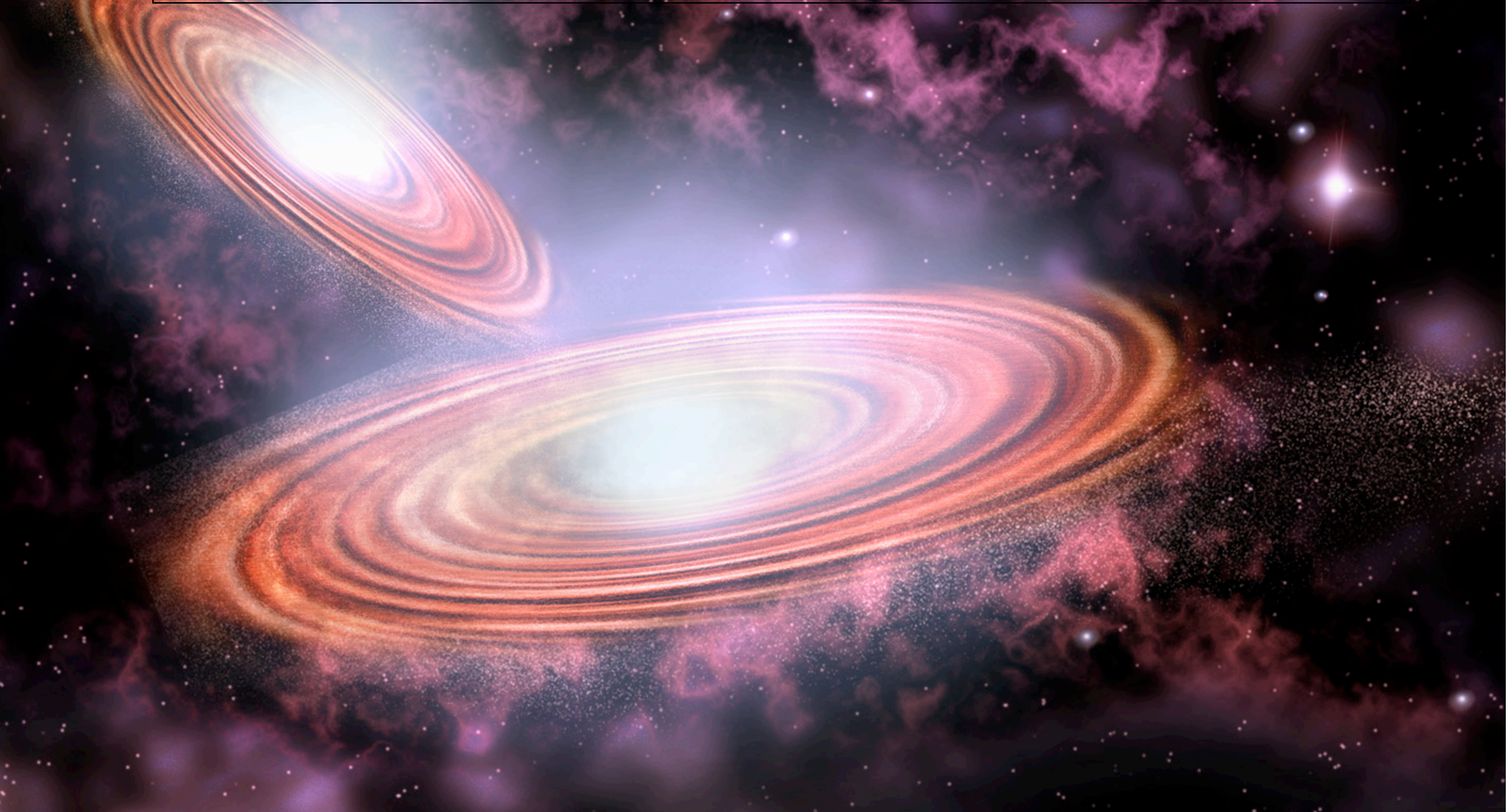
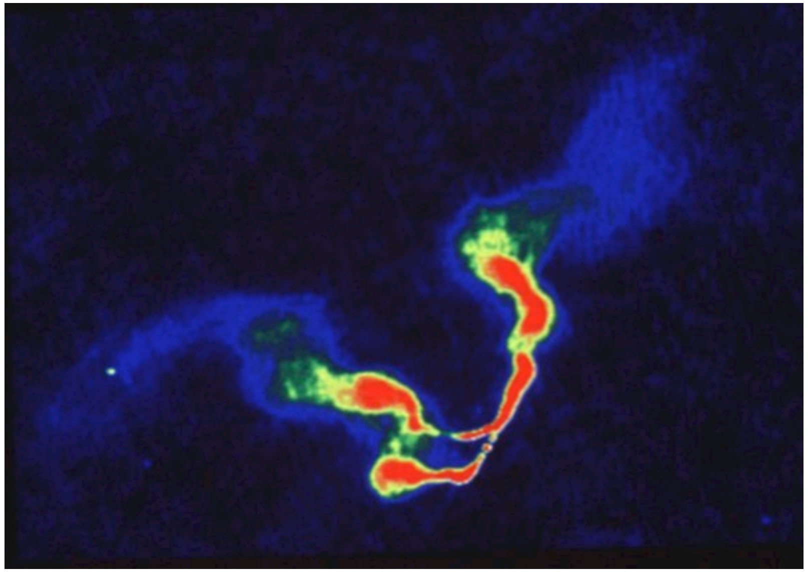
The BLR Profile Signature of a Binary BH

