Search for high-energy neutrinos from U/LIRGs in the Great Observatories All-Sky LIRG Survey (GOALS)

VRIJE UNIVERSITEIT BRUSSEL

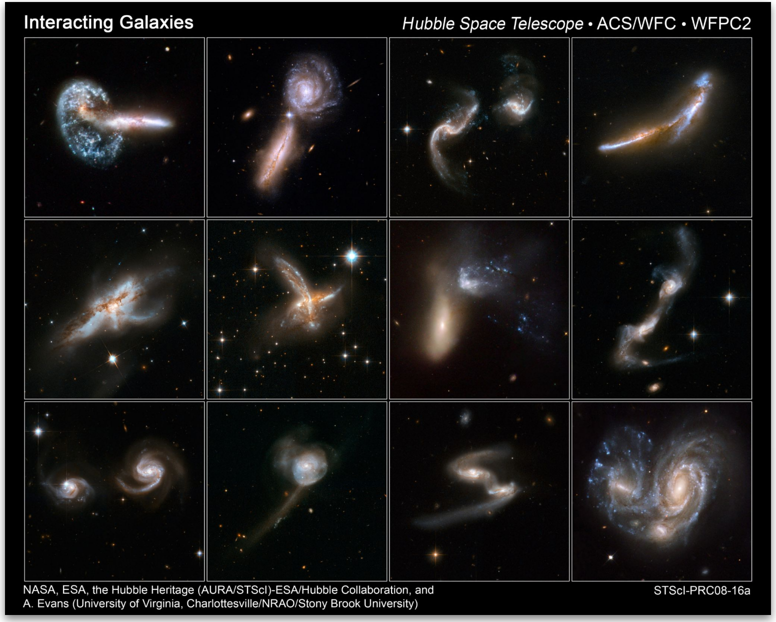
Speaker*:* Yarno Merckx

VUB-GOALS collaboration: Krijn de Vries, Nick van Eijndhoven, Pablo Correa, Kumiko Kotera, and George Privon

U/LIRGs

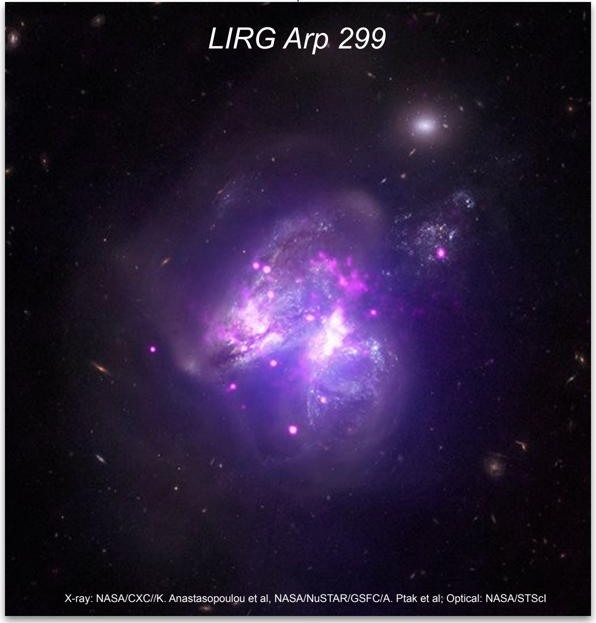
- (Ultra-)Luminous Infrared Galaxies (= U/LIRGs)
  ⇒ extreme IR luminosity:
  - **LIRG**: $10^{11}\ L_{\odot} \leqslant L_{IR} < 10^{12}\ L_{\odot}$
  - **ULIRG**: $L_{IR} \geqslant 10^{12}\ L_{\odot}$

- Local U/LIRGs are primarily mergers and interactions between gas-rich spiral galaxies



