

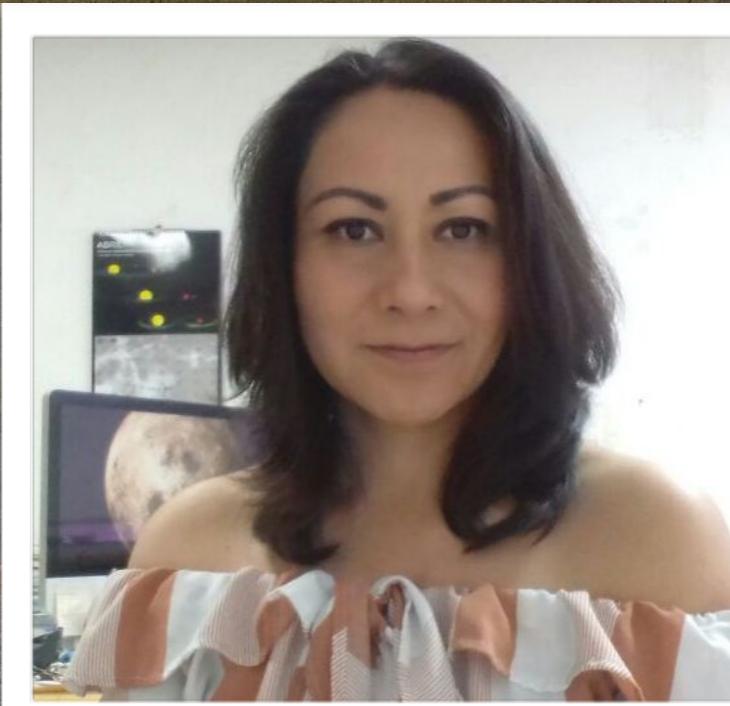
The five axes of the Turtle: symmetry and asymmetry in NGC 6210

William Henney, IRyA-UNAM
2020-06-23

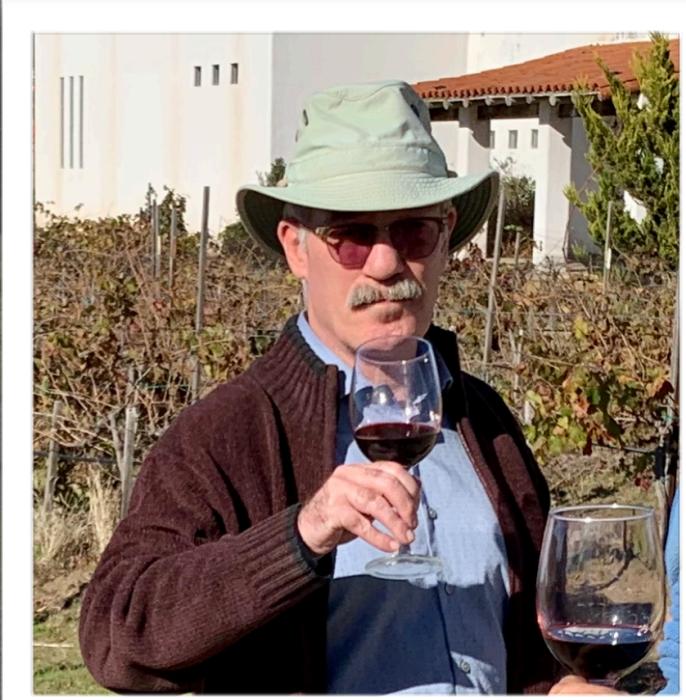
Collaboration with IA-UNAM-Ensenada



Beto López



Ma. Teresa García Díaz



Michael Richer

N e b u l æ d é t e c t a e .

Lustratio nostra in complures nos duxit nebulas, plerumque in quaestore sunt conspicias, itaque non ex debilissimis, tum in nonnullas cum stellis examinandis una in campo oblatas. Longe major ipsarum pars in catalogis admirabilibus Herscheli occurrit. Recens detectarum hic afferro positiones pro 1826.

	A. R.	DECL.	D E S C R I P T I O .
1	0 ^{h.} 55,4	+ 39 [°] 56'	Nebula exigua. Stellula (12) in parallelo sequitur 12'' temporis.
2	1 25,3	+ 72 0	Nebula difformis, in qua stellulae tres videntur.
3	9 49,2	+ 69 33	Nebula rotunda tenuis diametri 1'.
4	15 4,4	+ 19 [°] 5	Nebula rotunda.
5	16 37,5	+ 24 7	Nebula planetaris lucida diametri 6'', in quaestore est stella (7).
6	18 3,8	+ 6 50	Nebula planetaris maxime memorabilis, in quaestore stella (8), in magno tubo primum die 18 Jul. 1825 ex difformitate pro duplii habita, non distincte disjuncta ob aeris conditionem, ex (8.9) et (8.9) cl. I, sed dubiosa. In mensuris vero apparuit discus formae planetaris diametri 5'' egregie splendidus et uniformis die 16 Sept. 1825. Stellula altera (8) sequitur 14'',4 temporis, et est 52'',7 borealior.
7	18 24,0	+ 64 53	Nebula circumfusa circa duplēm cl. III ex (8.9) et (11). Nt. 2332.
8	20 54,5	- 12 0	Stella (8) in quaestore. In tubo magno nebula planetaris, cuius diameter altera 25'', altera 17'' inventa. Forma est regulariter elliptica et splendor uniformis.
9	21 21,6	+ 11 27	Nebula lucida, partim in stellas dissoluta.

Nebulae 5, 6 et 8, praecipue vero 6, mihi inter objecta maxime curiosa in coelo numerandas esse videntur, quae in quaestore a stellis (7) et (8) nullo modo differre viderentur, at disci planetares uniformes in magno tubo apparerent. Objecta certe sunt in coelo rarissima, quippe in quae, tot examinatis stellis, ter tantum incidi.

Discovery of
NGC 6210

Friedrich Georg Wilhelm
von Struve (1827)

*Catalogus novus stellarum
duplicium et multipli-
cium: maxima ex parte in
specula Universitatis
Caesarea Dorpatensis per
magnum telescopium
achromaticum Fraunhoferi
detectarum.*

Typis J. C. Schuenmanni,
Typographi Academicci

Historical descriptions of the Turtle

“Shows a bizarre form”

– Duncan (1937)

“... resembling the popular artist’s conception of an atom”

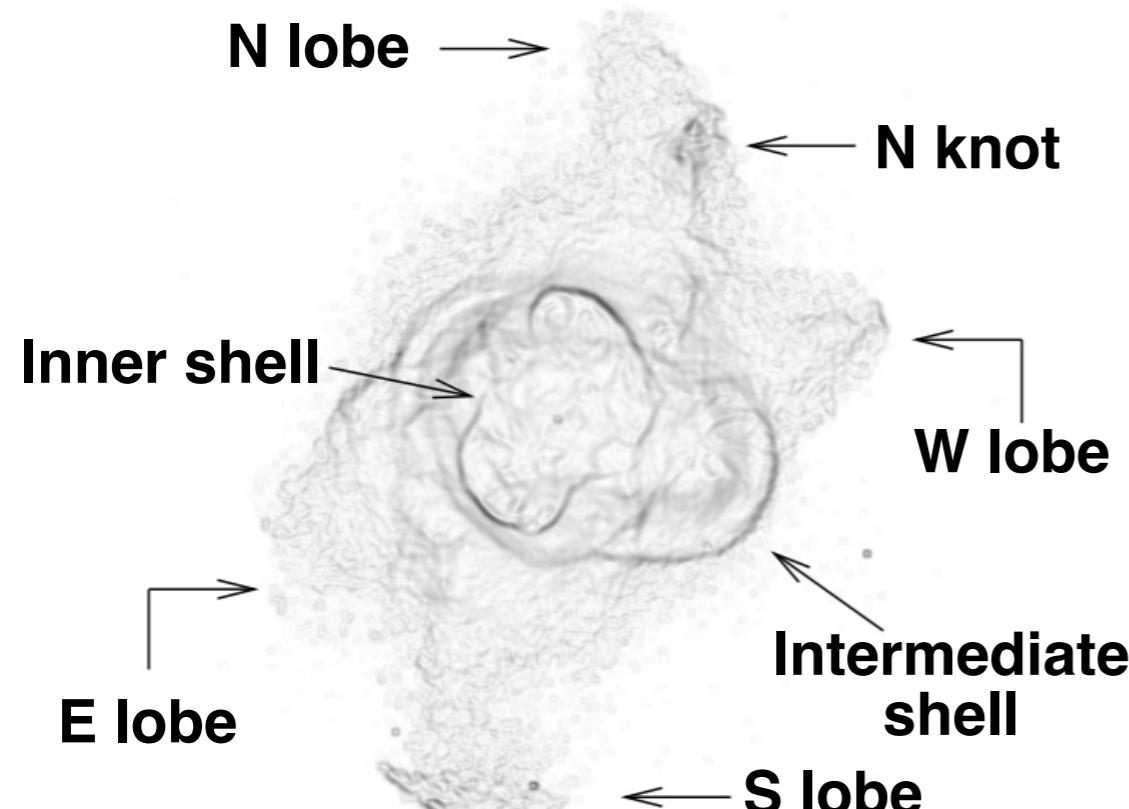
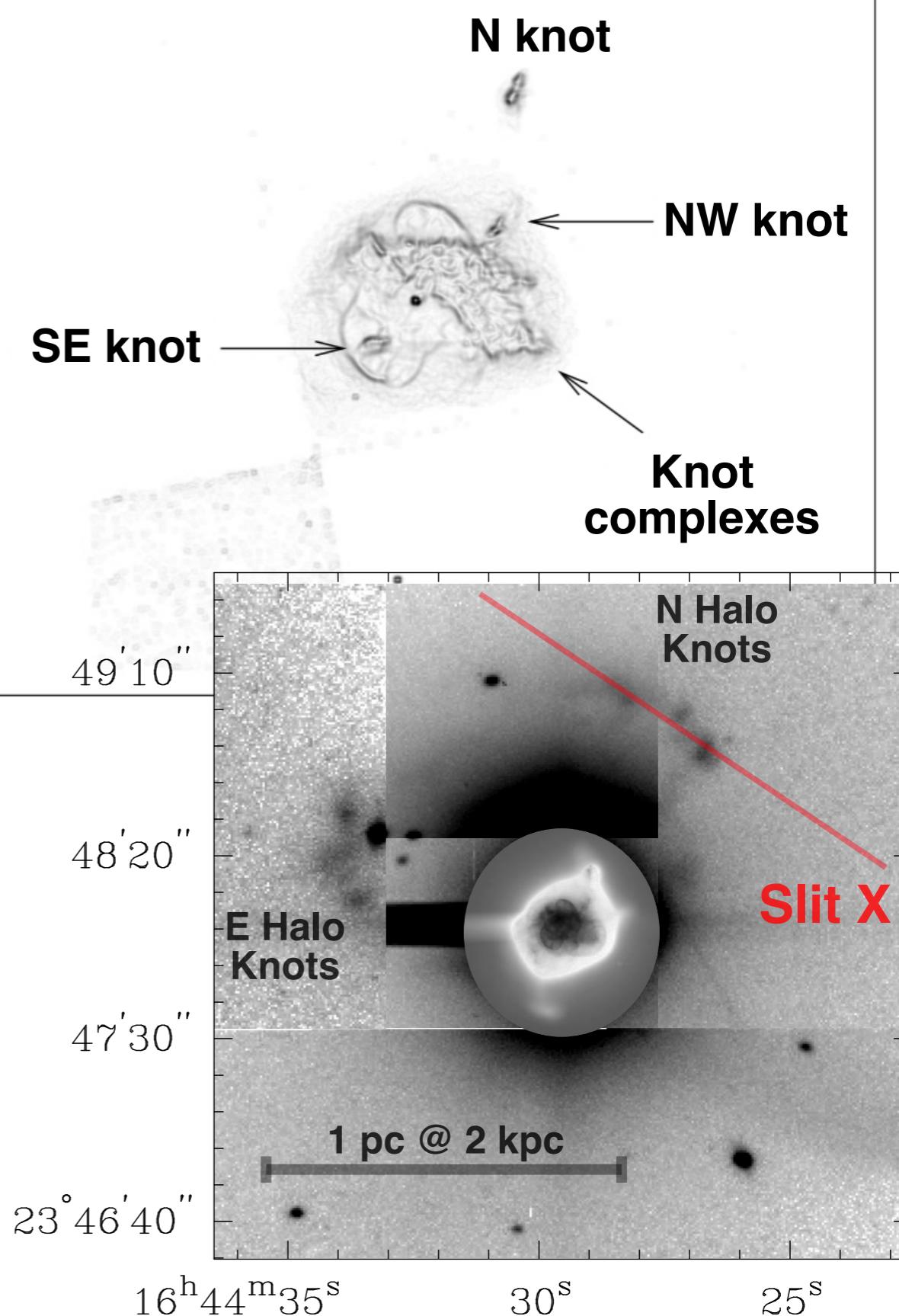
– Feibelman (1971)

“a mid-air collision of two intergalactic warships”

– O’Meara (2007)

“messy”

– Soker (2004)

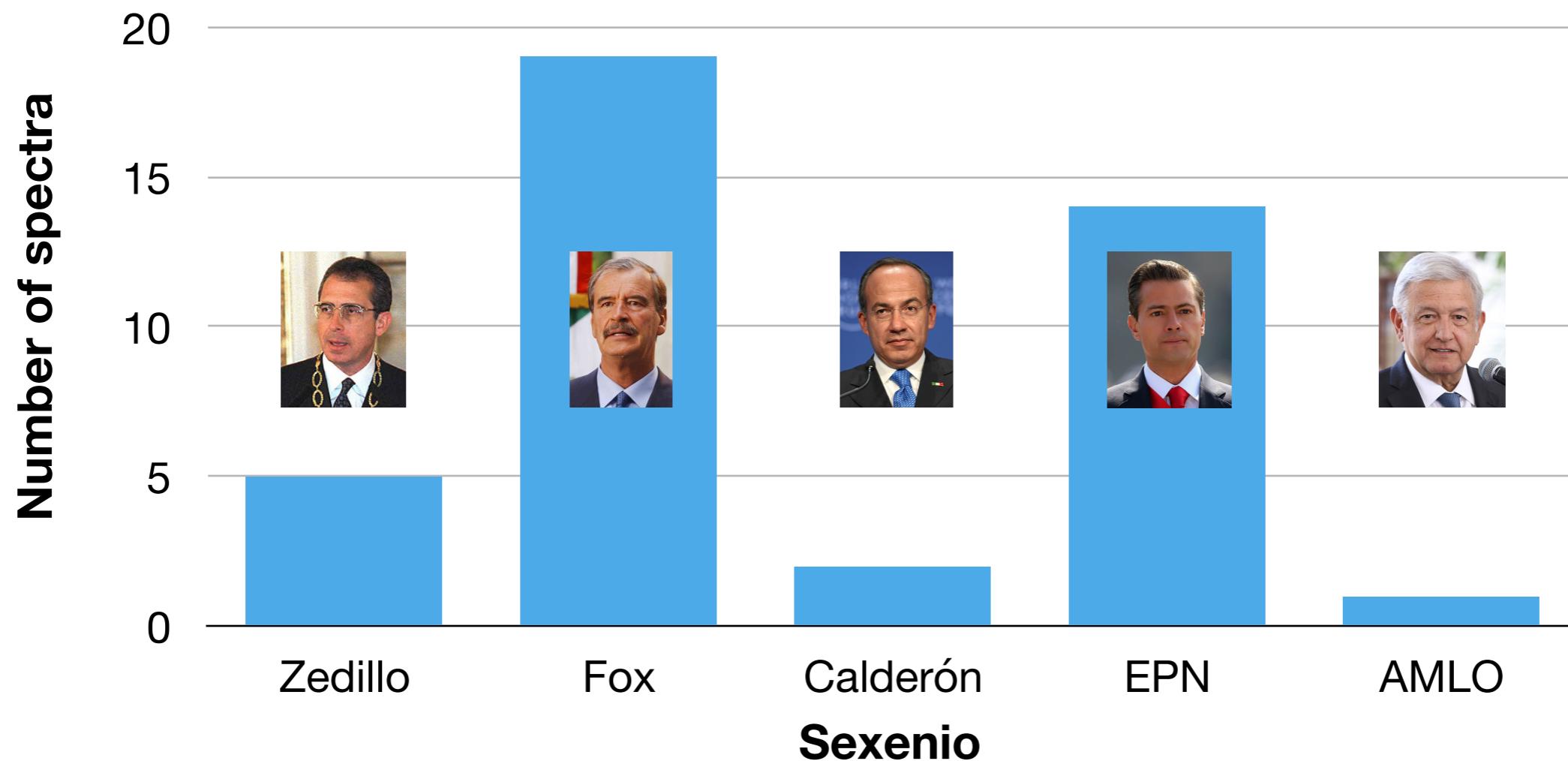
a**b**

Nebular components:

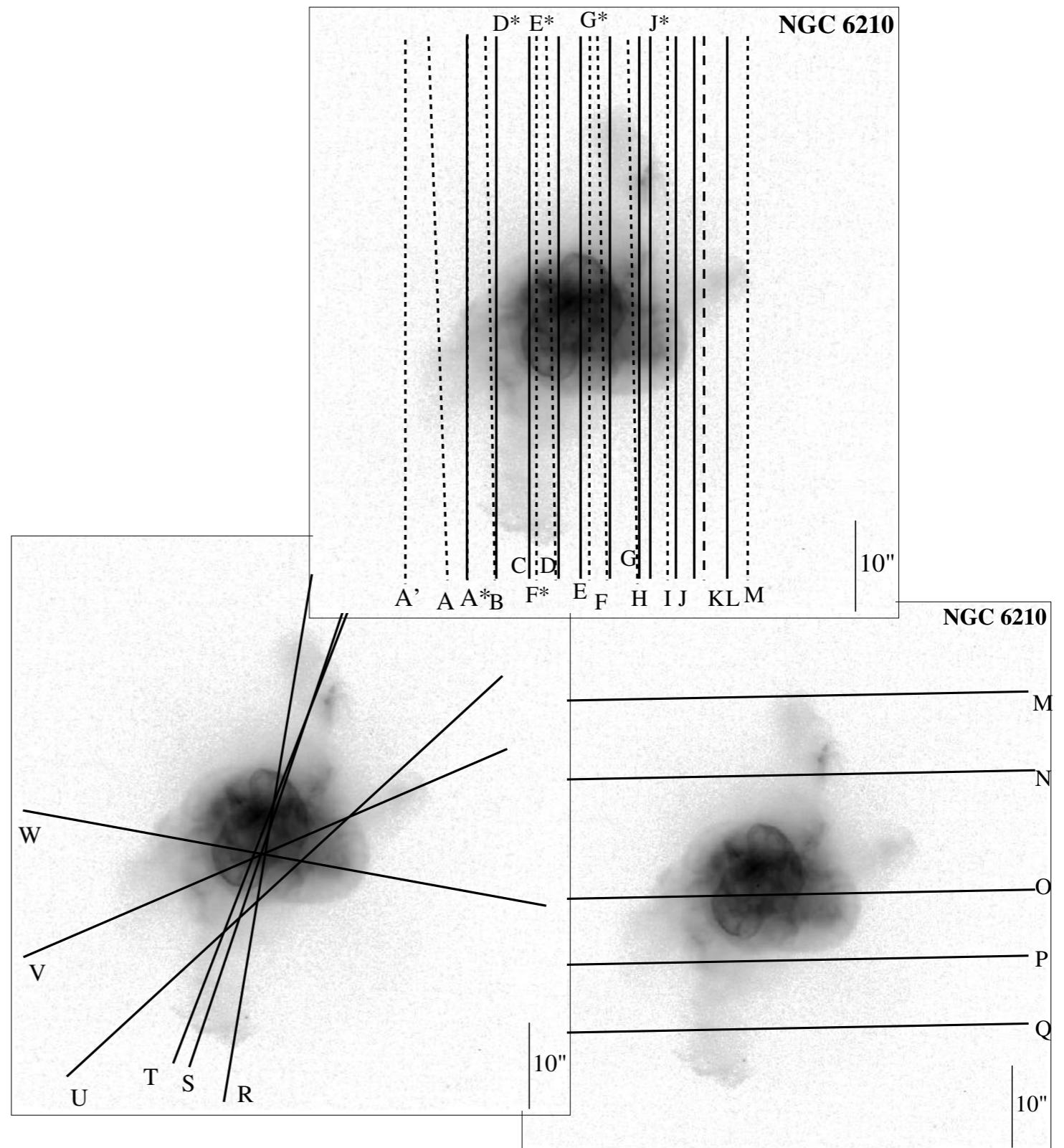
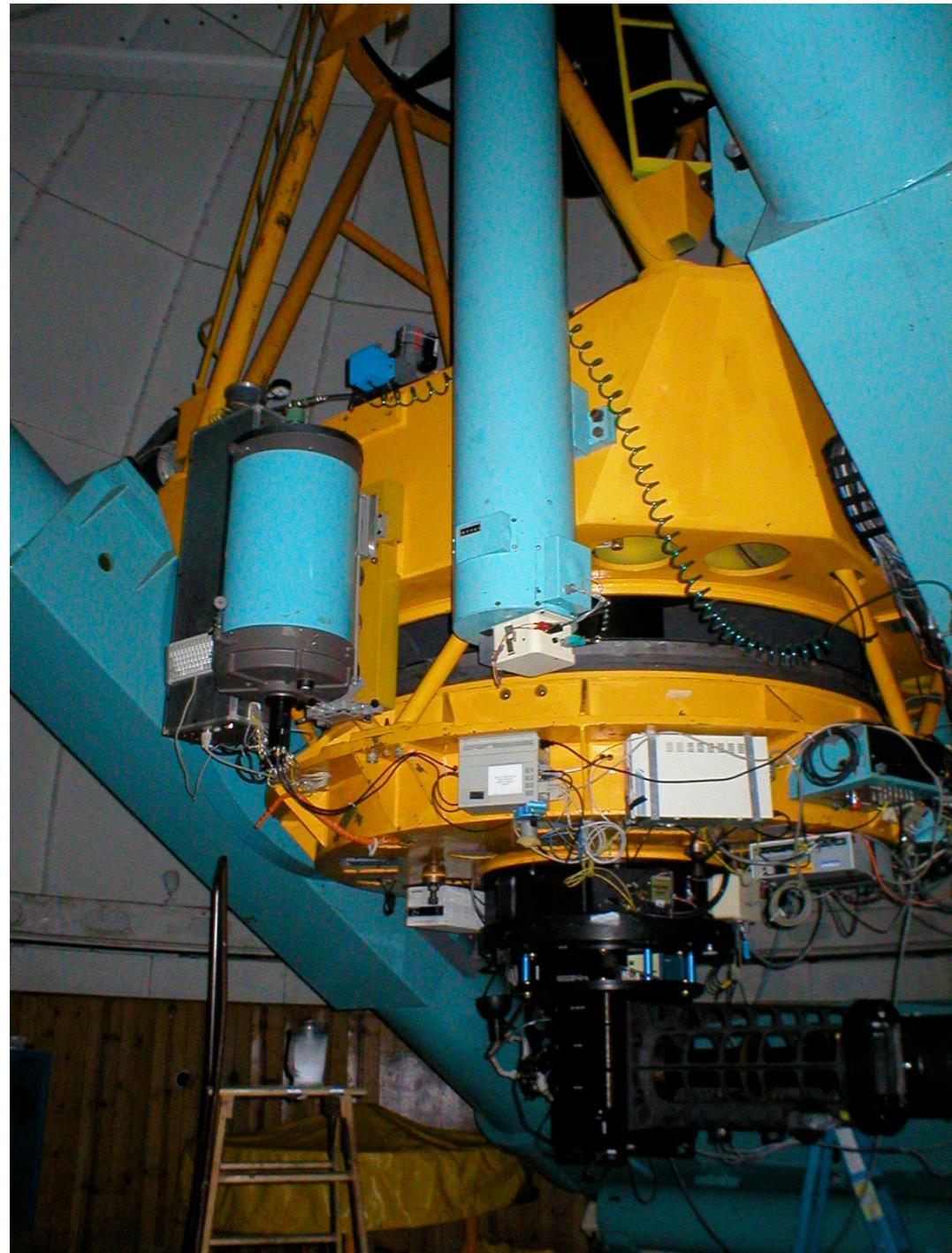
- Shells • Knots
- Lobes • Halo

Echelle long-slit observations:

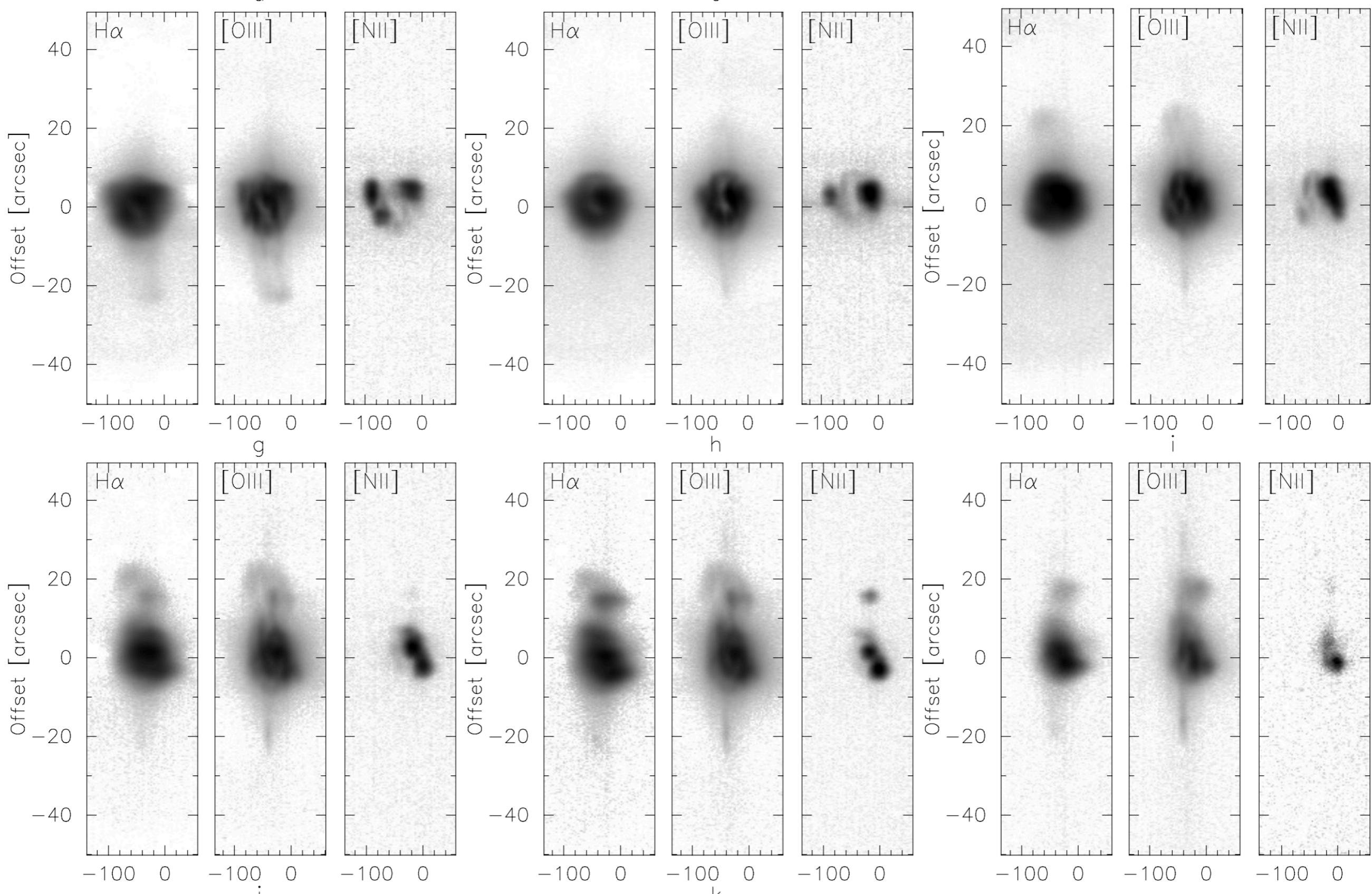
- H α λ 6563, [N II] λ 6583, [O III] λ 5007, He II λ 6560
- Data from MEZCAL spectrograph
- OAN San Pedro M \acute{a} rtir
- Observations span a **long** period: 1998–2019



