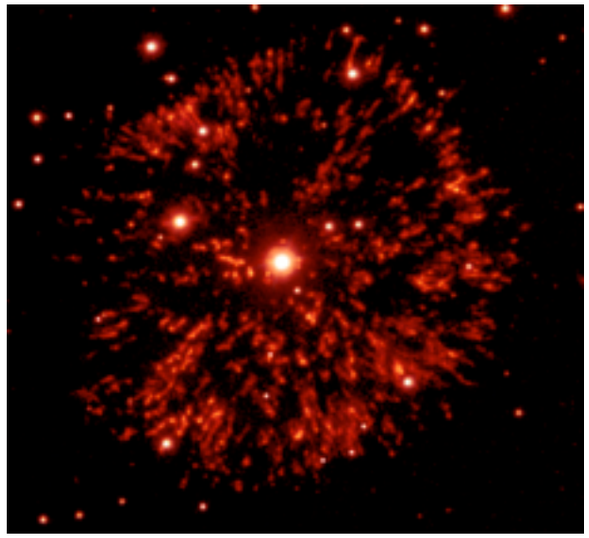
# A dynamic study of the nova remnant of GK Per

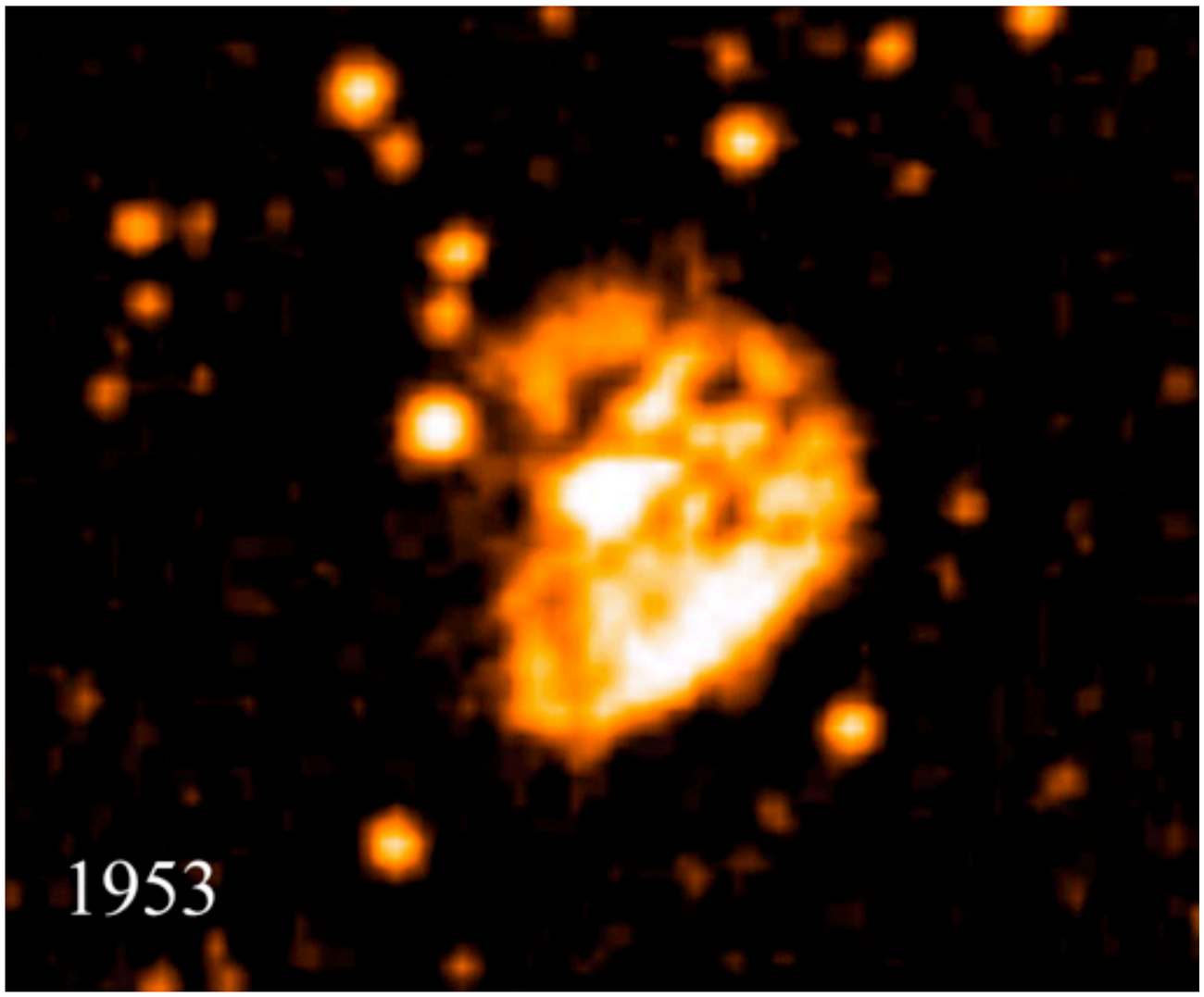
Tiina Liimets *(Tartu Observatory)*

Romano Corradi *(IAC)*

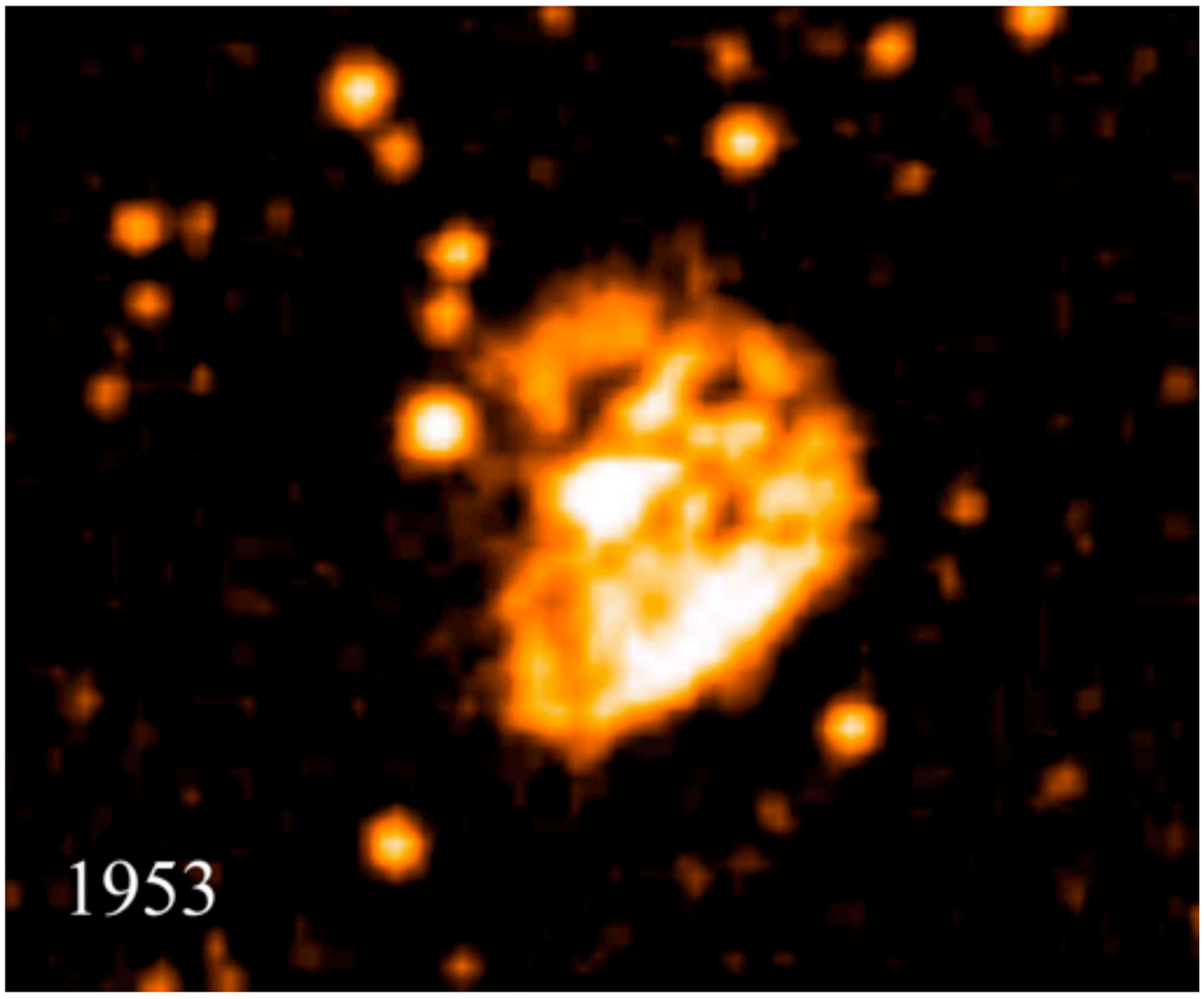


TARTU OBSERVATORY

M. Santander-García, E. Villaver,
P. Rodríguez-Gil, K. Verro, I. Kolka

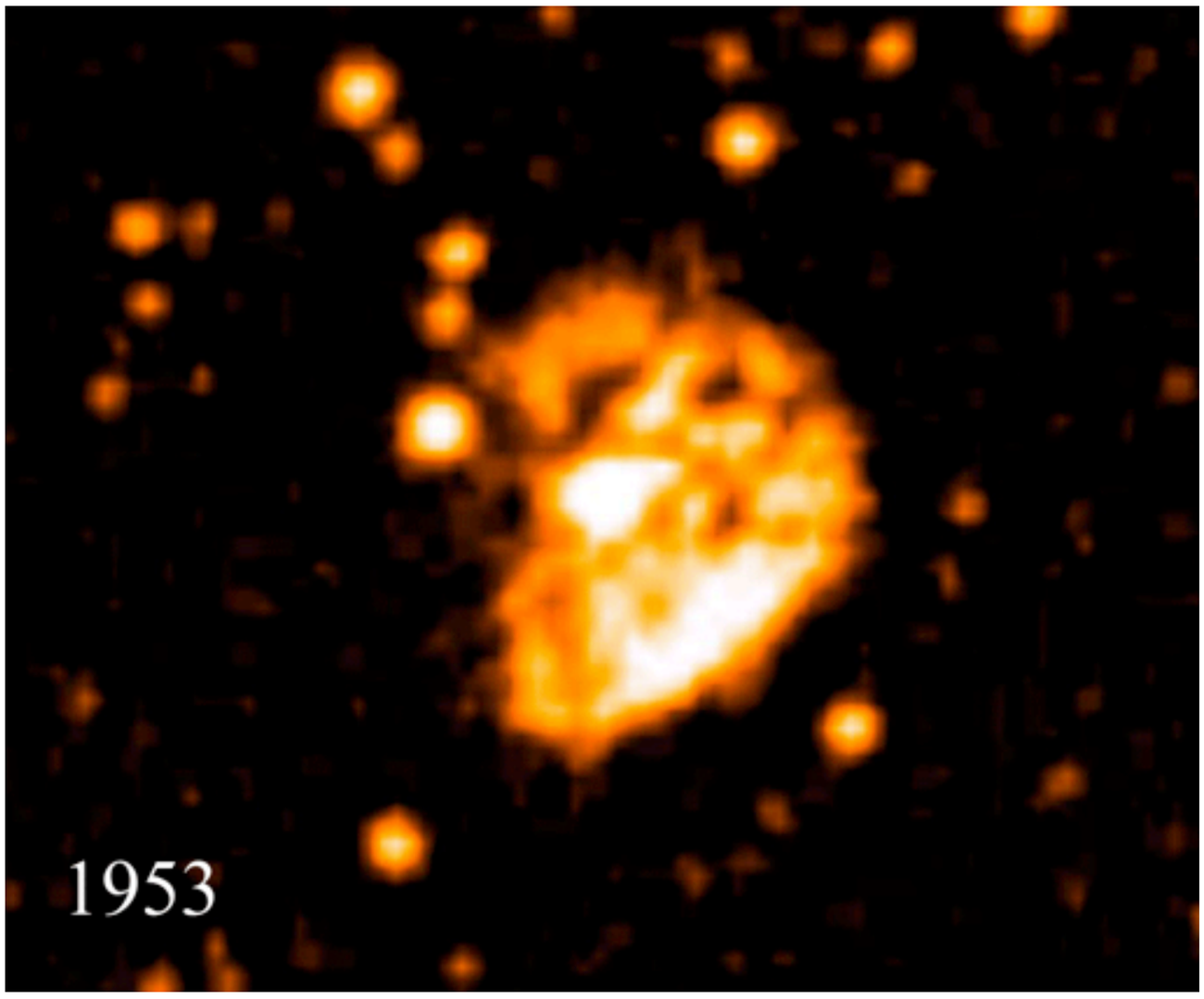

1953

# DATA



# IMAGING

# DATA



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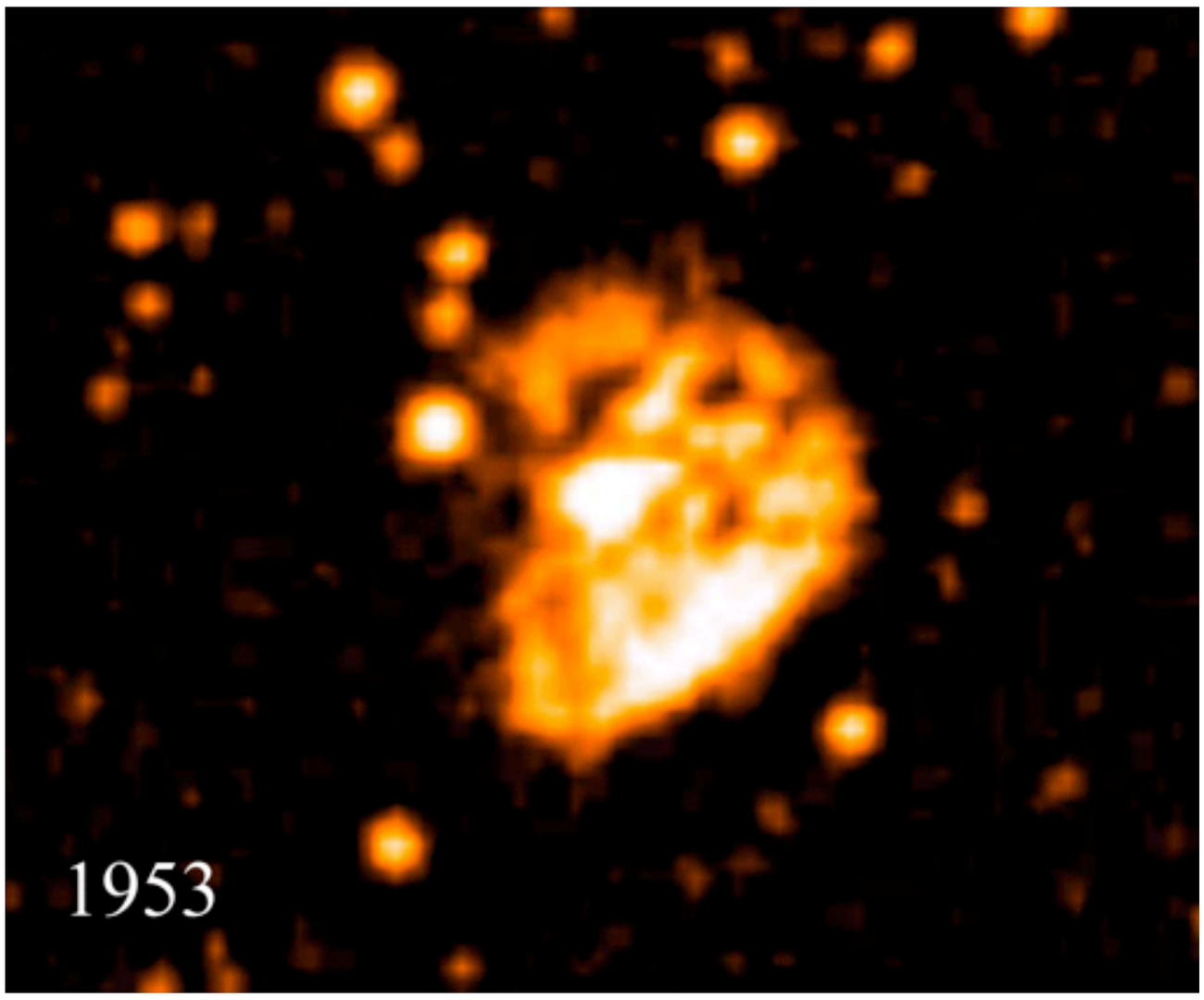
★ 2004 - 2011

2.5m Isaac Newton Telescope (INT) and 2.6m Nordic Optical Telescope (NOT).

19 narrow band Hα+[NII] frames (seeing 0.5” - 1.3”).



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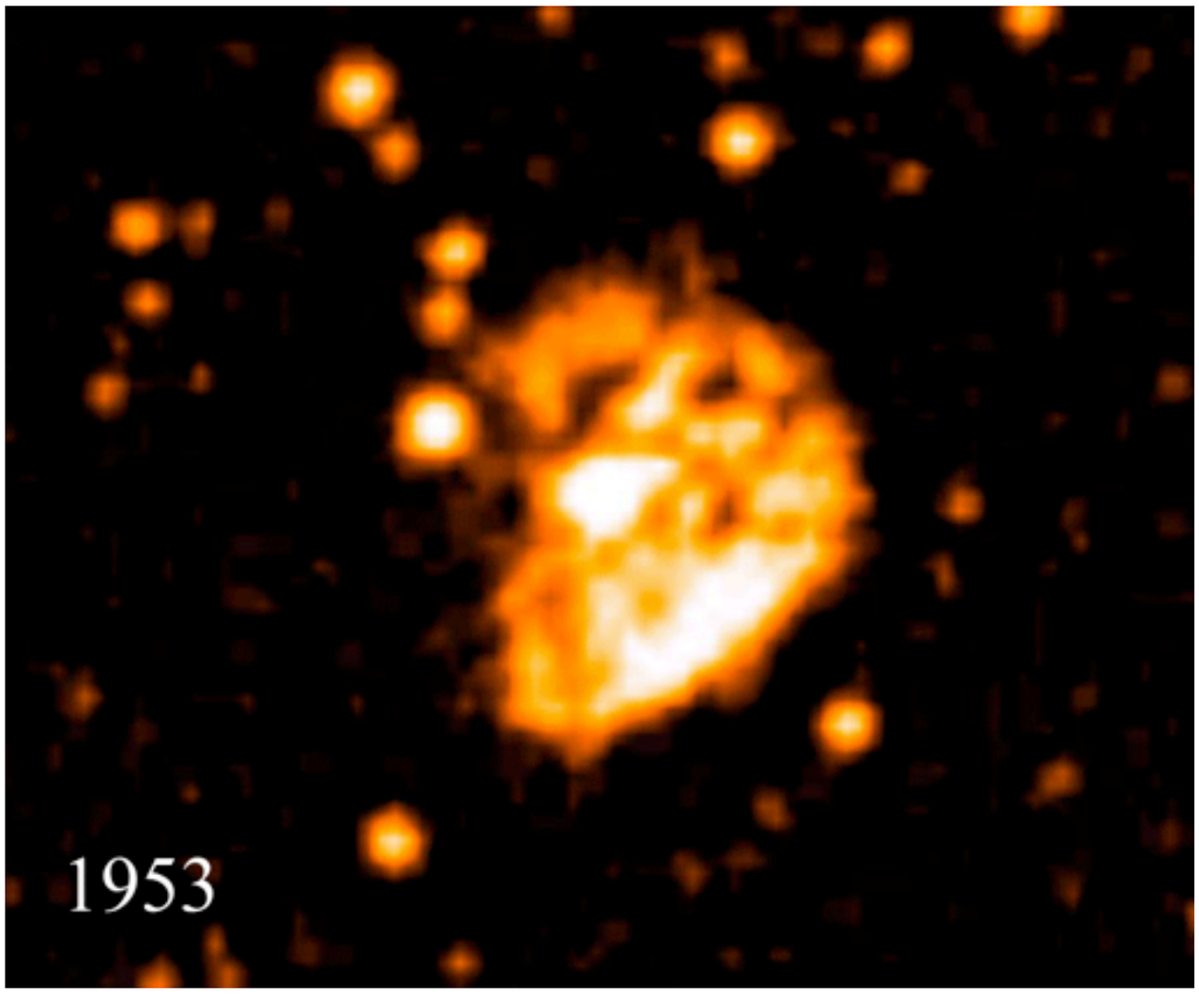

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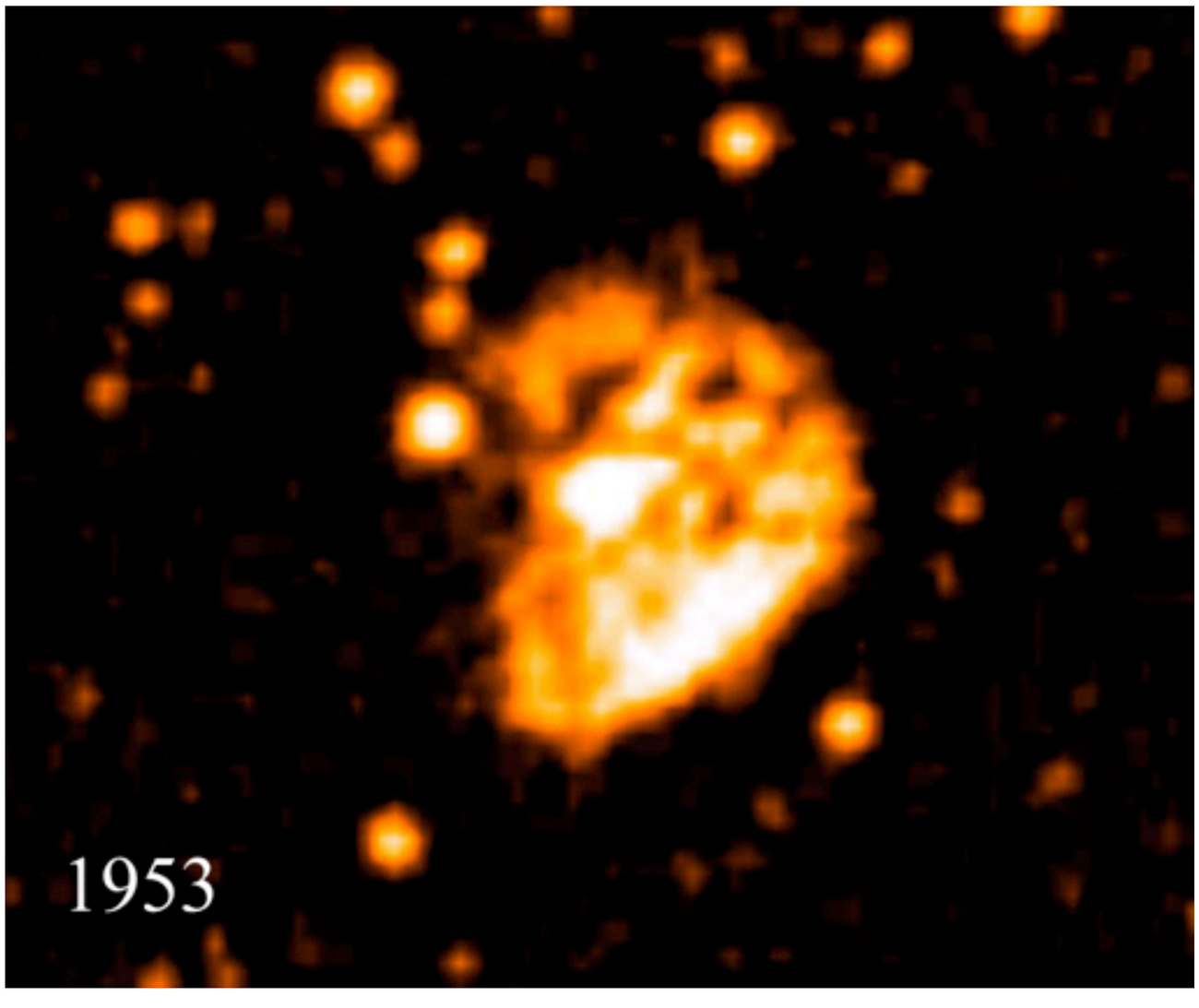
## ★ Long-slit SPECTRA

N[II] Doppler shifts



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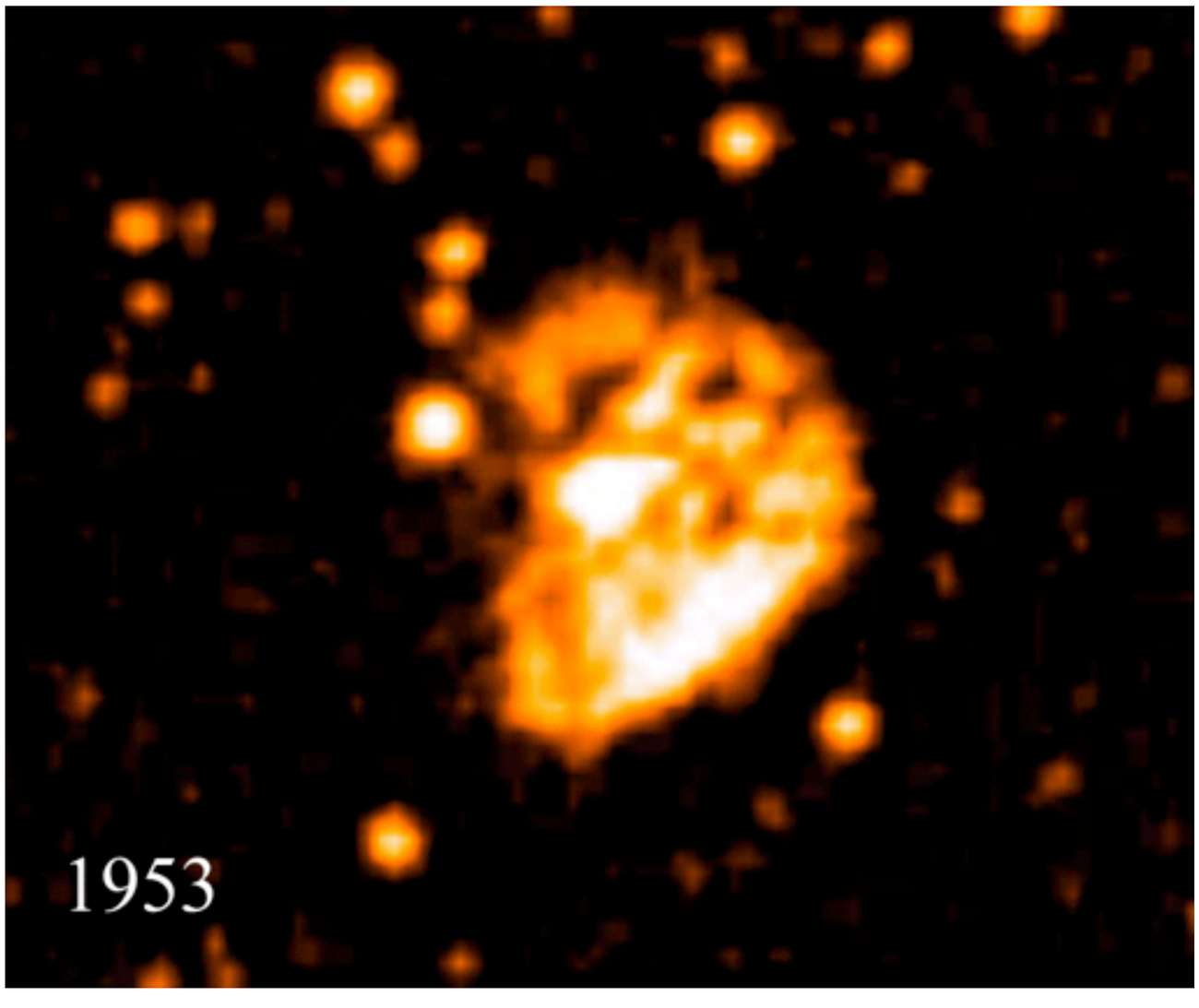


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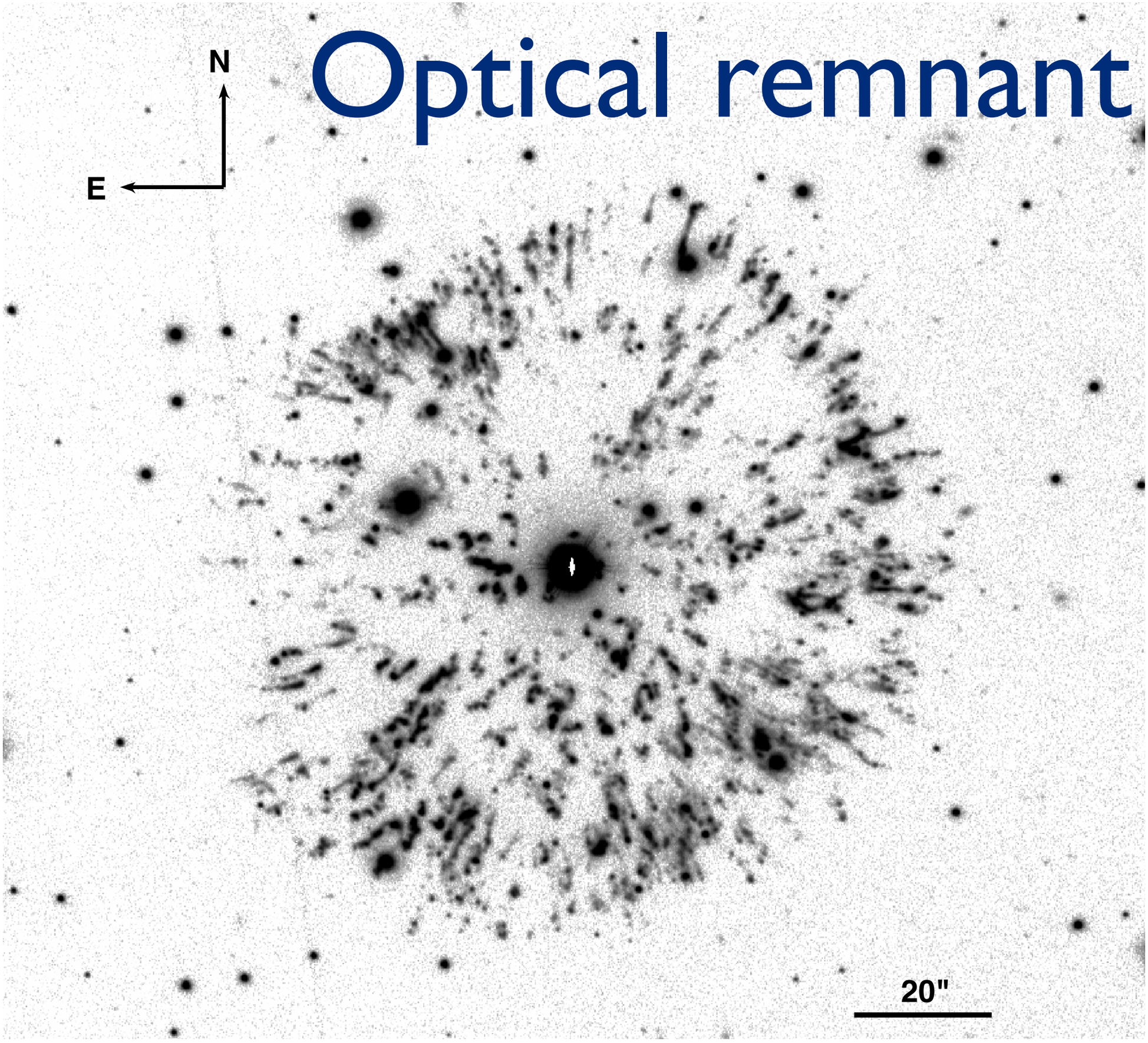
N[II] Doppler shifts

★ 2007
INT (5730-7610Å) and
NOT (6350-6850Å). 12 PA

# Optical remnant




NOT, 2007 Hα+[NII], FOV=2.8'x2.8'

# Proper motions

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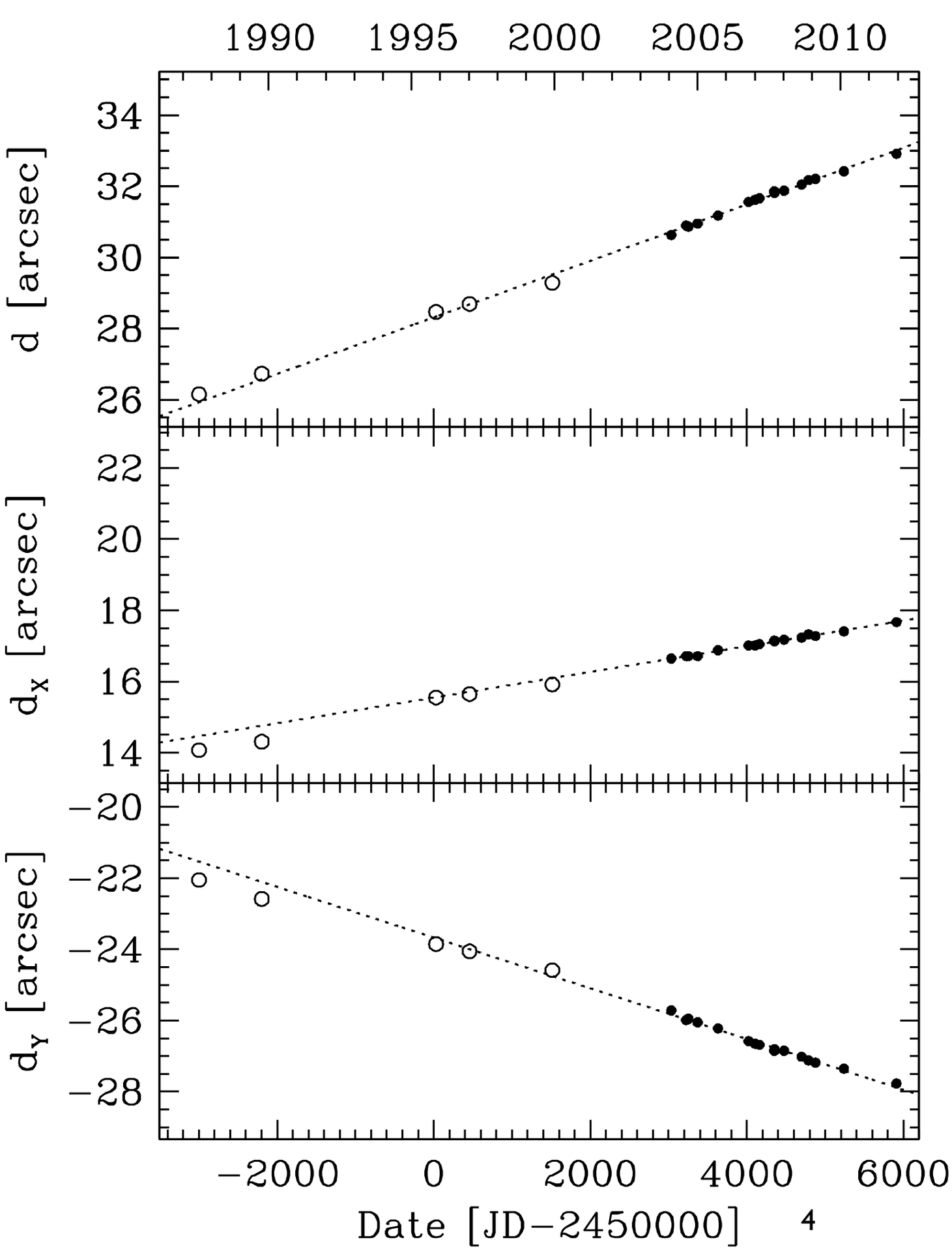

