An update of the Megamaser Cosmology Project

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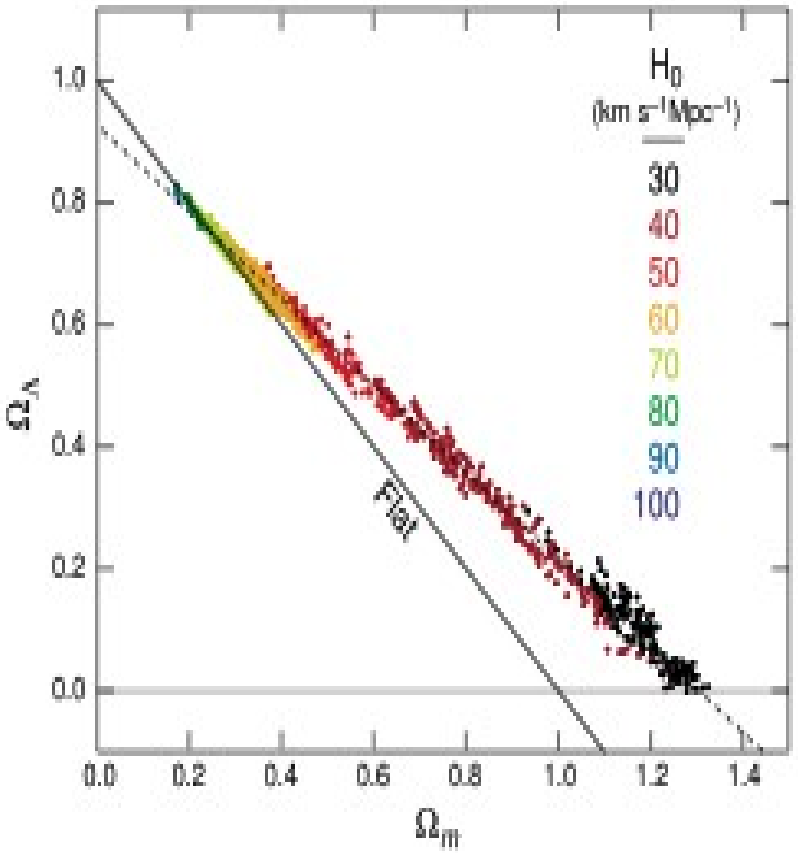
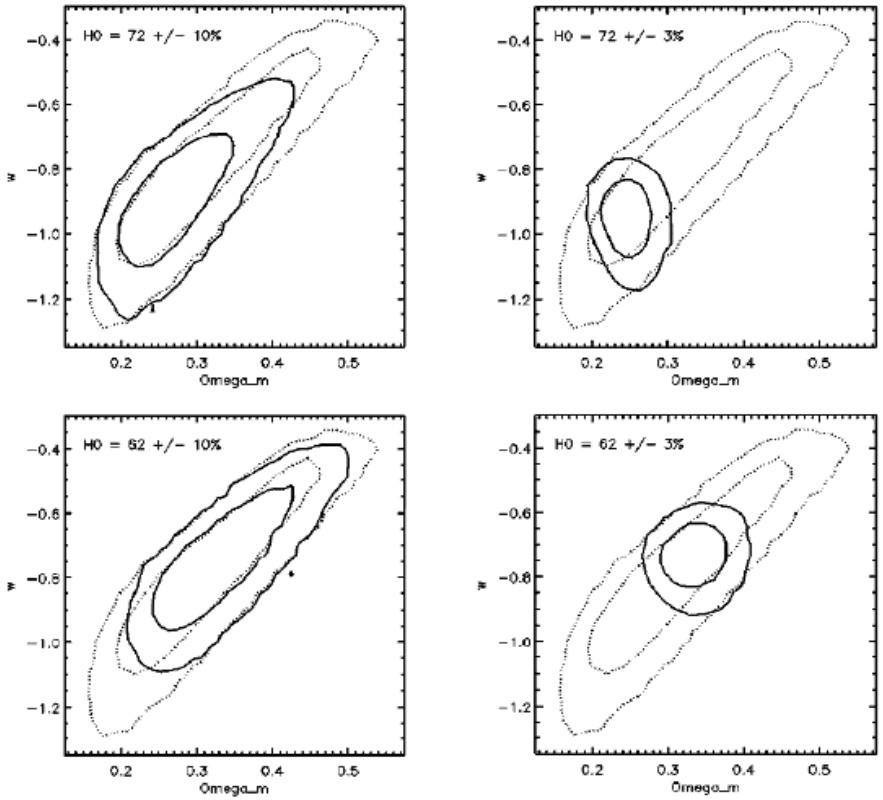
C.-Y. Kuo, V. Impellizzeri, J. Greene, A. Constantin, W. Zhao

Nov, 2012

Why MCP ?

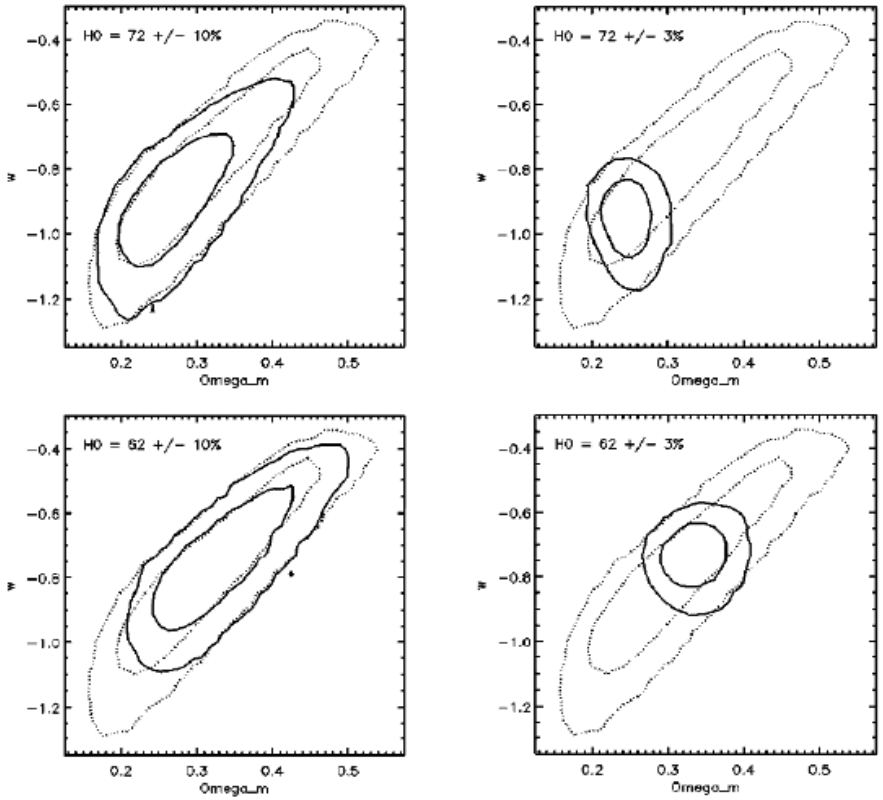


Spergel et al. 2007



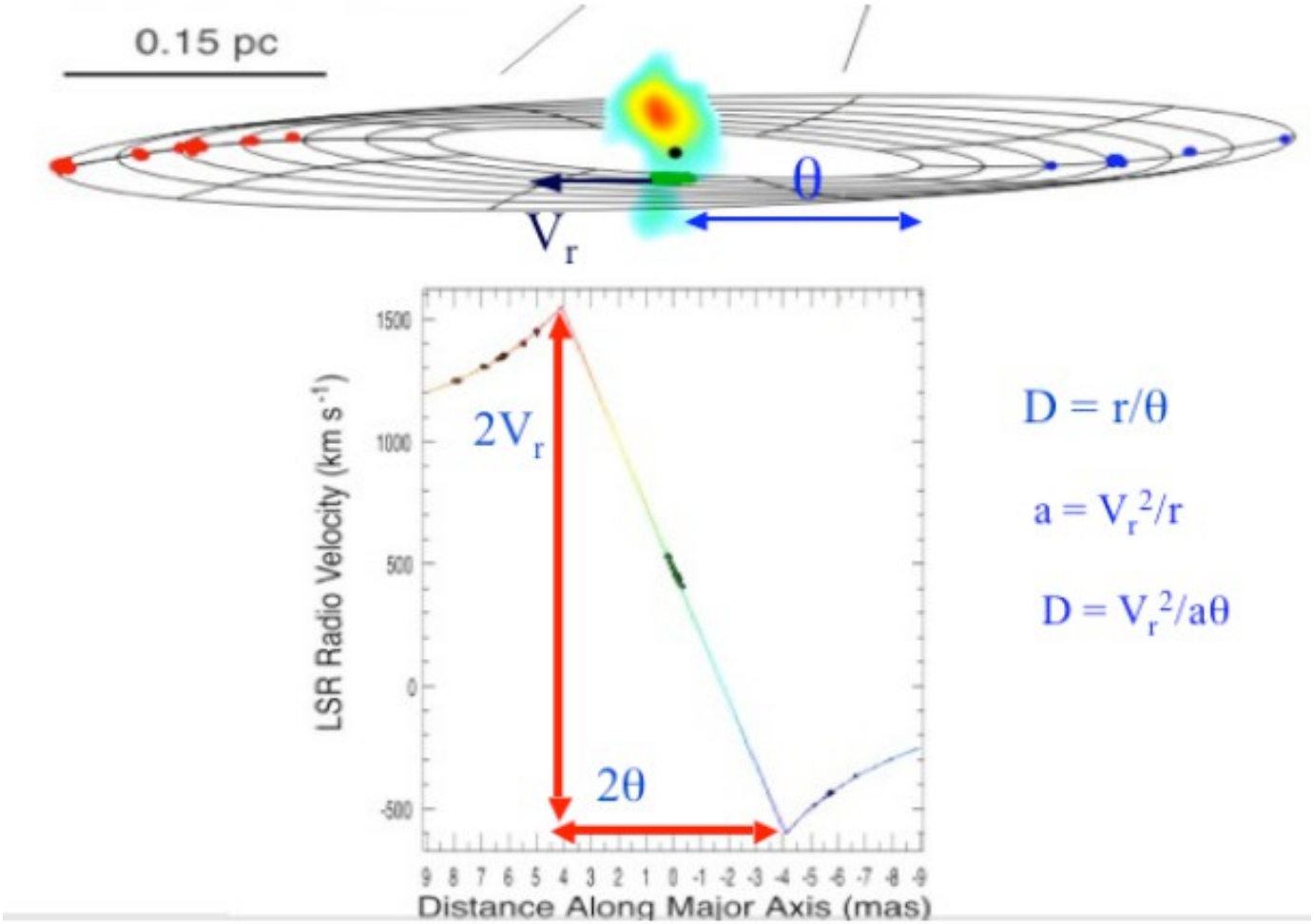
Why MCP ?