Ari Laor & Yohai Meiron

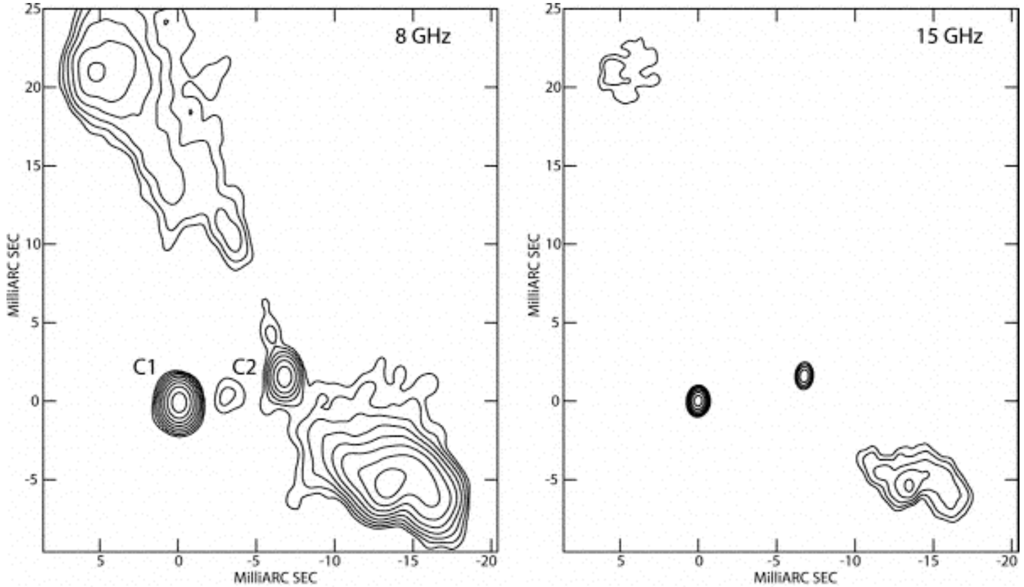


Evidence for Binary BHs

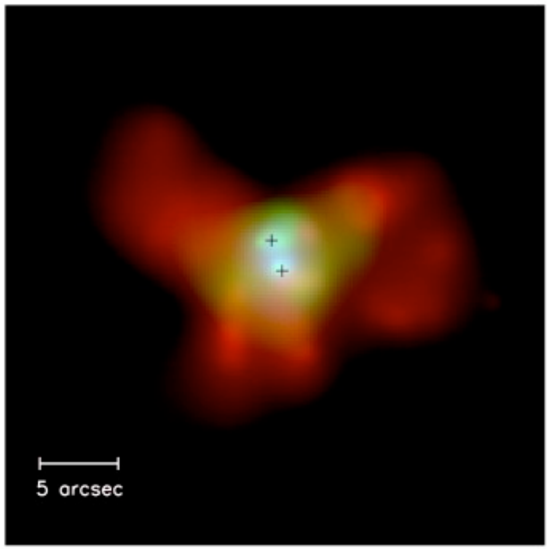
3C 75



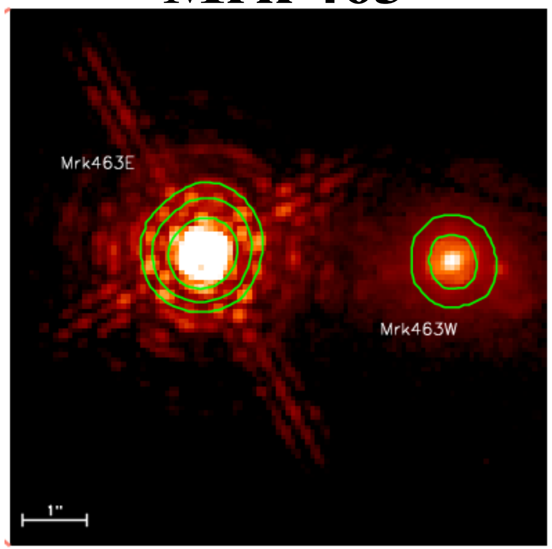
0402+379



NGC 6240



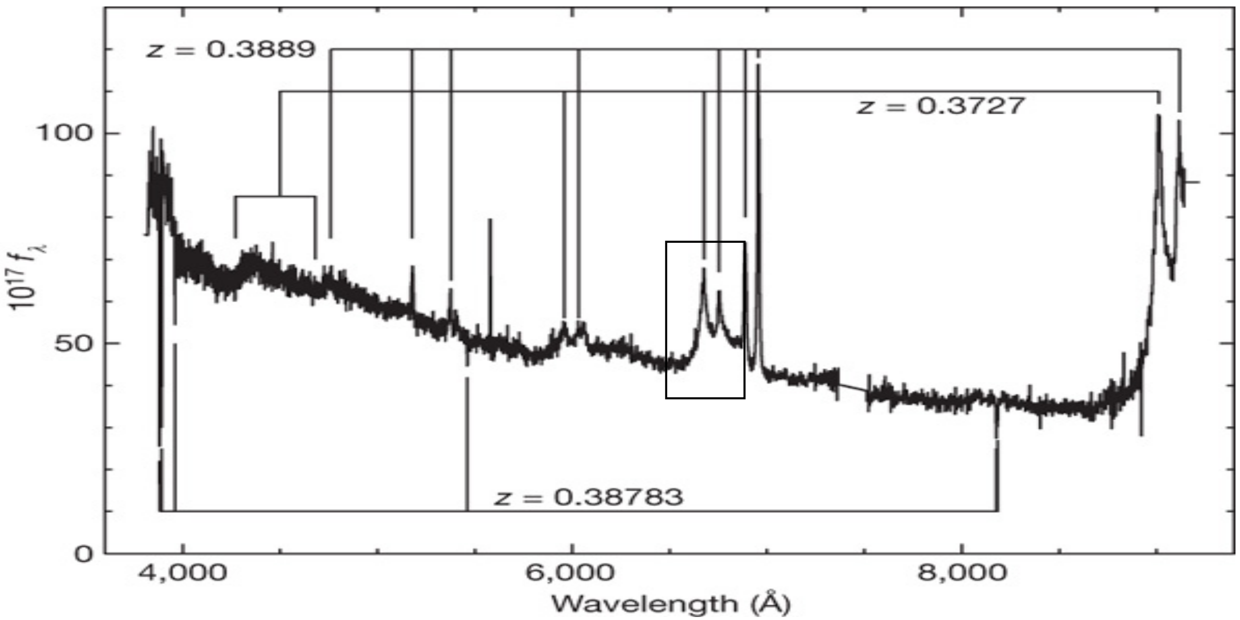
Mrk 463



A new compact binary BH revealed?

(March 2009)*Nature*

A candidate sub-parsec supermassive binary black hole system **Todd A. Boroson & Tod R. Lauer**



The **BLR profile** reveals a compact 0.1 pc massive binary BH

ΔV=3500 km/s, FWHM(r)=6000 km/s, FWHM(b)=2400 km/s

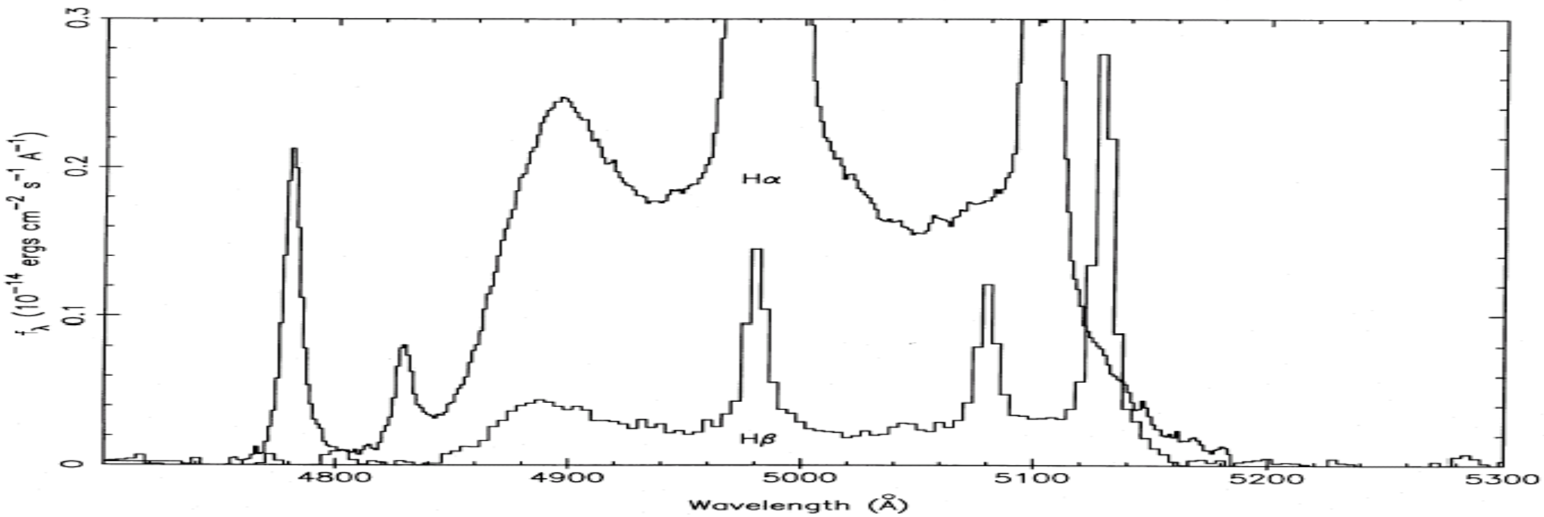
⟶ M(r)=$10^{8.9}$, M(b)=$10^{7.3}$ M_{sun}

Actually an old idea

A test of the massive binary black hole hypothesis: Arp 102B

J. P. Halpern & Alexei V. Filippenko

Nature 331, 46 - 48 (1988)



The H-alpha line profile of Arp 102B has been measured for 5 yr without detecting any change in velocity.