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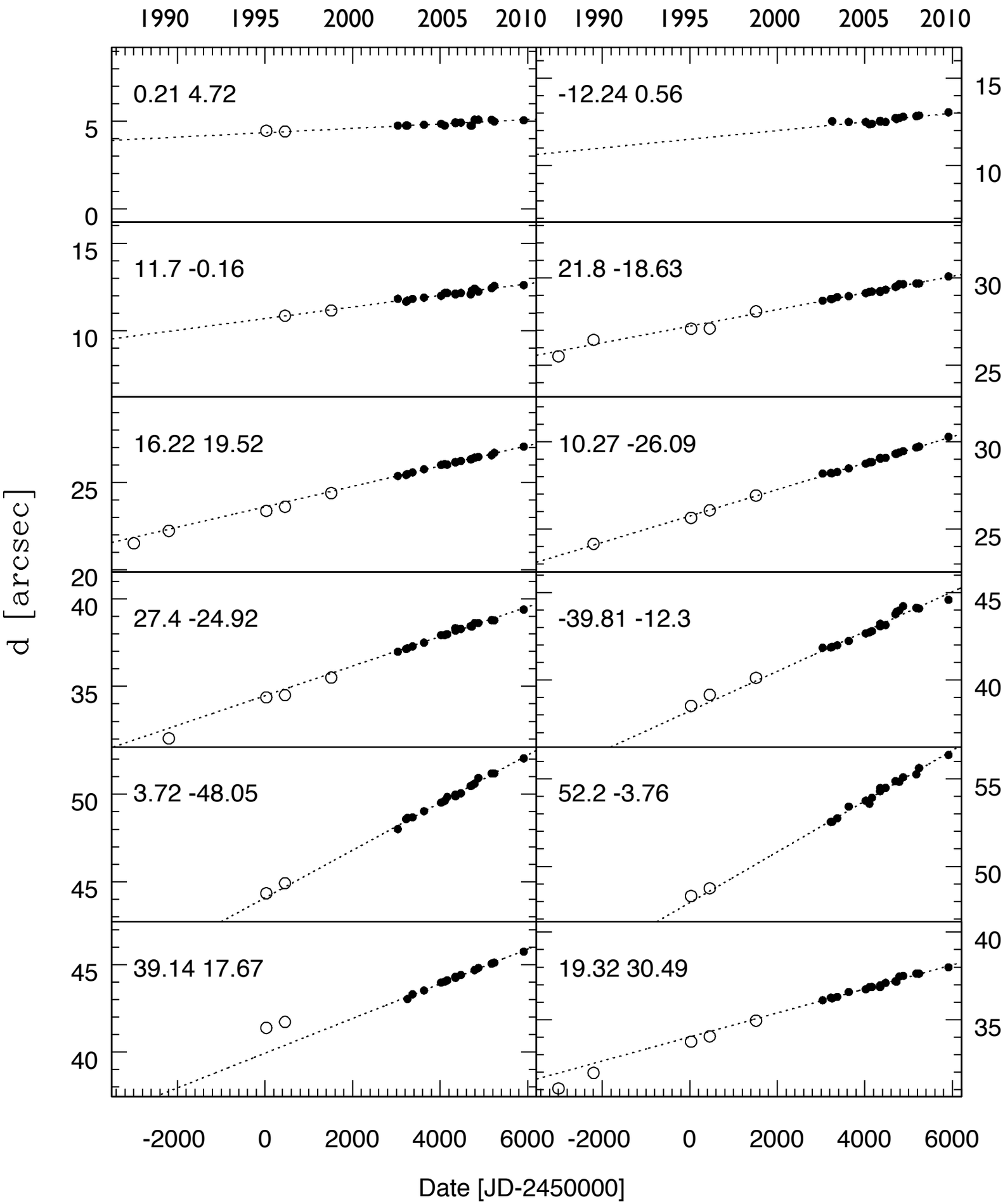

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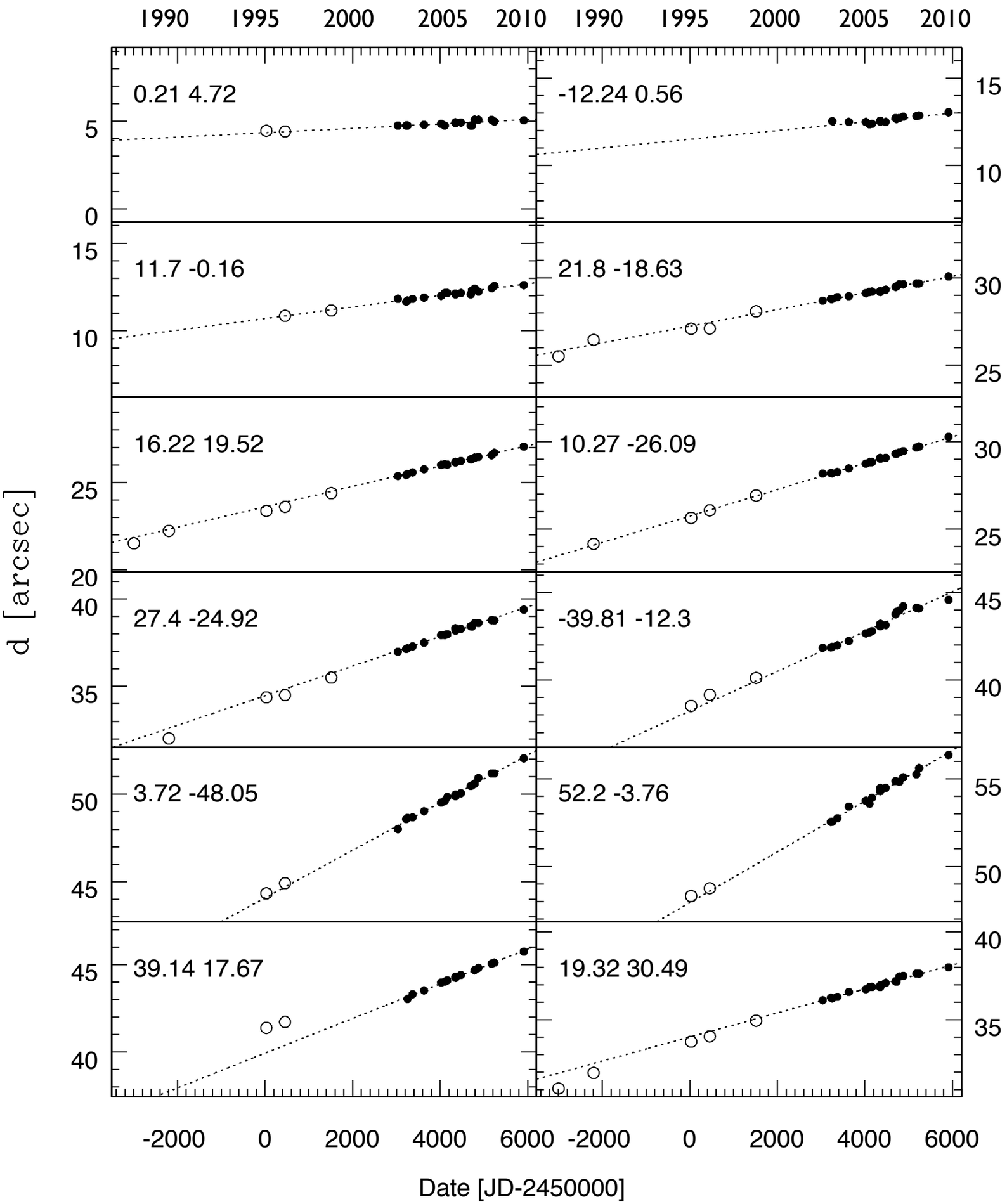
282 knots



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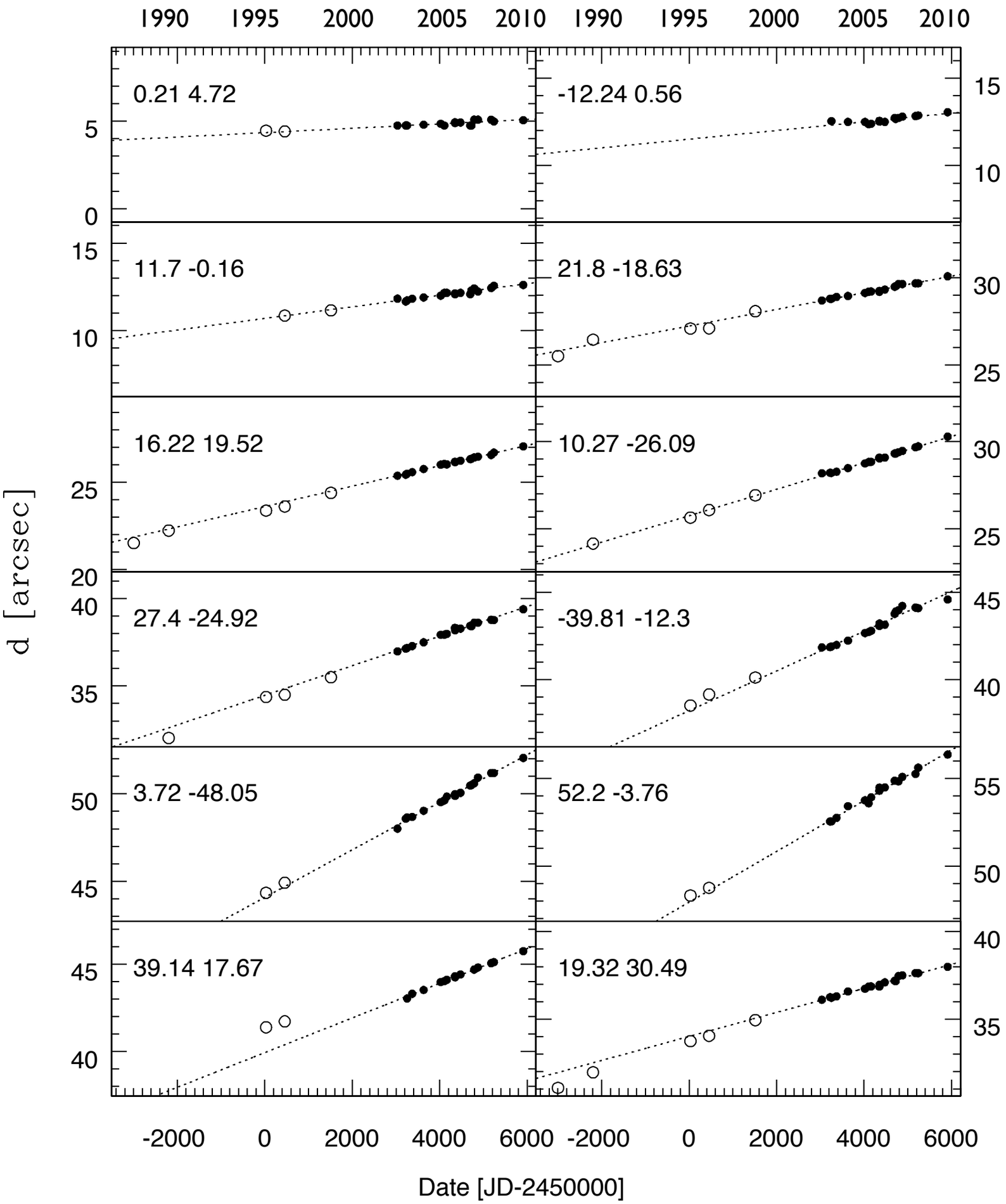
0.007 to 0.53 “/yr



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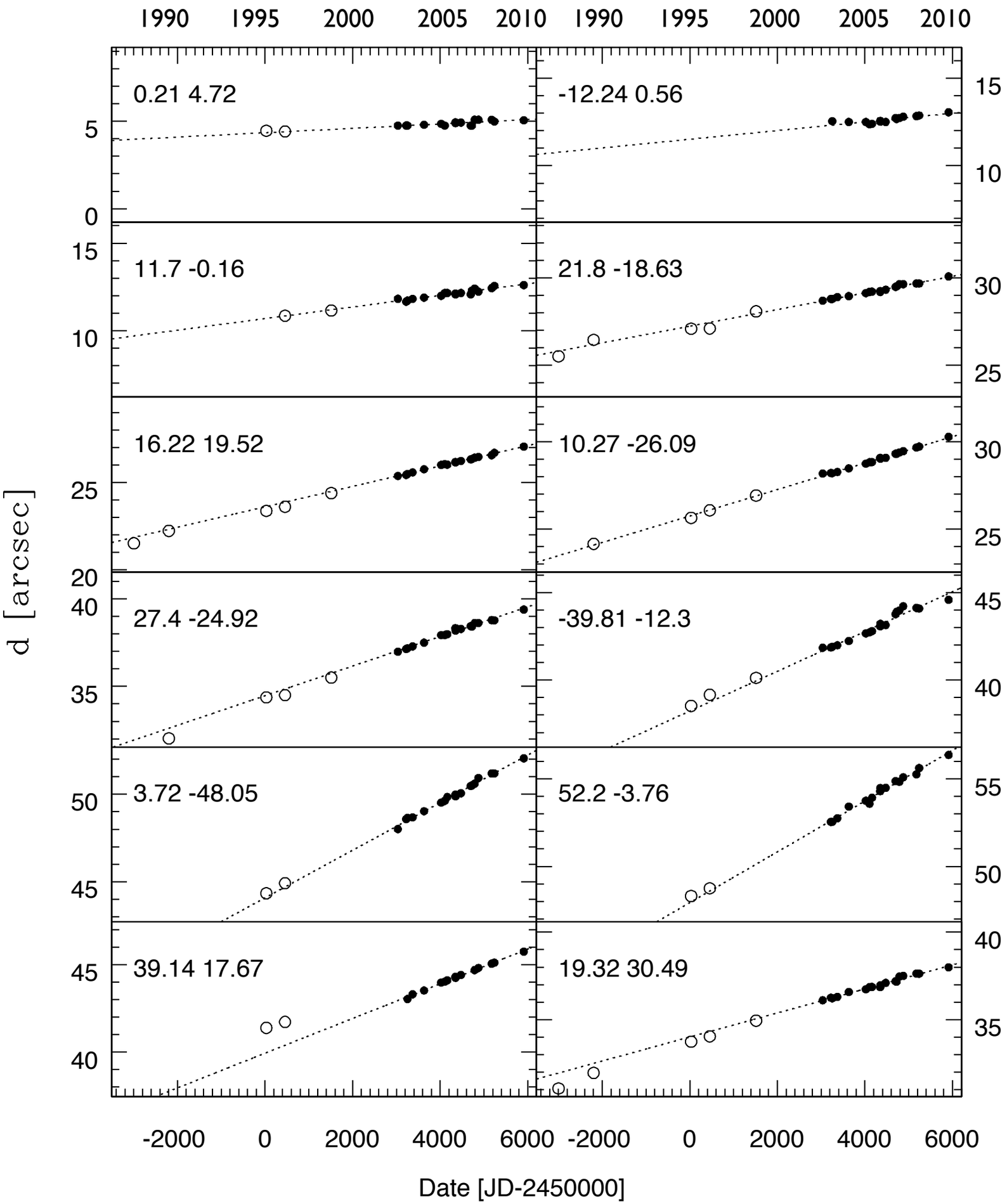


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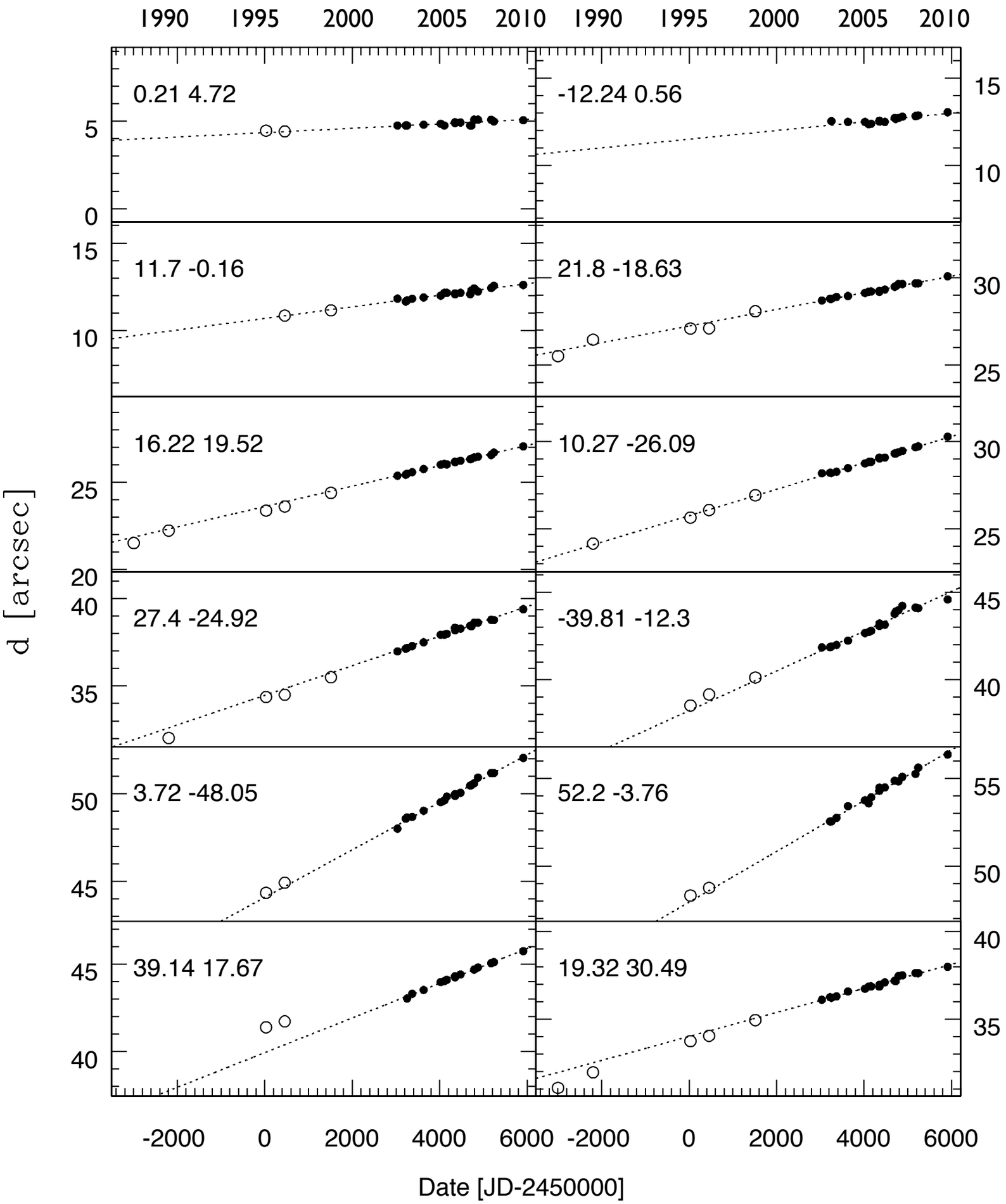


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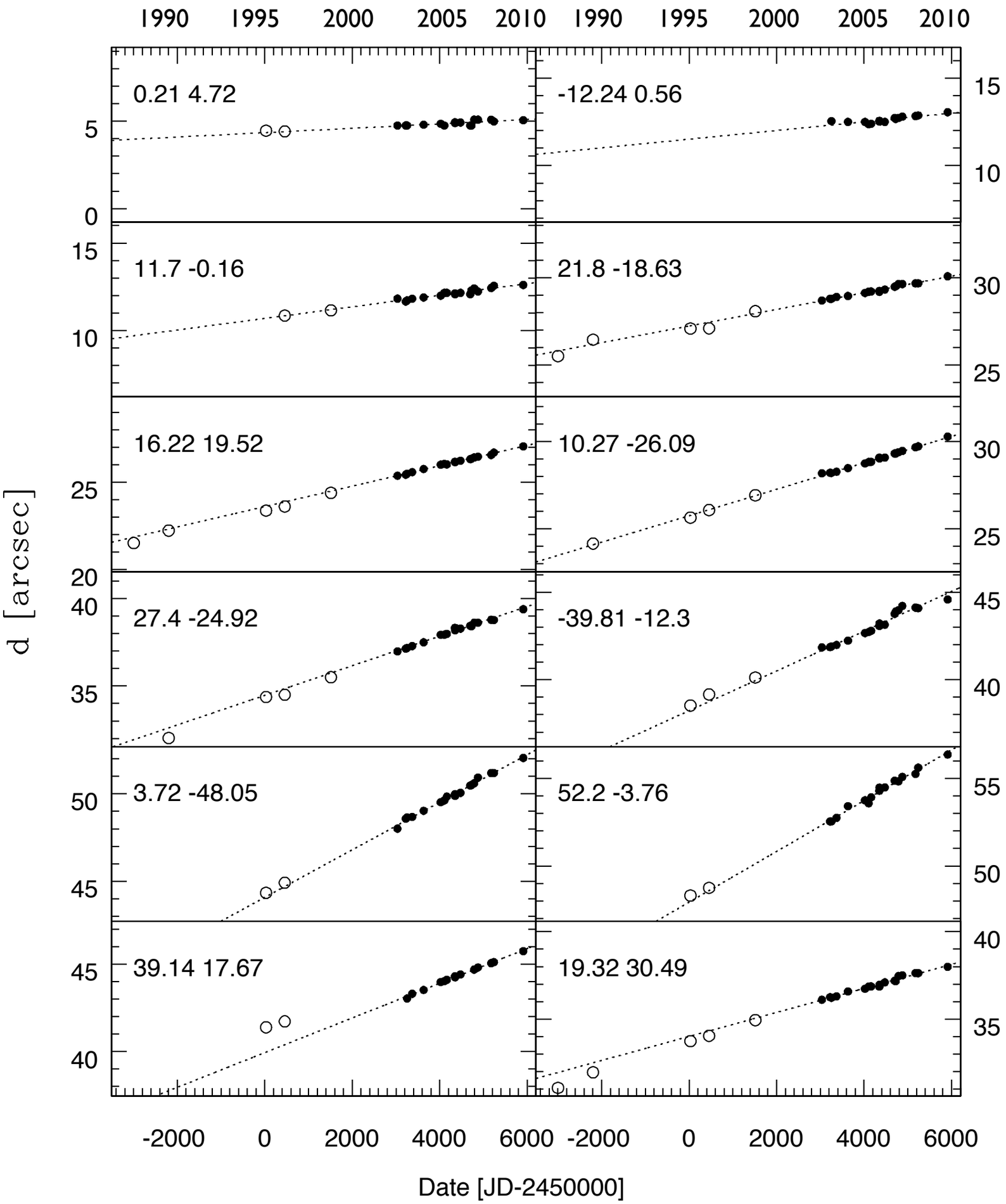


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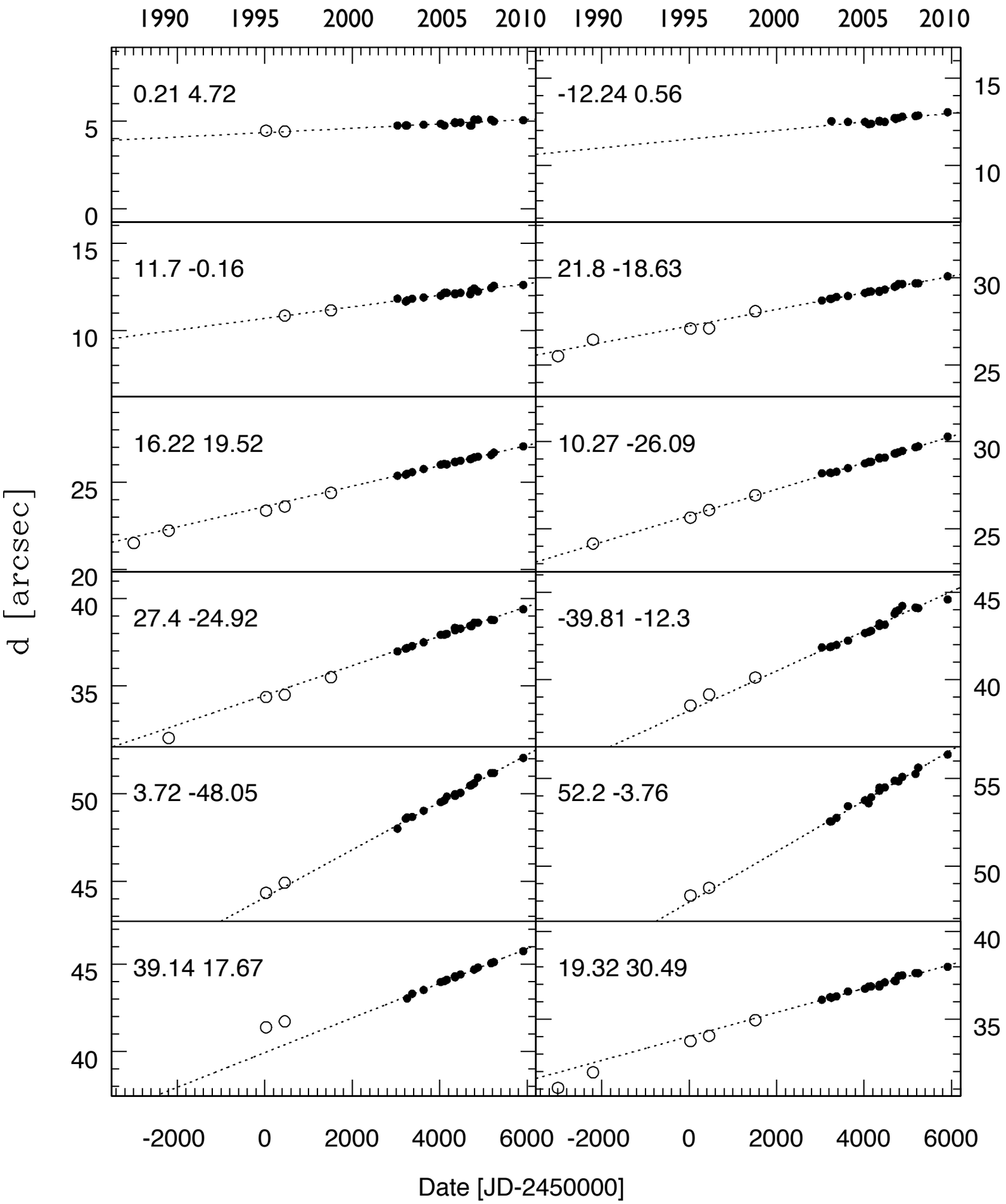


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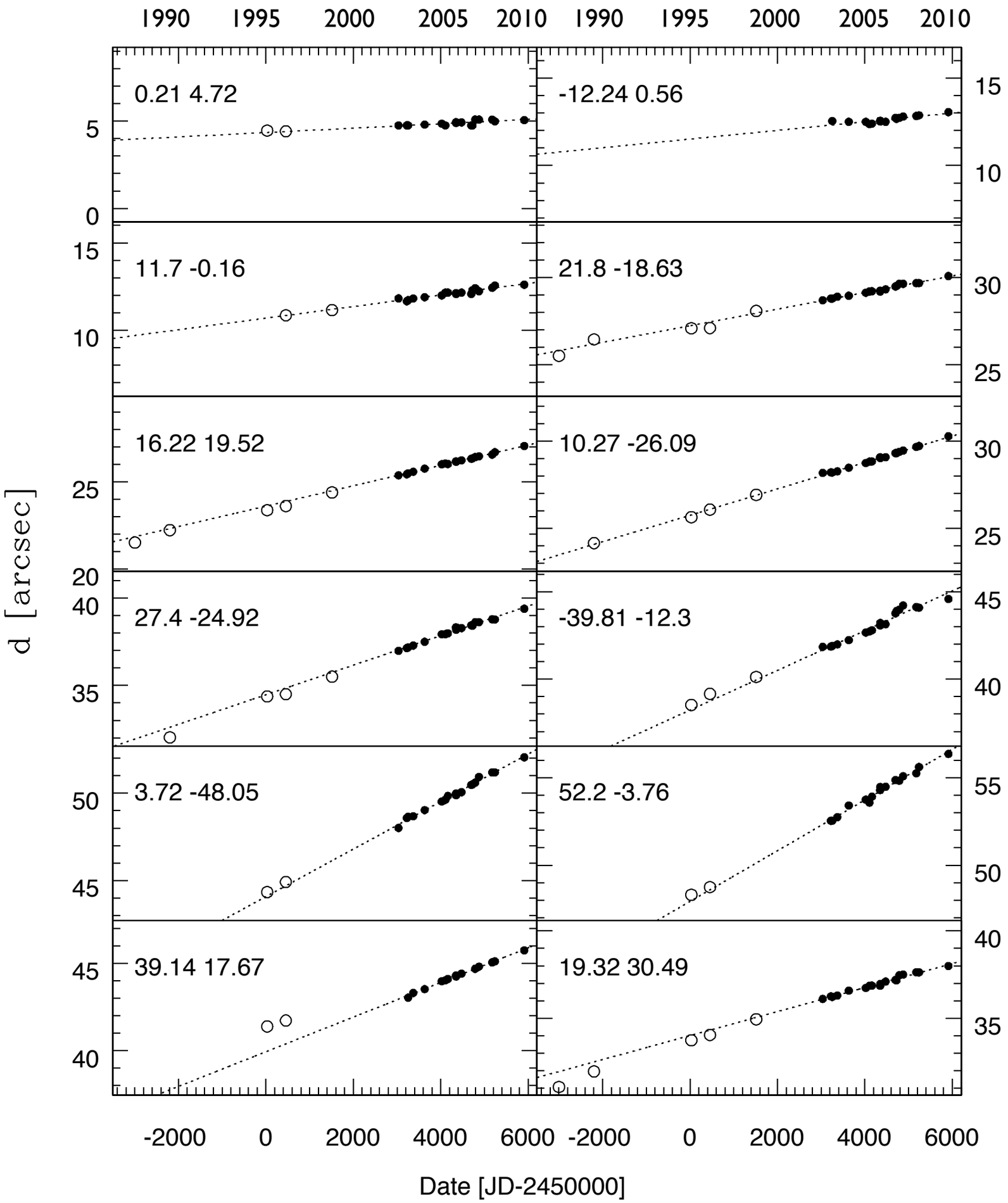


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No systematic acc/dec

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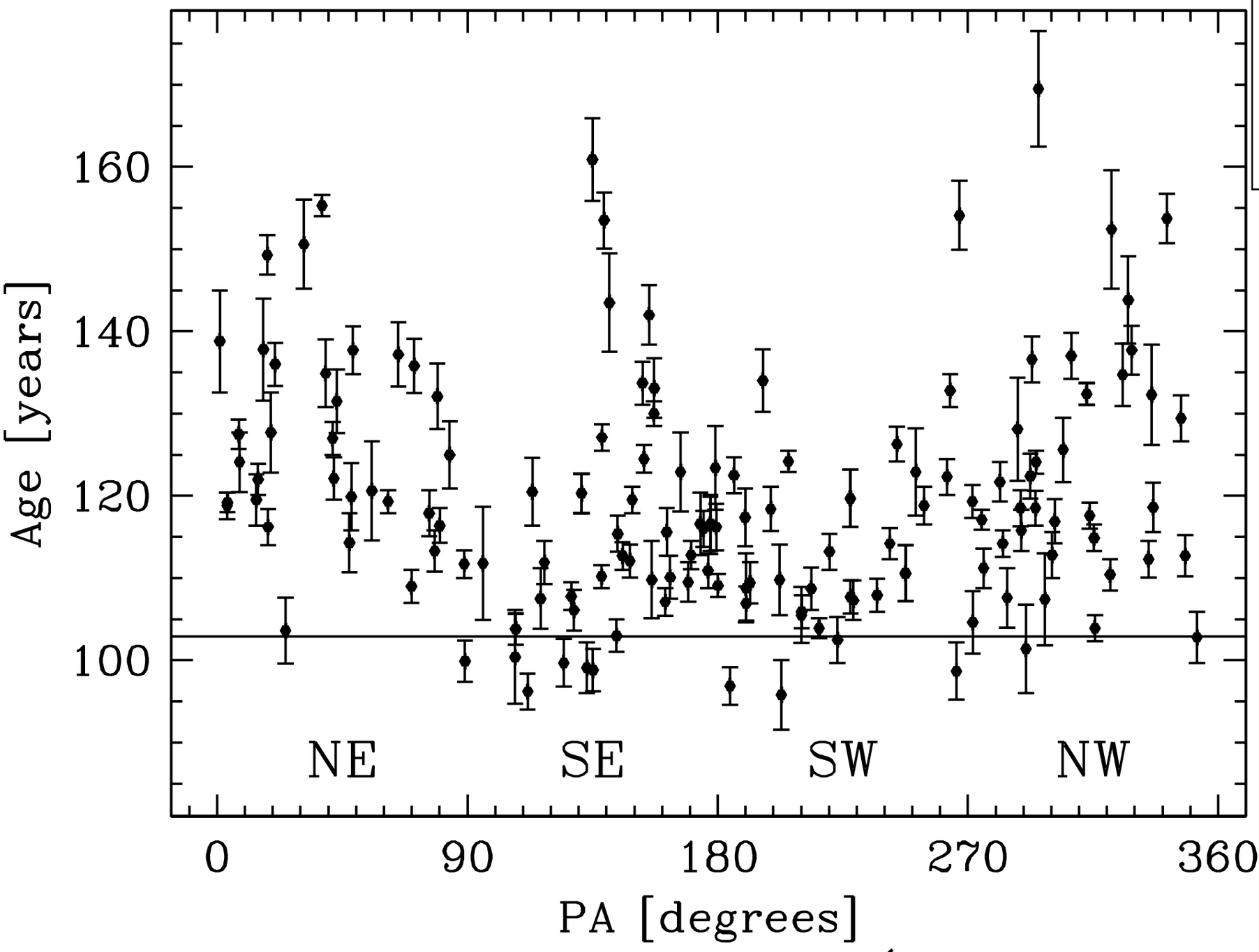


