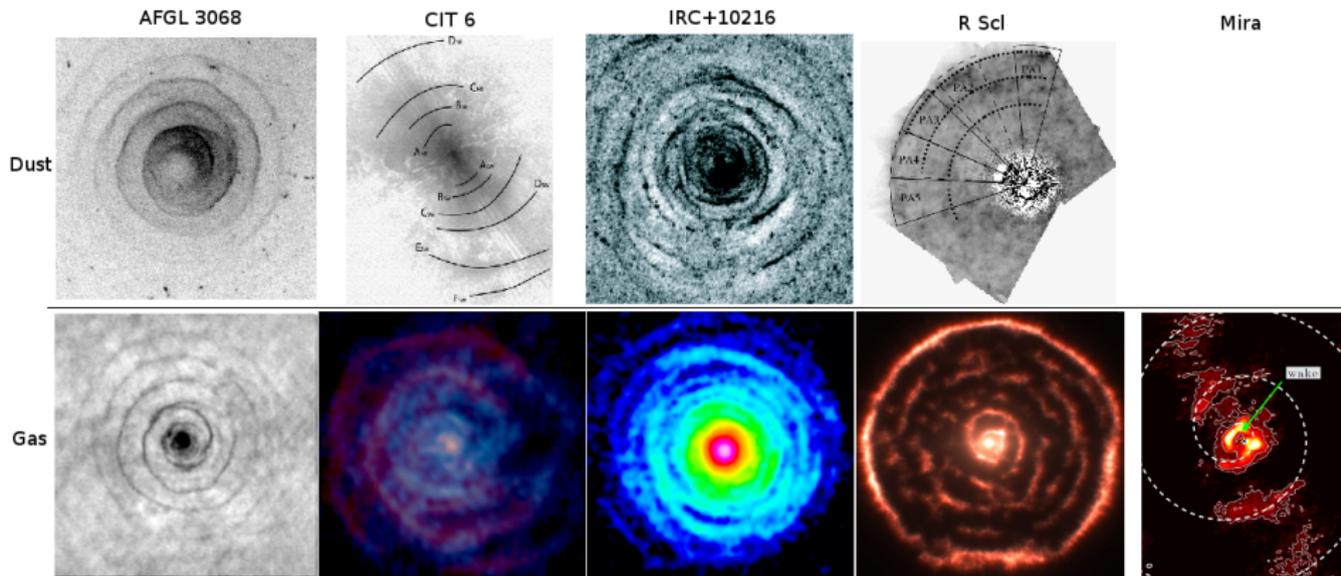


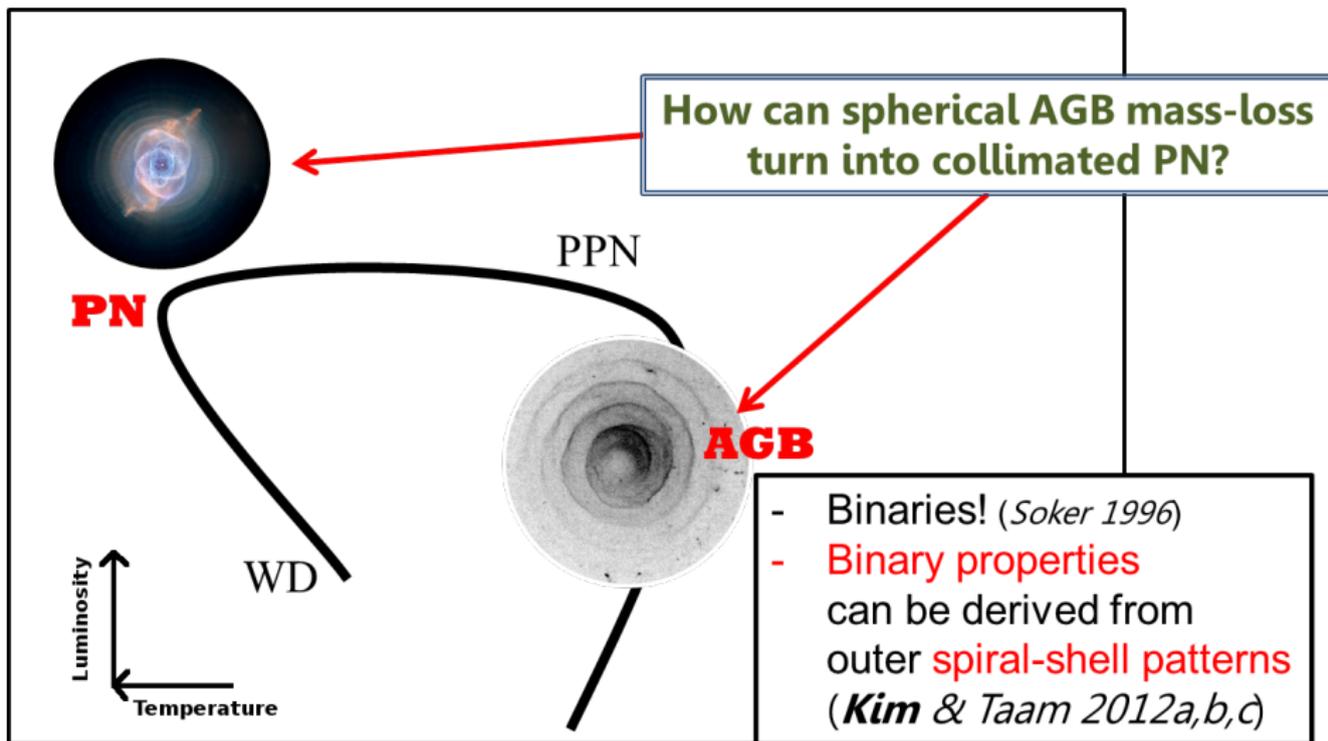
Spiral-Shells and Nascent Bipolar Outflow in CIT 6: Hints for an Eccentric-Orbit Binary?