Compact binary massive BH **ruled out**.

The rotating frame potential in a binary system

At the L_1 point $M_1/R_1^2=M_2/R_2^2$

Therefore $R_1/R_2=\sqrt{(M_1/M_2)}$

since $\sigma^2=GM/R$ near each BH

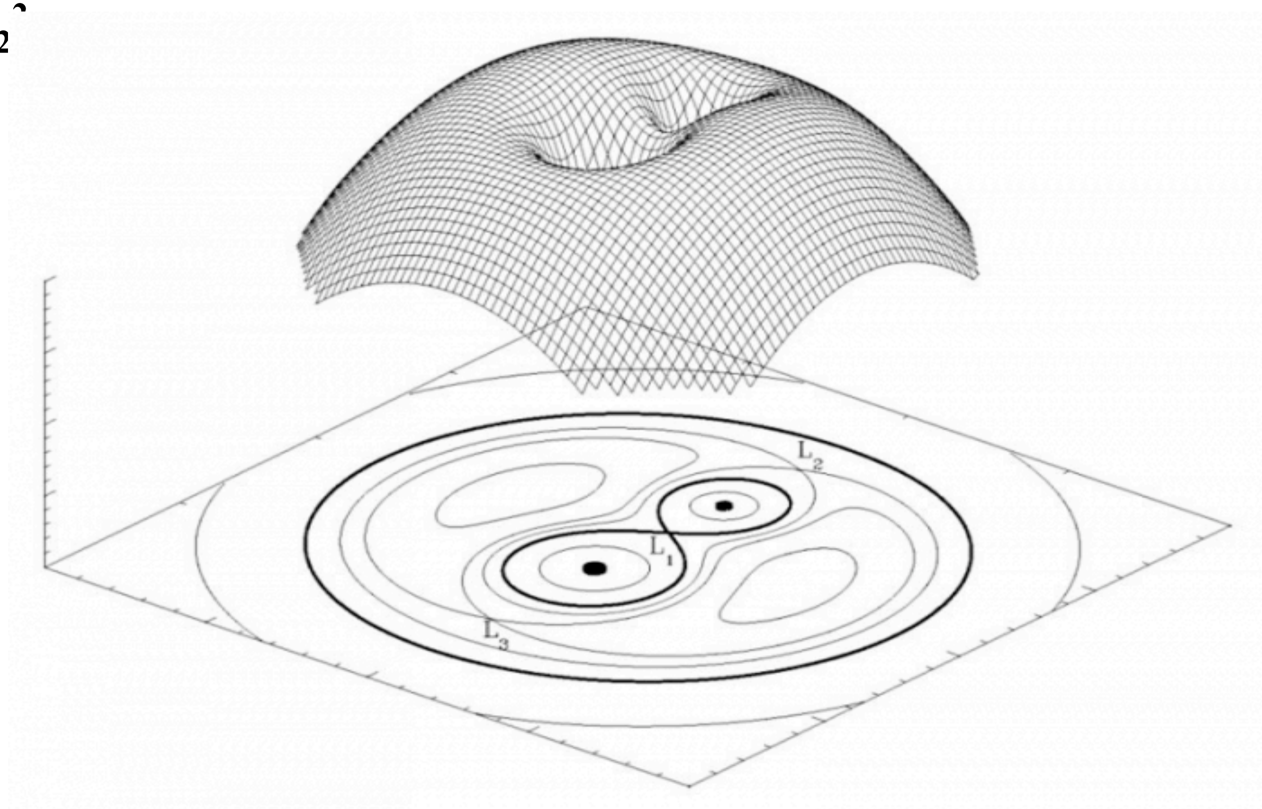
$\sigma_1/\sigma_2= \sqrt{(M_1/R_1)}/\sqrt{(M_2/R_2)}$

or $\sigma_1/\sigma_2=(M_1/M_2)^{1/4}$

For a mass ratio $M_1/M_2=q$

it is simple to show that

$\sigma_1^2/V_{rot}^2=2(q+\sqrt{q})/(1+q)>1$ for $q>1$



The dispersion around the more massive object always > binary rotation velocity
One BLR line is always broader than the line velocity separation.

What about that BLR line from the other companion?

Calculation of the velocity distribution near a binary BH

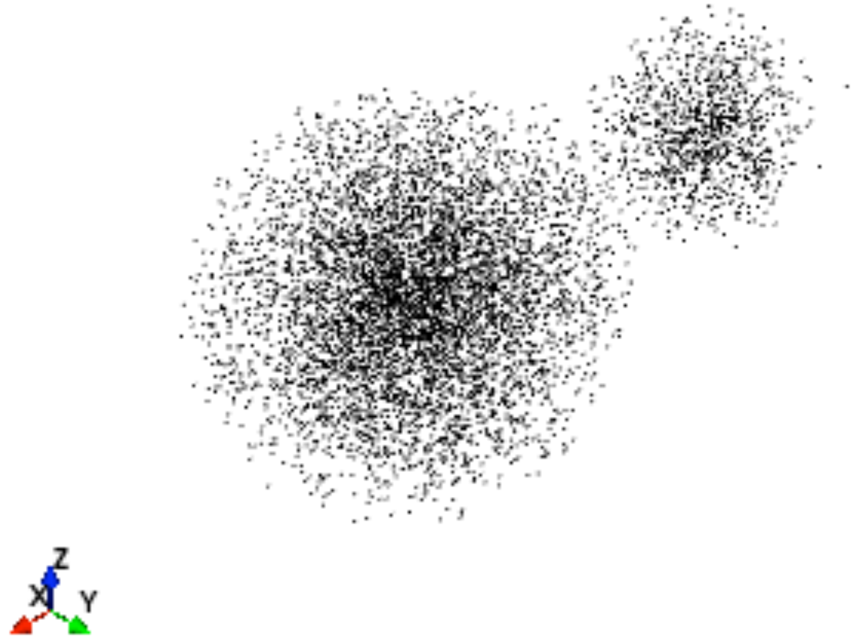
Initial condition for M_1:M_2=3:1

Uniform phase space distribution within the common Hill sphere.