- Type Ia Supernovae
- Cepheids
- Tip of the Red Giant Branch
- Gravitational Lens Time Delays
- Baryon Acoustic Oscillations
- Surface Brightness Fluctuations
- Masers



- Using masers to get the geometric distance
- Independent and straightforward
- Calibrate other methods and test the cosmological model

How does it work

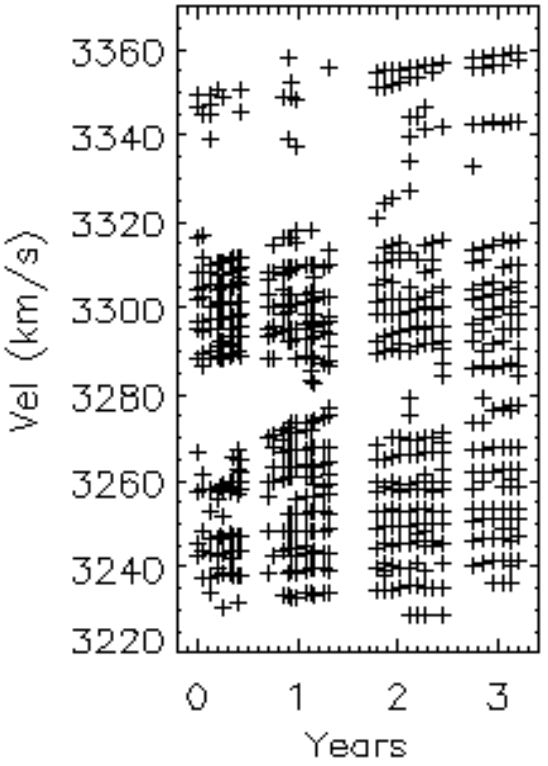


$D = r/\theta$

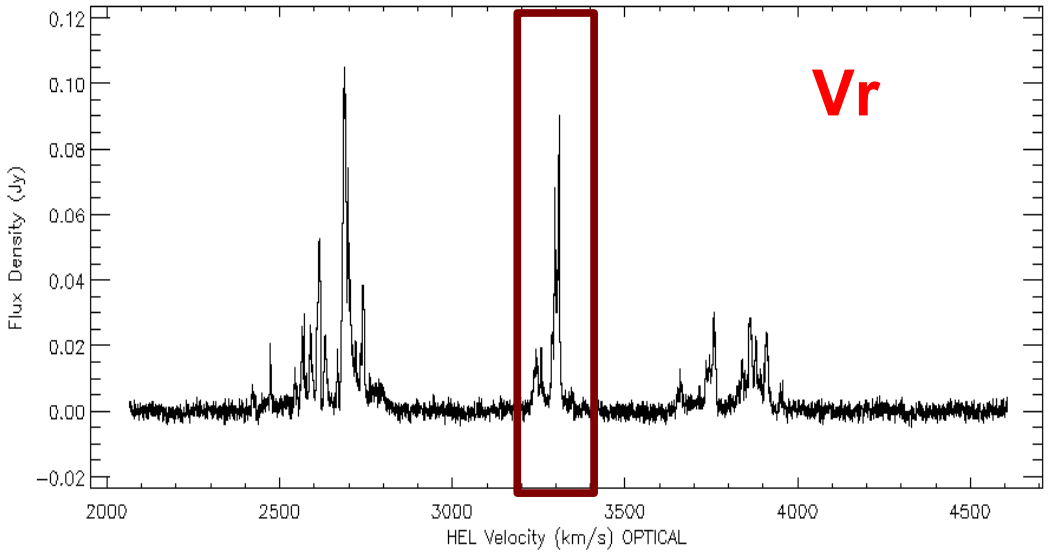
$a = V_r^2/r$

$D = V_r^2/a\theta$

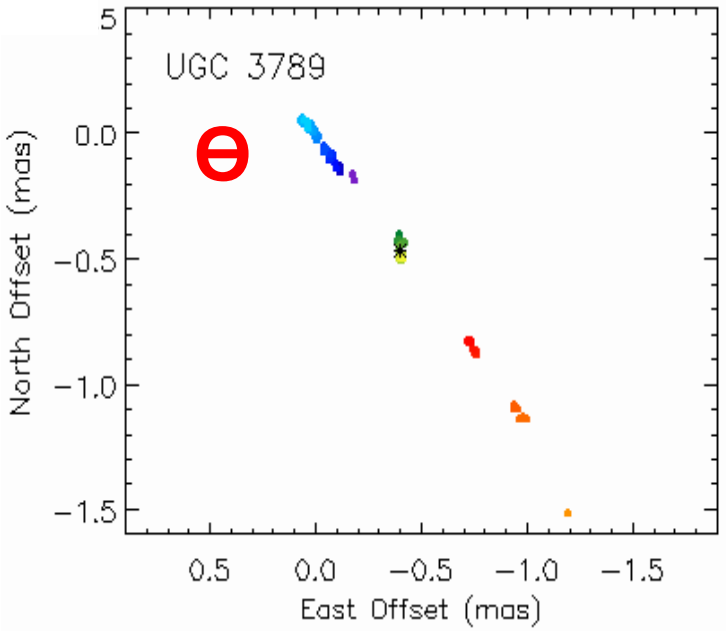
Braatz et al. 2010


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

a

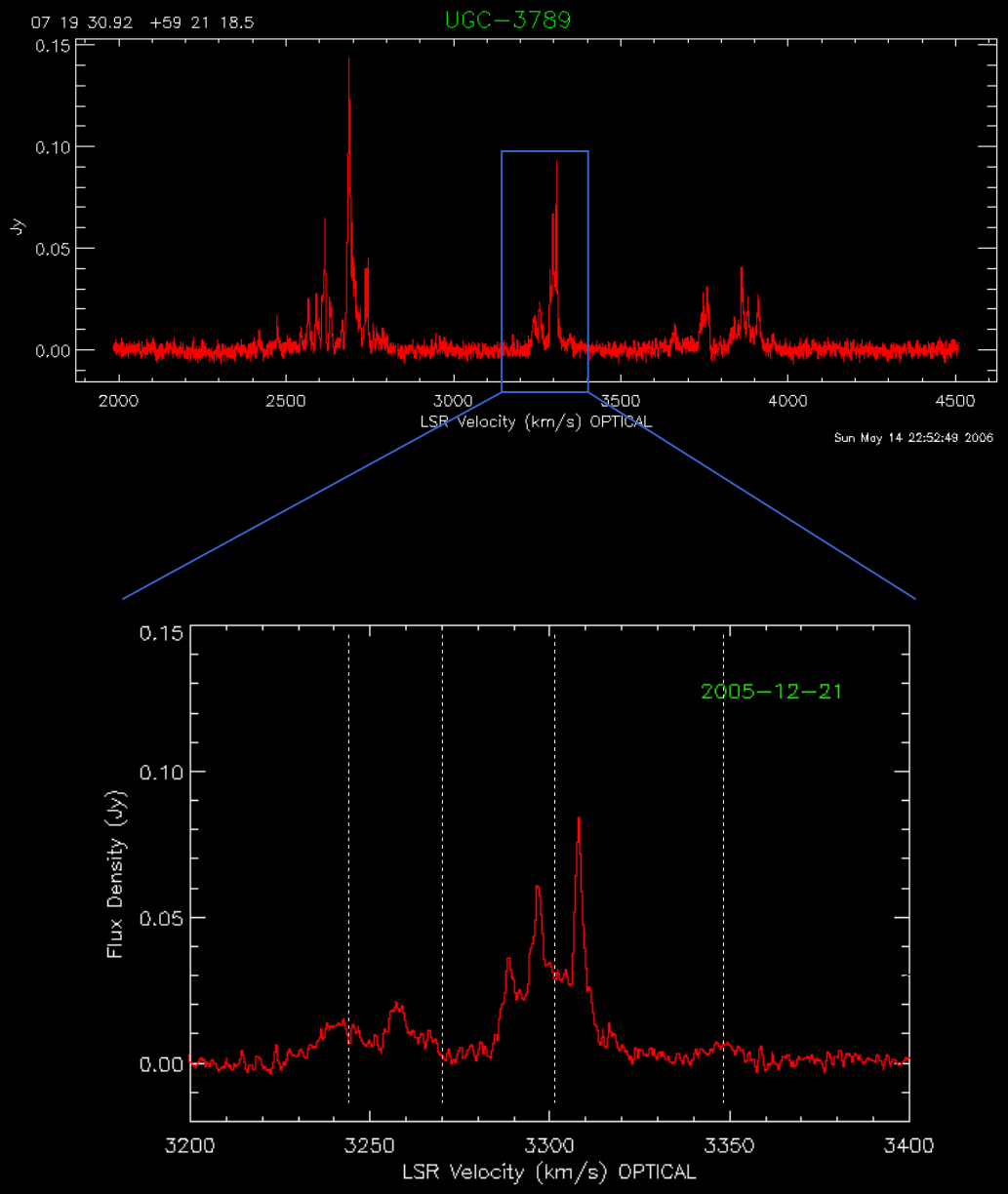