Hyosun Kim (ASIAA, EACOA fellow)

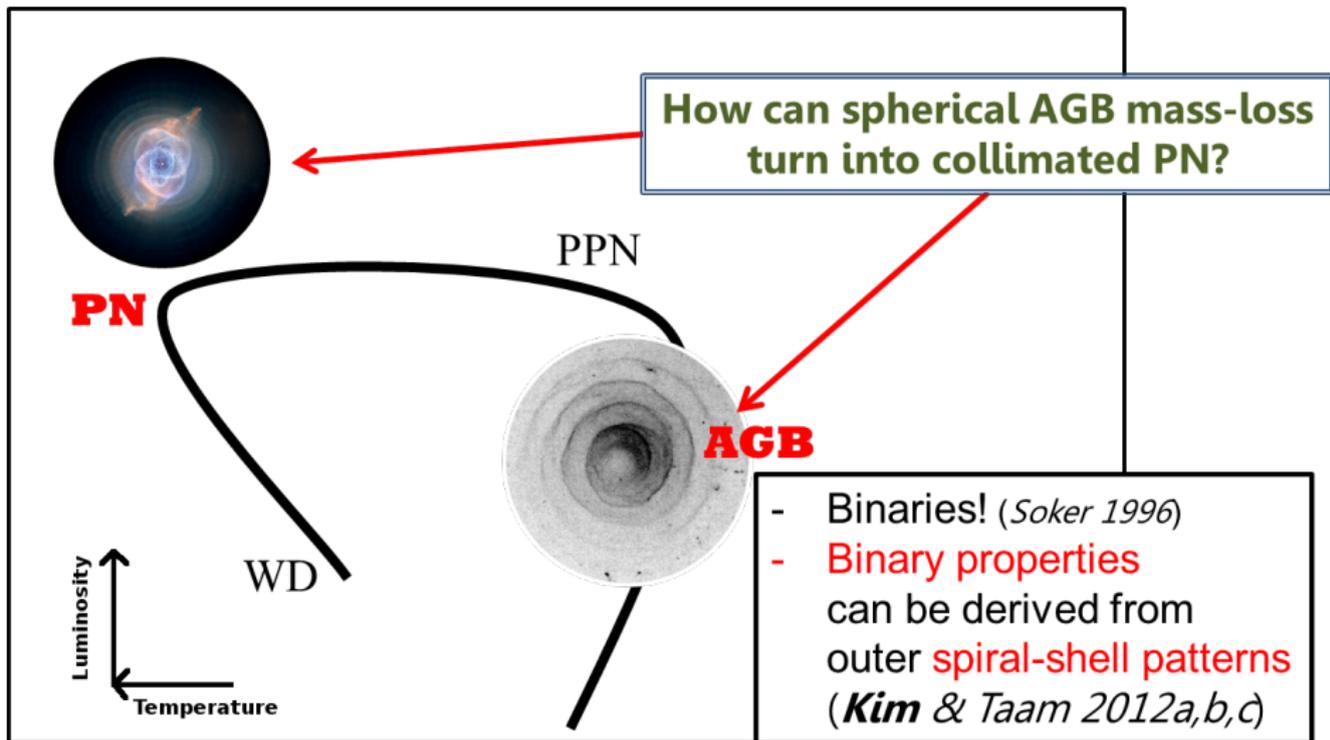
SMA Science in the Next Decade, Taipei @ 2016-10-27