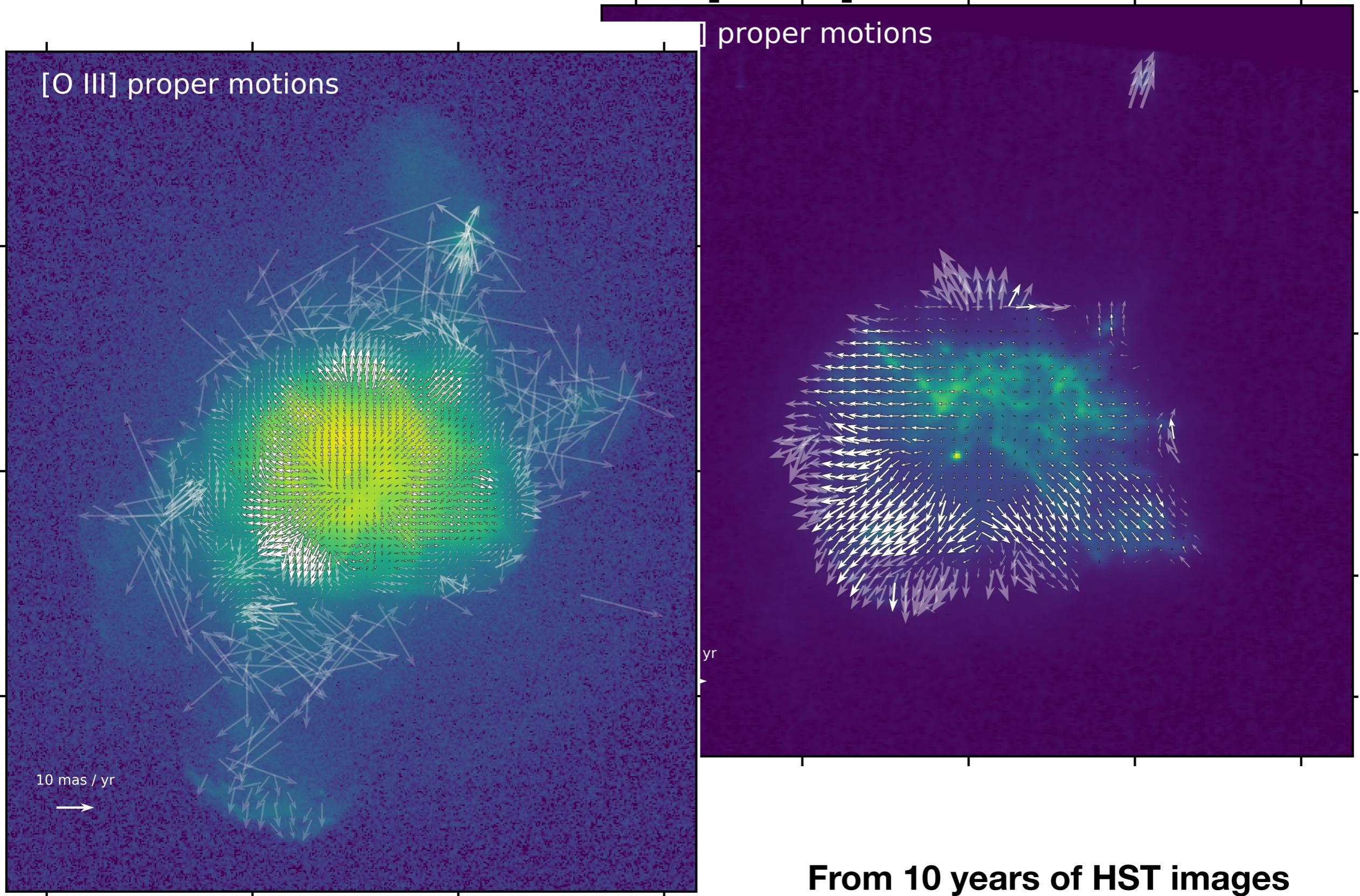
32 slit positions



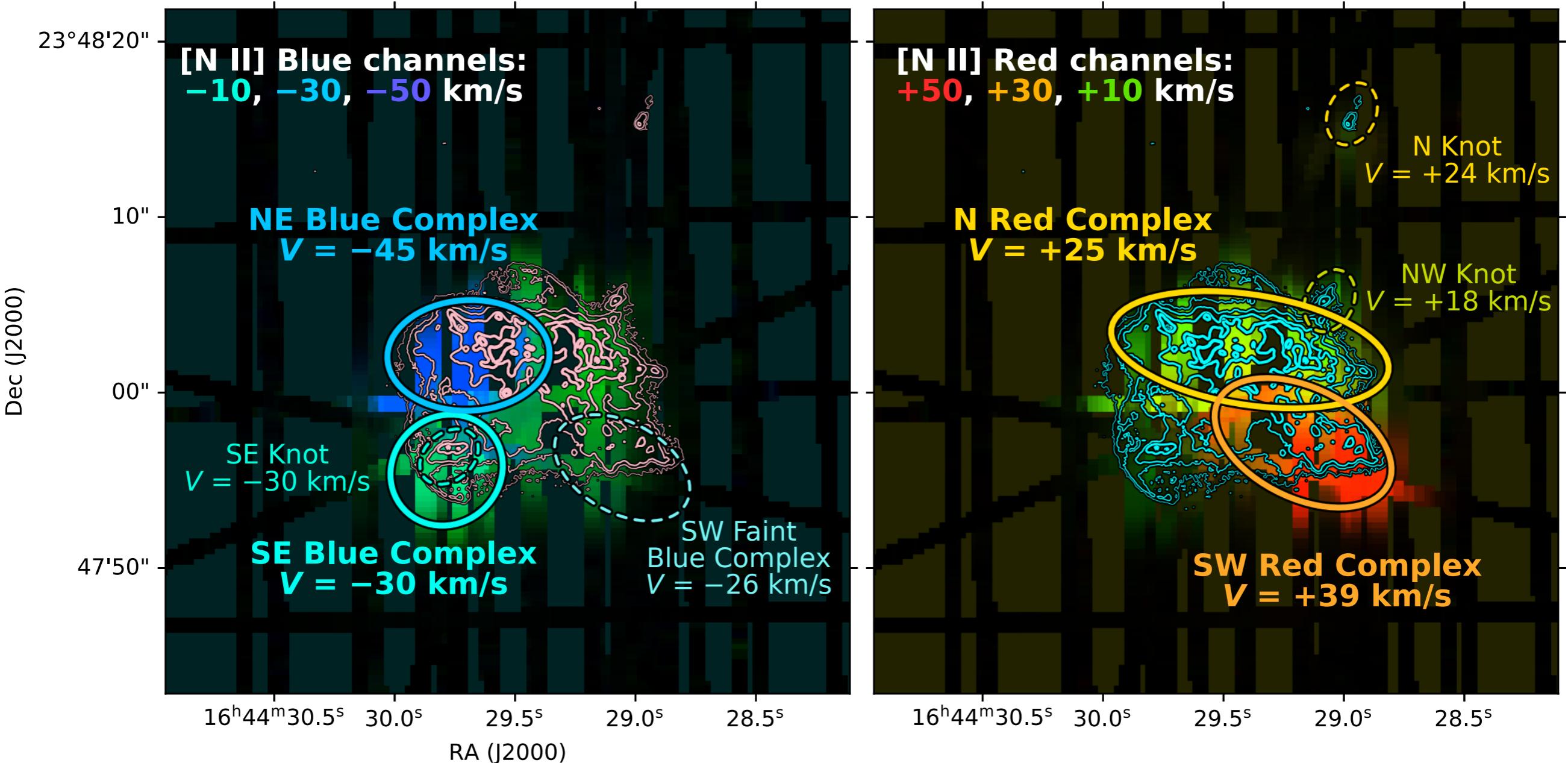
Sample line profiles



Combined with proper motions

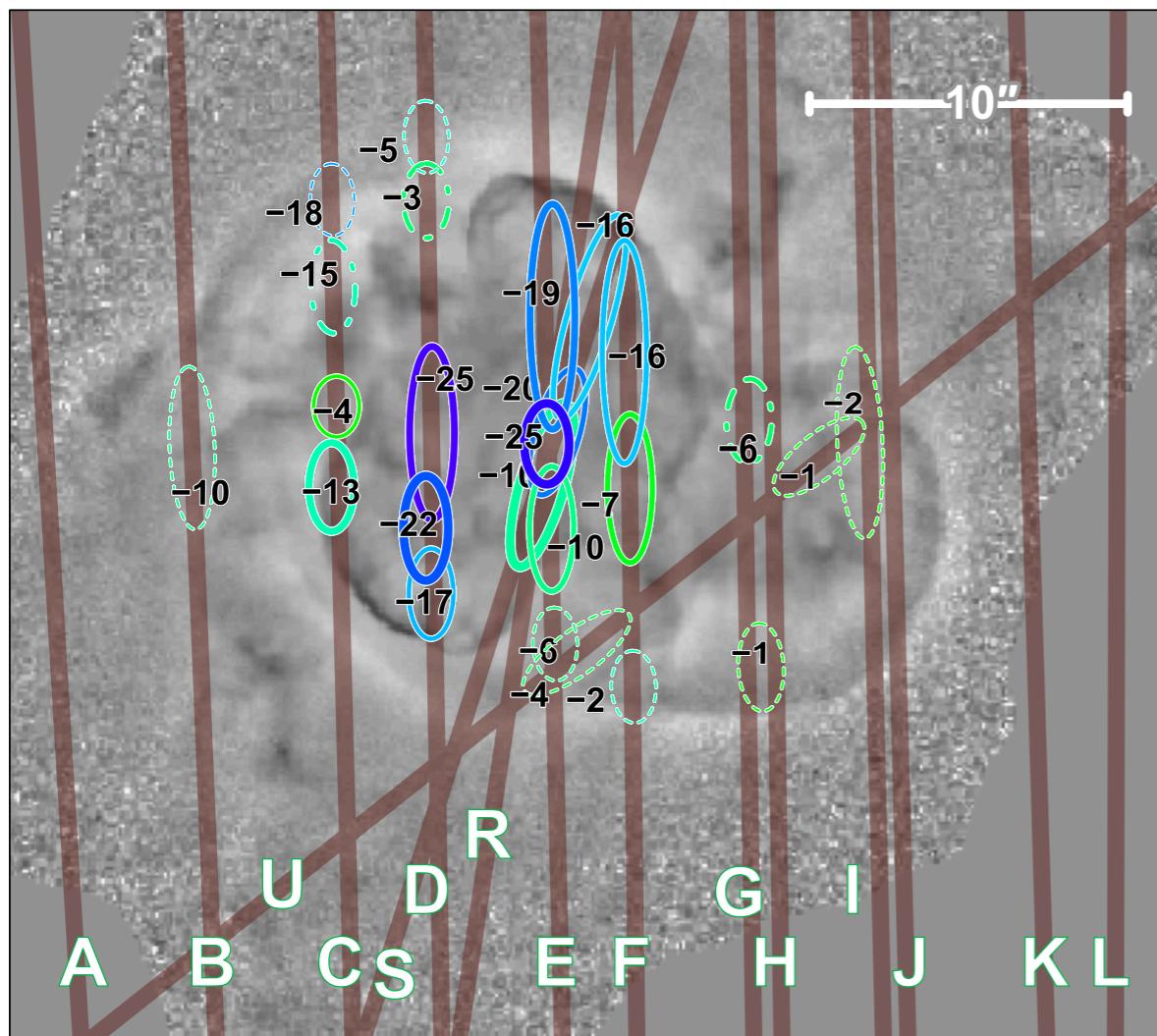


Reconstruct channel maps from slit spectra

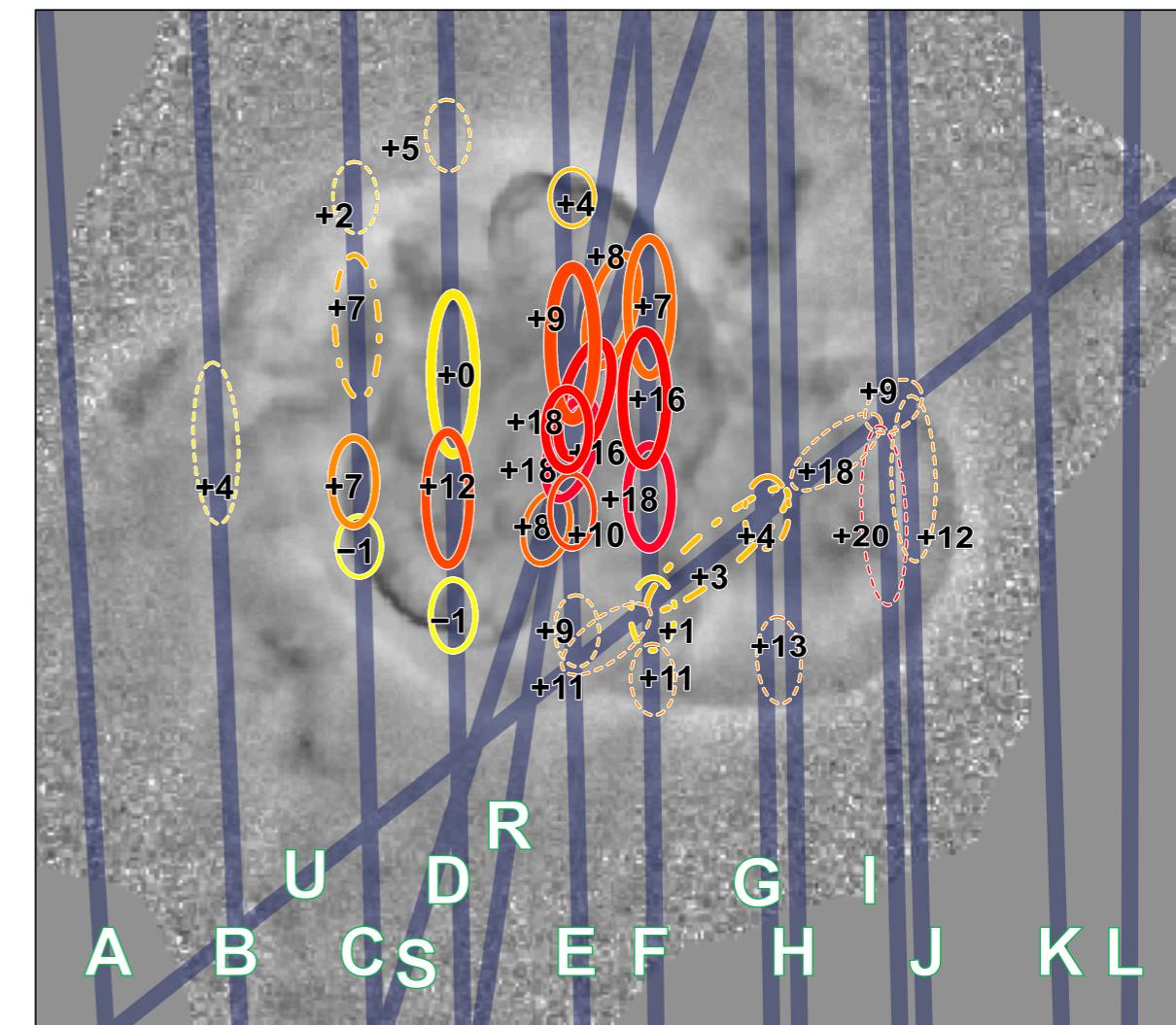


See my previous talk on Tetrablok algorithm

Better approach: simply map all spectral features in all slits



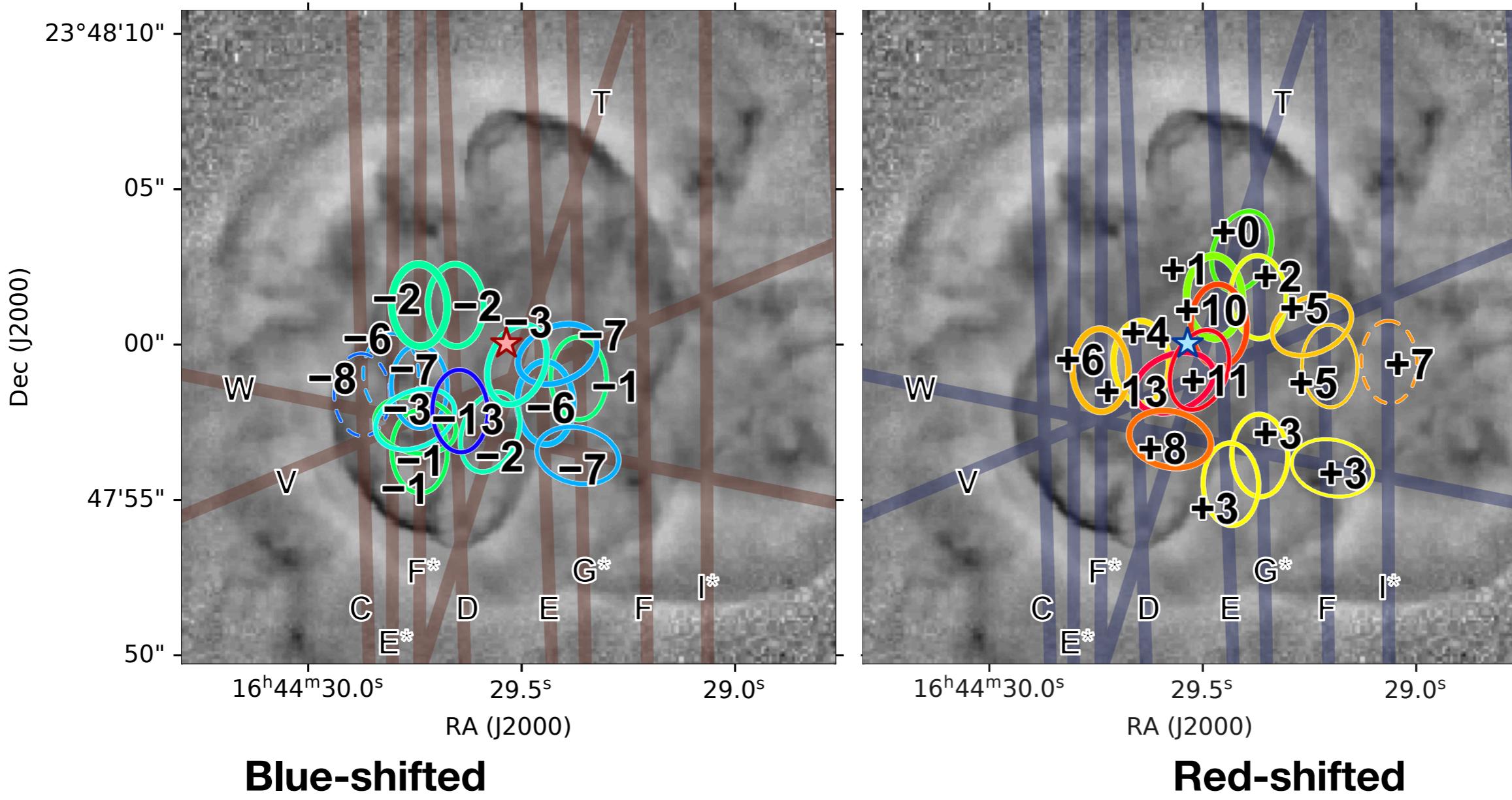
Blue-shifted



Red-shifted

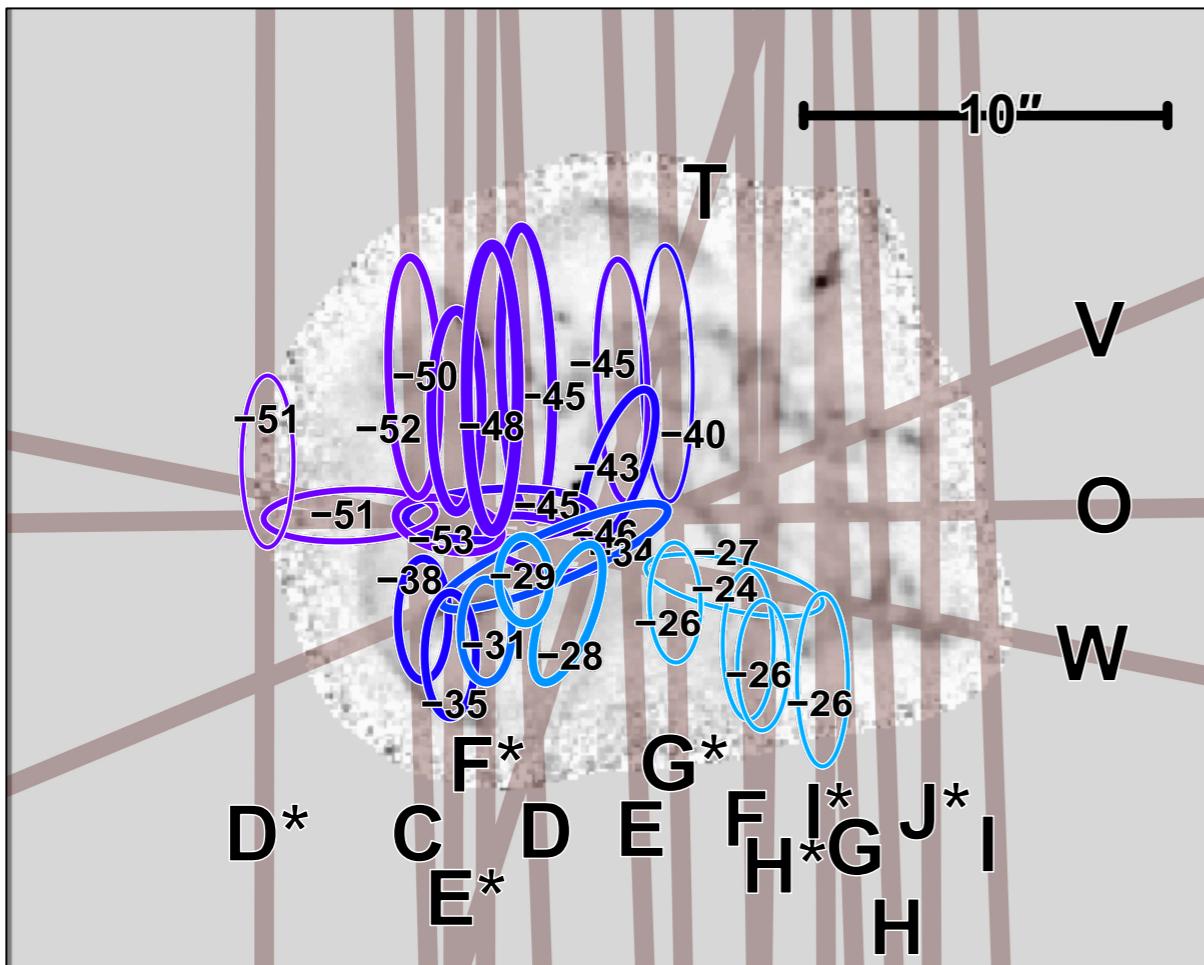
[O III] features in inner and intermediate shells

