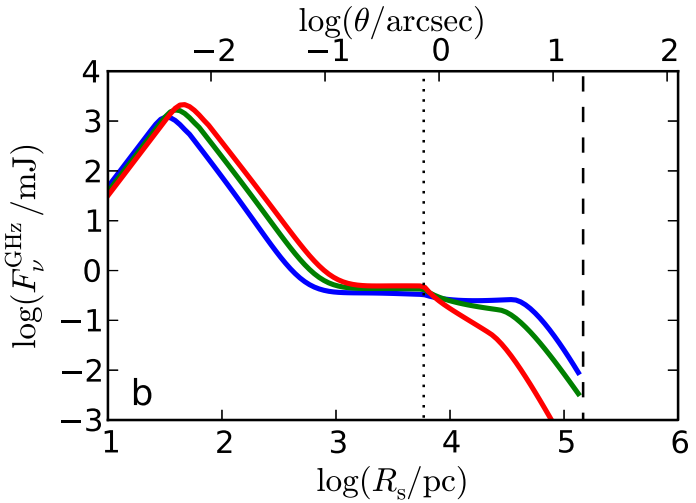
Wang & Loeb 15 also Nims+ 15





z~1
radio, X-ray observable
by SKA, Athena
->
probe of SMBH feedback in action





identifiable with radio emission of radio-quiet quasars?

Zakamska & Green 14

summary AGN feedback and particle acceleration

- widespread existence of fast, powerful, baryonic(ionic) winds in AGN, independent of relativistic jets
- likely to provide important feedback onto host galaxy gas directly observed in some nearby objects like NGC 1068
- GeV (+radio) observed from NGC 1068: starburst interpretation difficult
- interpretation plausible in terms of particle acceleration via AGN wind (or jet) feedback (interaction with host gas) either leptonic or hadronic feasible -> discriminate with CTA
- new type of particle accelerator: search for other similar objects warranted
- new perspective on observing the effects of AGN feedback