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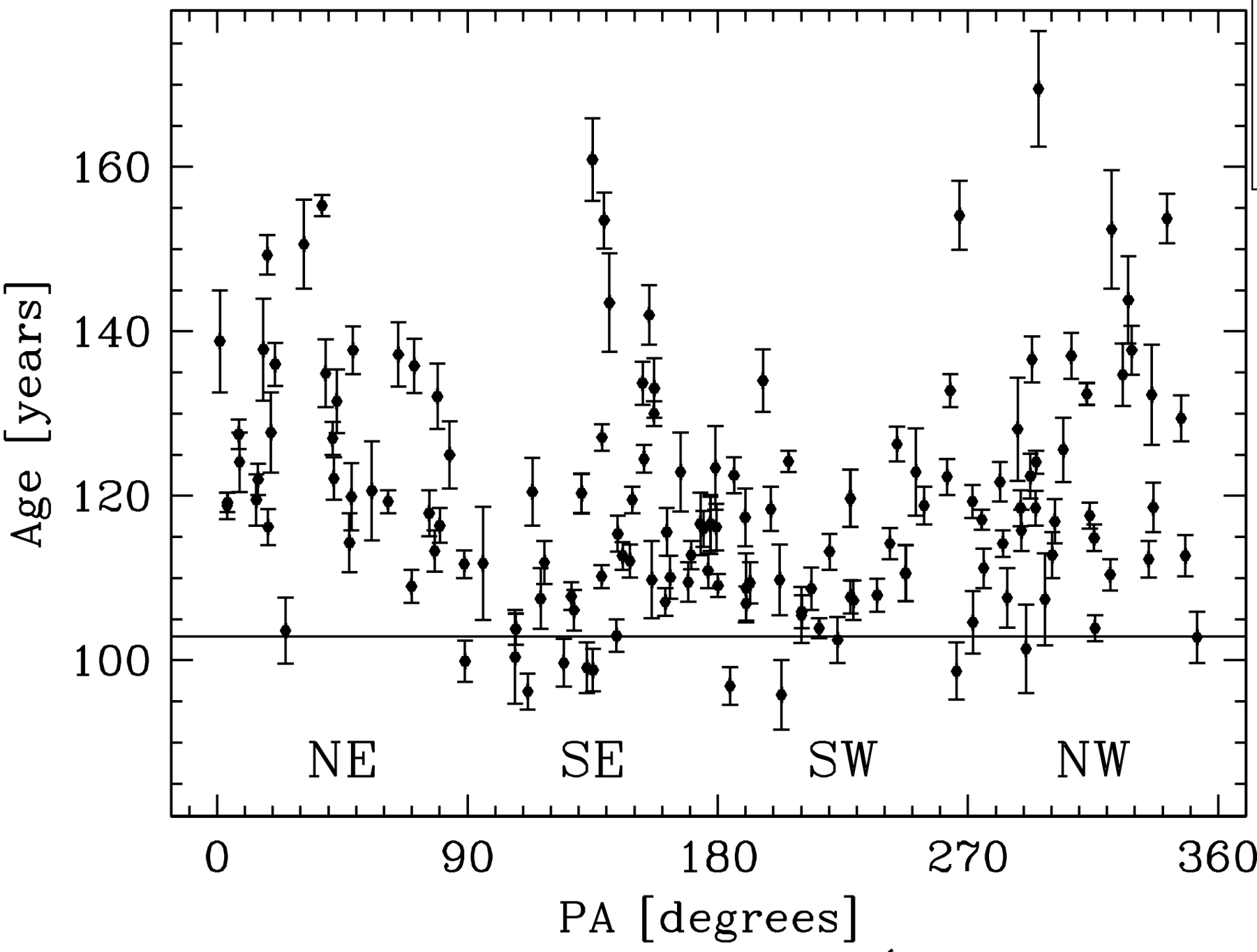


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t =118 ± 12 yr

# Radial velocities (6583Å)

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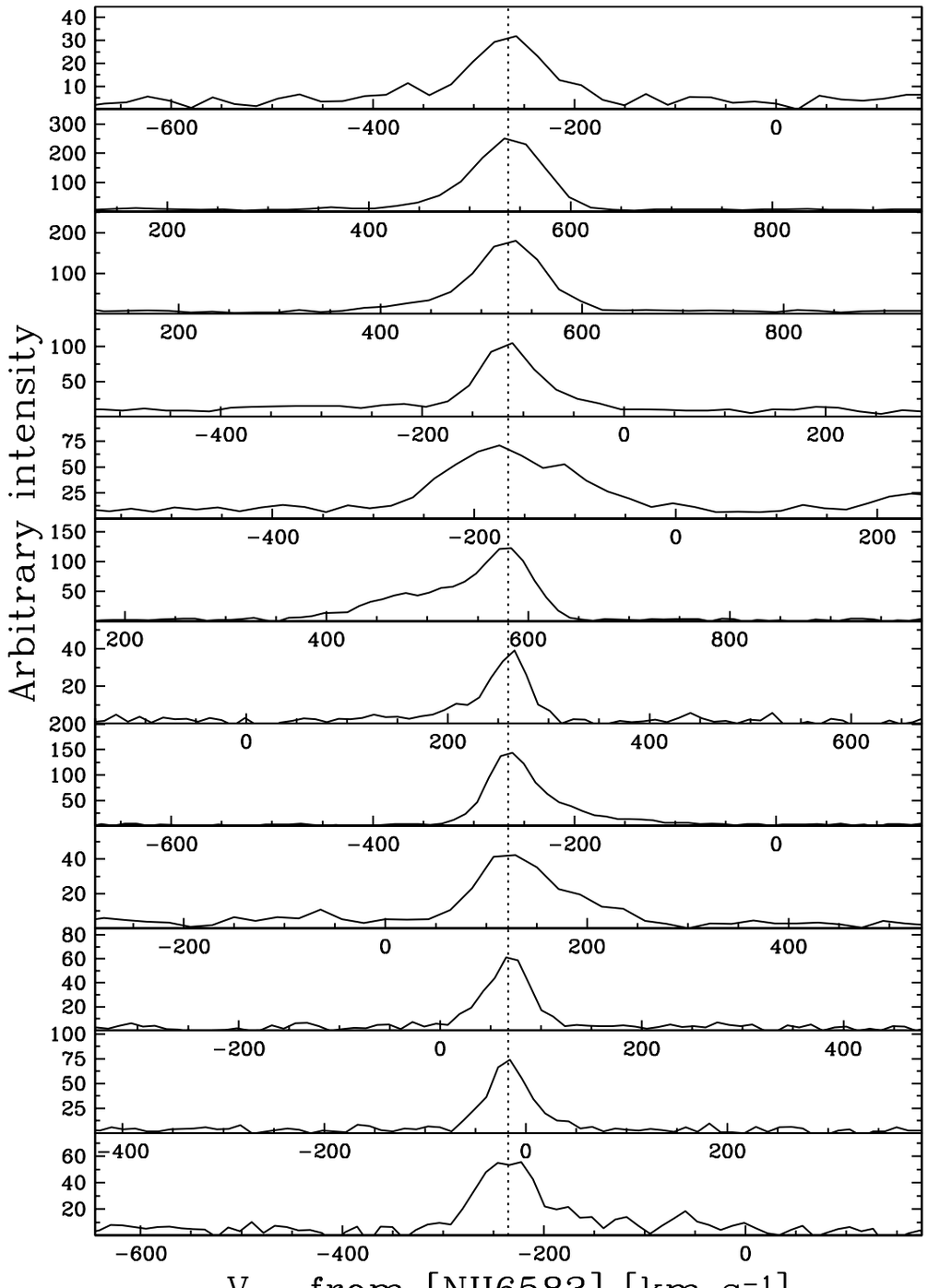
## Edge of the nebula
## FWHM ≅ 200 km/s



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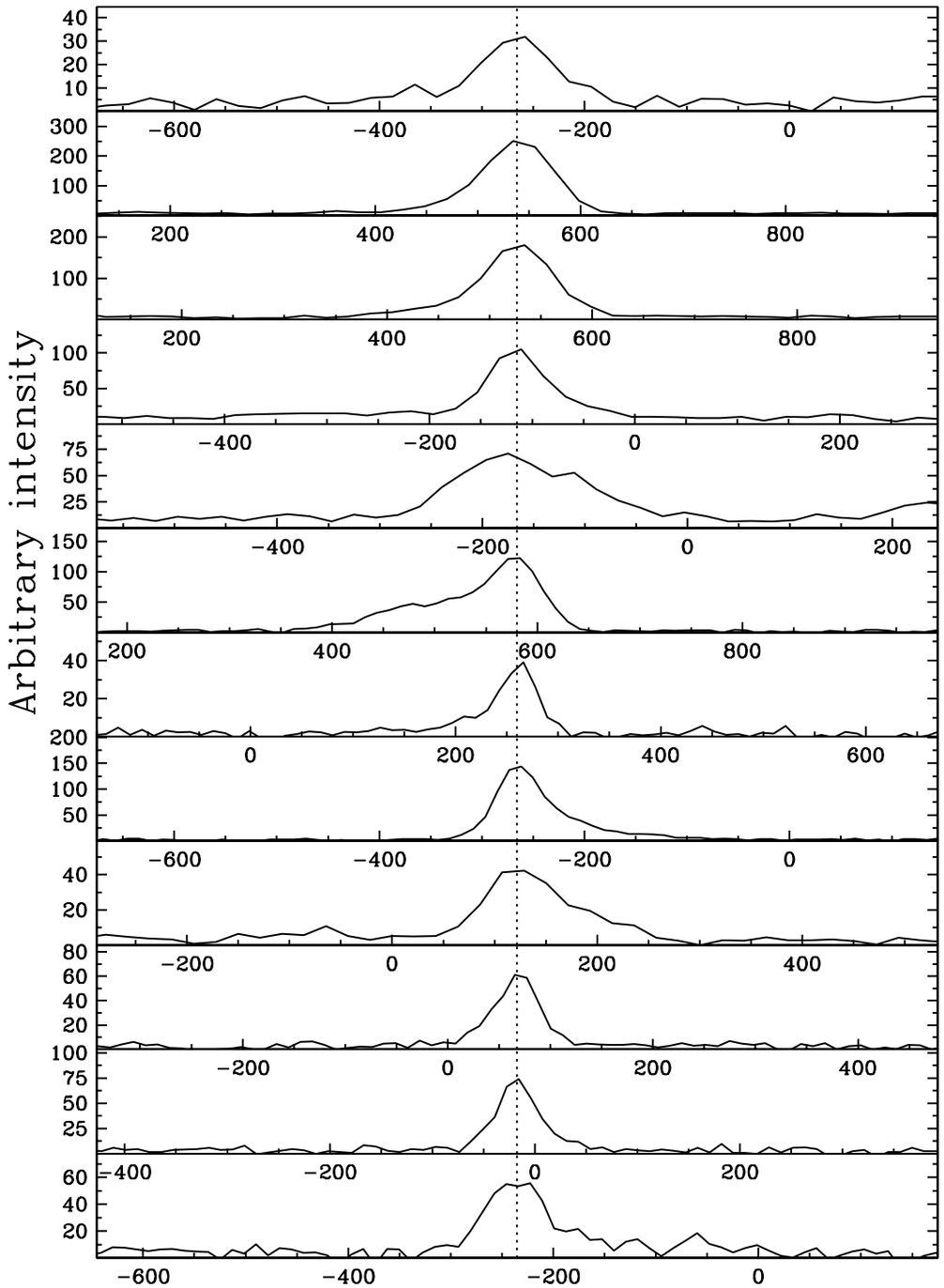
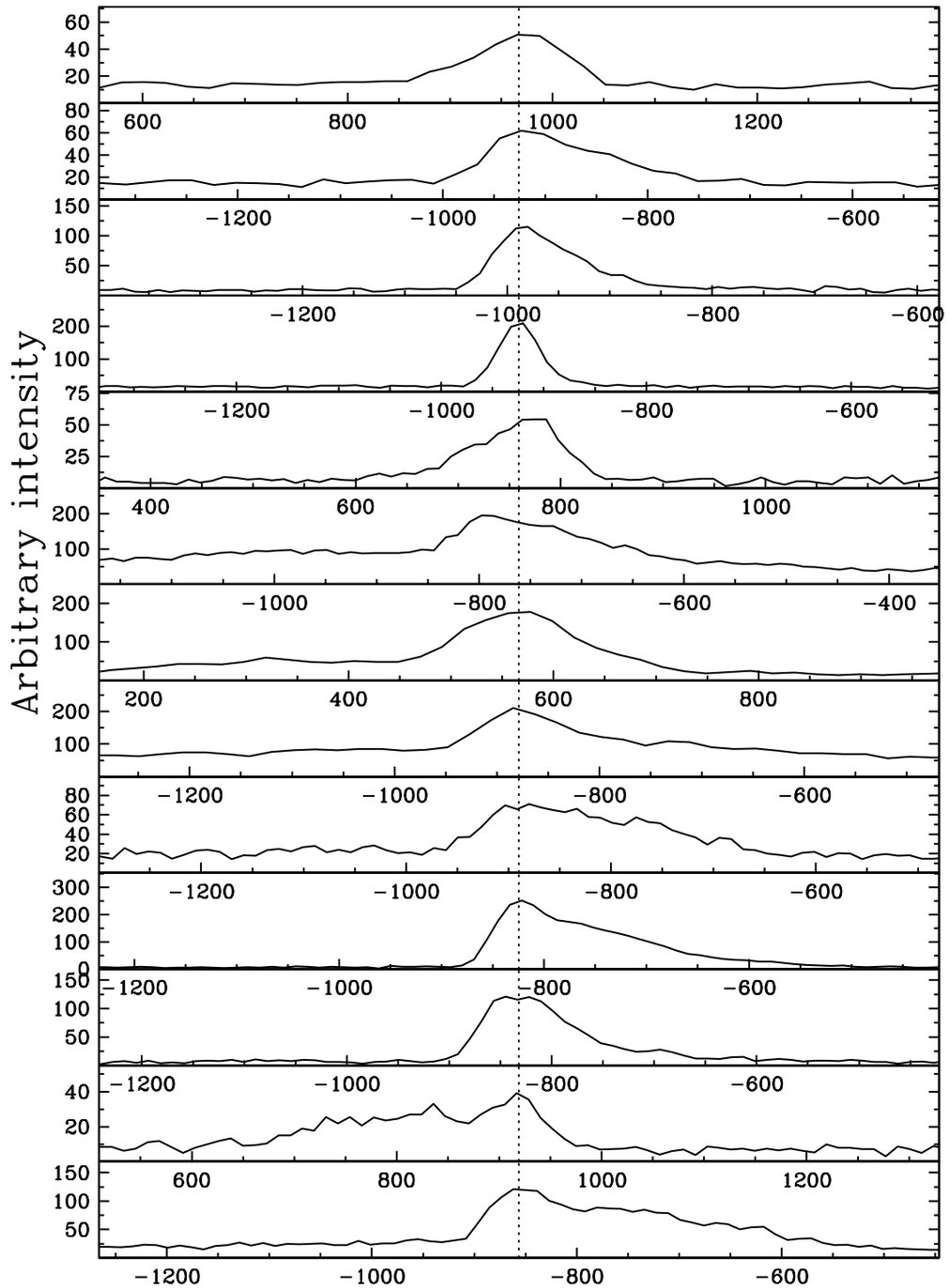



## Near the center
## tails ≅ 300 km/s



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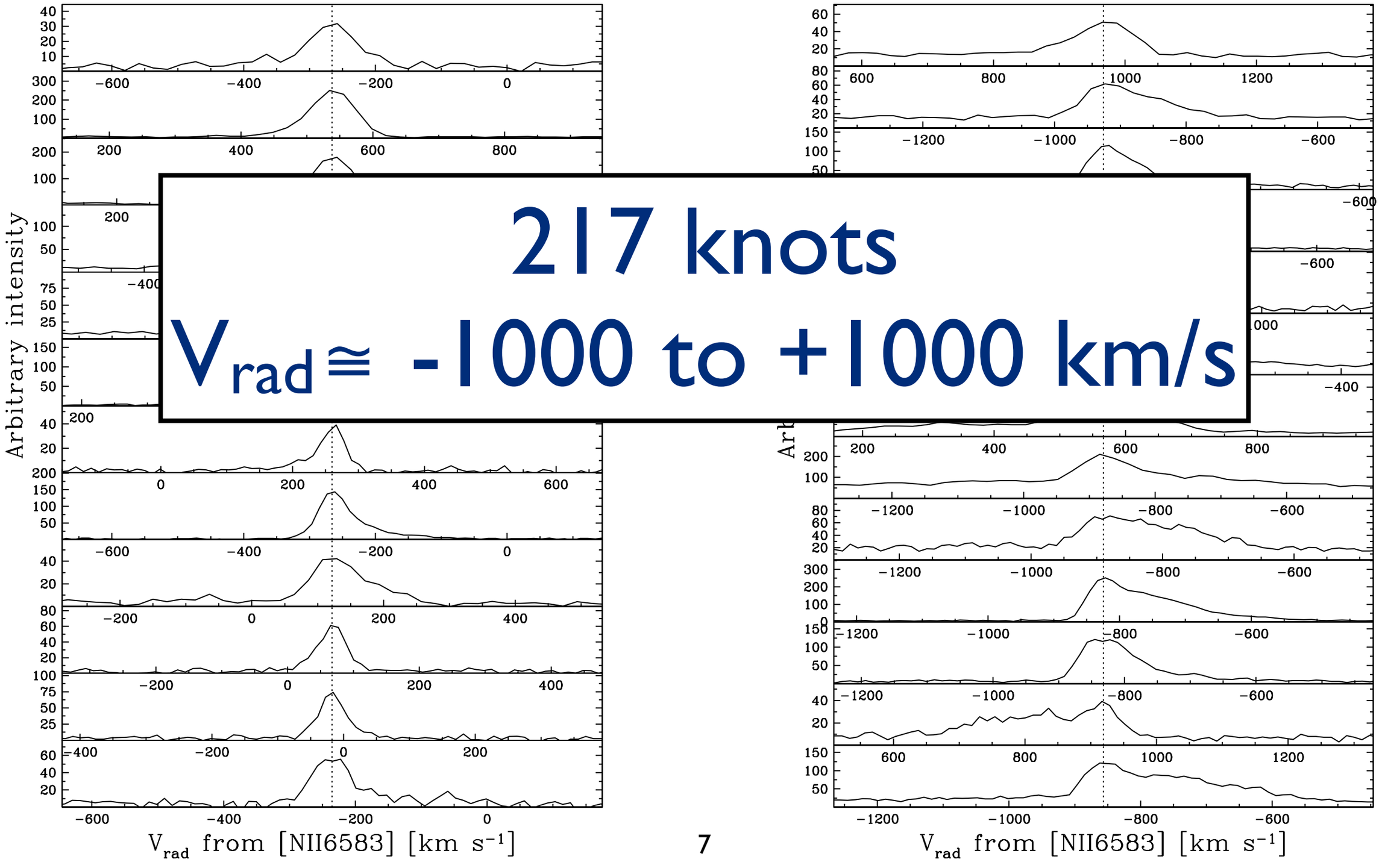


## 217 knots

## $V_{rad} \cong$ -1000 to +1000 km/s

# Quasi spherical thick shell?

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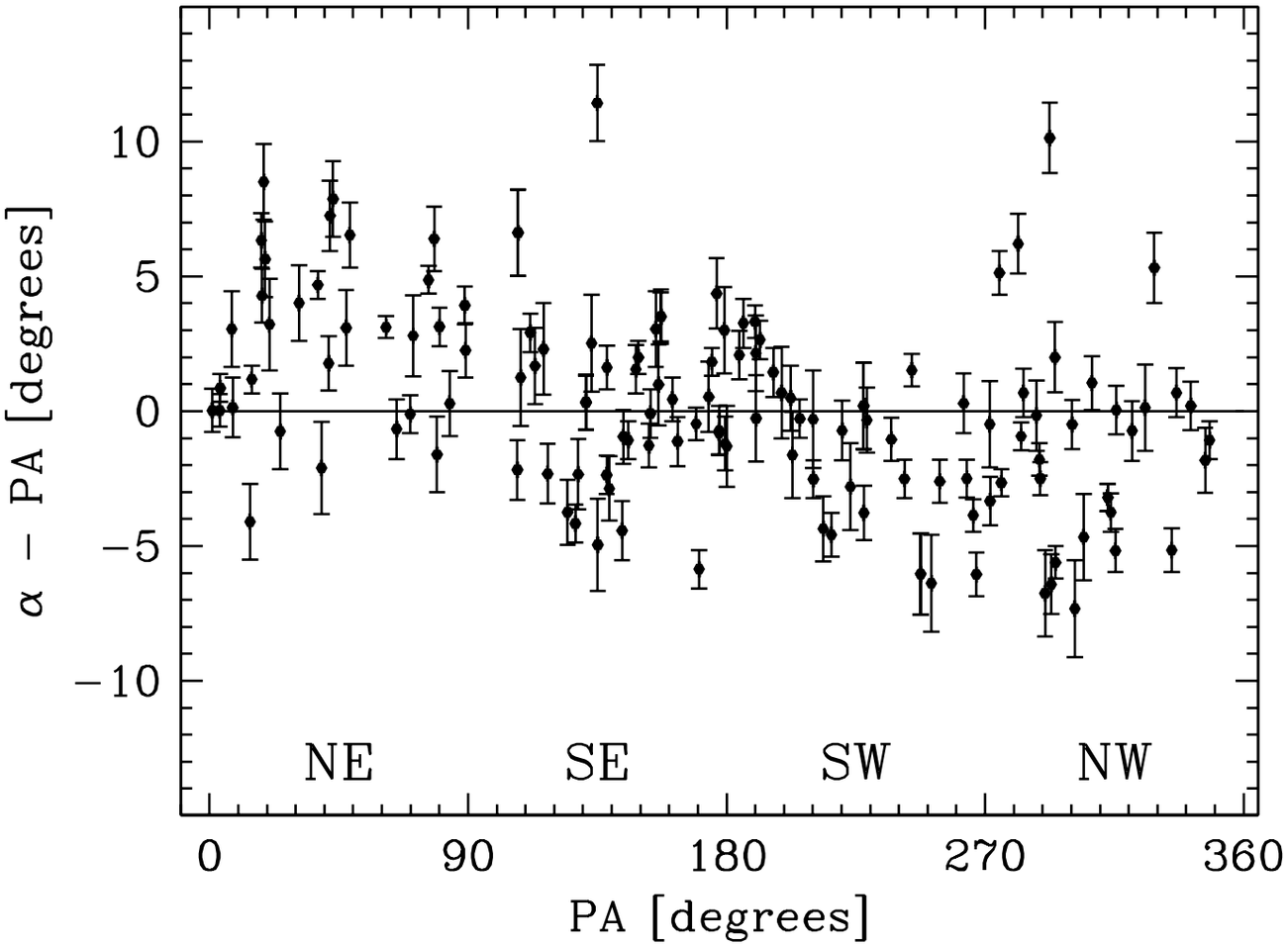

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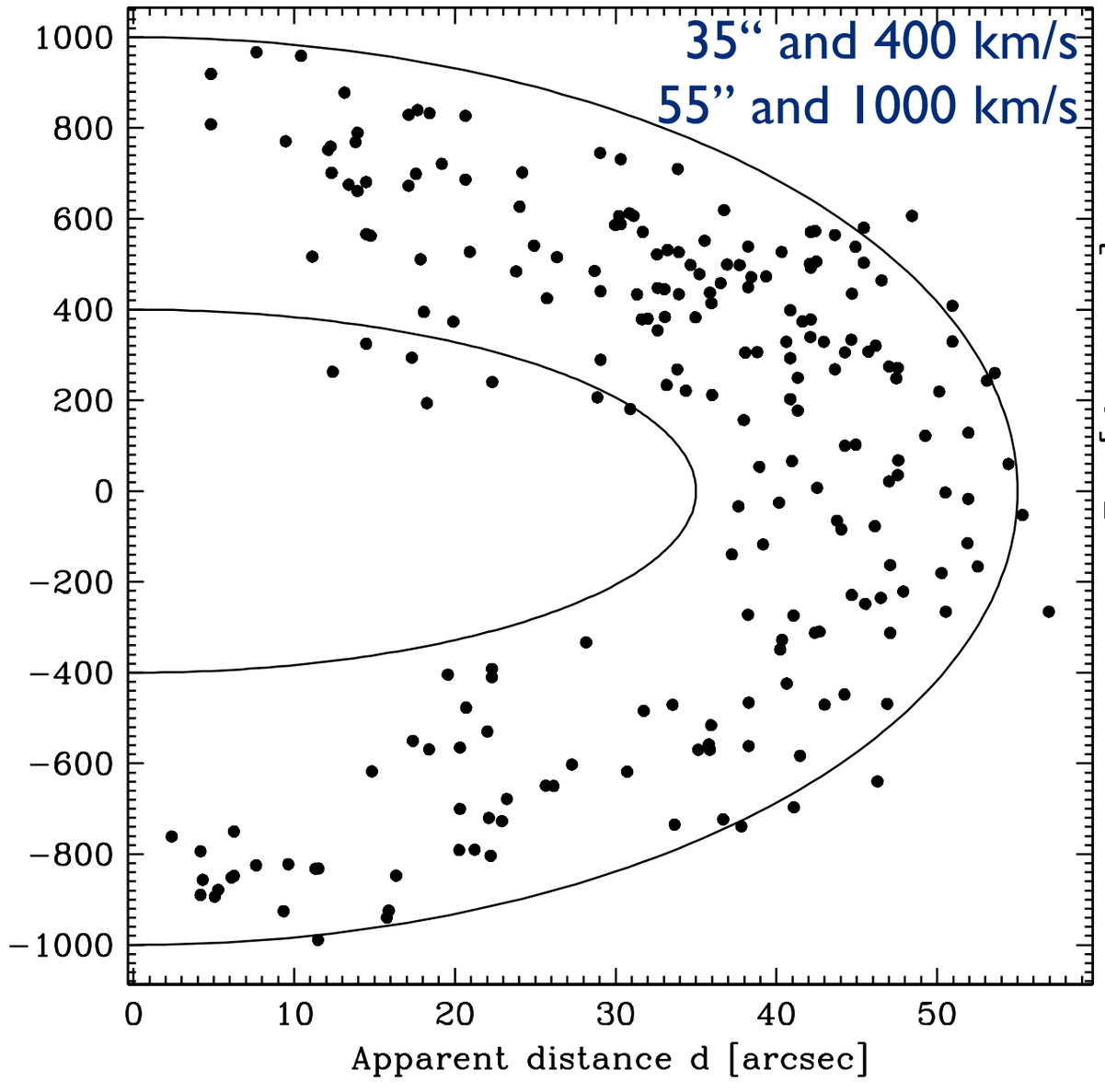


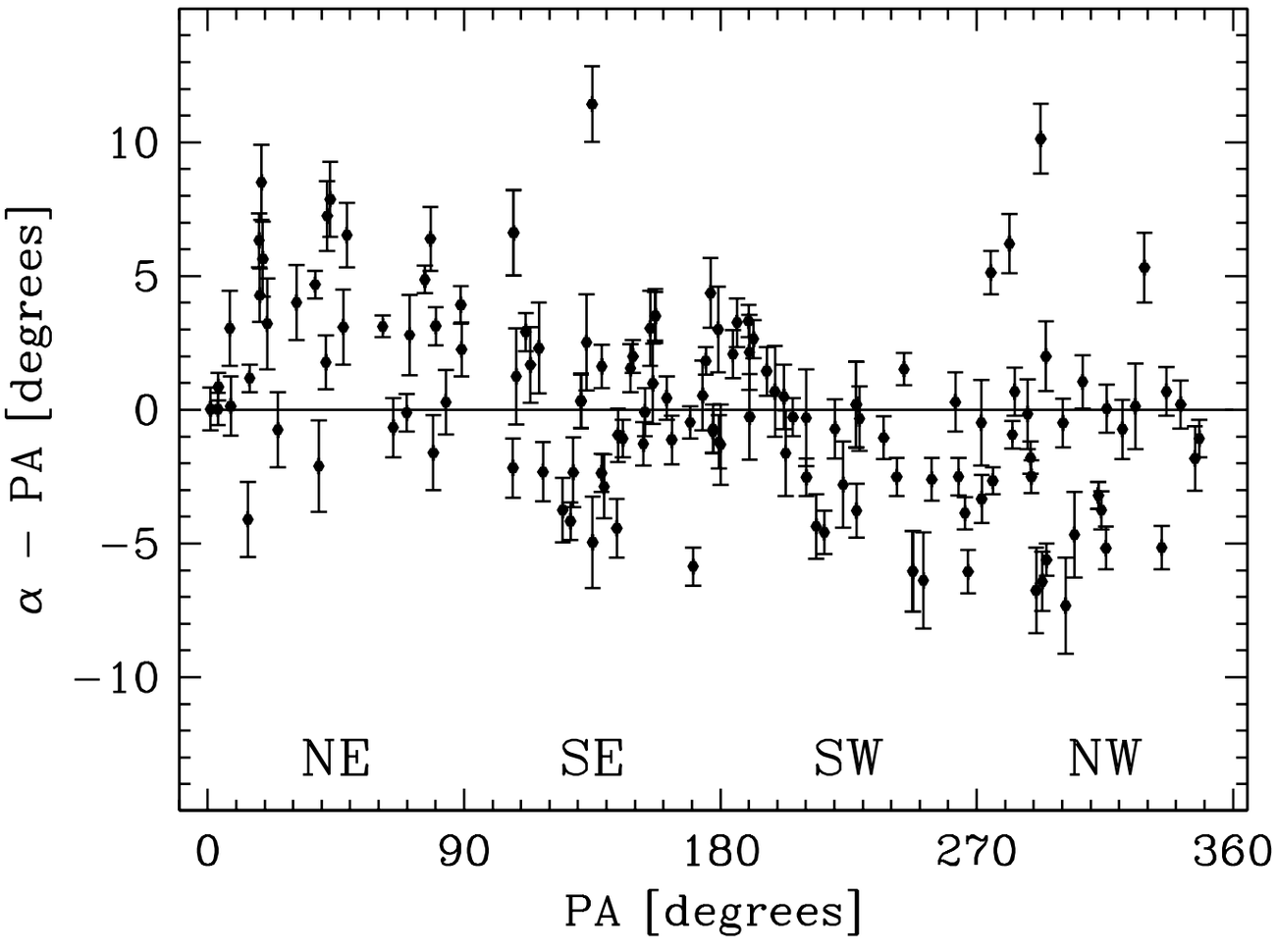

# Kinematical analysis

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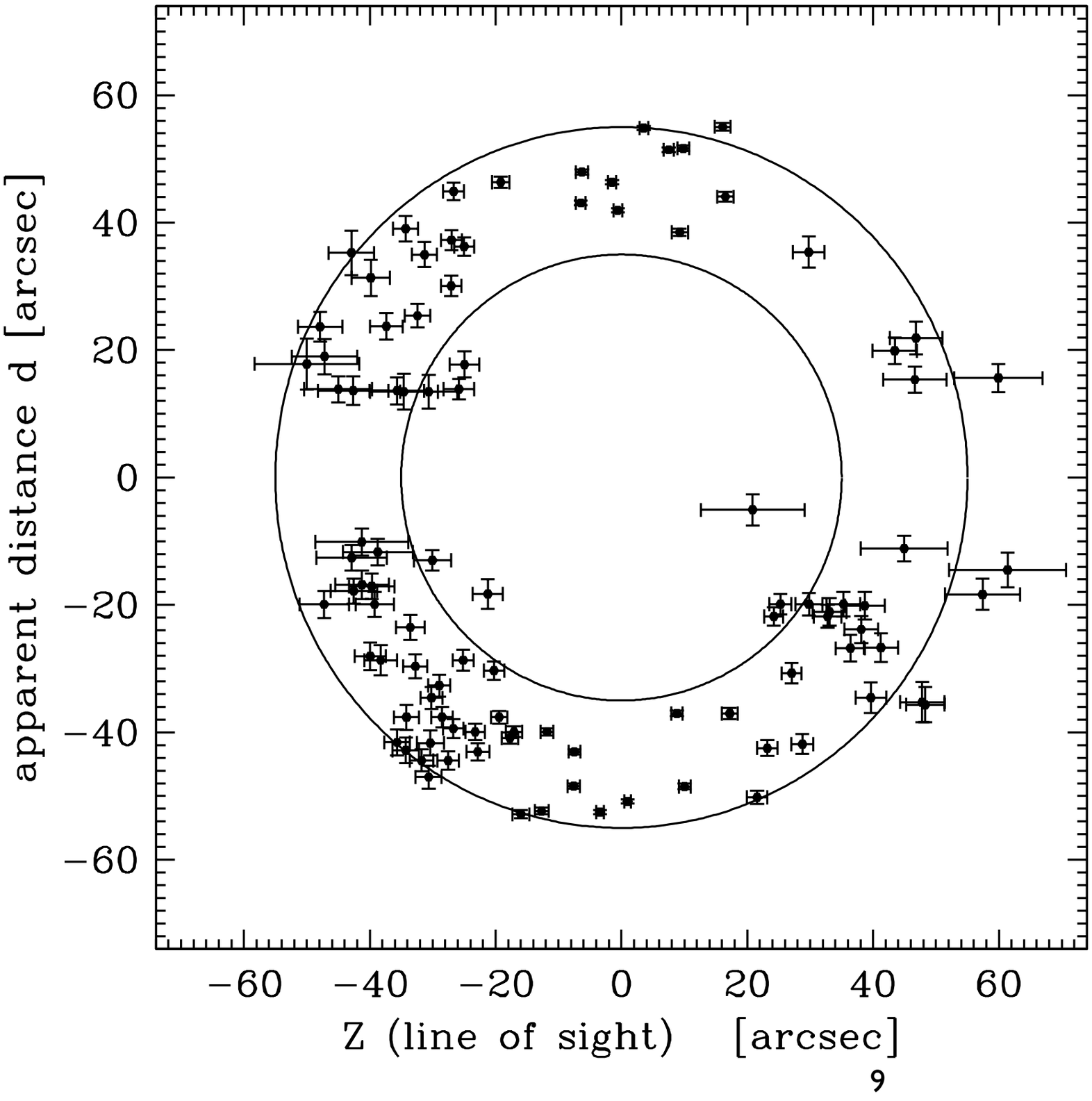

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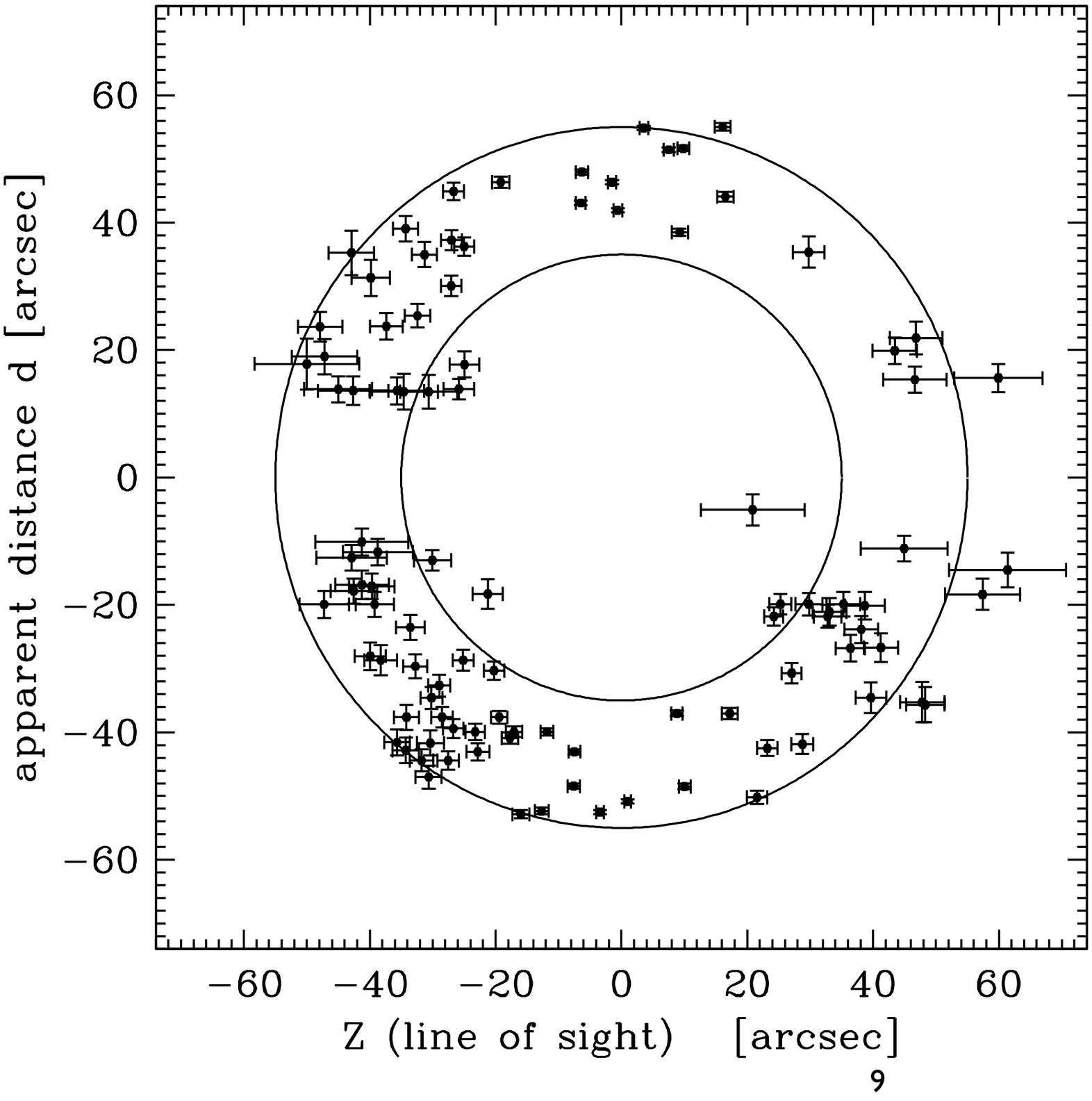