Integrate test particle orbits

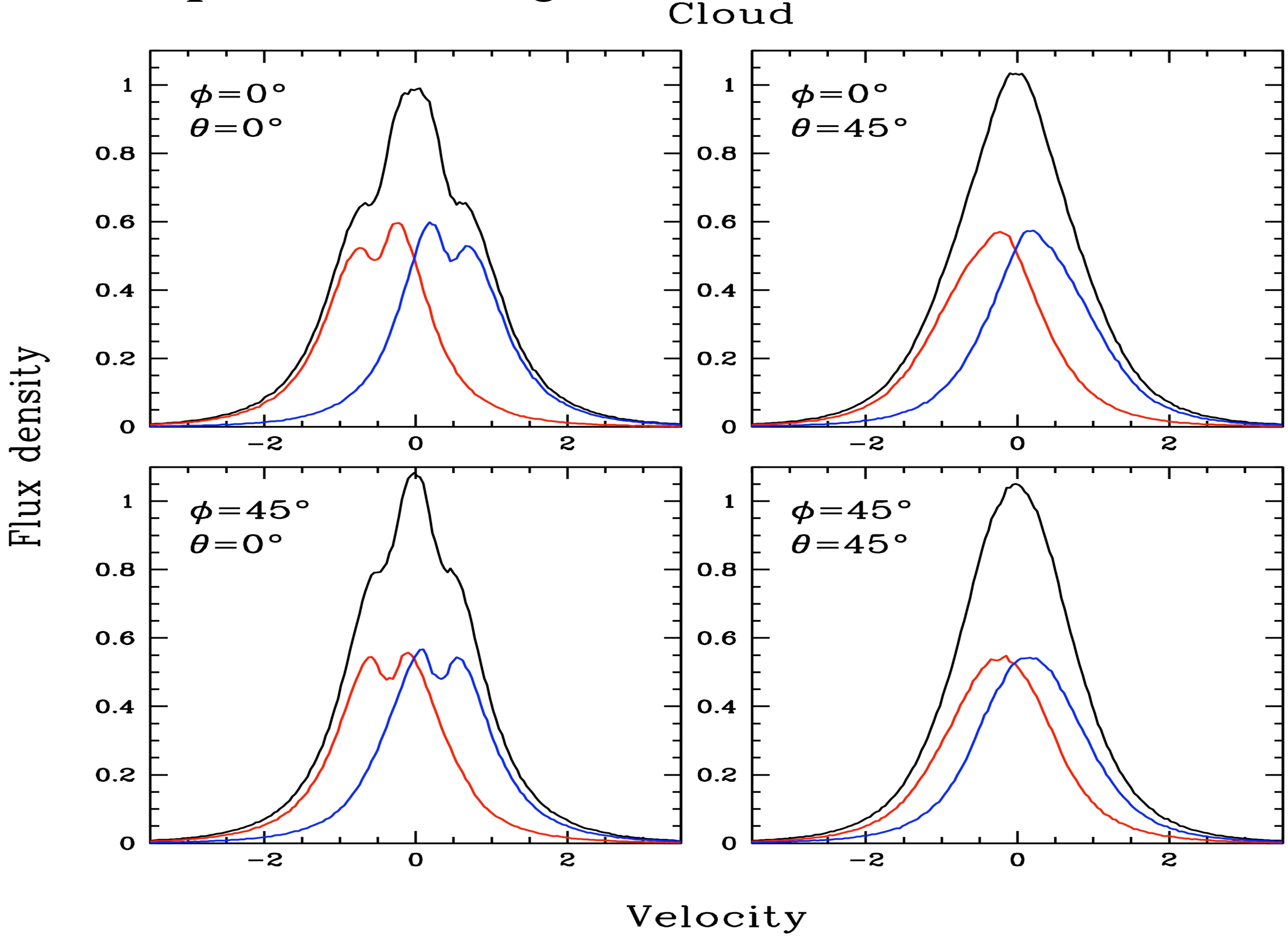
t=0

$t=800t_{period}$



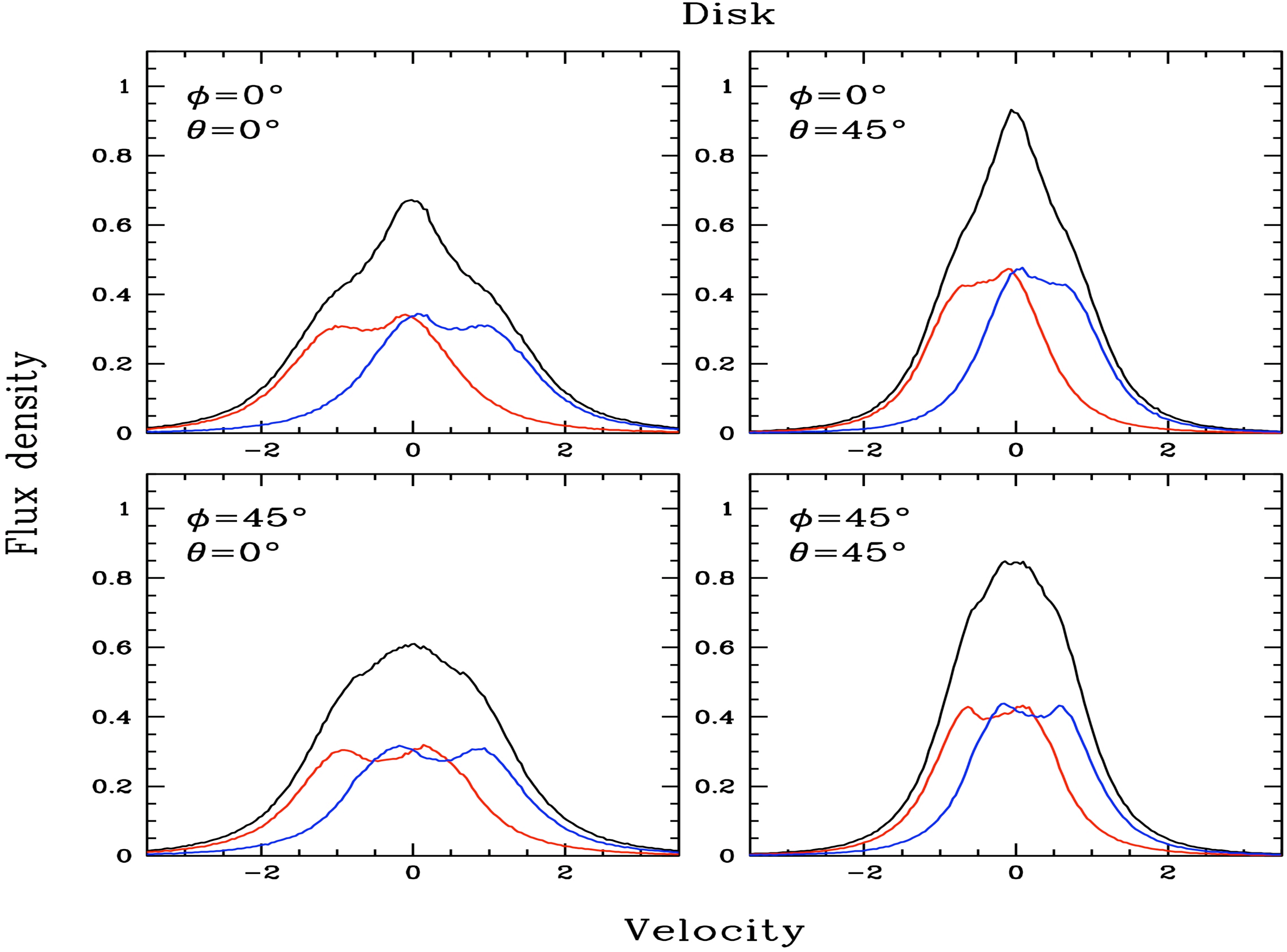
A 1:1 binary observed at different angles