Better approach: simply map all spectral features in all slits

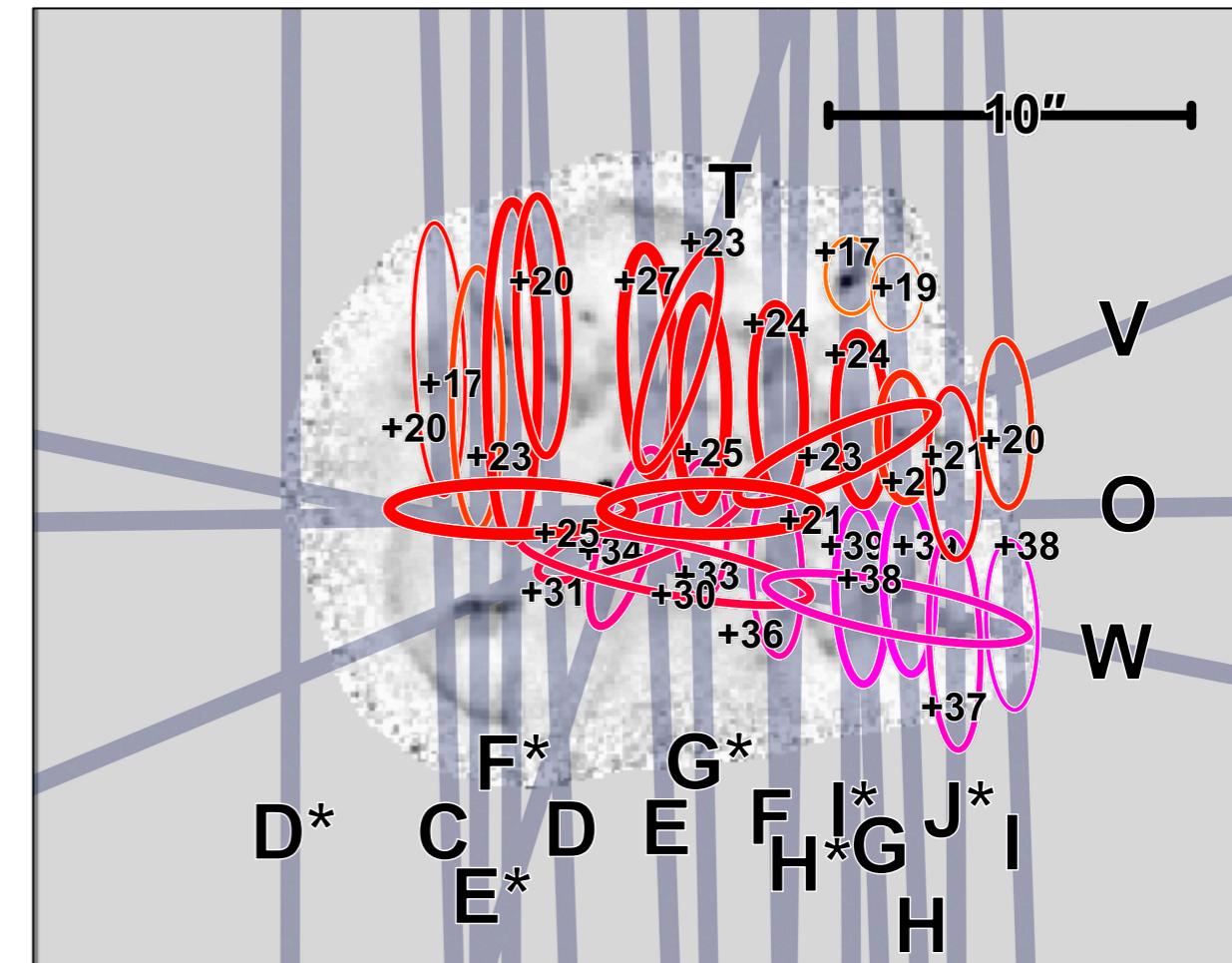


He II features in inner and intermediate shells

Better approach: simply map all spectral features in all slits



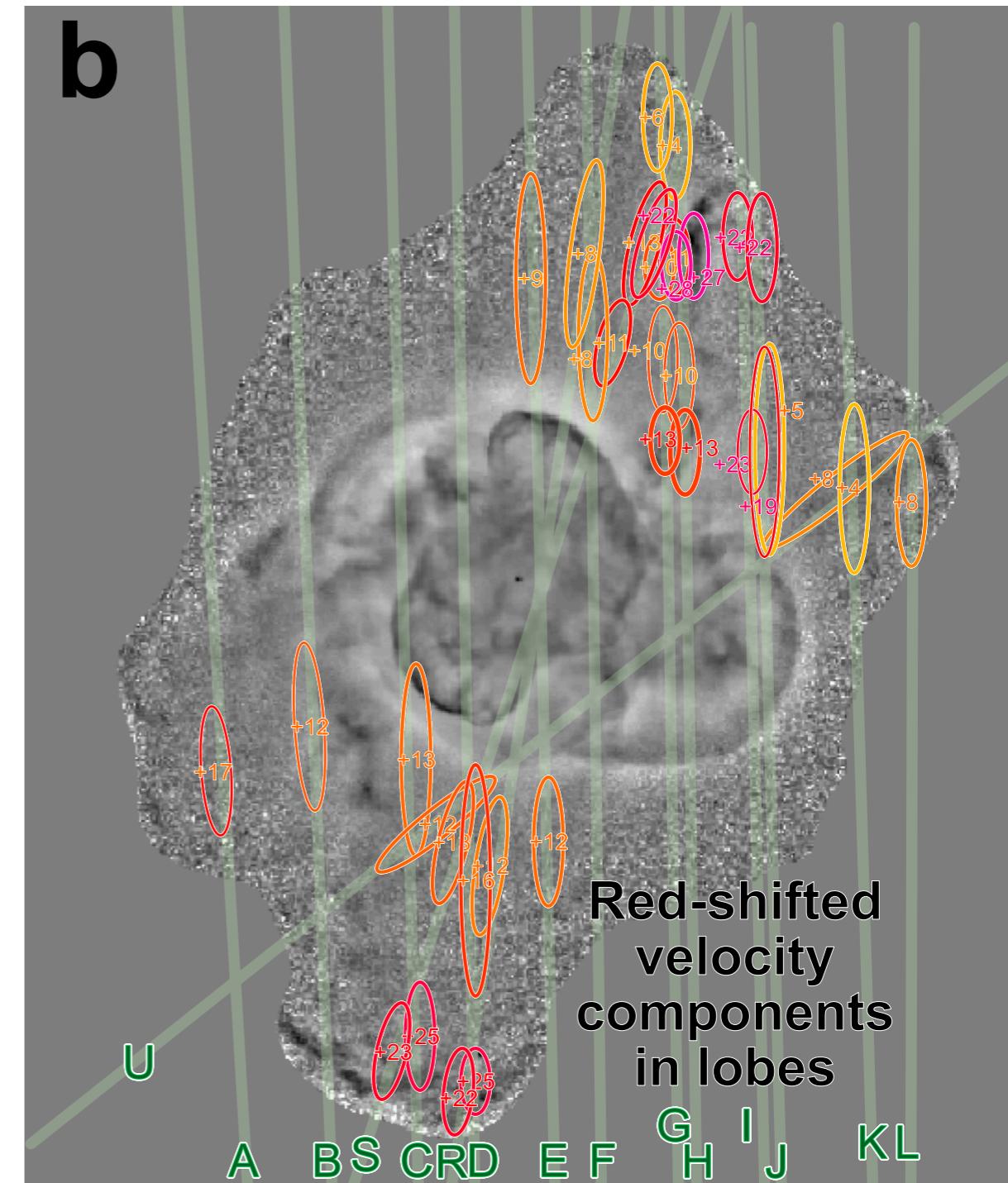
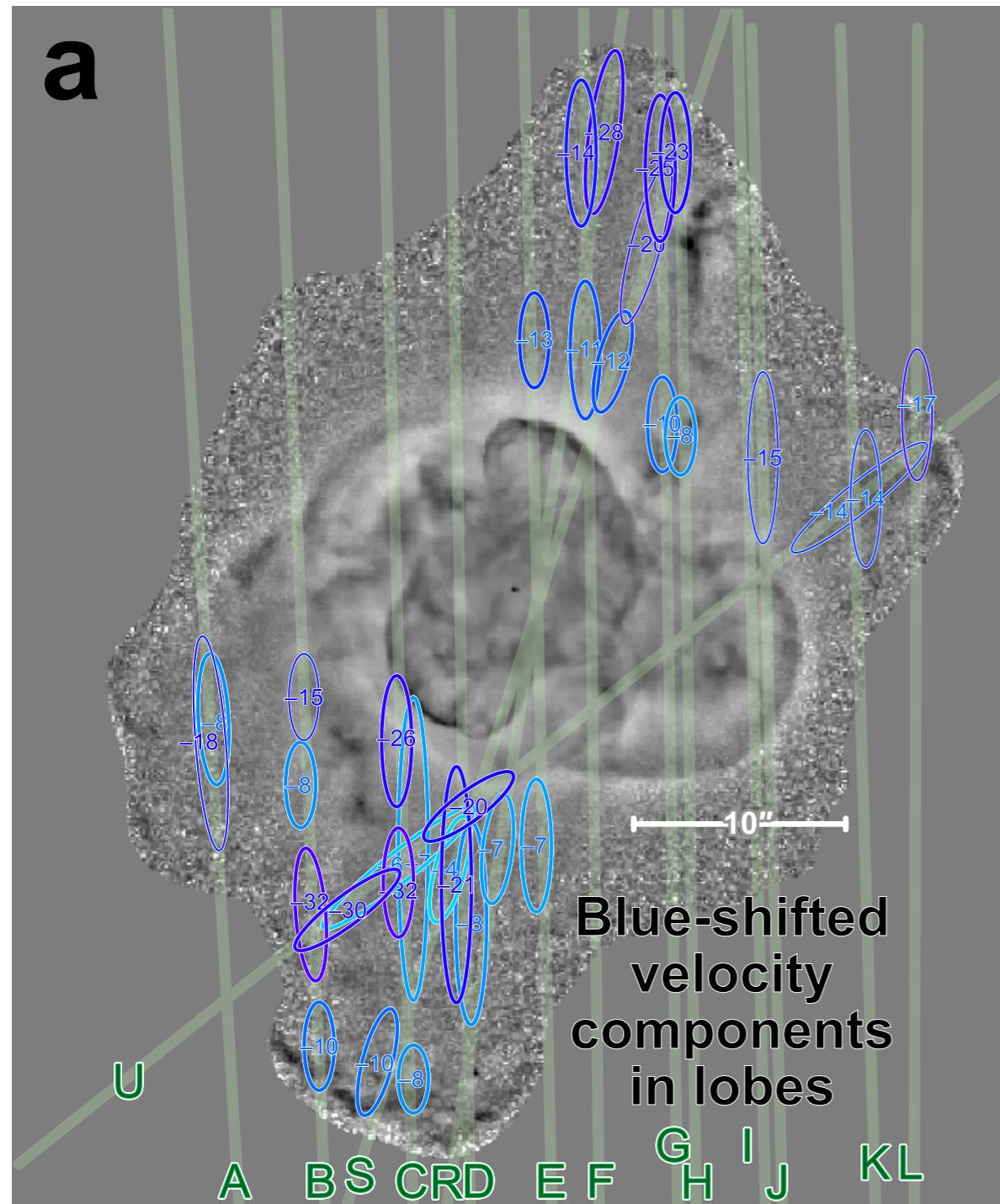
Blue-shifted