U/LIRGs

gas & dust flow towards nuclear regions during merger

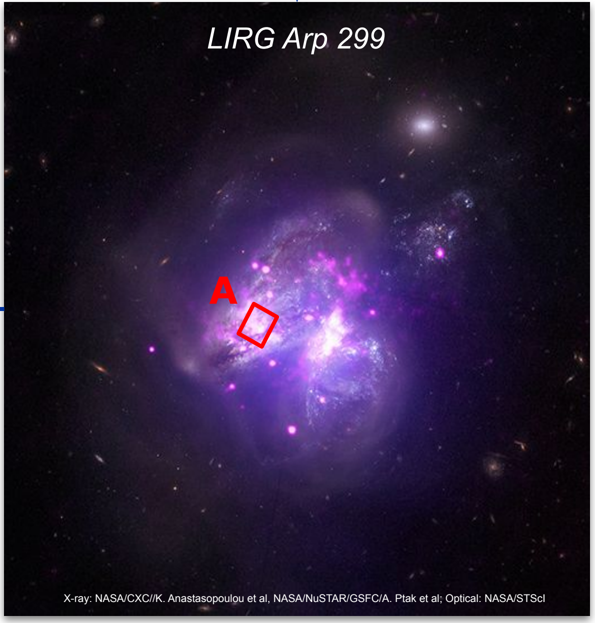


U/LIRGs

gas & dust flow towards nuclear regions during merger

A: Nuclear starburst

- Colliding gas masses
  ⇒ starburst activity ↑
  ⇒ supernova rate ↑
- Radio observations of **A** reveal prolific supernova rate > 0.8 yr^{-1}
- **Cosmic-ray acceleration** in strong shocks driven by supernova explosions



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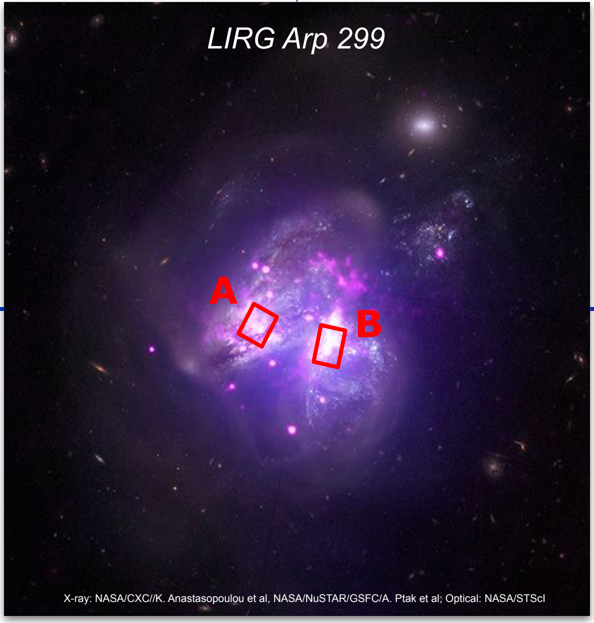

B: Obscured AGN

- X-ray observations of **B** reveal strongly obscured AGN activity
- Gas accretion onto supermassive black hole induces AGN activity
- **Cosmic-ray acceleration** in relativistic jets and/or accretion disk corona

U/LIRGs

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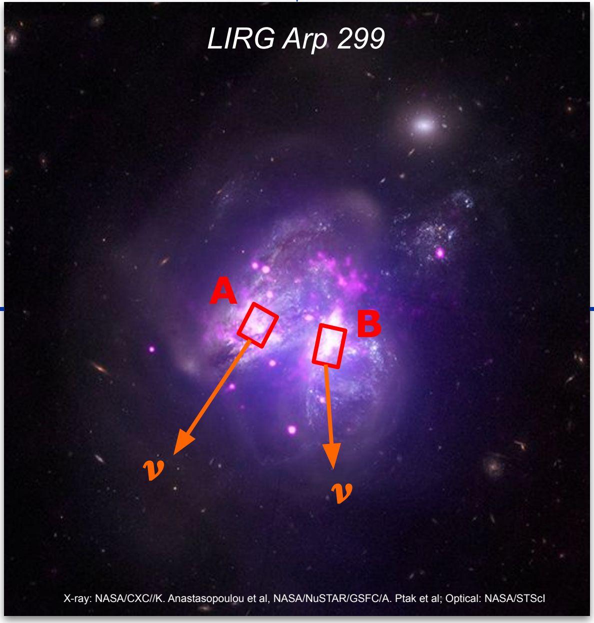

