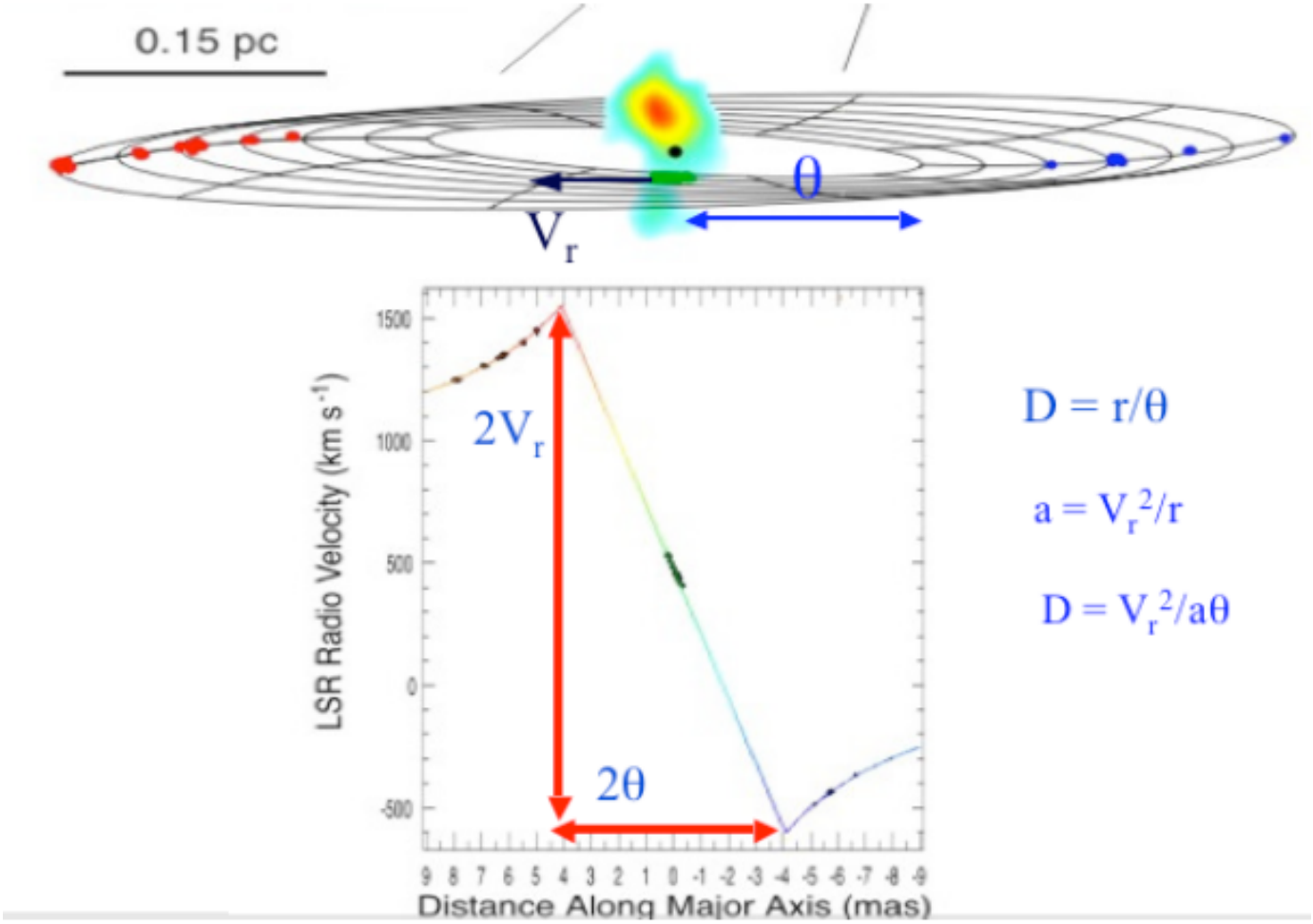
NGC 5765b: A New Cornerstone Galaxy for MCP

Feng Gao (高峰) (NRAO/SHAO)