spherical configuration



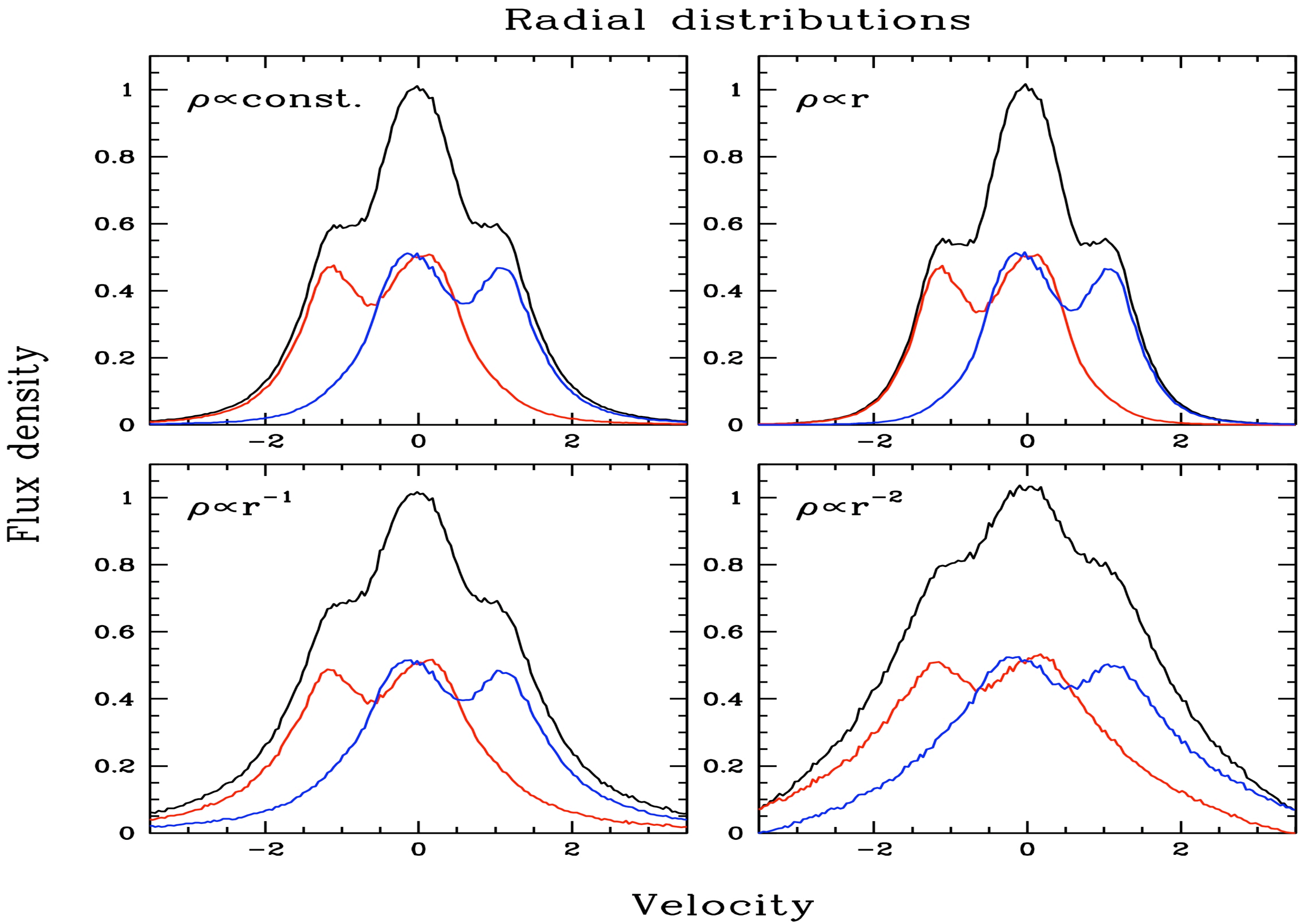
A 1:1 binary observed at different angles

Disk-like configuration



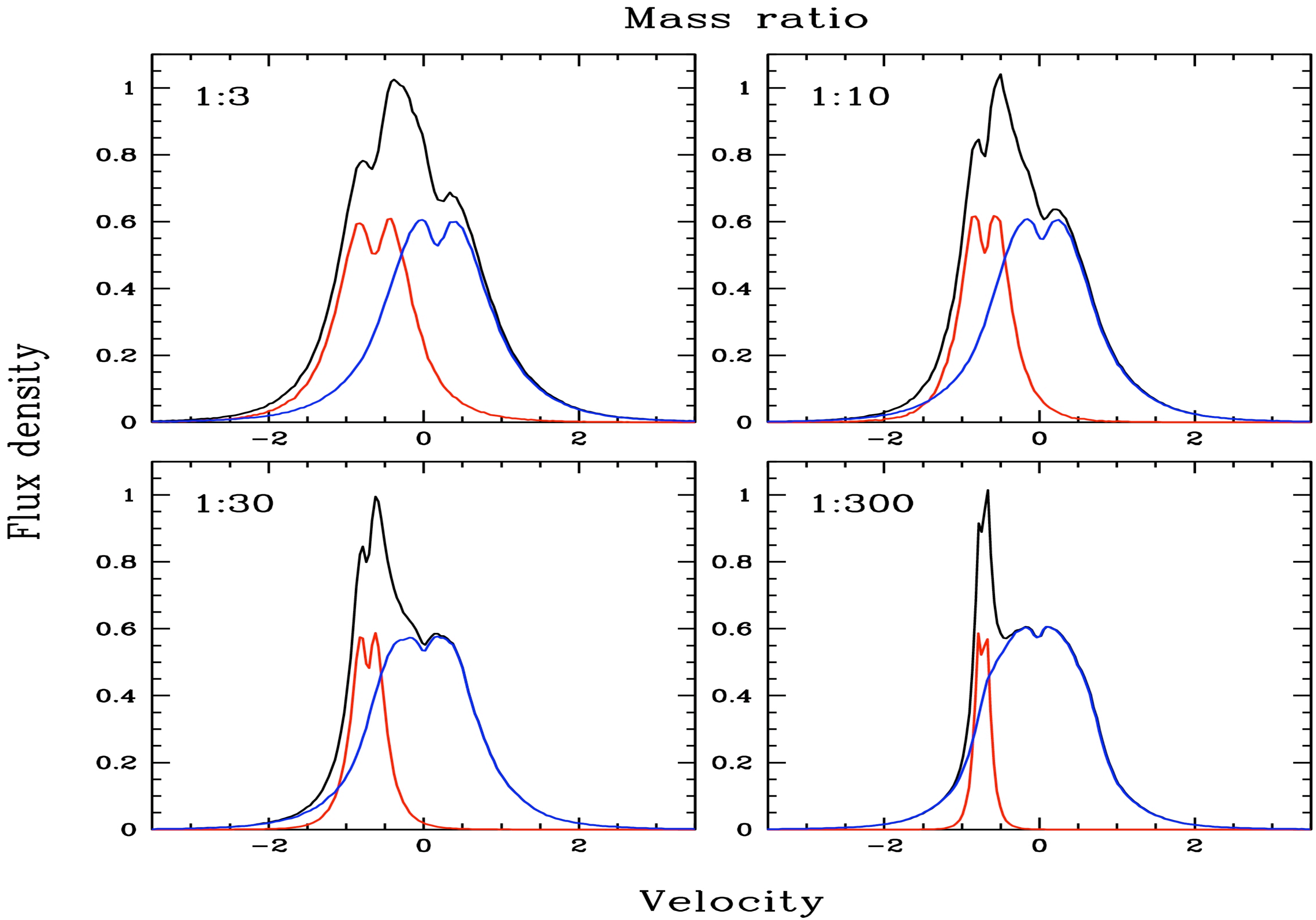
A 1:1 binary, different radial gas distribution