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CR acceleration + high target density ⇒ ν production

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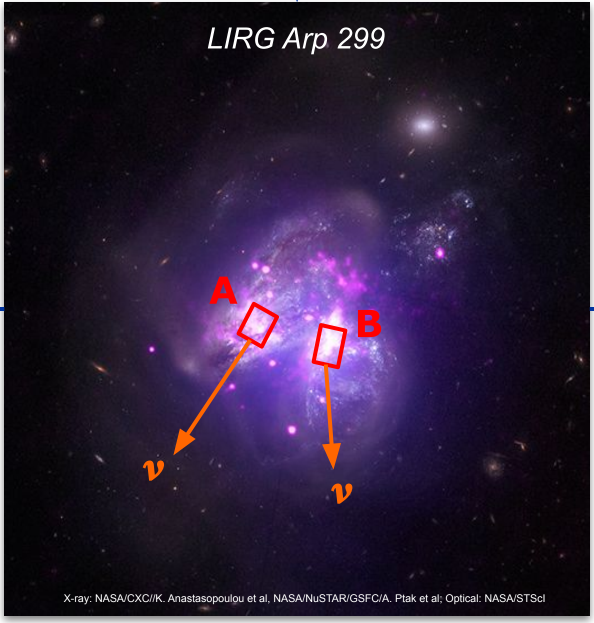

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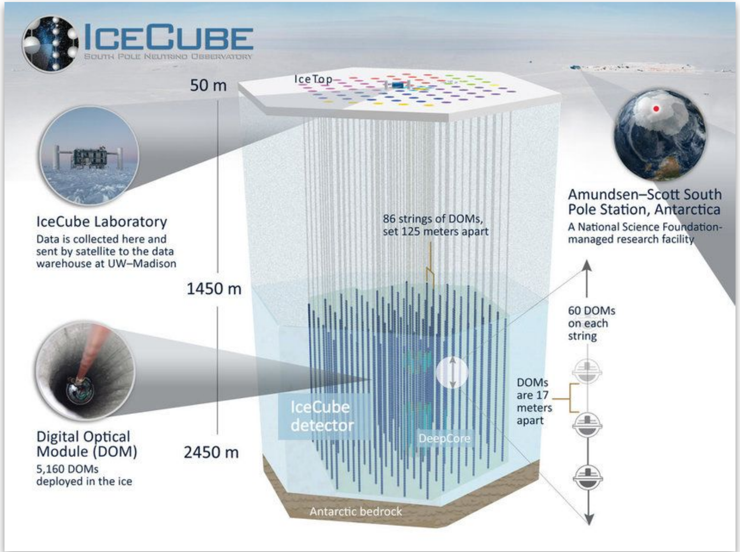
IceCube analysis U/LIRGs

- Recent ULIRG search with IceCube
  ⇒ no significant excess over background
- LIRGs:
  - Less luminous but much more numerous
  - Similar conditions as ULIRGs
  - Start at ~ 20 Mpc vs. closest ULIRGs at ~ 80 Mpc
- My research: investigate U/LIRG contribution to IceCube neutrino flux



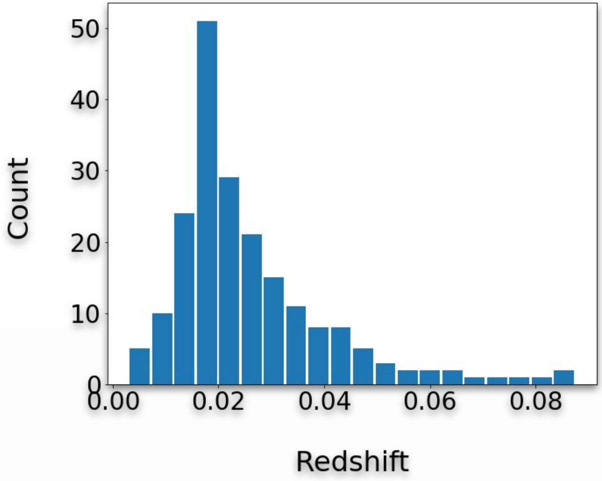
The GOALS sample

Great Observatories All-Sky LIRG Survey (GOALS)[1]