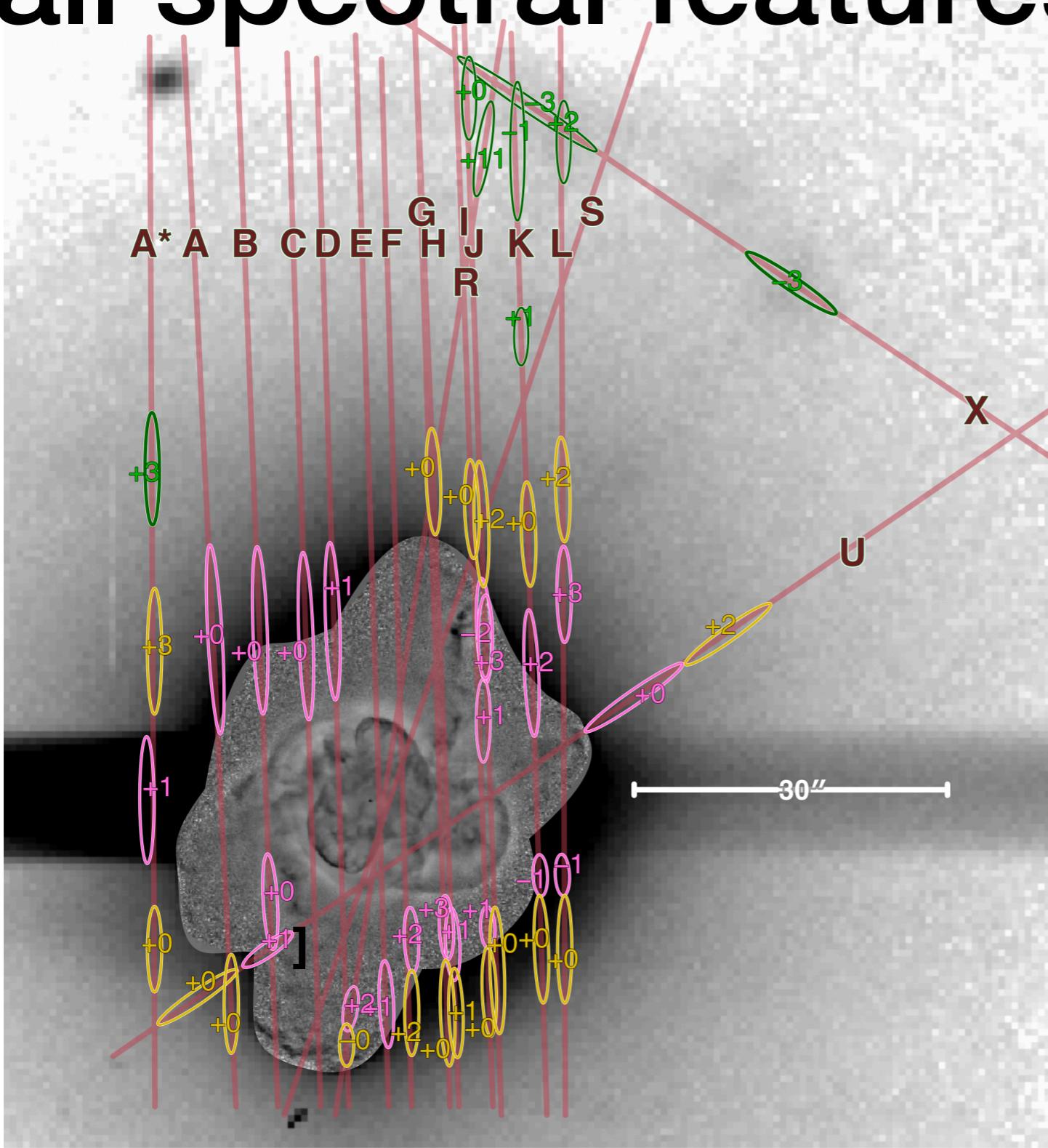
Red-shifted

[N II] features in knot complexes

Better approach: simply map all spectral features in all slits

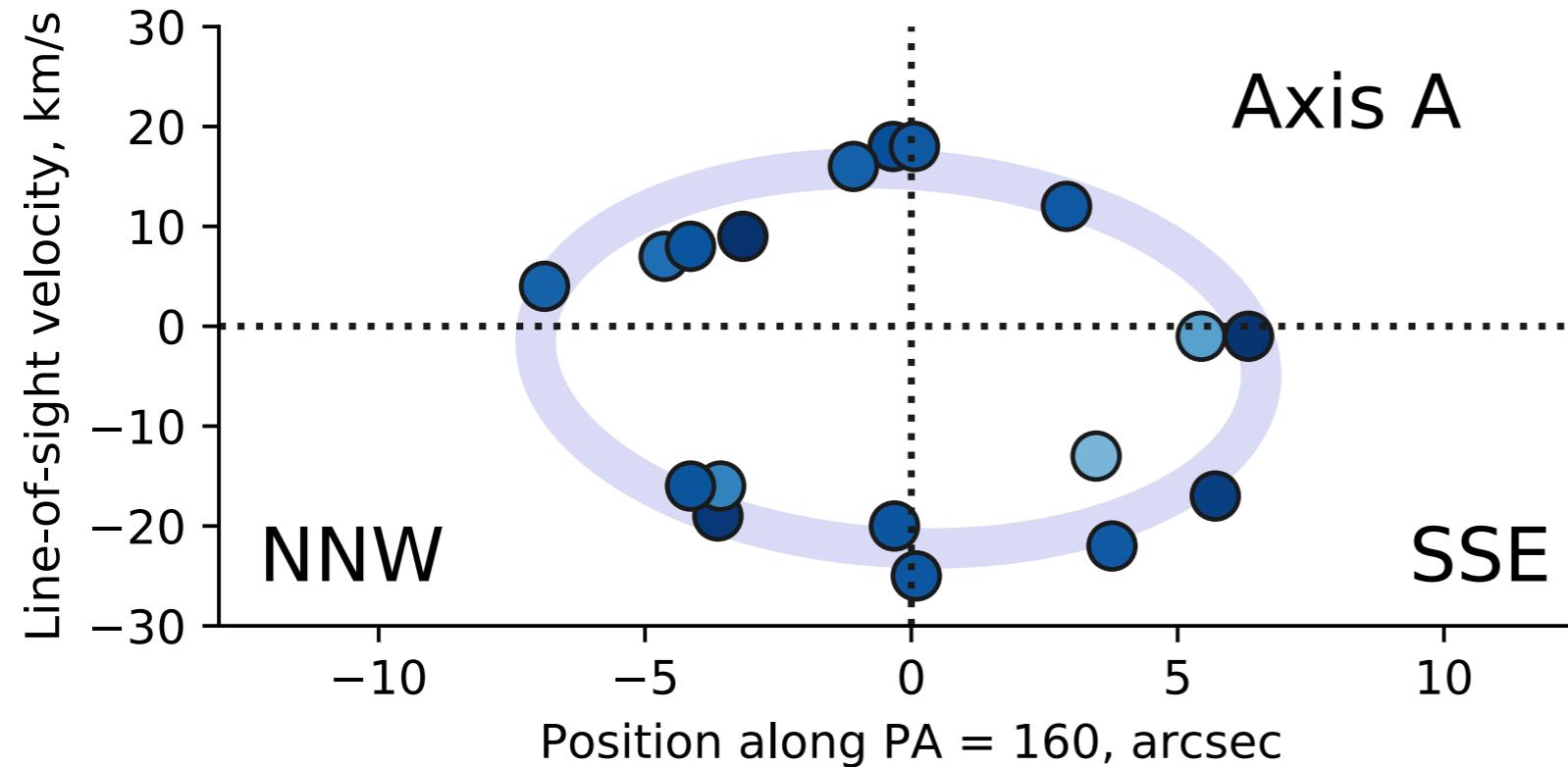


Better approach: simply map all spectral features in all slits



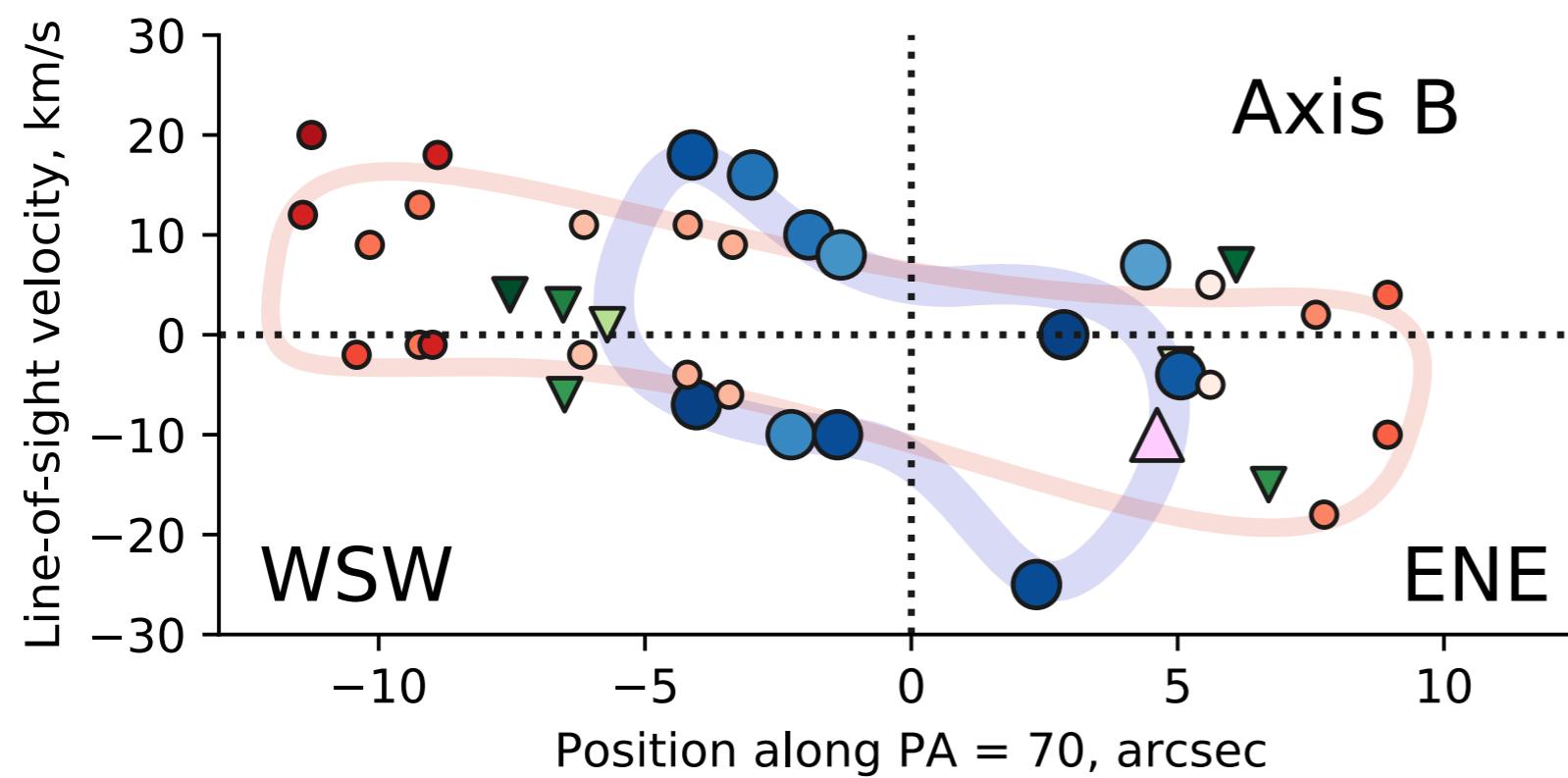
Halo and halo knots

Velocity patterns along axes A and B



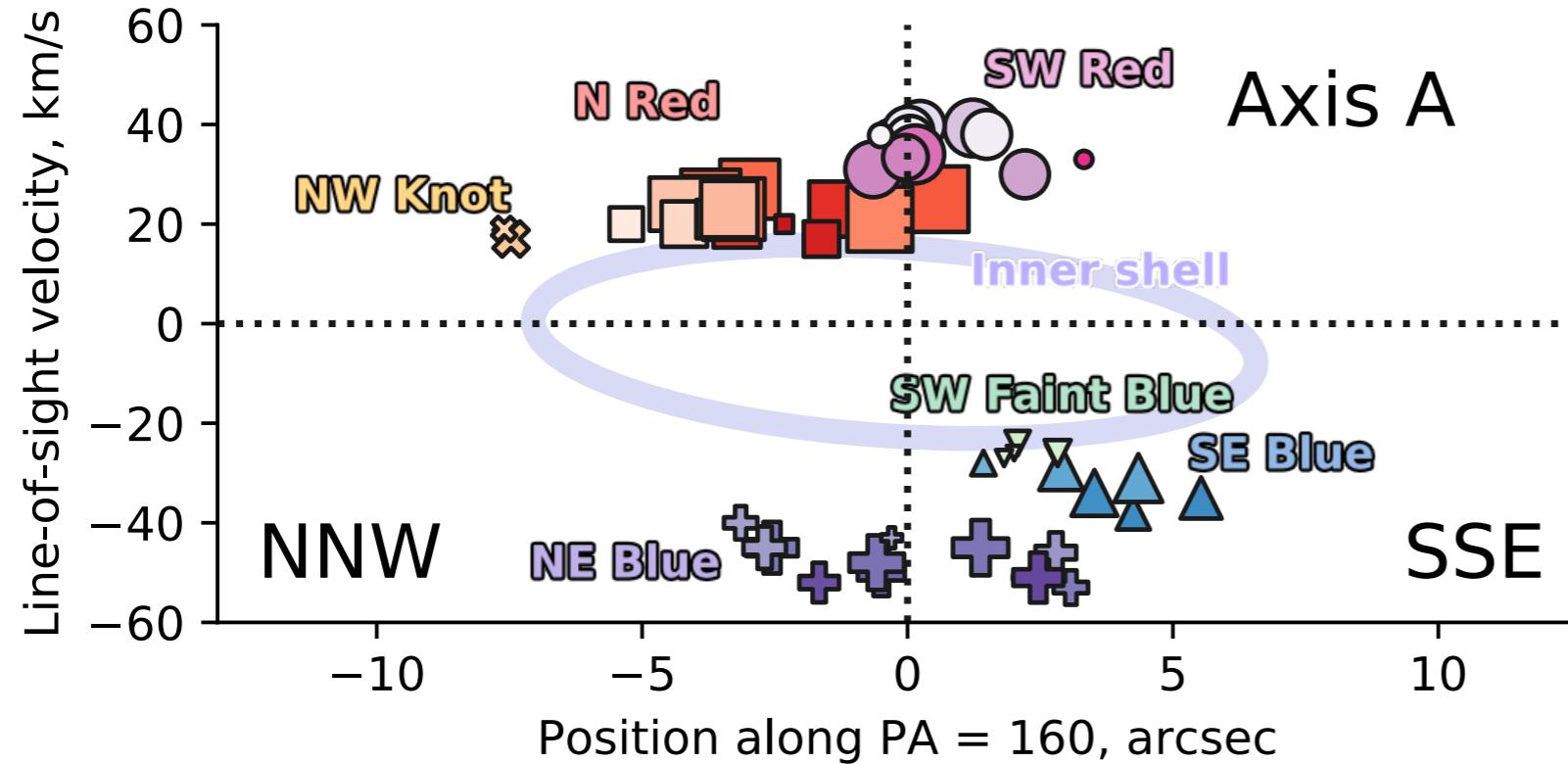
Axis A is major axis of inner shell

[O III] features in inner and intermediate shells

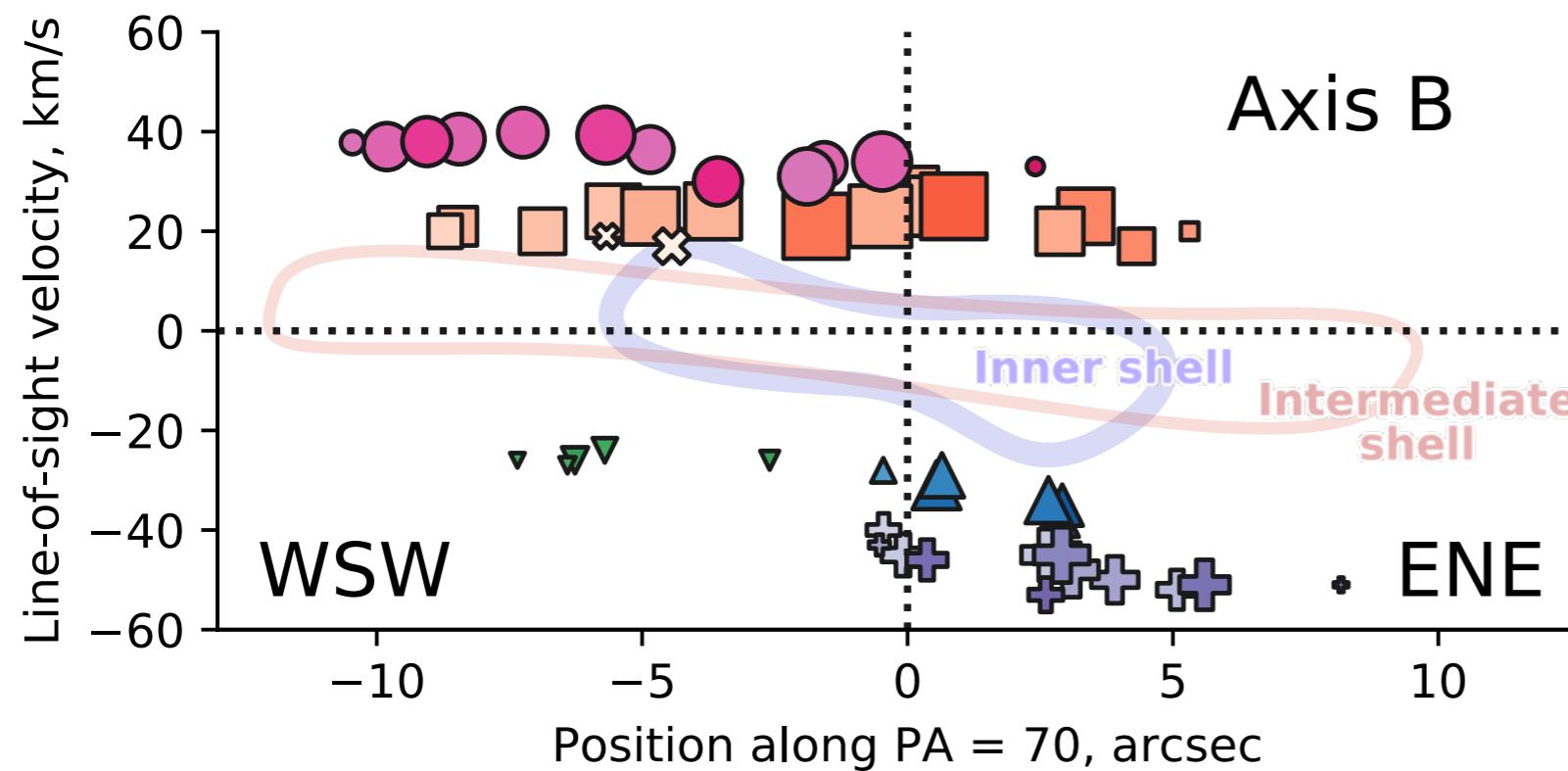


Axis B is major axis of intermediate shell

Velocity patterns along axes A and B



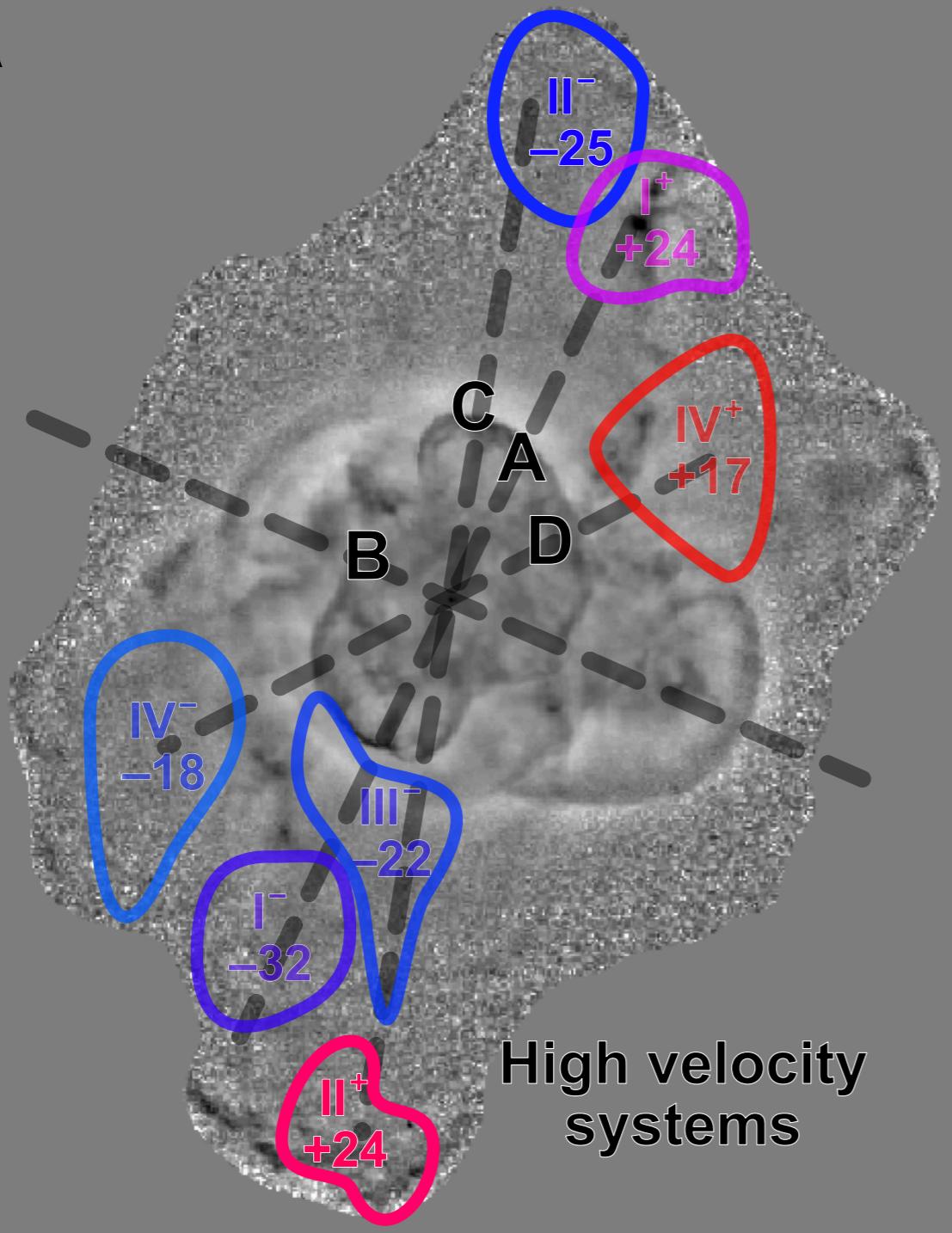
[N II] features in knots
and knot complexes