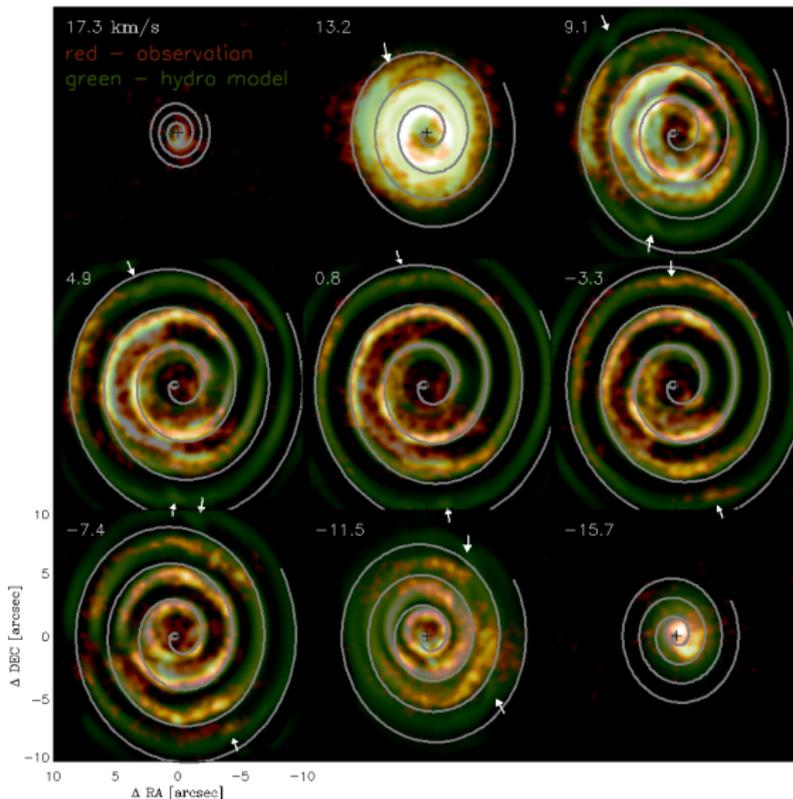
Binaries, key of diverse outflow features in PNe



How transit from near- to non-spherical?