J. Braatz, M. Reid, K.-Y. Lo, J. Condon, C. Henkel,
C.-Y. Kuo, V. Impellizzeri, D. Pesce, W. Zhao

May, 2014

How does it work

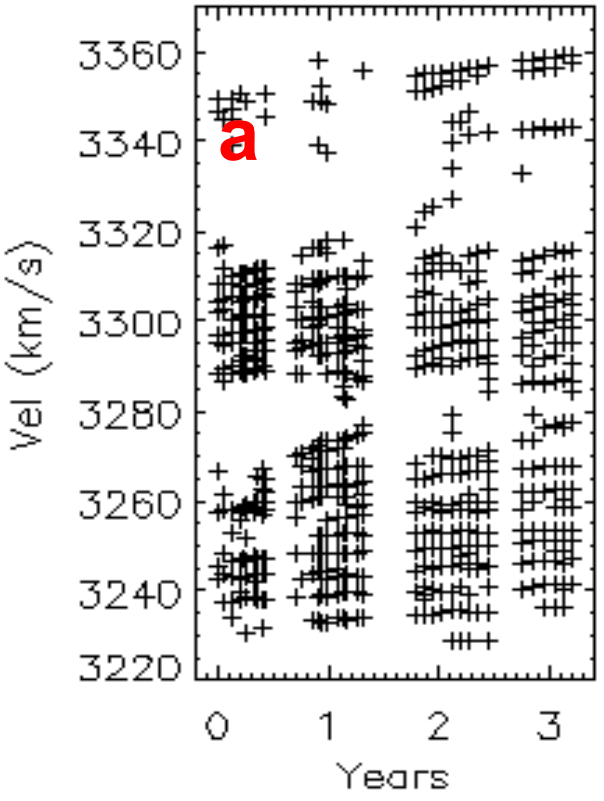


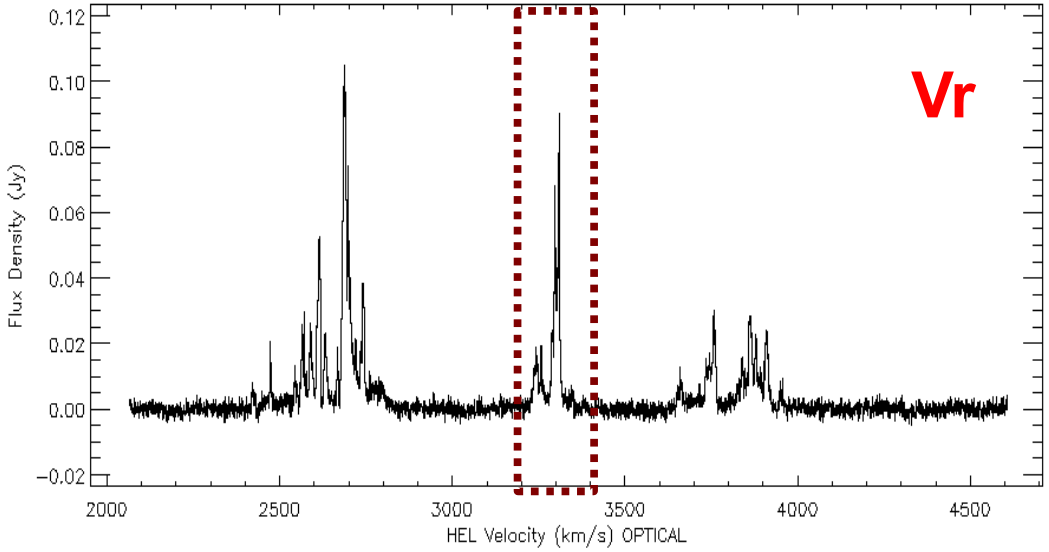
$D = r/\theta$

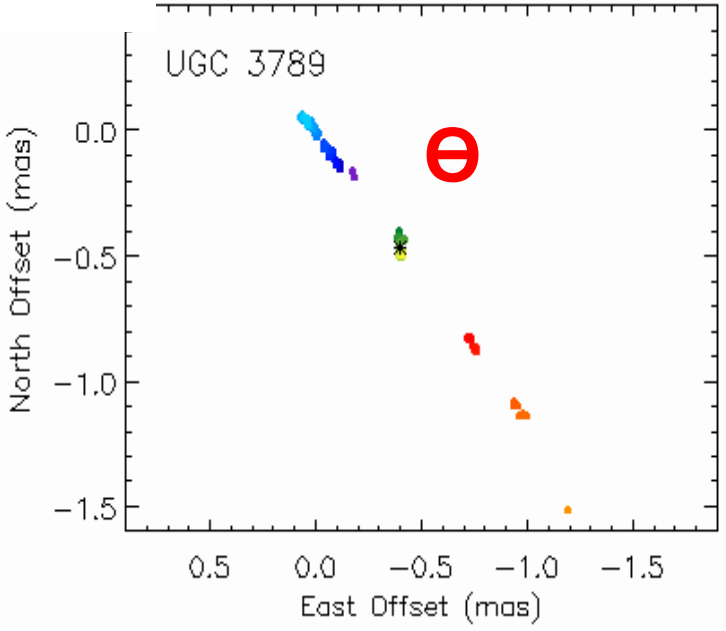
$a = V_r^2/r$

$D = V_r^2/a\theta$

Braatz et al. 2010


a
Vel (km/s)
3360
3340
3320
3300
3280
3260
3240
3220
0
1
2
3
Years


Vr
Flux Density (Jy)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
2000
2500
3000
3500
4000
4500
HEL Velocity (km/s) OPTICAL


UGC 3789
θ
North Offset (mas)
0.0
−0.5
−1.0
−1.5
0.5
0.0
−0.5
−1.0
−1.5
East Offset (mas)

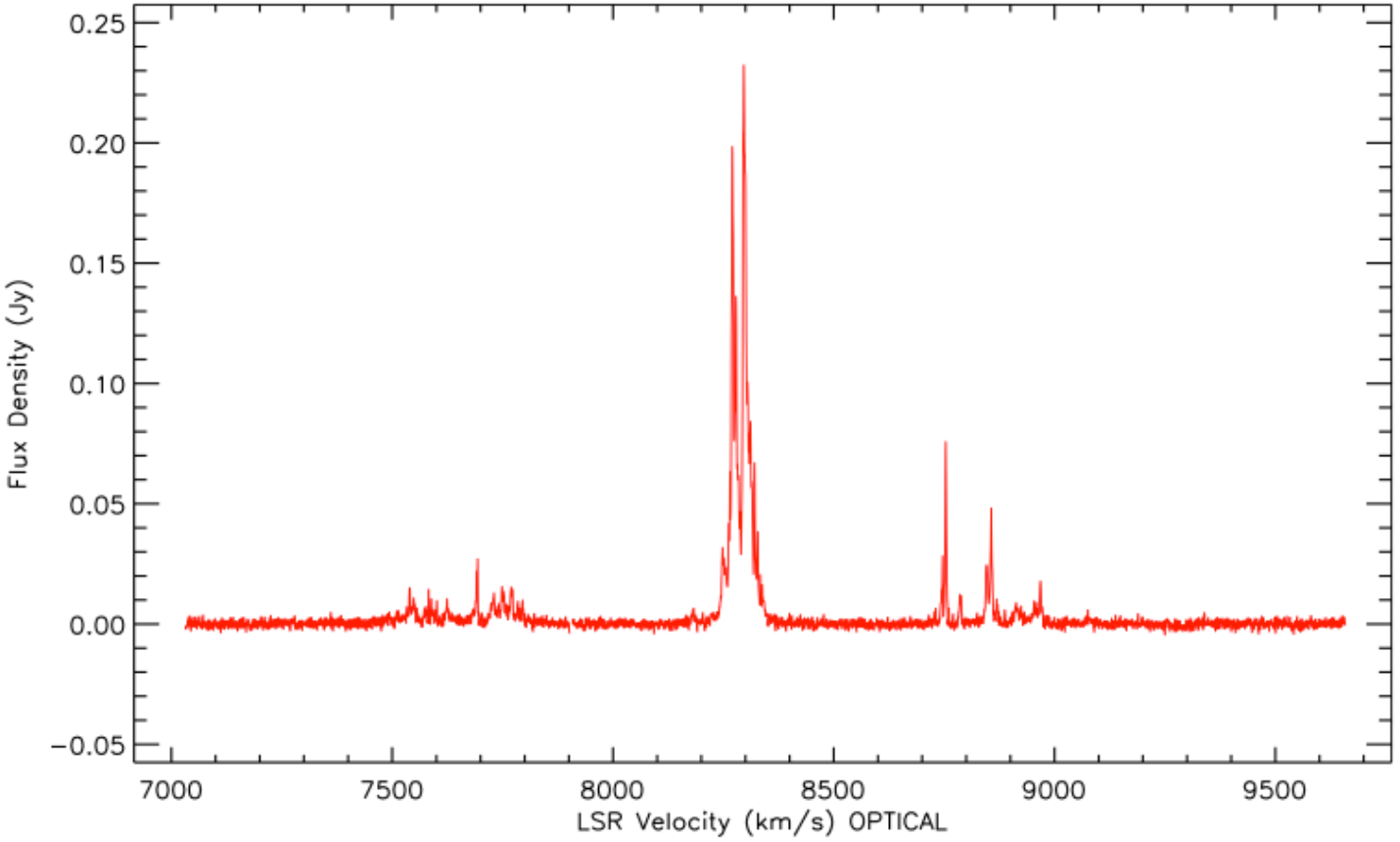
NGC 5765b

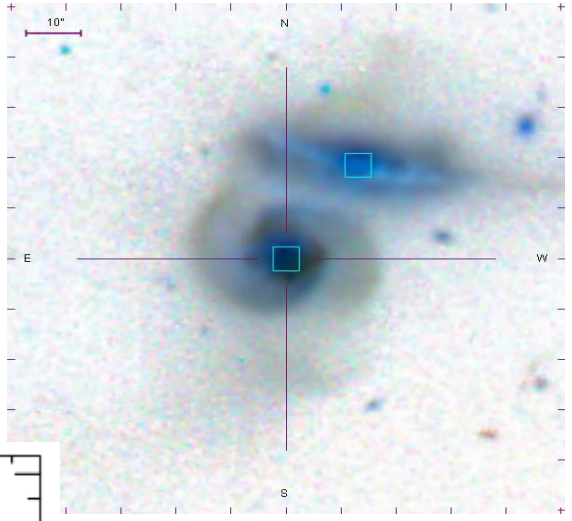
Recession Velocity : 8333 km s^{-1}
NGC 5765a : 8469 km s^{-1}

Galaxy Morphology : Sa-b

AGN Type : Seyfert 2

(from NED)





(from SDSS)

Discovered in Feb-2012

The most recently found distance-candidate.

Strong enough for VLBI self-cal imaging.

