Optical Spectroscopy of local type-1 AGN LINERs

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**Low Ionisation Nuclear Emission-line Regions**

LINERs are LLAGNs

\[ \text{L}_{\text{H}\alpha} \sim 0.5-3.7 \times 10^{39} \text{ erg/s} \quad \text{and} \quad \text{L}_{\text{X} [2-10\text{KeV}]} \sim 1.2-8.8 \times 10^{39} \text{ erg/s} \]

**Narrow Lines**
- Strong low-ionisation and faint high-ionisation emission lines
- Different profiles, *stratification of the NLR?*

**Broad Lines**
- Faint
- *Does the BLR disappear?*

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**Wavelength [\AA]**

| Intensity [A.U.] | Heckman+80 | Filipenko+92 | Dopita+96 | Shields+97 | Ho+97,+03, +08 | Elitzur&Shlosman+06 | Gonzalez-Martin+09 | Singh+13 | Elitzur+2014 | Balmaverde+14,+16 | Netzer+2015 | Constantin+15 | Padovani+17 | Marquez+2017 |
|------------------|------------|-------------|-----------|------------|----------------|--------------------|-------------------|---------|-------------|----------------|-------------|-------------|-----------|-------------|

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**Optical spectroscopy of nearby type-1 LINERs**

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The ionisation mechanism of optical lines is debated:

- AGNs – e.g. Heckman+80
- Shock-heating models – e.g. Kewley+01
- pAGBs stars models – e.g. Sarzi+10, Singh+13

\textbf{Which is the dominant ionisation mechanism?}
LINERs are important population to study: Ho+08

- Most numerous local AGN population
- Bridge the gap between normal and luminous active galaxies

LINERs are unexplored laboratory for outflows !!

- Very few works, mainly via H$\alpha$ imaging, e.g. Pogge+00, Masegosa+11
- Detection rate? kinematics ?
- Does the broadening of lines hamper the detectability of the BLR component?

Veilleux+05, review

M 82

Smith, Gallagher & Westmoquette

NGC4438

optical+IR

Hubble archive

Masegosa+11

H$\alpha$

OUTFLOW

NGC1052 - Cazzoli+18

H$\alpha$-[NII]

H$\beta$

[OIII]

[OI]

[SII]
### LINER-population as a case of study:

- Does the BLR disappear?
- Is the NLR stratified?
- Which is the dominant ionisation mechanism?
- Are outflows frequent?
- Most numerous local AGN population
- Bridge the gap between normal and luminous active galaxies

### Our Goals:

- Detectability and properties of the BLR component
- Low and high ionisation lines do (not) have the same profiles
- Discriminate between ionisation: from AGN, shocks and pAGBs
- Frequency and kinematics of outflows

**Type 1 LINERs, \( L_1 \) \( \rightarrow \) direct sight, BLR visible**
Sample: 22 L1 from the Palomar Survey, Ho+97

All L1 in the Northern hemisphere, $z \sim 0.006$, $D \sim 30$Mpc (on average)

- Genuine AGNs from X-rays studies (González-Martín+09, Hernández-García+14)

Ground-based spectra from $\text{H}\beta$ to $[\text{SII}]$

- TWIN @ CAHA 3.5m
  - 20 LINERs
  - slit width 1.2” – 0.5 Å/pixel
- ALFOSC @ NOT 2.5m
  - 2 LINERs
  - slit width 1.0” – 1.5 Å/pixel

Space-based spectra from $[\text{OI}]$ to $[\text{SII}]$

- HST / STIS (Balmaverde+14)
  - 12 LINERs
  - slit width $\leq 0.2”$ – 0.6 Å/pixel

NGC4203 excluded

- double peaked H$\alpha$ from the accretion disc

ground: 21 L1  space: 11 L1
Strategy

- **STELLAR MODELING and SUBTRACTION**: 3 techniques
  - pPXF (Cappellari+17), STARLIGHT (Cid Fernandez+11), ‘template galaxies’ (Ho+08)

- **MODELS**: [OI] and/or [SII] as template for the Hα-[NII] blend

- **THREE COMPONENTS FOR EMISSION LINES** (ionised gas):
  - Narrow, Second and Broad (AGN)

- **TWO COMPONENTS FOR ABSORPTION NaD LINES** (neutral gas)
**On the AGN nature of LINERs**

NLR stratification is often present in L1
- **Ground:** 9/21 vs. **Space:** 5/11

The broad H$_\alpha$ component is ubiquitous in HST spectra **ONLY**
- **Ground:** 7/21 vs. **Space:** 11/11
- Difference of $>1000$ km/s with previous measurements the FWHM(H$_\alpha$)
- Choice of the model, number of components and stellar subtraction
- .. what about type-2? Hermosa-Muñoz+19 *POSTER*

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**ground: CAHA/TWIN**

- H$_\alpha$-[NII]
- [SII]
- [OI]

**space: HST/STIS**

- H$_\alpha$-[NII]
- [SII]
- [OI]
Non rotational motions and kinematic classification

Second component, possibly associated to non rotational motions, seem common

- Ground: 14/21 vs. Space: 7/11

Kinematic classification: the $\sigma$-V diagram

Limits from rotation curves

- Narrow component: rotation – all cases
- Second component: all possibilities, outflow detection rate $\sim 60\%$
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**Discriminating ionisation mechanisms: narrow component**

**BPTs constraints**

- Dividing curve by Kauffmann+03, Kewley+06, Filipenko+92
- AGN (Allen+08) and pAGBs (Binette+04) models

\[ \text{LOG} \left( \frac{[\text{OIII}]}{H\beta} \right) \]

\[ \text{Log U : } \]

\[ \begin{array}{ccc}
-3.6 & -3.0 & 0.0 \\
\end{array} \]

**Models:**

- AGNs
- pAGBs

**Weak [OI]**

**Strong [OI]**

\[ > 0.16 \]

**N\text{el} : 100 \text{ cm}^{-3}**

\[ \text{AGN} \text{ as the dominant mechanism of ionisation} \]
Discriminating ionisation mechanisms: second component

As for the narrow component but we focus [OI] BPT: the most sensitive to shocks

- **Shocks** models reproduce well the line ratios for the second component

[OI] BPT + shocks models (Groves+04) + kinematic measurements/classification

- **Inflows**
  - Weak [OI]
  - V$_{\text{shocks}}$ = 100-300 km/s
- **Outflows**
  - Strong [OI]
  - V$_{\text{shocks}}$ = 400-800 km/s

![Graph showing the relationship between [OI] and Hβ line ratios and shock velocities]

- Models: Shocks
- N$_{\text{el}}$: 100 and 1000 cm$^{-3}$

- Mild shocks associated to perturbation of the rotation
- Strong shocks associated to non rotational motions
The AGN nature of L1
- BLR elusive in ground based spectroscopy, ubiquitous in HST data
- AGN as the dominant mechanism of ionisation
- NLR stratification is often present

The BLR-component detection and properties are sensitive to:
- template for Hα-[NII] blend, number of Gaussians and starlight subtraction

Kinematics and ionisation mechanism of the line components
- Narrow component: Rotation – all cases
  - AGN photoionisation
- Second component: Non-rotational motions / outflows are frequent
  - Associated to shocks ([OI] BPT + kinematics)
- The lack of neutral outflows might be a consequence of our classification

Type-2 LINERs: Hermosa-Muñoz+19 - POSTER

Ongoing work
- 3D outflows and feedback with MEGARA/GTC and MUSE/VLT