CIT 6 – Shells vs. Spiral



Spiral-shell model

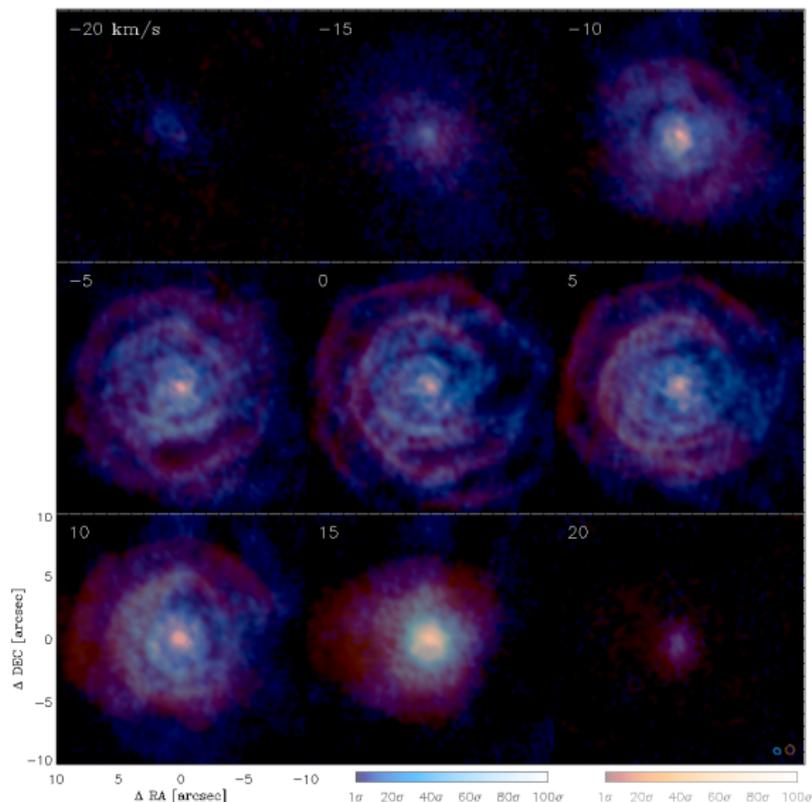
Kim, Hsieh, Liu, & Taam 2013

=> a **single** spiral
(w/ an inclination)
matches *all* arcs

but still, shells vs. spiral
was controvertible due to
one-sided disconnection

line : analytic model
green : hydrodynamic model
red : HC₃N(4-3) @ JVLA

CIT 6 – Spiral

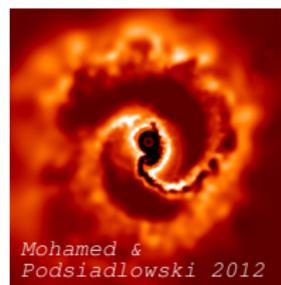
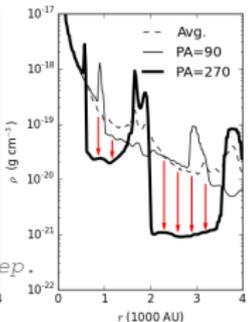
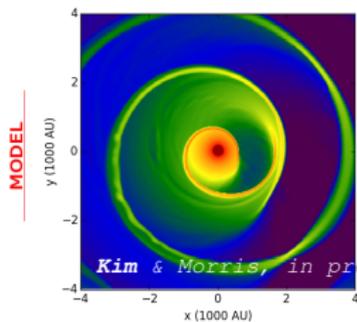
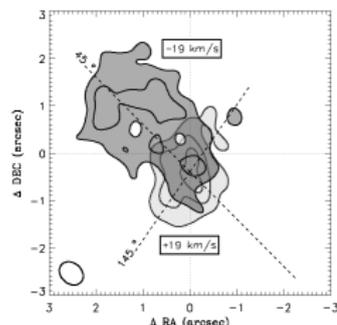
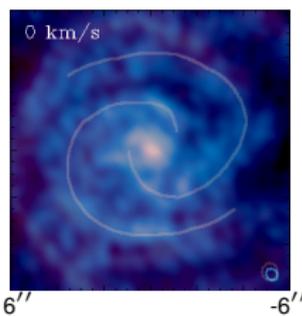
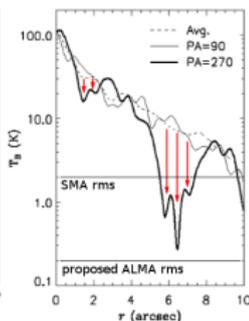
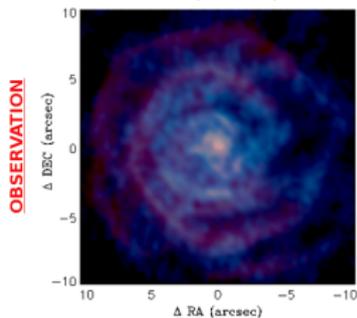


Kim, Liu, Hirano et al. 2015b

blue : CO(2-1) @ SMA
red : HC₃N(4-3) @ JVLA

Eccentric Orbit – One-sided gaps & Double spiral & Bipolar lobes

SMA (+ JVLA)

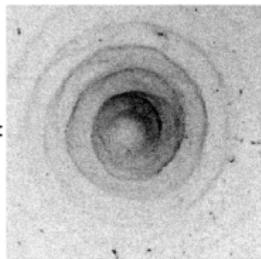


Kim, Liu, Hirano
et al. 2015b

... to be continued with ALMA in Cycle 4 (Kim, Liu, Sahai et al.)