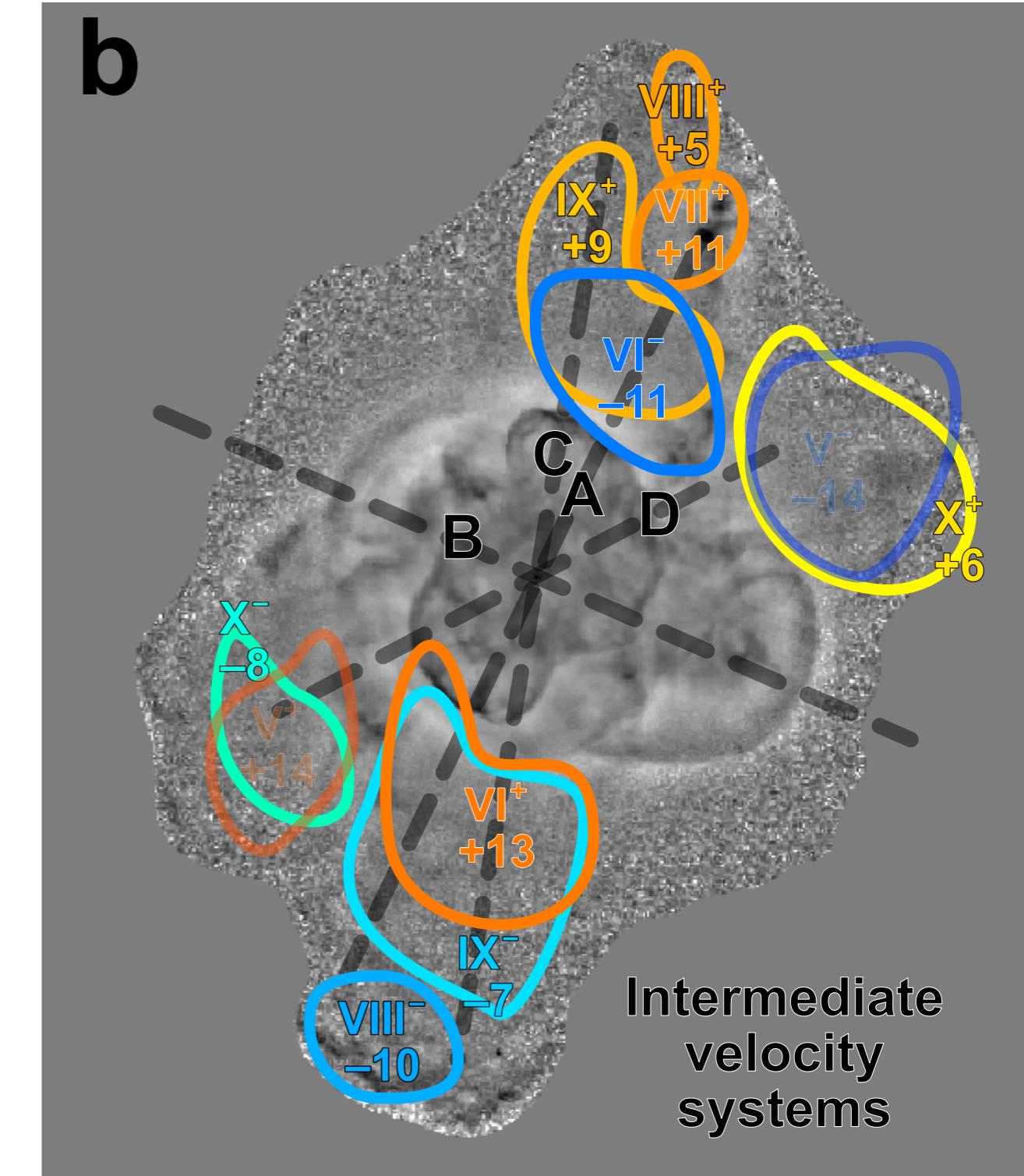
No clear trends along
these axes

Axes A, C, & D form the lobes

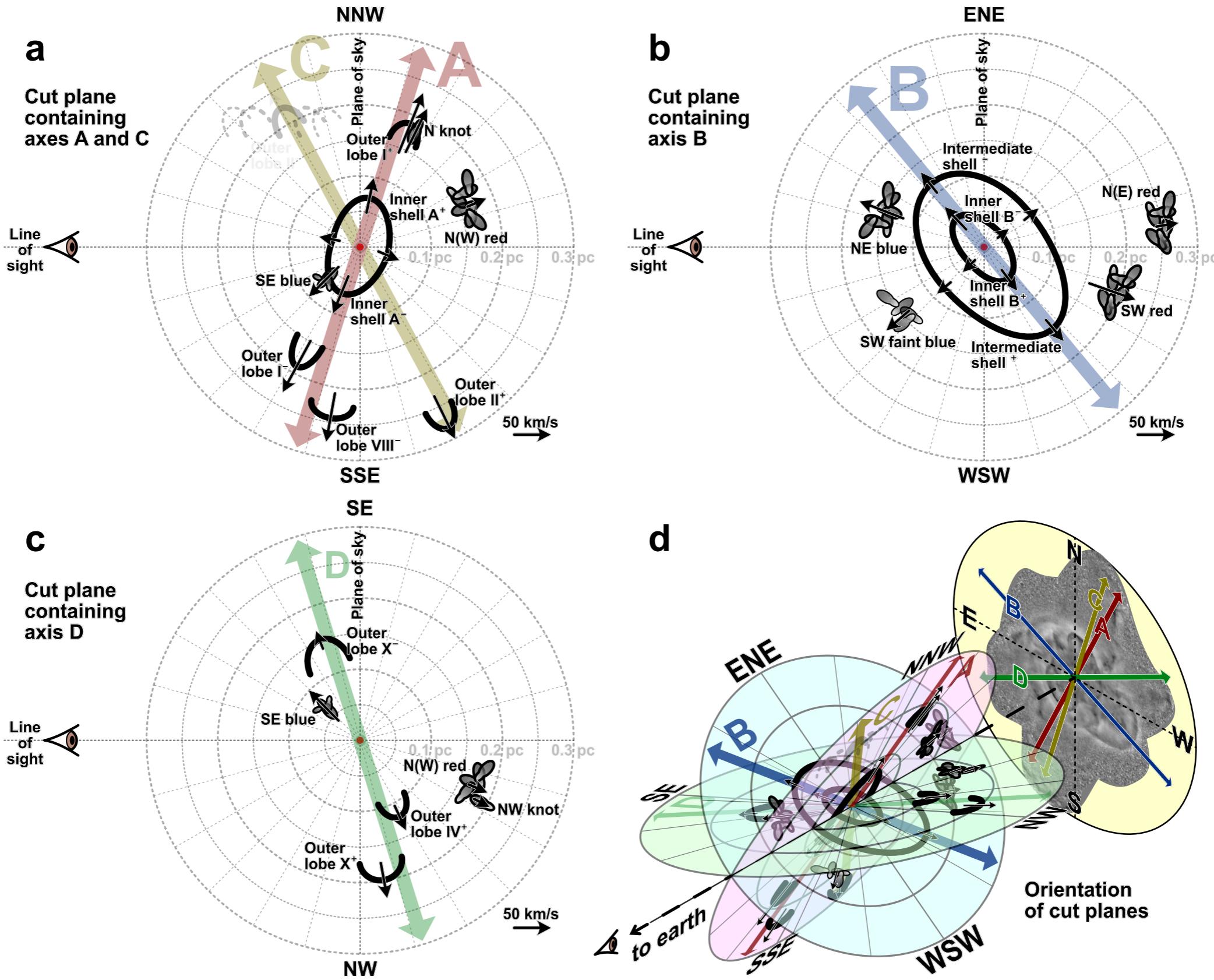
a



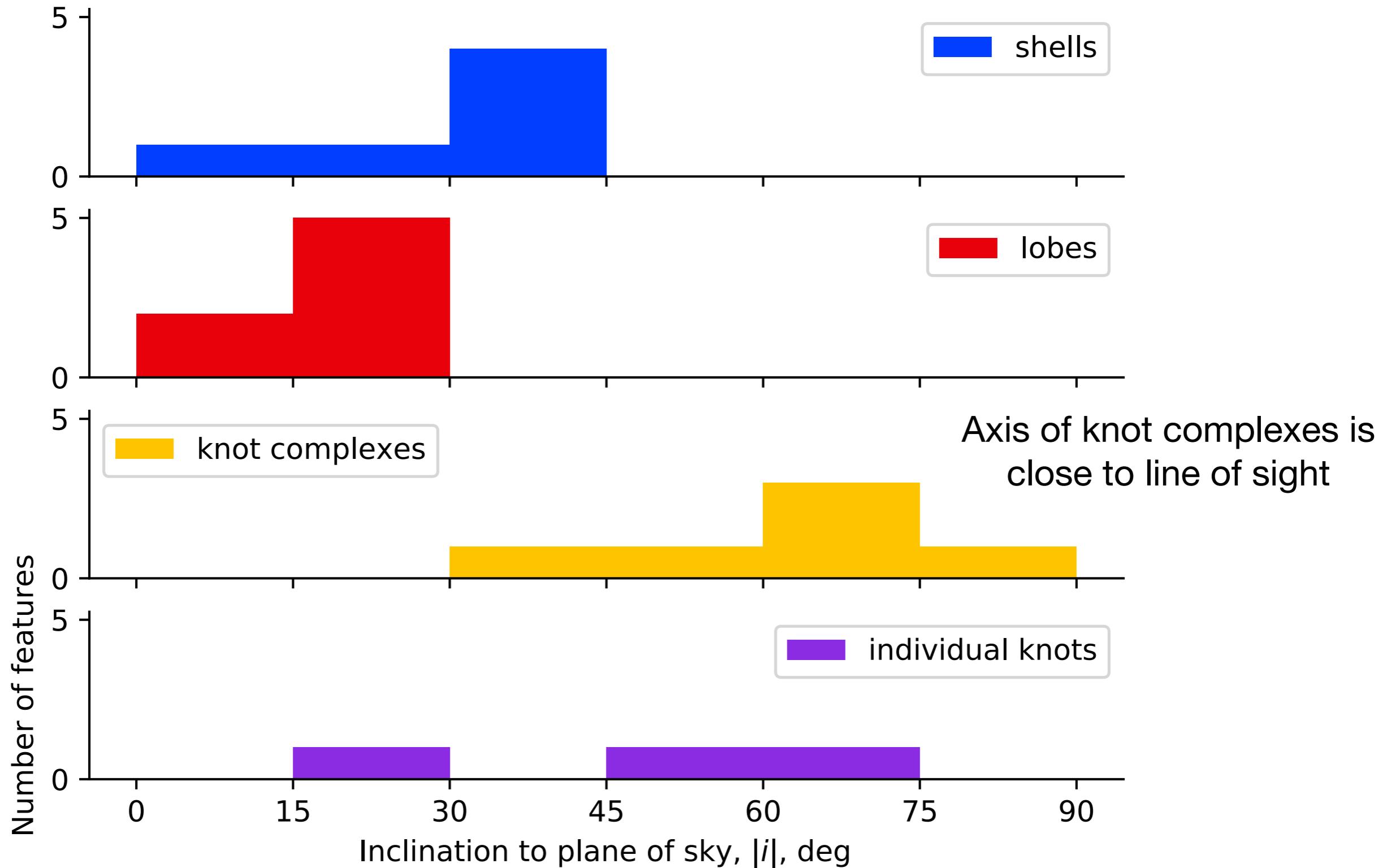
b



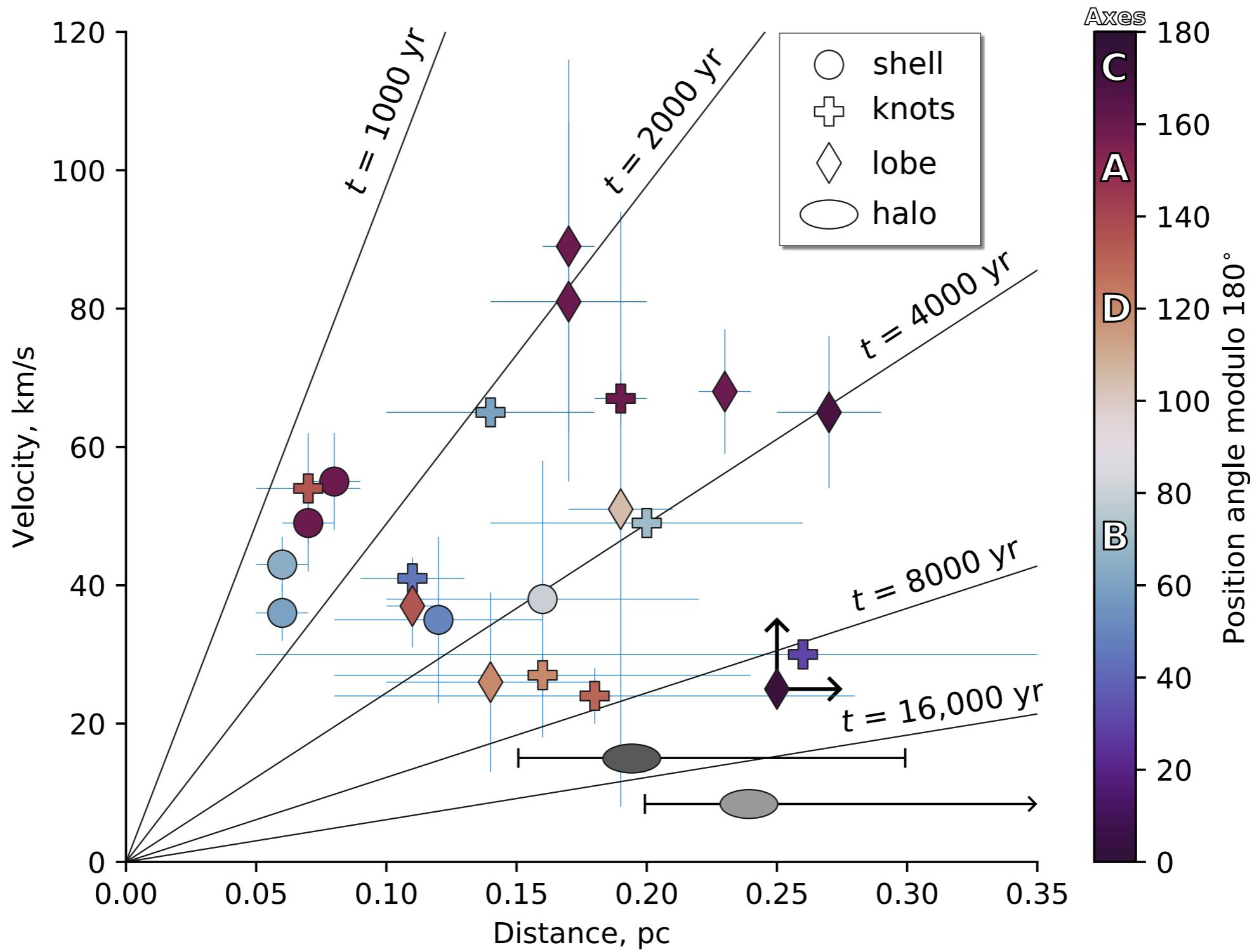
3D reconstruction of outflows



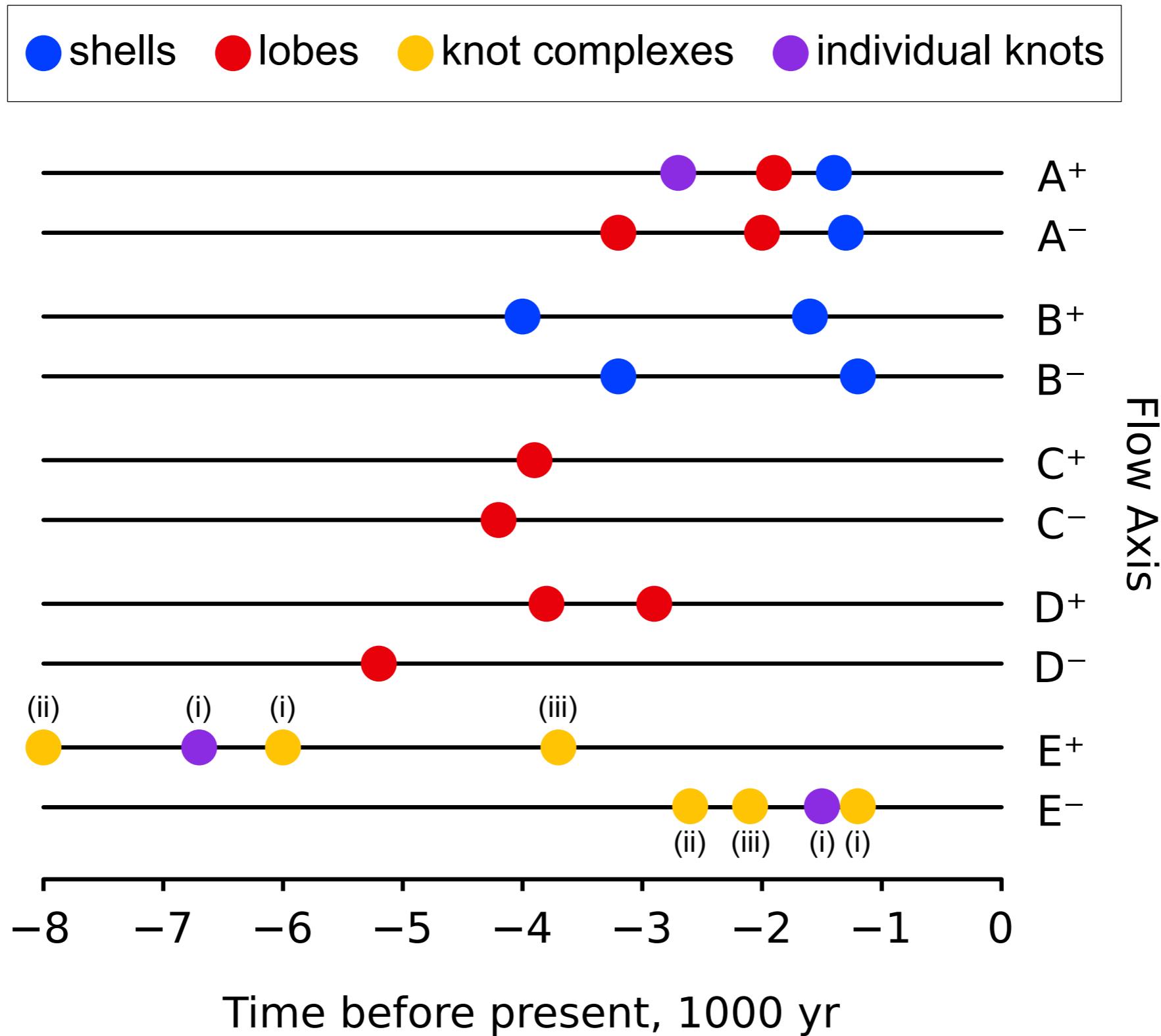
Axis E – the hidden axis



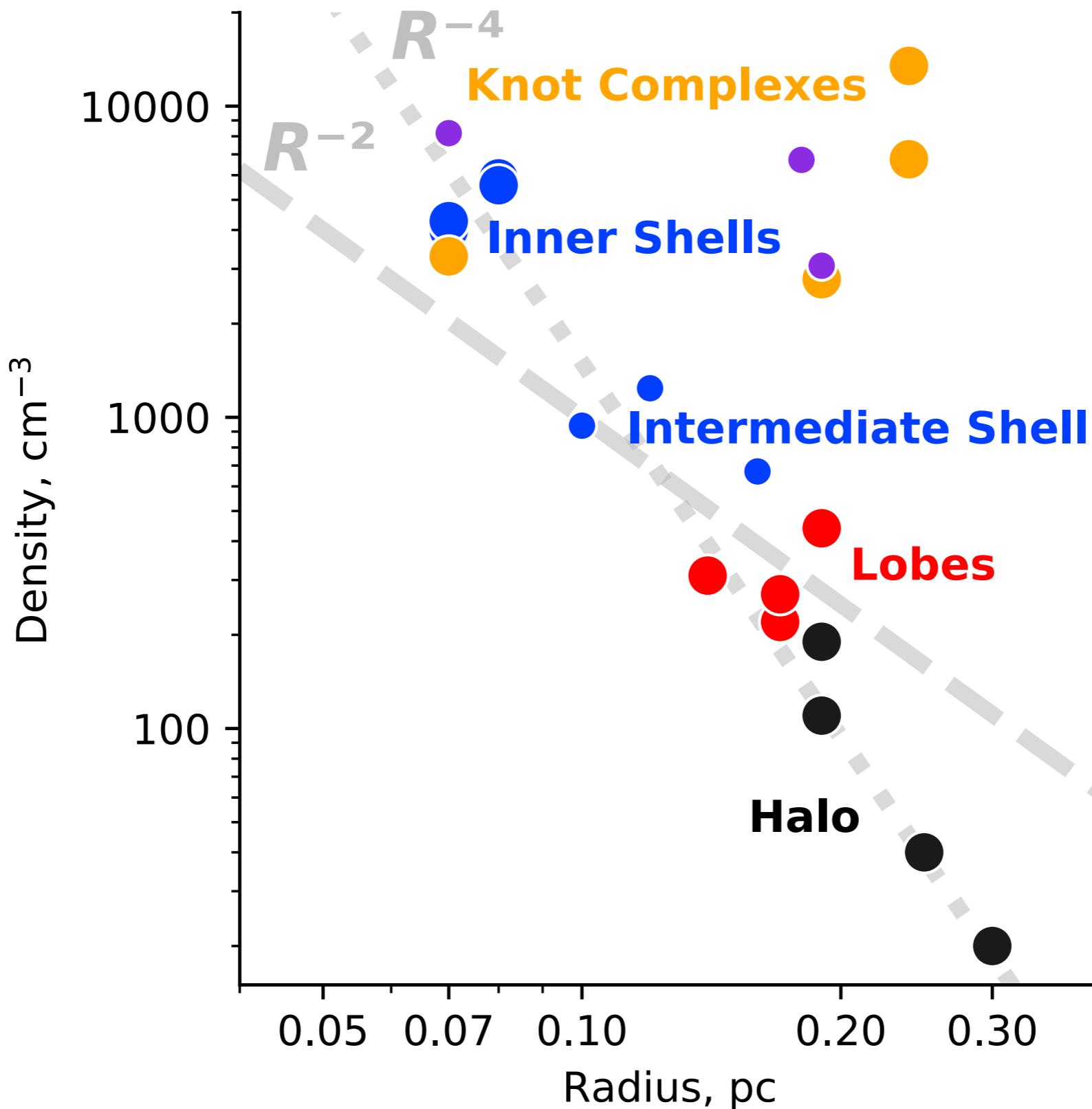
Kinematic timescales



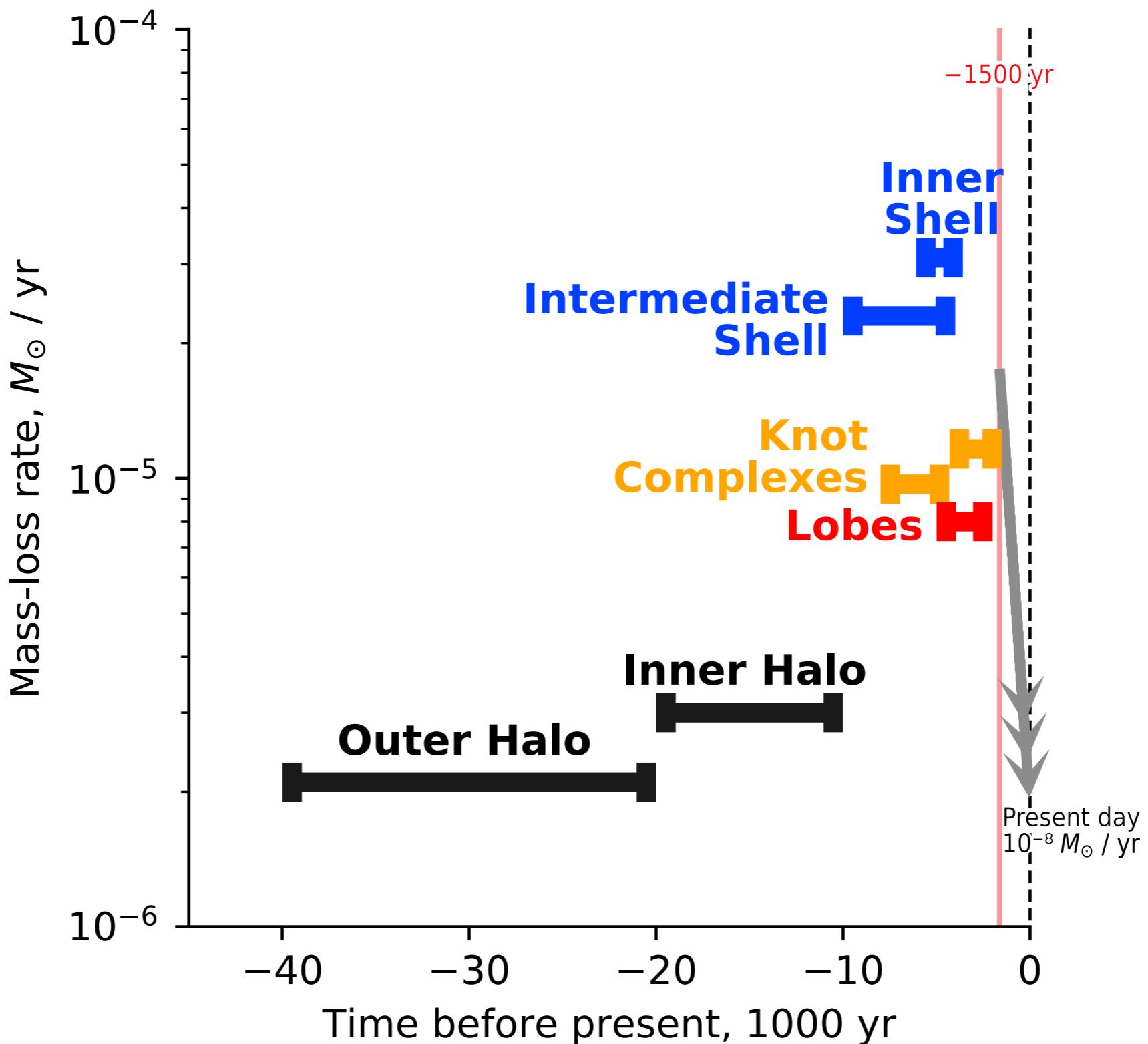
Ejection history along each axis



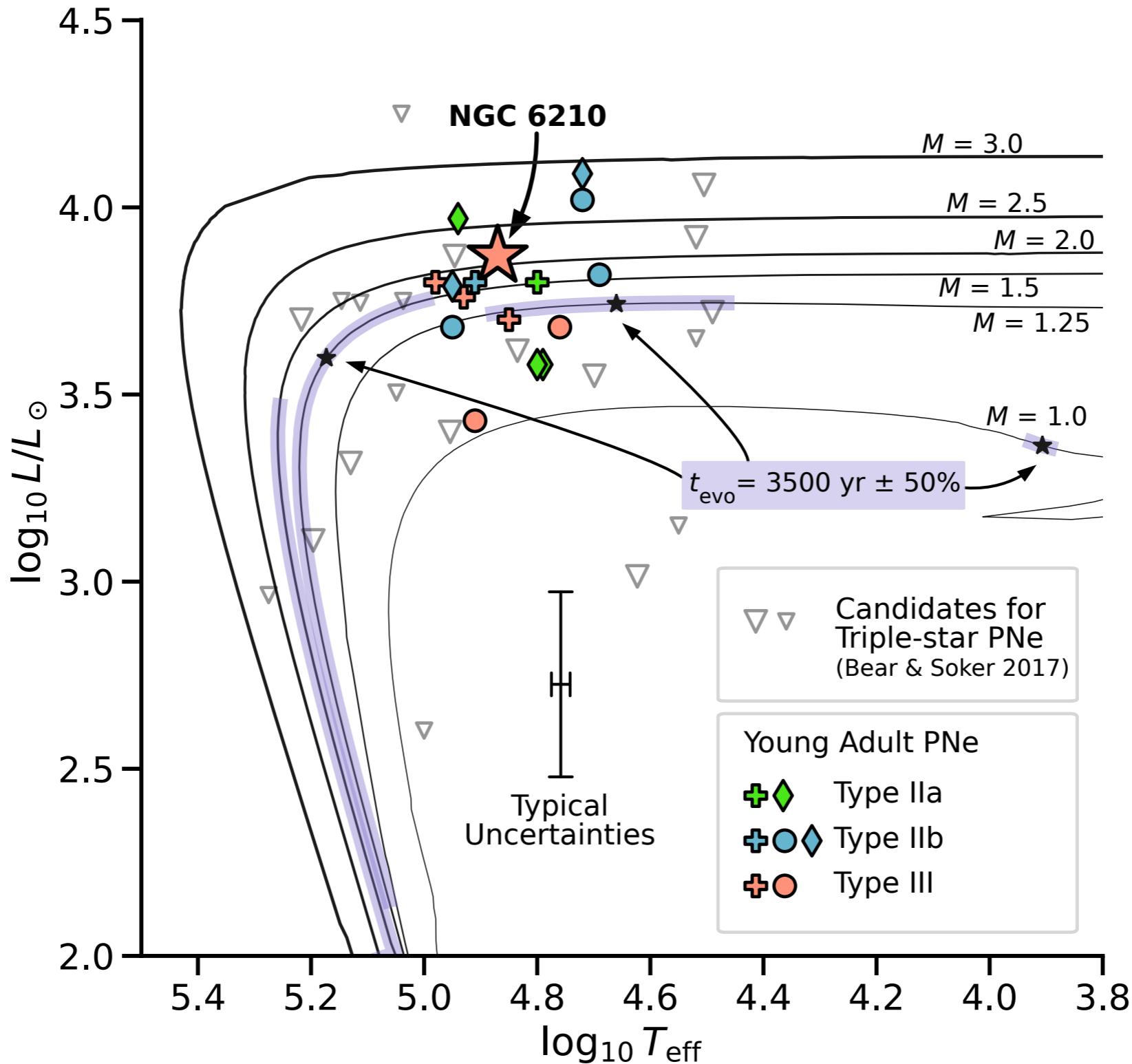
Electron densities



Mass-loss history



Post-AGB evolution



The Turtle's Cousins: Young-Adult PNe

Higher mass



0.2 pc

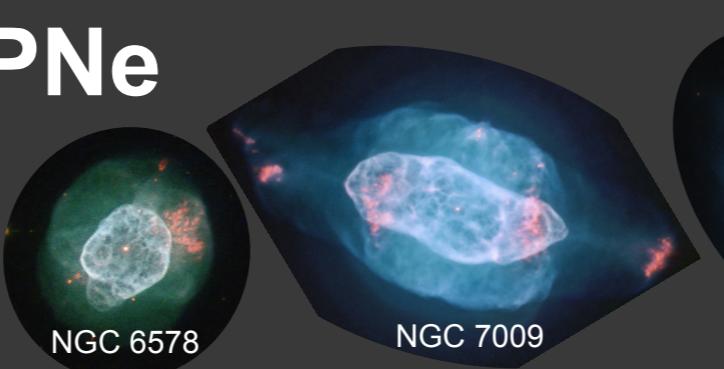


Lower mass

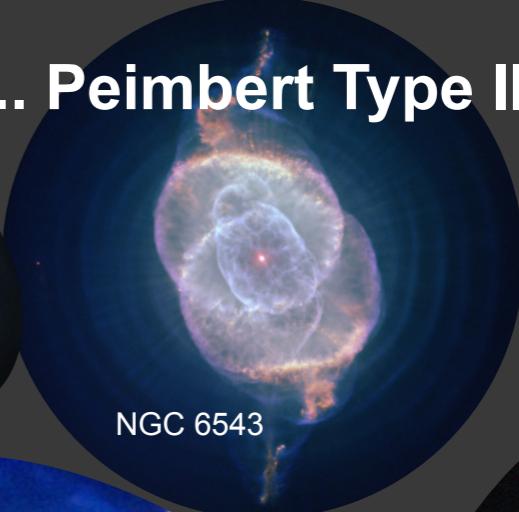
Simple
Geometry

Complex
Geometry

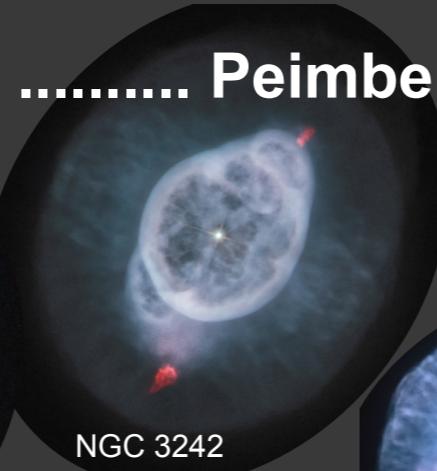