Sensitivity also needed for high-velo spots

Improvement of the VLBI

- Phased-JVLA as one VLBI station

  Acting like “another” GBT

  Sensitivity increased by 40% at least

  First phased-array obs after the EVLA project

- The VLBA sensitivity upgrade project

  new RDBE_DDC and Mark 5C system

  higher data rate & larger frequency coverage:

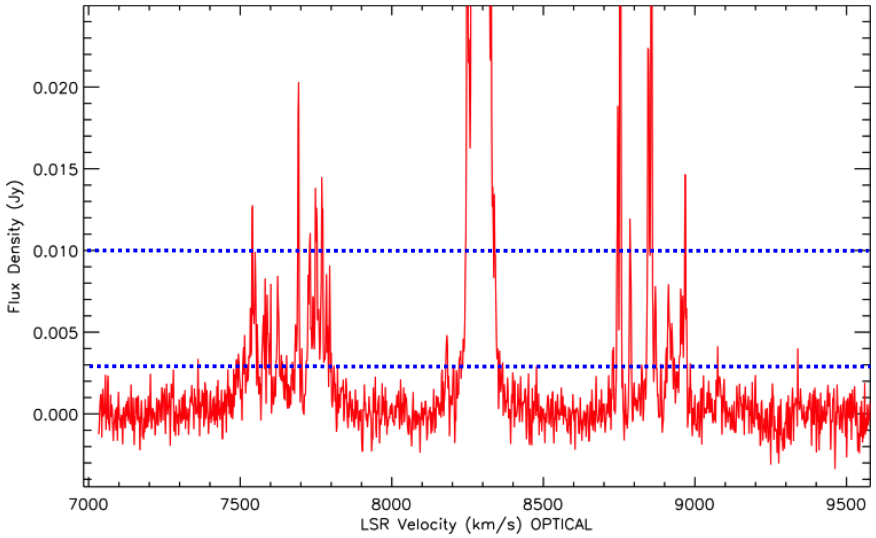
  4 x 16MHz vs. 2 x 128MHz (VLBA)

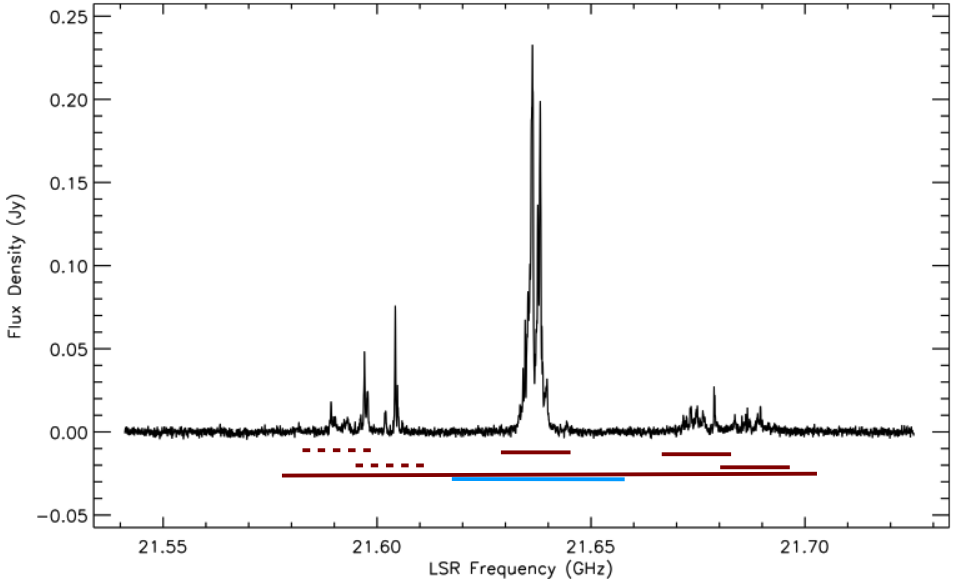
  40MHz vs. 2 x 128MHz (VLA)

  Zoom-band mode in DiFX correlation

  Same spectral resolution as GBT (0.3km/s)