Distance:
400 ± 30 pc

# Expansion velocities

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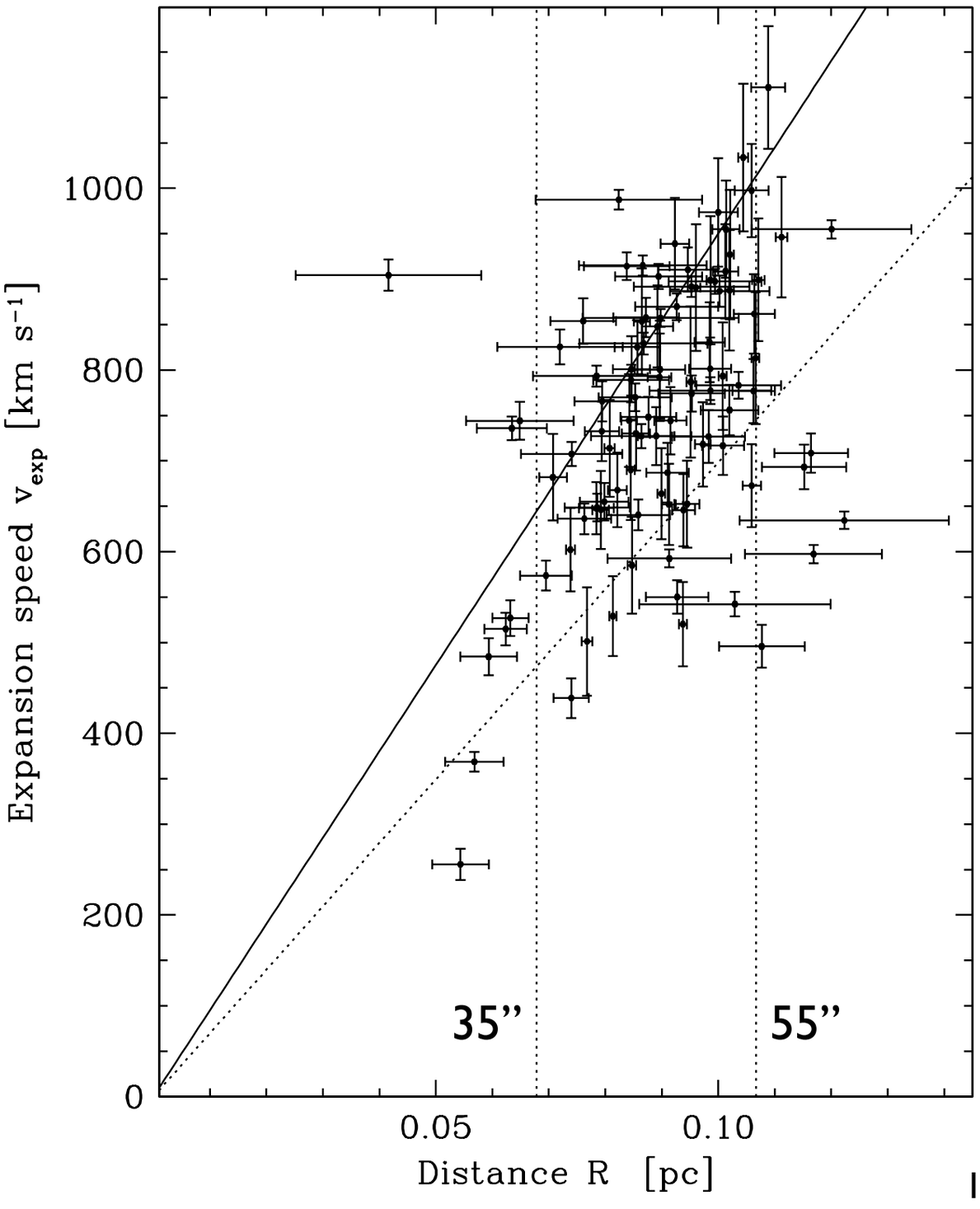

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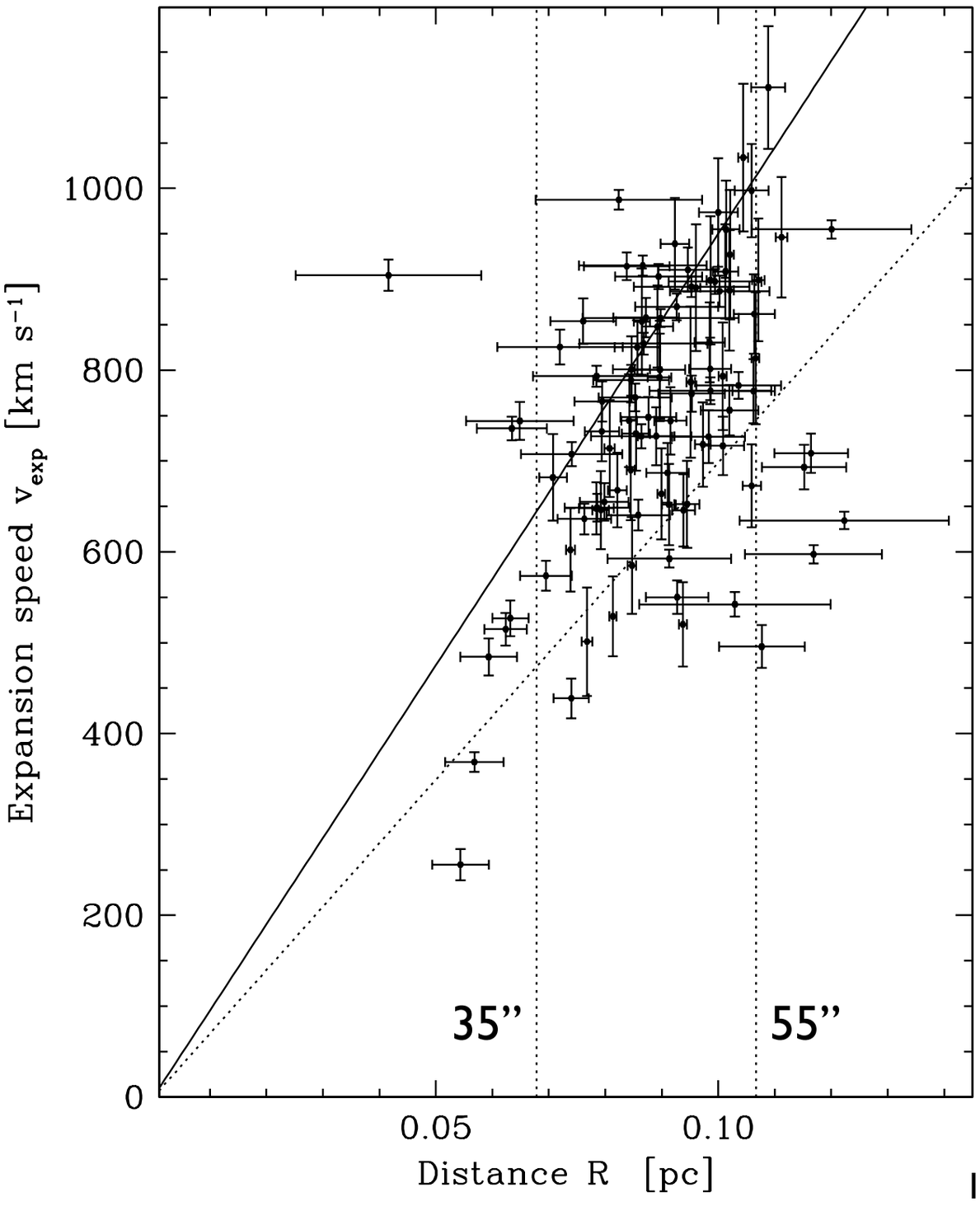
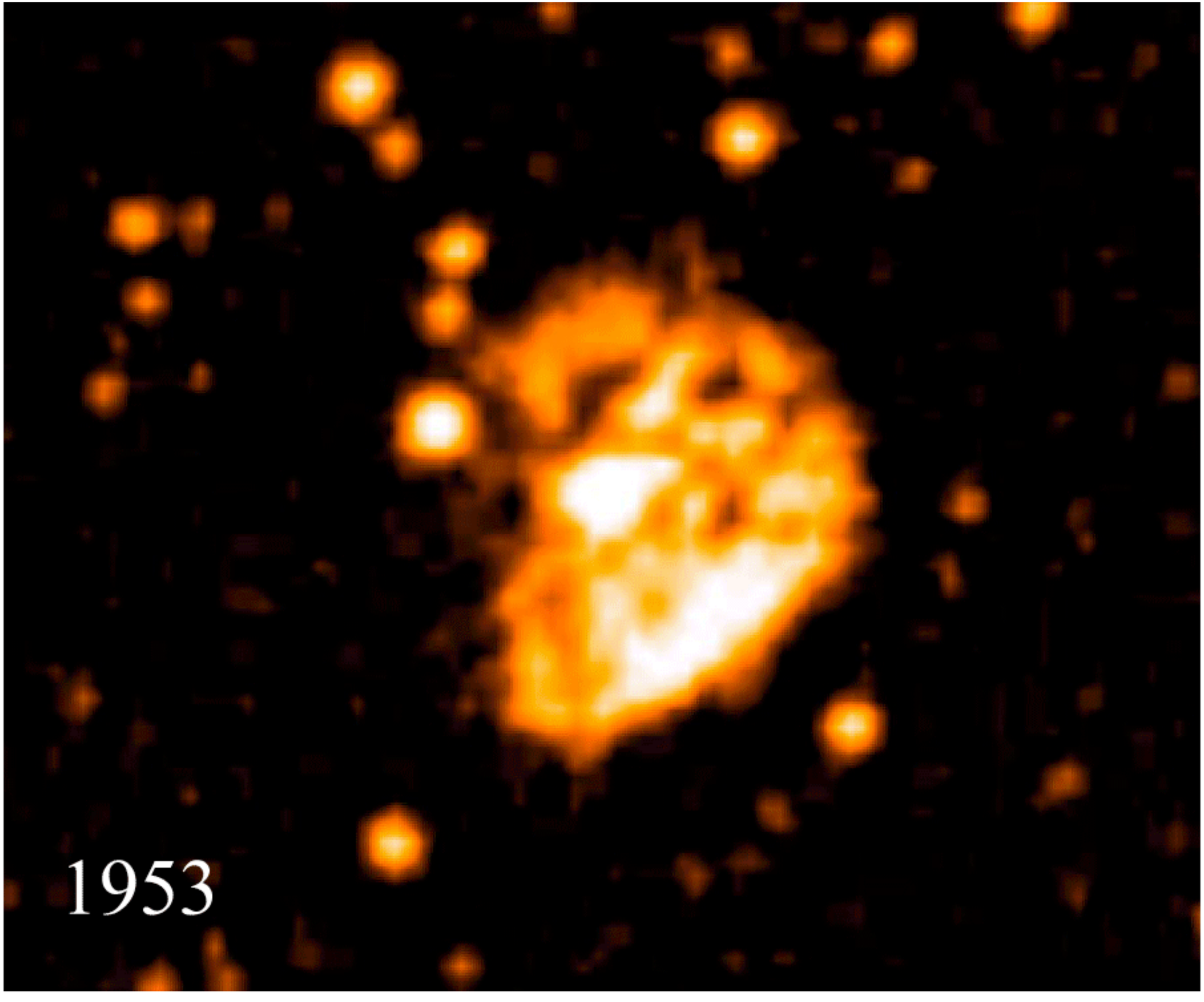



117 knots

$V_{exp} \cong$ 600 to 1000 km/s


1953

# Total Hα+[NII] flux

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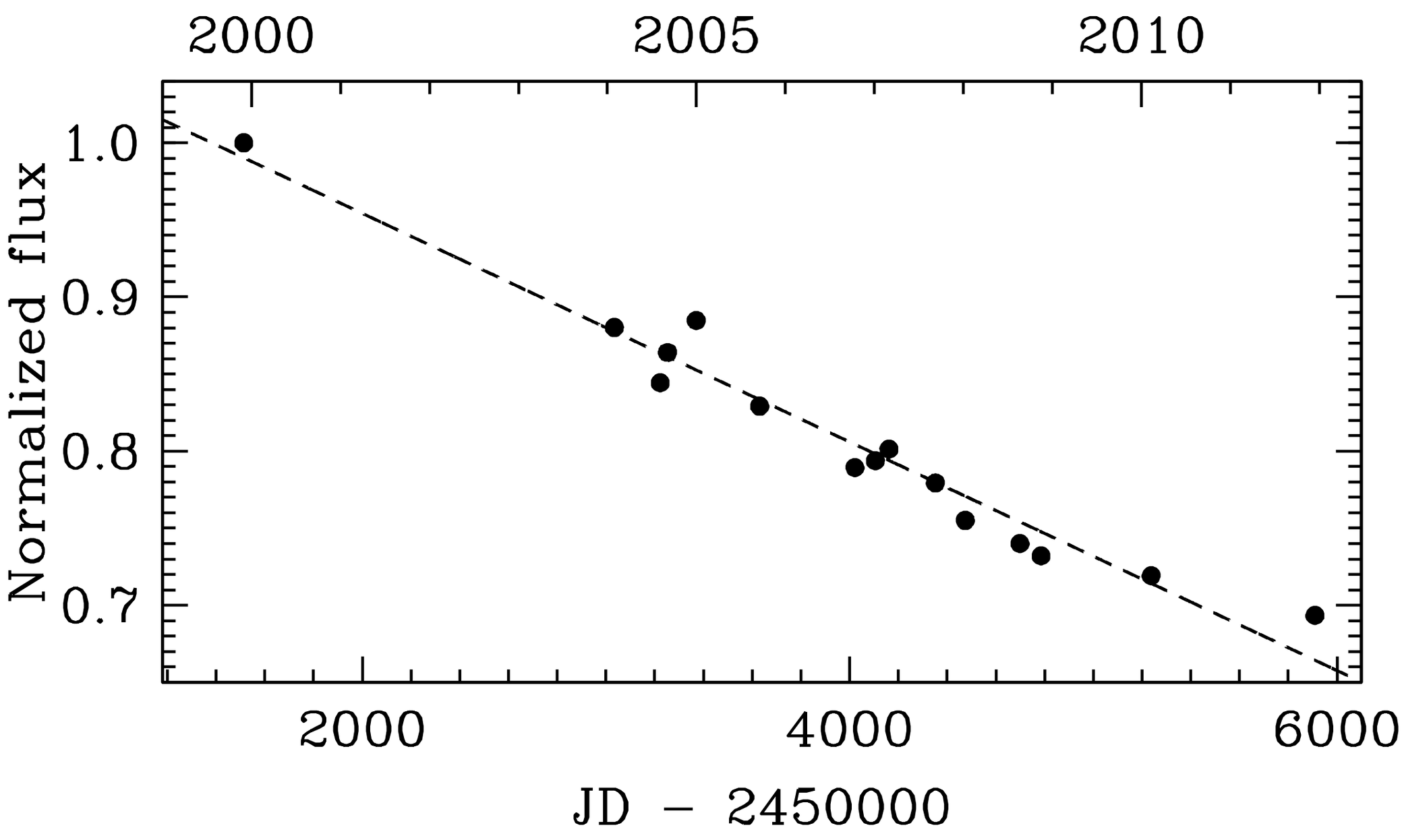

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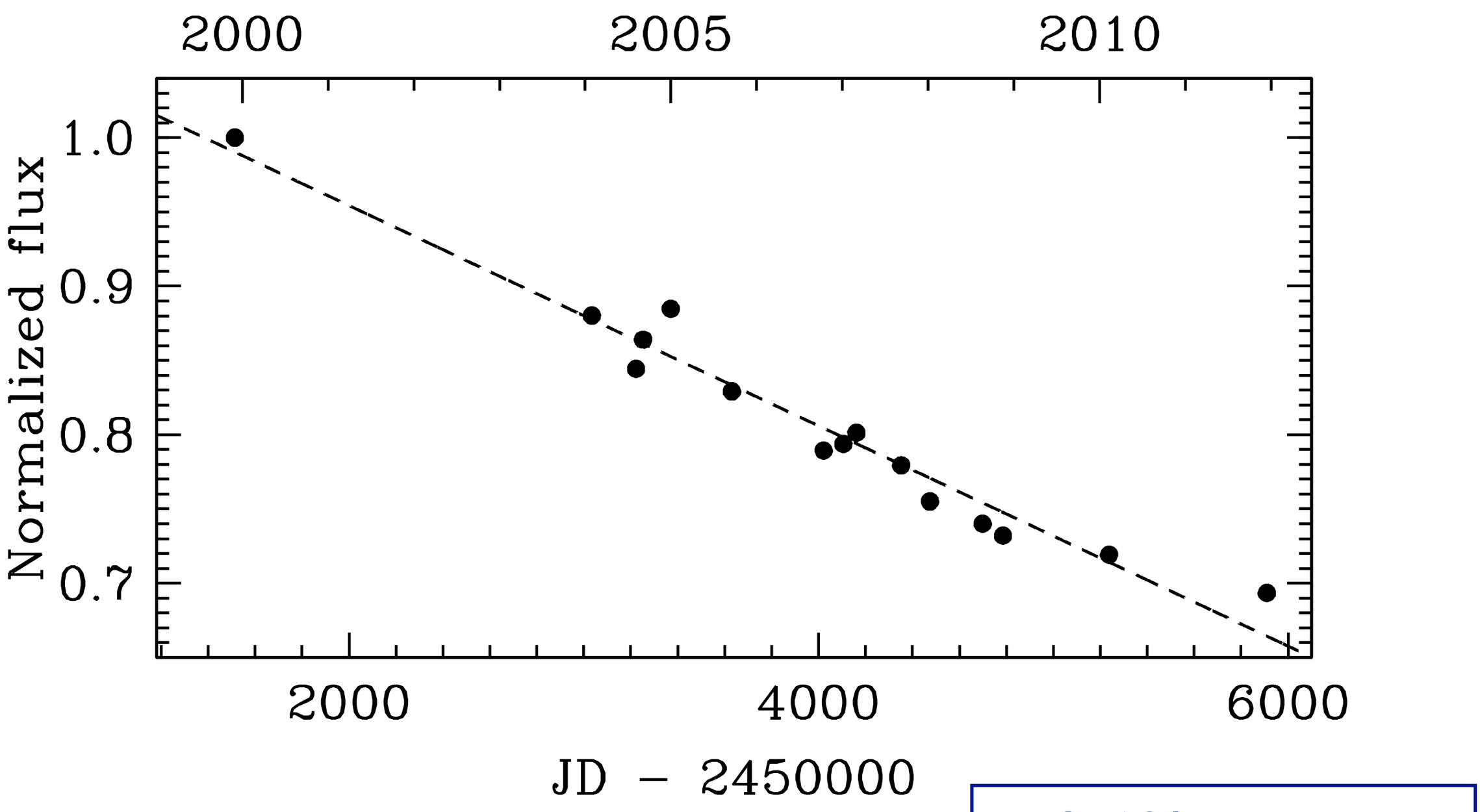
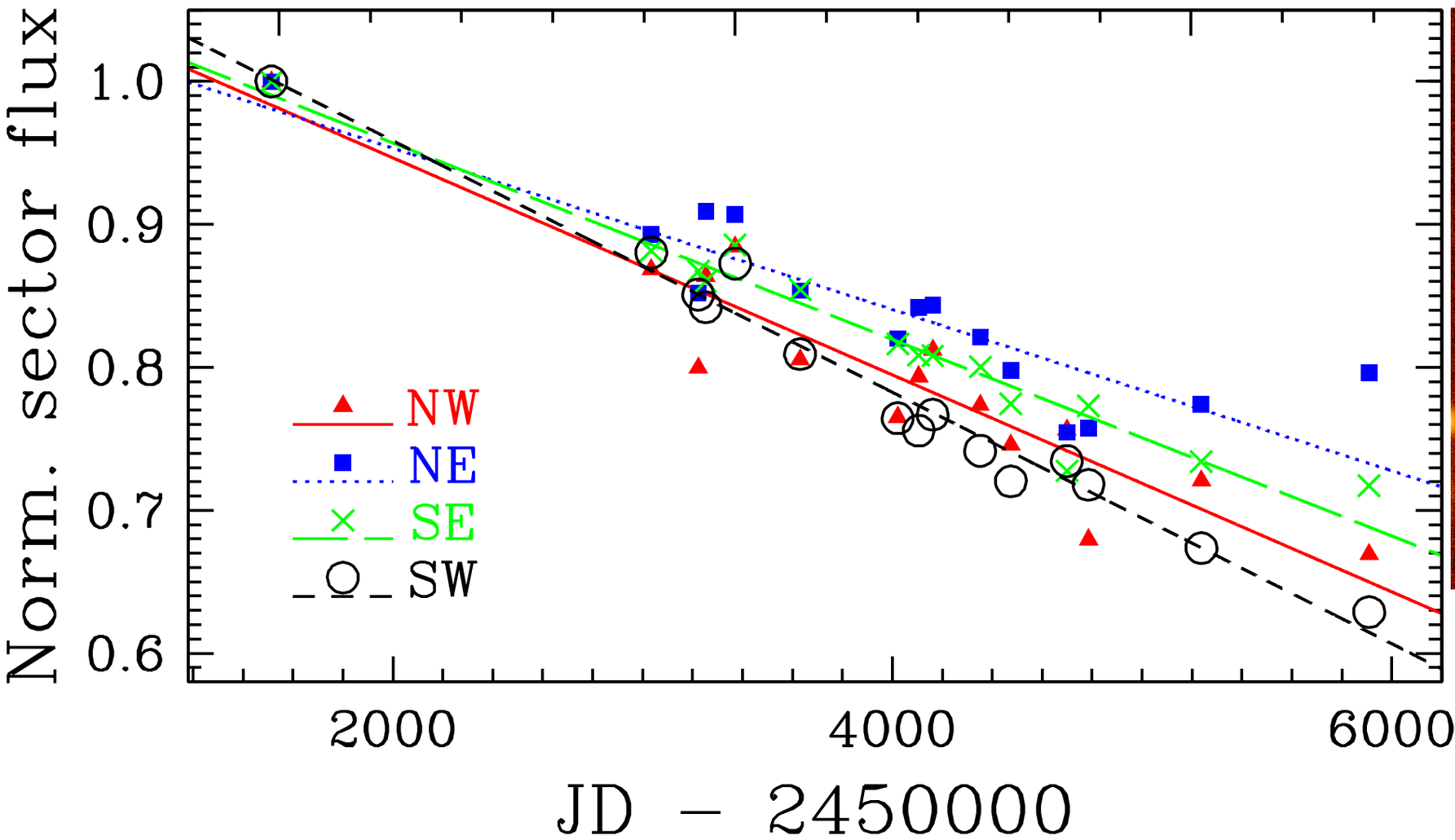
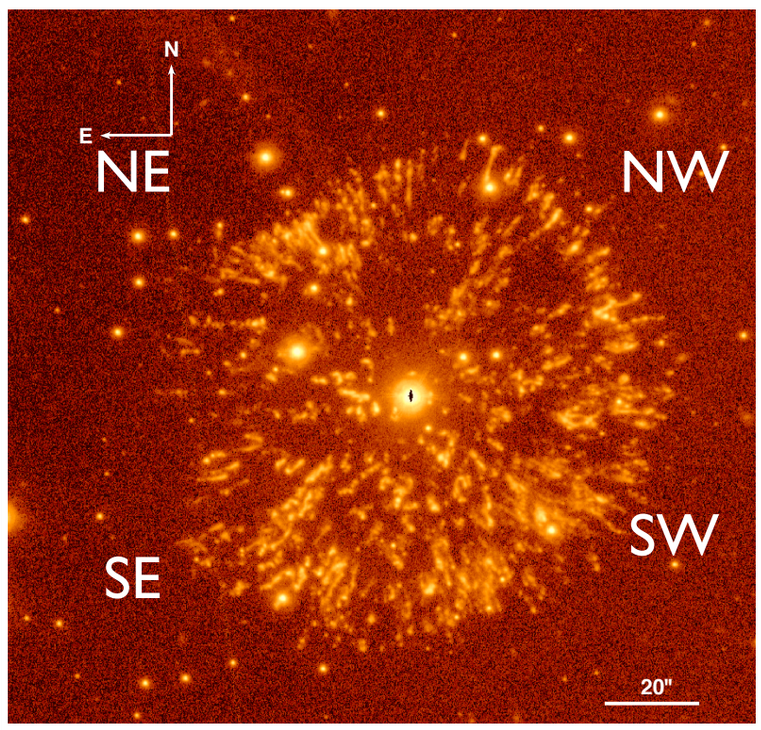



2.6% per year

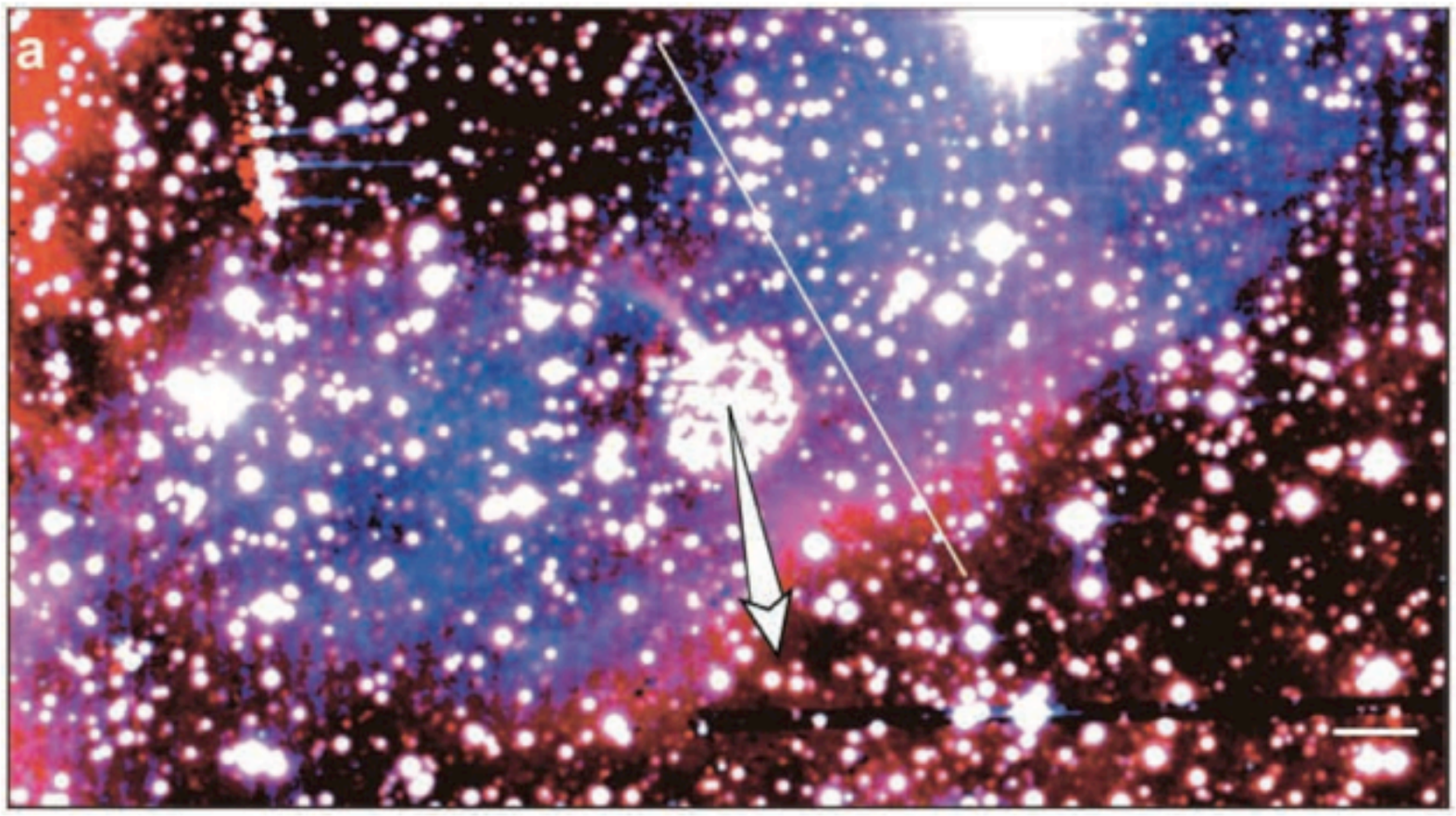
# Hα+[NII] flux in quadrants




*NOT 2007 Sept.*

# Nebular dynamics




Ancient bipolar nebula

*Credit: Bode et al. 2004, ApJ, 600, 63.*

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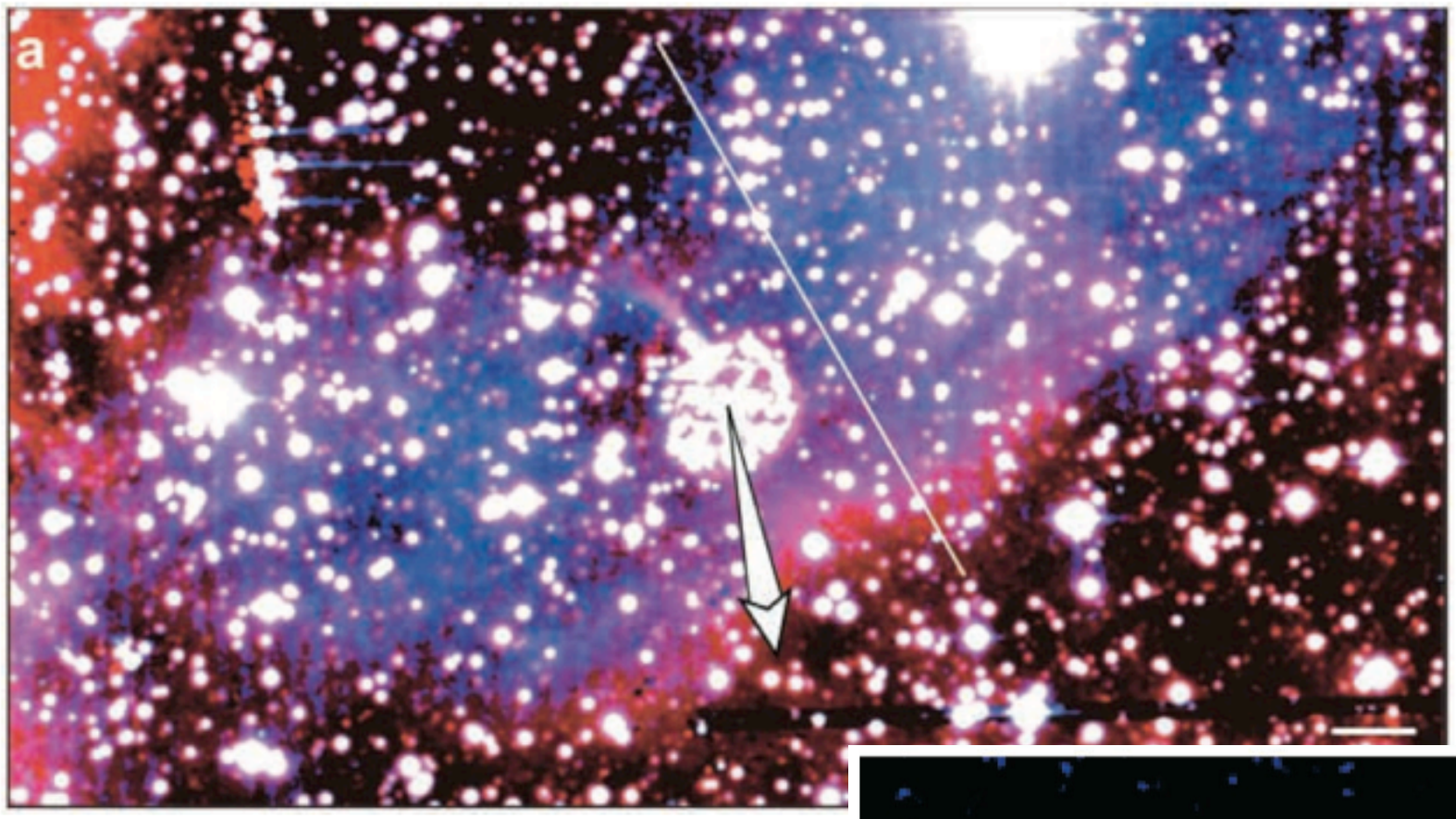