Flux Density (Jy)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
2000
2500
3000
3500
4000
4500
HEL Velocity (km/s) OPTICAL

Vr

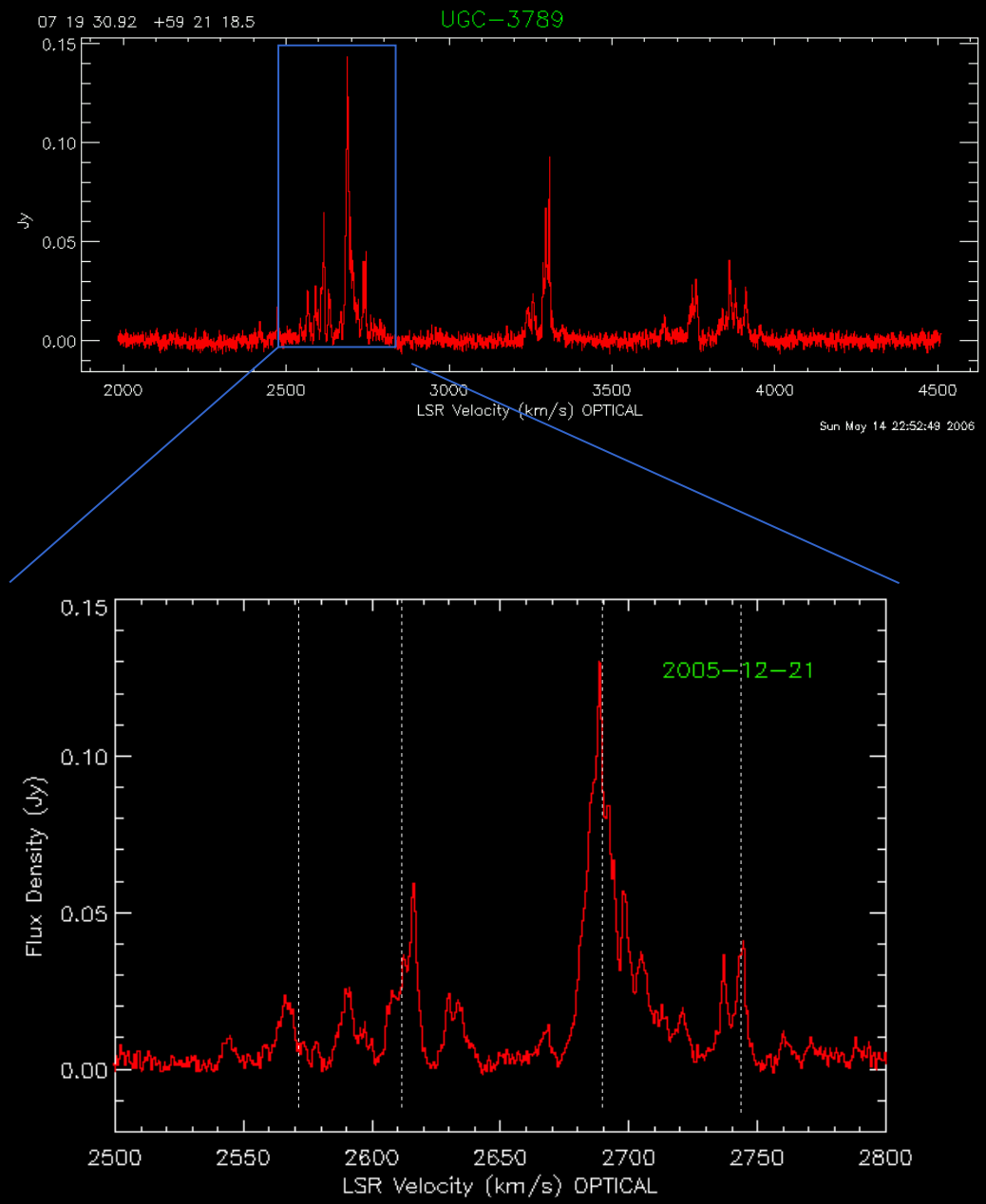

UGC 3789
North Offset (mas)
5
0.0
−0.5
−1.0
−1.5
0.5
0.0
−0.5
−1.0
−1.5
East Offset (mas)

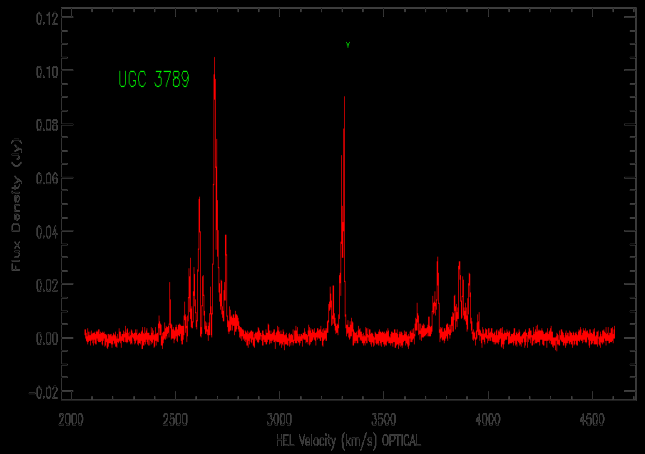
Θ

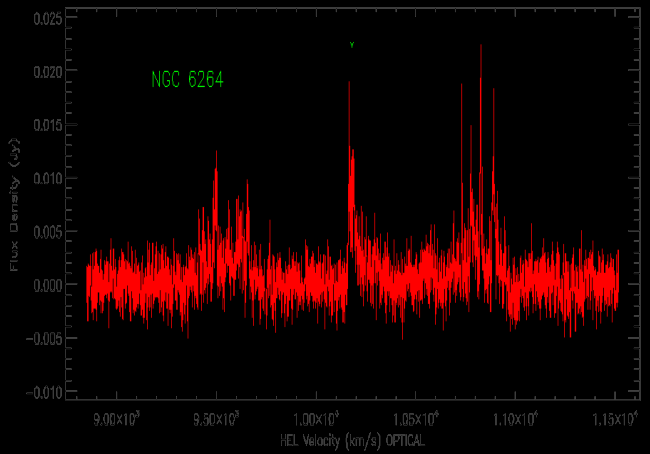
UGC 3789

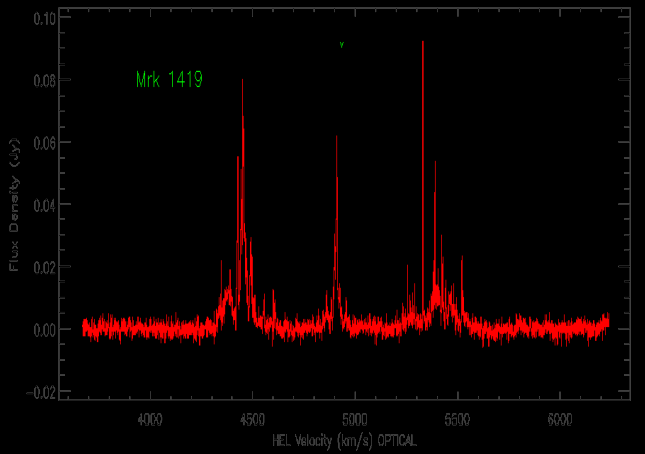

07 19 30.92 +59 21 18.5
UGC-3789
0.15
0.10
0.05
0.00
Jy
2000
2500
3000
3500
4000
4500
LSR Velocity (km/s) OPTICAL
Sun May 14 22:52:49 2006
2005-12-21
Flux Density (Jy)
3200
3250
3300
3350
3400
LSR Velocity (km/s) OPTICAL