Disk-like configuration



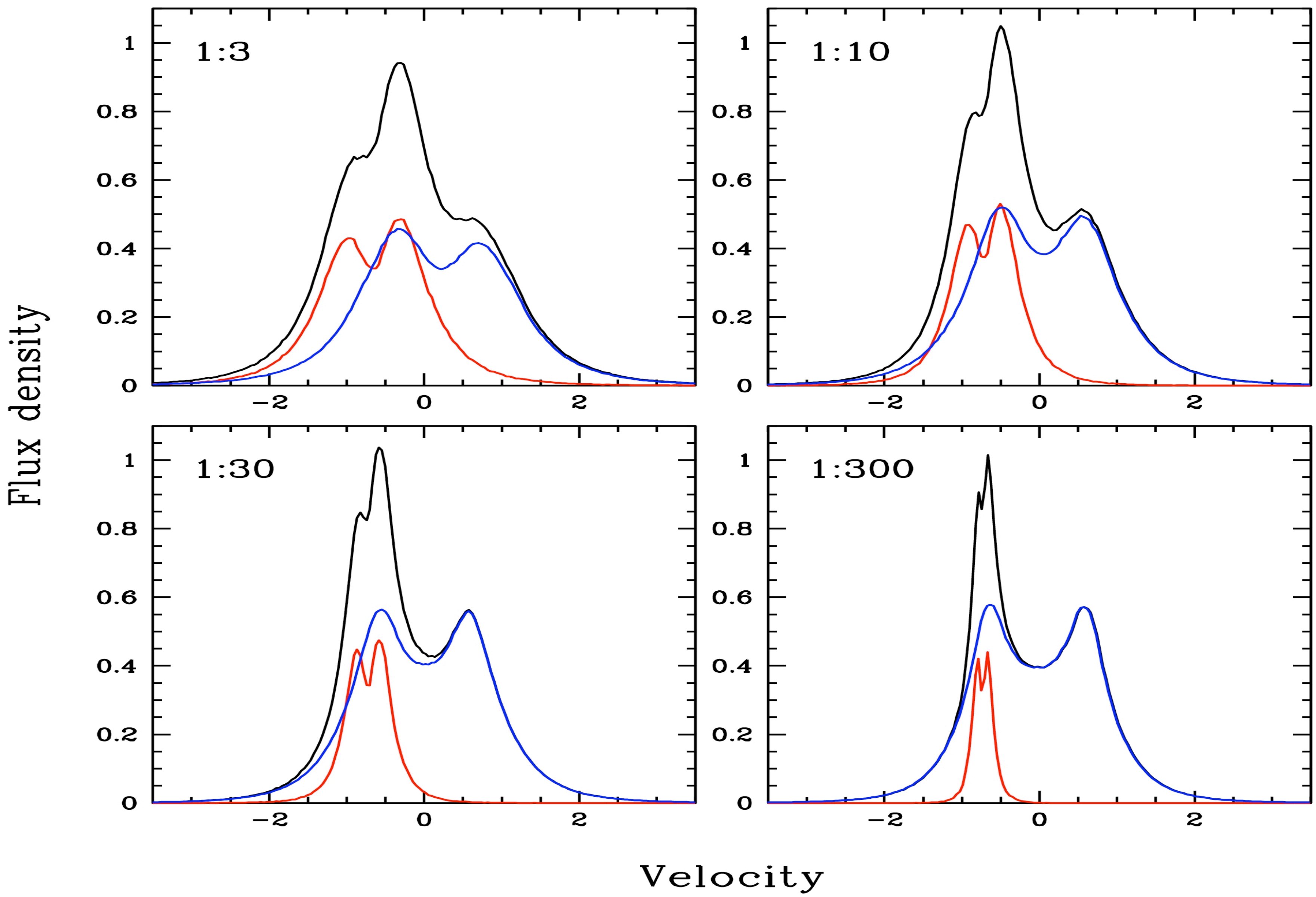
Different binary BH mass ratio

Spherical configuration

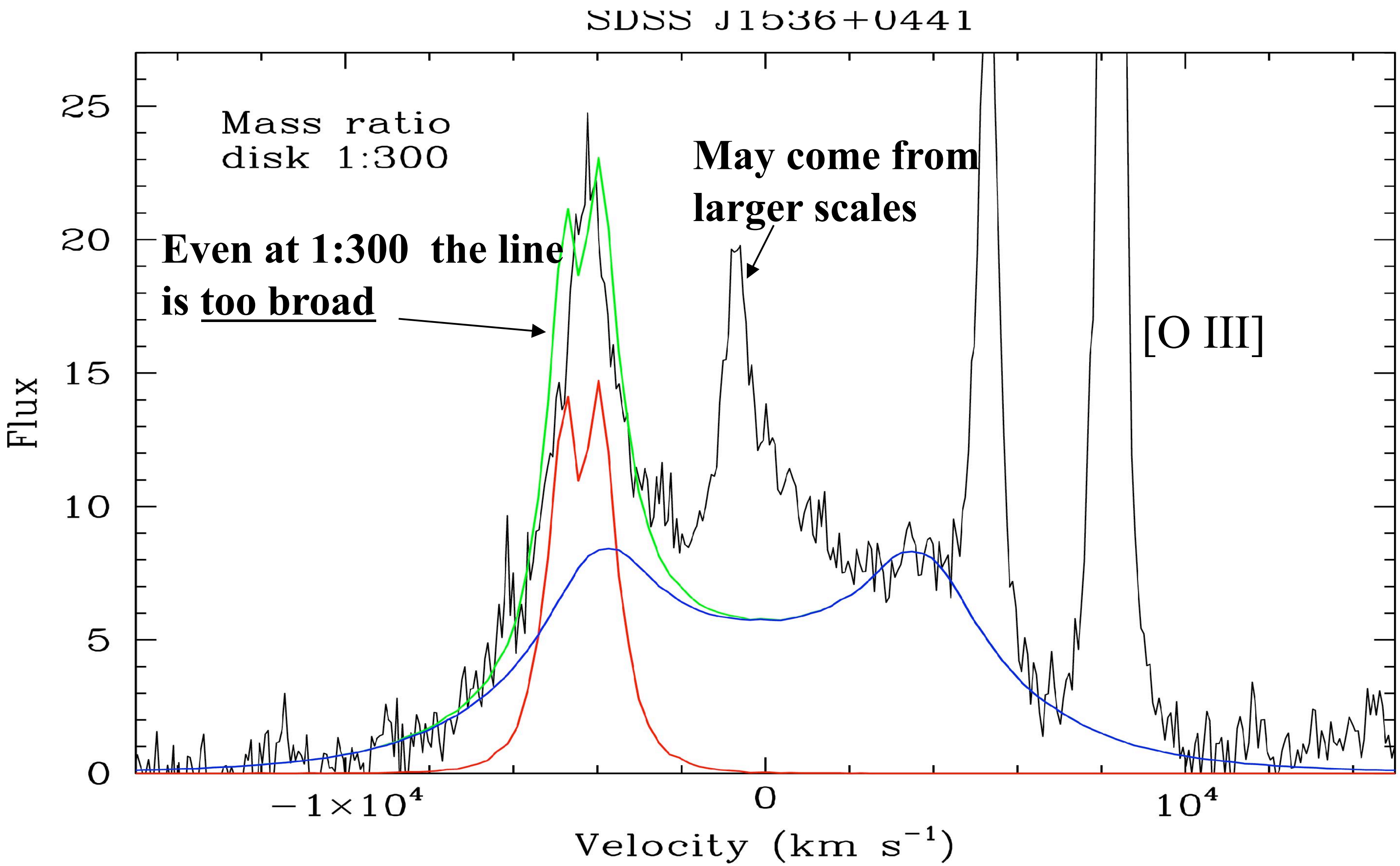


Different binary BH mass ratio

Disk configuration



A binary BH fit to the B&L Quasar