- Multi-wavelength survey of 202 nearest and brightest U/LIRGs:
  - Cover all merger stages
  - Pure starbursts, AGN, and composite systems

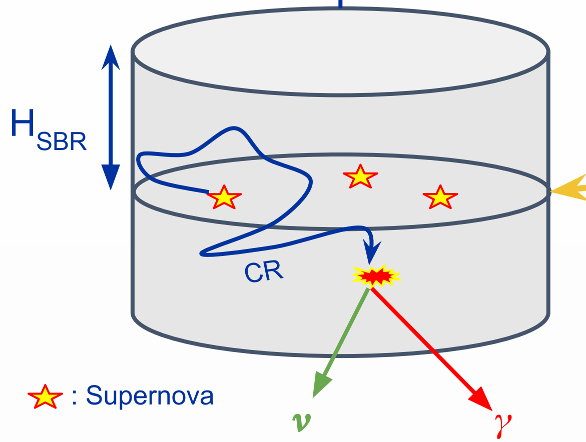
GOALS ⟷ ICECUBE

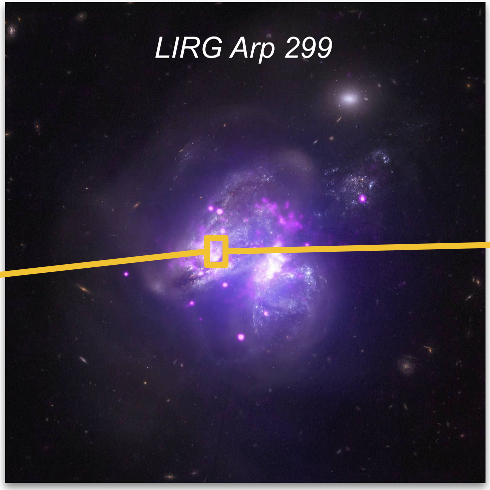
[1]goals.ipac.caltech.edu

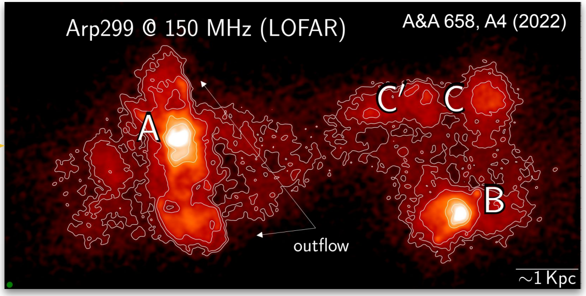


Neutrino production model

Observational evidence for nuclear disks in U/LIRGs at ~100 pc scale







Neutrino production model

CR injection CR propagation

$$F_\nu = F_\nu(R_{SN}, \alpha_{SN}, p_{max}, n_{ism}, v_{gwind}, H_{SBR}, D_L)$$

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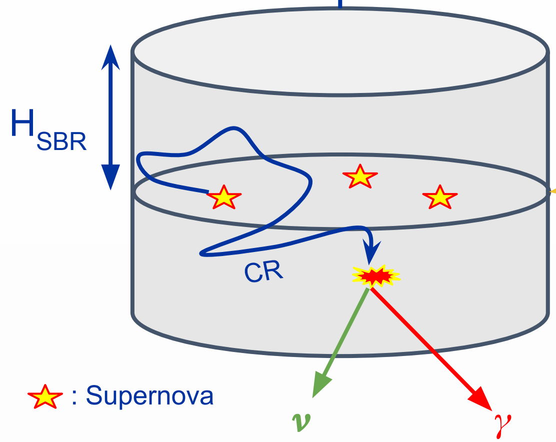