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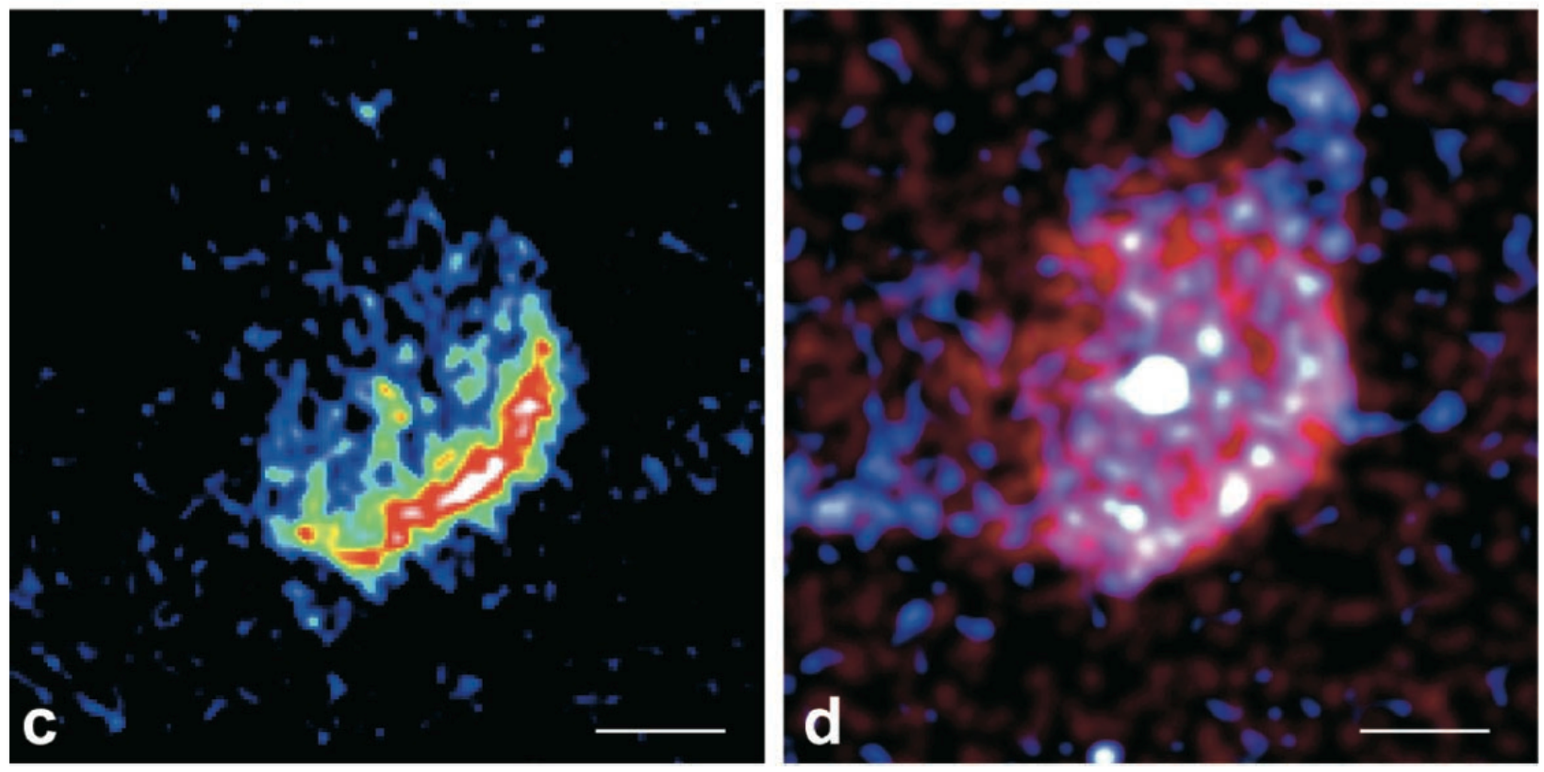
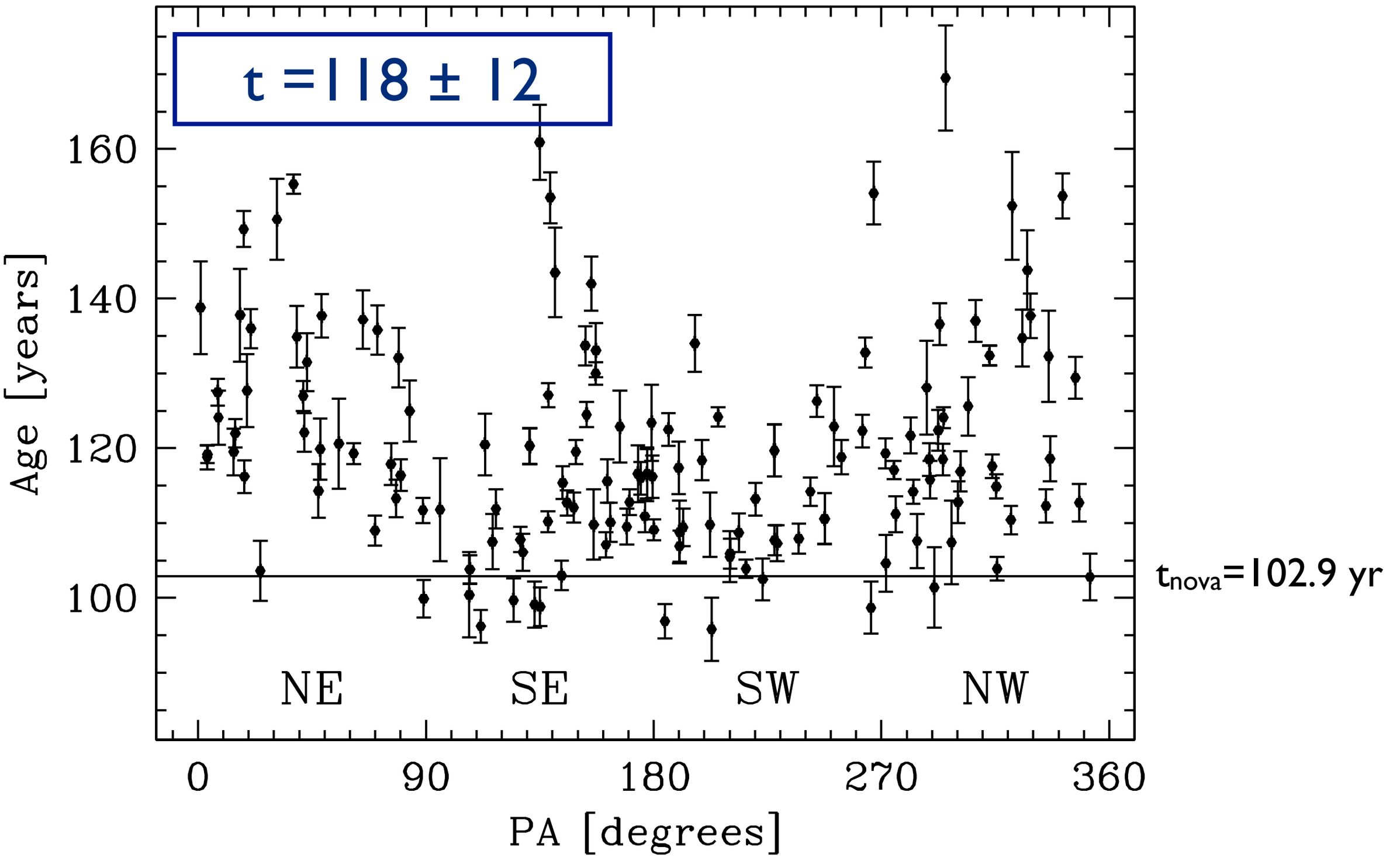
Radio and X-ray emission




*Credit: Bode, et al 2004; E. R. Seaquist; Balman et al. 2002, AIPC, 637, 365.*

# Kinematical ages



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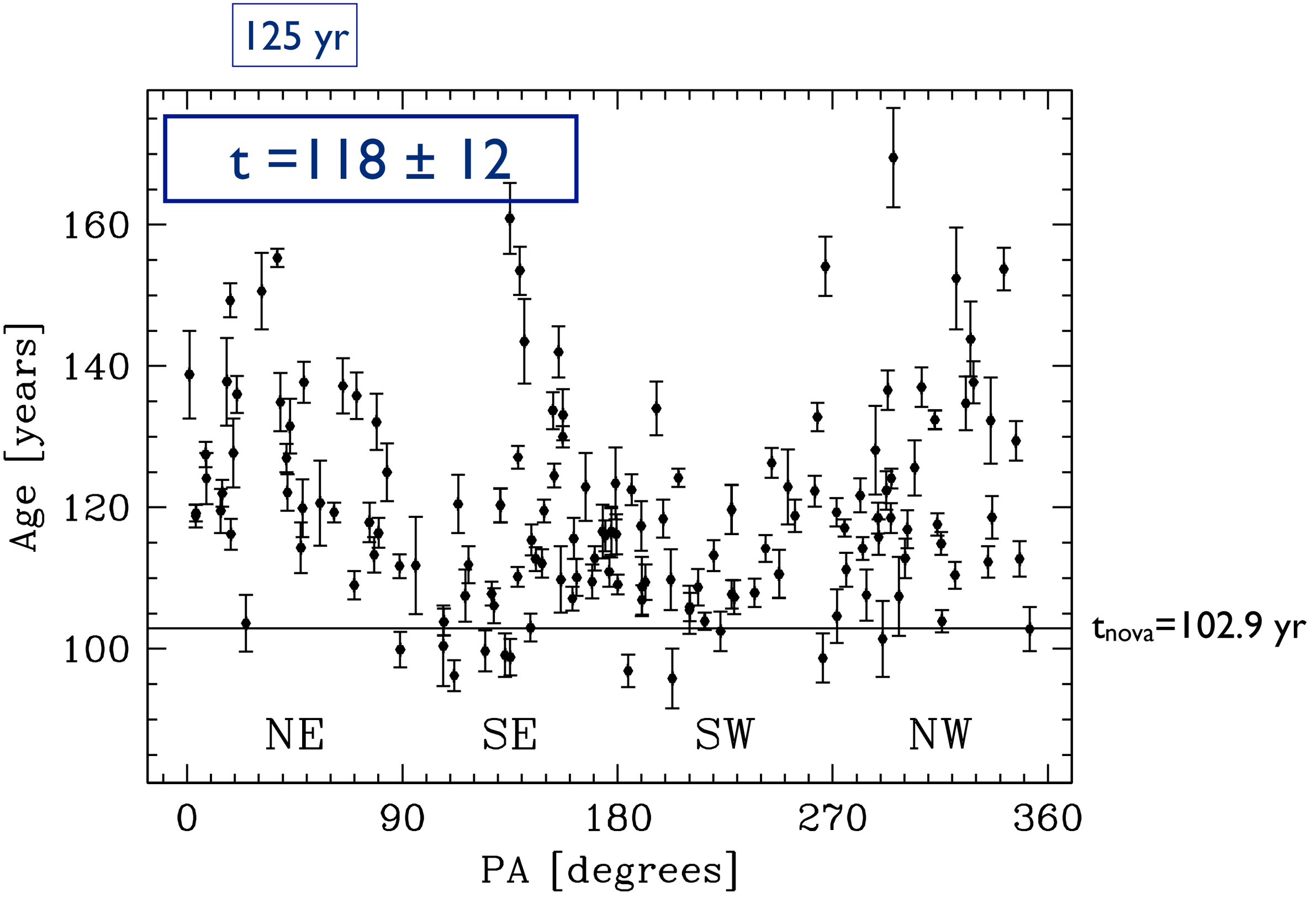

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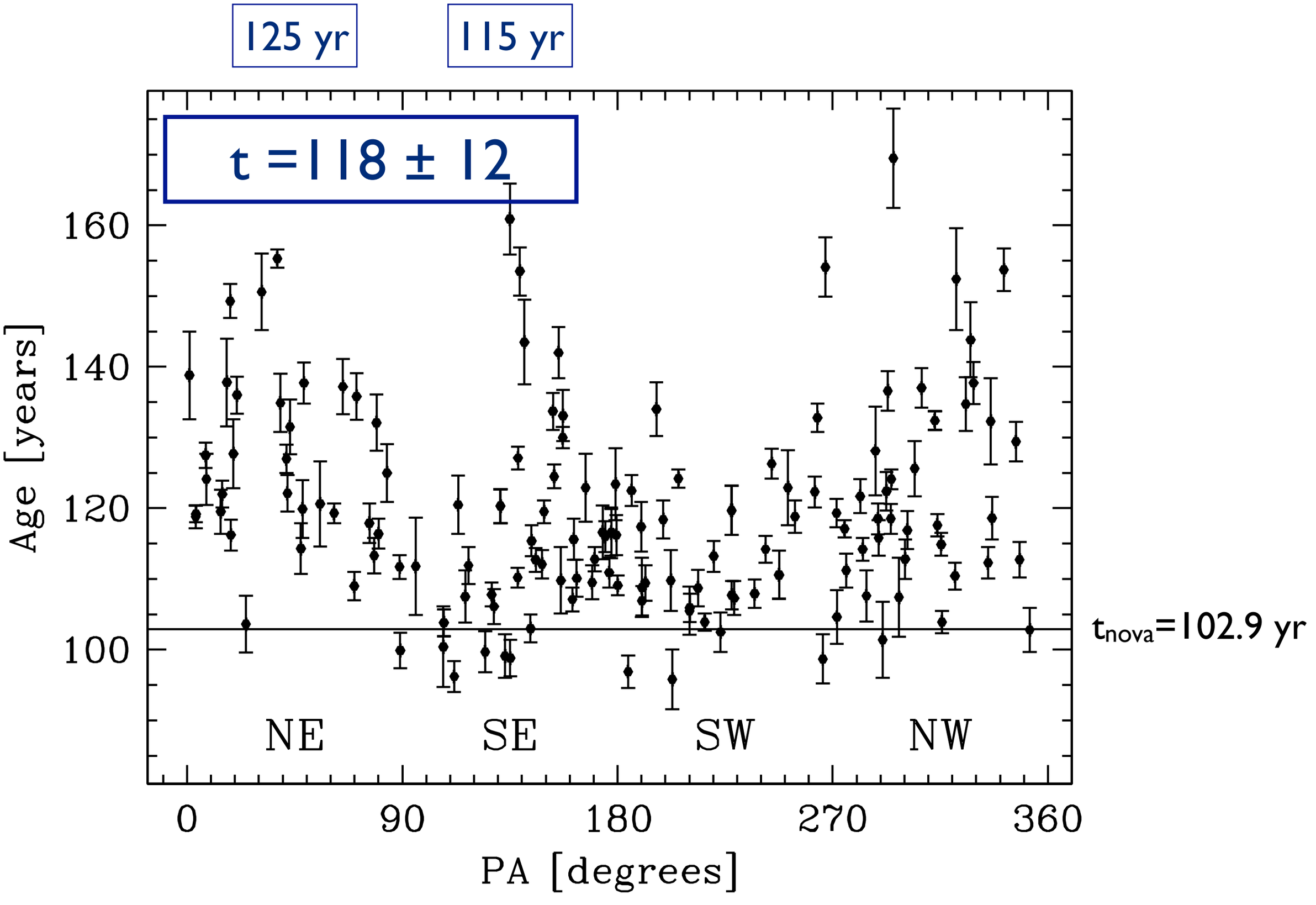

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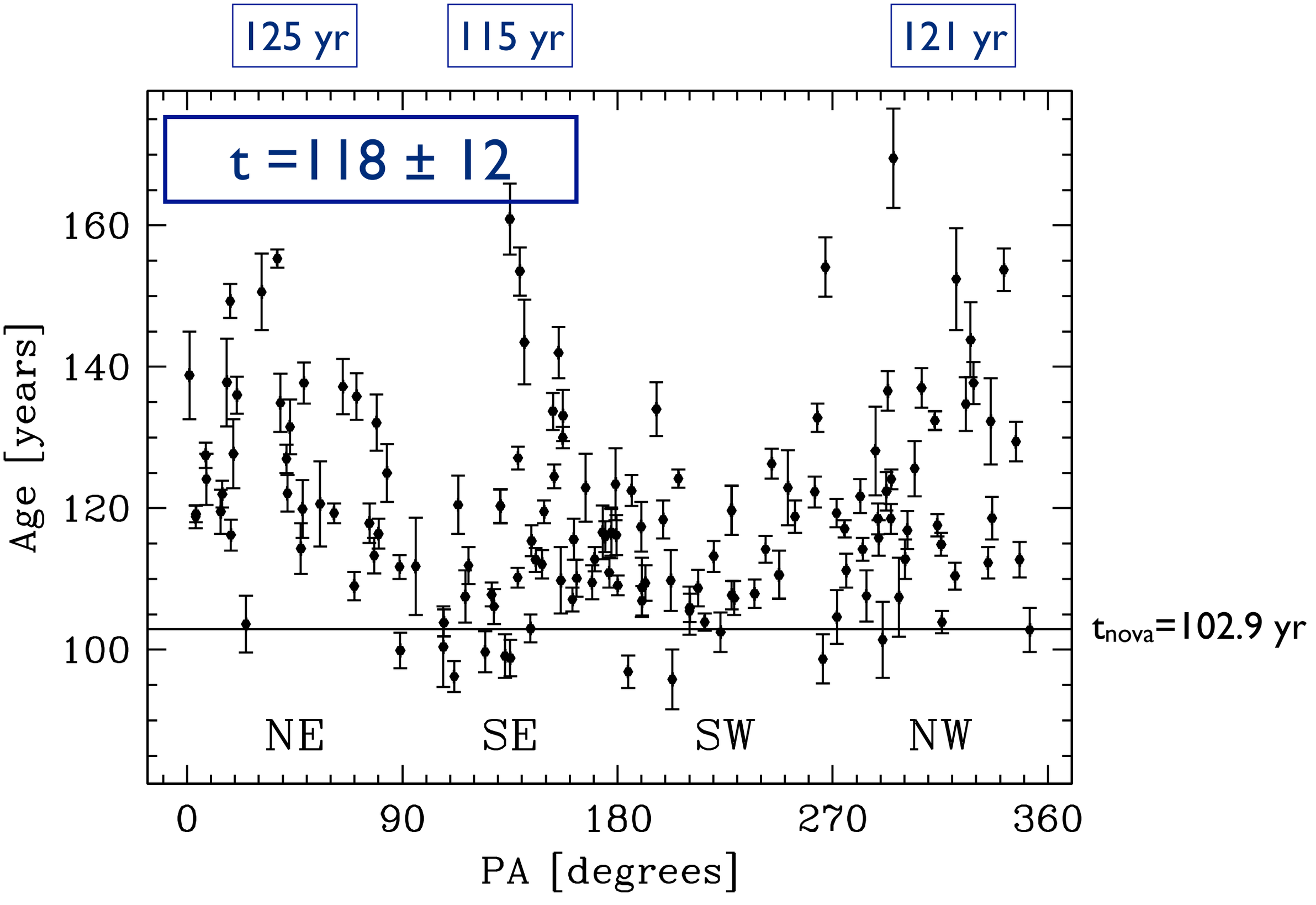

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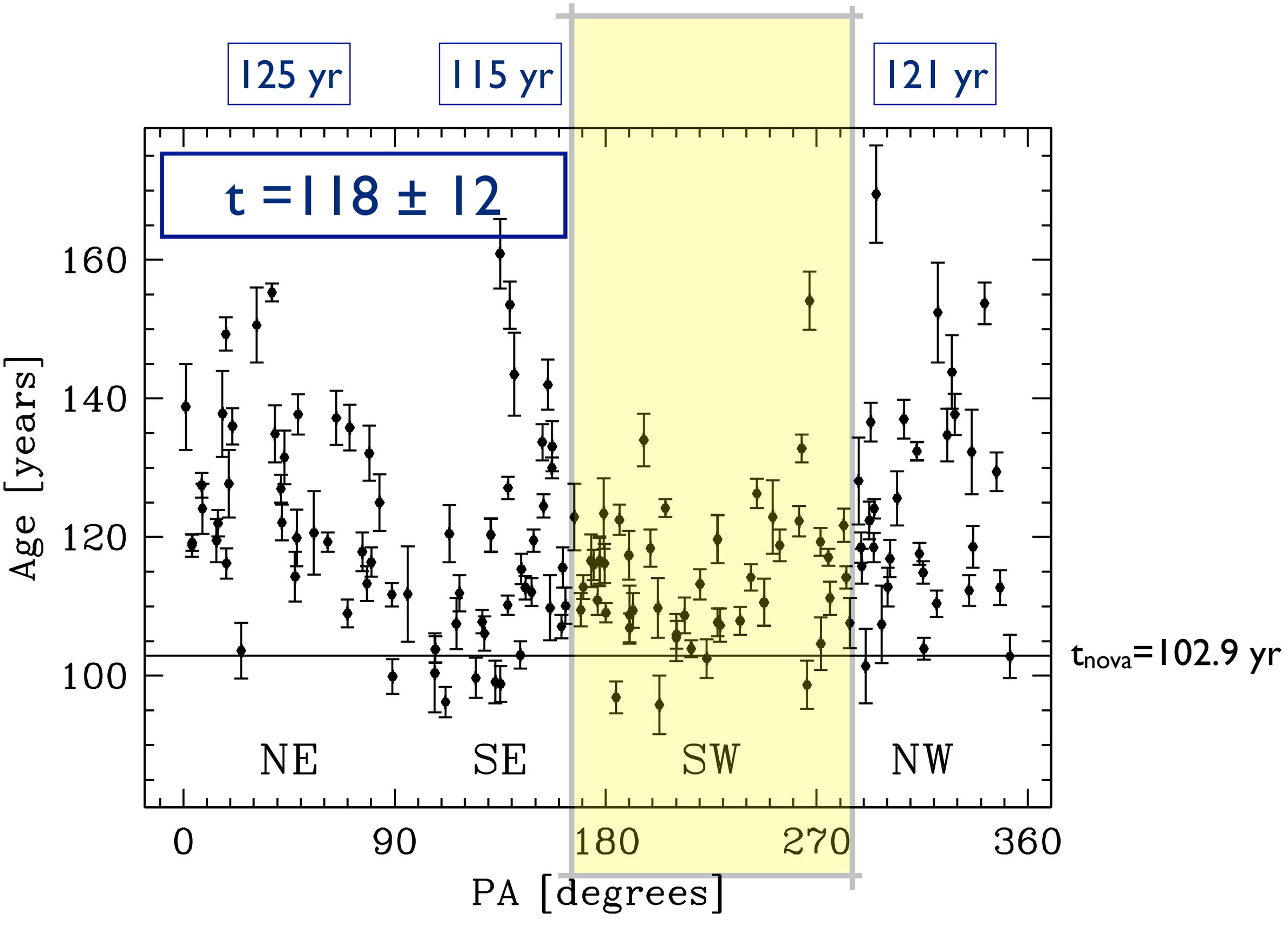

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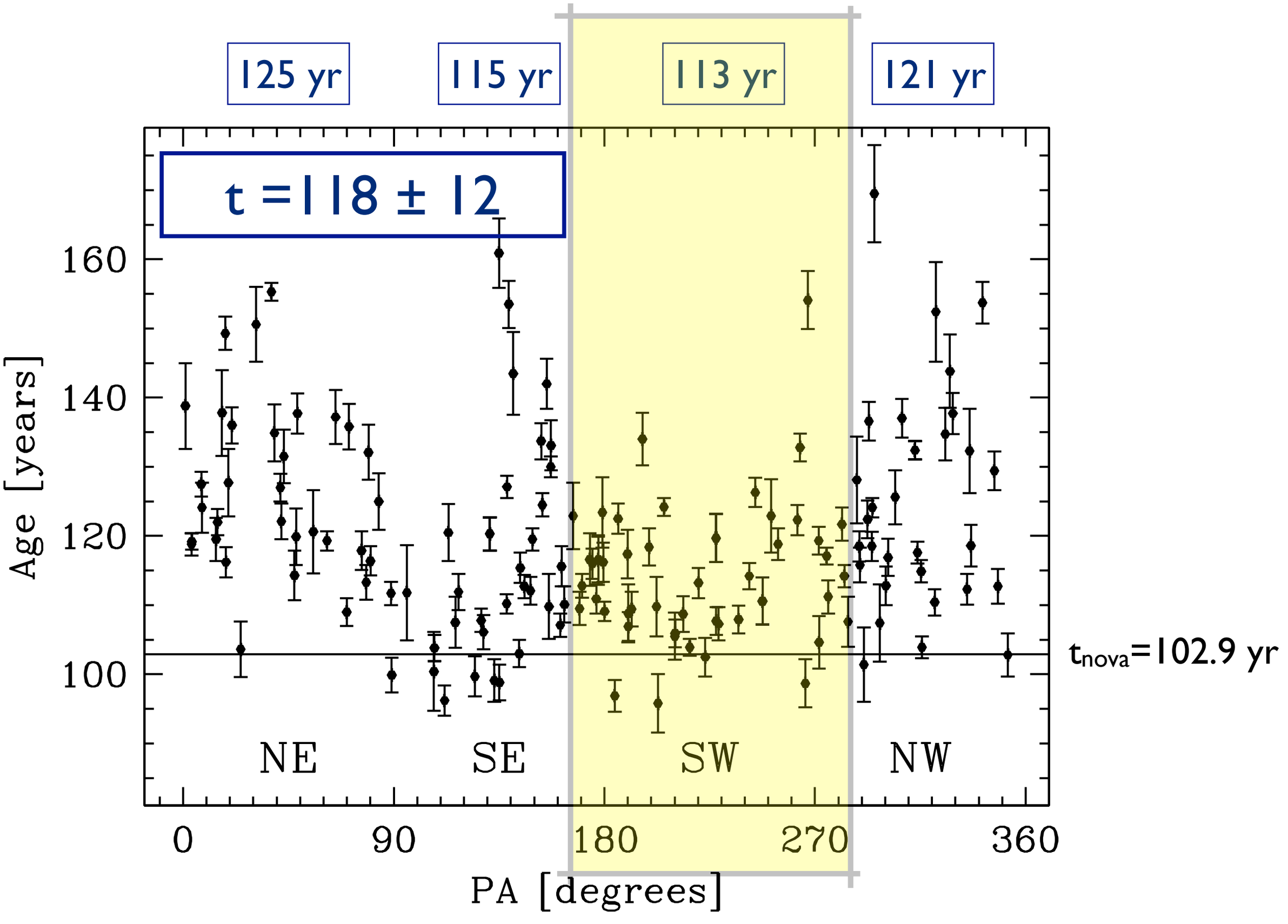

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  Interaction of PN with magnetized ISM (Soker & Dgani 1997)

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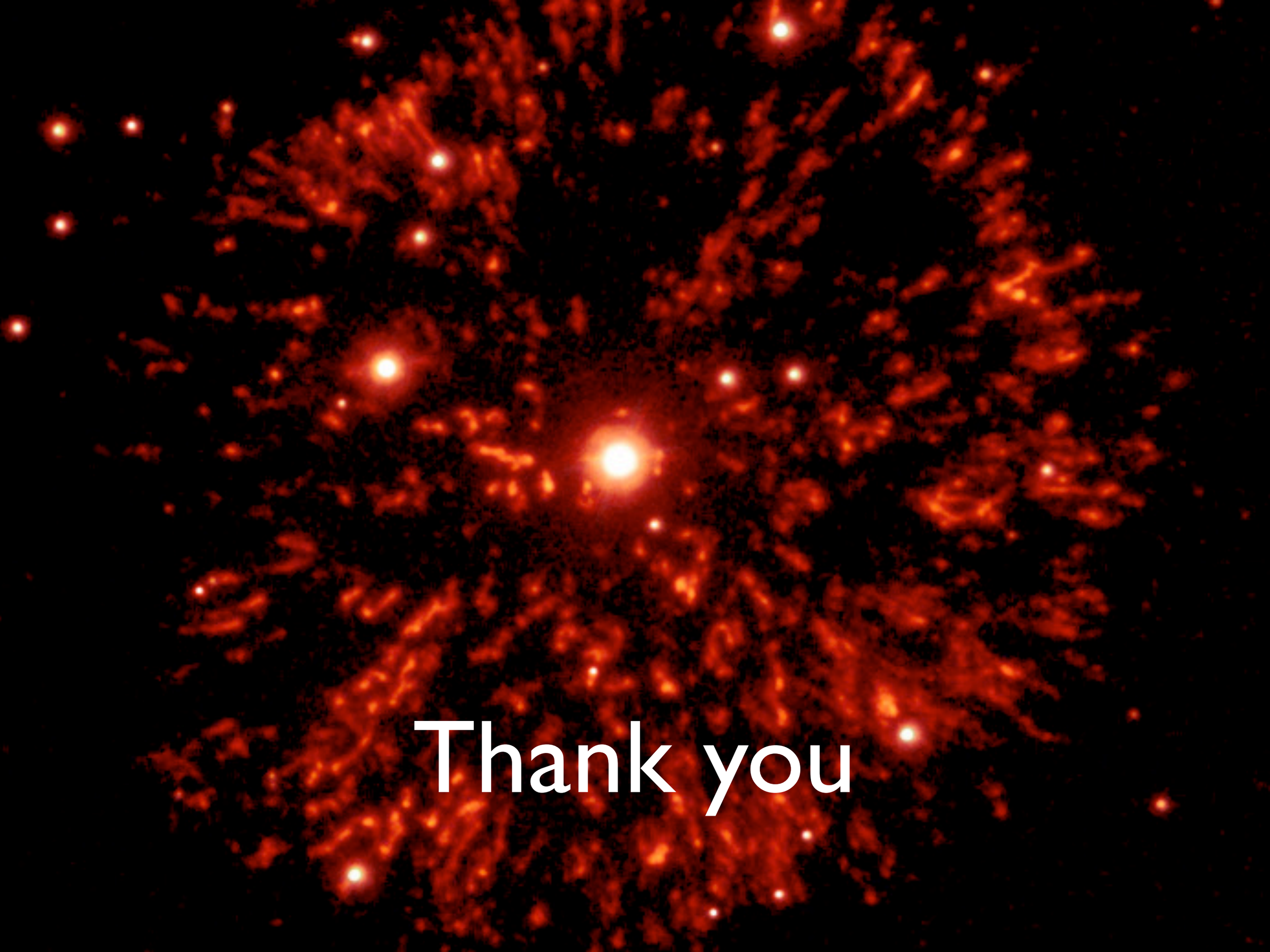
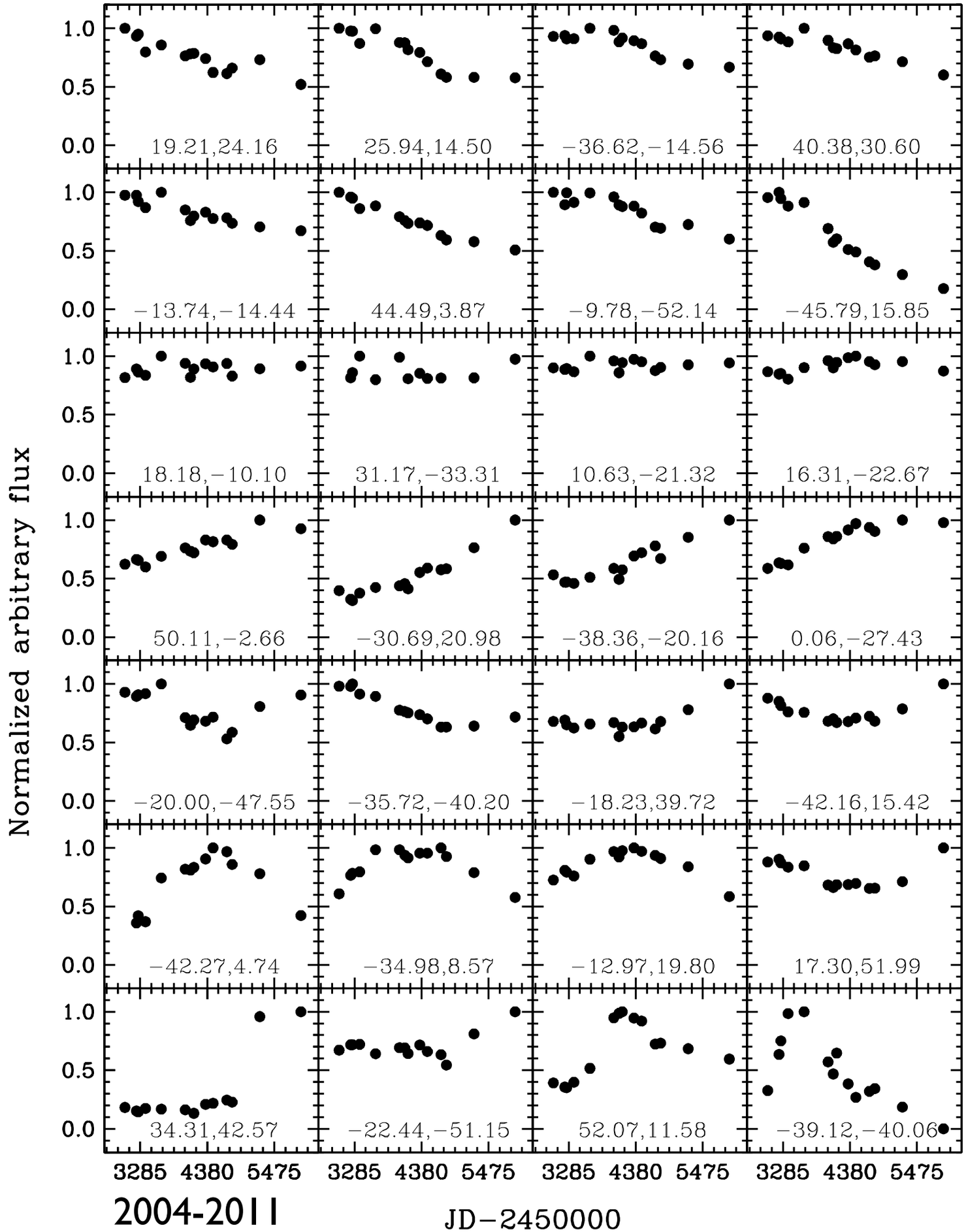
- Continues observations in all wavelengths required!
- See more from *Liimets et al. 2012 ApJ, 761, 34*