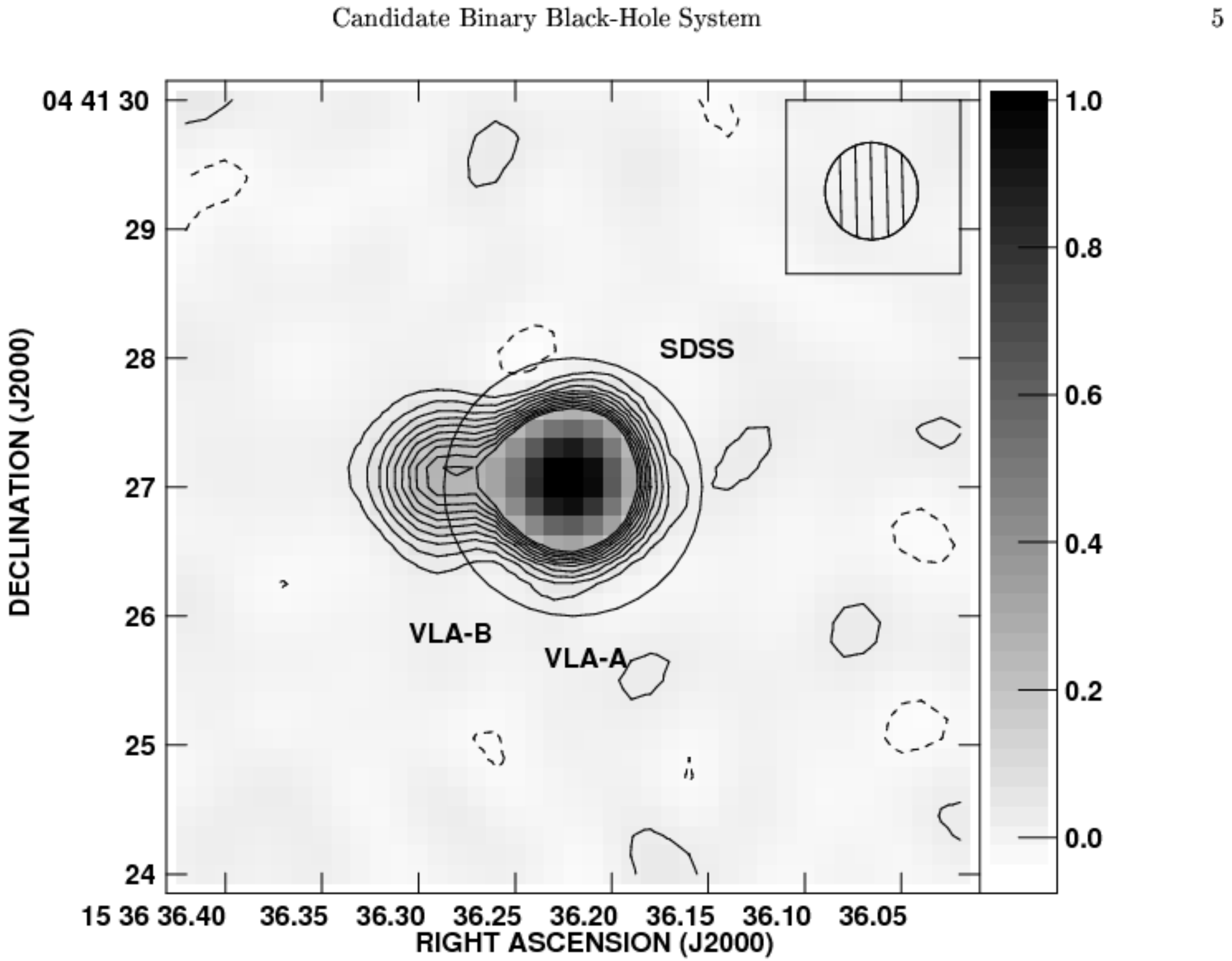


FWHM(r)=10,000 km/s   FWHM(b)=2,000 km/s

M(r)/M(b)=[σ(r)/σ(b)]4 → M(r)/M(b)=5^4=625

Highly unlikely given the similar luminosity

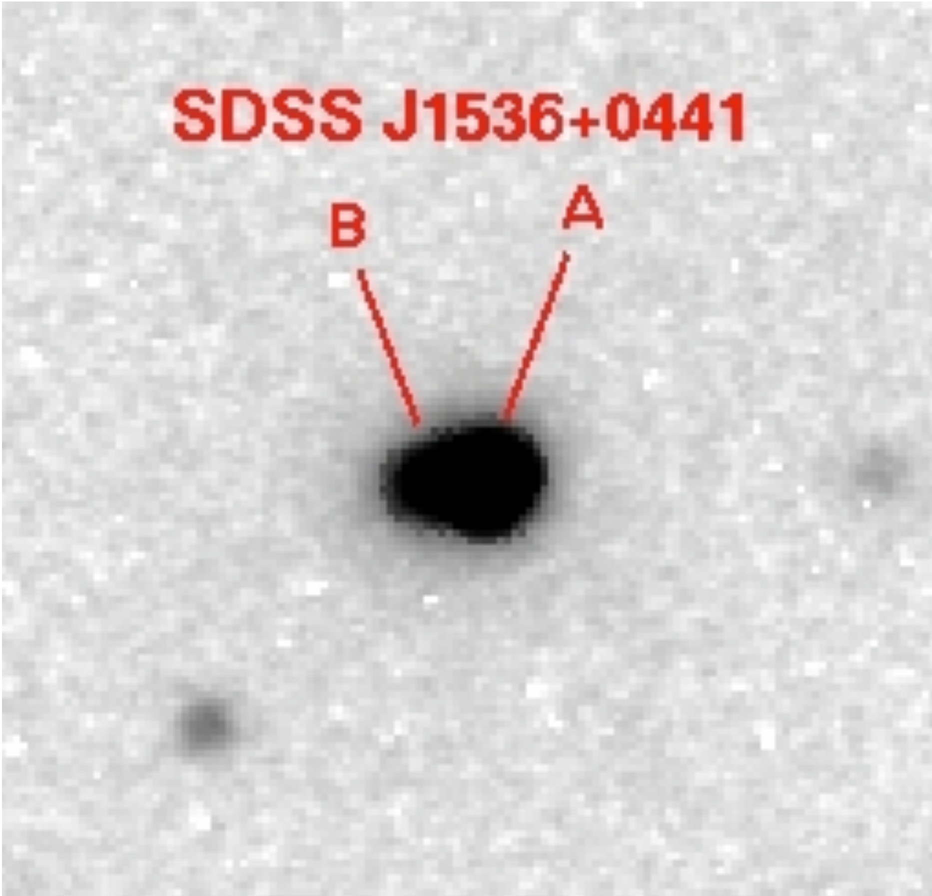
Further developments with SDSS J1536+0441