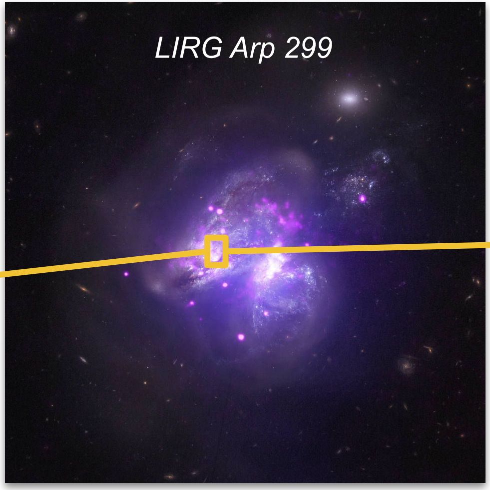

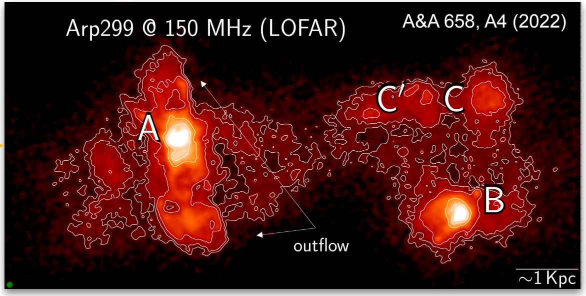

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CR injection:

- *CR injection rate by supernovae (Q_p):* $Q_p \propto p^{-\alpha_{\mathrm{SN}}} \cdot e^{-\frac{p}{p_{max}}}$

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GOALS

Research Foundation Flanders
Opening new horizons

Neutrino production model

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- *Calibrate L_{IR} to supernova rate* ($\mathfrak{R}_{SN}$)
  - GOALS provides L_{IR} for individual galaxies

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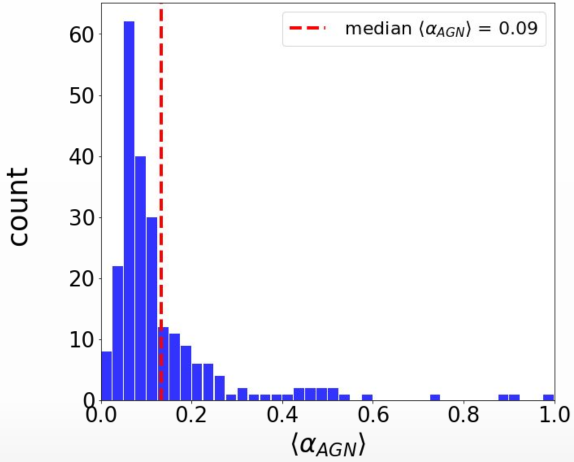
    - GOALS provides L_{IR} for individual galaxies
- Correct for AGN contribution to L_{IR} via $\langle\alpha_{AGN}\rangle$
    - Available for all galaxies with individual L_{IR}



Neutrino production model

CR injection | CR propagation

$$F_\nu = F_\nu(\mathcal{R}_{\rm SN}, \alpha_{SN}, p_{max}; n_{\rm ism}, v_{\rm gwind}, H_{\rm SBR}; D_L)$$

CR propagation & interaction:

- Total residence time of CR in starburst region (τ) determined by:

$$\tau = \left[\frac{1}{\tau_{\rm pp}} + \frac{1}{\tau_{\rm diff}} + \frac{1}{\tau_{\rm gwind}}\right]^{-1}$$

  - ***pp*-collisions** driven by ISM density (n_{ism}): $\tau_{pp} \propto n^{-1}_{ism}$
  - **Spatial diffusion**: $\tau_{diff} \propto H^2_{SBR}/D$
  - **Advection via galactic-scale outflow**: $\tau_{gwind} \propto H_{SBR}/v_{gwind}$

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→ ν efficiently produced if *pp*-collisions dominate over particle loss