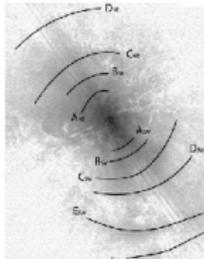
Now, several sources are claimed to have spirals thanks to the high-sensitivity/resolution of sub-mm/mm interferometers

AFGL 3068

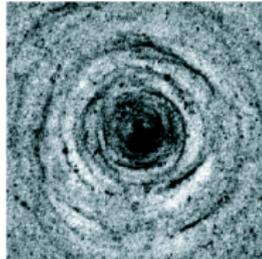


Dust

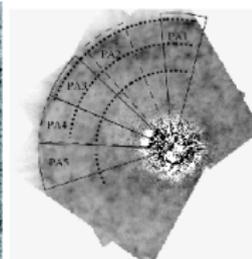
CIT 6



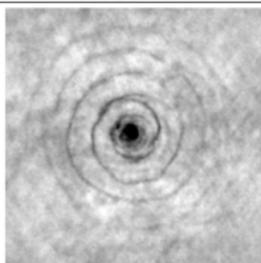
IRC+10216



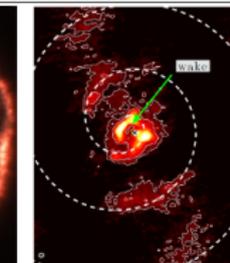
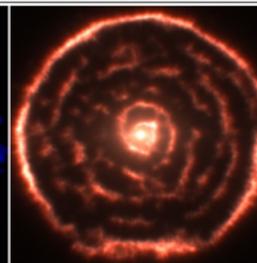
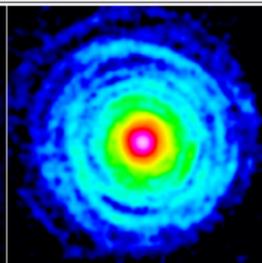
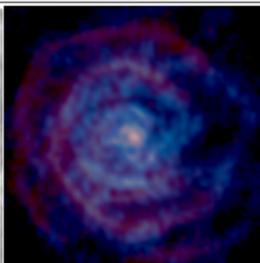
R Scl