  Increased observation efficiency





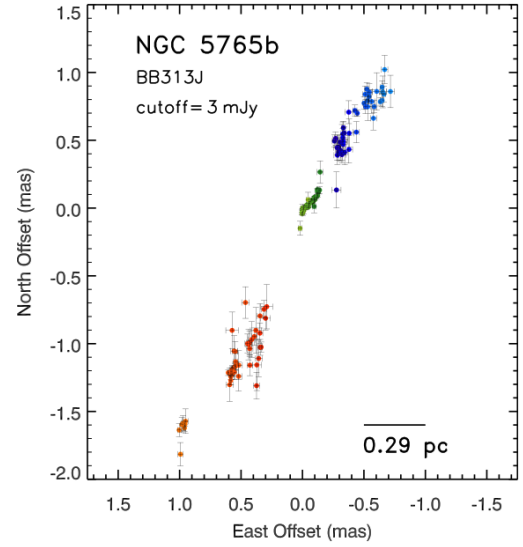
VLBI results

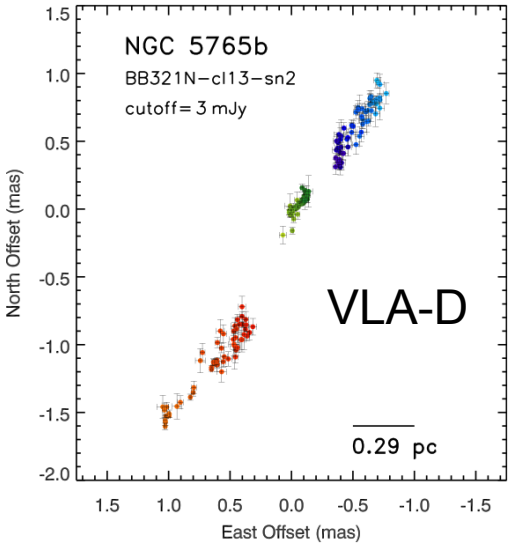
first track (“old”)
6.7h
1.1 mJy

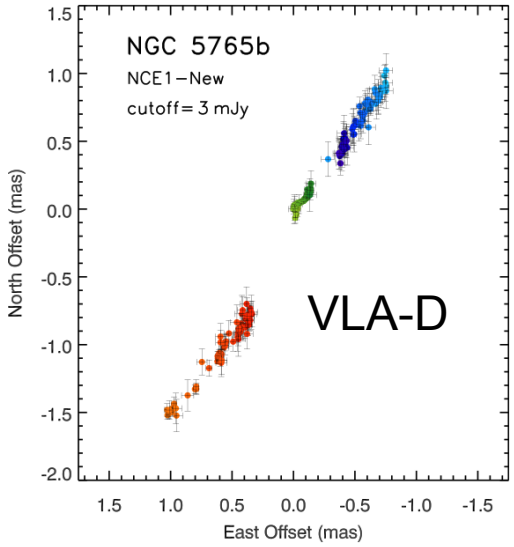
first track (new)
4.5h
0.6 mJy

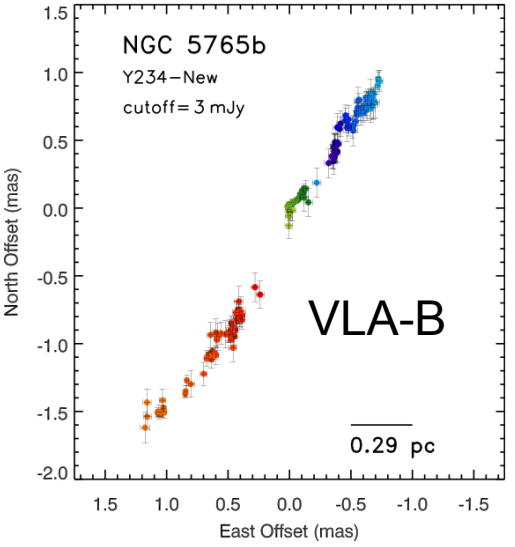
combined from 2013
3 x 4.5h
0.4 mJy

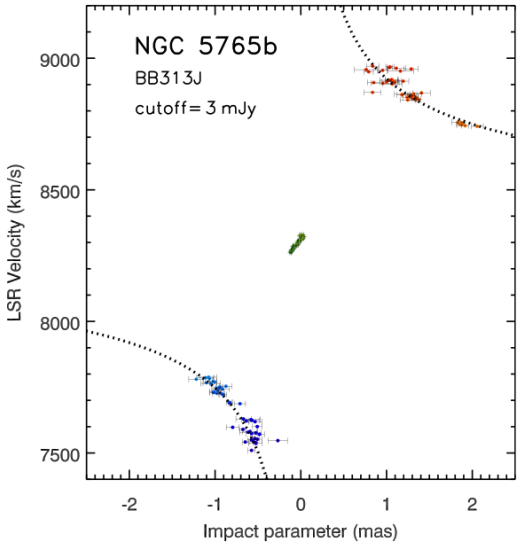
combined from 2014
3 x 5.4h
0.3 mJy

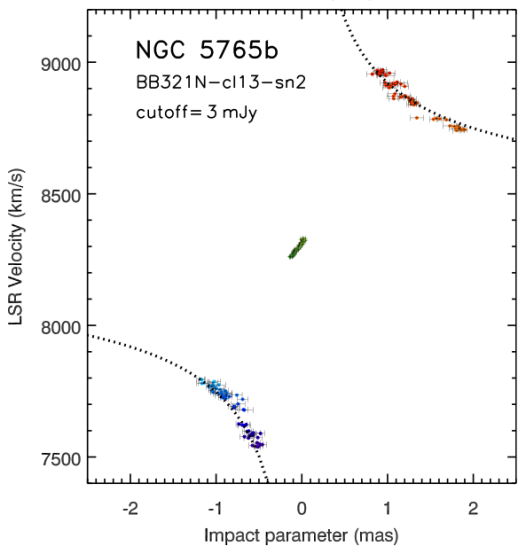


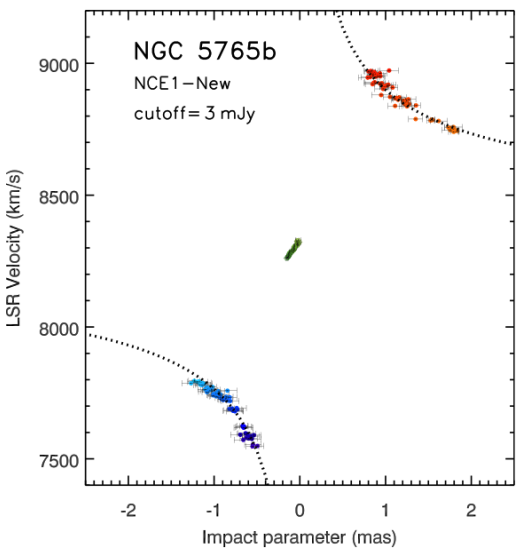


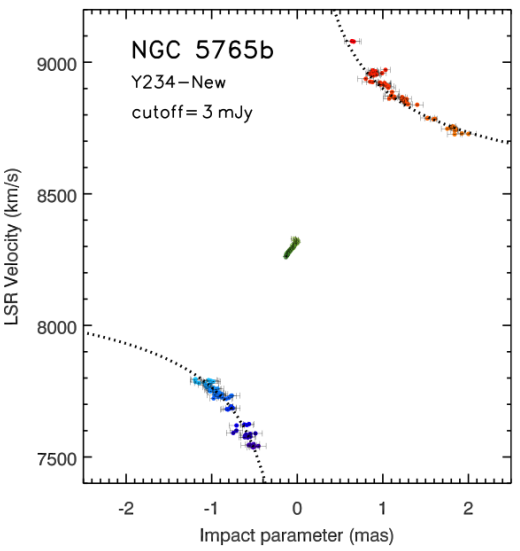