Neutrino production model

CR injection — CR propagation

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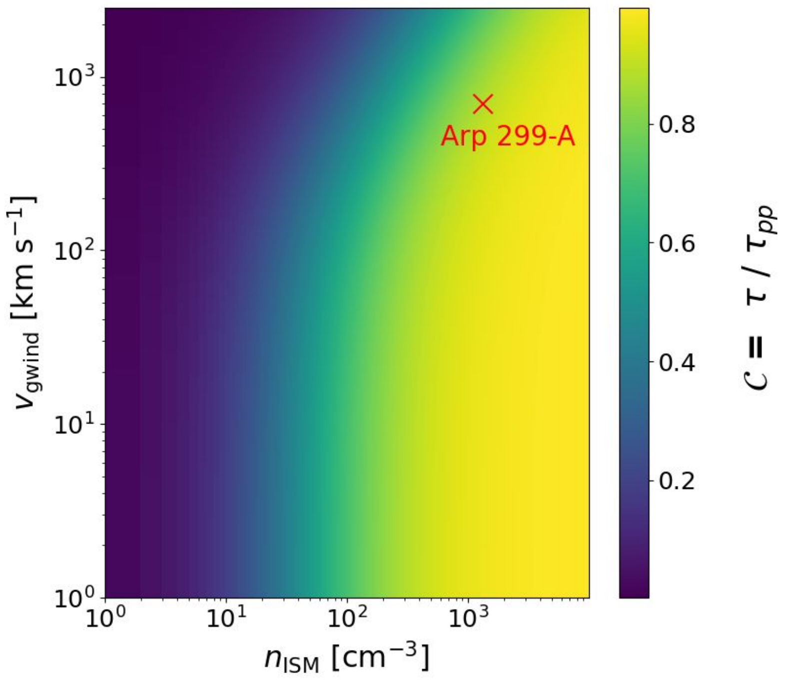
CR propagation & interaction:

- Efficiency neutrino production quantified by *C*

$$\tau = \left[\frac{1}{\tau_{\rm pp}} + \frac{1}{\tau_{\rm diff}} + \frac{1}{\tau_{\rm gwind}}\right]^{-1} \rightarrow \mathcal{C} = \frac{\tau}{\tau_{\rm pp}}$$