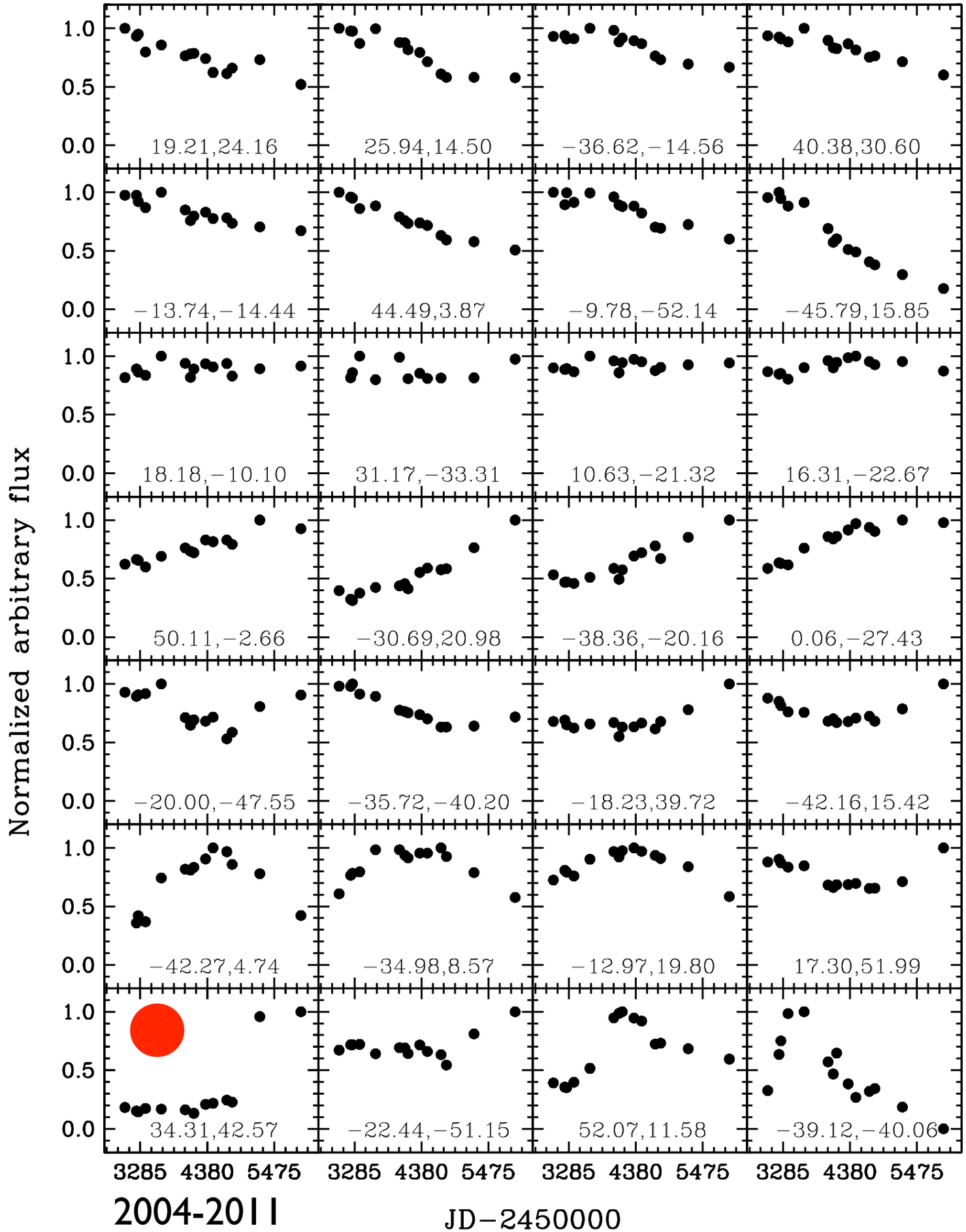

Thank you

# FEW extra slides

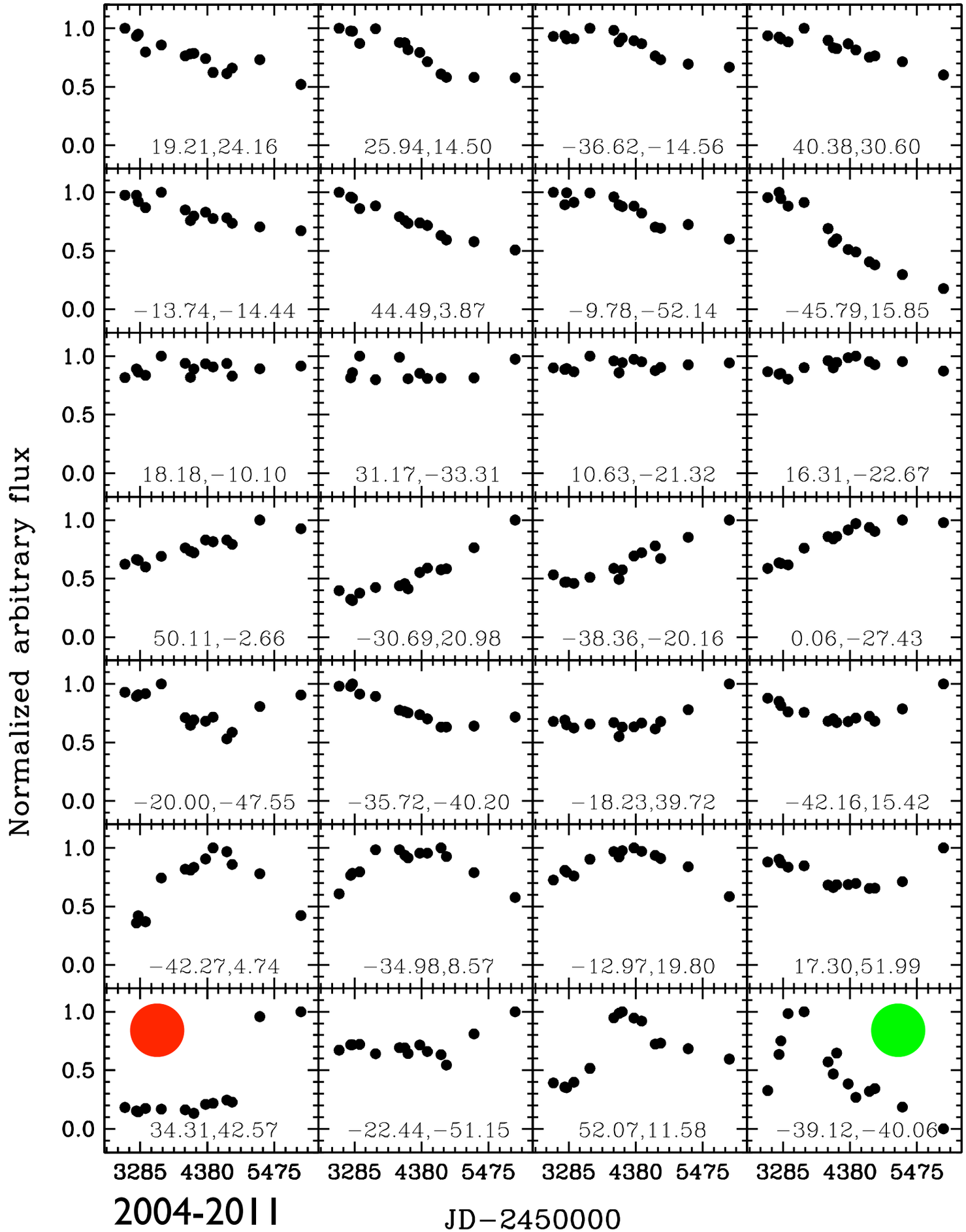
# Fluxes of individual blobs

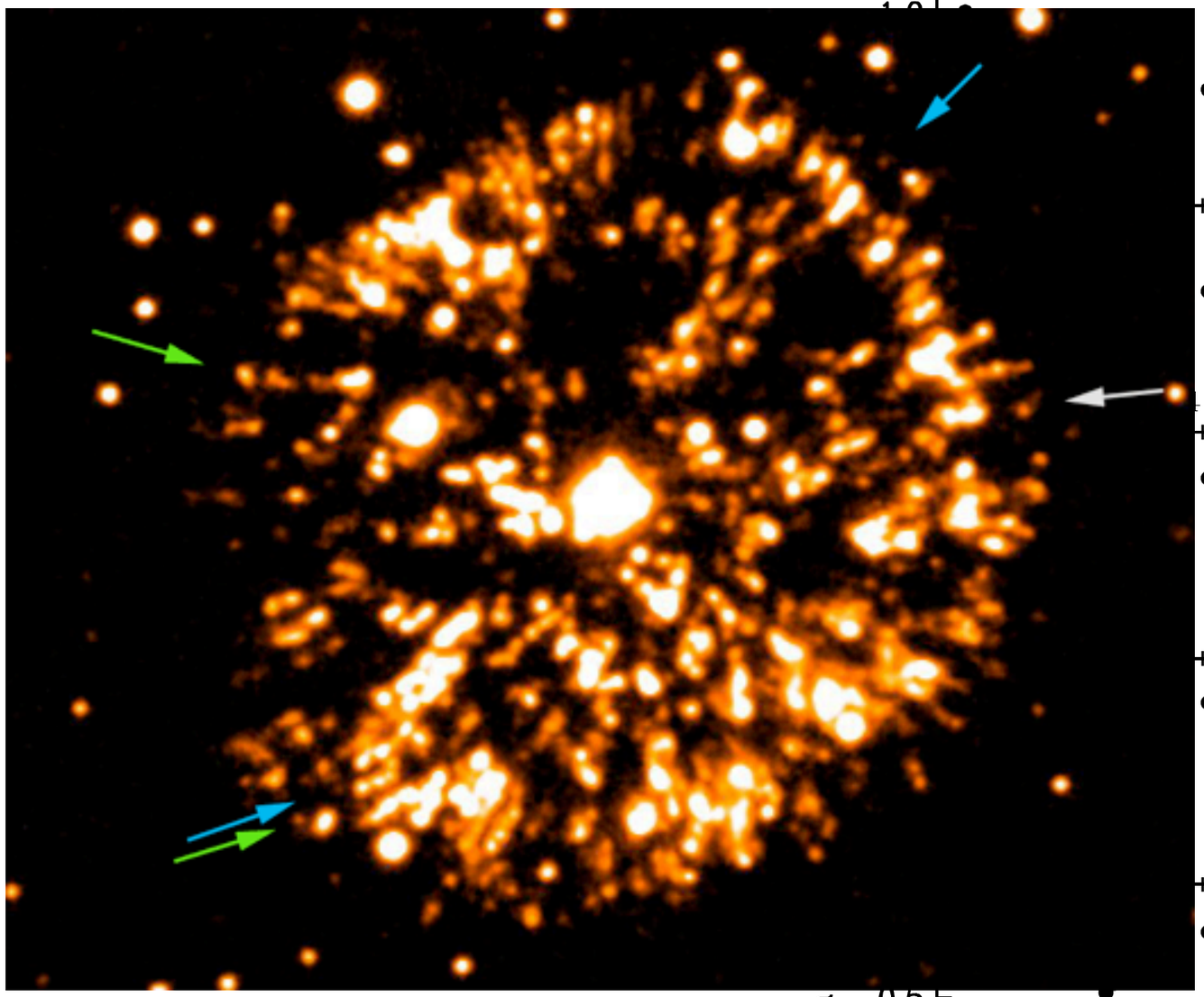


# Fluxes of individual blobs

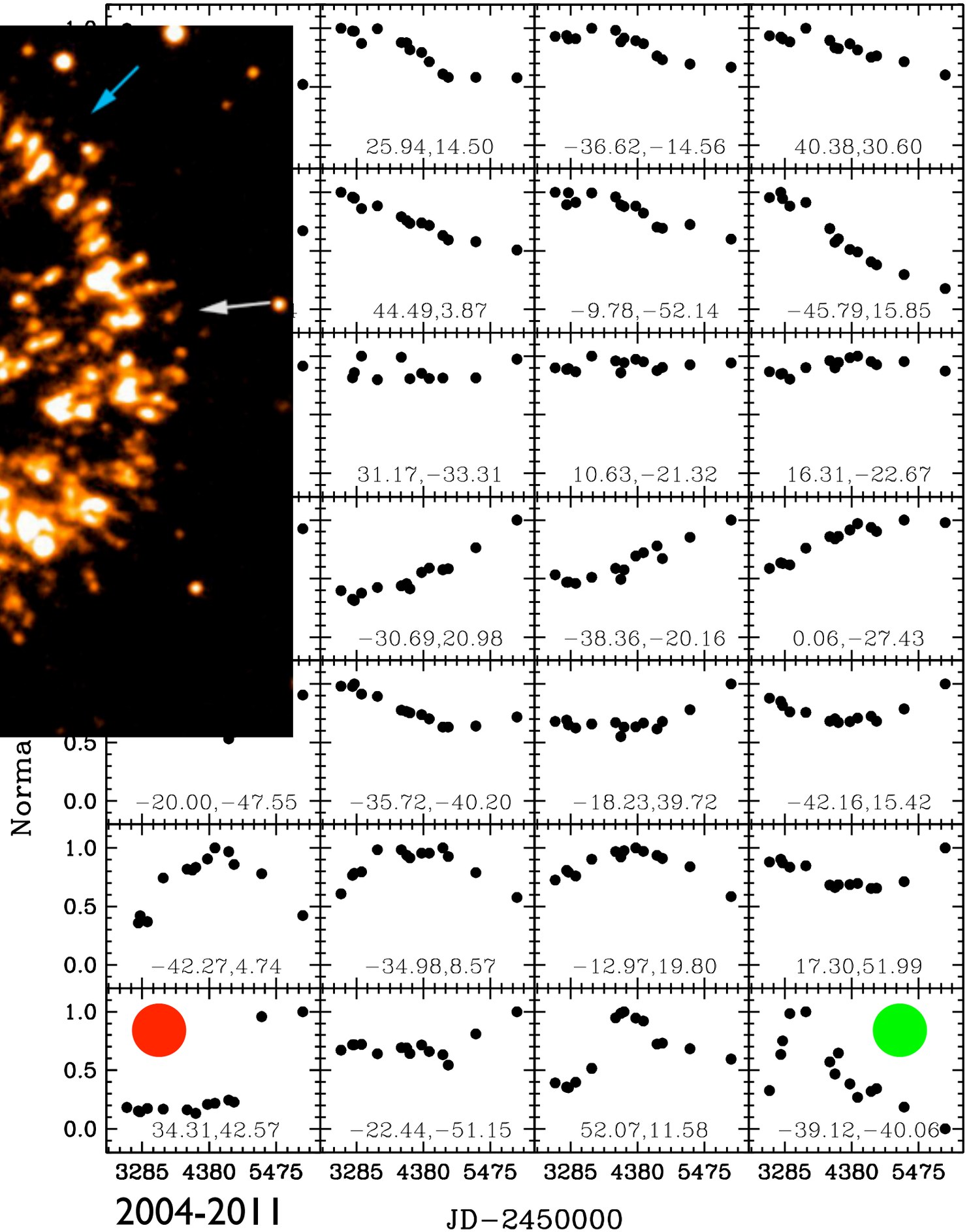


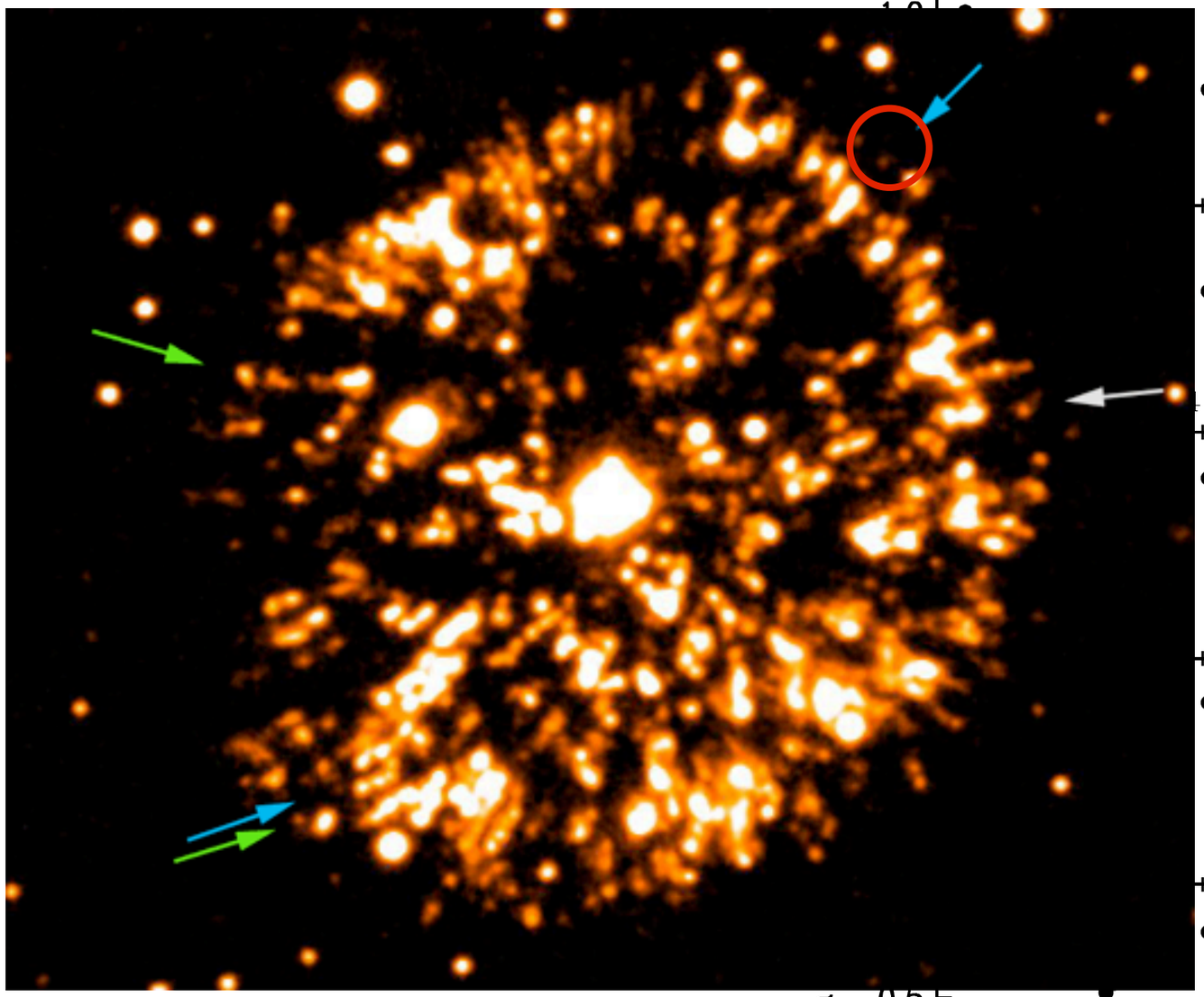
# Fluxes of individual blobs



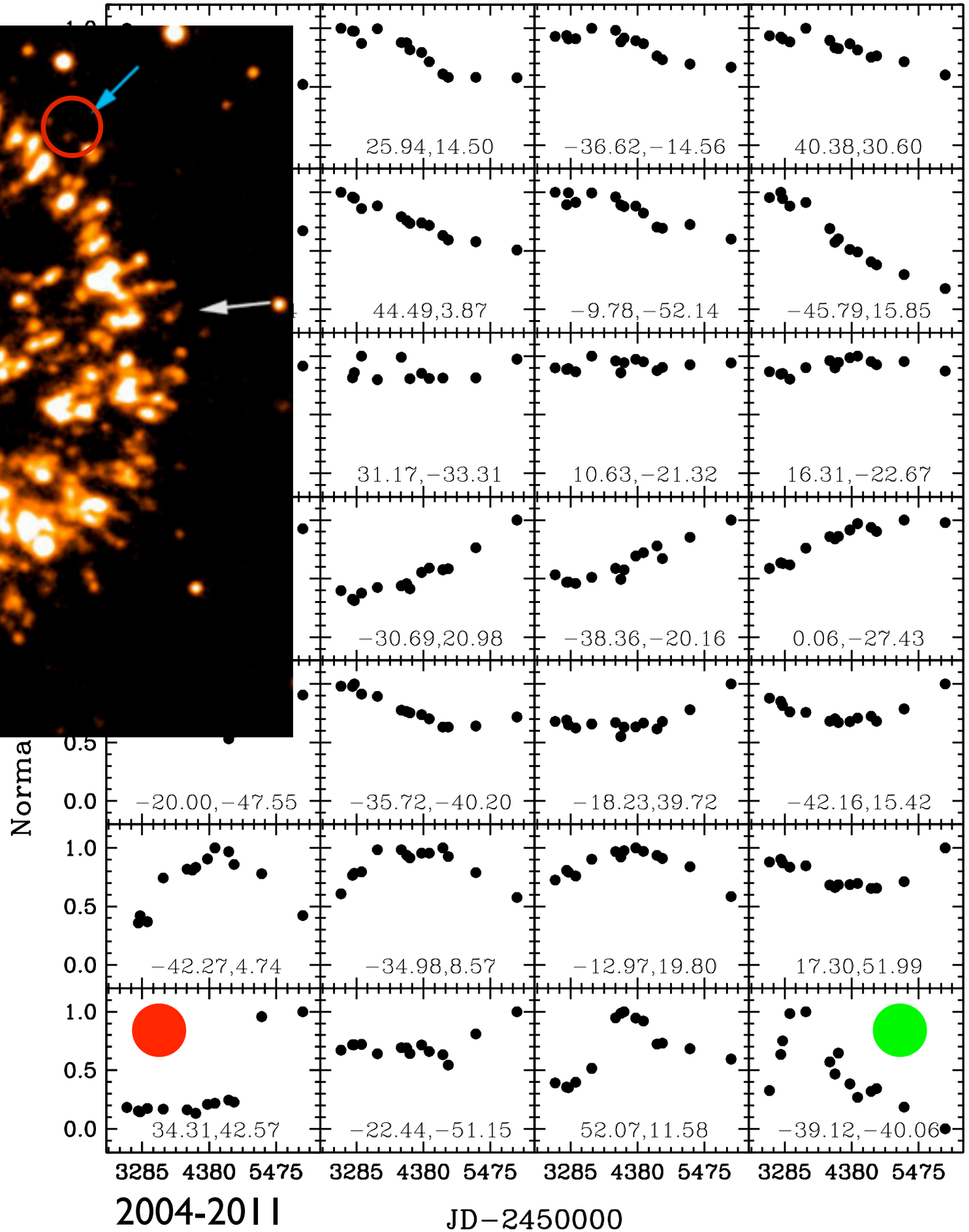


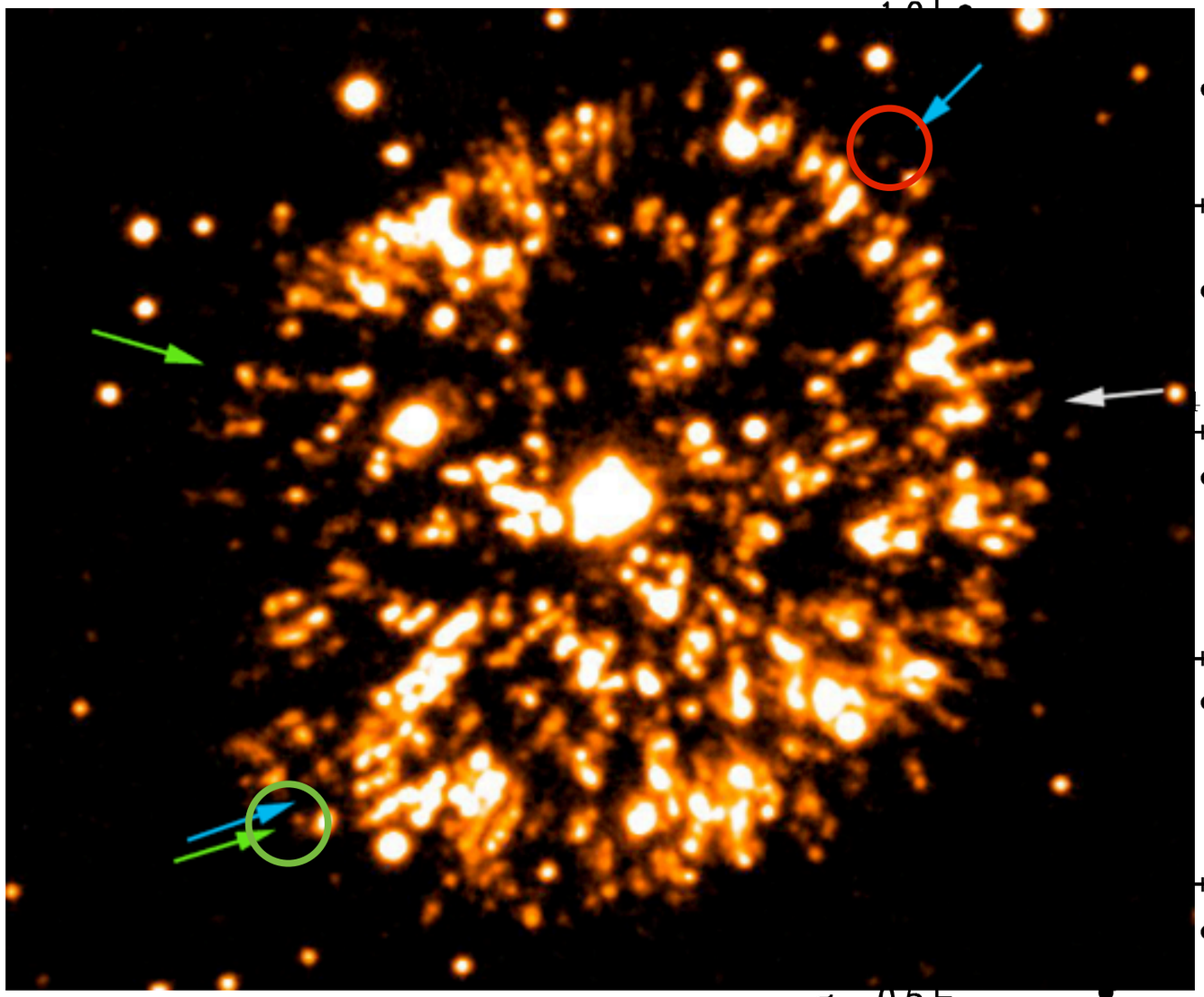
# Fluxes of individual blobs



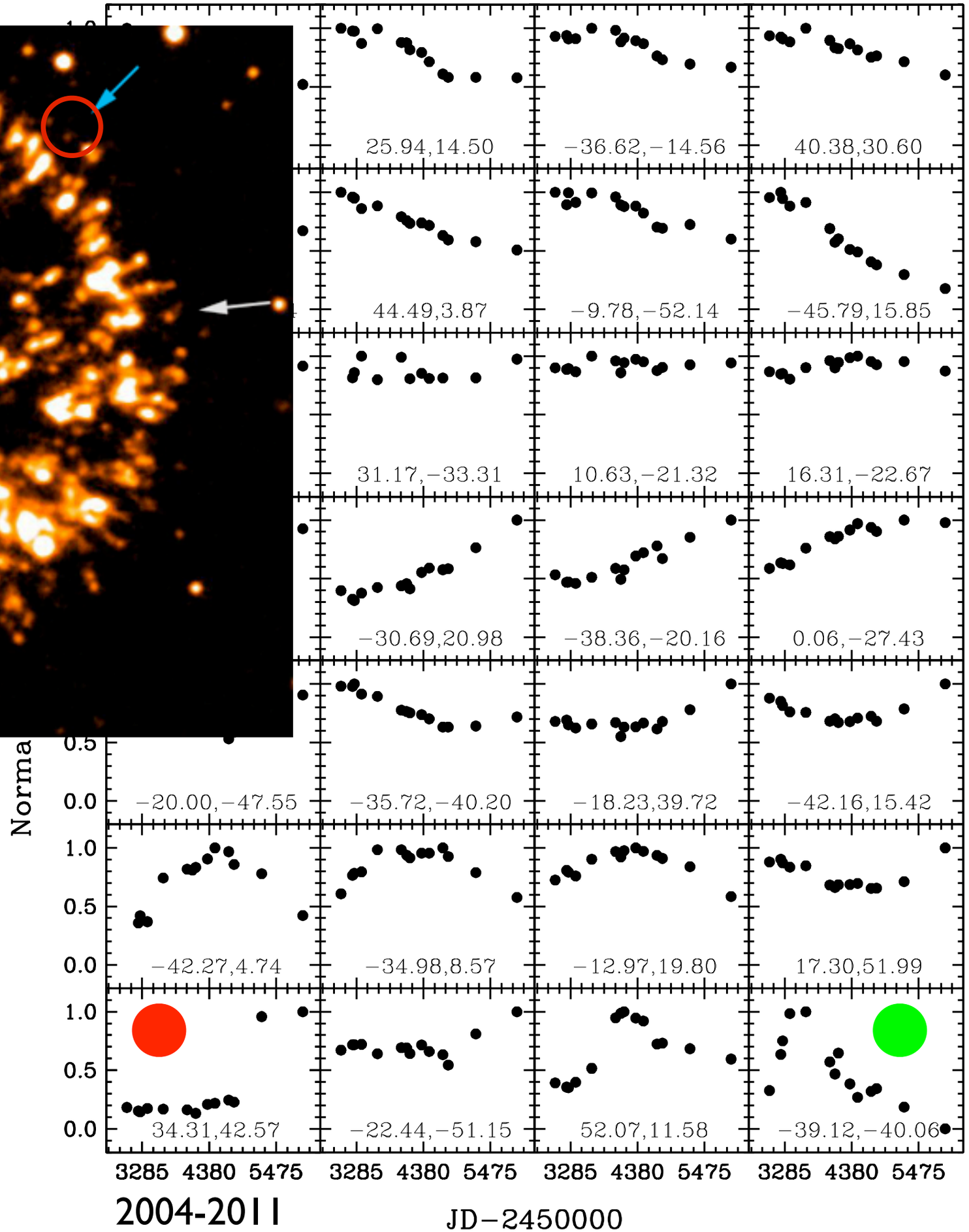


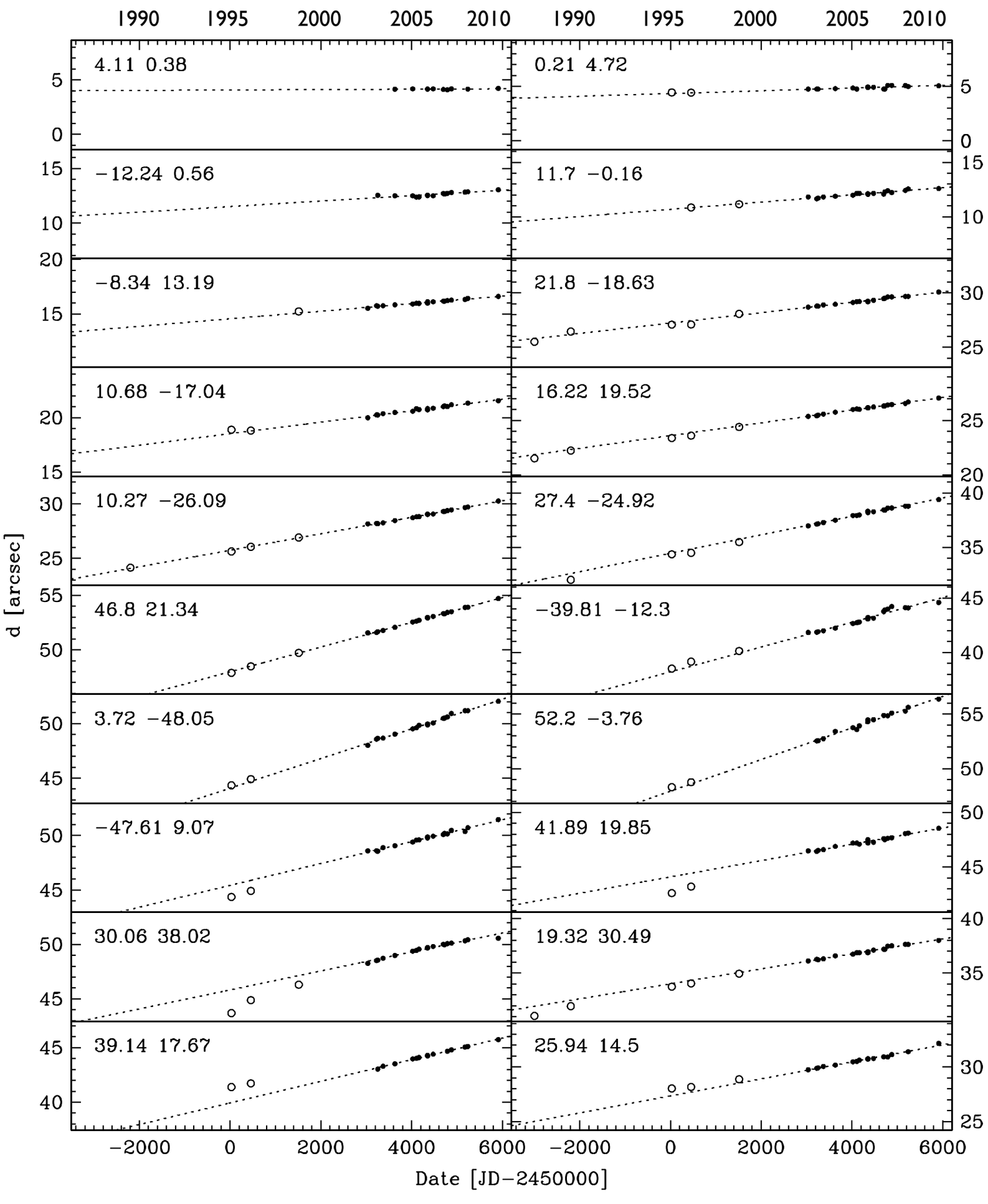
# Fluxes of individual blobs



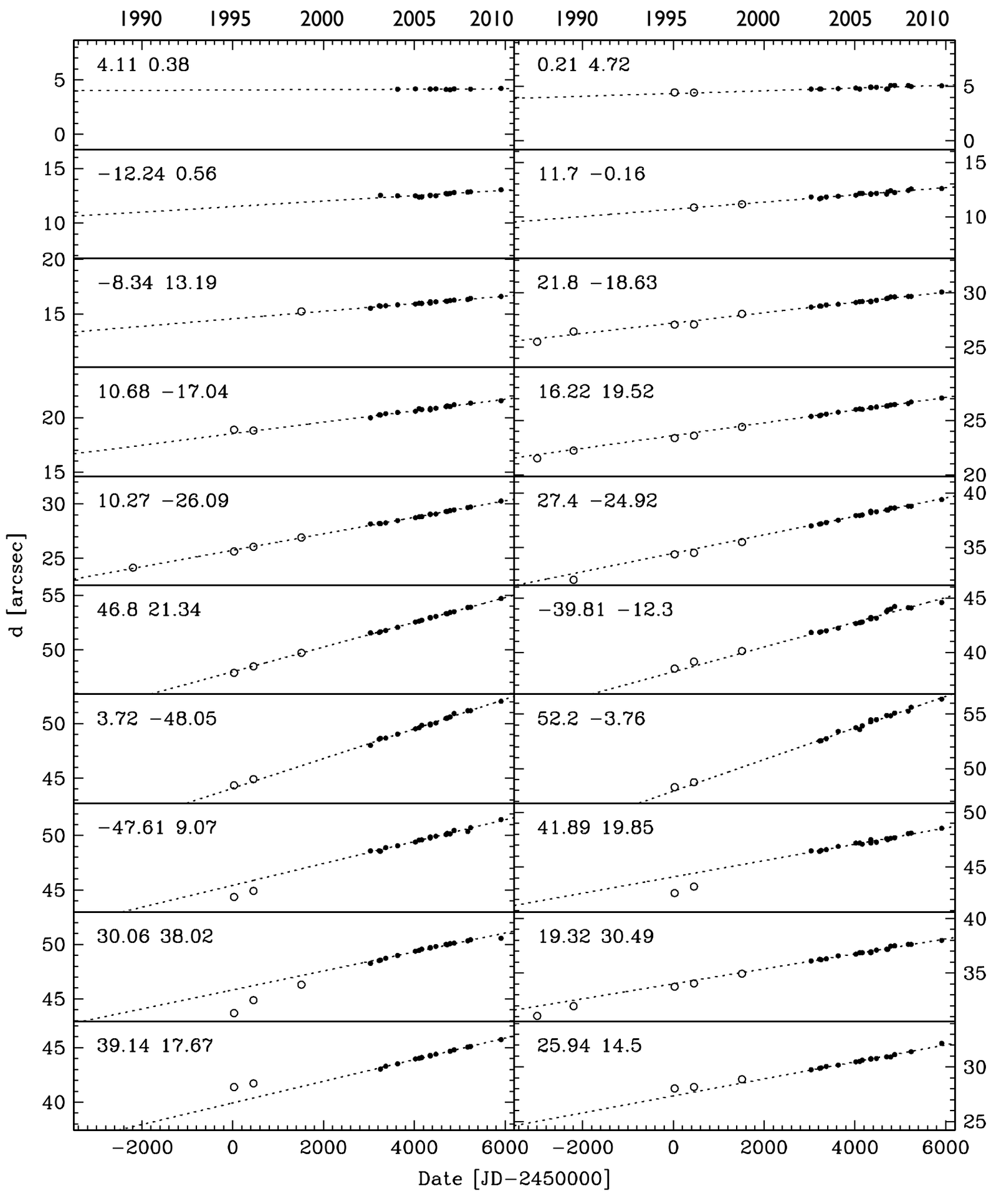


# Fluxes of individual blobs






# Proper motions

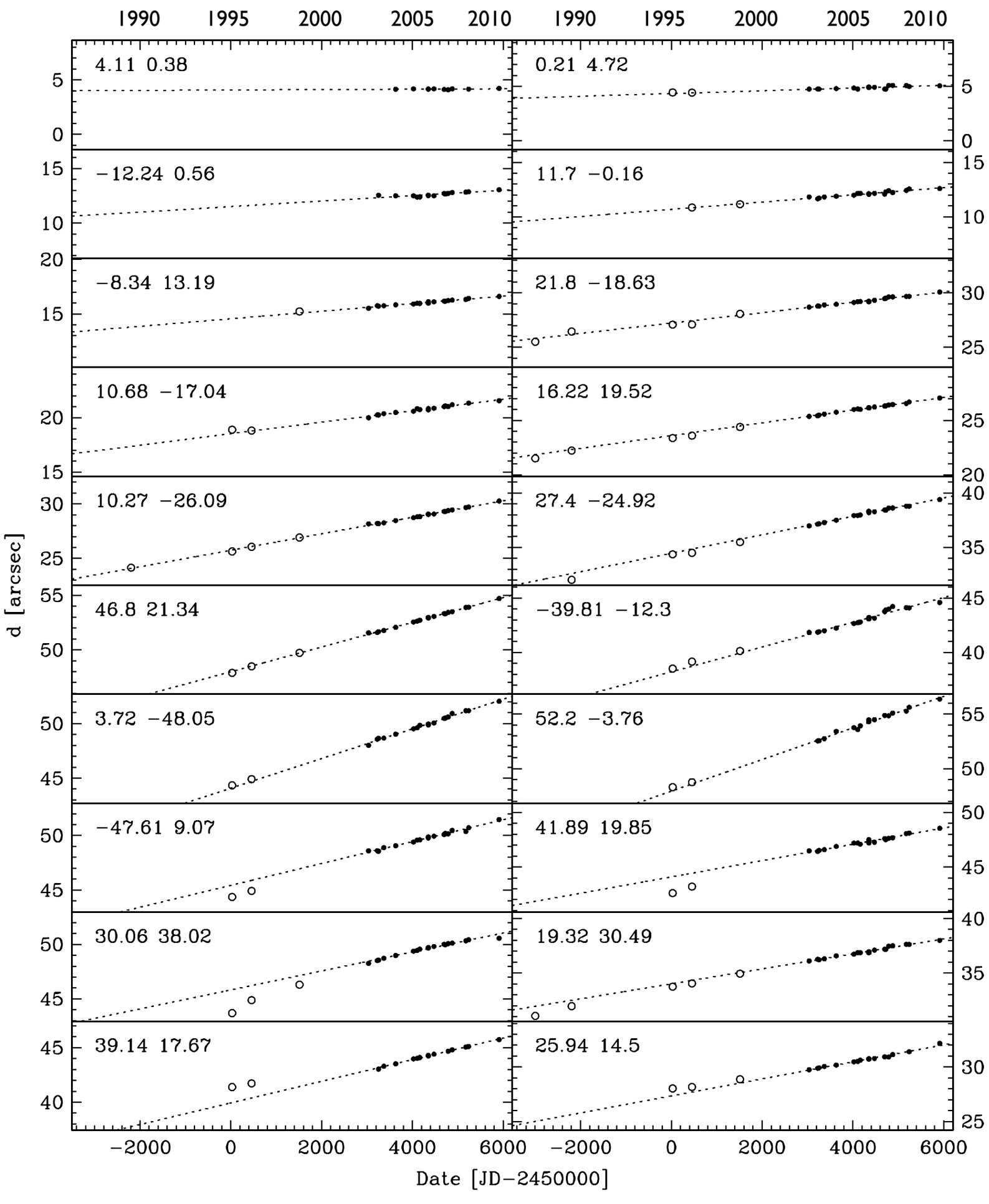


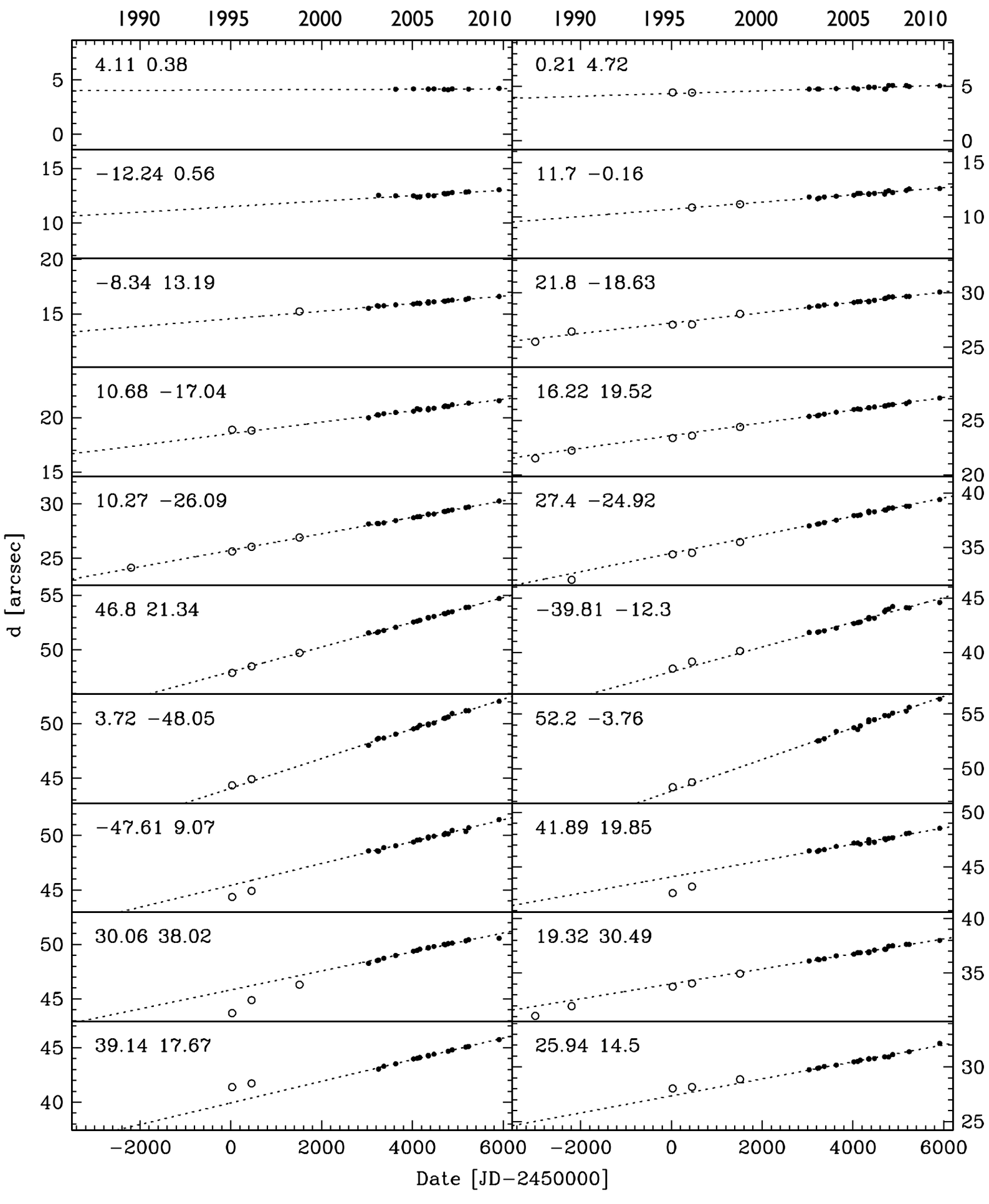

# Proper motions

282 knots

# Proper motions

282 knots
0.007 to 0.53 “/yr






# Proper motions

282 knots

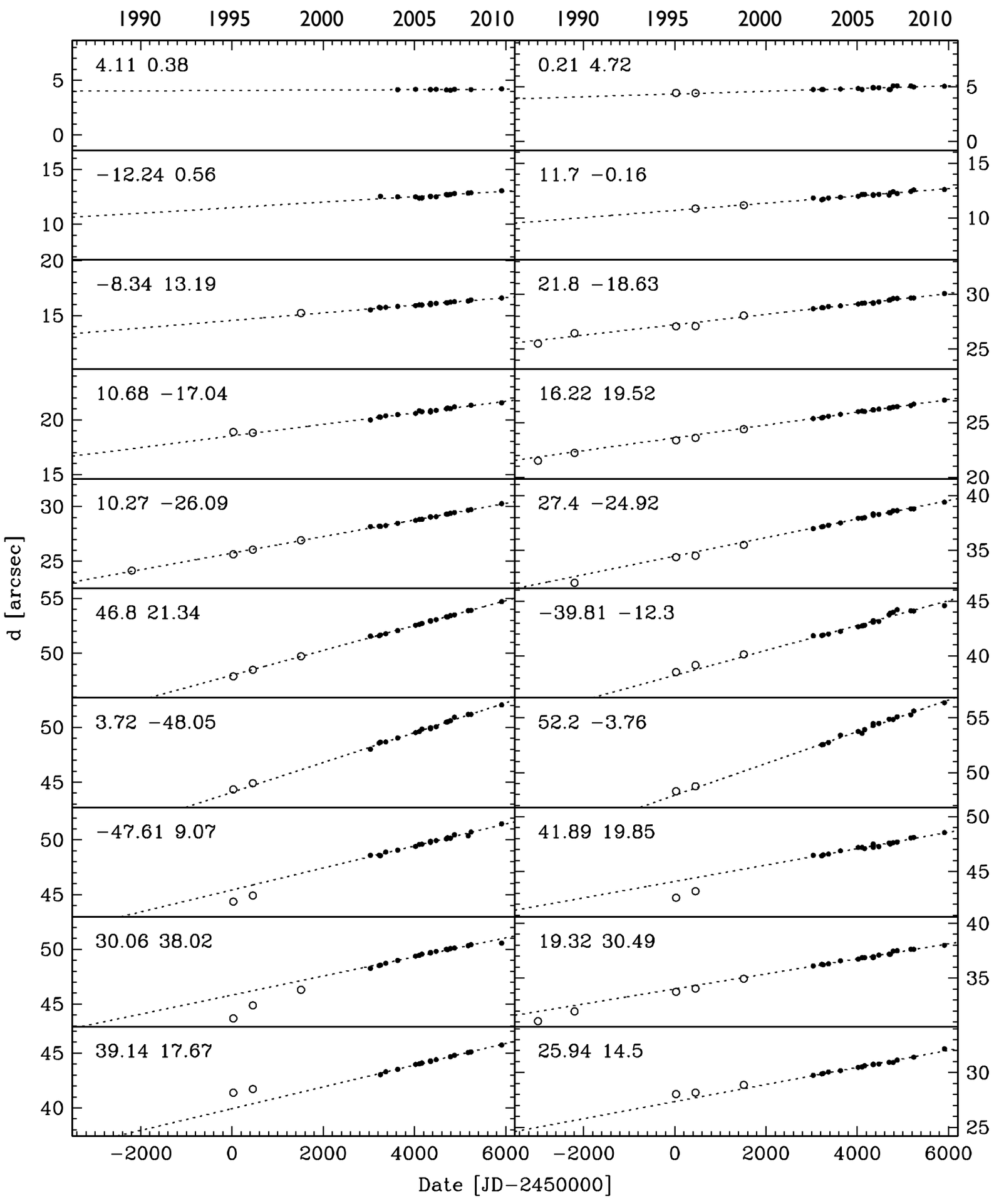
0.007 to 0.53 “/yr

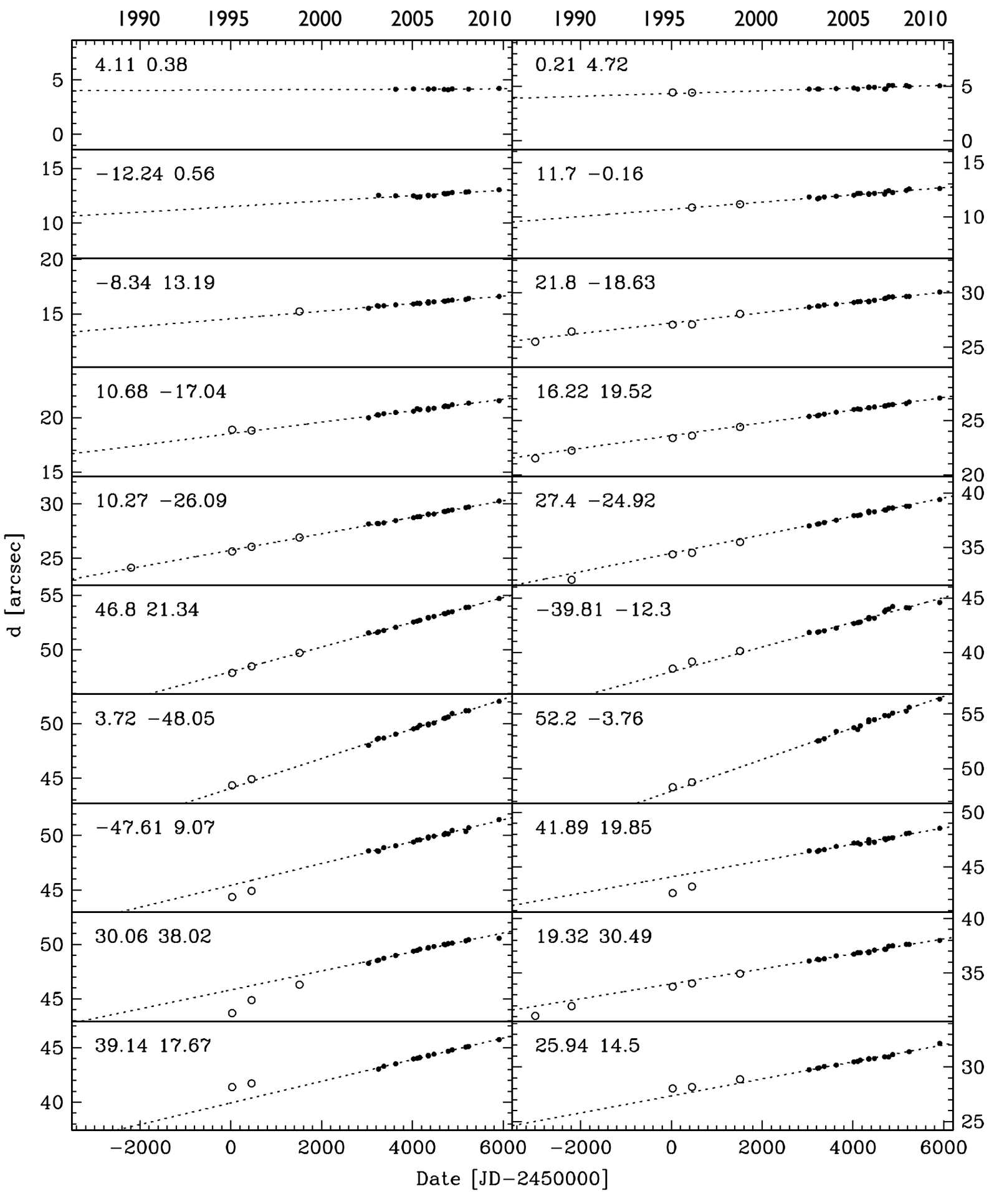
Errors:

# Proper motions

282 knots
0.007 to 0.53 “/yr

Errors:
0.010 ± 0.006 “/yr



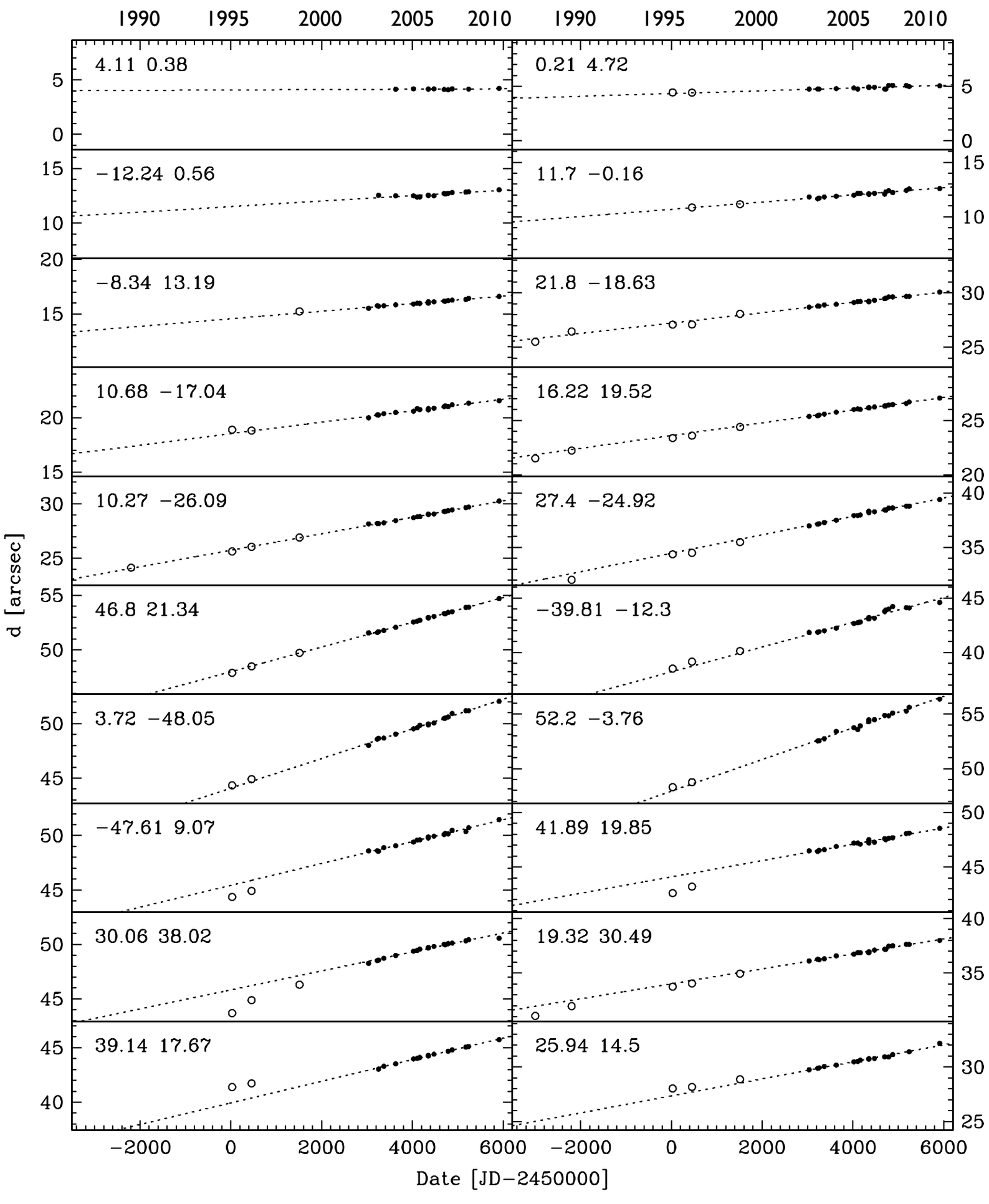



# Proper motions

282 knots
0.007 to 0.53 “/yr

Errors:
0.010 ± 0.006 “/yr

$$v_{\rm sky}\ [{\rm km\ s^{-1}}] = 4.74 \cdot \mu\ [''\ {\rm yr^{-1}}] \cdot D\ [{\rm pc}]$$




# Proper motions

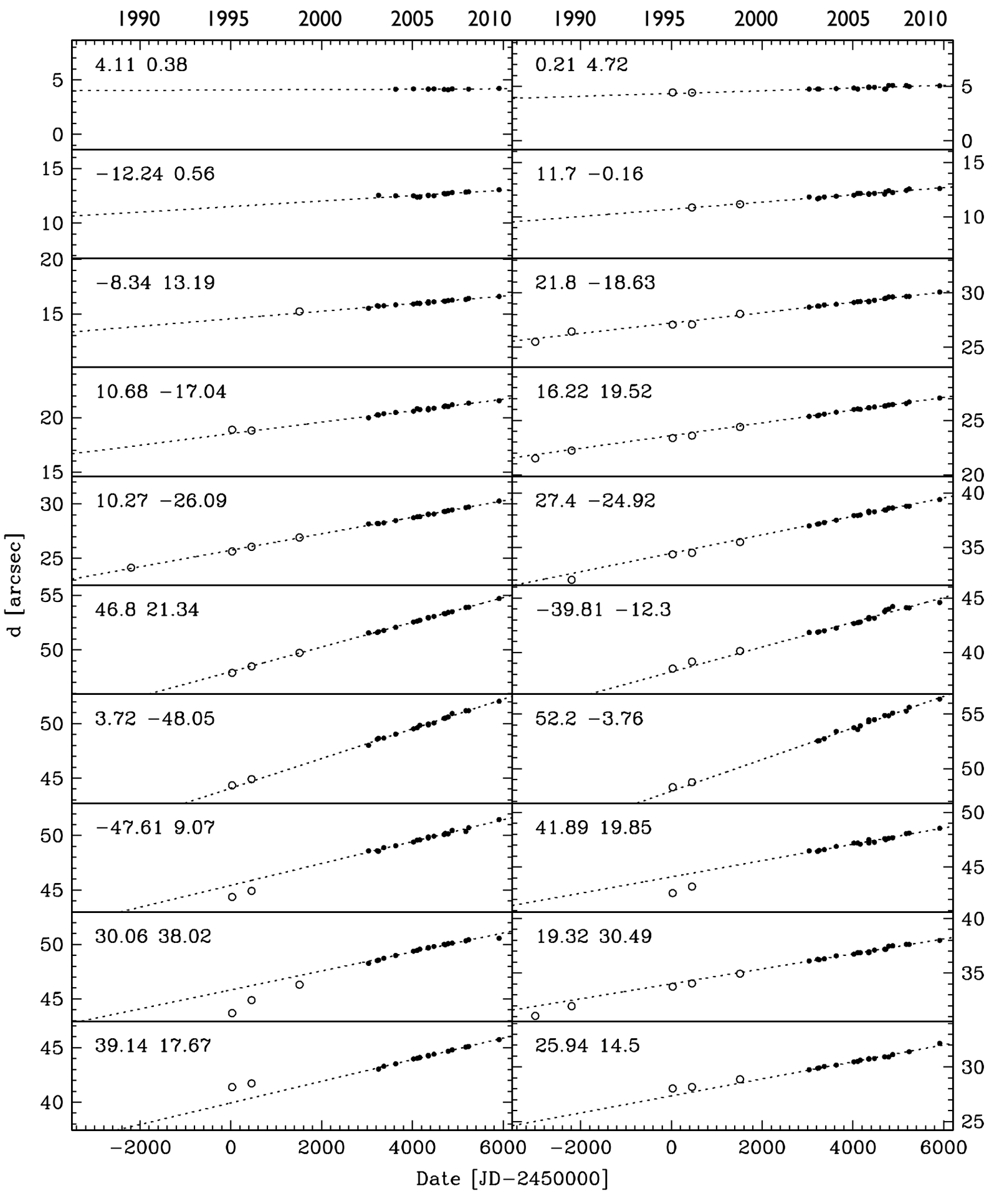
282 knots
0.007 to 0.53 “/yr

Errors:
0.010 ± 0.006 “/yr

$$v_{\rm sky}\ [{\rm km\ s^{-1}}] = 4.74 \cdot \mu\ [''\ {\rm yr^{-1}}] \cdot D\ [{\rm pc}]$$

13 to 1005 km/s

# Proper motions



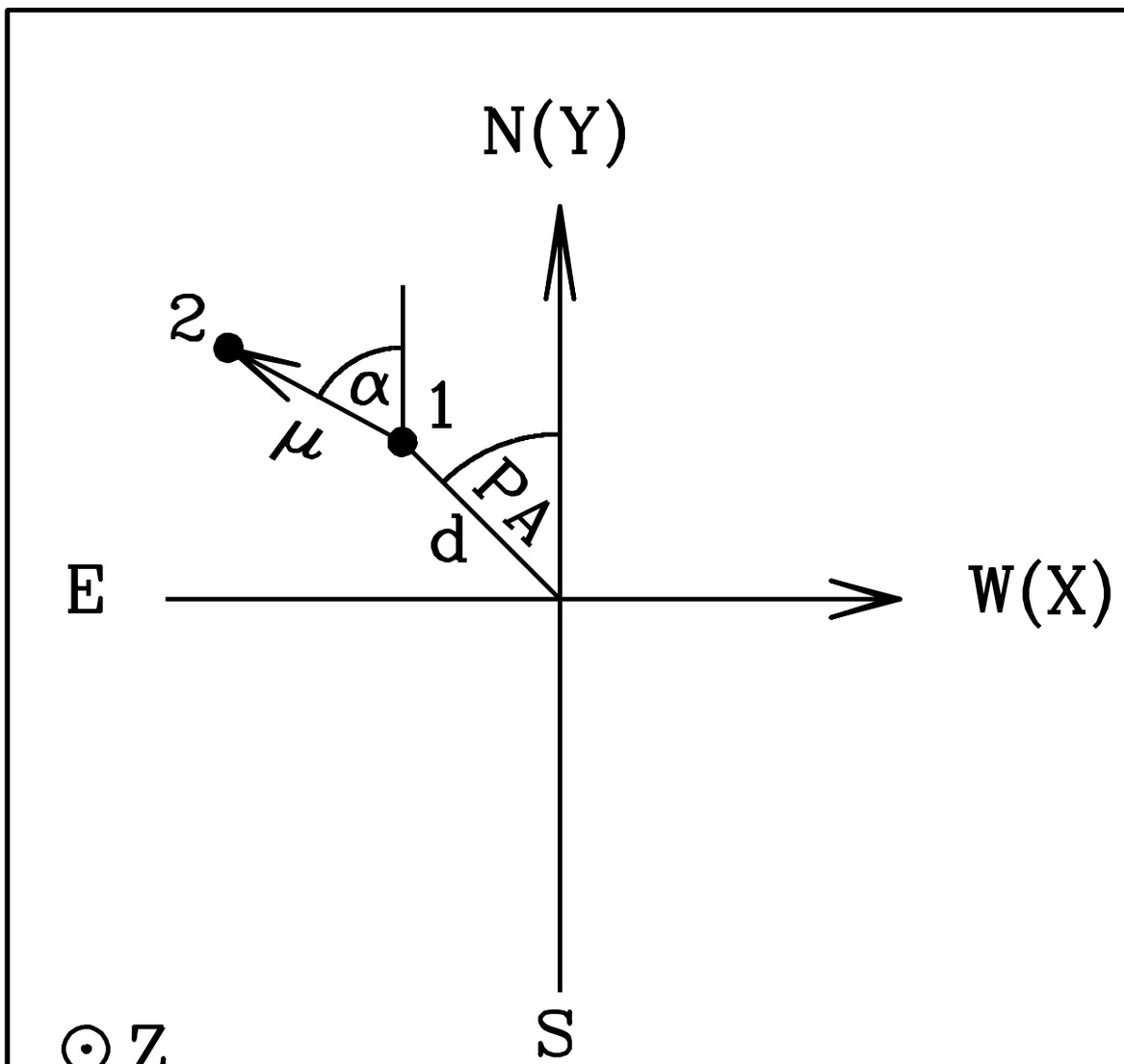

282 knots
0.007 to 0.53 “/yr

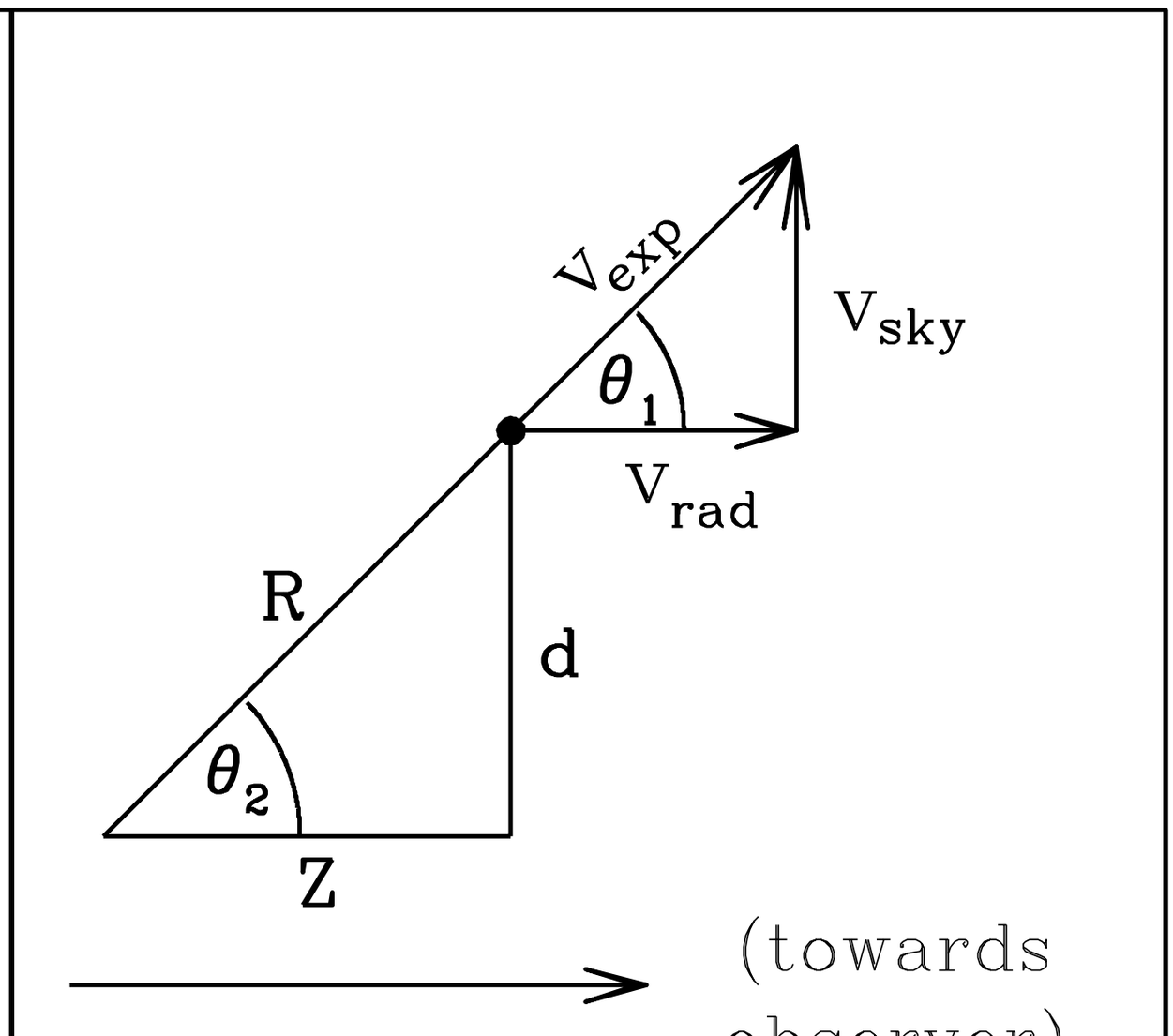
Errors:
0.010 ± 0.006 “/yr

$$v_{\rm sky}\ [{\rm km\ s^{-1}}] = 4.74 \cdot \mu\ [''\ {\rm yr^{-1}}] \cdot D\ [{\rm pc}]$$

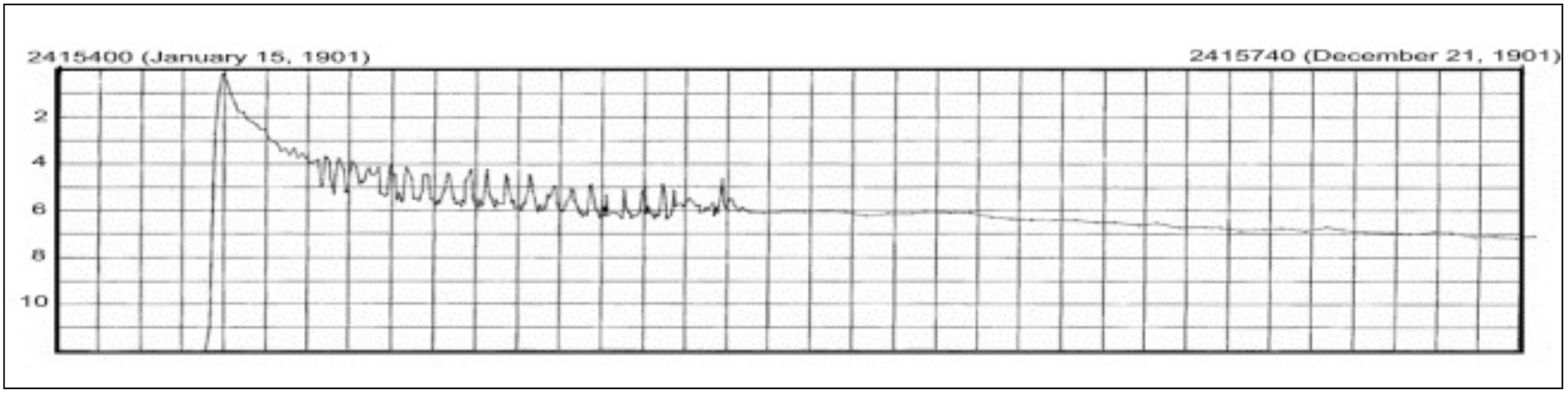
13 to 1005 km/s

No systematic acc/dec

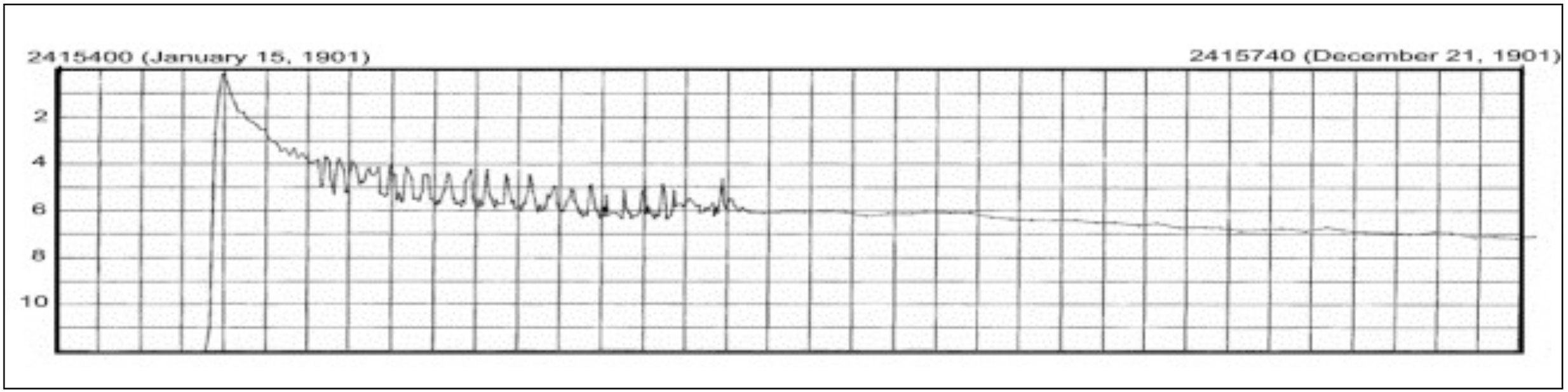

N(Y)
2
α
1
μ
PA
d
E
W(X)
⊙Z
S


V exp
V sky
θ 1
V rad
R
d
θ 2
Z
(towards
observer)