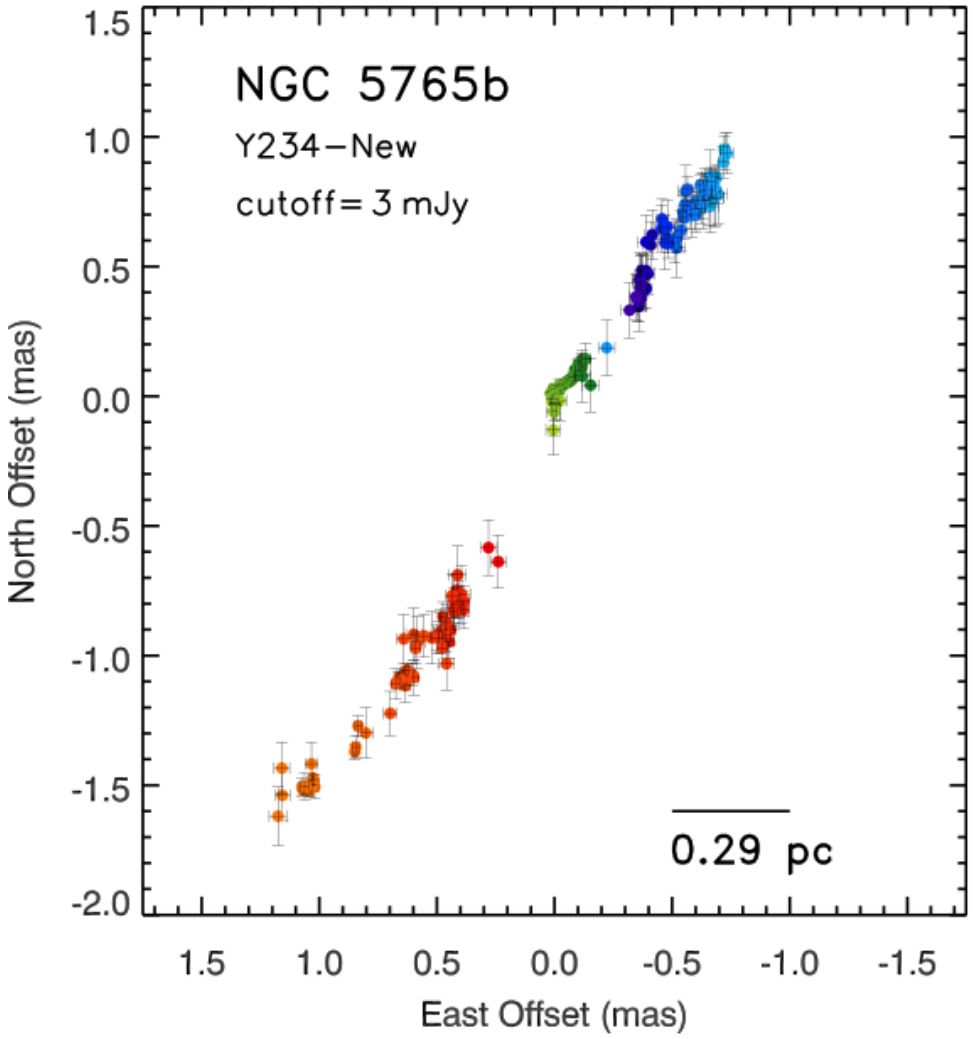


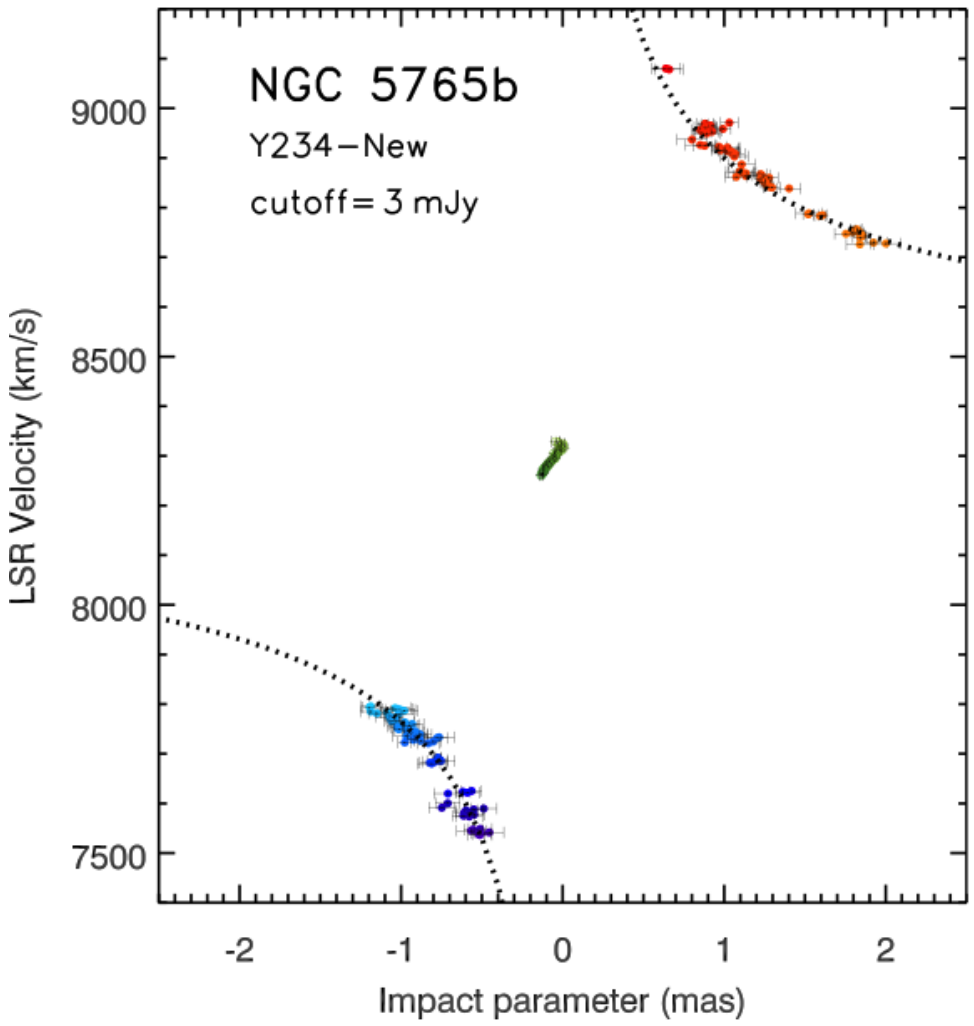












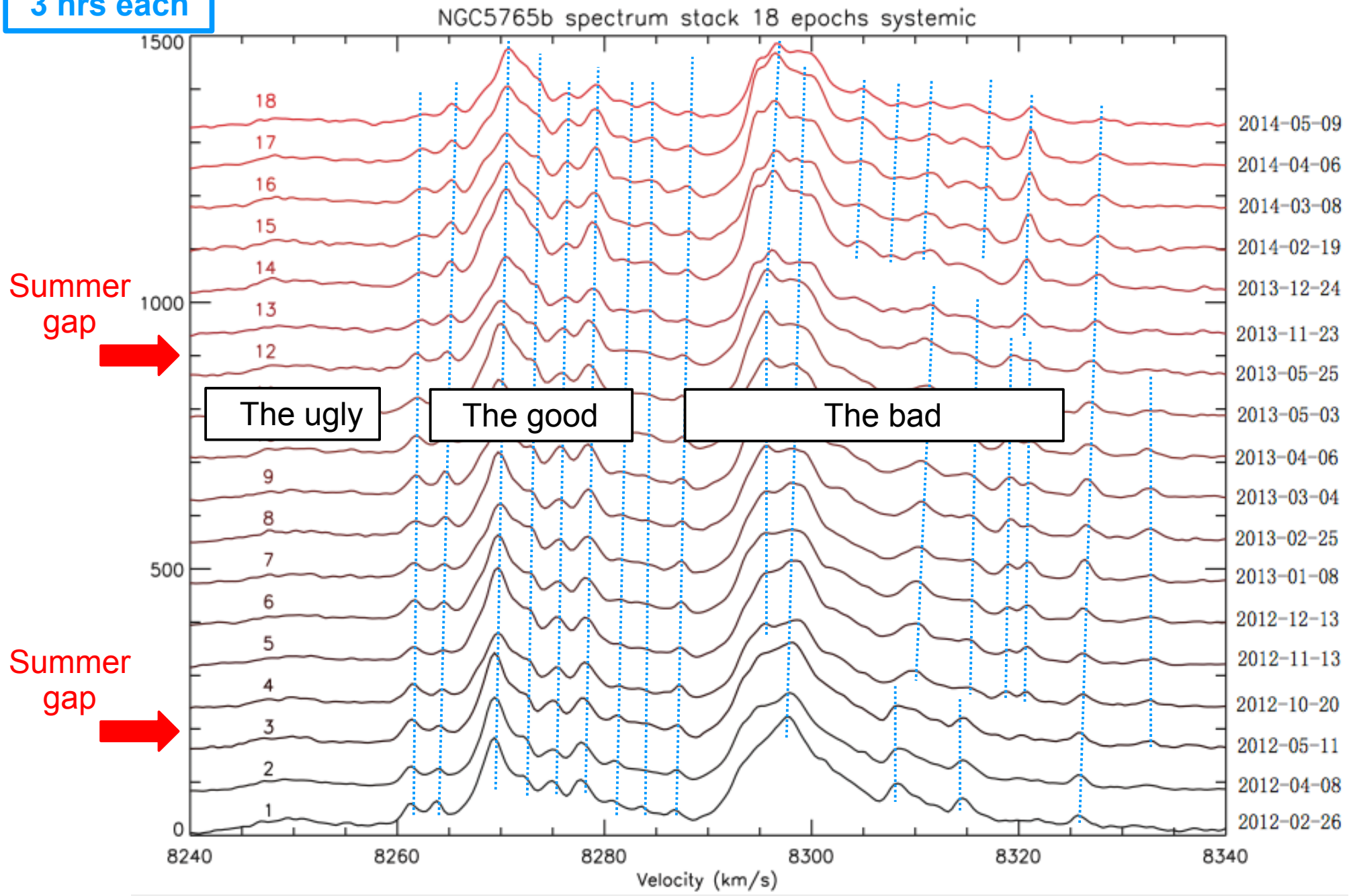
SMBH mass: 4.5 x10^7 M_{sun} Maser disk size: 0.3 – 1.1 pc

High-velo spots asymmetric sky distribution & slightly warping

High-velo spots follow “pure” Keplerian rotation curve well, constraining the dynamic center

Acceleration measurement

3 hrs each



Acceleration measurement

Initial “guess” by tracing the velocity peaks by eye

Multiple gaussian decomposition

Basic Fitting Results:

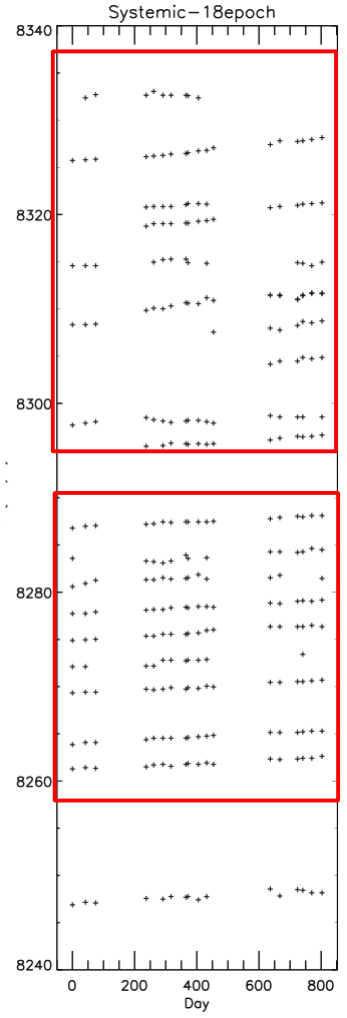
Systemic spots:

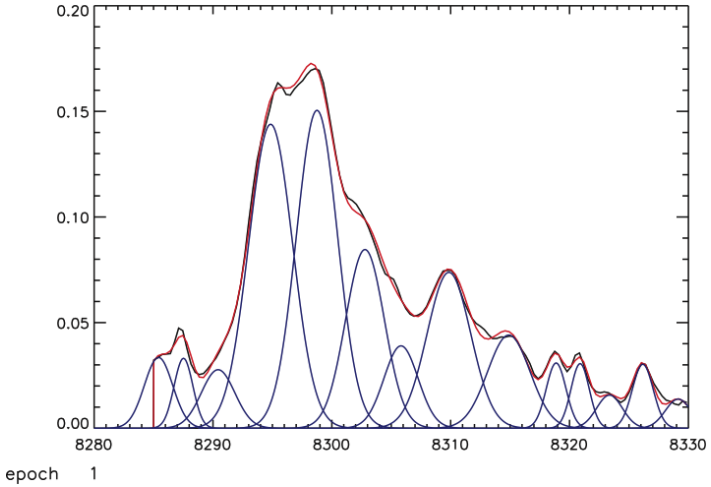
“higher part” 0.3 ~ 1.5km/s/yr
features appear & disappear
some part highly-blended
different radius, interaction ?

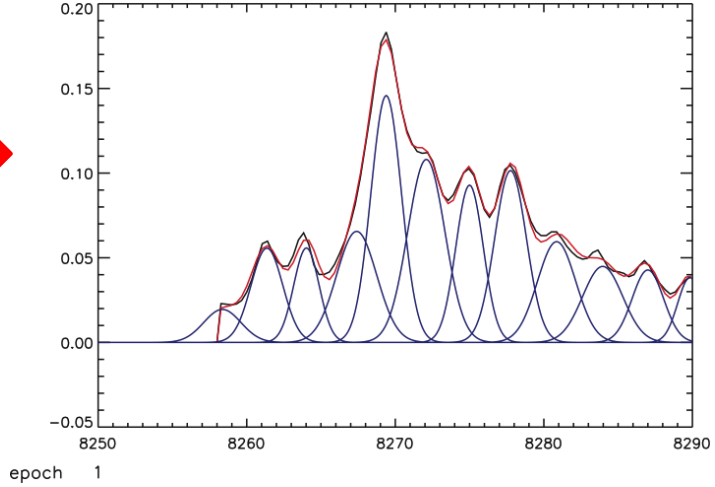
“lower part” ~ 0.6km/s/yr
features clean and stable,
perfect for measuring A
all from a “stable” clump of gas

High Velocity spots:

most consistent with 0
few are clearly deviated from 0
off the midline, warping ?







Bayesian fitting model

prob(M|D, I) = prob(D|M, I) * prob(M|I) / prob(D|I)

Information from data:
N sets of (x,y,v,a)
Error floor on each data point

3-D warping disk model:
15 Global parameter:

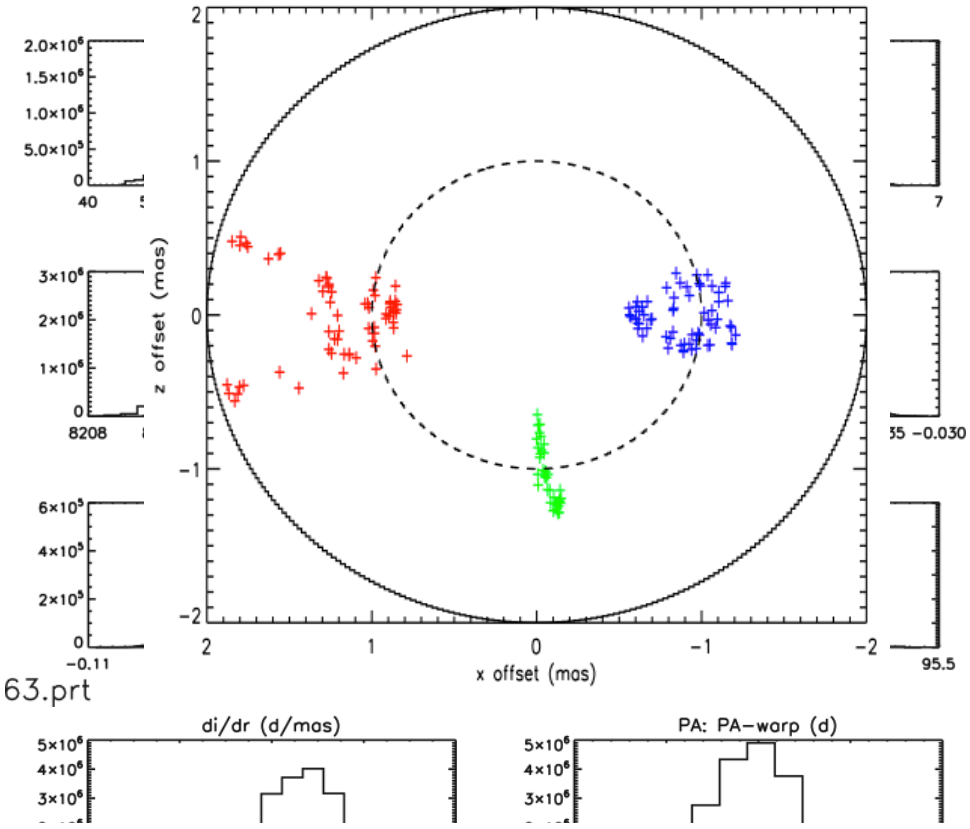
H_0 M_{BH} V X_0 Y_0
i di/dr d^2i/dr^2 PA dPA/dr d^2PA/dr^2
e P-az dP-az/dr V_{cor}

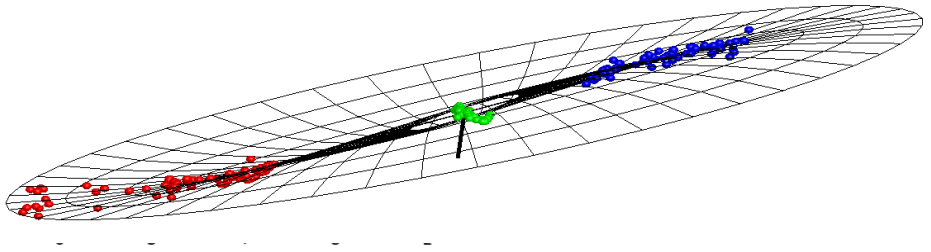
N sets of (R,Θ) for each maser spot

McMC approach to get probability distribution of each global parameters

Typically 50M trials (4hrs)

Slow to reach convergence due to highly correlation between H_0 and M_{BH}





Current Status & Beyond

All data-collection has been finished.

Acceleration for the “higher-part” of the systemic is yet to be finalized.