- **X:** n_{ism} and v_{gwind} Arp 299-A from radio and IR observations

- *C* = 0.88 ⇒ Arp 299-A is a **calorimeter**



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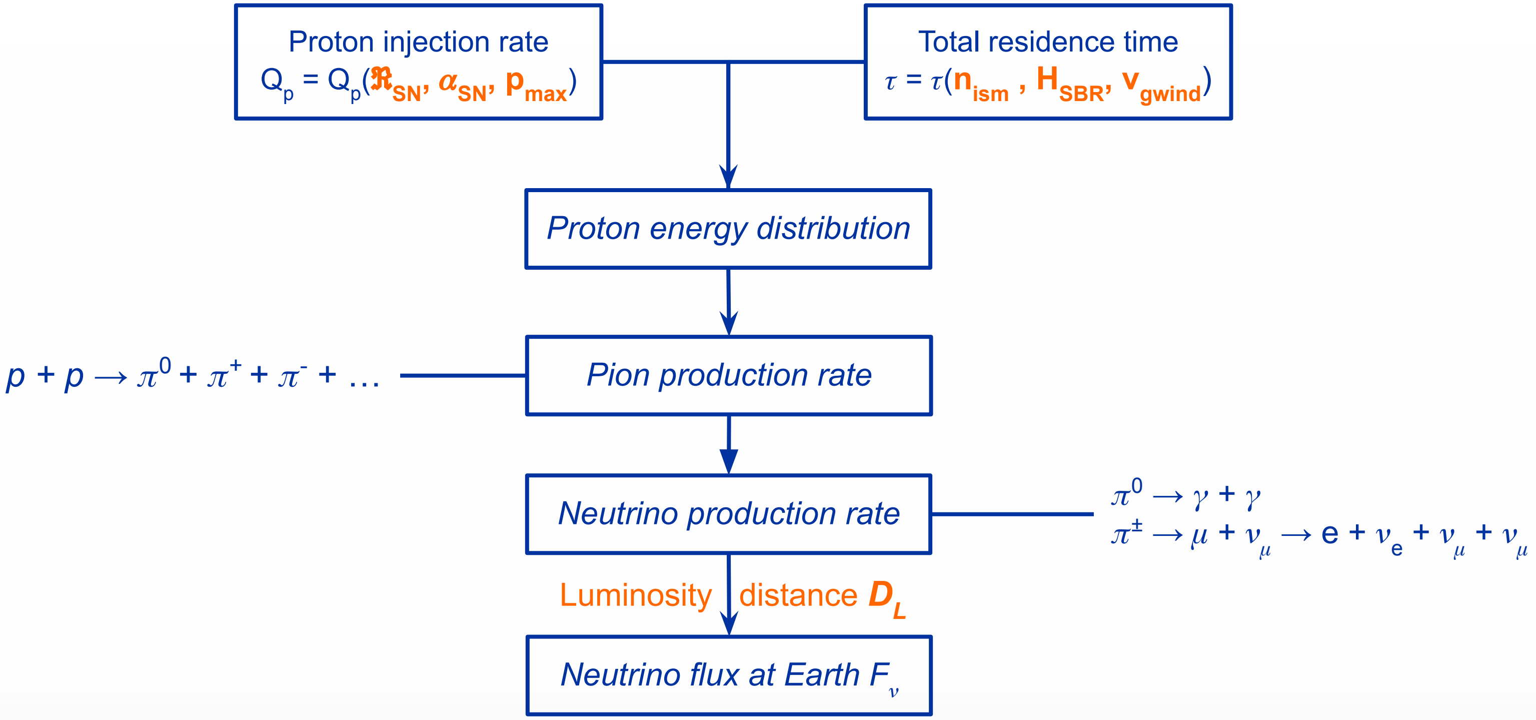

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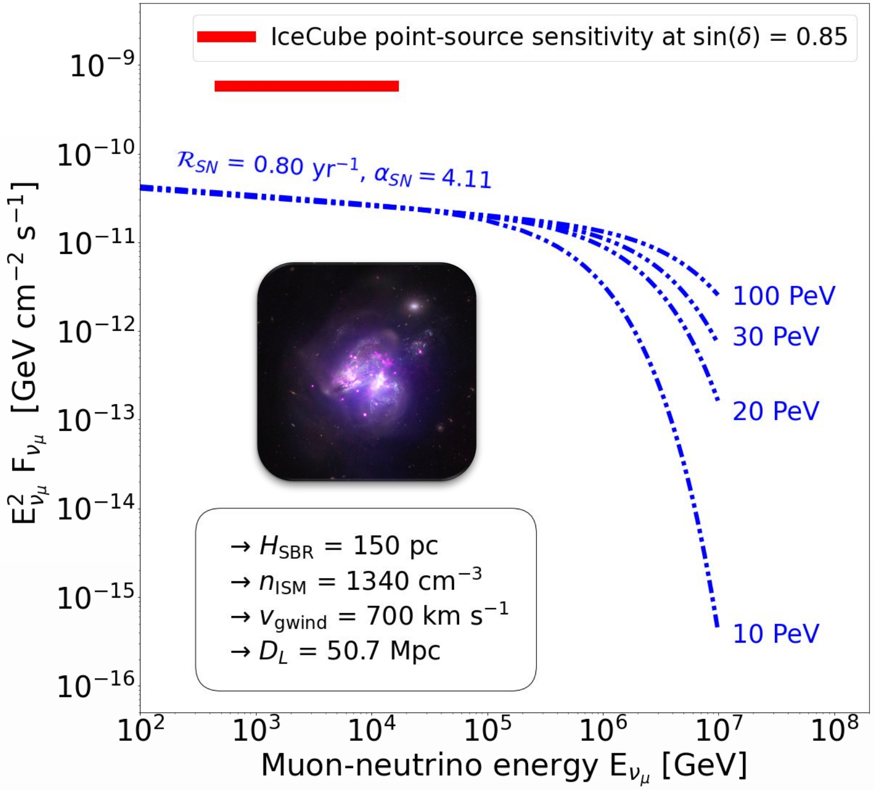
Outlook:

- Apply framework to all GOALS galaxies
- Select and perform IceCube analysis based on results



Questions

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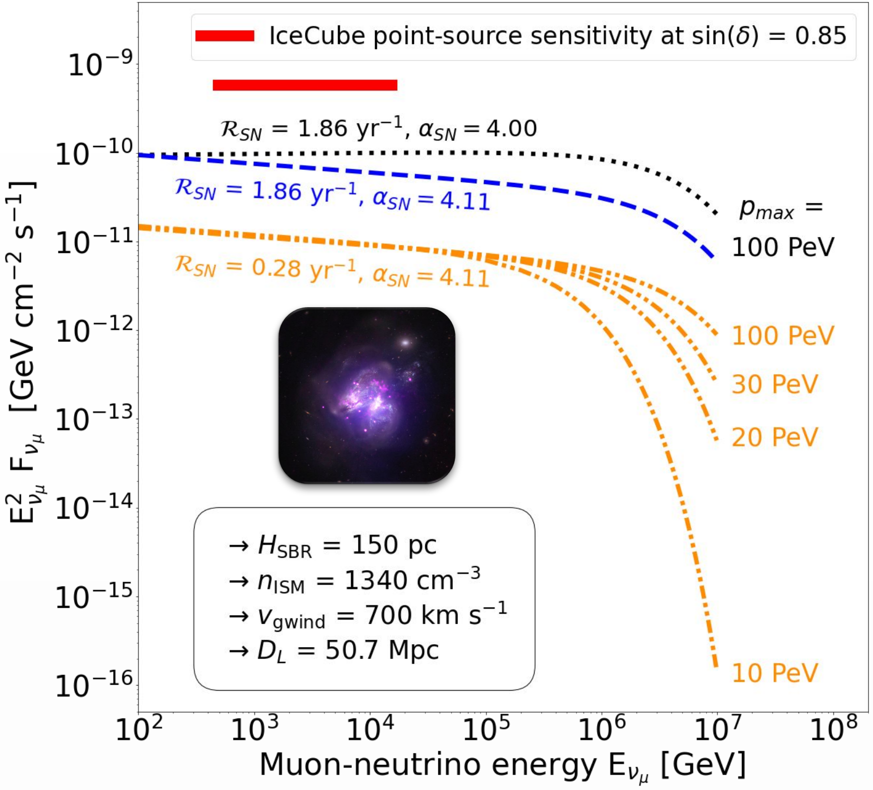
Backup

Neutrino production model



Overview and outlook

VUB-GOALS framework

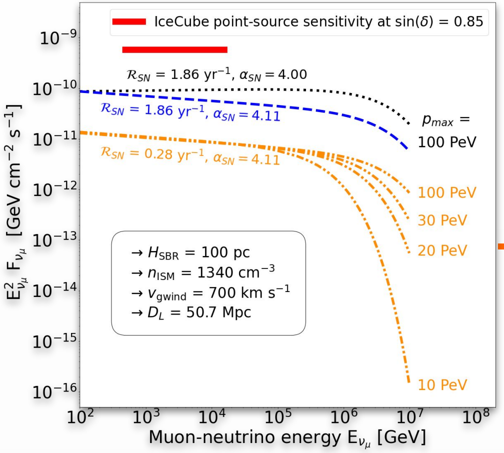
GOALS Data

$$F_\nu = F_\nu(\mathcal{R}_{\rm SN}, \alpha_{SN}, p_{max}, n_{\rm ism}, v_{\rm gwind}, H_{\rm SBR}, D_L)$$

ν-flux prediction for each GOALS (U)LIRG

Constrain framework parameters

Characterize GOALS U/LIRG contribution to IceCube ν-flux



Select IceCube analysis based on flux predictions