VLA image at 8.5 GHz, Wrobel & Laor (2009)

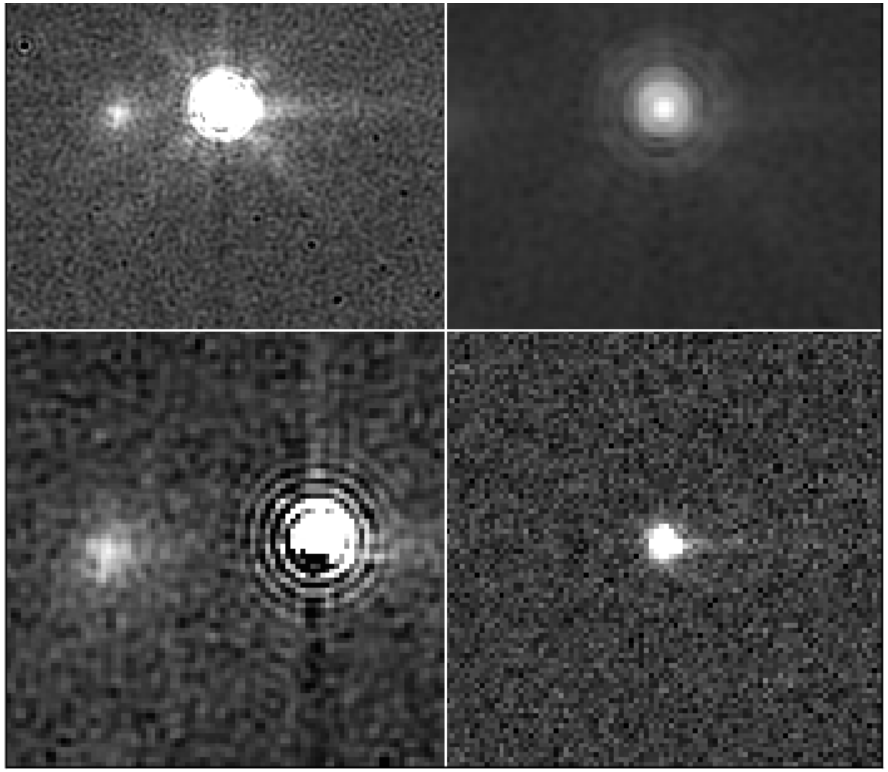
A 5 kpc binary quasar?

K-band image by HAWK-I at the ESO/VLT



Decarli et al. 2009, ATel 2061

HST WFPC2/PC F675W Image



Source B is 1/30 of source A → Elliptical galaxy?

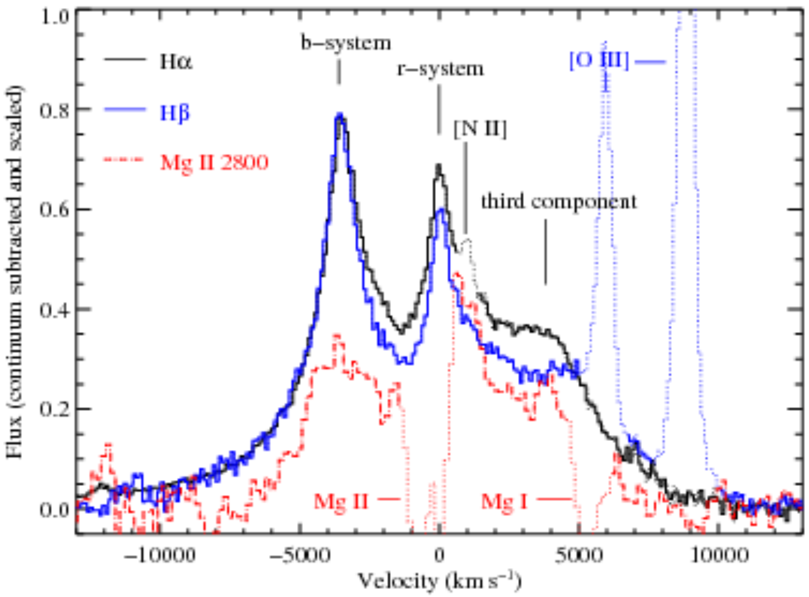
but K-mag/L(8.5GHz) as in the primary quasar.

Lauer & Boroson 2009 (arXiv:0906.0020)

Keck/ESI spectrum

2

Chornock et al. 2009



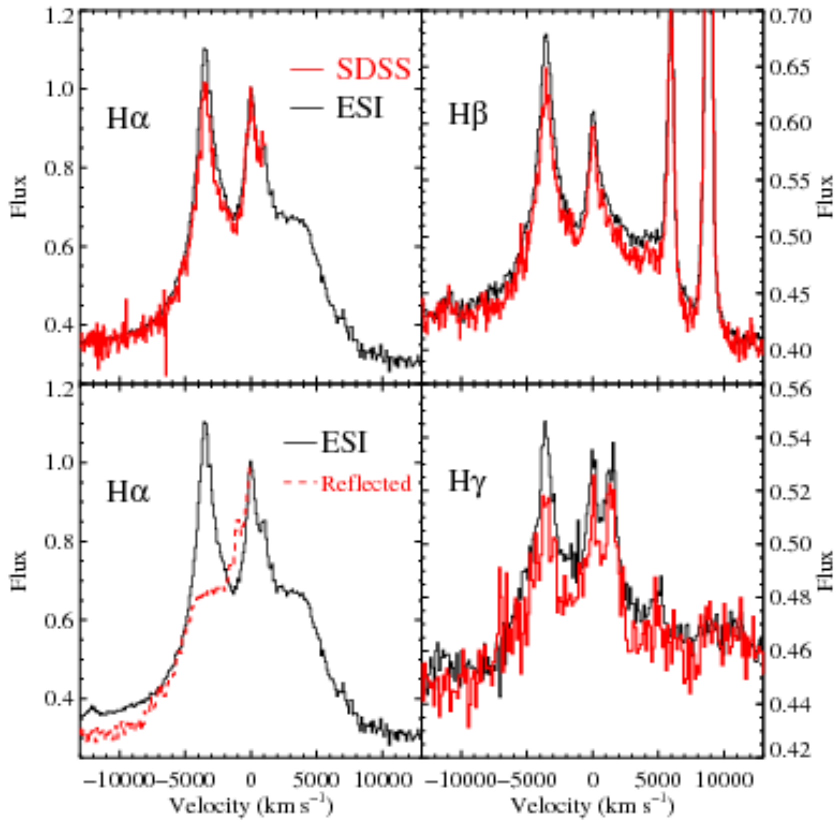


FIG.
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A Double Peaked Emitter

+ source B does not emit component b

→ A 5 kpc binary quasar ruled out

+ No velocity shift

→ A 0.1 pc binary BH ruled out

The narrow cores varies.

What produces the double peaks?

What is the companion object?

Conclusions

A binary BH produces highly blended BLR lines,
and generally an asymmetric profile (detectable?)

Well separated narrow components cannot be produced
by a binary BH.

SDSS J1536+0441 not a binary, but remains a mystery.