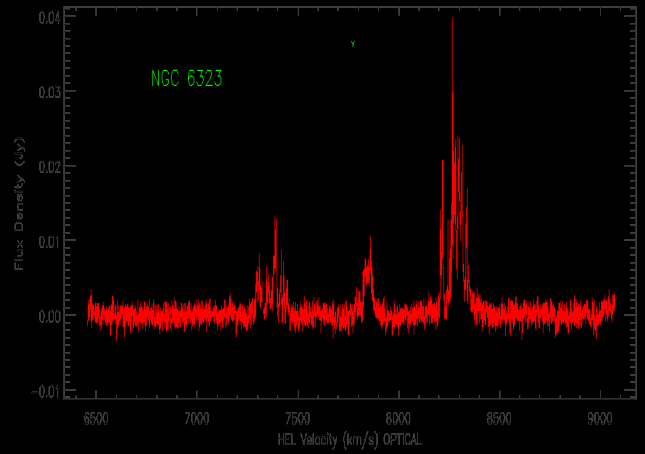
UGC 3789

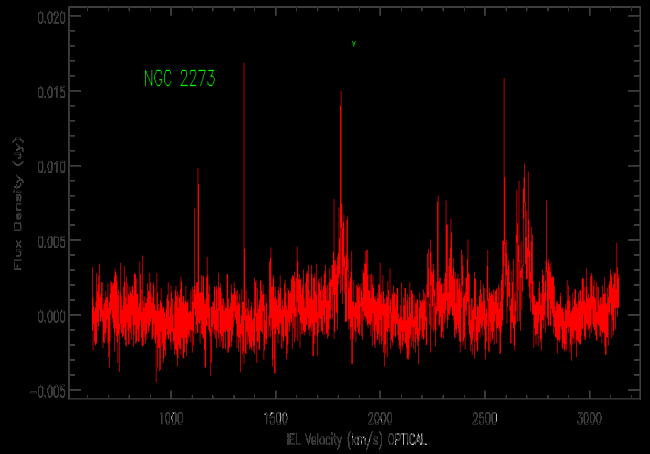

07 19 30.92 +59 21 18.5
UGC−3789
0.15
0.10
0.05
0.00
Jy
2000
2500
3000
3500
4000
4500
LSR Velocity (km/s) OPTICAL
Sun May 14 22:52:49 2006
2005−12−21
Flux Density (Jy)
2500
2550
2600
2650
2700
2750
2800
LSR Velocity (km/s) OPTICAL

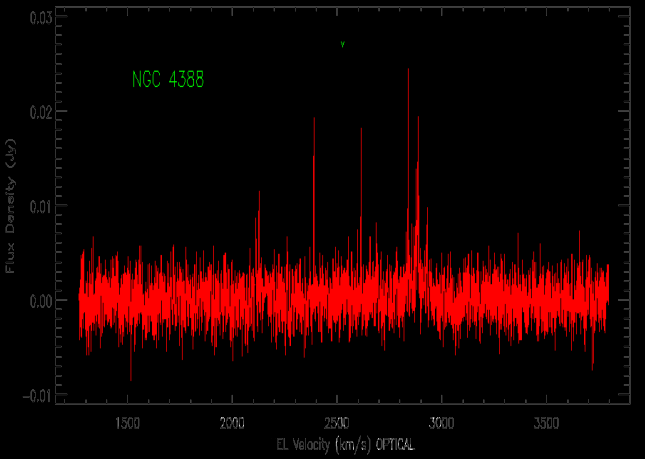

UGC 3789
Flux Density (Jy)
HEL Velocity (km/s) OPTICAL

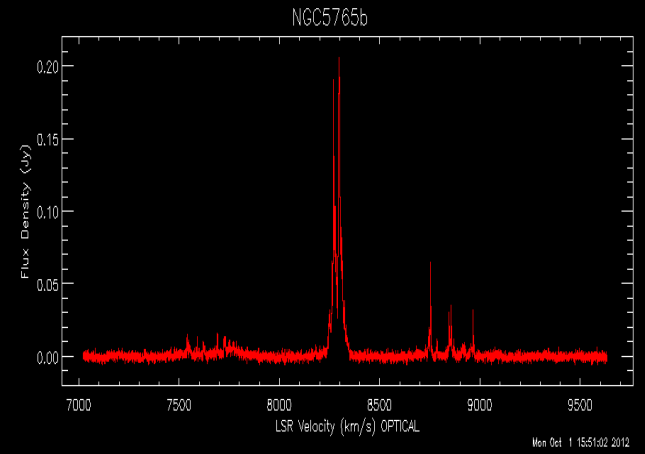

NGC 6264
Flux Density (Jy)
HEL Velocity (km/s) OPTICAL

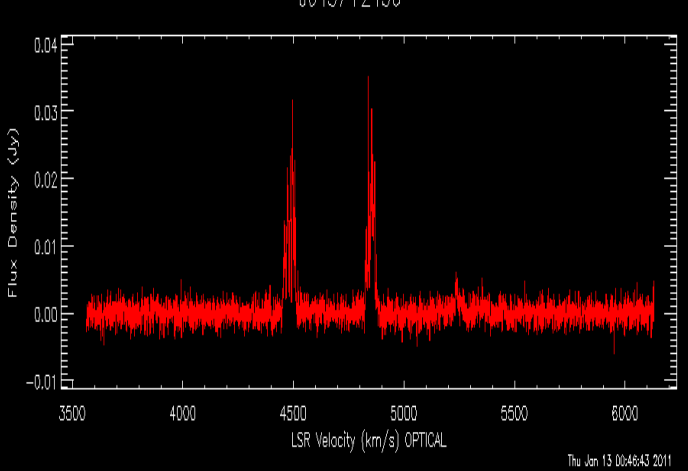

Mrk 1419
Flux Density (Jy)
HEL Velocity (km/s) OPTICAL

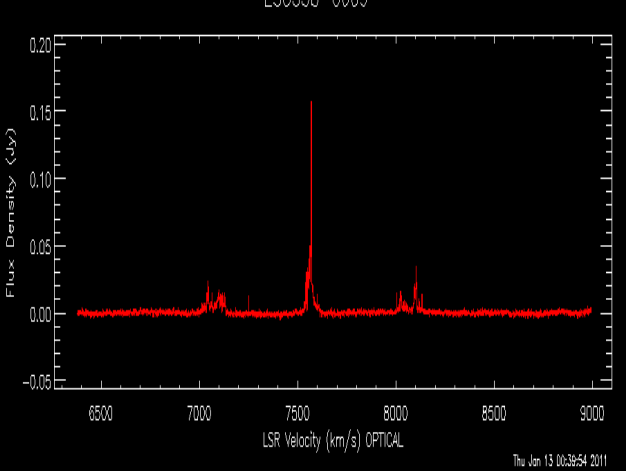

NGC 6323
Flux Density (Jy)
HEL Velocity (km/s) OPTICAL


NGC 2273
Flux Density (Jy)
HEL Velocity (km/s) OPTICAL


NGC 4388
Flux Density (Jy)
EL Velocity (km/s) OPTICAL


NGC5765b
Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
Mon Oct 1 15:51:02 2012


J0437+2456
Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
Thu Jan 13 00:46:43 2011


ESO558-G009
Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
Thu Jan 13 00:39:54 2011

For the distance

Galaxy	H_0 (km s^{-1} Mpc^{-1})
UGC 3789	71.6 ± 5.7
NGC 6264	74.3 ± 10.3

H_{0_com} = 72.2 ± 5.0 km s^{-1} Mpc^{-1} 7%

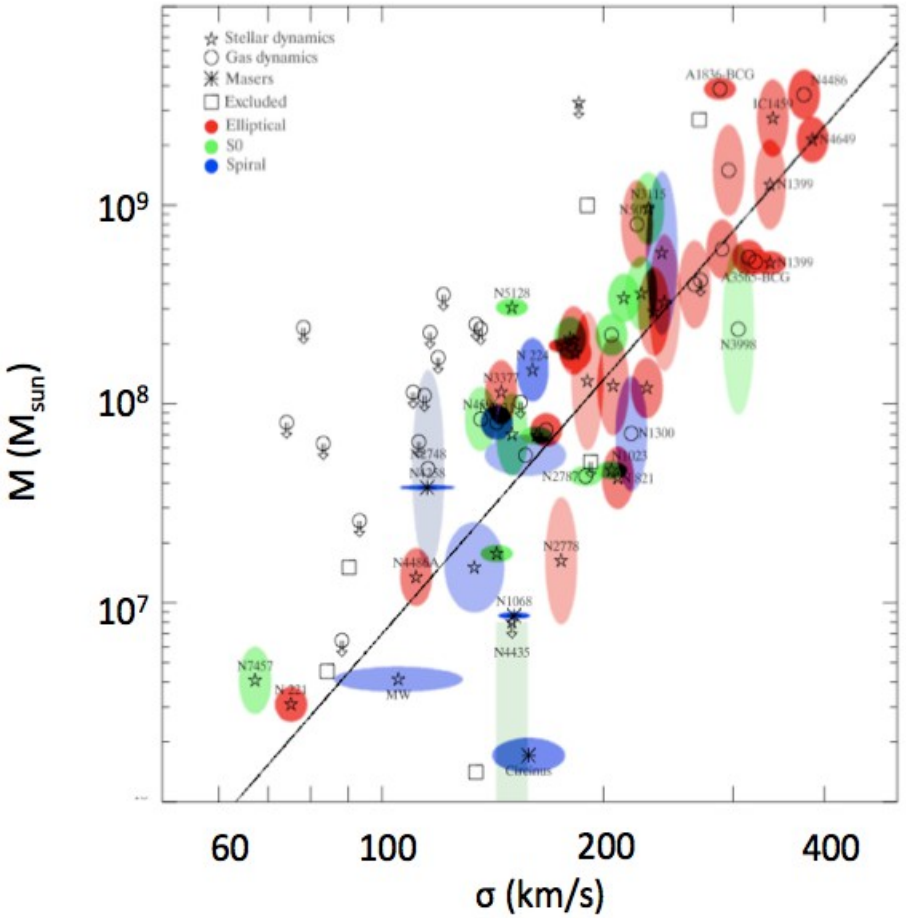
(Reid et al. 2012 in press)