..... Peimbert Type Ia



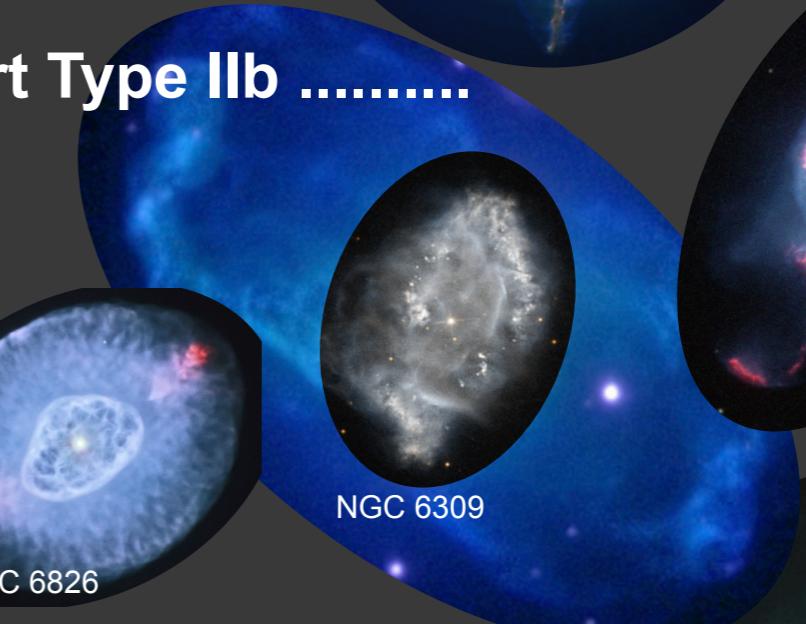
NGC 5882



NGC 6543

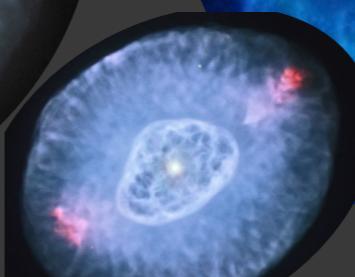


NGC 3242

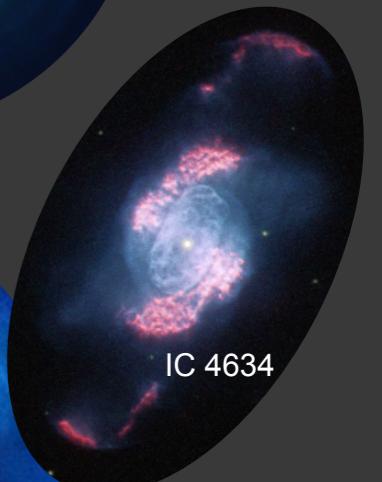


NGC 6309

..... Peimbert Type IIb



NGC 6826



IC 4634

..... Peimbert Type III



NGC 5307



NGC 6326



NGC 6210

Mass-transfer and jets in triple star systems

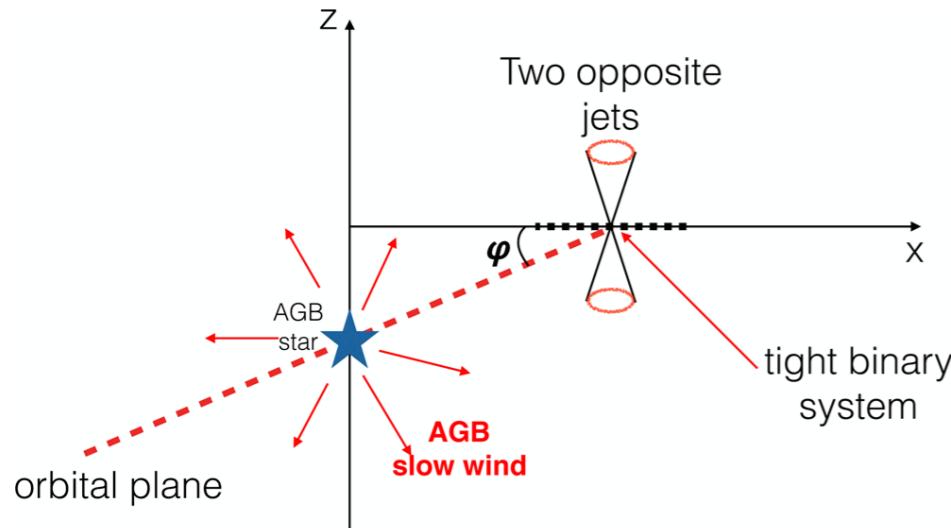
MNRAS **469**, 3296–3306 (2017)
Advance Access publication 2017 May 4

doi:10.1093/mnras/stx1058

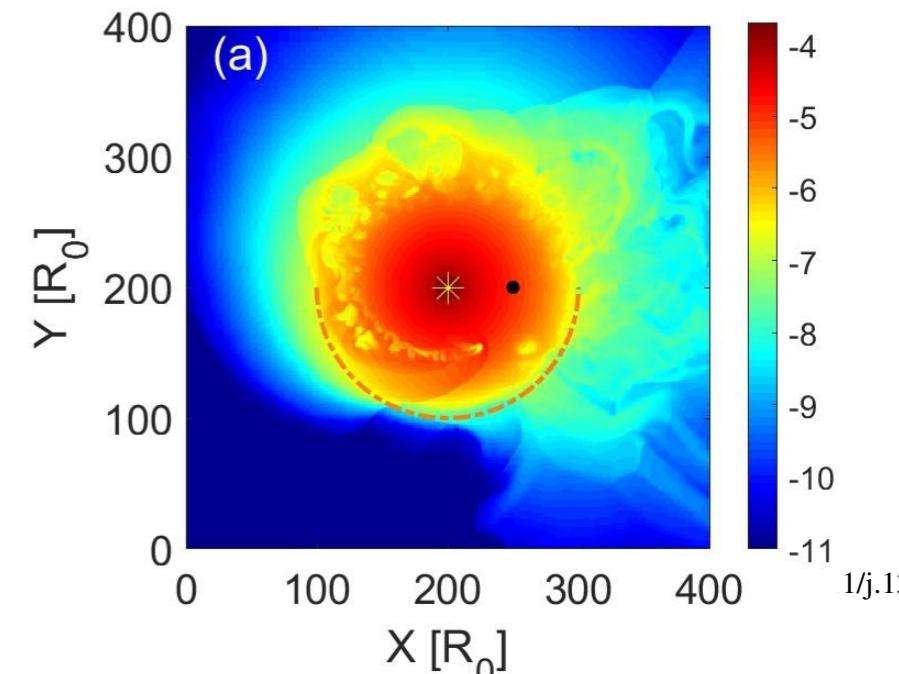
Shaping planetary nebulae with jets in inclined triple stellar systems

Muhammad Akashi[★] and Noam Soker

Department of Physics, Technion – Israel Institute of Technology, Haifa 32000, Israel



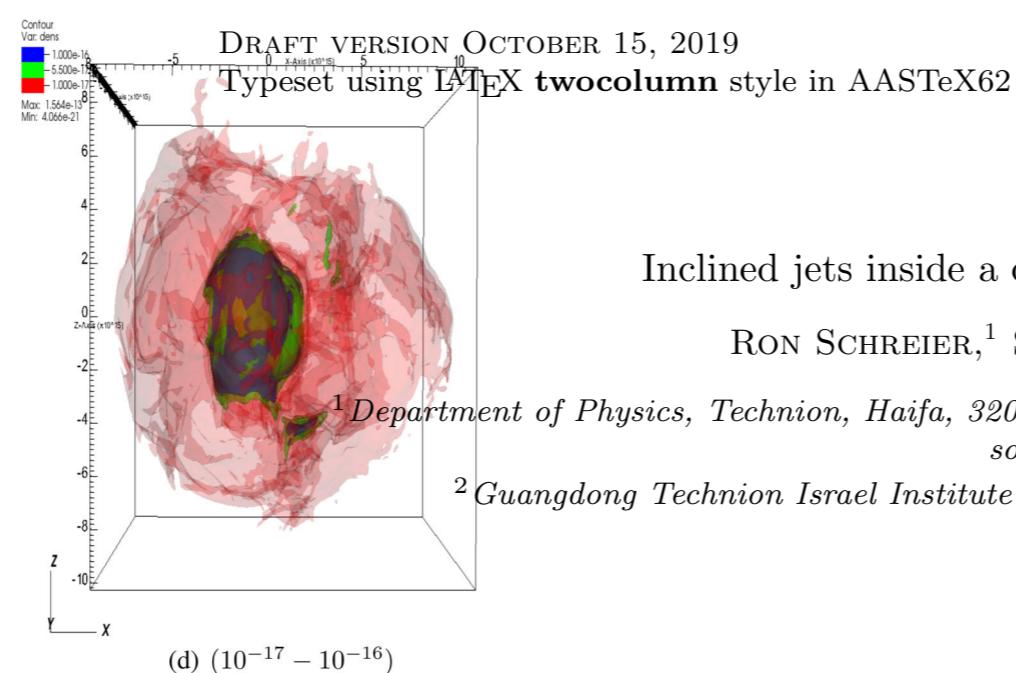
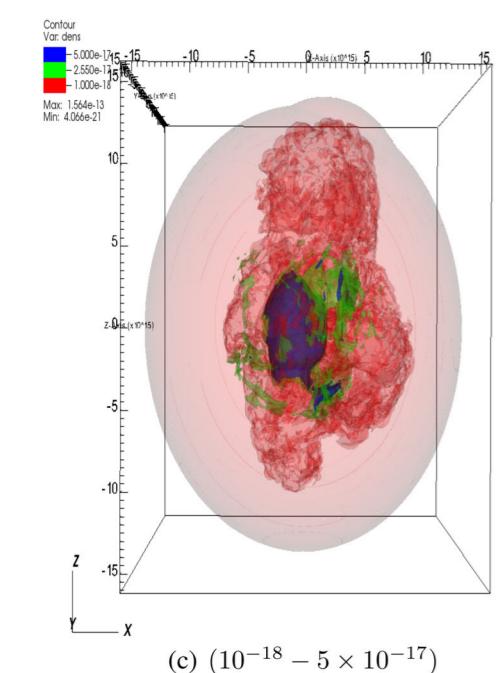