Preliminary result :

$H_0 = 65.5 \pm 7.04$ km $s^{-1}Mpc^{-1}$ 10.7% from 2013 data
$H_0 = 66.5 \pm 8.16$ km $s^{-1}Mpc^{-1}$ 12.3% from 2014 data

To improve the results:

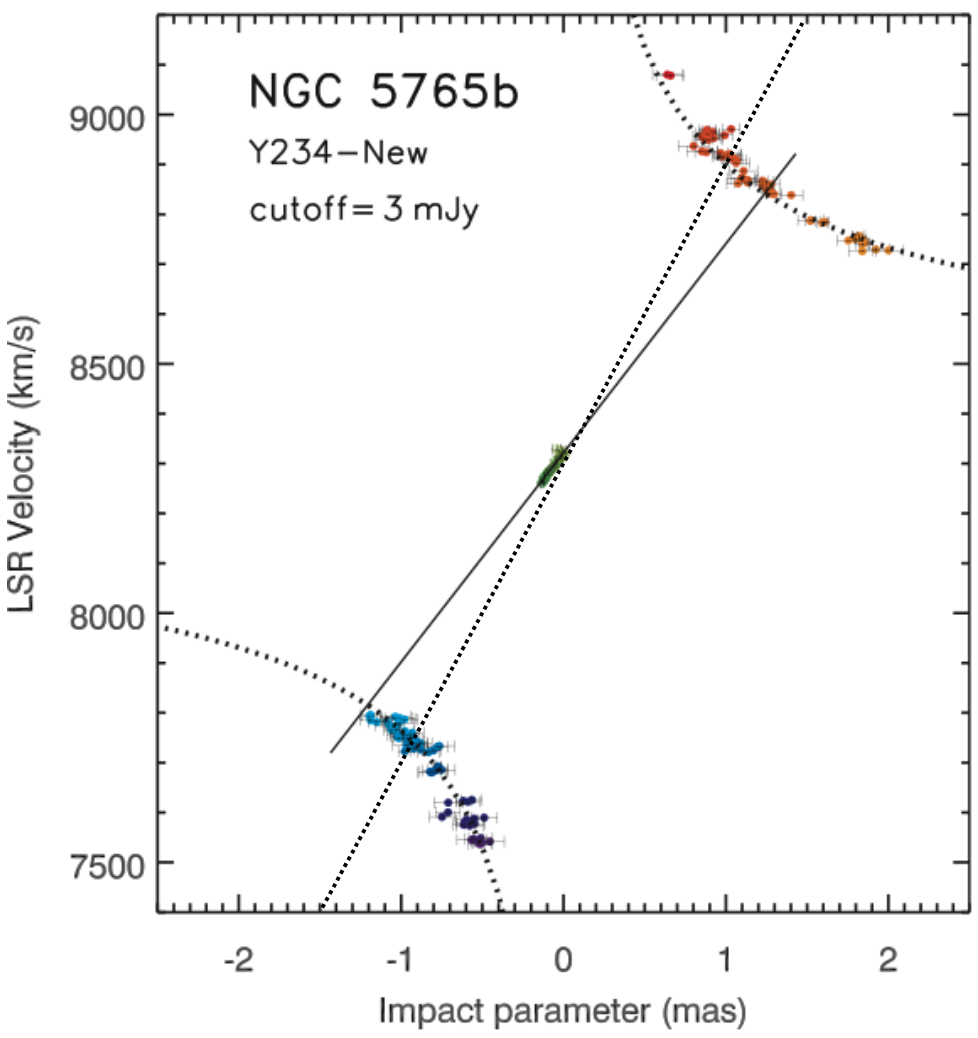
Better error assignment

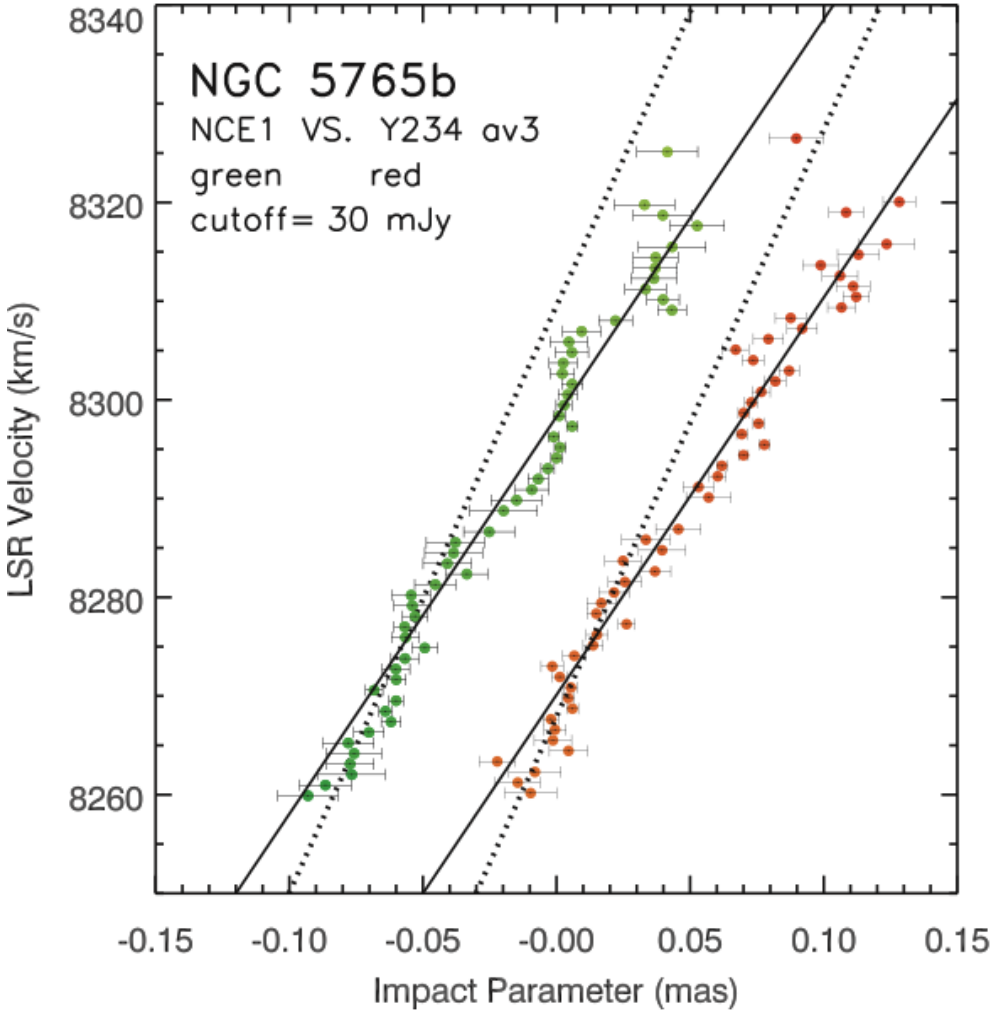
The role of other parameters in the Bayesian fitting process
(e.g. initial value, error floor, eccentricity)