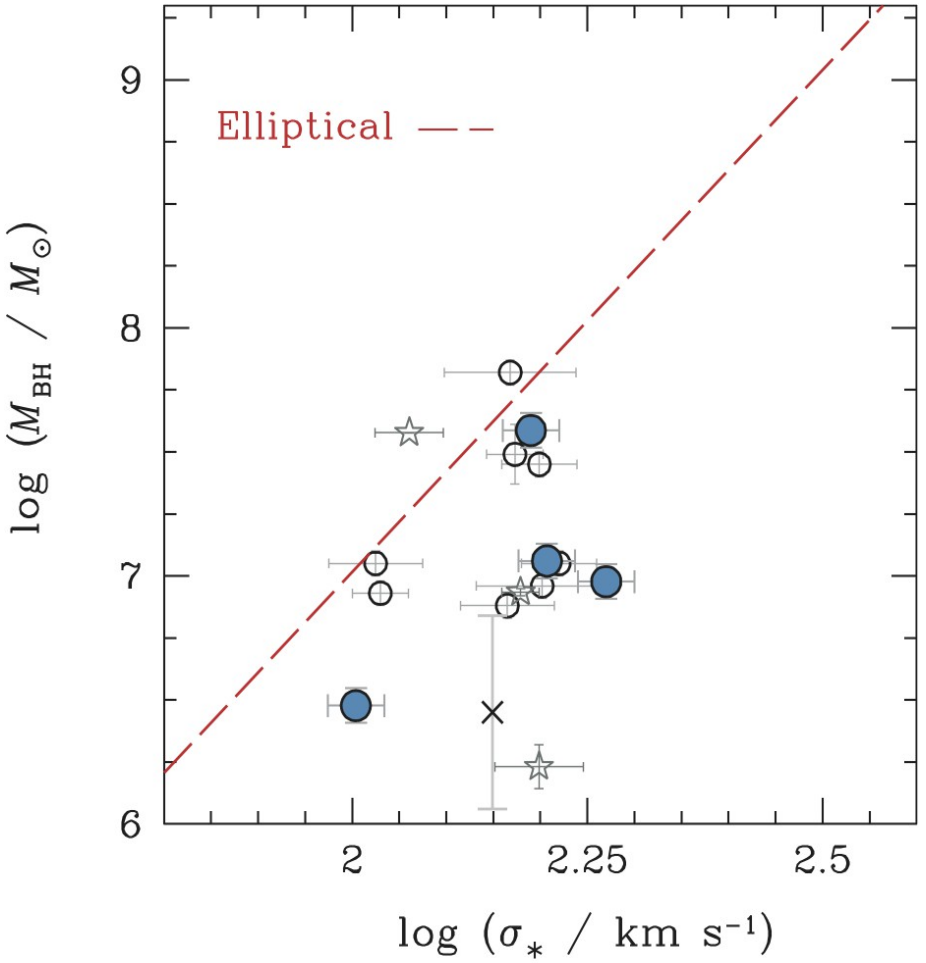
(Kuo et al. 2012 in press)

For the BH-mass

Galaxy	MBH (Msun)
Mrk 1419	6.5 x 10^6
NGC 1194	6.6 x 10^7
NGC 2273	7.6 x 10^6
NGC 6264	2.5 x 10^7
NGC 6323	1.0 x 10^7
UGC 3789	1.1 x 10^7
NGC 4388	1.5 x 10^7
NGC 5728	2.3 x 10^6
ESO 558-G009	2.0 x 10^7
J0437+2456	2.6 x 10^6
Mrk 1	1.0 x 10^6
Mrk 1210	1.3 x 10^7
NGC 5765b	4.4 x 10^7
UGC 6093	2.5 x 10^7
NGC 5495	1.2 x 10^7