Mon. Not. R. Astron. Soc. **350**, 1366–1372 (2004)



Wind accretion by a binary stellar system and disc formation

Noam Soker[★]

Department of Physics, Technion-Israel Institute of Technology, Haifa 32000, Israel
Department of Physics, Oranim, Israel



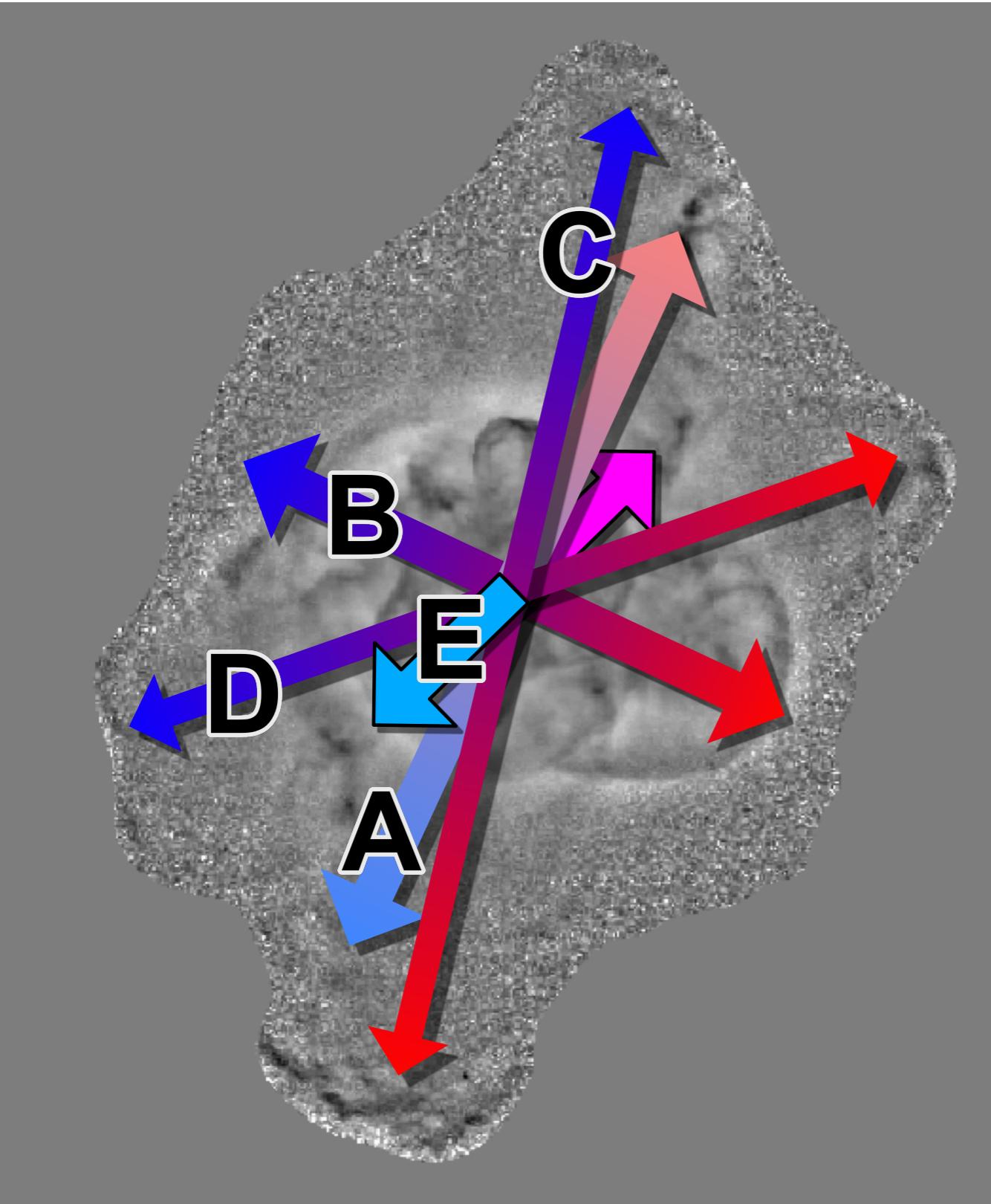
Inclined jets inside a common envelope of a triple stellar system

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²Guangdong Technion Israel Institute of Technology, Shantou 515069, Guangdong Province, China

Conclusions



- The Turtle has symmetric and asymmetric outflows along 5 axes
- Two qualitatively different types of bipolar flows:
 - high-ionization lobes
 - low-ionization knots
- Outflow directions have changed during 5000 years of nebular evolution
 - 180° flip in axis E, 2000 years ago

Thank you!