Mira



Gas



ALMA c2

Kim et al. submitted

JVLA+SMA

Kim et al. 2015

IRAM

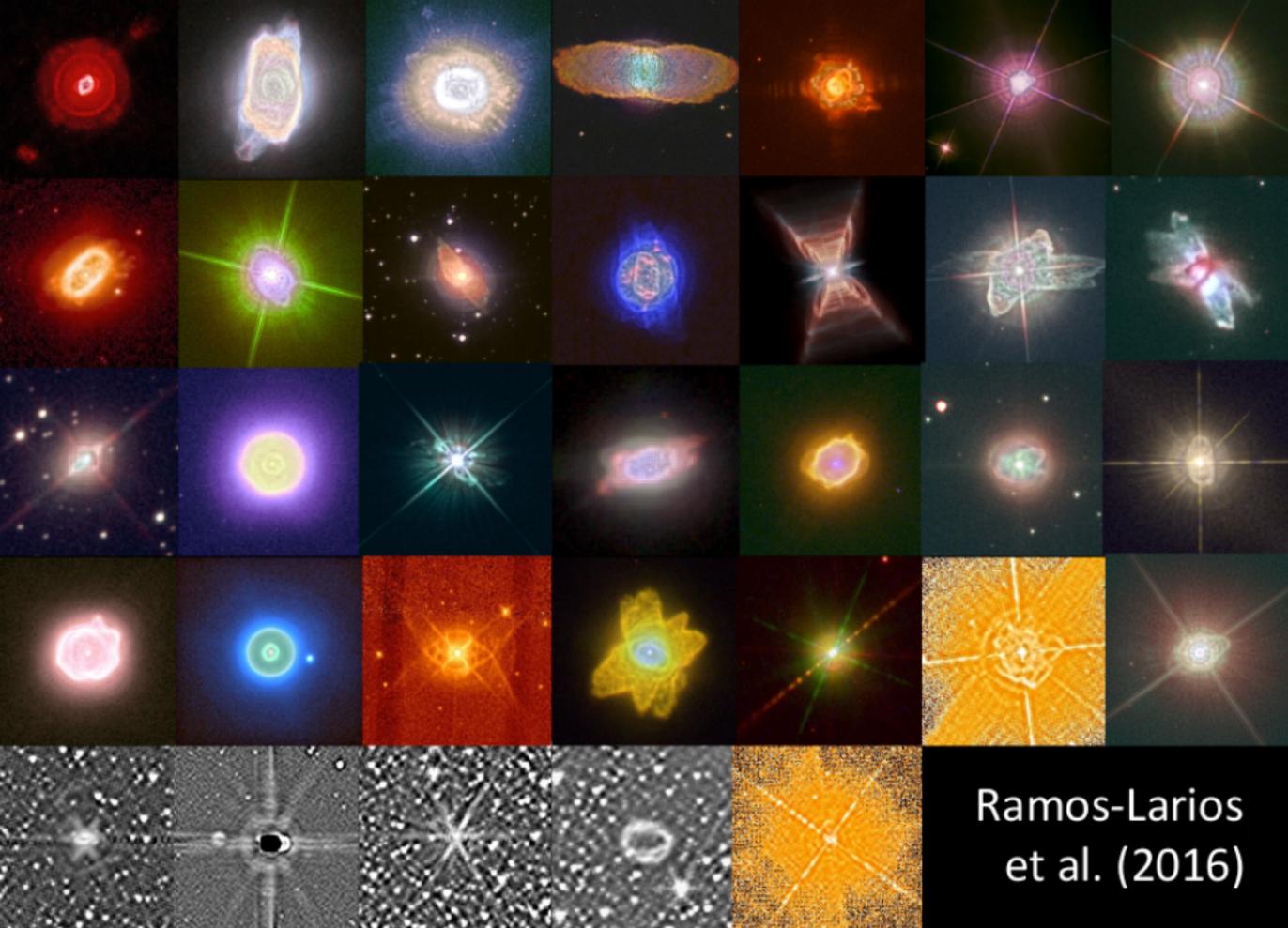
Cernicaro et al. 2014

ALMA c0

Maercker et al. 2012

ALMA c1

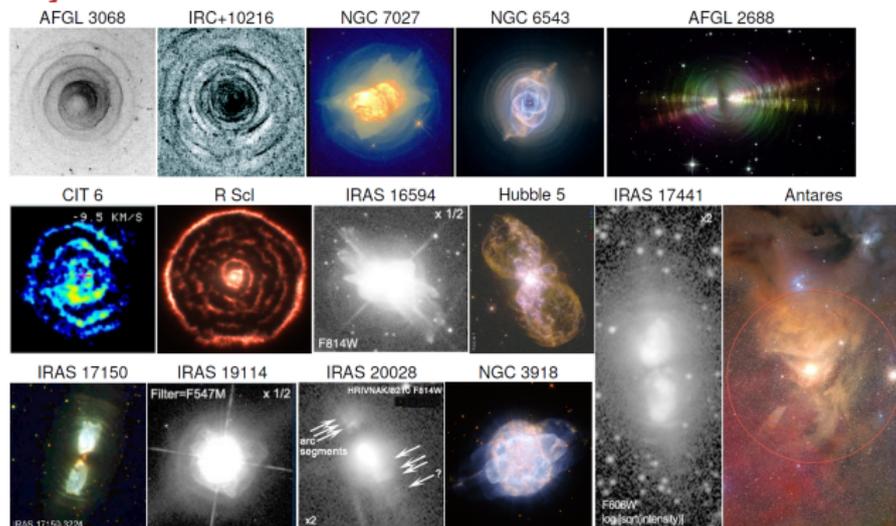
Ramstedt et al. 2014



Ramos-Larios
et al. (2016)

AGB/PPN/PN sources showing spiral/rings/arcs

Are they all binaries?



Binary detection
in AGB/PPN/PN
 $\approx 20\text{-}30\%$

$\sim 80\%$ of PNe
are not spherical

AGB spirals in post-AGB sources (*Kim, Alcolea, Sanchez-Contreras et al.*)

- A pilot study on going (IRAM 30-m observed + NOEMA proposed)

Statistical study (*Lee, Kim & Toala*)

- ~ 80 sources found from *HST/Spitzer* images & literature search
(Ramos-Larios et al. 2016; Corradi et al. 2004; and many more individual references)

Summary

- **Eccentric binary**, the key of diverse features of AGB/PPN/PN
- Through molecular line observations, we aim
 - to obtain the **binary properties** imprinted in circumstellar **spiral-shell patterns**, and
 - to find the evidence of binary impacts on the formation of circumstellar/circumbinary **disks/tori** and the initiation of **bipolar/multipolar** structures.
- SMA provides the appropriate angular resolution as the pattern spacing is order of $1''$, but somewhat better sensitivity is desired.