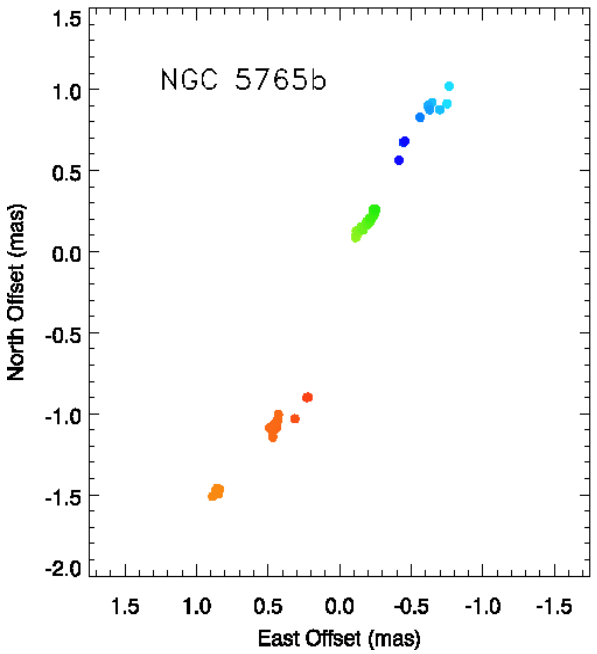
The M-σ relation

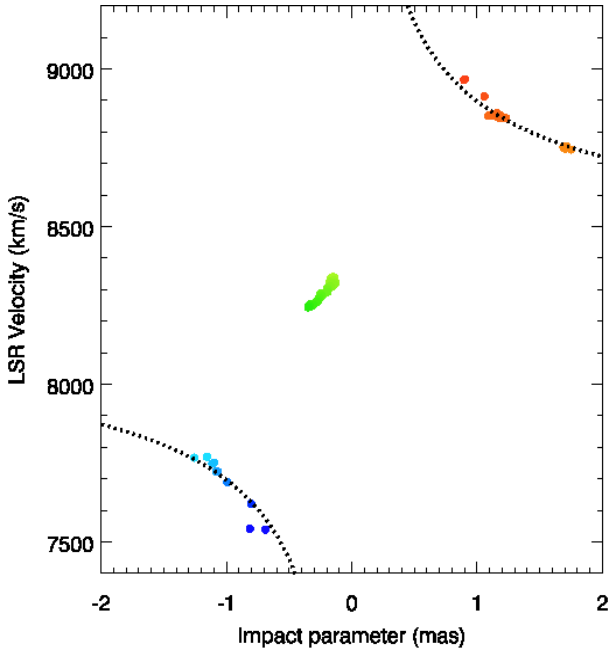


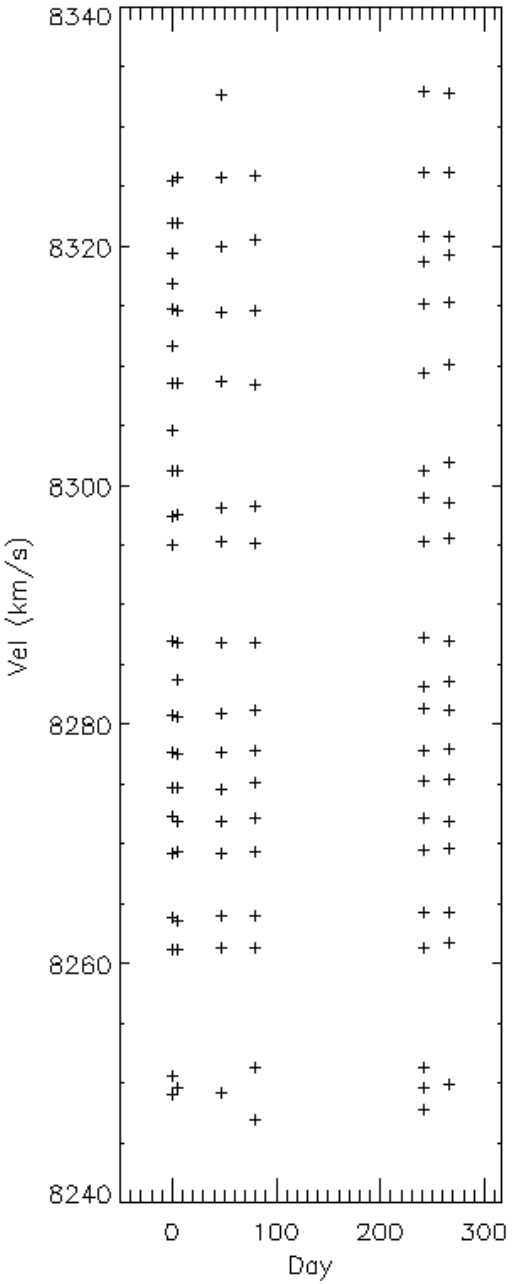


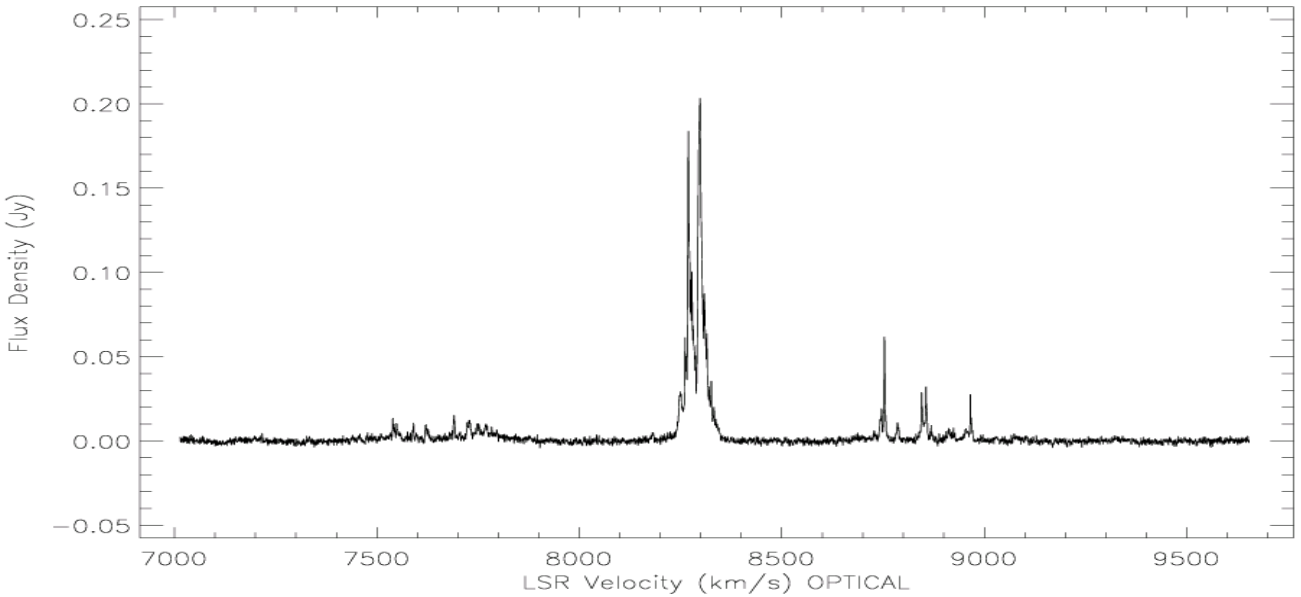
Gultekin et al. 2009

NGC 5765b

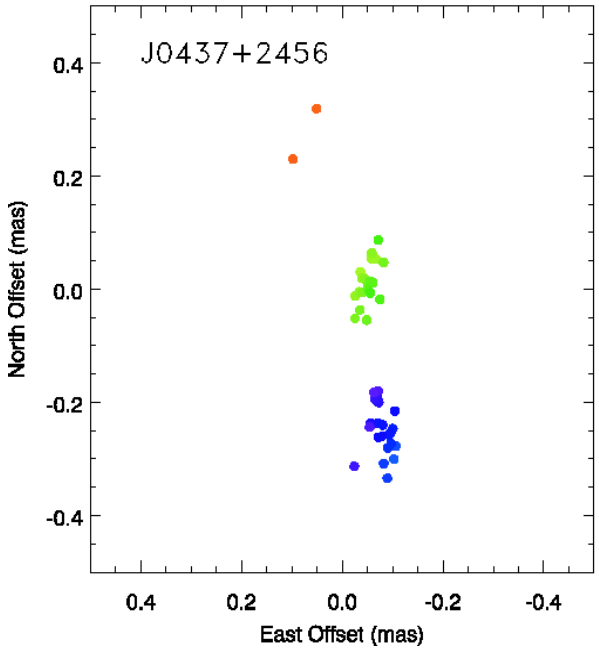

NGC 5765b
North Offset (mas)
East Offset (mas)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0