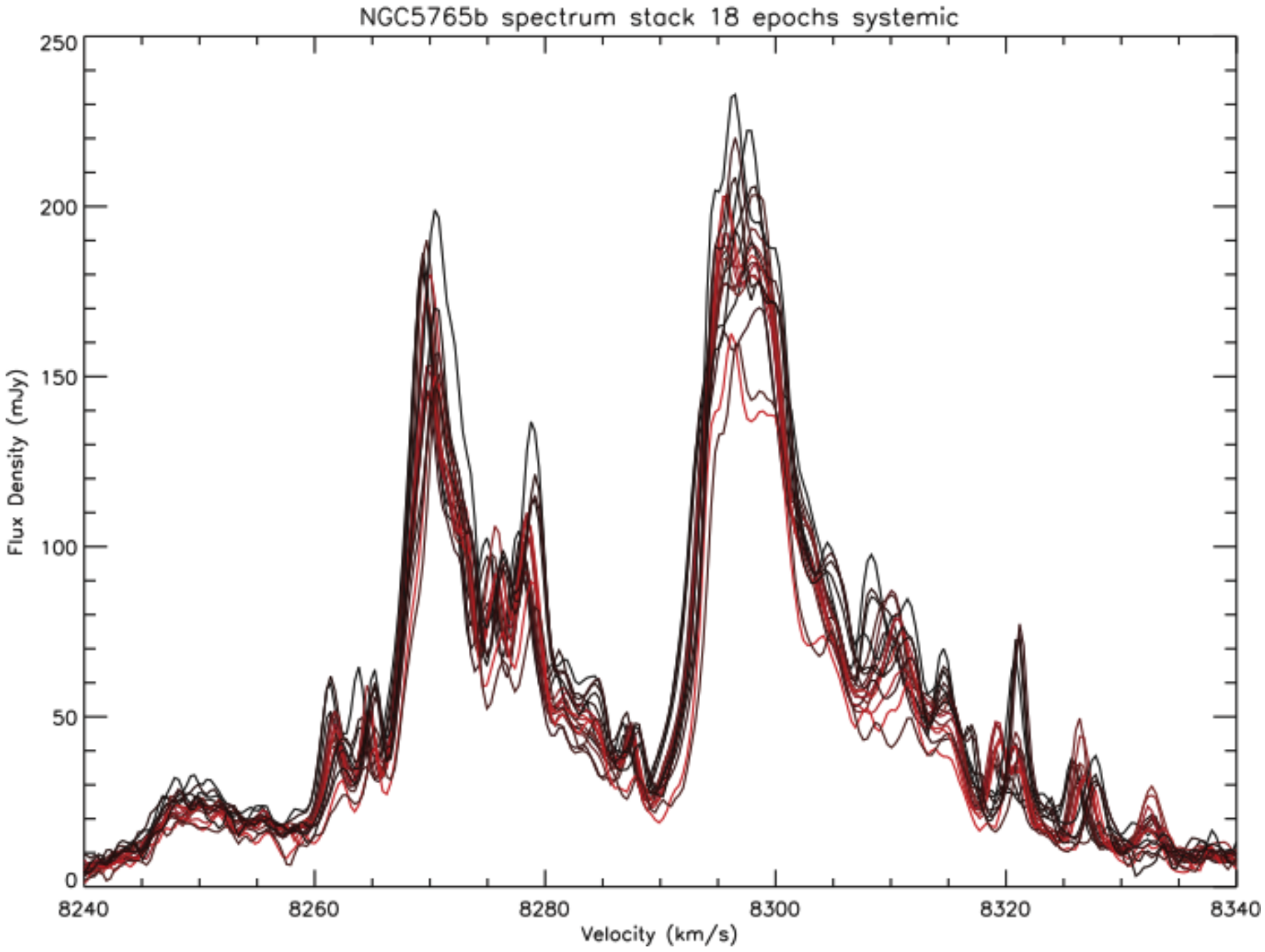
New opportunities for astrophysics study at sub-parsec scale around the SMBH
(e.g. warping, dynamic, maser pumping, accretion rate, X-ray properties)

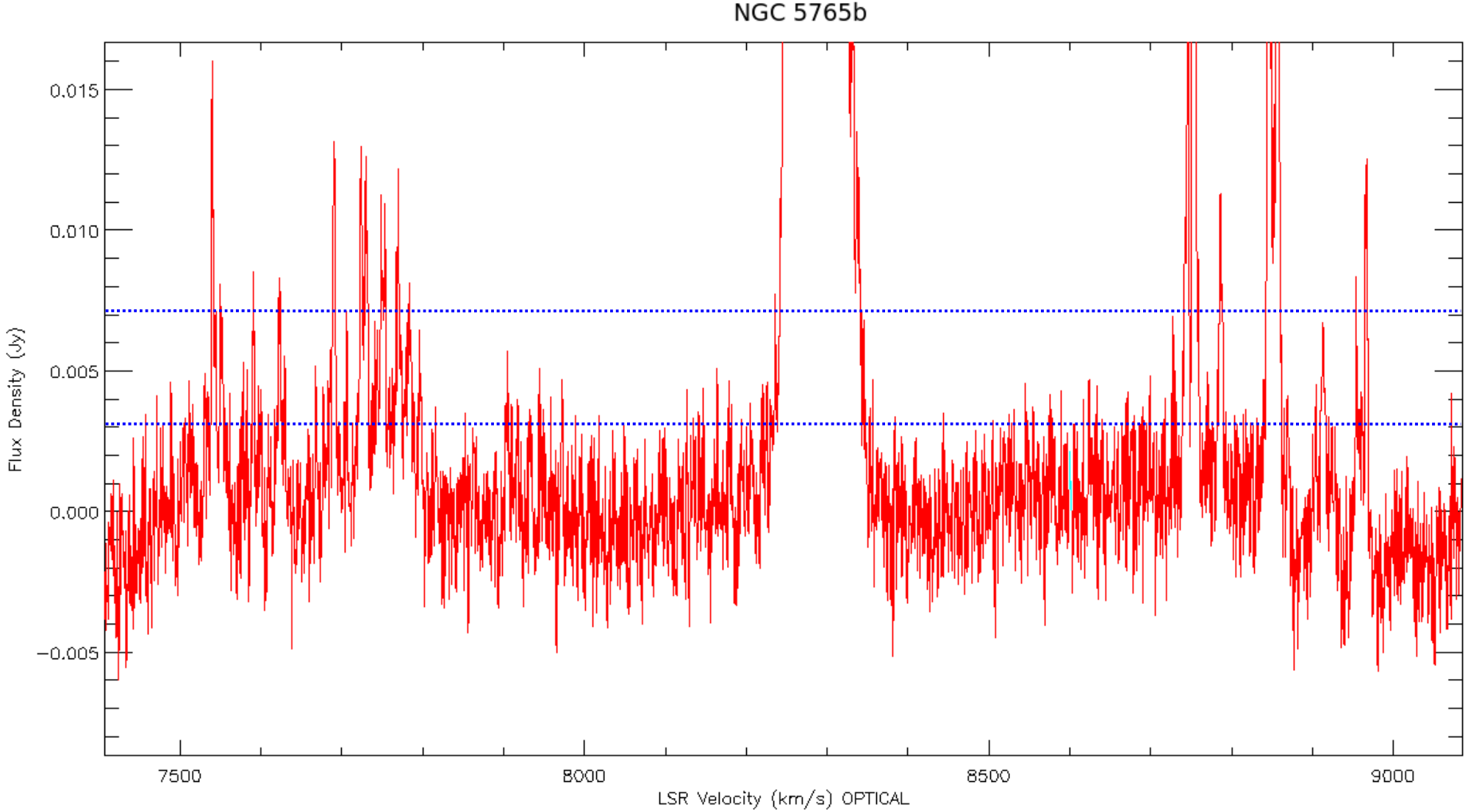
NGC 5765b is so far the best case for measuring H_0, and we're shooting for 5%!

“Old-style” P-V diagram fitting






NGC5765b spectrum stack 18 epochs systemic
Flux Density (mJy)
250
200
150
100
50
0
8240
8260
8280
8300
8320
8340
Velocity (km/s)


NGC 5765b
0.015
0.010
0.005
0.000
−0.005
Flux Density (Jy)
7500
8000
8500
9000
LSR Velocity (km/s) OPTICAL