# Nova Persei 1901 (GK Per)

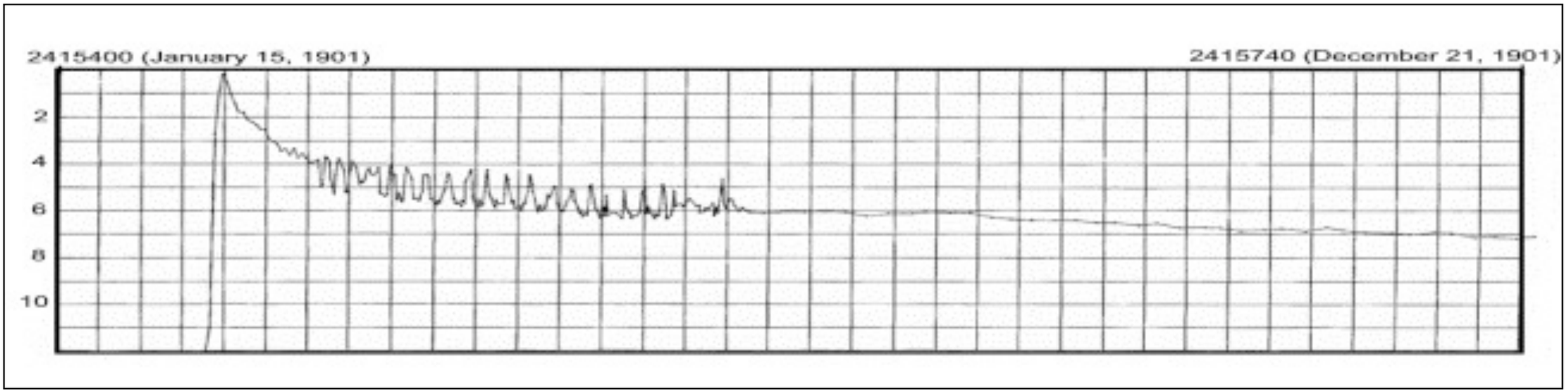


# Nova Persei 1901 (GK Per)



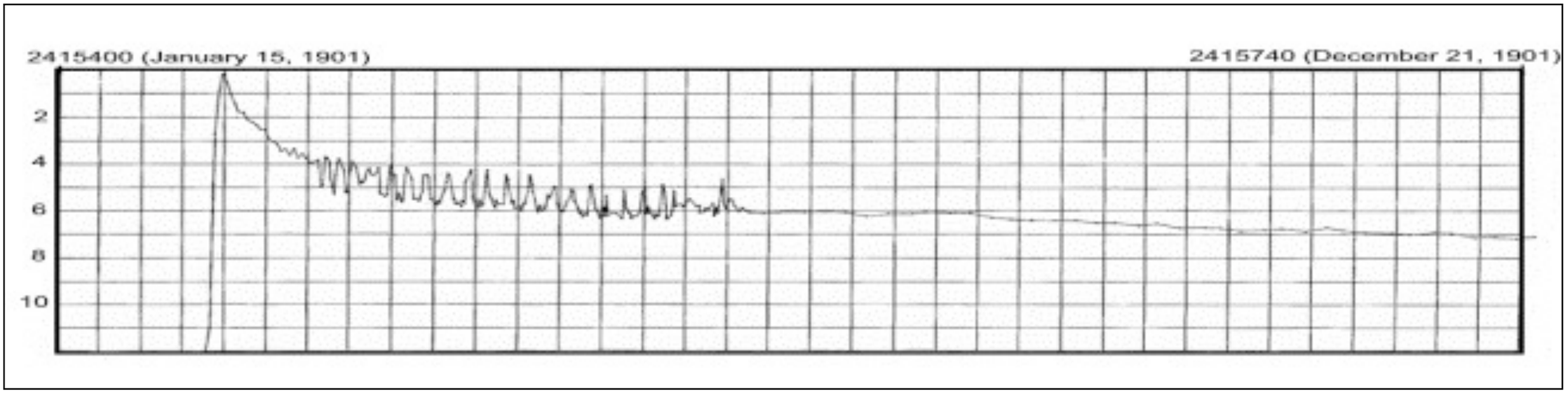

- 4 days 13-0.2 mag

# Nova Persei 1901 (GK Per)



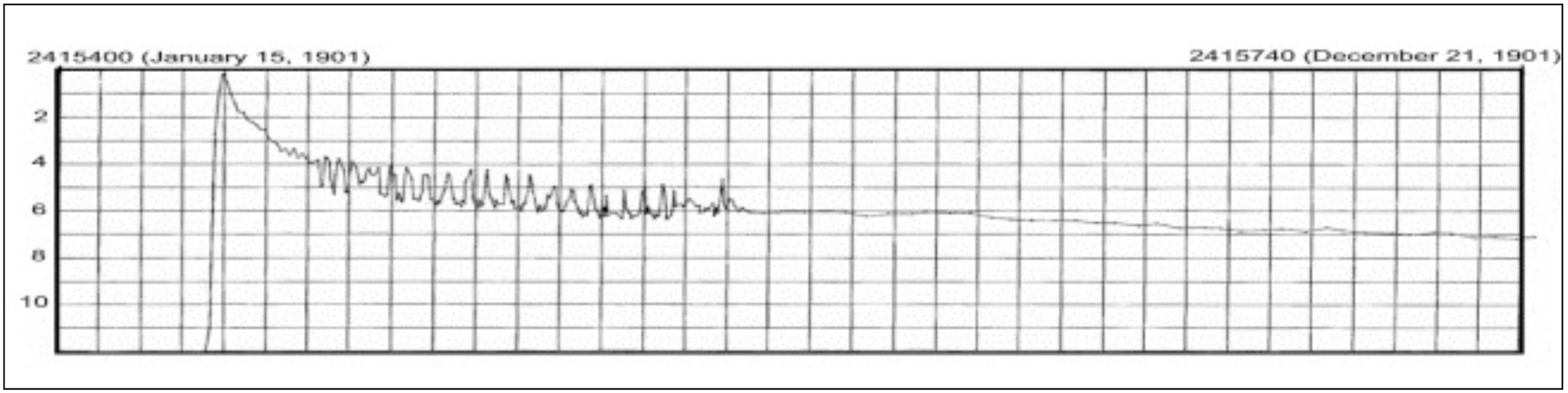

- 4 days 13-0.2 mag
- 2 weeks later 0.2-4 mag

# Nova Persei 1901 (GK Per)



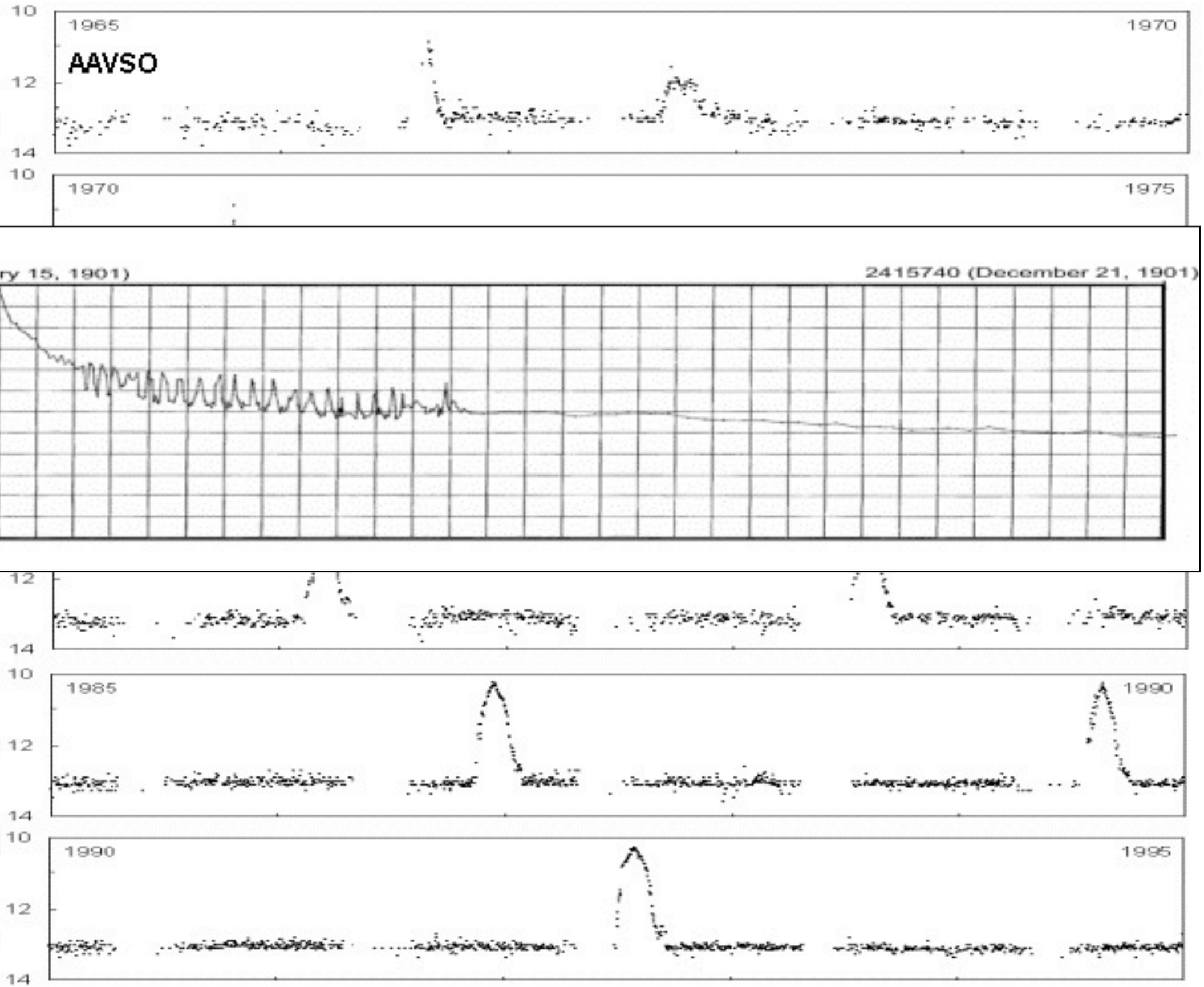

- 4 days 13-0.2 mag
- 2 weeks later 0.2-4 mag
- Oscillations (period 4d, amplitude 1.5 mag, duration many months)

# Nova Persei 1901 (GK Per)




- 4 days 13-0.2 mag
- 2 weeks later 0.2-4 mag
- Oscillations (period 4d, amplitude 1.5 mag, duration many months)
- 11 years later 13 mag

# No







- 4 da
- 2 we
- Oscil
- 11 ye

*Credit: AAVSO*

# Superluminal motions

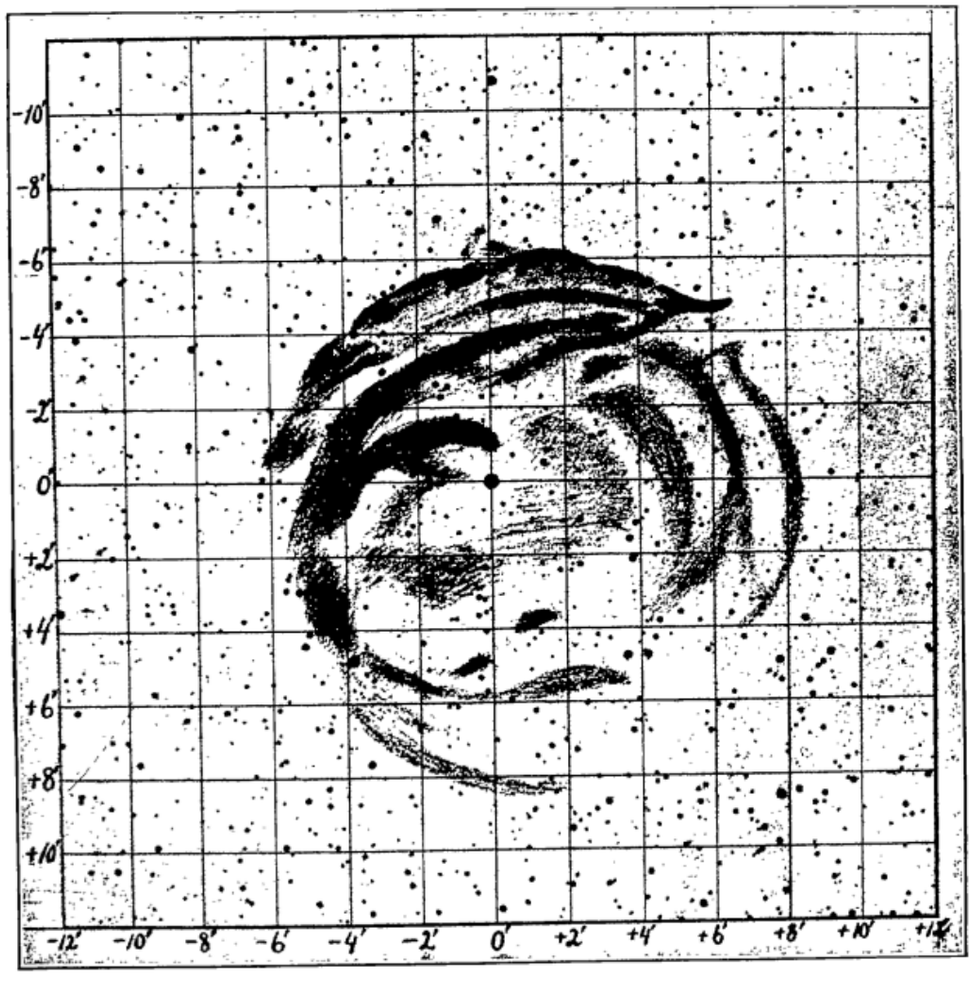



FIG. 2.—DIAGRAM FROM ORIGINAL NEGATIVE.

NEBULOSITY AROUND *NOVA PERSEI*, Sept. 20, 1901.

By G. W. RITCHEY, Yerkes Observatory.

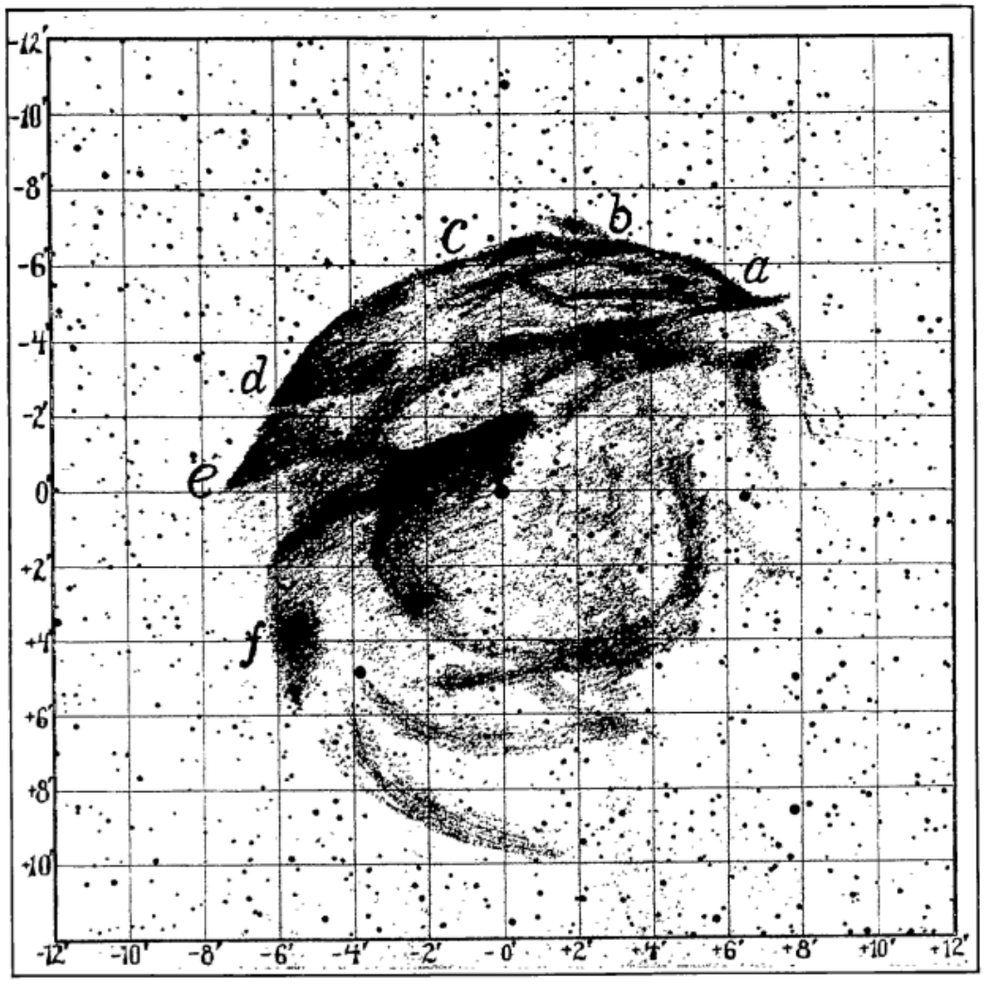


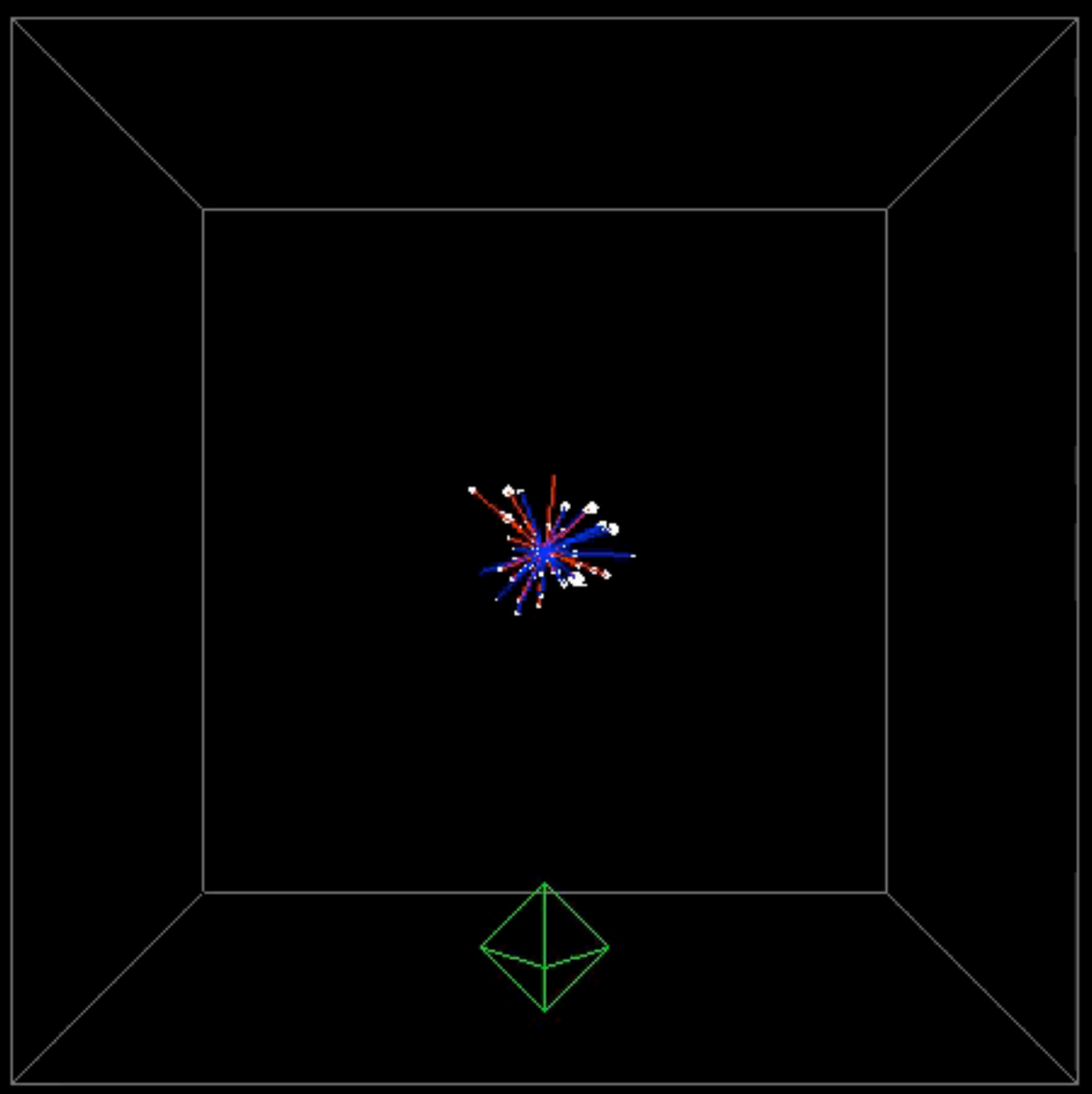

FIG. 2.—DIAGRAM FROM ORIGINAL NEGATIVE.

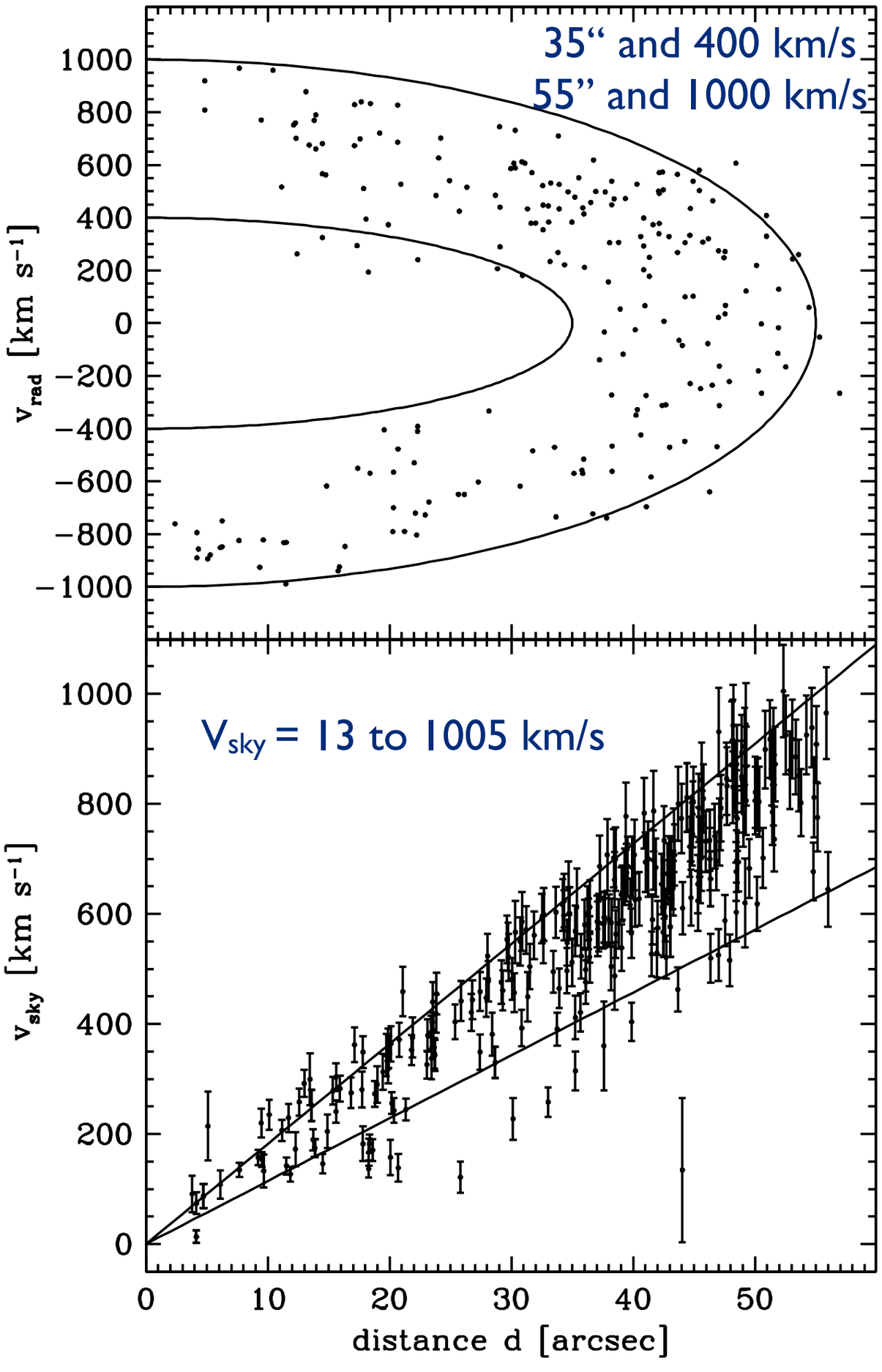
NEBULOSITY AROUND *NOVA PERSEI*, Nov. 13, 1901.

By G. W. RITCHEY, Yerkes Observatory.

*Credit: Ritchey, 1902, ApJ, 15, 129*

1920







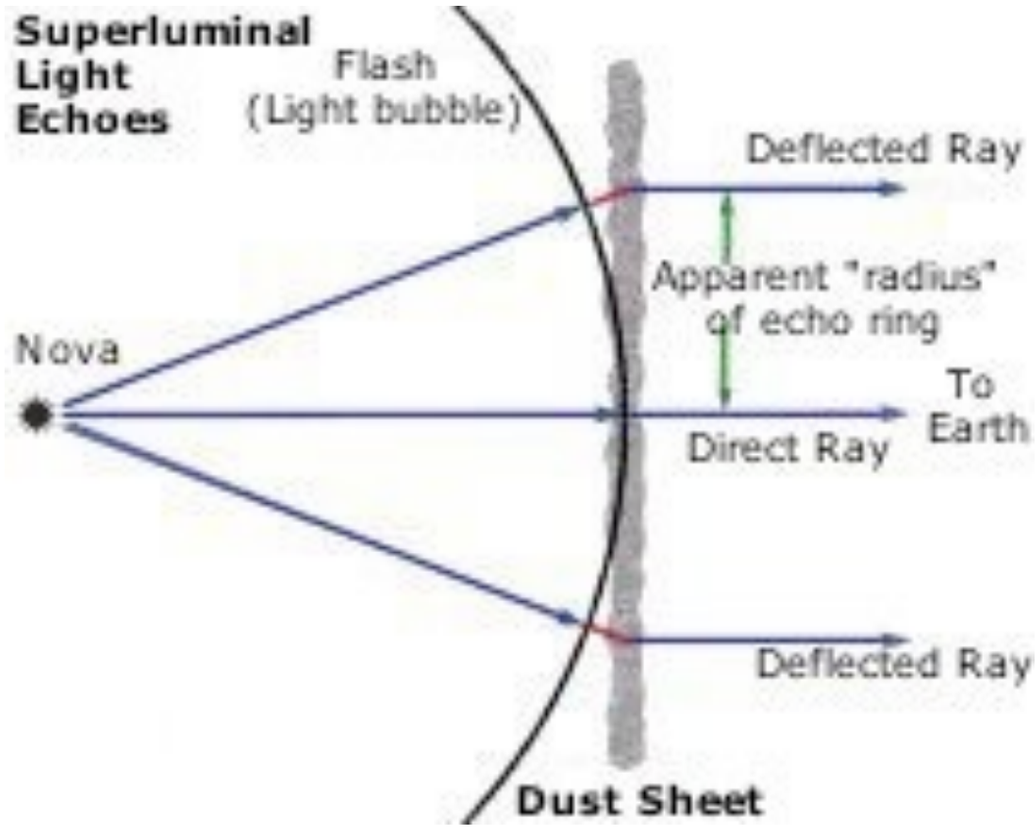


# Quasi spherical shell?

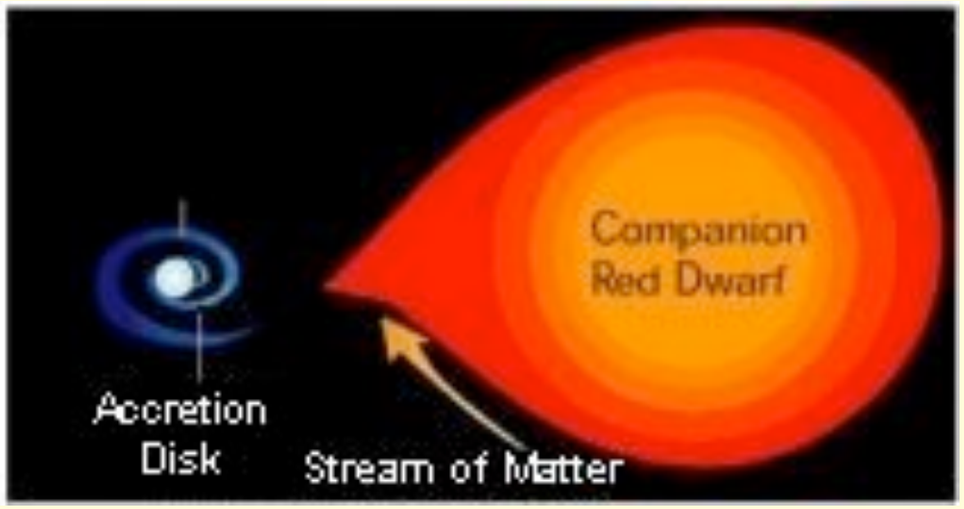
$$v_{\rm sky}\ [{\rm km\ s^{-1}}] = 4.74 \cdot \mu\ [''\ {\rm yr^{-1}}] \cdot D\ [{\rm pc}]$$

$t_{nova}$=102.9 yr

$t_{nova}$=140 yr

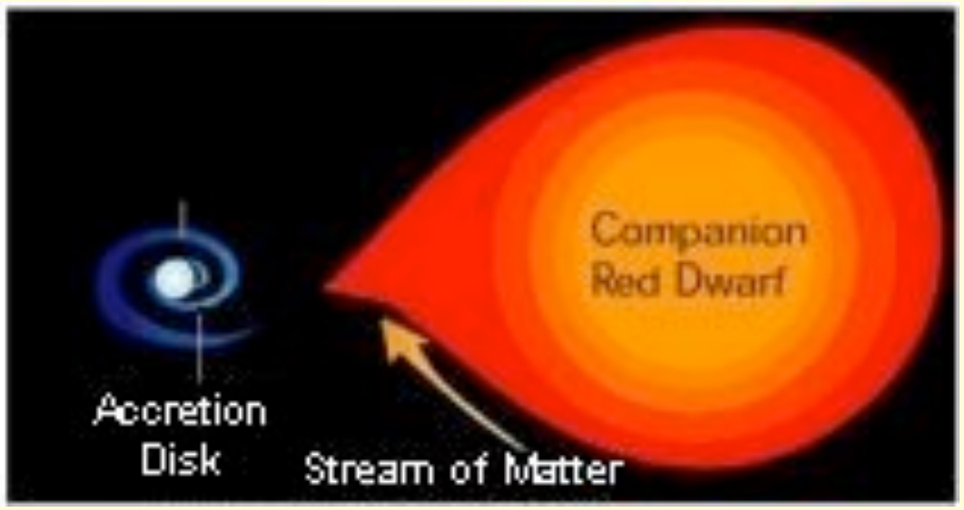

Superluminal
Light
Echoes
Flash
(Light bubble)
Deflected Ray
Apparent "radius"
of echo ring
Nova
To
Earth
Direct Ray
Deflected Ray
Dust Sheet

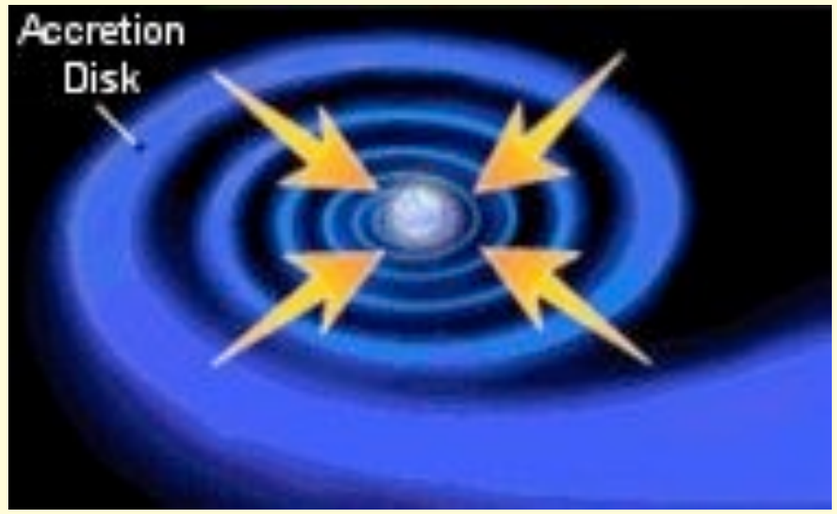
# Klassikaline noova




*Allikas: NASA/STSsI*

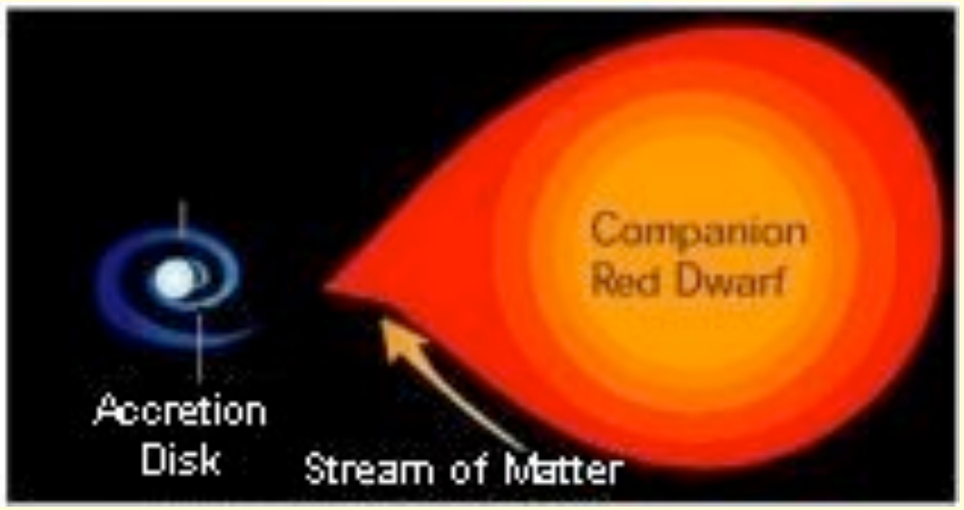
# Klassikaline noova

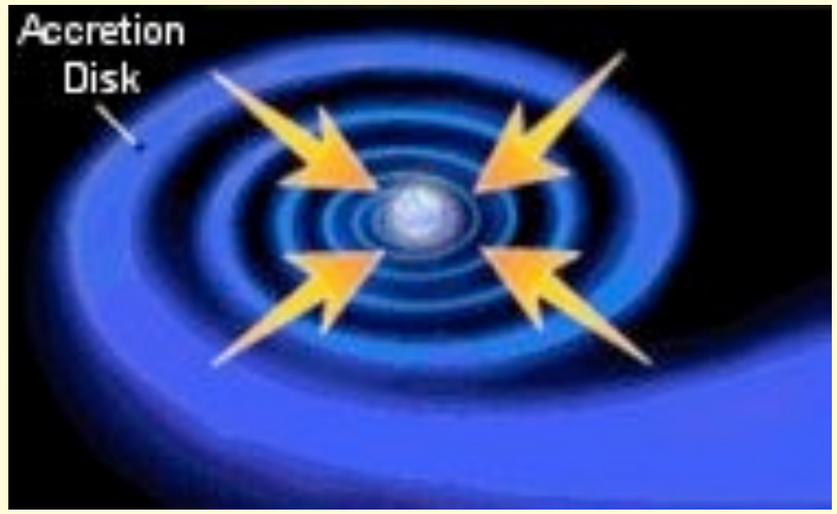


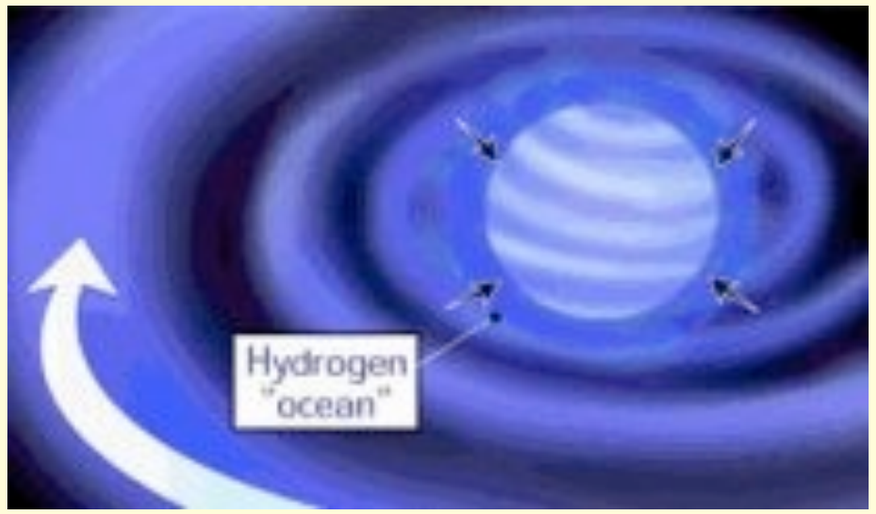




*Allikas: NASA/STScI*

# Klassikaline noova




*Allikas: NASA/STScI*