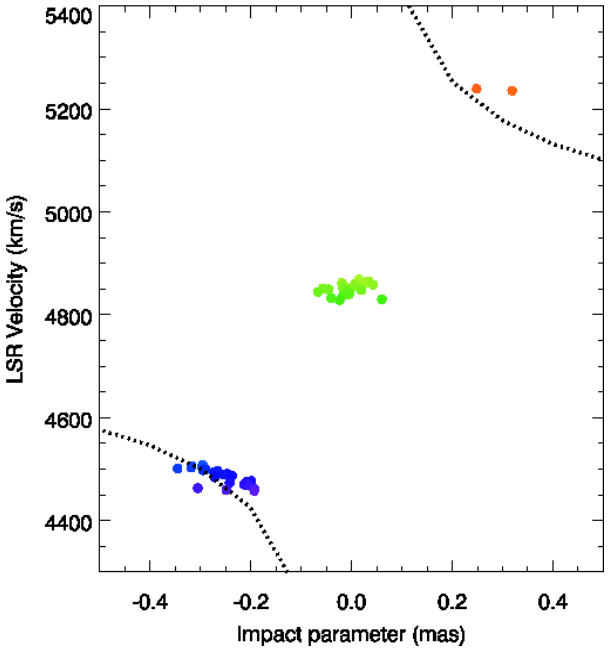

LSR Velocity (km/s)
Impact parameter (mas)
9000
8500
8000
7500
-2
-1
0
1
2

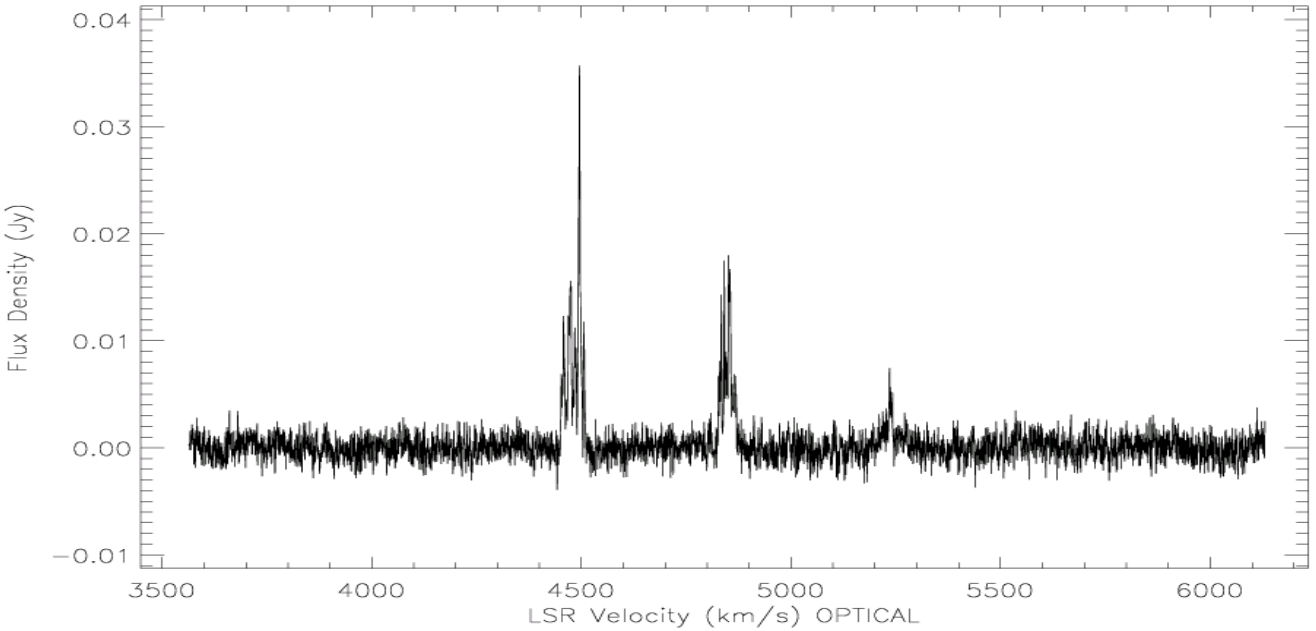

Vel (km/s)
Day
8340
8320
8300
8280
8260
8240
0
100
200
300

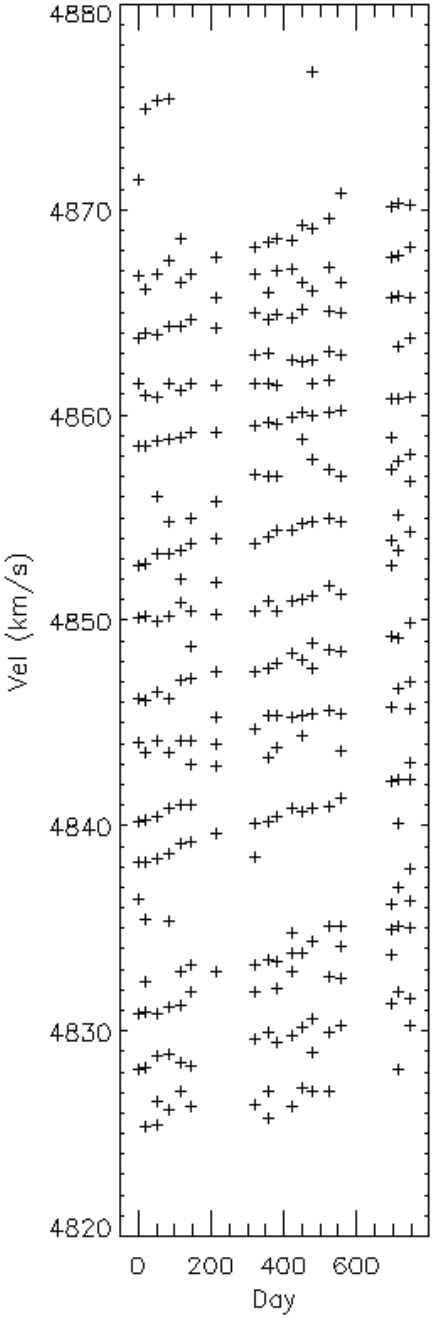

Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
0.25
0.20
0.15
0.10
0.05
0.00
−0.05
7000
7500
8000
8500
9000
9500

J0437+2456

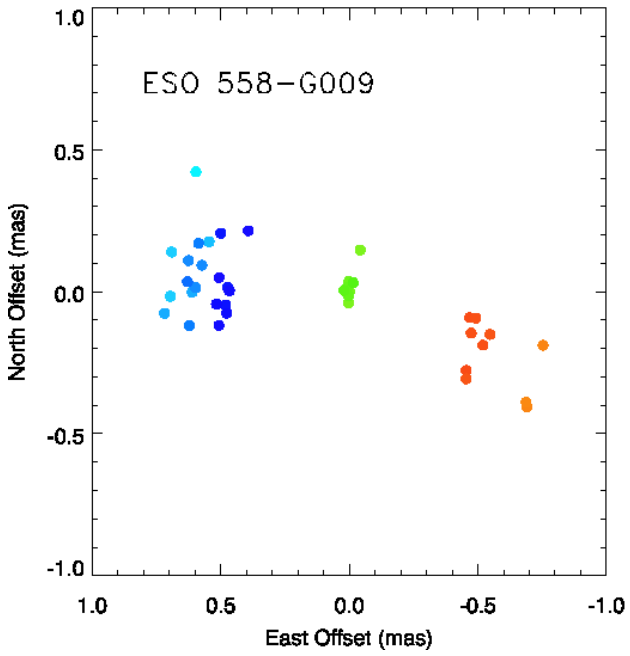

J0437+2456
North Offset (mas)
East Offset (mas)
0.4
0.2
0.0
-0.2
-0.4

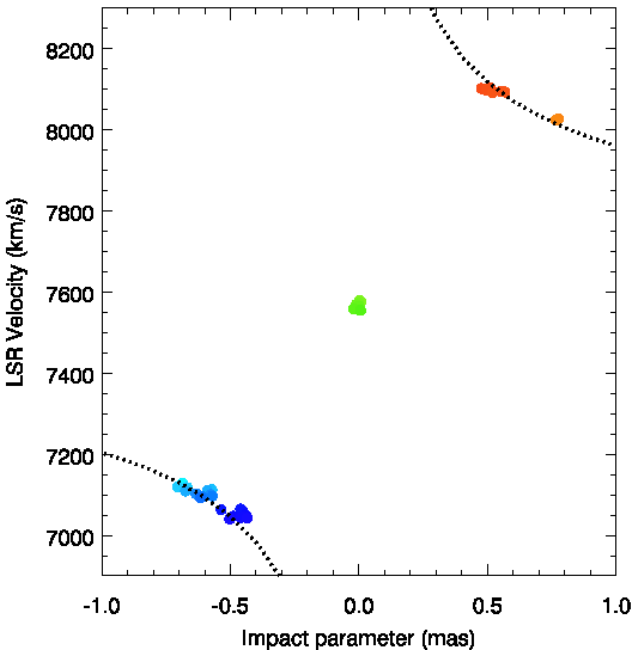

LSR Velocity (km/s)
Impact parameter (mas)
5400
5200
5000
4800
4600
4400

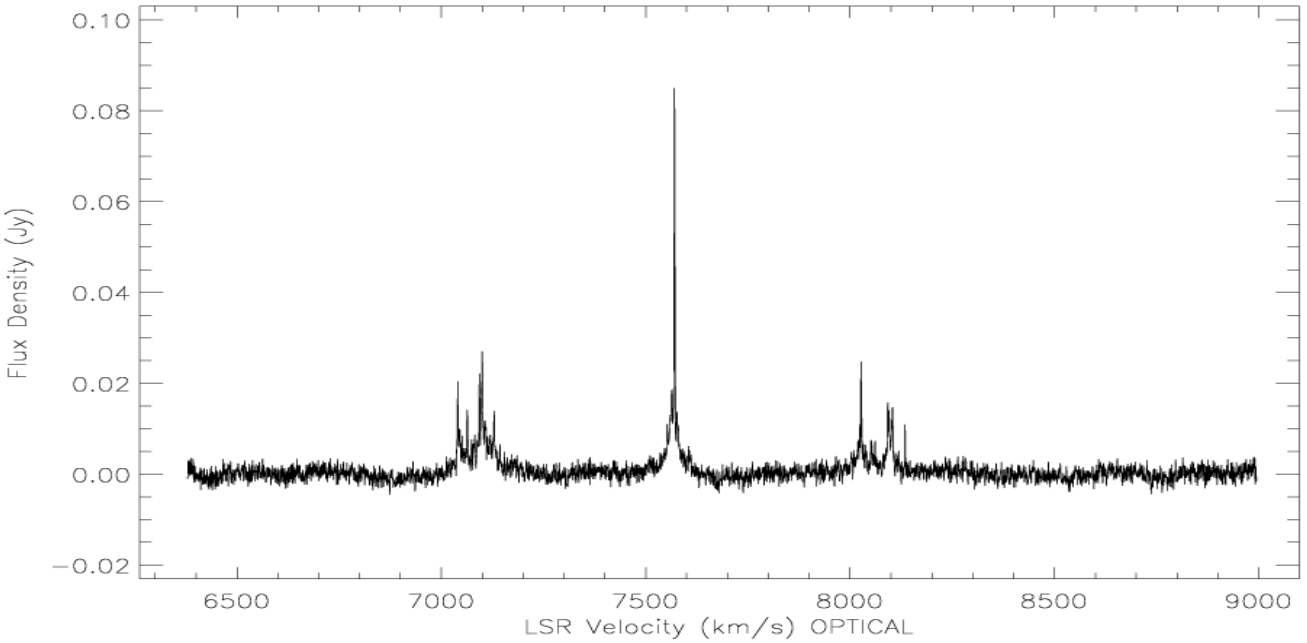

Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
0.04
0.03
0.02
0.01
0.00
−0.01
3500
4000
4500
5000
5500
6000

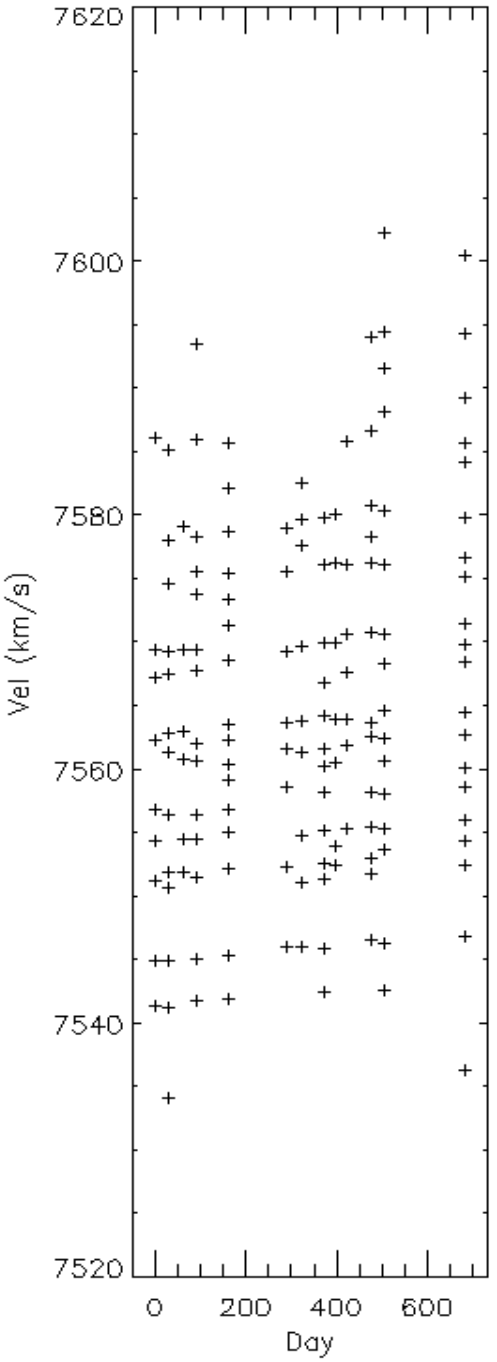

Vel (km/s)
Day
4880
4870
4860
4850
4840
4830
4820
0
200
400
600

ESO558-G009

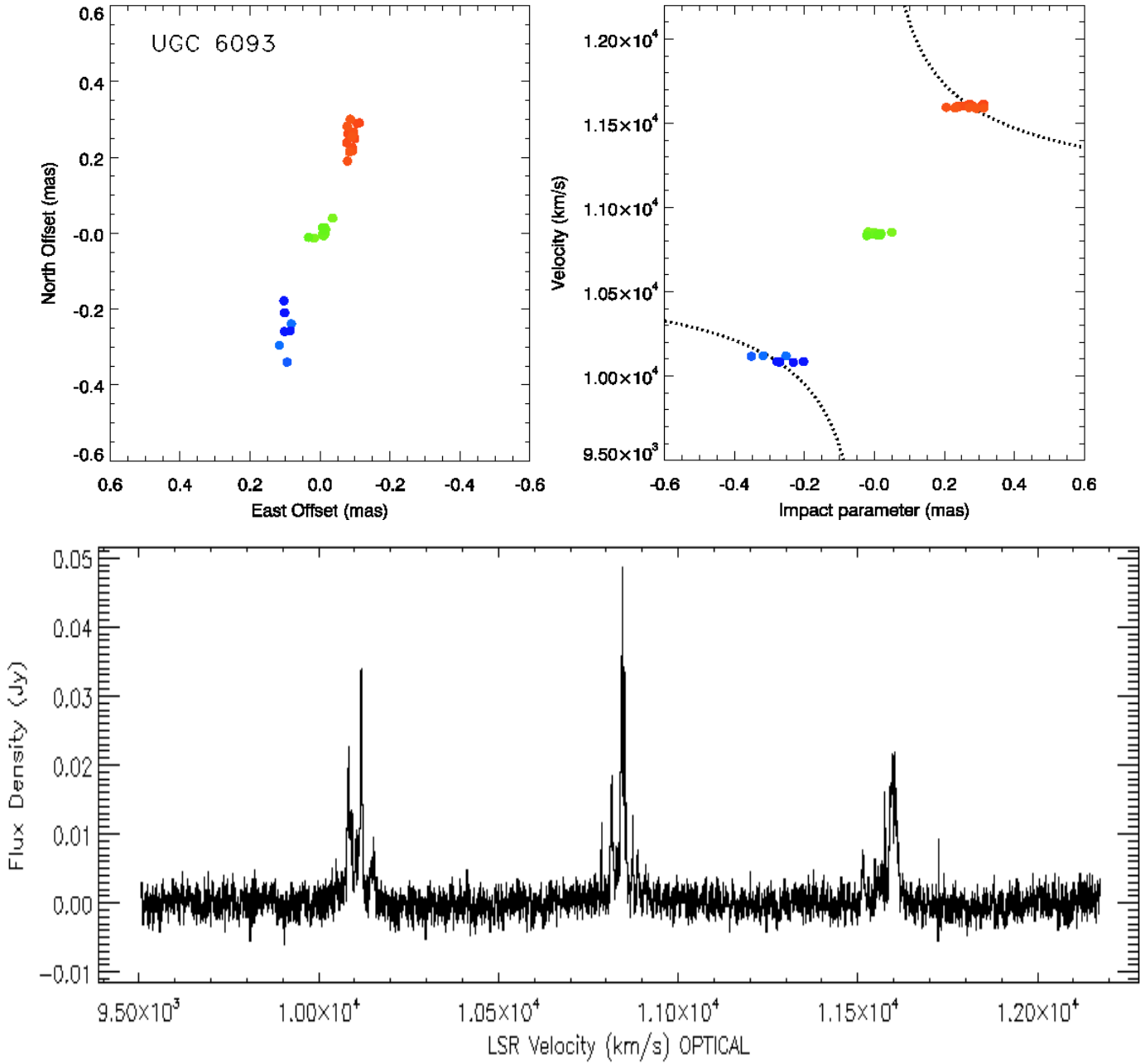

ESO 558−G009
North Offset (mas)
East Offset (mas)
1.0
0.5
0.0
-0.5
-1.0


LSR Velocity (km/s)
Impact parameter (mas)
8200
8000
7800
7600
7400
7200
7000


Flux Density (Jy)
LSR Velocity (km/s) OPTICAL
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
6500
7000
7500
8000
8500
9000


Vel (km/s)
Day
7620
7600
7580
7560
7540
7520
0
200
400
600

UGC 6093


UGC 6093
North Offset (mas)
East Offset (mas)
Velocity (km/s)
Impact parameter (mas)
Flux Density (Jy)
LSR Velocity (km/s) OPTICAL

The next step

- The phased-EVLA

  raise the sensitivity by 40%

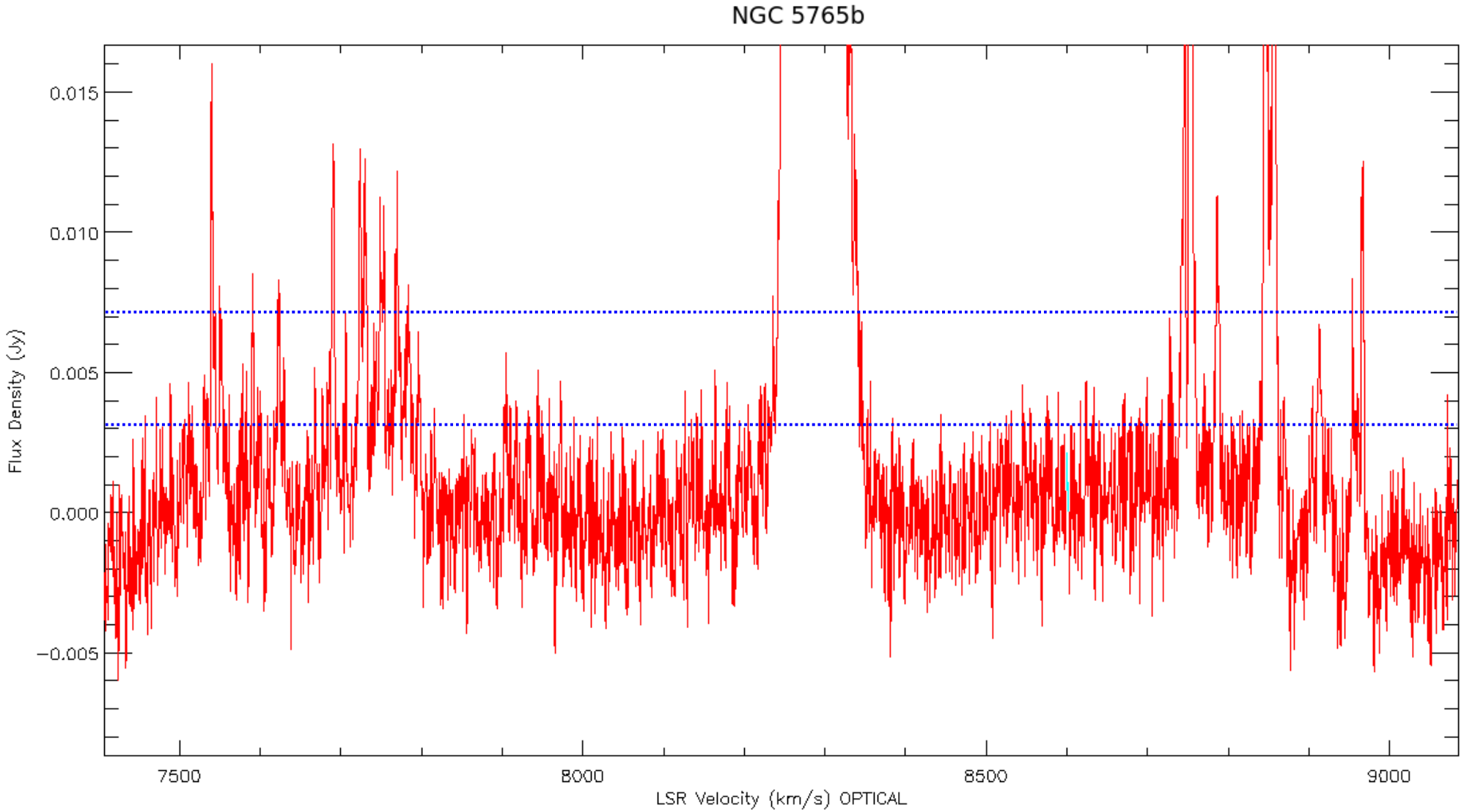
  coming in next Feb!

- Keep searching

  current maser detection rate: 3%~5%

  physics of the disk maser

  better survey strategy


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